I.O.S.

CONTAINS FOLDOUT FIGURES

# SWANSEA BAY (SKER) PROJECT

## TOPIC REPORT : 2

# EVIDENCE FOR BEACH STABILITY : PHOTOGRAMMETRIC AND TOPOGRAPHIC MEASUREMENTS

M.W.L. BLACKLEY AND A.P. CARR

REPORT NO 51

1977

This project is supported financially by the Department of the Environment

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Institute of Oceanographic Sciences
Crossways
Taunton
Somerset

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Professor H. Charnock)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051-653-8633)

(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823-86211)

(Assistant Director: M. J. Tucker)

Marine Scientific Equipment Service
Research Vessel Base,
No. 1 Dock.
Barry,
South Glamorgan, CF6 6UZ.
(0446-737451)
(Officer-in-Charge: Dr. L. M. Skinner)

SWANSEA BAY (SKER) PROJECT

TOPIC REPORT : 2

# EVIDENCE FOR BEACH STABILITY : PHOTOGRAMMETRIC AND TOPOGRAPHIC MEASUREMENTS

M W L Blackley and A P Carr

REPORT NO 51

1977

This project is supported financially by the Department of the Environment

Institute of Oceanographic Sciences
Crossway
Taunton
Somerset

October 1977

CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF FIGURES

SUMMARY

This Report is the second in the topic series concerning Swansea Bay. It discusses evidence for recent elevational changes affecting the beaches along the eastern shore of the Bay between the River Neath and Sker Point. The two principal sources are maps derived from aerial photography carried out in 1968, 1970 and 1975, and beach sections levelled at monthly intervals between September/October 1975 and April/May 1977. This information is put in an overall context.

The map evidence, which is restricted to the beaches S of the Port Talbot tidal harbour, shows that peat and clay exposures increased between 1968 and 1970 and again between 1970 and 1975, although some areas (south of the tidal harbour and around the River Kenfig) remained free throughout. In the central area of Kenfig Beach patches of cobbles became far more conspicuous. Little movement of the contours was detected on Margam Beach between 1968 and 1970. During the same period on Kenfig Beach, however, the contour spacing near low water mark was reduced indicating a steepening of the beach there. Both beaches tended to erode between 1970 and 1975 but this was concentrated at mid-tide level.

The extremes shown by the beach profiles usually occurred during the winter months. The stability of the beaches appeared to decrease (ie the extreme recorded height range increased) from N to S. Data recorded from section Q showed that there was a close correlation between the packing density of the sand and the beach height changes.

In general most of the overall change in beach volume from month to month was accounted for by movement of material over the upper beach face. The lower beach tended to follow the erosional or accretional pattern of the upper beach but to a lesser extent. Volume change calculations showed that although some individual sections underwent large gains or losses of material from month to month, the net imbalance over the whole shoreline was small. Although Margam Beach showed the greatest variability of erosion and accretion, maximum losses over the 18 month period were recorded on the Kenfig Beach. They were greatest on Section Z where the loss of material was equivalent to the whole profile being lowered by 21 cm. A re-survey of the beach profiles in October 1977, ie after two complete years, showed the effects of summer accretion around the River Kenfig, and erosion on Margam Beach near a new pipeline. Otherwise, previous trends continued.

Future work will include correlations of the recorded beach changes with wave energy and meteorological conditions over the period. These will be discussed in a subsequent Report.

# 1. INTRODUCTION

1.1 Preface. This is the second in a series of Topic Reports concerning specific aspects of the work undertaken by the Institute of Oceanographic Sciences in Swansea Bay. The first Topic Report (IOS Report 42/77) provided an Introduction describing the Institute's involvement in the area, and events culminating in a Public Inquiry held in 1973. Thereafter it outlined the general geology and topography and discussed the documentary evidence for the evolution of the area especially that of the eastern side of the bay. However, information derived from maps produced from pre-1973 aerial photography was specifically omitted from the study in order that it might be included here.

Thus the purpose of the present report is to describe the maps produced from aerial photography - both pre- and post-Inquiry - and the series of monthly levelling surveys undertaken mainly between September 1975 and May 1977. From these data, volumes of material gained and lost from the exposed part of the beach are calculated. Figure 1 shows the boundaries of the air photo surveys, the location of the 11, latterly 12, regularly surveyed sections, and the place names mentioned in the text. Some other data - notably the figures given to the 1973 Public Inquiry as to the areas of clay and peat exposed - are discussed in the context of the new information.

1.2 Description of the beach. The three beaches which form the subject of this Topic Report run from the mouth of the R Neath in the north to Sker Point in the south, a distance of approximately 12.5 km. They are the Aberafan Beach, here defined as extending from Witford Point to the Port Talbot tidal harbour; the Margam Beach, whose limit is the tidal harbour in the north and, if Morfa Mawr Beach is included, the R Kenfig in the south; and, finally, the Kenfig Beach bounded by the R Kenfig and Sker Point (see Fig 1). The Port Talbot tidal harbour and associated deep water channel appear to separate Aberafan Beach from those further to the south. The Margam and Kenfig Beaches are similarly, but less effectively, divided by the R Kenfig. The latter is not well defined as it passes across the beach face, consisting as it does of a series of separate braided streams which can be easily crossed by a vehicle at low water. Additionally a buried outfall pipe, and factory effluent from a culvert, traverse the Margam Beach 0.2km and 1.5 km south of the southern breakwater of the tidal harbour, respectively. (The British Steel Corporation's culvert is in the process of being replaced by a large diameter pipe whose outfall will be some 3.5 km offshore).

At one time all three beaches were backed by sand dunes but today only Kenfig Burrows remains in a largely natural state. Further north the dunes have been used as a source of building sand and the levelled areas either then built upon or used to deposit slag or other waste materials. Until 1973 sand was also won from the foreshore along parts of the Margam and Kenfig beaches (See Topic Report 1, IOS Report 42/77). South of Section N (Fig 1) a thin belt of dunes has been left landwards of Margam Beach. To some degree this acts as a protective barrier. Elsewhere, from the breakwater of the tidal harbour to Section N, the beach abuts an artificial cliff of slag waste, some 10 - 12m above high water mark. This, too, has protective value.

North of the Port Talbot tidal harbour a sea wall and promenade extend some 2.3 km towards the R Neath. Thereafter, remnants of dunes occur, these extending as far N as Witford Point.

