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Capricorn Coast Beaches

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CAPRICORN COAST BEACHES

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UNIVERSITY COLLEGE OF CENTRAL QUEENSLAND

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ABSTRACT

The University College of Central Queensland has been recently involved in investigations of coastal problems along the Capricorn Coast. The purpose of the investigation is to analyse beach changes caused by man–made structures (seawalls and causeways) and find solutions to improve beach conditions. The paper presents general information about the hydrodynamical conditions and considers three particular examples based on initial analysis. The presented problems show the importance of further investigation.

CONTENTS

1. INTRODUCTION

The Capricorn Coast is the name of the Central Queensland coastline extending from Cattle Point on the northern side of the Fitzroy River mouth, northward to Stockyard Point, a distance of about 80km (Fig.1.). The Capricorn Coast is uniquely placed along Queensland's coastline. Its location in relation to the Great Barrier reef, the continental shelf and the shape of the adjusted coastline exposes it to wave, current and tidal forces different from those experienced elsewhere on Australian coasts. Yeppoon and Emu Park are the largest towns along the coast while other settlements such as Lammermoor, Mulambin, Kinka Beach and Keppel Sands have been established as a narrow corridor of beachfront development.

The coast exhibits a variety of land forms, vegetation types and geological systems and contains a range of resources for human use. Some of the more important coastal resources are as follows: recreation areas, residential areas, sheltered waters, fisheries, tourist attractions and natural environments.

The favourable climate and recreational opportunities have encouraged extensive residential and commercial development with such development often being located as close as possible to the beach itself.

For a long time, decisions made by the Livingstone Shire Council on beach protection matters along the Capricorn Coast were made without the benefit of any recorded field data and relied heavily on intuition and local knowledge of the areas involved.

The first and only, until now, intensive complex field investigations were carried out by the Beach Protection Authority, Queensland (BPA) over the three year period 1975–1977 and the results were presented in the published report [1] and some papers like [12].

The information and conclusions included in this report provide an excellent basis for development of a proper coastal management plan for further development of the Capricorn Coast. Unfortunately, 10 years after the publication of the report nothing has been done to establish such a plan.

The paper examines the modern approach of Coastal Engineering for a few particular problems of this area where man's impact has influenced the natural beach conditions:

> Yeppoon Main Beach has completely lost its natural recreation characteristics since the seawall was constructed along the entire beach and about 100,000m^3 of sand was removed from the beach for various work programmes. There is almost no usable beach available at most high tides and at low tide the sand remains saturated with ground water and is useful only for walking and fishing activities.
>
> Dramatic changes at Kinka Beach have taken place since a Causeway was constructed across the lake estuary which was adjusted to Pinnacle Point in 1939. Extensive erosion of the dunes has left virtually no protection for road, water supply pipes and local residents' properties.
>
> At Keppel Sands, houses are located on narrow, but relatively high dunes with only a residential access road between the allotments and the beach. The rubble seawall constructed several years ago is not capable of preventing further serious erosion during extreme conditions.

2. COASTAL FEATURES

The physical appearance of the coast is one of great contrasts. Prominent rocky headlands separate numerous sandy pocket beaches in the central sections while to the north and south long stretches of uninterrupted beach have been developed. The beaches of the Capricorn Coast are gently sloping, consisting of relatively fine sand containing a significant proportion of muds. The semidiurnal tides with a range of up to 5m rises and falls across a beach width exceeding 200m. The overall median (50% exceedance) wave height for the offshore waves is about 0.8m. Wave generated within Keppel Bay are typically 0.3 to 0.8m in height. Cyclonic waves can reach 3 to 4m in height and are likely to exceed 5m for a duration of 12 hours and with an average return period of 50 to 100 years. Spectral peak energy periods in the Capricorn region are widely distributed over the range from 3 to 15 seconds.

The most common coastal landform along the beaches of the area is extensive sand dune development in various forms including recent foredunes, older parallel beach ridges and both mobile and stabilized transgressive dune formations.

The Fitzroy River is by far the largest of the streams flowing into Keppel Bay, and its mouth is located adjacent to Cattle Point at the southern end of the coast. The river has a comparatively large catchment area of about 144,000km^2. However the major part of the Fitzroy's catchment receives only 600 – 700mm of rainfall per year on average, and significant fresh water flows in the river are typically associated only with cyclonic activity in that region.

The Fitzroy River carries with it vast quantities of sand and silt which are discharged to the sea and settle to the bed of Keppel Bay. The zone of deposition and transport of sediment supplied from the Fitzroy River is shown in Figure 2 and is unusual in that it forms a well defined nearshore belt along the entire Capricorn Coast rather than extending directly seaward from the river mouth. It was estimated that an average quantity of 450,000m^3 of sand is supplied by the river each year. A grainsize plot indicates the Fitzroy River delivers predominantly very fine sands (0.063 – 0.12mm) with a certain proportion of fine sands (0.12 – 0.25mm).

In the light of the initial investigations done by BPA 12 years ago, it would be worthwhile to initiate investigations to determine problems and propose a possible solution for the stabilization of the Fitzroy River estuary to improve the standard of the Capricorn Coast. The recent development in mathematical modelling together with physical models will allow simulation of any possible future solution.

3. CLIMATIC VARIATION

The variation in climate with which people are most familiar is the annual or seasonal variation from summer to winter. It results in the heating or cooling of the Australian continent, thus influencing the movement of air masses and hence wind direction and rainfall distribution.

In the longer term, two to seven years, it has been shown recently that climatic trends are related to El Nino – Southern Oscillation (ENSO) events.

El Nino, originally referred to a warm current that flows southward along the coast of Equador and Peru, has come to be used to describe interannual events when anomalously warm waters cover much of the eastern Pacific Ocean. The Southern Oscillation involves a see–saw in the surface pressure between the southeast Pacific high pressure zone and the north Australian–Indonesian low pressure zone.

It has been found that there is a tendency for greater frequency of cyclones in years with a high Souther Oscillation Index [10].

In the still longer term, 20 to 40 years, there appears to be a further less readily discernible trend, but one that may have important ramifications when considering the coastal zone. Ward and Russell [19] have shown that noticeable changes in wind strengths and directions have occurred on the east coast of Australia since 1945.

Historical records of climatic variations of these and longer time spans can be expended over longer periods. The climatic variations which most influence the present coastal zone are those of intermediate length, including those with 2 to 7 and 20 to 40 year time spans as well as specific events of short duration, but large magnitude.

3.1 Wind Action

Even quite minor shifts in wind direction and strength can cause noticeable changes to the coastal environment. The nearest regular daily observation of wind data is from Heron Island (100km E of Yeppoon) and Cape Capricorn (65km SE of Yeppoon).

For the period from 1962 to 1981 in terms of total percentage occurrence, SE winds are clearly predominant with 28% occurrence followed by S winds with 18% occurrence. The high percentage occurrence of S and SE winds is accompanied by a high persistence of these winds in that they typically blow at speeds above 10 – 15km/hr for several days at a time whereas NE an N winds of similar magnitudes tend to be of much shorter duration. Offshore winds total (SW, W, NW) are less than 8% occurrence.

Of interest is the annual wind energy vector calculated as Σv^3, where v is wind velocity in knots, over the period 1962 to 1981 [8]. It indicates nearly 40^0 changes over that period (Figures 3 and 4).

It is clearly seen that there is a tendency for shifting the vector from SSE to SE direction. Except 1967, when there was a severe cyclone, there were no remarkable changes in the wind energy. Thus there is only one direction which could be considered as a factor which has an extra influence on instability of the beaches.

3.2 Cyclone Erosion

Extensive erosion of the Capricorn Coast beaches and dunes occurs when abnormally large waves attack the dunes during high tides with accompanying storm surges, that move sand in an offshore direction. On most beaches experiencing a long term dynamic stability, this sand is subsequently pushed back onto the beaches at a relatively slow rate by smaller normal waves and is blown into the dunes to reform the beach.

The incidence of tropical cyclones is a significant feature of the area's climate. On the average, the Capricorn Coast suffers the effects of tropical cyclones once every two years, although the occurrence of widespread cyclonic destruction in the area is a much rarer occurrence. Details for all documented cyclones passing within 320km of the Capricorn Coast since 1909 is shown in Table 1 [1,2]

The tracks of the cyclones within a 320km radius of the Capricorn Coast exhibits no preferred pattern of movement through the area of interest. The cyclones have crossed that area from both landwards and seawards and have moved parallel to the coast both offshore and inland. It is surprising that only one cyclone of central pressure less than 990 mb has passed within 100km of Yeppoon in some 80 years. This was in April 1921. Of the 41 cyclones since 1909, 3 have occurred outside the normal cyclone season of December to April.

An examination of cyclone occurrences in the 30 years between 1959 and 1989 reveal that only two cyclones came within 150km of the Capricorn Coast and only three came within 200km. Thus, cyclone occurrences in the last 30 years appear abnormally low and may not be representative of long term behavior patterns.

TABLE 1

TROPICAL CYCLONES AFFECTING THE CAPRICORN COAST BEACHES

Date	Central Pressure [mb]	Distance from Yeppoon [km]	
12.2.11	988	100	NE
1.1.13	–	200	N (moving E)
8.2.15	986	100	E
15.12.17	996	30	N (moving E)
6.4.21	988	15	W
19.2.22	995	170	E
20.6.25	999	50	W
27.2.29	982	180	NE
4.2.31	–	100	E
8.6.35	1002	100	NE
28.1.39	995	70	N
31.5.39	–	80	E
9.2.42	992	150	NE
30.1.43	990	60	N
14.2.43	999	60	N (moving E)
20.1.46	999	170	NW
5.3.46	990	170	E
16.2.49	972	180	NE
3.3.49	1002	30	W (moving N)
17.1.50	994	180	NE
10.3.50	992	60	NE
7.3.55	965	200	N
24.12.61	1000	250	NE
28.1.67	945	220	E
15.1.71	983	250	N
22.2.71	983	20	NE
2.4.72	948	120	SE
19.1.76	970	130	N
–.2.79	995		
–.1.80	989		
–.2.80	950		

The probability of a storm of a given intensity occurring within the area of influence has been estimated, assuming that the intensity of each storm is characterized uniquely by its central pressure. The resulting central pressure – recurrence interval curve for Yeppoon is of influence as shown on Figure 5 together with 95% data confidence limits and correctness of relevant statistics [2].

The effect of cyclones is generally unpredictable because it depends upon the path and intensity and the state of the tide. The net effects may be extremely erosional if water levels are high.

3.3 Wave Climate

Waves affecting the Capricorn Coast may be generated locally within 100 to 500km of the study area or may arrive as decaying swell generated outside the vicinity of the region. The possible directions from which waves can arrive are confined to the seaward sector between north (0^0) and south (180^0), being the general alignment of the coast. Swell waves are further restricted by the shape of the coast and offshore reefs to directions between 60^0 and 120^0, being intercepted by the Great Barrier Reef to the north–east and Fraser Island to the SE. Figure 6 illustrates the available fetches and access windows for sea and swell reaching the Capricorn Coast.

Daily hindcast wave heights for the period 1957 to 1977 of available wind data from Cape Capricorn is shown on Figure 7 as percentage exceedance curve for all directions combined.

Wave steepness has been calculated using the equivalent deep water H_{sig} and deep water wave length (L_0). The percentage occurrence of various wave steepnesses is shown on Figure 8.

A clear division between sea and swell is evident at a steepness value of about 0.015. A limiting maximum steepness of 0.04 is evident.

Wave steepness can also be expressed as a relationship between wave height and wave period. Figure 9 illustrates this relationship.

3.4 Swell

Swell analysis of Cape Capricorn swell observations over the 10 years of the period 1972 – 1981 undertaken shows the predominance of SE and E swell. The direction–frequency, average for 10 years is presented in Table 2 [17]. Figure 10 illustrates the average daily frequency with and without low and short swell. The difference is mainly in E direction.

Table 2

State of swell vs direction of swell (1972 – 1981)

Ks	0	NE	E	SE	S	SW	W	NW	N	Indef	Tot
0	502	0	2	0	0	0	0	0	0	26	530
1	15	199	640	519	47	21	10	30	372	11	1864
2	1	30	178	320	8	1	1	5	68	1	613
3	1	16	154	302	2			2	35	1	513
4		3	32	73					3		111
5			5	12					1		18
6				1							1
7			1								1
8				1							1
9											0
Tot	519	248	1012	1228	57	22	11	37	479	39	3652

Note: Ks – state of swell in open sea

No swell	0
Short or average length low swell	1
Long low swell	2
Short swell of moderate height	3
Average swell of moderate height	4
Long swell of moderate swell	5
Short heavy swell	6
Average length heavy swell	7
Long heavy swell	8
Confused swell	9

4. SHORELINE PROTECTION

A natural beach alignment changes almost continuously in shape due to varying boundary conditions. The on/offshore transport involved, causes the reshaping of the beach profile. Continuous erosion of the coast occurs mostly due to gradients in the longshore sediment transport process. To reduce expected erosion the following approaches can be considered:

traditional armouring of the dune front (seawall);
artificial reduction of the effect of the boundary conditions.

A seawall is able to prevent erosion of the dunes, however, serious erosion in front of the seawall may occur. Yeppoon beach is a good example of such a situation. If a seawall is designed for a potentially eroding coast it cannot be applied without other measures. The general practice in coastal engineering is to avoid this type of structure as long as possible.

Artificial reduction of the effect of the boundary conditions could be considered by:

offshore barrier;
reinforcement of the dune formation;
formation of a dynamically stable bay.

Offshore barriers in situations where there are flat beaches and high tides have not been fully investigated. A reduction in wave height and thus wave energy absorption by the barrier will be ineffective under design conditions when the water depth above the crest of barrier is of the order of a few metres at high tide.

The dune system is a natural storage of sand which could be eroded during a storm season and returned back by swell waves. Considering safety, the necessary dune width and/or height can be computed. From the point of view of minimal sand supply, widening of the dunes seems most appropriate. Also a heightening of the dunes and a supply of sand to the beach and foreshore (nourishment) will meet the requirements.

Observations of beach behaviour indicate the existence of bays which are in a stable condition over geological time. Silvester [18] first proved the principle of equilibrium shaped bays between headlands in the presence of persistent oblique swell and defined them as "crenulate shaped bays".

The recent approach, termed "headland control" [9] involves the construction of fixed points on the coast, between which bays are formed that retain sediment in place for Nature to act on in Her laudable defense mechanism. This involves the use of the beach itself, which acknowledges renourishment as the ideal solution.

5. YEPPOON MAIN BEACH

5.1 General Characteristics

Yeppoon Main Beach is about 1,300m long and is aligned north–south from the Ross Creek outlet in the South to Spring Head at the Northern end. Yeppoon was proclaimed a Town in 1868. The favourable climate and recreational opportunities have encouraged extensive residential and commercial development which are often located as close as possible to the beach itself. This has created several management problems associated with beach stability. Significant changes to the Yeppoon foreshore are summarized in Table 3 and Figure 11 [17].

Table 3

Significant Changes to Yeppoon Main Beach

DATE	EVENT
early 1920's	early timber fence dune protection and change sheds at the tide line;
late 1920's	road pushed along crest of dune;
1931	change sheds on beach destroyed in cyclone
early 1930's	kiosk and shelters built on beach;
1935 – 37	foreshore protection scheme: construction of rubble seawall, dunes levelled;
1955	extension after cyclone damage to end of seawall;
1960's	breakwater to Ross Creek entrance and harbour walls;
1976	destruction of large part of seawall in cyclone, extension in rubble along entire beach;

As can be seen from the Table 3 the development of Yeppoon forced the construction of the seawall along the seaward slope of the main dunes. Cyclones in that region had appreciable effects on the beaches and damaged the seawall, which then required major reconstruction. The seawall has generally achieved its purpose of protecting the esplanade area in front of the Yeppoon township. On the other hand, the seawall has also led to a steady deterioration of the beach itself to the extent that the Main Beach can no longer be claimed as one of the Coast's most popular beaches.

In the meantime, other activity has accelerated the depletion of the beach. From around 1965 to 1970, an unknown quantity of sand was carted out by train to Mt Isa for construction purposes. The use of trains suggests that this would have been a considerable volume of sand. Local Shire Council removed about 100,000m^3 of sand from this beach for various work programmes in Yeppoon somewhere between 1970 and 1972.

The beach system therefore is no longer able to maintain itself by accommodating natural short term erosion and accretion movements within the dune system which do not exist any more. Reflection of waves in front of the wall increases movement of sand during high water levels of storm events, accelerating the rate of sand loss and reducing the accretion rate.

Early photographs showing the original dune alignment clearly show the wall was constructed about 20m forward of the dune scarp, and the dune levelled and pushed forward against it. This gives an indication that the wall is in an active beach zone.

Figure 12 shows the typical profile of the Yeppoon Main beach superimposed on a section at Farnborough beach to the north. The difference between the beach with a seawall and the dunal system to the north is highlighted. The material moved offshore is not allowed to be returned, lowering the profile slope and showing up in a recession of the waterline in aerial photographs. The beach profile has the following characteristics:

(a) the average slope from HWL to LWL marks is about 1:50 with a change in grade to 1:40 below LWD.

(b) the slope up to the depth –4m below LWD, is 1:100 and further showing only slight reduction in the depth so that at about 2km offshore the depth is only 6m.

This profile provides for a potential longshore transport about 300m width surf zone. Characteristic diameter of beach material is: D50 = 0.20 – 0.30mm, D90 = 0.30 – 0.70mm.