The large tidal range ( $\sim$ 9.2m on normal spring tides), an easily erodable coastline, and the dominance of fine sand grade material (for terminology on particle size grading see Fig 2), are all factors which have contributed towards the formation of wide beaches with 450m or more occasionally exposed between high and low water spring tide levels. Although the gradients remain relatively gentle the documentary evidence (see Section 3.2.3 of Topic Report 1) suggests that at one time they were still more so. At the present time slopes at mid-tide level are of the order of 1:50 at the northern end of Aberafan Beach. Gradients increase to between 1:40 and 1:45 towards the tidal harbour, possibly because of the restricting influence of the sea wall which extends along the back of the beach in that area and the effects of the northern tidal harbour breakwater.

To the south of the Port Talbot tidal harbour the gradients are more variable with mean mid-tide values ranging between 1:48 and 1:61. This variability may be attributed, at least in part, to the diversity of sediment types present on Margam and Kenfig beaches, as compared with Aberafan's uniform sand beach. Throughout almost the entire length of Margam and Kenfig beaches a scatter of coarse material - generally within the pebble size range - is found at about high water mark, while above high tide level there is a well-developed, but intermittent, cobble storm beach which is subject to short-term, mainly random, topographic changes. This storm beach is noticeably absent both immediately south of the tidal harbour and south of the R Kenfig. In consequence, in the latter area the sand dunes are less effectively protected and undergo periodic erosion through wave attack. During the 24 months that measurements were taken this amounted to recession of about 5m on Section T.

Deposits of Flandrian age are exposed along the Margam and Kenfig foreshore (see Figs 3 - 5). They range from blue plastic clays and sandy clays to sandy peats and pure peats. Scrobicularia shells are found in some of the blue clays whilst certain of the peat exposures contain quite large roots amongst the fibrous material. In general, the peat is fairly resistant to erosion and tends to form a protective capping over the softer clays. The result is the formation of horizontal peat ledges. Where erosion is at an advanced stage isolated peat blocks are left standing as much as 60cm above the surrounding beach level. Protruding clays tend to be eroded into deep gulleys running parallel to the slope of the beach. It is possible that these fissured outcrops are eventually planed down to beach level but the wide, flat expanses of clay at, or just below the beach surface may equally well reflect the original level of the geological discontinuity.

Margam, and especially Kenfig, beaches include a number of areas covered with large rounded cobbles and boulders. Such deposits are most prevalent towards the southern end of Kenfig Beach (for example, on Section X) and may represent a lag deposit following recession of the beach. However, this view was disputed at the 1973 Public Inquiry (see Section 4.2.2 of Topic Report 1). The cobbles and boulders seem either to occupy depressions in the beach or the site of previously eroded clay outcrops. Their distribution appears reasonably constant for months at a time only being subject to intermittent covering by sand. Nevertheless some movement is apparent over longer periods of time.

1.3 Outline of analytical techniques used. As noted in Section 1.1, two approaches have been used to assess changes in beach level and composition during recent years. These are comparisons of aerial surveys carried out between 1968 and 1975 covering the area between Port Talbot tidal harbour and Sker Point, and the survey of beach profiles. The latter include 3 representative sections N of the tidal harbour in addition to those coincident with the area covered by the air surveys.

1.3.1 Maps derived from aerial surveys. A total of 4 flights of the coast were carried out by Meridian Airmaps Ltd in 1966, 1968, 1970 and 1975 for the British Transport Docks Board and three of these aerial surveys have been used by the Institute of Oceanographic Sciences to produce comparative maps of the beach S of the tidal harbour. (For full details of these and other flights see Appendix 1). All the relevant photography was flown to give a nominal scale of 1:6000 during the summer half of the year when conditions are generally more stable. The 1968 flight corresponds with the beginning of construction of the new harbour; 1970 with its completion; that of 1975 some 5 years after. Because IOS only became involved in 1974 the policy was adopted of installing additional ground control for the 1975 survey and incorporating the information on the earlier photography which was subjected to photogrammetric analysis thereafter.

At the scale of the photography, heights can be plotted to an accuracy of ± 0.15m. All 3 derived maps were produced using a Kern PG2 photogrammetric plotter belonging to the Nature Conservancy Council. Contours were drawn at 1m intervals and other detail, notably the exposures of clay, peat and cobbles and boulders, was recorded. Comparisons were then made as to the displacement of the contours, the computed volume changes between the 3 flights and the areas of peat and clay exposed on each occasion. Exposures of peat and clay - labelled as Submerged Forest Beds - had also been mapped by the Geological Survey in 1952 and that information, together with data from other sources, is included in Table 1 and discussed in Section 2.

1.3.2 <u>Beach sections</u>. The changes of beach topography were measured on a monthly basis by surveying sections at right angles to the beach (see Appendix 2). The number of sections chosen was limited by the ground area that had to be covered and the time available around low tide over, typically, a 2-day period. Eleven sections, each approximately 1 km apart, were laid out: C, E and G on Aberafan Beach; L, N, P, R and T, V, X and Z on Margam and Kenfig beaches respectively. Alternate lettering was used in case intermediate sections, such as 'Q', were surveyed subsequently. For Sections C, E and G heights were related either to an existing concrete post or to the promenade. For the other profiles concrete blocks were levelled in on firm ground some way back from the line of section. Wooden posts were then placed at various points along the landward part of each section and their heights recorded with respect to the appropriate concrete block, the latter having been related to Ordnance Datum by a closed traverse. Each month the sections were surveyed on spring tides starting and finishing two hours either side of low water. However, because the first section was invariably levelled down to, and the last up from, the sea, profiles were effectively made within 1½ hours of the time of low water. The average length of the beach sections was 420m from the seawards bench mark, but they could vary between 320m and 520m reflecting geographical location, time of survey and the particular spring tide range. The sections on Aberafan Beach and L, T and V were all virtually free from peat and clay outcrops. All breaks of slope and changes of lithology were recorded plus some additional points on apparently extensive uniform stretches of beach.

After several months' surveys had been plotted it was realised that changes in height were for the most part small, and a visual comparison of profiles, month by month would be difficult. A simple computer program was therefore written that would use the surveyed heights at known distances from the seawards wooden stake or its equivalent, and interpolate these to produce heights at a fixed interval, in this case every 20 m. The program would then compare the profiles in successive months and calculate the difference in area between them. A positive change indicated accretion and a negative change erosion. A typical printout can be seen in Appendix 3.

It was assumed that the computed changes reflected the variation in available sand on the foreshore. As noted above, over the survey period the length of a section on a profile could vary greatly depending at what state of the tide the survey was carried out and the particular spring tide range. In order to be able to compare changes from month to month a mean length of profile was calculated for each section and only changes over this length were used. It was also assumed for convenience that each section had a width of 1 metre so that volumes were then produced, these being expressed in $m^3$ (Table 4).

In addition some supplementary survey work was undertaken, for example one specific profile in the area of the maximum peat outcrop ( ~ 260m N of Section P ). More significant, however, was that along the line of 'Q' (see Fig 1) which was the location utilised for 2 beach experiments in November 1976 and April-May 1977. Between those dates Section 'Q' was surveyed 14 times at a series of identical positions and the results tabulated into a mean beach profile, together with range and standard deviation. These data are represented graphically in Figure 13.

## 2. EVIDENCE FROM PHOTOGRAMMETRY (1968, 1970 and 1975).

### 2.1 Peat and clay exposures:

2.1.1 Background: As reported in Section 4.2.1 of Topic Report: 1 (IOS Report 42/77), clay has been exposed on the beaches south of Port Talbot harbour since at least the late 1930's. Mr Beynon, Manager of Margam Sand and Gravel Co, estimated that in 1940 about 4000 $m^2$ of clay were exposed in an area just north of the access ramp. In 1952 the Geological Survey mapped these exposures (as Submerged Forest Beds) on both Margam and Kenfig beaches. Their survey showed that 81,000 $m^2$ of peat and clay were exposed on the Margam Beach whilst the Kenfig Beach was free from any exposures. The total figure was made up of 23,000 $m^2$ in an area now covered by the Port Talbot tidal harbour, 29,000 $m^2$ just north of the River Kenfig and a similar figure, 29,000 $m^2$, in the intervening area. According to Beynon, exposures in this middle area in March 1973 had increased to 37,600 $m^2$ but by December of the same year had fallen to only 17,300 $m^2$. However, also in March 1973 Dr, now Professor, Gilbert Kelling, in his consultancy report 'Preliminary evaluation of the effects of sand and gravel abstraction' on Margam Beach produced a map outlining the areas that actually had peat or clay exposed or within 8 cm of the beach surface. This gave an area of 180,000 $m^2$. These figures, together with those obtained from the maps derived from aerial photographs, are given in Table 1. The maps comprise Figures 3, 4 and 5.

2.1.2 Records from aerial photography:

2.1.2.1 The values obtained from using photogrammetric techniques are likely to be minimum ones because scattered areas of clay eroded level with the beach are very difficult to differentiate from the rest of the sand cover, while clay covered with a thin veneer of sand would be interpreted as sand. Neither during the 1968, 1970 nor 1975 aerial surveys, nor during the 1975-1977 beach survey work, were peat or clay outcrops encountered in two areas. These were between the tidal harbour and the British Steel Corporation culvert, and south of the River Kenfig, towards Section V. Absence of such deposits may be explained by the fact that the River Afan once flowed across the first area mentioned before it was diverted during the construction of the original Port Talbot Docks. Similarly, meandering of the course of the River Kenfig may have eroded away any peat and clay exposures in the second area at an early date.

2.1.2.2 Area between Port Talbot tidal harbour southern breakwater site and the R Kenfig. In 1968 the exposures were rather scattered. They occurred at levels of between -2 and +2m OD (Ordnance Datum) between Sections N and P, while just S of the access ramp they were between +2 and +3m OD. (For note on datums see Appendix 4). By 1970 by far the largest area of peat and clay lay on Section N at between low water ( ~ 4m OD) and +1m OD. A new exposure was apparent at low water just S of Section P. The highest outcrops were no longer visible. Five years later the areas of the exposures had increased and were higher up the beach.

While there is a seasonal element that has to be taken into account because exposures are most likely to be greater in the winter than in the summer when the beach tends to accrete, Table 1 nevertheless shows that since 1940 there has been a steady increase in the area of peat and clay exposed on the foreshore. Only Kelling's 1973 figure is anomalous and is, as noted above, based on different criteria.

2.1.2.3 Area S of the R Kenfig. No clay or peat exposures were apparent in the 1968 survey whilst by 1970 only a small exposure was noted just S of Section X at a level of between -3 and -2m OD. By 1975 this area had greatly increased, and extended northwards towards Section V at between -3 and zero m OD. In a similar fashion, the cobble exposures somewhat nearer high water mark (assumed to be lag) had also become more extensive.

The rate of erosion on Kenfig Beach has been very striking, the exposures increasing from a few thousand $m^2$ in 1970 to over 28,000 $m^2$ in 1975.

2.1.2.4 From the aerial distribution of the outcrops relative to Ordnance Datum it seems that within the Flandrian sediments exposed over the beach face there are three zones of more resistant material (peat), the first around +3m OD, the second +2 to zero m OD and the third -1 to -2m OD. The peat ledge at around +3m OD is very narrow and appears to be protected by the storm beach, only being revealed when this beach is pushed back.

2.2 Comparison of beach contours:

2.2.1 Introduction: The positions of the contours obtained from the three flights in 1968, 1970 and 1975 were compared one with another. For this purpose the 8 sections on Margam and Kenfig beaches used for the topographic surveys were supplemented by a further 8 lines, one to the north of the levelled sections and the remainder intermediate to them. The distance that a given contour had moved landward or seaward between any two flights was recorded. A landward movement of a contour indicated retreat of the beach with respect to that height level and thus a loss of sediment, while a reduction of the horizontal interval between contours would reflect a steepening beach gradient. The converse is equally true. The changes have been represented diagrammatically in Figures 6, 7 and 8. Distance changes of less than 20m have been ignored in order to allow for the plotting error of the photogrammetric technique.

2.2.2 Comparison of 1968 and 1970 flights (Fig 6): Between these two dates the Margam Beach remained fairly static apart from some limited accretion at about mean tide level along Sections K, M, N and O. Margam and Kenfig beaches are separated by the R Kenfig, the river area being best described by Section S although R and T are also peripheral to it. Erosion was marked on Section S, notably immediately above and below zero OD. This reflects changes in the course of the river across the beach surface. Some of these changes may be man-induced as a result of sand winning in the area.