The calculated longshore transport by the Beach Protection Authority, with the net transport of about 28,000m^3/y southward, is in apparent conflict with the transport direction suggested by the shape of the coastline in the area. The report concluded that it was apparent that a general northward transport occurs offshore in the advective transport stream and only a proportion of the calculated total transport capacity takes place in the upper beach zone above low tide level.

The calculation carried out by the author using the Bijker's formula had shown the net longshore transport northward (Tab 4).

TABLE 4

AVERAGE LONGSHORE TRANSPORT – YEPPOON MAIN BEACH

(in m^3/year)

Profile	Northern	Southern	Net
1	33,400	–16,400	17,000
2	39,800	–10,400	29,400
3	28,400	–6,900	21,500

The distribution along the profiles is shown on Figure 13.

5.2 Beach Protection Authority Recommended Solution

BPA [1] concludes that the seawall constructed along most of Yeppoon Main Beach located seaward of the main dune is, in itself, inadequate to protect the esplanade development behind it against severe cyclone conditions. Further, the seawall has caused depreciation of the beach itself. Therefore the beach requires restoration and proper protection from both a safety and an economical point of view.

The proposed solution considers construction of a groyne near the entrance to Ross Creek and alternatively nourishment of the beach with a minimum $50m^3$ of sand per running metre of beach (Figure 14). The suggested location of the groyne is to prevent sand from the replenished beach entering the creek as the southward net longshore transport capacity of about $25,000m^3/y$ has been estimated by assumed study.

Field measurements of currents and sediment transport as well as the calculations done so far by the author do not confirm southward predominant longshore transport in this region. Any slipways along the coast which may be treated as short groynes do not indicate any sand accumulation on their side. The reflecting effect of the seawall seems too strong to allow the sand to accumulate in that region.

The location of the groyne of the suggested length about 60m near the Ross Creek entrance is not in a proper place as it has meaningless influence on the sand accumulation. Ross Creek with a mean cross–section about $100m^2$ is presently in dynamic stability. A training wall rather than groyne may be considered to maintain the stability of its mouth. Protection for this beach is necessary but the proposed groyne, even with beach nourishment, in the author's opinion, will not achieve that goal.

5.3 Optional Solution for Beach Restoration

Prominent rocky headlands separate numerous sandy pocket beaches in the central section of the Capricorn Coast. Therefore the concept of "headland control" is appropriate in this region.

The Yeppoon beach is located in the most northward bay of the region. It could be seen from the map (Figure 1) that its natural crenulate shape is blocked by the bluff. The probable shape of the bay, north from the Bluff, created by nature, is calculated and presented in Figure 15. The calculations show that the predominant swell direction which created this bay has an azimuth of about 110^0 (ESE direction) and the shape is in good agreement with the predicted dynamically stable shape.

The other part of the bay involving the Main Beach, assuming the same swell direction, has a shape close to the theoretical one as well. However, the shape itself indicates that the seawall was constructed in an eroding part of the beach profile. Thus it is obvious that this construction is strongly effected by Nature and changes in the wind direction, northward shift (chapter 3.3), increases that action. Therefore any suggested armoured structure in that region requires proper design against strong wave action.

The suggested solution proposes to divide the bay into two parts using natural rocky Spring Head as a headland. Swell analysis (chapter 3.4) shows predominant swell from E and SE. Refracted 9 second swell was incident on the study beach from 75^0 to 108^0. Stable beach shape has been predicted for these refracted directions and is shown on Figure 16.

The bay formed in this manner would provide the Yeppoon Main Beach with a reinforced dune buffer zone providing protection to esplanade development.

The existing seawall may significantly influence the beach stabilization process therefore nourishment will be recommended. Without nourishment the replenishment of the beach will occur only through natural accretion of part of the longshore transport.

The downcoast region of the proposed headland is sheltered by rocks parallel to the shore and has an underlying platform of bedrock which should prevent damage there.

The recommended solution has been the subject of detailed study carried out by University College of Central Queensland.

6. KINKA BEACH/CAUSEWAY LAKE

6.1. Introduction

Most inlets/estuaries on littoral drift coasts are in a state of dynamic equilibrium between littoral drift and current forces. The tidal motion, and therefore the equilibrium of the system is affected by man–made changes in the cross–sectional areas of the inlet/estuary. The hydrographical and morphological consequences of changes such as dams, dikes, causeways, training walls, bridges, channels dredging, etc. are largely unknown at the construction stage and therefore any information from an analysis of a real system is particularly valuable.

The Main Roads Department of Queensland commissioned the Capricornia Institute (now UCCQ) in 1987 to conduct one such investigation of an area of beach/estuary interaction, before embarking on major Civil Engineering works in the Causeway/Kinka Beach area on the Capricorn Coast in Central Queensland.

Interim works already implemented, and design work currently in progress are based on the findings of this study [6].

During the years 1939–40, the townships of Yeppoon and Emu Park were linked by the construction of a causeway and bridge across a creek estuary immediately north of Kinka Beach (Figure 1). The bridge was constructed on a concrete sill, founded on rock. This construction formed a permanent lake into which tidal flow was possible only when tides were higher than the ridge sill level. Examinations of aerial photographs, and site inspections have revealed that the following changes have occurred since this initial construction:

(i) The outlet to the creek across the beach has moved progressively towards the south, and a sand spit has formed offshore.

(ii) Major siltation has occurred in the man–made lake.

(iii) Substantial erosion of the coastal dune system along Kinka beach has occurred.

Between 1982 and 1985 the Main Roads constructed a 700m rubble seawall along Kinka Beach to protect the Yeppoon – Emu Park road. This wall is now undermined and can not be regarded as a permanent solution. Major erosion of the dunes at the northern end of this seawall has occurred since its initial construction. By the beginning of 1988, there remained virtually no dunal protection for the road and adjacent houses against a strong tidal surge or cyclone.

Investigations and analysis

6.2.1 Changes to the Estuary

Estuary: Aerial photographs and surveys indicate a major change in the beach line between 1961 and 1988. This change is indicated in Figure 17. Associated with the change, the outlet channel between the Causeway Lake and the sea had considerably increased in length and moved closer to the shore by almost 200m, causing approximately 50m of dunal erosion.

Sand Spit: Shoal Bay is very flat in the nearshore region, with an average slope of 1:500 between MWL and MLWS, 1:30 near the dunes, and 1:50 adjacent to the rockwall (See Figure 18.)

Assuming that these slopes applied when the Causeway was built, and accretion commenced at that time, it can be calculated that approximately 1.1 X 106m^3 of sand has accreted in the sand spit. This equates to an average of approximately 23,000m^3/y of sedimentation since initial construction.

Tidal prism: Tides along the Capricorn Coast produce variations in sea levels of the order of up to 5m. The tides are semi–diurnal, and there is moderate to strong inequality in the two high and low tide levels each day. Tide height frequencies have been analyzed, and probabilities of exceedance for both high and low tide peaks determined (Figure 19).

The volume of water which can enter the lake (the tidal prism) is restricted by the causeway embankment and a concrete sill under the causeway bridge (3.7m LWD). As a result, the tidal variation within the lake is considerably less than outside. The tidal prism, of 580,000m^3, was calculated from field measurements taken on 28 February 1987 during a spring tide with a probability of exceedance of only 1 percent. This tide peaked at 4.2m LWD inside the lake and 4.8m outside.

Only 290,000m^3 of water left the lake during the next ebb tide, so the effective tidal prism for use in a stabilization analysis was 290,000m^3.

Stream runoff: The Causeway Lake has a total catchment area of 1300ha. Applying the Rational Method, maximum discharges of 11.6m^3/s for a recurrence interval of one year, and 136.1m^3/s for 50 years were computed. Clearly, stream runoff makes only a minor contribution to the tidal prism.

Contribution to accretion in sand spit from:

(i) erosion of the dunes by the creek. Field measurements taken previously by the Capricornia Institute indicated that up to 6,000m^3 of sand each year could be transported by the creek from the frontal dunes to the sand spit (unpublished study).

(ii) longshore transport. Estimates of longshore transport by wave action were derived using CERC formula and Bijker's method [3]. To apply Bijker's method, a computer programme was developed.

Separate calculations were made for high, mean and low water levels. The resulting transport for the average one–year period is summarized in Table 5, and the cumulative transport curve is shown in Figure 120.

TABLE 5

LONGSHORE SEDIMENT TRANSPORT – KINKA BEACH PROFILE
(in m^3/year)

Direction	Bijker's method	CERC eq.
Northward	12,800	11,700
Southward	700	1,600
Gross	13,500	13,300
Net (northward)	12,100	10,100

Results: When the contribution to accretion in the sand spit from dunal erosion (6,000m^3/y) was aggregated with that from longshore transport (13,500m^3/y) the total accretion of 19,500m^3/y correlates well with that derived earlier from beach profile surveys.

6.2.2 Stability of Inlet Channel

Bruun [5] postulates that the dynamic stability of an estuary depends on the relationship between the spring tidal prism, P, and the yearly gross longshore sediment transport, M, passing the entrance. A stability index P/M in excess of 150 is required for a stable channel whereas a channel with an index of less than 20 would be unstable.

For the Causeway Lake, following construction of the bridge, the index was approximately 15.

To improve the stability of the estuary, it was necessary to increase this index by reducing the magnitude of the longshore sediment transport, or increasing the tidal prism, or both.

6.2.3 Stability of the Beach

When waves approach a coast at an angle, a stable beach assumes a distinctive asymmetrical shape which is characterized by a "crenulate shaped bay" as defined by Silvester.

As Kinka Beach has a natural tendency to crenulate, stabilization could theoretically be achieved by construction of a headland type structure near the outlet from the Causeway Lake.

6.3 Possible Options for Estuary Improvement

Options considered comprised widening the bridge opening, lowering the bridge sill, relocating the bridge, dredging a new channel, and various combinations of these.

The options were assessed theoretically by determining the effect of the proposed changes on the Bruun index, and/or by use of a physical model [6]. The fixed bed physical model was constructed at the Capricornia Institute to a horizontal scale of 1:140 and a vertical scale of 1:25.

The model tests indicated that the addition of a single 9m span would increase the tidal prism by about 70,000m^3. However, this action would also increase lake levels by about 80mm. Lowering the sill level would increase the magnitude and frequency of the tidal prism, but would result in lower lake levels at low tide. This would expose a greater area of mudflats at low tide.

The Main Roads did not favour any changes which could increase flooding of private property, or reduce the amenity of the area.

Since relocation of the bridge alone would not effect the tidal prism, this measure would not improve the stability of the channel. The concrete substructure of the existing bridge is sound, and can be incorporated in a new widened structure, so no advantages were seen in this option.

Dredging of a new channel would not alter either the longshore movement of sand, or the tidal prism, so there would be no change to the Bruun index. With a Bruun index of only 15, any new channel would be unstable, and would require frequent dredging to maintain its alignment.

Combinations of these measures could be expected to result in combinations of their undesirable effects.

It was concluded that there was little scope for applying any of the measures already considered, as they would either not improve the stability of the channel, or would not be acceptable to local residents and/or recreational users.

6.4 Solution – Dredged Channel with Tidal Lagoon

6.4.1 Stability of Dredged Channel

Stability of a new dredged channel requires a Bruun index, P/M, of not less than 75 and cross–sectional area, related to the tidal prism, in agreement with the O'Brien relationship [11]. The O'Brien relationship, developed for open coasts, was verified by Riedel and Gourlay [16] for sheltered inlets located along the Queensland Coast, and recently by Capricornia Institute for Ross Creek at Yeppoon (unpublished), (Fig.21).

It is evident that the required cross–sectional area of entrance for sheltered inlets is larger than for exposed inlets for a given tidal prism.

Assuming the "old" channel was blocked simultaneously with the construction of the "new" channel, a reduction of the longshore transport to approximately 4,000m^3/y could be expected. Therefore the required tidal prism should be not less than 4,000 x 75 = 300,000m^3 and the cross–sectional area at MSL should be about 50m^2. If the bridge opening remains unchanged, this volume of tidal prism would be possible only if a tidal lagoon of 12.5 ha were created. Figure 22 shows the extent of the proposed lagoon.

6.4.2 Improvement of the Beach Stability

If the lagoon embankment is considered to be a headland the dynamically stable shape of the bay is shown in Figure 23. The oblique angle created by the dominant swell crest line and the control line dictates the stable shape of the beach. The shape must be almost parallel to the adjacent, dynamically stable, Mulambin Beach.

The solution is substantially different to that originally proposed by the Beach Protection Authority following their study of Capricorn Coast beaches in 1975–77. The B.P.A. recommended relocation of the outlet channel, construction of a groyne and some beach nourishment. The solution proposed in this paper includes construction of the lagoon to provide a much larger tidal prism.

6.5 Site Works

6.5.1 An Interim Solution

Following confirmation of this concept with the model, the Capricornia Institute recommended that the Main Roads construct a new channel and block the existing channel, so that the effects could be assessed.

The Main Roads completed this construction using conventional earthmoving equipment during May 1988. The new 150m long channel was excavated to an initial width of approximately 5m, using an hydraulic excavator. Sand excavated from the channel was transported by scrapers along the beach to where the 200m long dam was constructed. The crown of the dam was 10m wide at 4.5m LWD level, with a slope on the seaward side of 1:20, and 1:5 on the leeward side. Swamp dozers were used to block the channel, and form the sand dam. As conventional earthmoving equipment was used, the operation was constrained by the necessity to remove plant from the site during high tides. A total of approximately 15,000m^3 of sand was relocated, at a cost of approximately $50,000.

The works were completed immediately before a spring tide, on 17th May, 1988. The spring ebb tide enlarged the original excavation of the channel to a width of almost 20m. It has since widened to about 40m. Since construction, the channel has also deepened, from an initial bed level of 0.0m MSL, to –1.6m MSL. This change is shown in Figure 24. The channel has remained open for the past year, and the sand dam is still blocking the old channel, despite some erosion by wind and tide. Accretion of the beach near the dam has also occurred.

6.5.2 The Permanent Solution

The proposed permanent solution includes extension of the dam and its enlargement with sand dredged from the lagoon. Dredged sand should also be used to nourish Kinka Beach and particularly to cover the existing seawall. The rubble wall protecting the remaining dunes at Kinka is being undermined by the lowering of the beach by wave reflection, and cannot be regarded as a permanent solution. The recommended dredging of the lagoon to a level of –1.0m AHD (1.3m LWD) will produce a sufficiently large tidal prism to keep the channel stable and open. At the same time it will provide an adequate volume of sand for nourishment purposes (Figure 25.).

It is expected that most replenishment of Kinka Beach should occur naturally as the beach assumes a stable crenulate shape bounded by the eastern extremity of the dam to the north, and the headland to the south.

Monitoring of beach changes, after extension of the sand dune up to new channel done in November 1989, has been carried out by UCCQ.

7. KEPPEL SANDS

Keppel Sands is a pocket beach contained between relatively minor headlands about 1,500m apart immediately south of Cawarral Creek (Figure 1). The beach is aligned in the NNW–SSE direction. The net sediment transport for that region has been estimated in the order of 16,000m^3/y northward (BPA). Significant also, is the extent of the possible annual erosion estimated at 6,000 to 11,000m^3/y. The geographical location provides an ideal opportunity to check Silvester's concept of crenulate shaped bays. The protective seawall along the southern end of the beach, constructed many years ago, was located in the active zone of the beach. It restricted recession there and the continuing erosion has been transferred to the unprotected area north of the wall. The lowering of beach levels increases the vulnerability of the seawall to damage during storms. Therefore the effect obtained by the seawall construction in the past is the same as on Yeppoon Main Beach or Kinka Beach.

The other important points indicating weakness of that structure are height of the structure and possible horizontal recession accompanying the cyclones. For the "design" cyclone with probability of occurrence 10% in 50 years it is expected that:

(a) surge together with tide may reach nearly 4.5m higher than mean sea level. This corresponds to about only 2.5m below the level of the road;

b) waves of approximately 2.2m in height will attack the dune at and above the surge level, that is above the level of the protection;

c) the horizontal recession expected to accompany the "design" cyclone could be about 20m.

[ence there is a need for protective works because of adjacent development.

ecause there are no beaches or vulnerable developments downdrift (to the north) of eppel Sands, the BPA proposed a groyne construction at the northern end of the beach 'igure 26). The Livingstone Shire Council followed this suggestion and constructed a bble type groyne at the northern headland in 1981. The groyne extended the headland r about 50m.

vo control profiles were monitored over the next 5 years showing a positive action of the nstructed groyne to a certain extent. The locality plan and changes along the profile are own in Figure 27. The accretion can be seen 400m southward from the groyne. The al accretion of the sand for the 5 year period was 15,000m^3 or 3,000m^3/y. The extension the groyne should be considered to improve its effectiveness.

e theory of crenulate shaped bay could be used for recommended extension of the groyne achieve the dynamic stability of that region. That problem is at present analyzed as a d year student project at UCCQ.

CONCLUSIONS

Capricorn Coast has major potential for development . The problems of proper beach ection, prediction of future changes, verification of the buffer zone requirements are lems which have to be considered in the coastal engineering part of the coastal zone agement plan.

educe expected erosion, a seawall is still the solution most widely accepted by the nunity living along the vulnerable beaches. It can be a proper solution for dune on along a stable (stable considering a number of years) coastline but in eroding s sea defence cannot be applied without other measures. Usually, the depth before the all increases, the wave attack increases and as a result problems arise with the lity of the wall.

over, the beach itself will disappear with the additional harmful effects to the ational use of the seaside. In all of the cases discussed, this was confirmed by the l situation in the vicinity of the seawall. Therefore, the construction of a seawall as a ire to prevent further erosion should be avoided wherever possible.

ecommended solution must be replenishment of the dune formation. The necessary width and/or height can be computed and, its proper maintenance should be led. The Causeway/Kinka Beach solution is an example of proper dune ishment by sand nourishment, and of creation of a tidal lagoon.

term erosion problems occur due to gradients in the longshore sediment transport s. The proper approach to the solution of the problem is to alter the transport in the area to a constant value. With the disappearing of the gradient in the longshore ort, the erosion problem will not exist.