Between 1968 and 1970 the rest of Kenfig Beach became steeper, ie there was greater retreat of the contours at the seaward edge of the beach as compared with the landward edge. On Section X the beach gradient between +4m OD and -3m OD increased from approximately 1:53 to 1:44 while a marked area of erosion occurred between -1 and -3m OD across both Sections V and X.

2.2.3 Comparison of 1970 and 1975 flights (Fig 7): By 1975 the areas of erosion had moved further landward ranging from approximately zero to +3m OD on both Margam and Kenfig beaches, and, like that around the R Kenfig between 1968 and 1970, may be partially man-induced especially as far as lines 'N' to 'R' are concerned. The erosion had the effect of increasing the exposures of peat and clay over much of the area of the two beaches.

Accretion is apparent over much of Section S (R Kenfig) and over nearly all the sections from N to Z at or near low water mark.

2.2.4 Comparison of 1968 and 1975 flights (Fig 8): The net result can be seen in Figure 8 which shows that, in spite of some build up of the beaches between 1970 and 1975 below mid-tide level, on the whole the beaches have suffered erosion. (In this context, it is important to point out that the comparisons for 1968-70, 1970-75 and 1968-75, were all done separately. Because on each survey changes less than 20m were ignored it is possible for the 1968-75 results to be up to 1 scale category different from that which would be obtained by summing 1968-70 and 1970-75 data).

In addition to the foregoing comparison, the height information was used to estimate the net change in volume of material over the period 1968-75 along similar lines to those decided for the 1975-77 beach levelling data (Section 3.2, below). Table 2 provides a summary of these data. It suggests a net loss of approximately $2.8 \times 10^6$ tonnes of material, equivalent to an overall fall in beach level of 0.40m between Port Talbot tidal harbour and Sker Point over the 7-year period. This is greater than the potential error of the survey. The plotting error for surveys based on 1:6000 scale aerial photography is

$\pm$ 0.15m. The least amount by which the beach could have changed between 1968-75 was then calculated by assuming the maximum potential plotting error. This gave a figure of approximately 800,000 tonnes which was equivalent to a drop of 0.11m in beach level if the loss of the material was spread evenly over the whole area.

3. EVIDENCE FROM BEACH PROFILES

3.1 Profile changes:

Section 1.3.2 outlines the procedures used while Appendix 2 tabulates the dates at which the various sections were surveyed. Figures 9 - 12 show comparative profiles for the 11 Sections surveyed monthly between September/ October 1975 and April/May 1977. The 2 profiles chosen correspond to the maximum volume change for that section during the 18-month period (see Section 3.2 below). The seven months October to April account for 19 out of 22 of such profiles and suggest that severe winter storms were the most likely cause of these changes. Nevertheless it is interesting to note that, with the exception of April 1977 (5 instances), no month is represented by more than 2 extreme records. There is thus little tendency for consistent erosion or accretion of the beaches overall.

The kink in profile E towards the top of the beach in October 1975 (Fig 9) was due to the removal of accumulated windblown sand from the Aberafan esplanade onto the beach. The recession of the sand dunes on the line of Section T (Fig 11) can also be clearly seen.

As noted in Section 1.3.2, Figure 13 depicts the results of a number of surveys along line 'Q' over the 6-month period November 1976 to May 1977 on a somewhat different basis. The beach zone showing the least change is also the most resistant area in penetration tests. Comparisons between height range and Cone Index* give correlation coefficients of 0.88 and 0.867 and a confidence level better than .01 (ie 1 possibility in 100 of the result occurring by chance).

Because the monthly changes were usually very small ( < 0.5m) the vertical scale on the profiles has had to be exaggerated in order to show differences between surveys. Sections C, E, G; L, N, P, R; T, V, X and Z (Figs 9 - 12) all have a vertical exaggeration of x10 and Section Q (Fig 13) one of x25. This change in proportions disguises the comparatively flat nature of the prototype beach over most of its length.

Table 5 records the maximum change in elevation for each section during the 18-month period within the ranges +3 to zero m OD and zero to -4 m OD. The +3 m value is approximately mean high water level. It was preferred to high water spring tides because, under calm conditions, the complicating effect of the pebble and cobble component at the back of certain sections along the beach is effectively eliminated. Comparisons are therefore restricted to the sand beach alone.

Table 5 suggests that the beaches become progressively less stable from



*Davidson (1965)

north to south, from Section C at least as far as Section V and probably as far as 'Z' (which has suffered the maximum overall loss (Section 3.2, below)). Although one atypical value for Section P at low water level proves a marked exception to this observation, other discrepancies are very minor. Correlations between maximum height range per section (x-axis) against distance from 'C' (y-axis), for example gives a confidence level of .01.

It is hoped in later Topic Reports to examine the variations in wave energy alongshore. Preliminary work (Fig 4 in Progress Report : 1 (IOS Report 20/75)) suggests an energy focus in the Sker Point area.

The Ogwr Borough Council have records of surveys taken by consultants (W S Atkins and Partners), their predecessors (Penybont RDC) and themselves on Kenfig Beach. These date from 1958 onwards and were carried out at varying time intervals. A series of 3 sections falls within a strip of beach 200 m either side of Section V. These sections run from a point above high water mark to approximately mid-tide position and suggest that between October 1959 and April 1977 the beach level dropped by at least 3 m over this length with a maximum fall of 4.5 m. The maximum change recorded on Section V by IOS between September 1975 and April 1977 was rather less than 1 m.

3.2 Calculations on changes in volume of beach material:

The volume changes for Aberafan, Margam and Kenfig beaches between each survey can be seen in Table 3. Each section was split into two taking the midwater position (~ zero m OD). This enabled any differences in response between the upper and lower beaches to be seen. The total volume changes along all three beaches have been combined and are shown on a monthly basis in Fig 14a. During the two winter periods, although there were extremes of accretion and erosion, the net effect was one of erosion. For the intervening summer period the extremes were not nearly so evident, the net effect this time being accretion. These results support observations on other beaches that the higher energy waves of the winter tend to comb down the beach and remove the material while the smaller waves during the summer have a more constructive effect.