With increasing knowledge of coastal engineering, there is tendency to avoid the construction of groynes, seawalls, etc., wherever possible and solve the erosion problems by proper sand supply (nourishment). The headland control scheme is the other modern alternative of the solution.

One has to realize the extreme importance of the natural dune system, its improvement and its stabilization, if we do not want to live protected by the awful rubble–mound seawalls which only give the illusion of the safety. Nature is too powerful and man must cooperate with her. To forget about that or work against Nature is simply to invite disaster.

University College of Central Queensland (previously Capricornia Institute) has begun the long term study to investigate beach processes of selected beaches along the coast. It will be continued as a research and postgraduate study. It is expected that obtained results in the nearest future could help to find optimal, environmentally accepted solutions for local beaches protection and help to establish a coastal management plan for Capricornia Coast development.

9. ACKNOWLEDGEMENT

The problems of Causeway/Kinka Beach described in this paper are part of the study carried out for the Main Roads Department, Queensland. The Keppel Sands monitoring profiles were observed by the Livingstone Shire Council. The author wishes to thank both of them for the friendly co–operation. The views expressed in the paper are those of the author.

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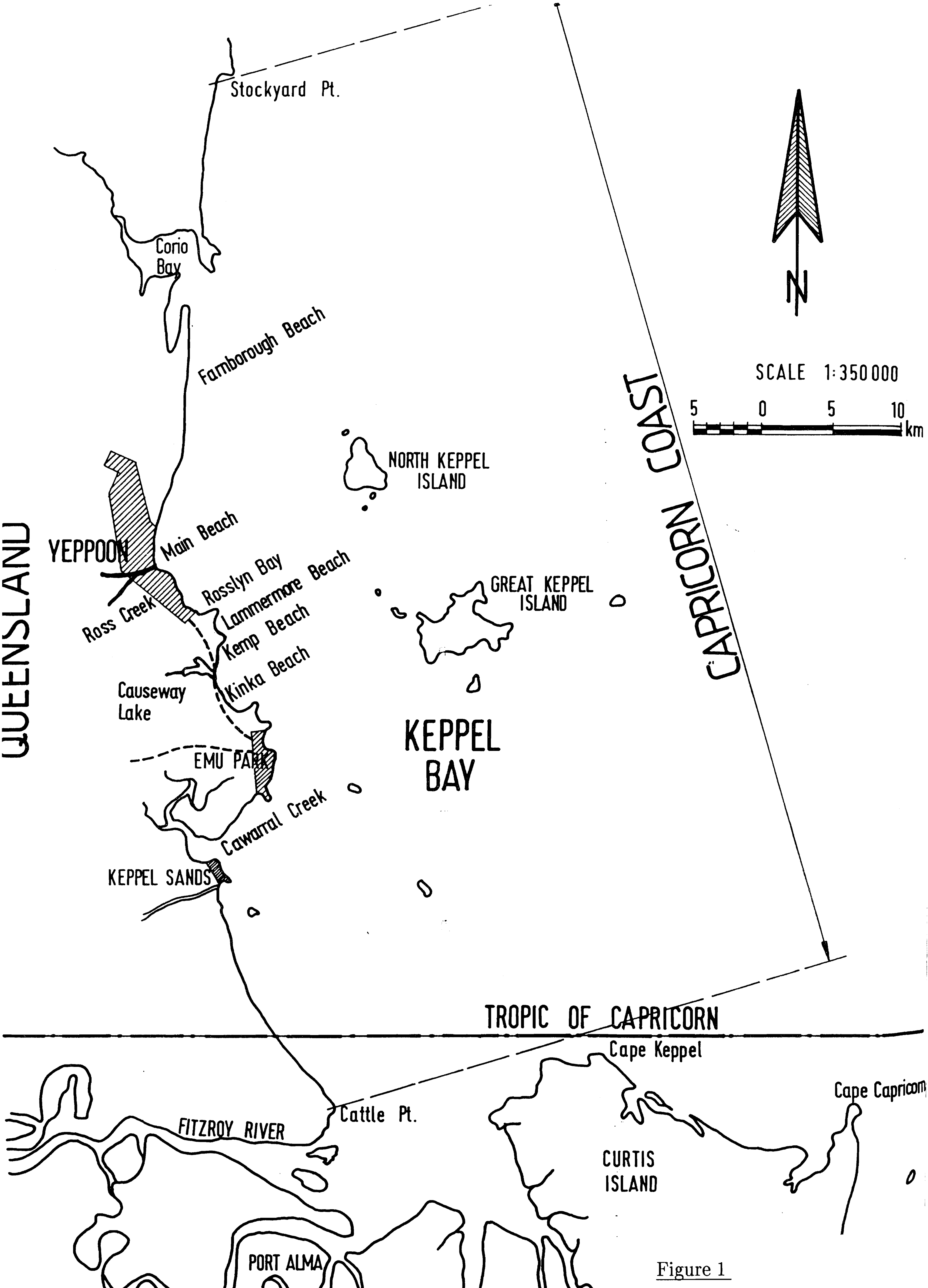

Figure 1

General Plan

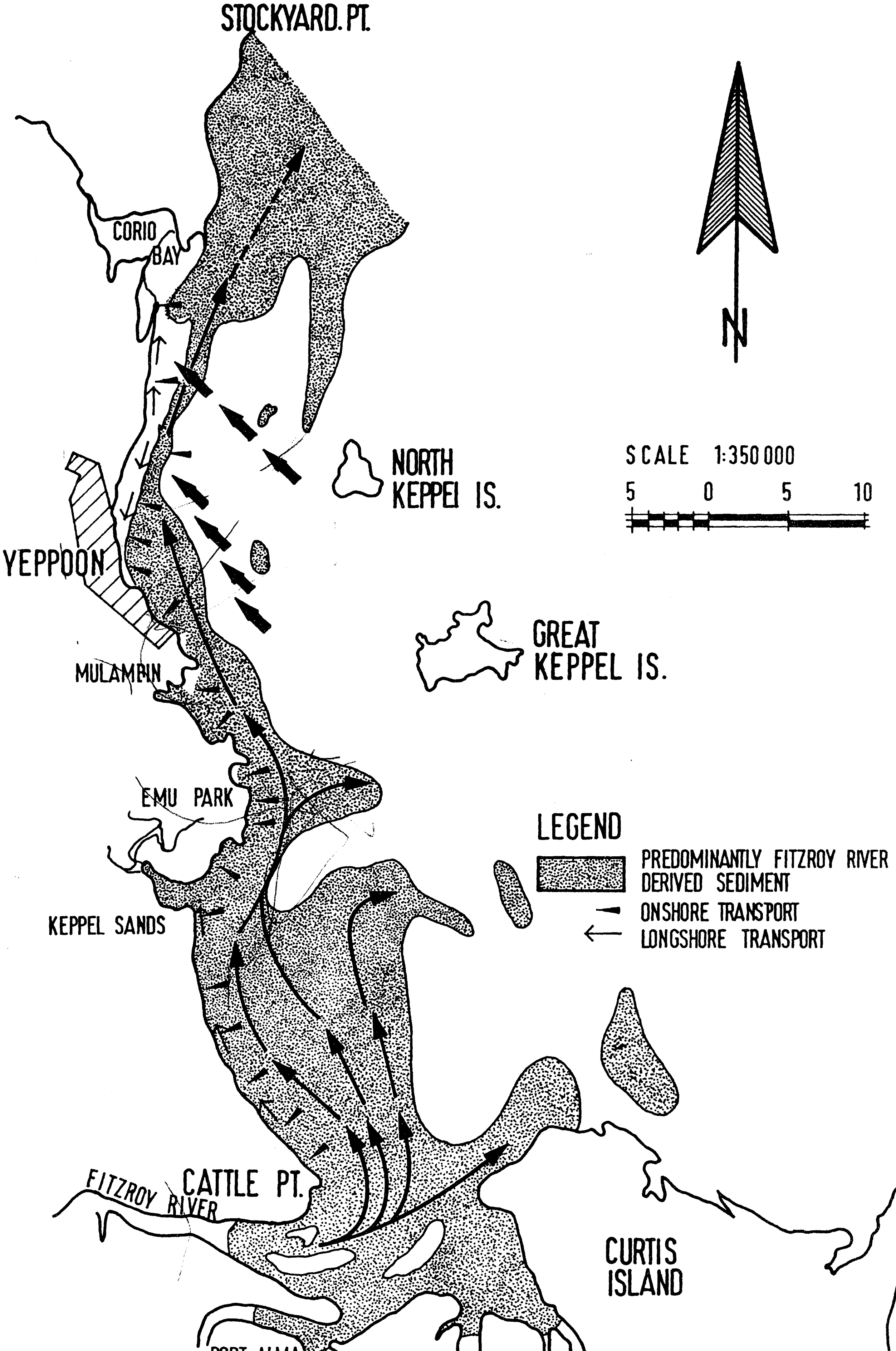

Figure 2

The zone of deposition and transport of sediment supplied from the Fitzroy River

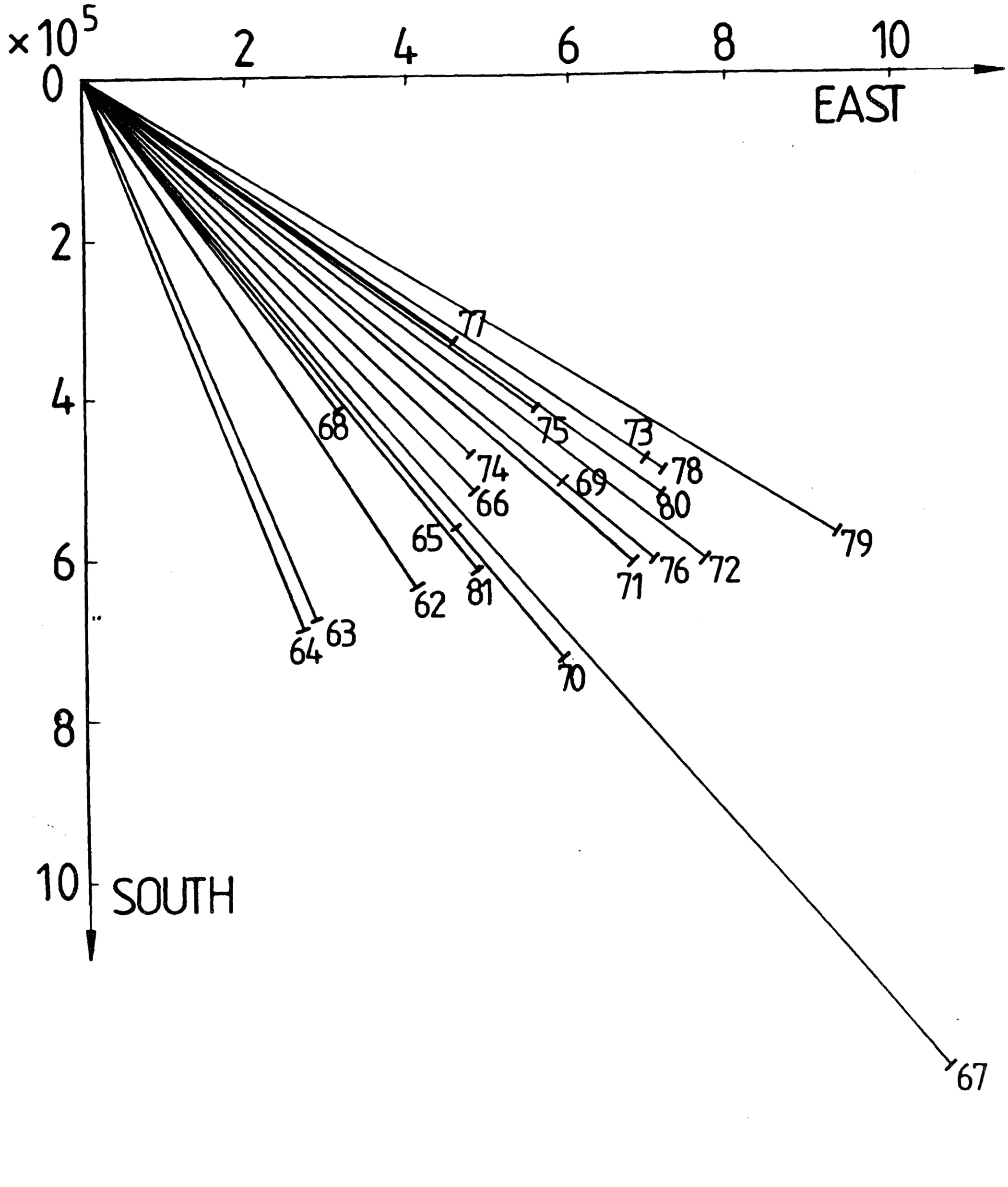

Figure 3

Annual wind energy vector calculated as Σv^3, where v is wind velocity in knots (after [8]).

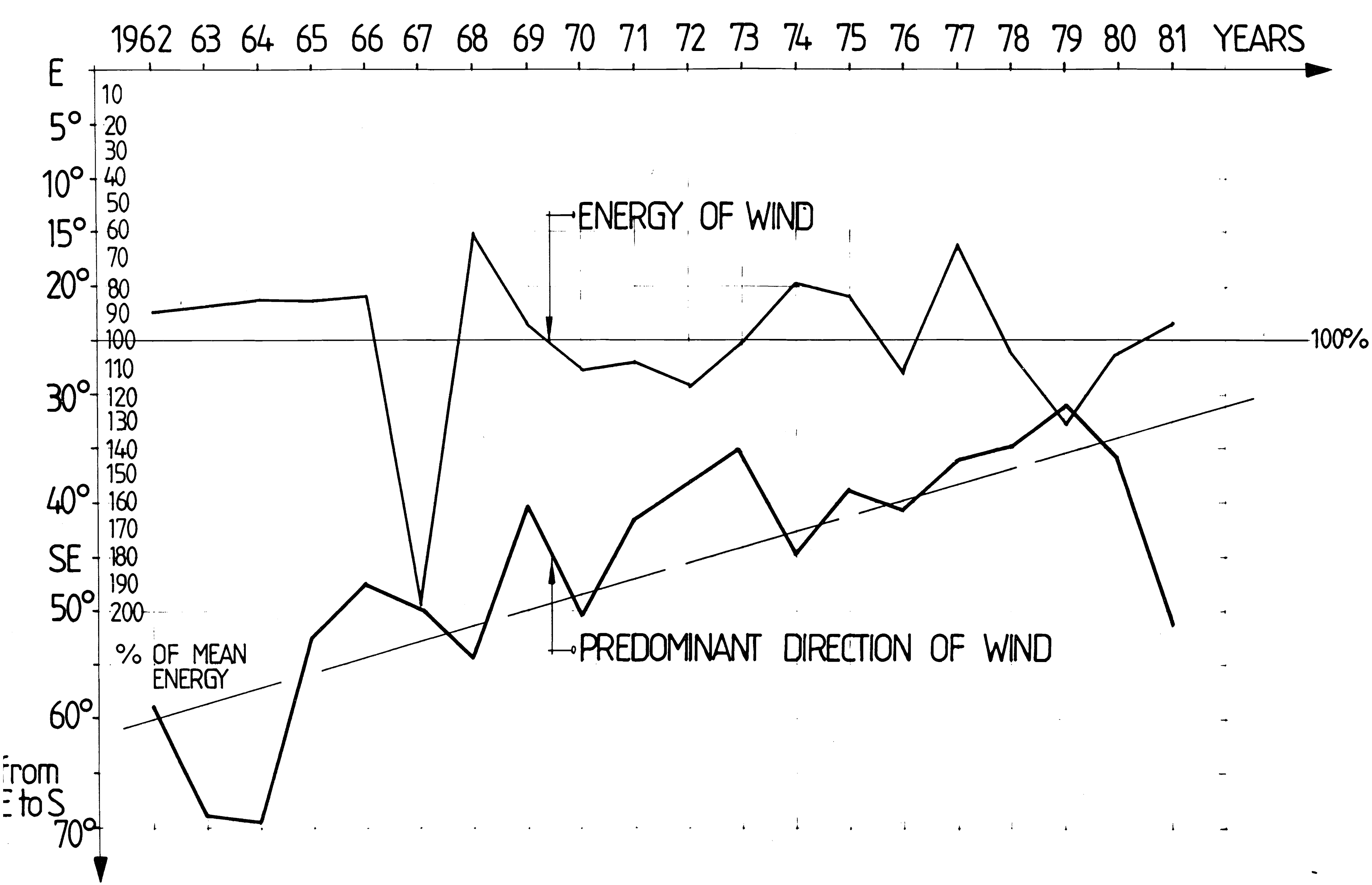

Figure 4

Changes of wind energy and predominate direction for the period 1962 – 1981.

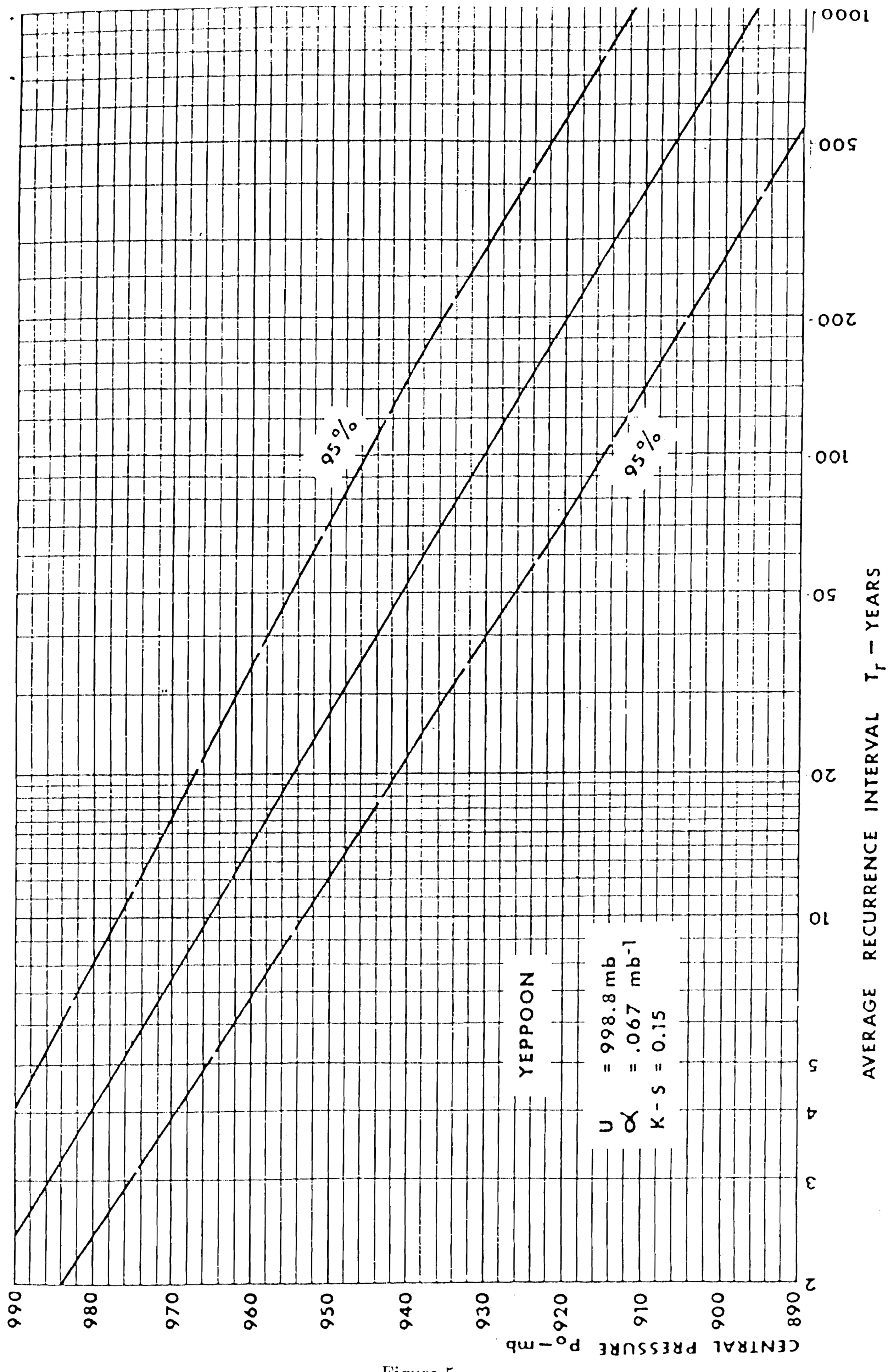

Figure 5

Central pressure – recurrence interval for Yeppoon

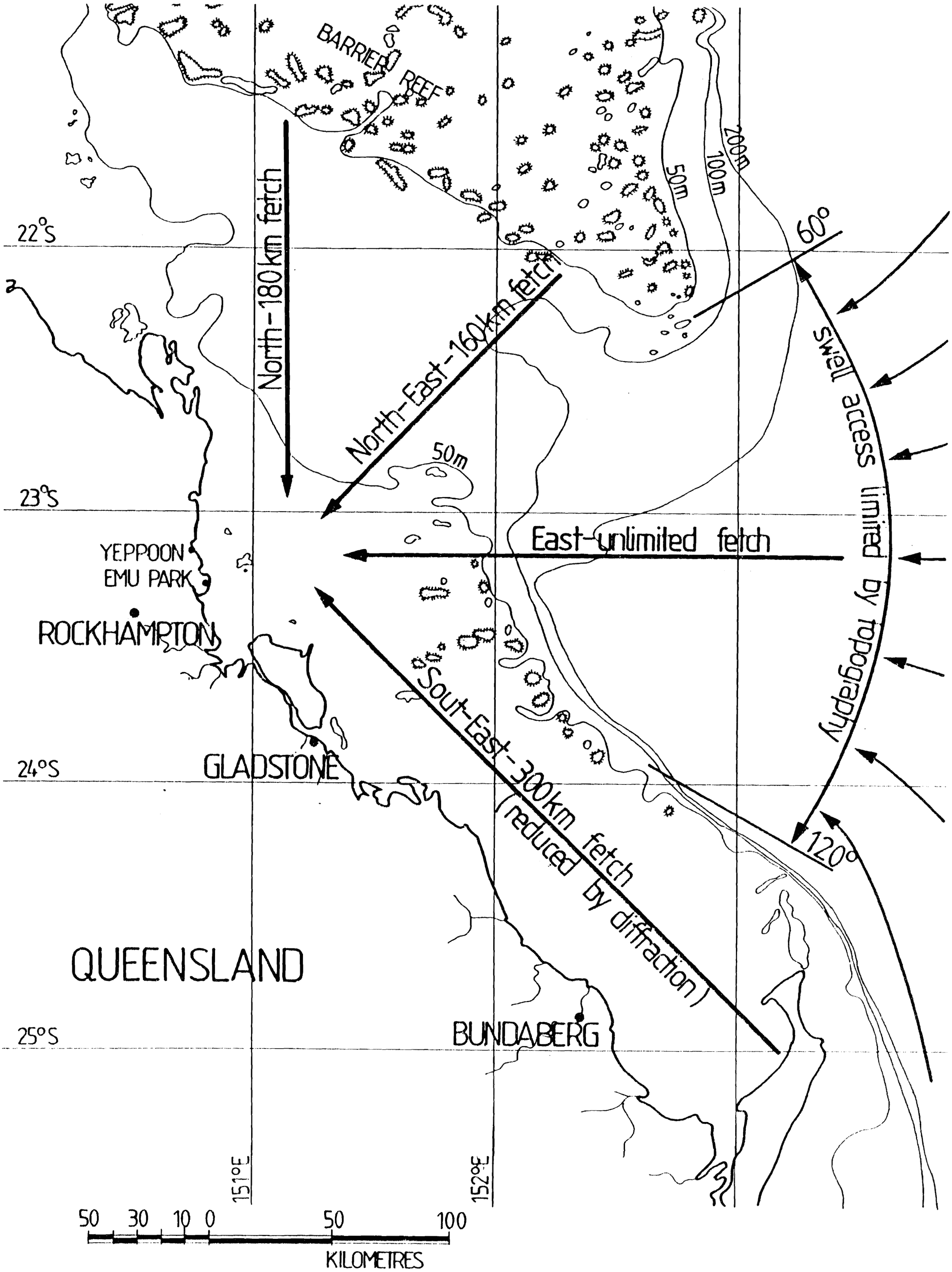

Figure 6

Available fetch for sea and swell reaching the Capricorn Coast (after [2]).

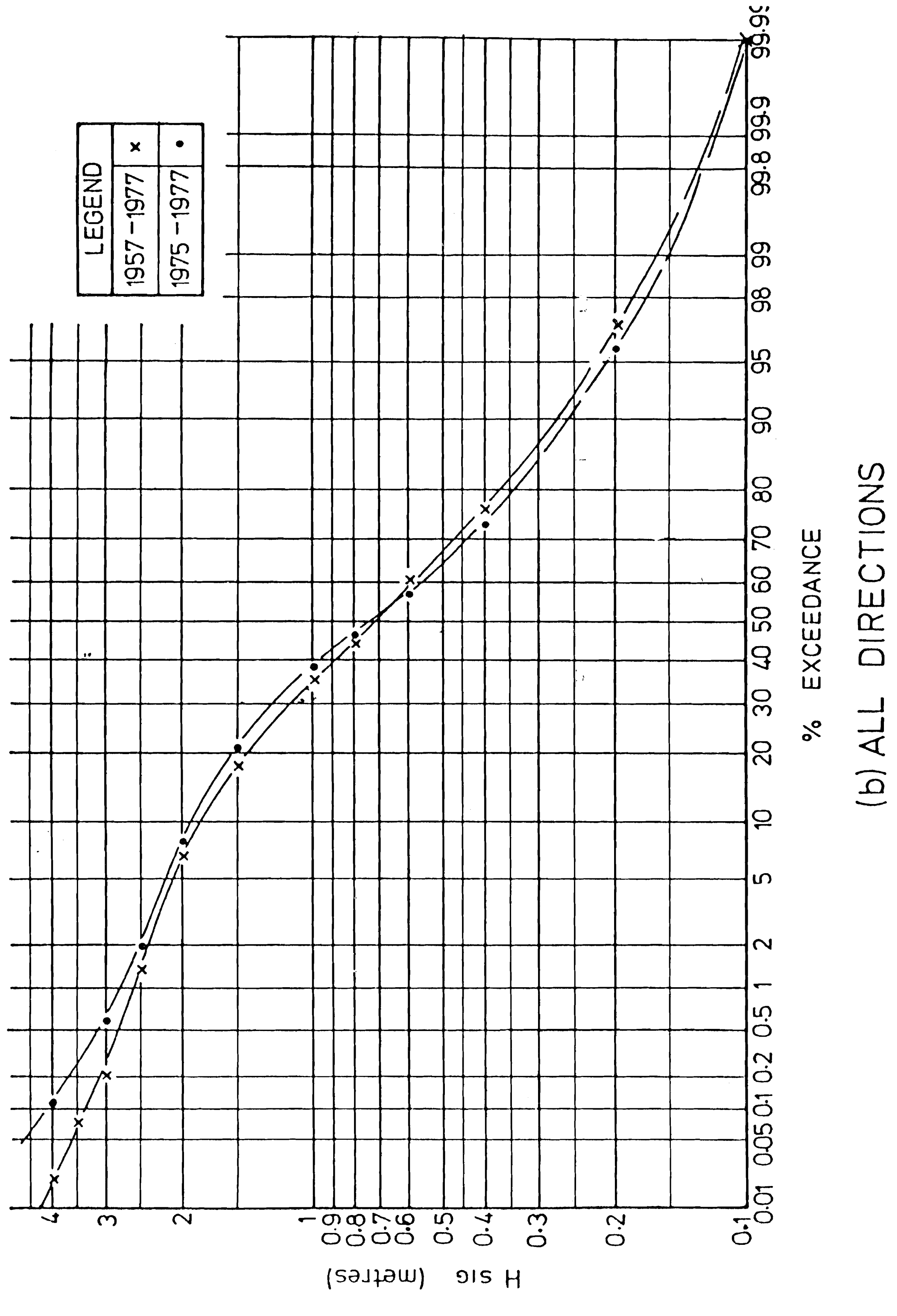

Figure 7

Hindcast wave height for Capricorn Coast (after [1]).

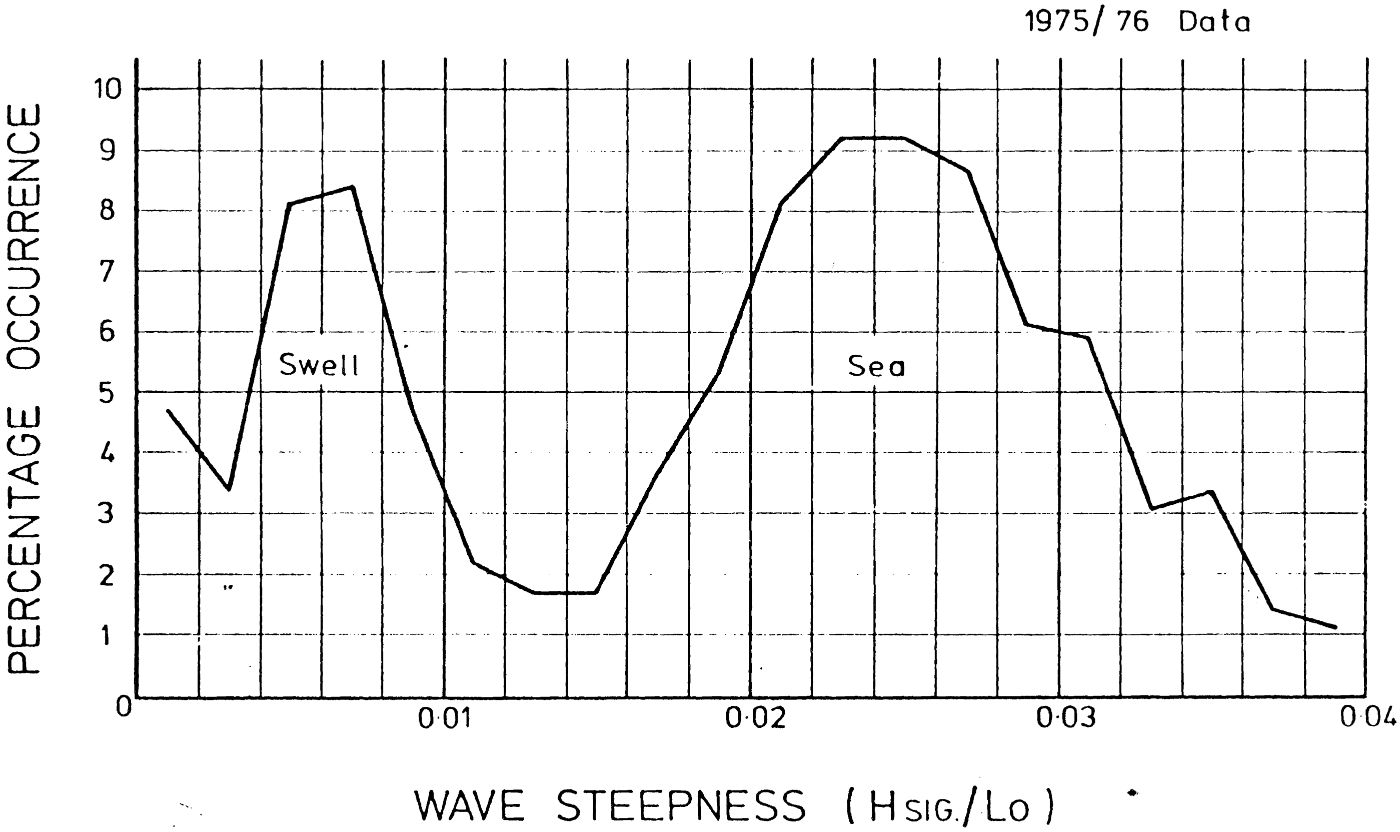

Figure 8

The percent occurrence of various wave steepness for Capricorn Coast (after [1]).

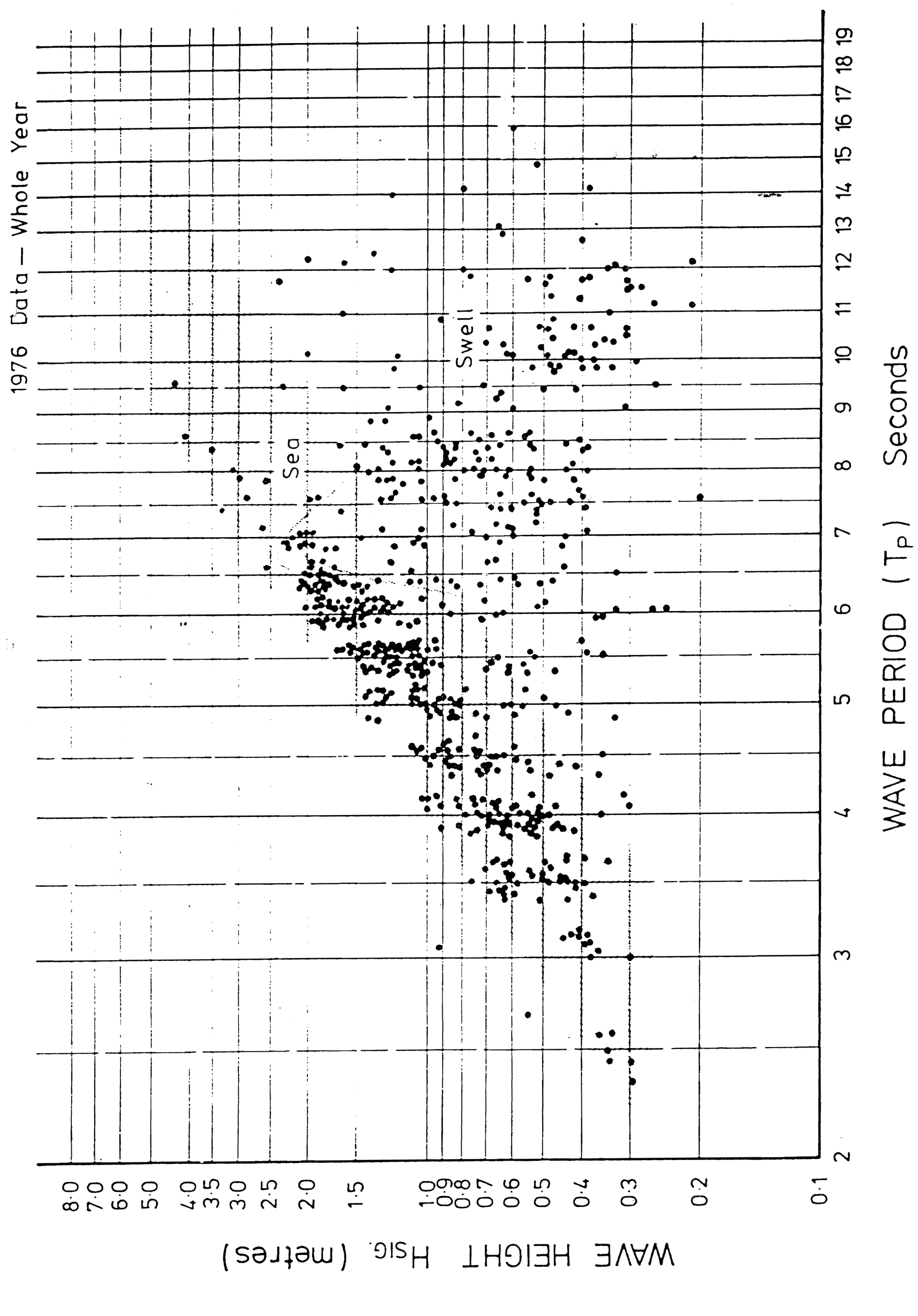

Figure 9

Relationship between wave height and wave period for Capricorn Coast (after [1]).