A comparison of the volume changes between the upper and lower parts of the beach over the same period is shown in Fig 14b.* For most of the months a change in the lower part of the beach was reflected by a similar change in the upper beach. More information can be gained from comparing the total volume change in material on each section over the 18 month period (Table 4a). Although the gains and losses in volume of material were appreciable, the resulting net inbalance was relatively small. For a section of 420m a height change of 1 cm



*For method see p.6

along its full length represents a change of 4.2 $m^3$. Therefore for the section that had the greatest change during the series of surveys, Section Z, a loss of 87 $m^3$ of material represented a fall in height equivalent to 21 cm over its entire length. In general the major loss of material has taken place between the seaward bench mark and the midtide mark on most sections. Although there has been some gain in material between midwater and low water - thus making the sections shelve more gently over the period autumn 1975 to spring 1977 as compared with the steepening shown by the long-term cartographic evidence - it accounts for under half the material lost higher up the beach.

More specifically, on the Aberafan Beach the two end sections have remained fairly constant (with some net gain on 'G') whilst the centre one has undergone some erosion. The amount of change on Margam Beach has been greater than Aberafan but there has been no consistent pattern between one section and another, erosion on one section apparently being balanced by accretion on the next. Across the other side of the R Kenfig on Kenfig Beach, the one notable feature has been the consistent losses on Section Z.

From Table 4a it is possible, if the results are treated with caution, to arrive at an order of magnitude for the amount of sand gained or lost from the beaches during the 18 month period. The assumption has to be made that the beach 500 m either side of a line of section responds in the same way as the section itself. The losses (converted into tonnes, where 2.08 tonnes = $m^3$ (Terzaghi and Peck, 1968)) are as follows:

| | | |
|---|---|---|
| Aberafan Beach | | 8,320 tonnes |
| Margam | " | 31,200 " |
| Kenfig | " | 166,920 " |

In order to eliminate seasonal effects all the beach sections were resurveyed in October 1977, ie after two complete years. The net results (Table 4b) for the whole period are:

| | | | |
|---|---|---|---|
| Aberafan Beach | | + 22,880 tonnes | |
| Margam | " | -166,400 " | (all due to changes near the new BSC pipe-/line) |
| Kenfig | " | + 9,360 " | |

The continuing losses on Section Z (by October 1977 equal to 29 cm) were outweighed by gains around the R Kenfig during the 1977 summer season.

Taking all 3 beaches together, the net change between October 1975 and April 1977 is equivalent to an overall fall in height of 0.021m and that between April and October 1977 to an overall gain of 0.007m. Such accuracy is outside that attainable in surveying profiles in an inter-tidal environment.

## 4. CONCLUSIONS

1. The beaches consist of predominantly medium to fine sands apart from the upper storm beach which was variable in form and composition. However areas of peat, clay and cobbles were exposed notably south of the Port Talbot tidal harbour. The beaches were broad (typically ~ 400m wide at low water) and gently sloping ( ~ 1:50).

2. Evidence from photogrammetry (1968-1975)

A comparison of the position of beach contours obtained from the aerial photographs showed that during the years 1968-70 there was a marked displacement landward only on the lower Kenfig Beach. Removal of beach material and a consequent steepening of the beach in this area resulted in the underlying peat and clays being exposed to erosion. Between 1970 and 1975 these areas of erosion tended to be concentrated higher up the beach face not only on Kenfig but also on Margam Beach. At the same time the lower beach face was tending to accrete but not at a sufficient rate to make up the losses of the previous years.

The aerial photographs showed that while 32,000$m^2$ of peat and clay were visible on Margam Beach in 1968 no such exposures occurred on Kenfig Beach. However, by 1970 3500$m^2$ were visible just N of Sker Point. The 1975 survey showed 44,500$m^2$ and 28,000$m^2$ of peat and clay on Margam and Kenfig Beaches respectively. In response to the changing contour levels these were generally concentrated further up the beach than in 1968 or 1970. Cobble spreads, possibly lag deposits, also became more extensive over the period, particularly on Kenfig Beach.

On no occasion were peat or clay recorded from S of the southern breakwater of the tidal harbour to the BSC culvert, nor S of the R Kenfig almost as far as Section V. This is probably the effect of earlier erosion by the former R Afan and R Kenfig. Even allowing for the seasonal element of accretion the peat and clay exposures have shown an overall increase on both beaches since 1940.

3. Evidence from beach profiles (Sept/Oct 1975 to April/May 1977)

The extremes of range of height on the sections occurred mainly in the winter months when short periods of stormy weather removed large quantities of material from the beach. Even so there was little accretional or erosional consistency between neighbouring sections in any one month. The gentle slope of the beach resulted in gradual height adjustments taking place. In general the upper part of the beach ( ~ +3 to zero m OD) showed the same range in height variation as the lower part, the maximum range encountered being just over

1m. This variation in height range increased from N to S indicating that the beaches become less stable in the same direction.

3.1 Calculation on changes in volume of beach material.

Although changes in erosion and accretion are appreciable on a month to month basis the resulting net imbalance of material was quite small. When treated on an individual basis section Z persistently suffered erosion. If the volume of material lost over the 2-year period were spread evenly over the entire section length it would be equivalent to a drop of 29 cm overall. Sections L, N and P also showed a net loss of material over the same time span. The intervening area covered by sections R, T and V showed gains which were appreciable as far as R was concerned. This may be explained by the addition of sand from the eroding dune system; the effect of the River Kenfig on sand transport; and the attempt of the area to regain equilibrium following the end of commercial sand extraction.

It is possible to calculate changes in volume for each beach assuming that the beach 500m either side of the surveyed sections acts in a similar way as the sections themselves. This gives losses of -8, -31, and -167 thousand tonnes for Aberafan, Margam and Kenfig beaches, over the 18-month period. Comparable figures for a complete two-year period are +23, -166 and +9 thousand tonnes, equal to overall changes in beach height of +1, -4 and $<$ +1cm (Table 6).

The differences between the two sets of figures are most likely due to the recent man-made changes in the Margam Beach and the seasonal accretion around the River Kenfig.

4. The areas of accretion and erosion that appeared to be most active between 1968 and 1975 are very similar to those which exist today. The recent data show that:

(a) the southern end of Kenfig Beach has suffered the most erosion;

(b) Margam Beach has shown considerable variability both in respect of the particular section and over time;

(c) in the intervening area, around the River Kenfig, material has tended to accumulate;

(d) Aberafan Beach has remained fairly stable.

Further analyses, relating to the beach changes described here to wave energy and meteorological conditions, will be discussed in a subsequent Topic Report.

REFERENCES


CARR, A.P. and BLACKLEY, M.W.L. (1977). Swansea Bay (Sker) Project. Topic Report : 1(a). Introduction. (b) Long-term changes in the coastline. Institute of Oceanographic Sciences Report 42/77. 63 pp.