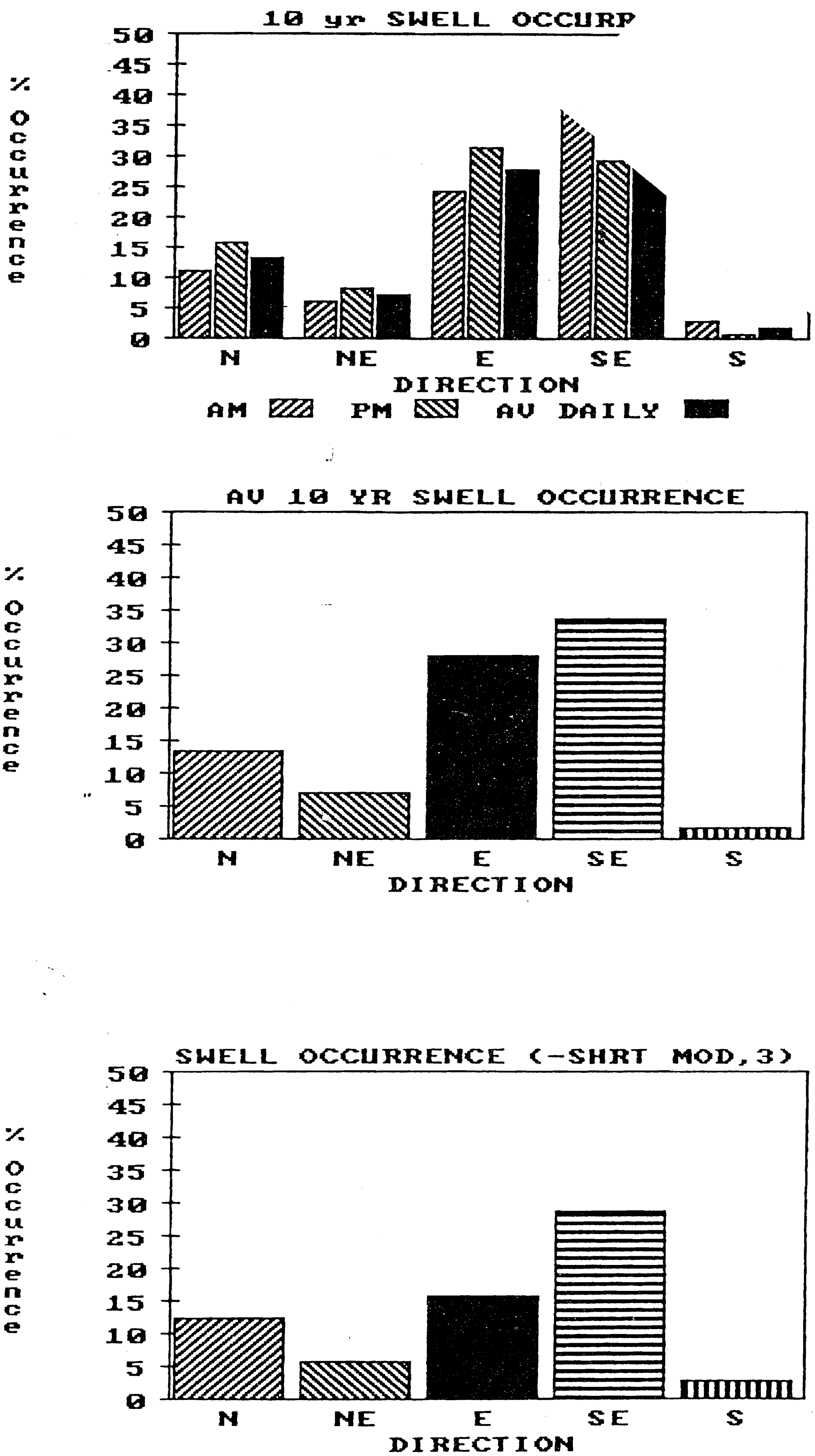

Figure 10

Average daily frequency of swell (after [17]).

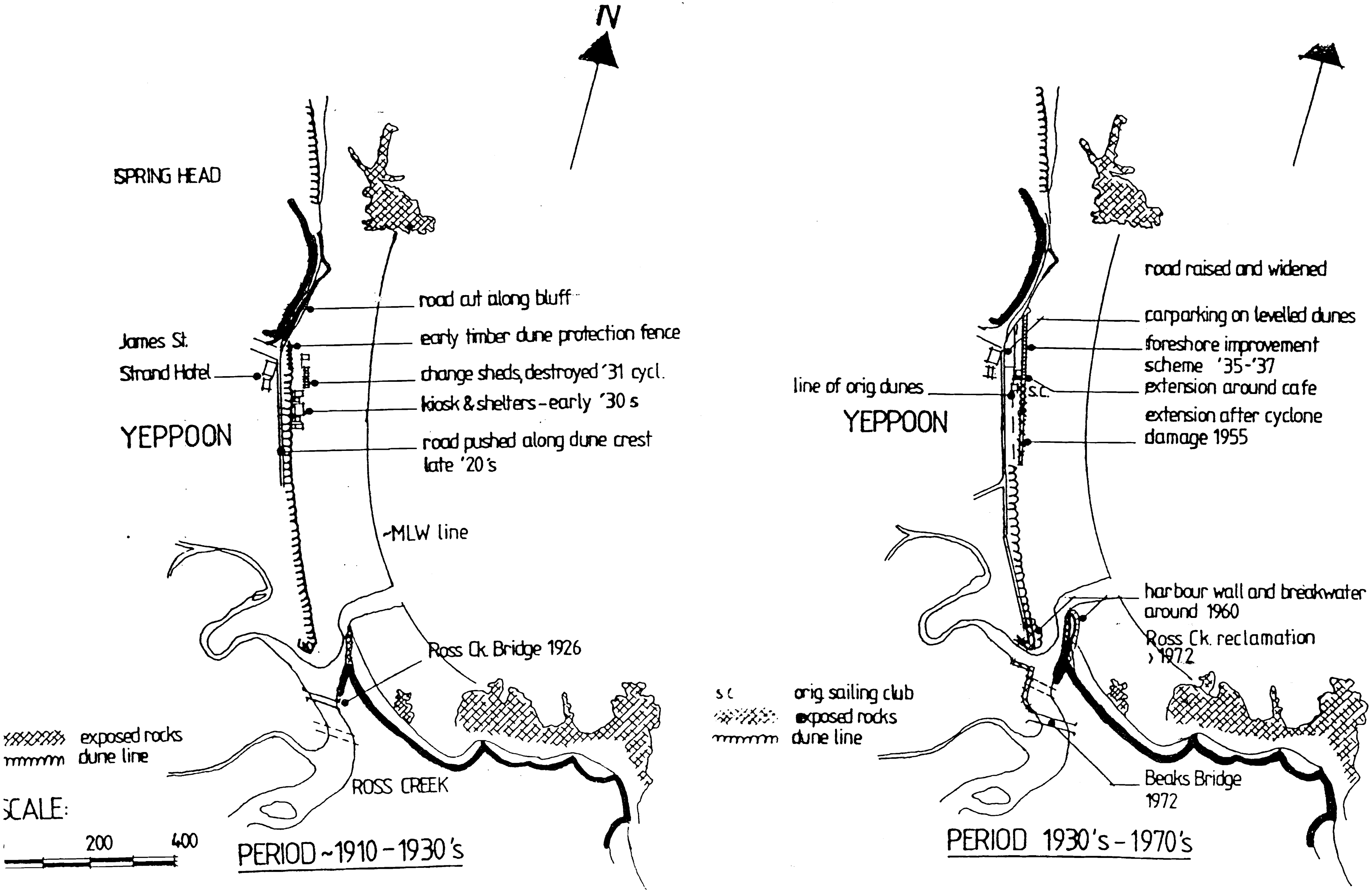

Figure 11

Human activities along Yeppoon Main Beach for the period 1910 – 1970 (after [17]).

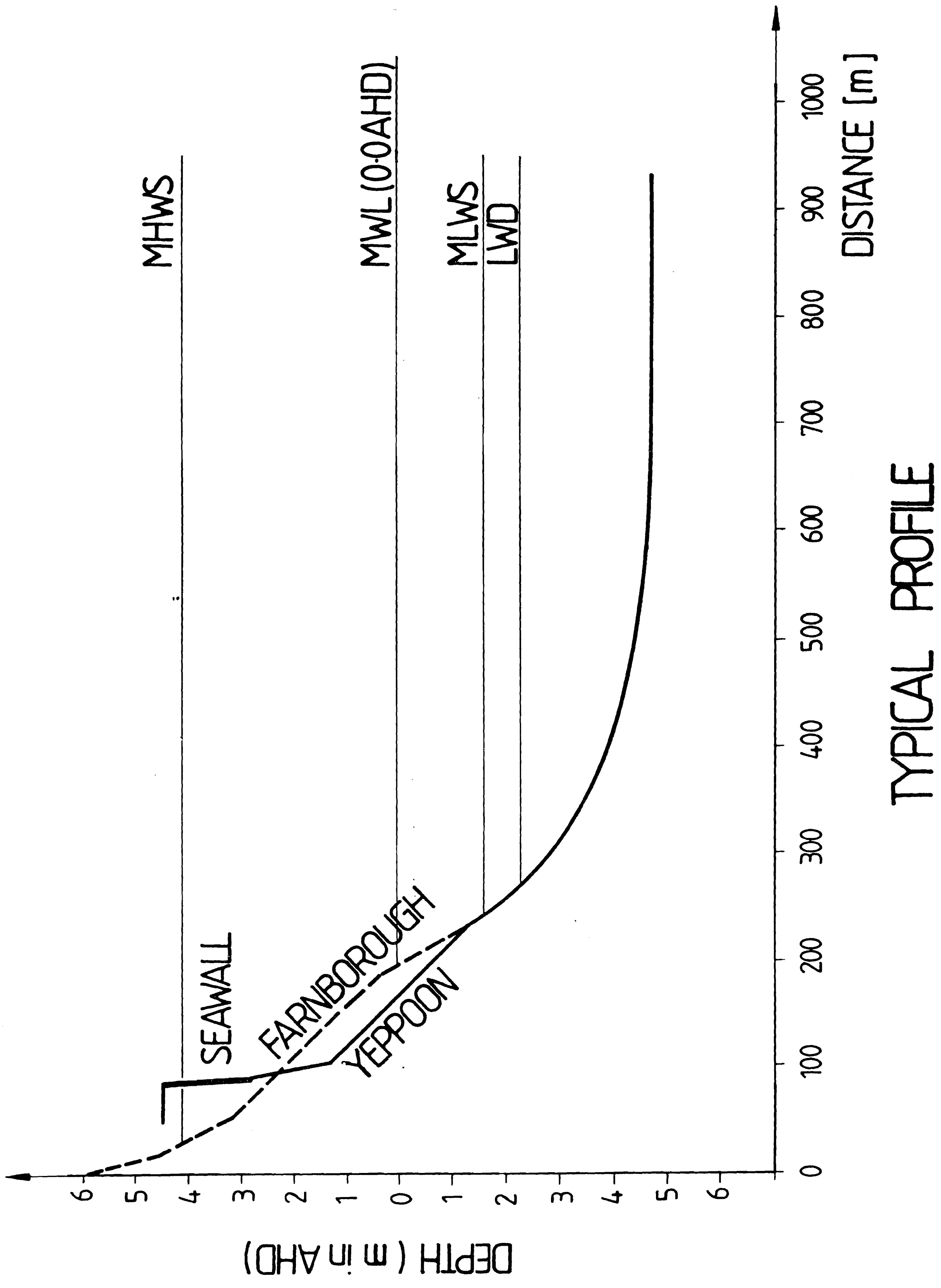

Figure 12

Typical profile of Yeppoon Main Beach.

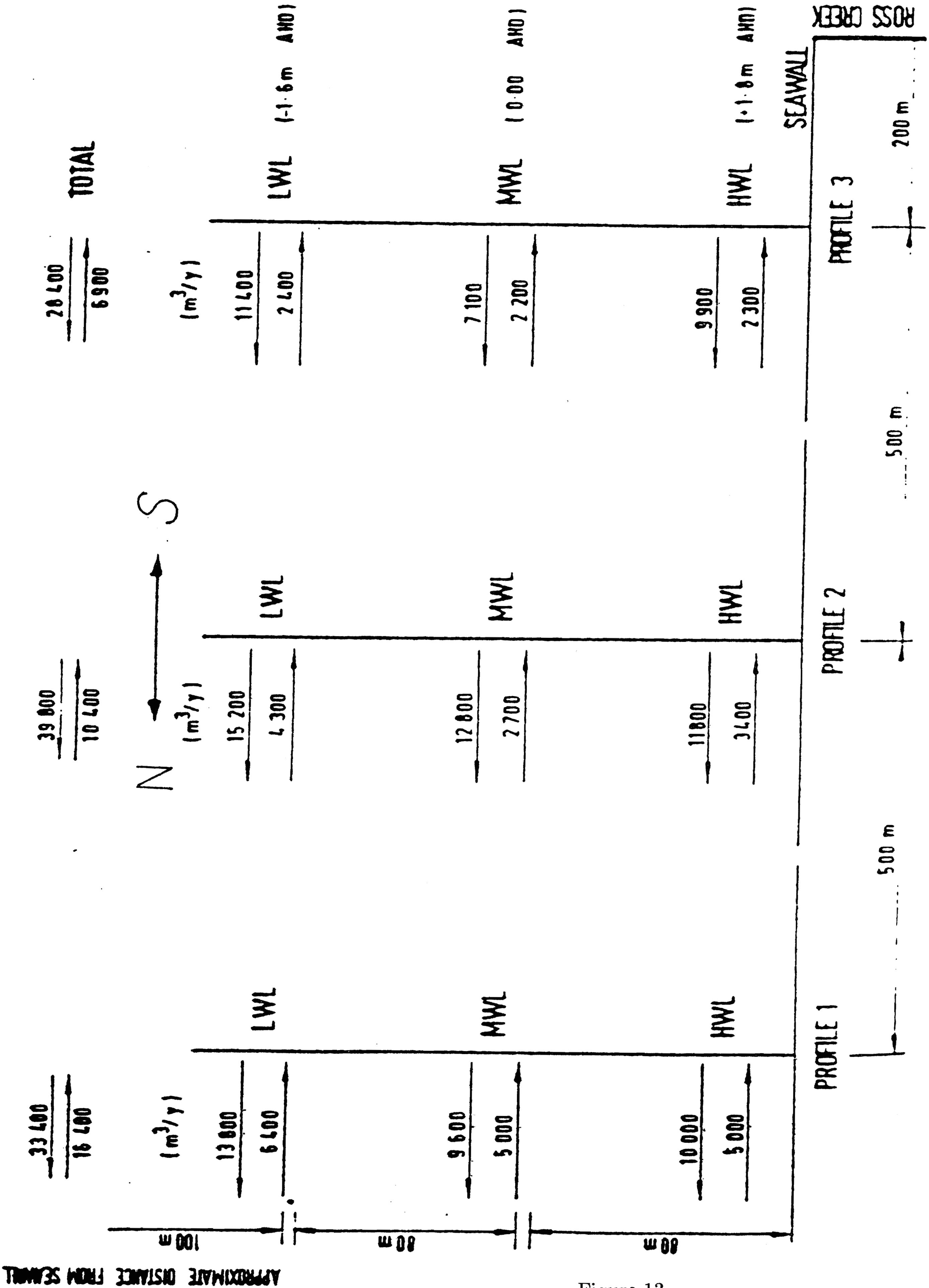

Figure 13

Longshore transport along the Yeppoon Main Beach.

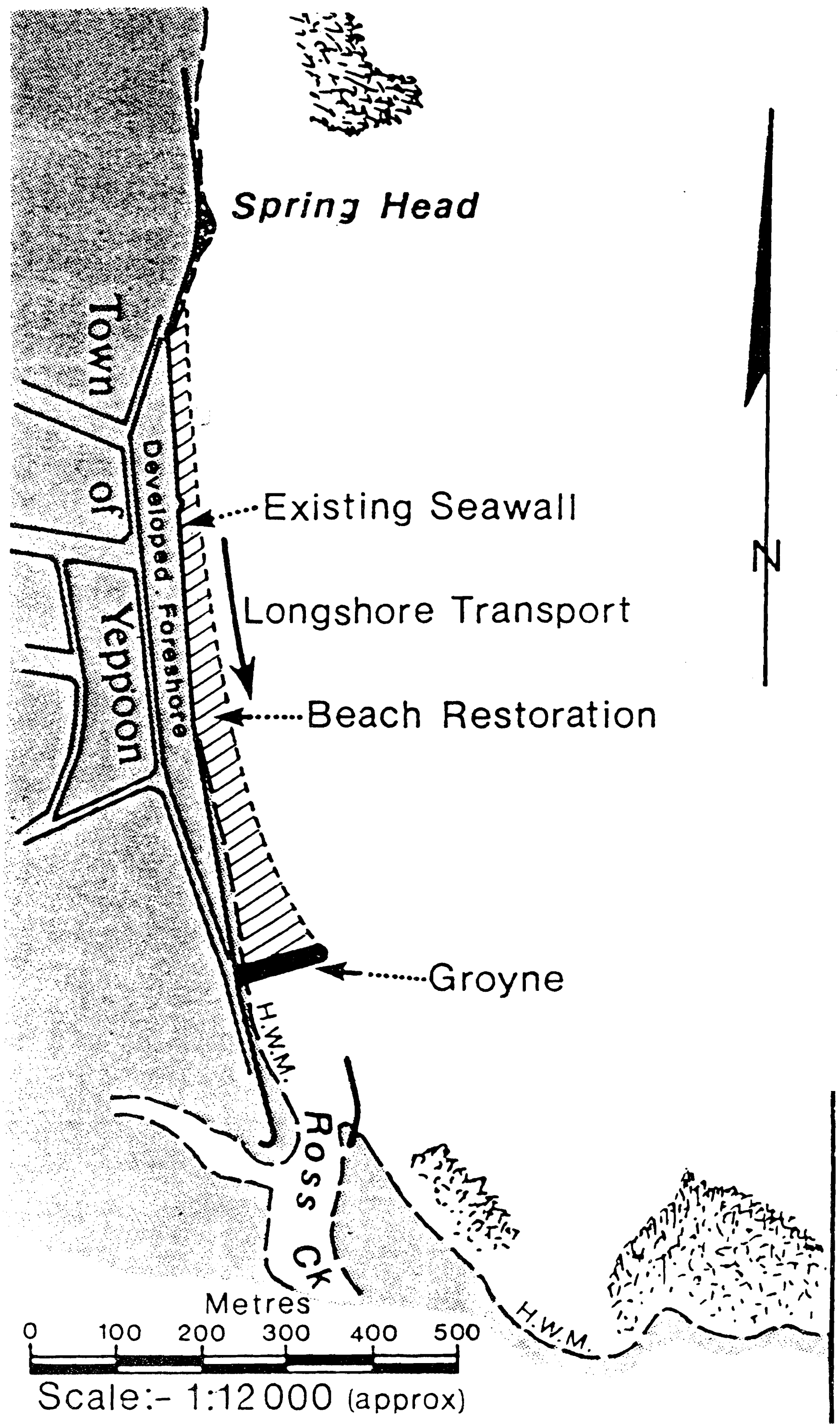

Figure 14

Recommended protection of the Yeppoon Main Beach by BPA (after [1]).

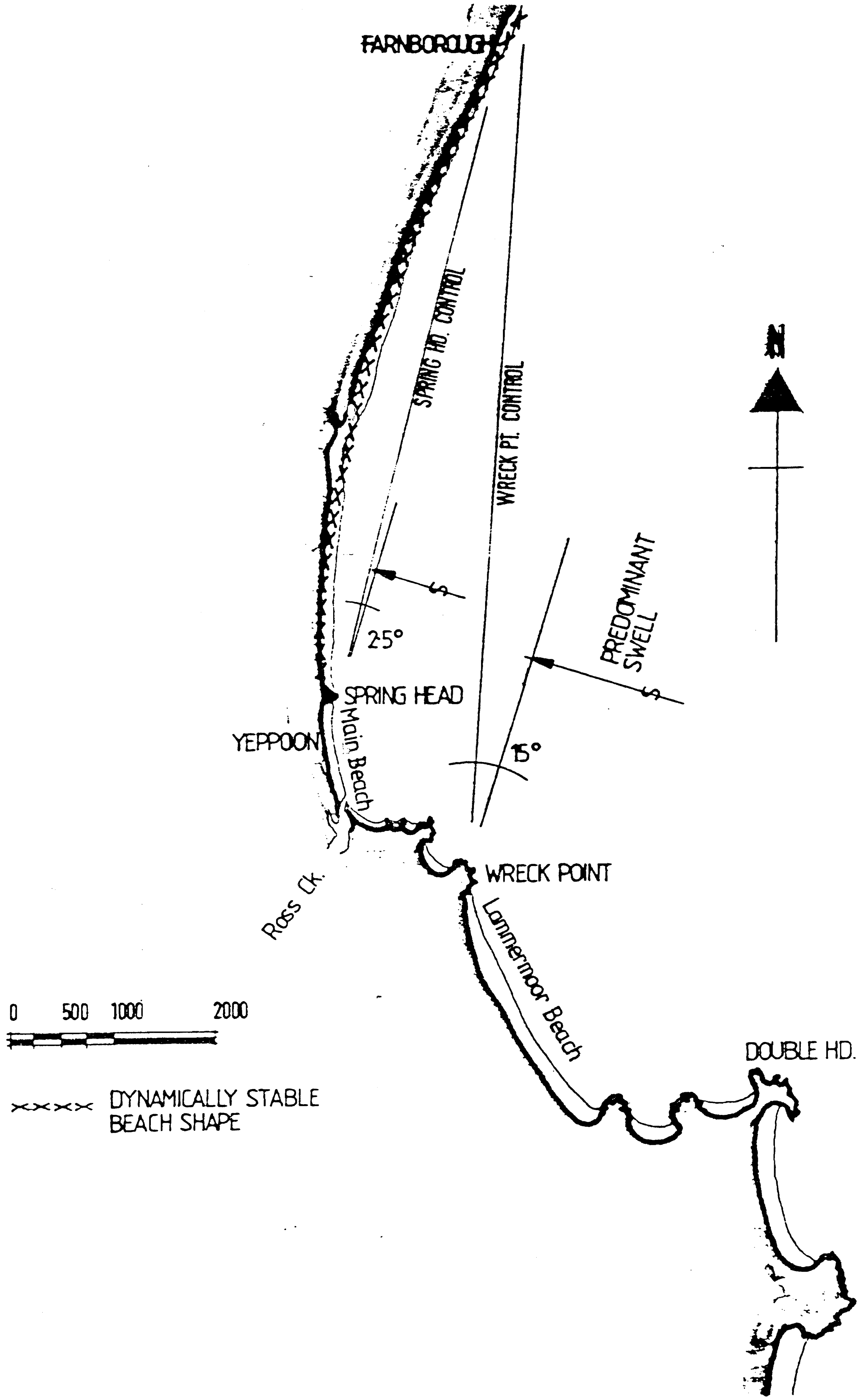

Figure 15

Theoretical prediction of crenulated shape of the Farnborough Beach (north from Yeppoon Main Beach).

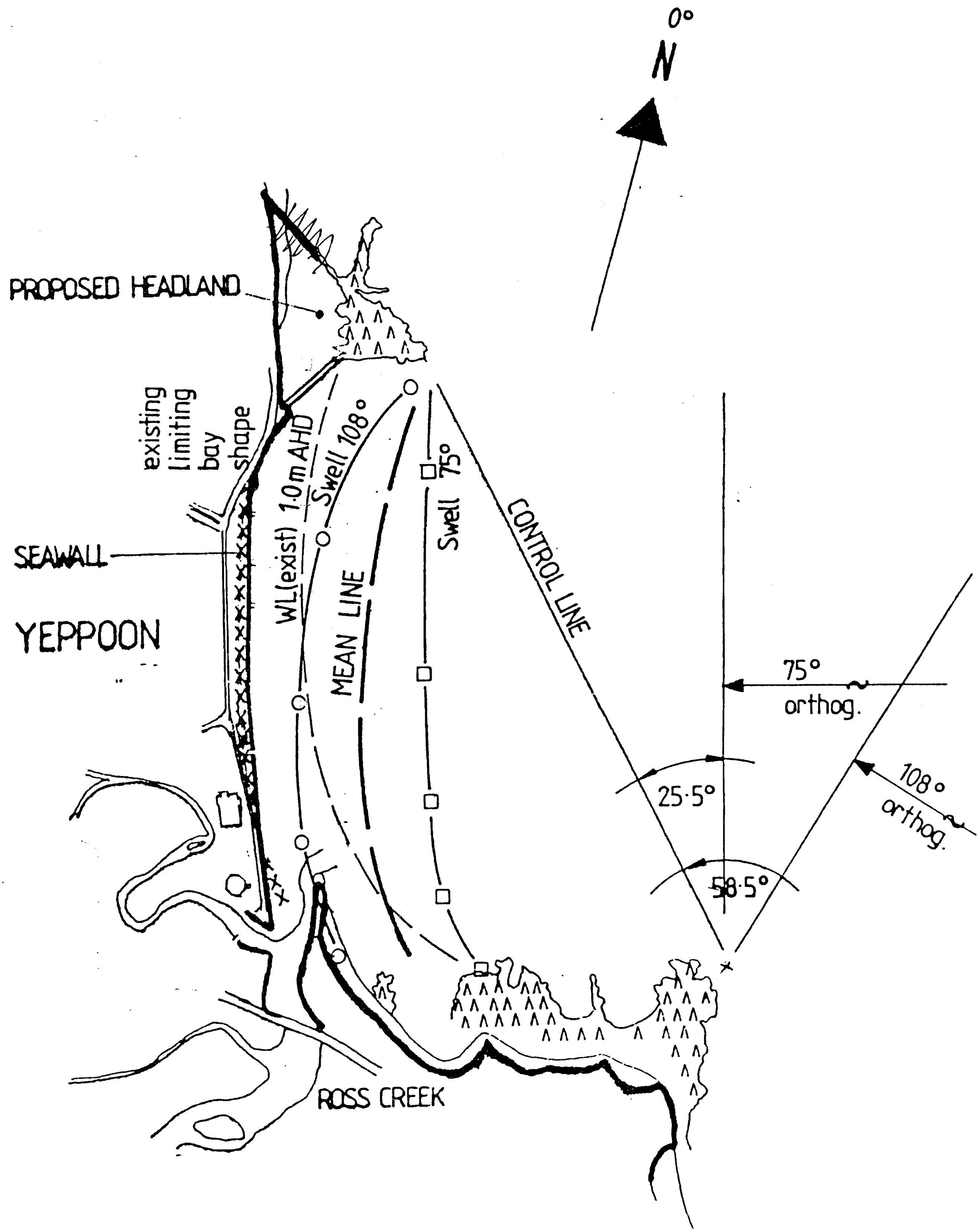

Figure 16

Proposed protection of the Yeppoon Main Beach by creating headland.

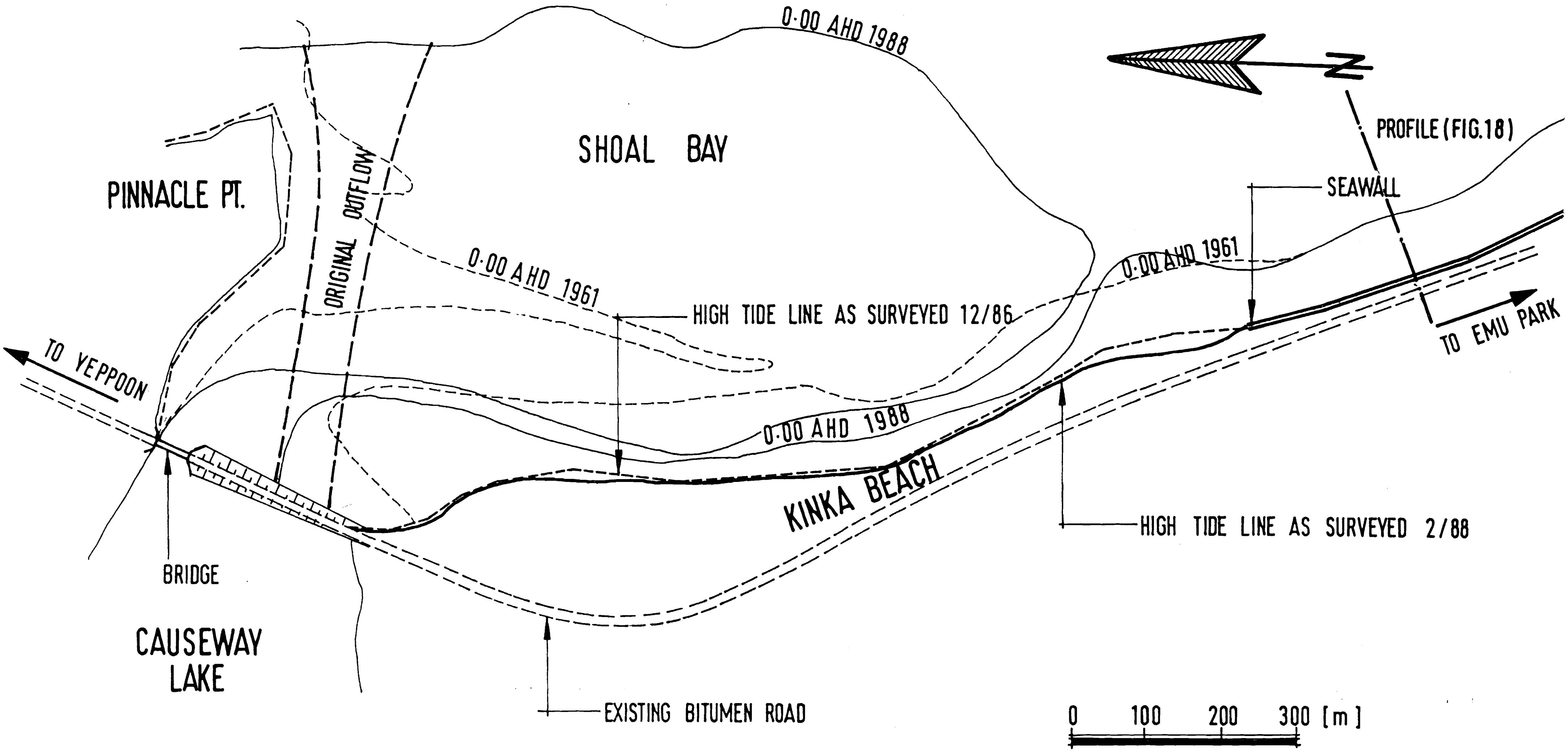

Figure 17

Kinka Beach erosion between 1961 – 1988.

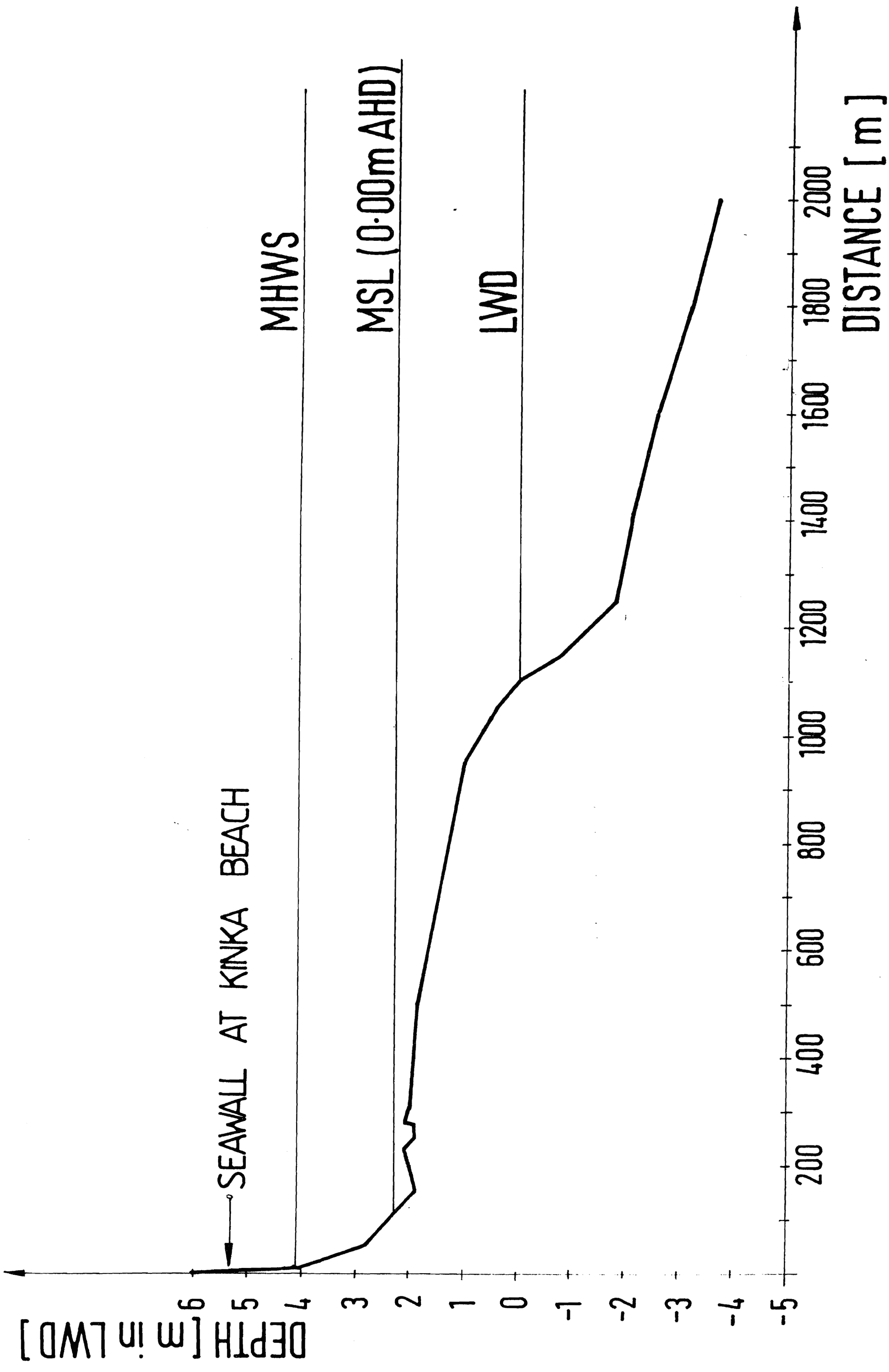

Figure 18

Typical profile at Kinka Beach.