DAVIDSON, D.T. (1965). Penetrometer measurements. In : Methods of soil analysis, Part 1, ed C.A.Black. pp.472 - 484. American Society of Agronomy, Madison, Wisconsin, USA.

KELLING, G. (1973). Morfa Mawr beach : Preliminary evaluation of the effects of sand and gravel extraction. Report to the (then) Port Talbot Borough Council, 13 pp + tables and figures. Unpublished.

TERZAGHI, K. and PECK, R.B. (1968). Soil mechanics in engineering practice, 2nd ed. Wiley, New York, 729 pp.

TABLE 1 AREAS OF PEAT AND CLAY IN $m^2$ EXPOSED ALONG THE FORESHORE BETWEEN PORT TALBOT AND SKER POINT 1940-1975

| Date | Source of data | Port Talbot - River Kenfig | S of River Kenfig - Sker Point |
|---|---|---|---|
| 1940 | 1973 Public Enquiry | 4,000 | - |
| 1952 | Geological Survey | 81,000 { 29,000; 29,000 (a); 23,000 (b) } | None mapped |
| 1968 April | Aerial photography | 32,000 | None visible |
| 1970 June | Aerial photography | 35,000 | 3,500 |
| 1973 March | Public Inquiry | 180,000 (c) | Not surveyed |
| 1973 March | Public Inquiry | 37,600 | Not surveyed |
| 1973 Dec | " " | 17,300 | " " |
| 1975 Oct | Aerial photography | 44,500 | 28,000 |

(a) Area now within tidal harbour

(b) Area in vicinity of River Kenfig

(c) Peat and clay covered by less than 8cm of sand.

TABLE 2 CHANGE IN VOLUME OF MATERIAL BETWEEN 1968 AND 1975 AERIAL SURVEYS

| | Section | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
| Width of beach (m) 1968 (or 1975 where greater)* | 403 | 423 | 415 | 410 | 345 | 348 | 378 | 408 | 613 | 380 | 390 | 338 | 360 | 385 | 418 | 388 |
| Mean lateral change of contour position (m) 1968-1975⁎ | 35.5 | 7.0 | 6.5 | 7.5 | 10.0 | 24.5 | 20.5 | 8.0 | (47) | 31.5 | 28.0 | 2.0 | 24.5 | 14.0 | 37.0 | 29.0 |
| Equivalent change in beach level (m). | .79 | .14 | .14 | .16 | .26 | .63 | .50 | .18 | .69 | .75 | .65 | .05 | .61 | .32 | .80 | .68 |
| Change in profile X-section ($m^2$) | -318 | -59 | +58 | -66 | -90 | -219 | -189 | +73 | -423 | -285 | -254 | -17 | -220 | -123 | -334 | -264 |
| Change in volume of beach ($m^3$) x $10^3$ Ø | -135.2 | -29.5 | +29.0 | -33.0 | -45.0 | -109.5 | -94.5 | +40.2 | -232.7 | -142.5 | -127 | -8.5 | -110 | -61.5 | -167 | -118.8 |

1353.4 x $10^3$ $m^3$

≏ 2,815,000 tonnes (net loss) = overall fall in beach level of 0.40 m

| | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accuracy of survey = ±0.15m vertically ∴ change(m) outside potential error = | .49 | .16 | .44 | .14 | .04 | .33 | .20 | .48 | .39 | .45 | .35 | .25 | .31 | .02 | .50 | .38 |
| Change in volume of beach ($m^3$) x $10^3$ Ø | -83.9 | -33.8 | +91.3 | +28.7 | +6.90 | -57.4 | -37.8 | +107.7 | -131.5 | -85.5 | -68.3 | +42.3 | -55.8 | -3.9 | -104.5 | -66.3 |

384.2 x $10^3 m^3$

≏ 799,100 tonnes (net loss) = overall fall in beach level of 0.11m

* Defined as distance between +5 and -3 m OD contours

⁎ All receding landward except where underlined

( ) Special circumstances apply: affected by changes in river course over period.

Ø Section +250m each side (except K 250m & 175m; R and S 250m & 300m; Z 250m & 200m)

TABLE 3 VOLUME CHANGES IN $M^3$ BETWEEN EACH MONTHLY SURVEY FOR THE PERIOD OCTOBER 1975 - APRIL 1977 FOR ALL THREE BEACHES COVERING THE AREA FROM THE BENCH MARK TO MID-WATER AND FROM MID-WATER TO LOW-TIDE LEVEL. OCTOBER 1977 FIGURES ALSO SHOWN ∅.

| | | BM* to MW | MW to LW | TOTAL VOLUME CHANGE |
|---|---|---|---|---|
| 1975 | Oct/Nov | 35 | 119 | 154 |
| | Nov/Dec | 74 | 3 | 77 |
| | Dec/Jan | -191 | -82 | -273 |
| 1976 | Jan/Feb | 60 | 83 | 143 |
| | Feb/Mar | -94 | -57 | -151 |
| | Mar/Apr | 114 | -30 | 84 |
| | Apr/May | -13 | -125 | -138 |
| | May/Jun | 157 | 35 | 192 |
| | Jun/Jul | -11 | 25 | 14 |
| | Jul/Aug | 67 | -16 | 51 |
| | Aug/Sep | 2 | -49 | -47 |
| | Sep/Oct | -49 | -56 | -105 |
| | Oct/Nov | 58 | 140 | 198 |
| | Nov/Dec | -256 | -6 | -266 |
| | Dec/Jan | 89 | 9 | 98 |
| 1977 | Jan/Feb | -153 | -55 | -208 |
| | Feb/Mar | -1 | -23 | -24 |
| | Mar/Apr | -122 | 202 | 80 |
| | Apr/Oct | 107 | -61 | 46 |

*BM - Temporary bench mark post at seawards edge of dunes or IOS benchmark on concrete structure.

∅ For explanation, see text.