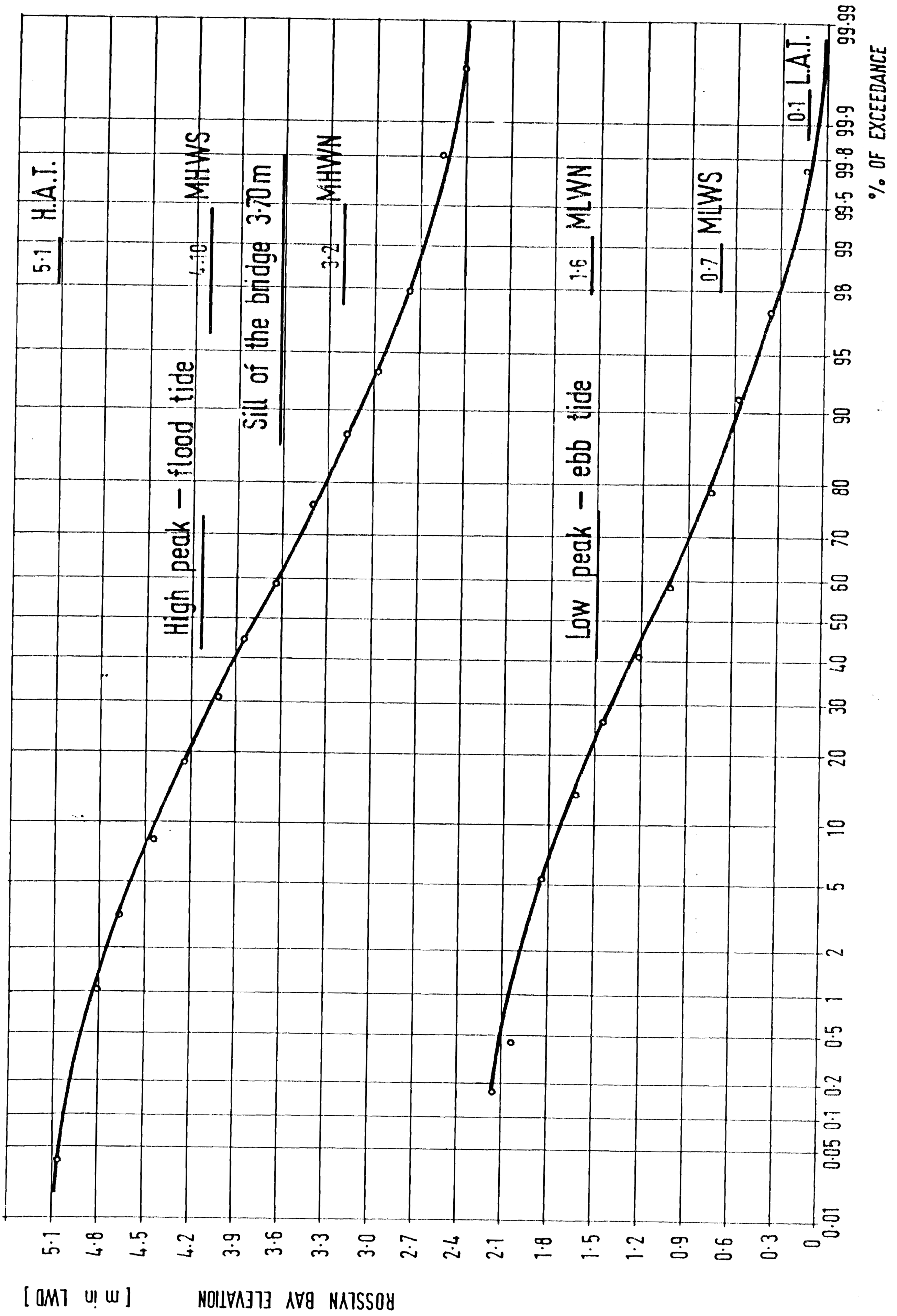

Figure 19

Probability of exceedance of high and low tide in the vicinity of Kinka Beach.

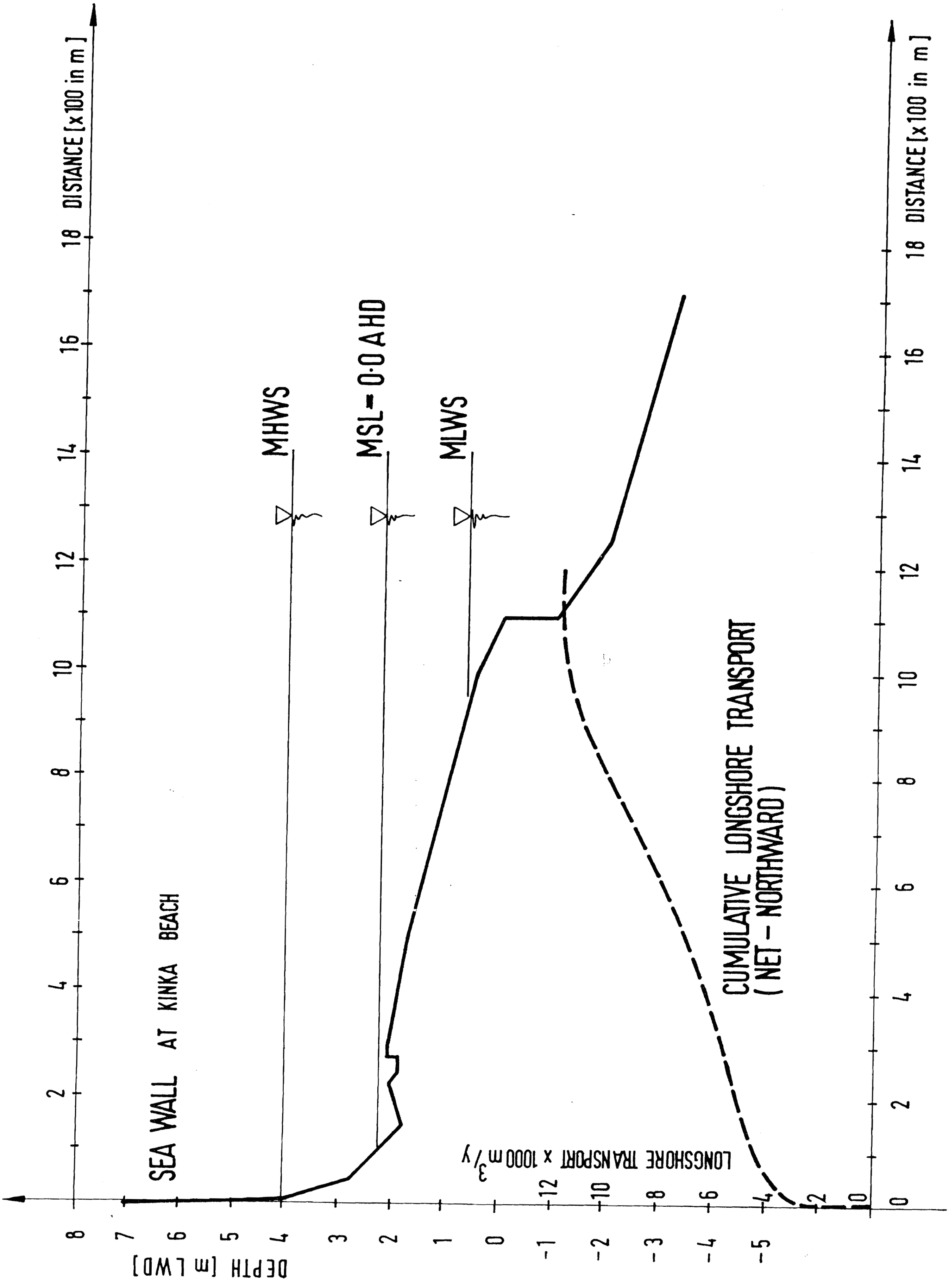

Figure 20

Cumulative curve of the longshore transport at Kinka Beach.

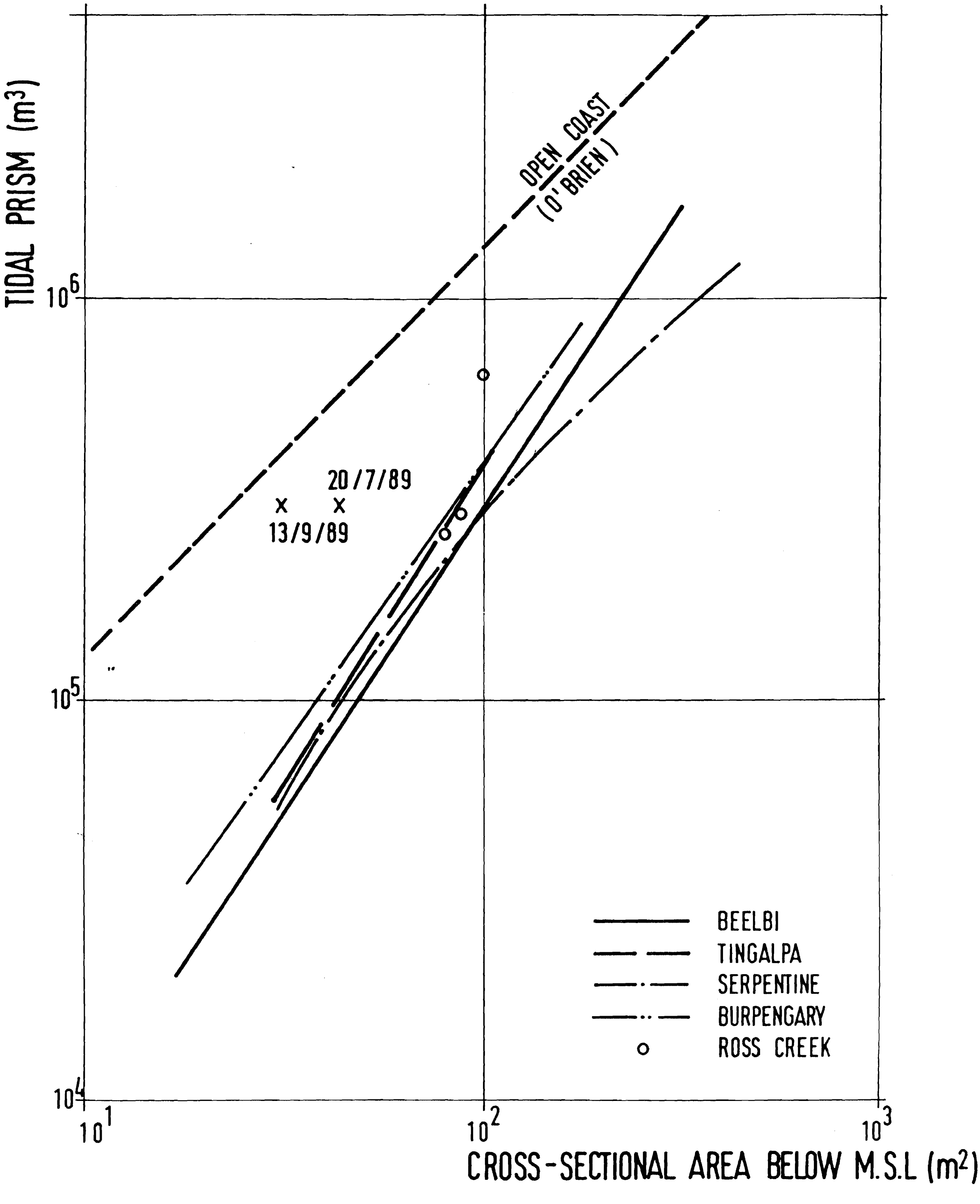

Figure 21

Tidal prism – cross–sectional relation for inlets
along the Queensland Coast
(x – measurements taken for Causeway Lake output) (after [16]).