TABLE 4a CHANGES IN VOLUME ($m^3$) FOR THE INDIVIDUAL SECTIONS AND MASS (TONNES) OVERALL FOR THE PERIOD OCTOBER 1975 TO APRIL 1977

| Section | From BM* to mid-water | | | From mid- to low-water | | | Volume Change overall | Change in tonnes over area 500m either side of section |
|---|---|---|---|---|---|---|---|---|
| | Accretion | Erosion | Balance | Accretion | Erosion | Balance | | |
| C | 128 | 122 | +6 | 106 | 99 | +7 | +13 | +27,040 |
| E | 127 | 150 | -23 | 153 | 177 | -24 | -47 | -97,760 |
| G | 116 | 116 | 0 | 137 | 107 | +30 | +30 | +62,400 |
| L | 110 | 147 | -37 | 174 | 197 | -23 | -60 | -124,800 |
| N | 167 | 153 | +14 | 108 | 79 | +29 | +43 | +89,440 |
| P | 57 | 122 | -65 | 81 | 77 | +4 | -61 | -126,880 |
| R | 159 | 156 | +3 | 197 | 137 | +60 | +63 | +131,040 |
| T | 133 | 180 | -47 | 179 | 129 | +50 | +3 | +6,240 |
| V | 132 | 148 | -16 | 116 | 103 | +13 | -3 | -6,240 |
| X | 156 | 163 | -7 | 121 | 129 | -8 | -15 | -31,200 |
| Z | 45 | 128 | -83 | 132 | 136 | -4 | -87 | -135,720ø |

*BM - Temporary bench mark post at seawards edge of dunes or IOS benchmark on concrete structure.

ø Calculated as 500m + 250m because of rock outcrop to S of line of section.

TABLE 4b CHANGES IN MASS (TONNES) FOR THE PERIOD OCTOBER '75 TO OCTOBER '77

Change in tonnes over area 500m either side of section April 77 - October 77

| Section | Tonnes |
|---|---|
| C | -22,880 |
| E | +41,600 |
| G | +12,480 |
| L | +79,040 |
| N | -245,440 |
| P | -70,720 |
| R | +101,920 |
| T | +158,080 |
| V | +64,480 |
| X | +8,320 |
| Z | -54,600 |

Change in tonnes over area 500m either side of section October 75 - October 77

| Section | Tonnes |
|---|---|
| C | +4,160 |
| E | -56,160 |
| G | +74,880 |
| L | -45,760 |
| N | -156,000 |
| P | -197,600 |
| R | +232,960 |
| T | +164,320 |
| V | +58,240 |
| X | -22,880 |
| Z | -190,320 |

TABLE 5 BEACH SECTIONS: MAXIMUM CHANGE IN HEIGHT (METRES) AT ANY POINT, BETWEEN SEPT/OCT 1975 AND APRIL/MAY 1977.

| | Section | Between: Mean high water (~ +3) and 0m O.D. | 0m to low water spring tides (~ 4m O.D.) | Overall Average | Overall Max. |
|---|---|---|---|---|---|
| Aberafan | C | 0.4 | 0.4 | 0.4 | 0.4 |
| Beach | E | 0.45 | 0.55 | 0.5 | 0.55 |
| | G | 0.4 | 0.55 | 0.475 | 0.55 |
| Margam | L | 0.6 | 0.45 | 0.525 | 0.6 |
| Beach | N | 0.6 | 0.55 | 0.575 | 0.6 |
| | P | 0.6 | 1.1 | 0.85 | 1.1 |
| | R | 0.4 | 0.65 | 0.525 | 0.65 |
| Kenfig | T | 0.7 | 0.7 | 0.7 | 0.7 |
| Beach | V | 1.1 | 0.9 | 1.0 | 1.1 |
| | X | 0.7 | 0.95 | 0.825 | 0.95 |
| | Z | 0.8 | 0.8 | 0.8 | 0.8 |
| Significance level: | C → Z | .01 | .02 | .01 | .01 |
| (Height range v.distance from Section C) | C → V | .05 | .05 | .01 | .02 |

TABLE 6: SUMMARY OF CALCULATIONS REGARDING BEACH LEVEL BETWEEN PORT TALBOT TIDAL HARBOUR AND SKER POINT

| | | Beach overall | Port Talbot - R Kenfig | R Kenfig - Sker Point |
|---|---|---|---|---|
| (a) Beach level fall attributable to sand-winning(m) | | | | |
| Pre-1964 | known extraction | 0.05 | 0.06* | 0.04* |
| | estimated " | 0.09 | 0.12* | 0.08* |
| 1964-73 | known " | 0.13 | 0.19* | 0.10* |
| | estimated " | 0.16 | 0.24* | 0.10* |
| Total period | known " | 0.18 | 0.21* | 0.15* |
| | estimated " | 0.25 | 0.31* | 0.18* |
| *Assumes no longshore transfer N and S of R Kenfig. | | | | |
| (b) Beach level fall calculated from aerial photographs (m) | | | | |
| 1968-75 | calculated | 0.40 ∅ | 0.33 | 0.53 |
| | " less potential plotting error for scale of map | 0.11 ∅ | 0.09 | 0.15 |
| ∅ Minimum losses in Sections L to O, R and V. | | | | |
| (c) Beach fall calculated from surveyed profiles (m) | | | | |
| October 1975 to April 1977 | | | <0.01 | 0.06 |
| October 1975 to October 1977 | | | 0.04 | 0.00 |

Maximum loss on Section Z (nr Sker Point)
(Latterly erosion on 'Z' may be influenced by changes in beach drainage pattern)

Note: The beach width and length used for these calculations varies slightly:

(a) uses a mean low tide width of 350m and a distance from the Port Talbot Docks breakwater;

(b) and (c) are observed distances down beach with a longshore distance calculated from the new Port Talbot tidal harbour southern breakwater.

APPENDIX 1 DATES OF AERIAL PHOTOGRAPHY

| Date | Scale | Area covered |
|---|---|---|
| 7 May 1966 | 1 : 6000 | Mumbles - Port Talbot |
| 12 April 1968 | " | Mumbles - Sker Point |
| 21 June 1970 | " | " " |
| 10 April 1971 | 1 : 7500 | Briton Ferry - Porthcawl |
| 12 April 1975 | 1 : 6000 | Mumbles - Port Talbot |
| 8 August " | " | Port Talbot - Sker Point |
| 8 October " | " | ( " " |
| | 1 : 10000 | ( Sker Point → offshore banks (at low water) |

All flights by Meridian Airmaps Ltd., except that of 1971 (Ordnance Survey)

APPENDIX 2 <u>DATES OF LEVELLING OF BEACH SECTIONS</u>

| Section / Month | C | E | G | L | N | P | Q | R | T | V | X | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/75 | | | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10/75 | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11/75 | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 12/75 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 6/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 8/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 9/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 4 | ✓ | ✓ | ✓ | ✓ | ✓ * |
| 12/76 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 2 | ✓ | ✓ | ✓ | ✓ | ✓ * |
| 1/77 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2/77 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3/77 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4/77 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 3 | ✓ | ✓ | ✓ | ✓ | ✓ ø |
| 5/77 | | | | ✓ | ✓ | ✓ | 2 | ✓ | ✓ | ✓ | ✓ | ✓ ø |
| 10/77 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | ✓ | ✓ | ✓ | ✓ | ✓ |

* Additional section 262m N of 'P'
Beach experiment at 'Q'

ø Beach experiment at 'Q'

## APPENDIX 3

Example of printout of changes between successive months for typical section. (P)

Survey distances (d) from concrete block with corresponding heights (h) below.