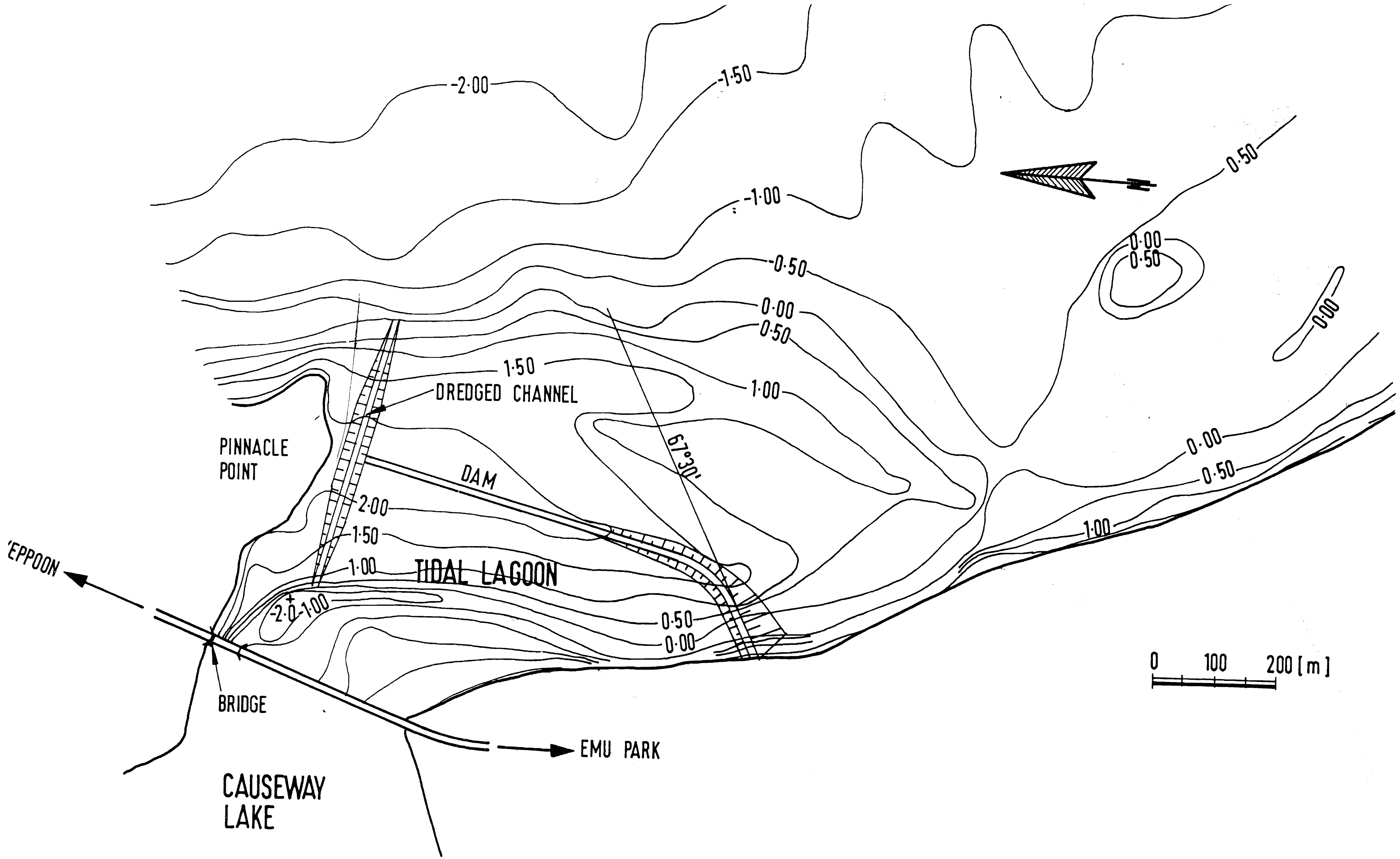

Figure 22

Proposed tidal lagoon to stabilize Kinka Beach erosion

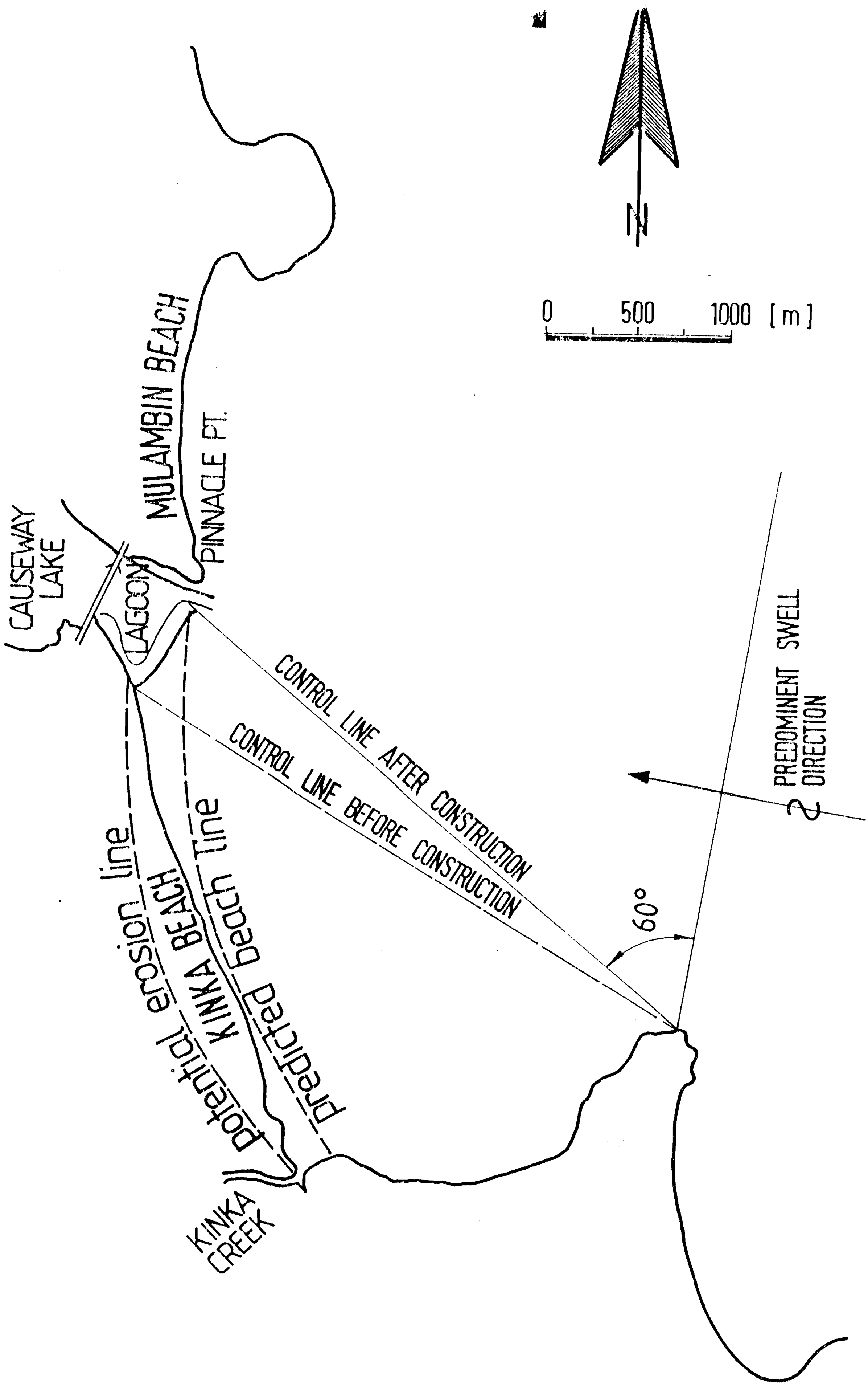

Figure 23
Predicted crenulated shape at Kinka Beach

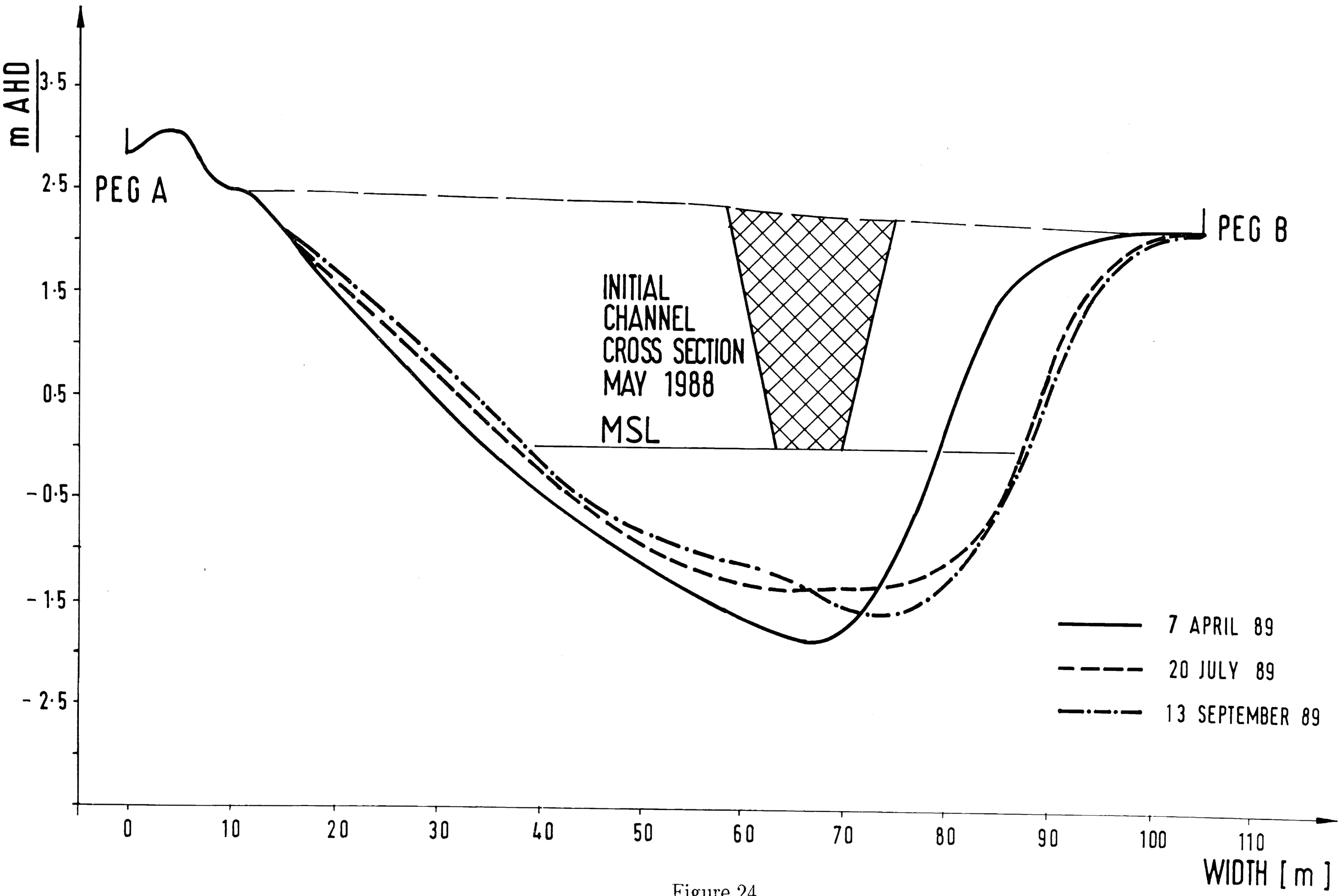

Figure 24
Changes in output dredged sand after its excavation.

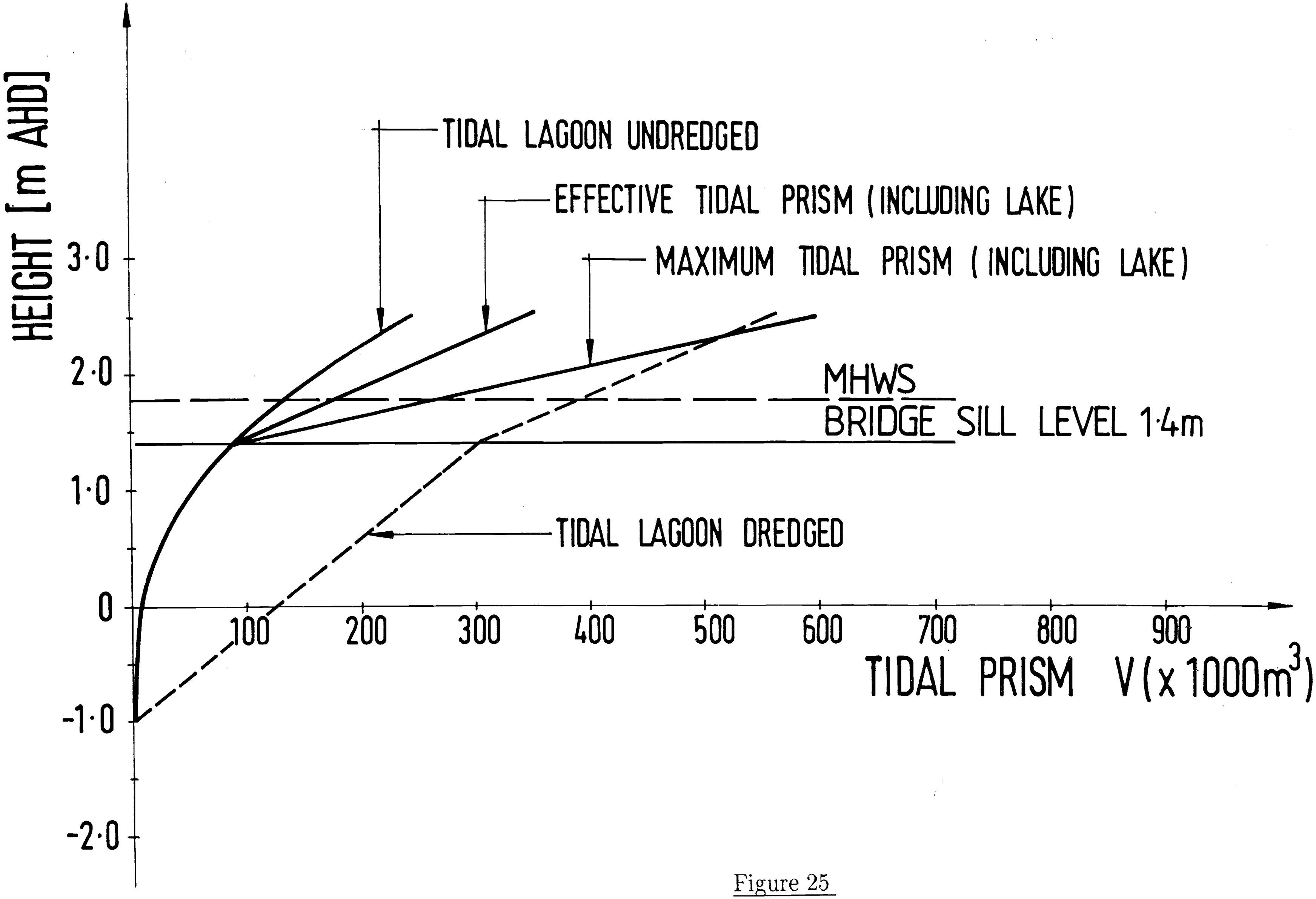

Figure 25

Changes to tidal prism connnected with tidal lagoon creation

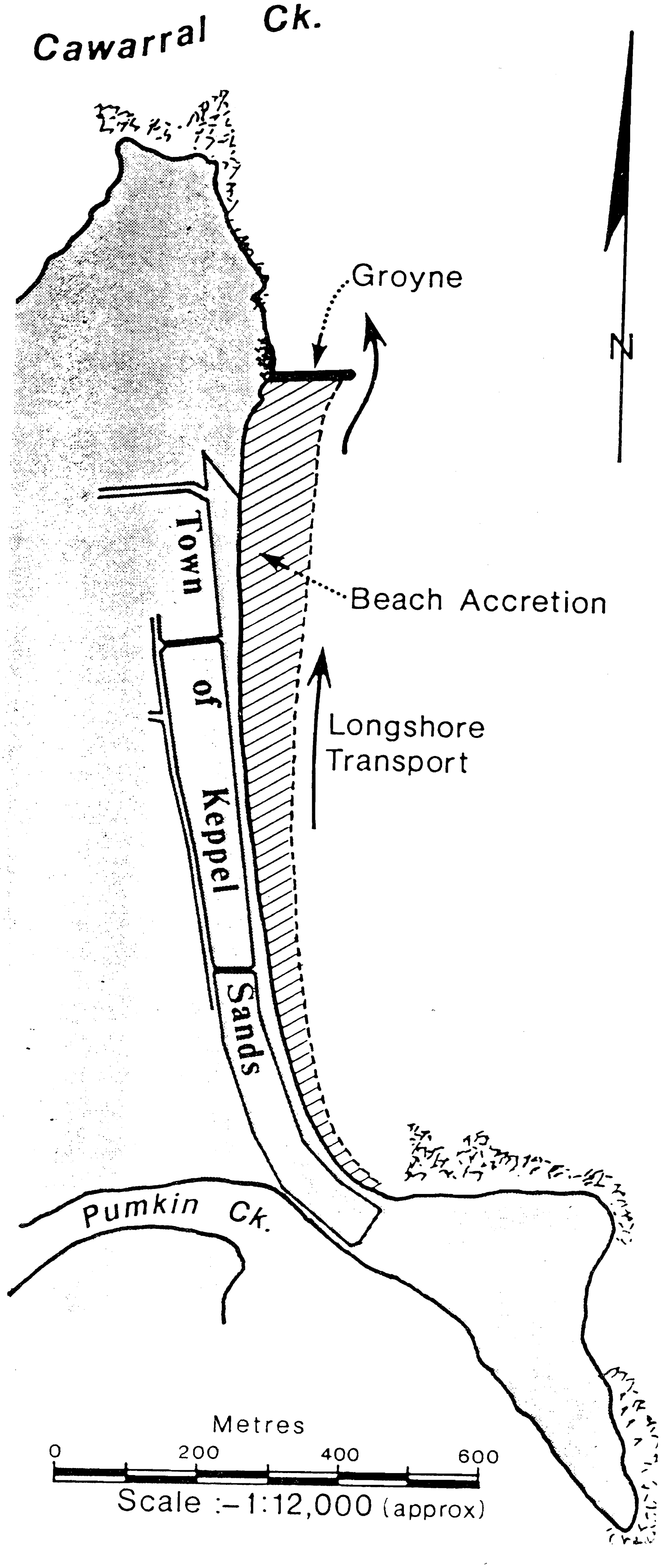

Figure 26

Recommended protection of Keppel Sands Beach by BPA (after [1])

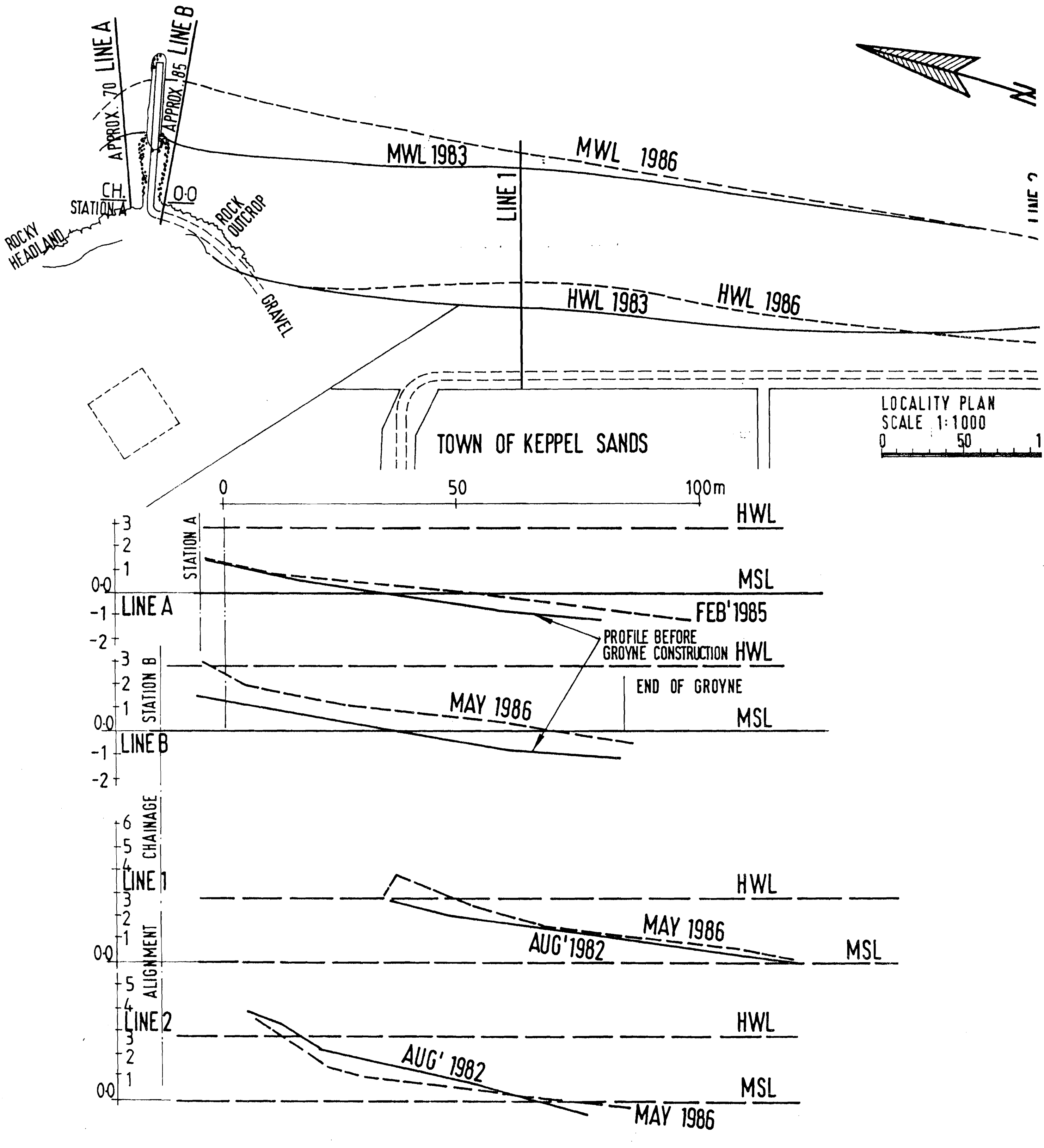

Figure 27

Observed changes to the Keppel Sands Beach