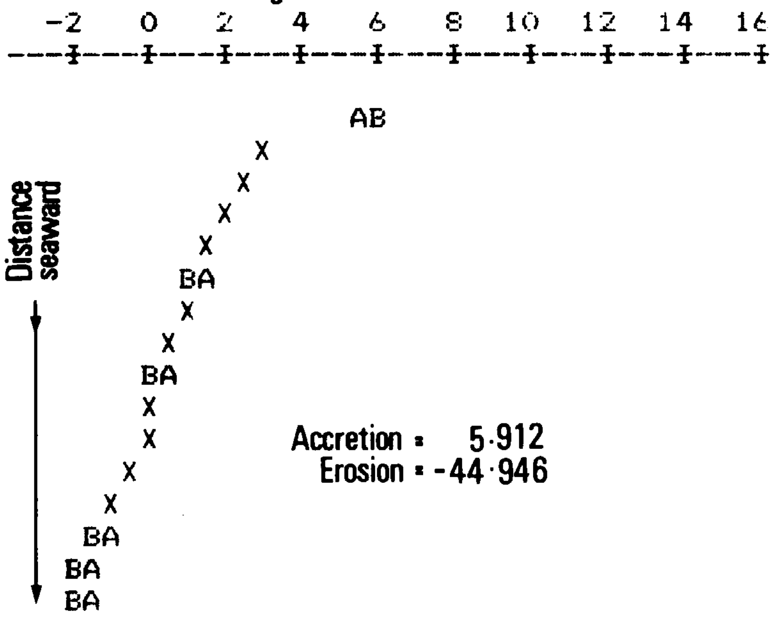
NOVEMBER 1975

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| d | 25. 000 | 31. 000 | 32. 000 | 33. 000 | 35. 500 | 39. 500 | 41. 500 | 45. 000 | 48 000 | 52. 000 |
| h | 10. 225 | 8. 360 | 8. 225 | 8 380 | 7. 285 | 5. 805 | 5. 265 | 4. 905 | 4. 535 | 3. 680 |
| d | 59. 500 | 66. 000 | 71. 000 | 108. 000 | 146. 000 | 154. 500 | 155. 500 | 165. 000 | 176 500 | 210. 500 |
| h | 3. 065 | 2. 880 | 2. 795 | 2. 150 | 1. 545 | 1. 470 | 1. 340 | 1. 325 | 1. 025 | 0. 315 |
| d | 220. 000 | 263. 500 | 273 500 | 332. 500 | 382. 500 | | | | | |
| h | 0. 130 | -0. 840 | -1. 020 | -1. 785 | -3. 160 | | | | | |

DECEMBER 1975

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| d | 25. 000 | 30. 500 | 34. 000 | 36. 500 | 40. 500 | 43. 500 | 45. 000 | 49. 000 | 53 000 | 62. 000 |
| h | 9. 950 | 8. 570 | 8. 250 | 7. 150 | 6. 050 | 5 050 | 4. 820 | 4. 180 | 3. 735 | 2. 950 |
| d | 64. 000 | 80. 000 | 120. 000 | 131. 500 | 142. 000 | 153. 500 | 164. 500 | 185. 000 | 218. 000 | 254. 000 |
| h | 2. 860 | 2. 510 | 1. 840 | 1. 750 | 1 390 | 1. 385 | 1. 110 | 0. 725 | 0. 075 | -0. 680 |
| d | 269. 000 | 356. 000 | | | | | | | | |
| h | -1 035 | -2. 815 | | | | | | | | |






| DISTANCE (METERS) | FIRST HEIGHT (METERS) | SECOND HEIGHT (METERS) | CHANGE IN AREA (SQ. M.) | TOTAL (SQ. M.) |
|---|---|---|---|---|
| 40. 0 | 5. 670 | 6. 187 | 0. 000 | 0. 000 |
| 60. 0 | 3. 051 | 3. 124 | 5. 912 | 5. 912 |
| 80. 0 | 2. 638 | 2. 510 | -0. 544 | 5. 367 |
| 100. 0 | 2. 289 | 2. 175 | -2. 426 | 2. 942 |
| 120. 0 | 1. 959 | 1. 840 | -2. 334 | 0. 608 |
| 140. 0 | 1. 641 | 1. 459 | -3. 009 | -2 401 |
| 160. 0 | 1. 333 | 1. 222 | -2. 923 | -5. 325 |
| 180. 0 | 0. 952 | 0. 819 | -2. 434 | -7. 759 |
| 200. 0 | 0. 534 | 0. 430 | -2. 377 | -10. 136 |
| 220. 0 | 0. 130 | 0. 033 | -2. 017 | -12. 153 |
| 240. 0 | -0. 316 | -0. 386 | -1. 674 | -13. 826 |
| 260. 0 | -0. 762 | -0. 822 | -1. 305 | -15. 131 |
| 280. 0 | -1. 104 | -1. 260 | -2. 158 | -17. 289 |
| 300. 0 | -1. 364 | -1. 669 | -4. 614 | -21. 903 |
| 320. 0 | -1. 623 | -2. 078 | -7. 612 | -29. 515 |
| 340. 0 | -1. 991 | -2. 488 | -9. 519 | -39. 034 |

APPENDIX 4 NOTE ON SURVEY DATUMS

In common with most areas of the United Kingdom early Ordnance Survey topographical maps and plans were based on mean sea level at Liverpool, hence OD (Liverpool). The Ordnance Survey established a new datum based on observations between 1915 and 1921 at Newlyn, Cornwall. This is known as OD (Newlyn).

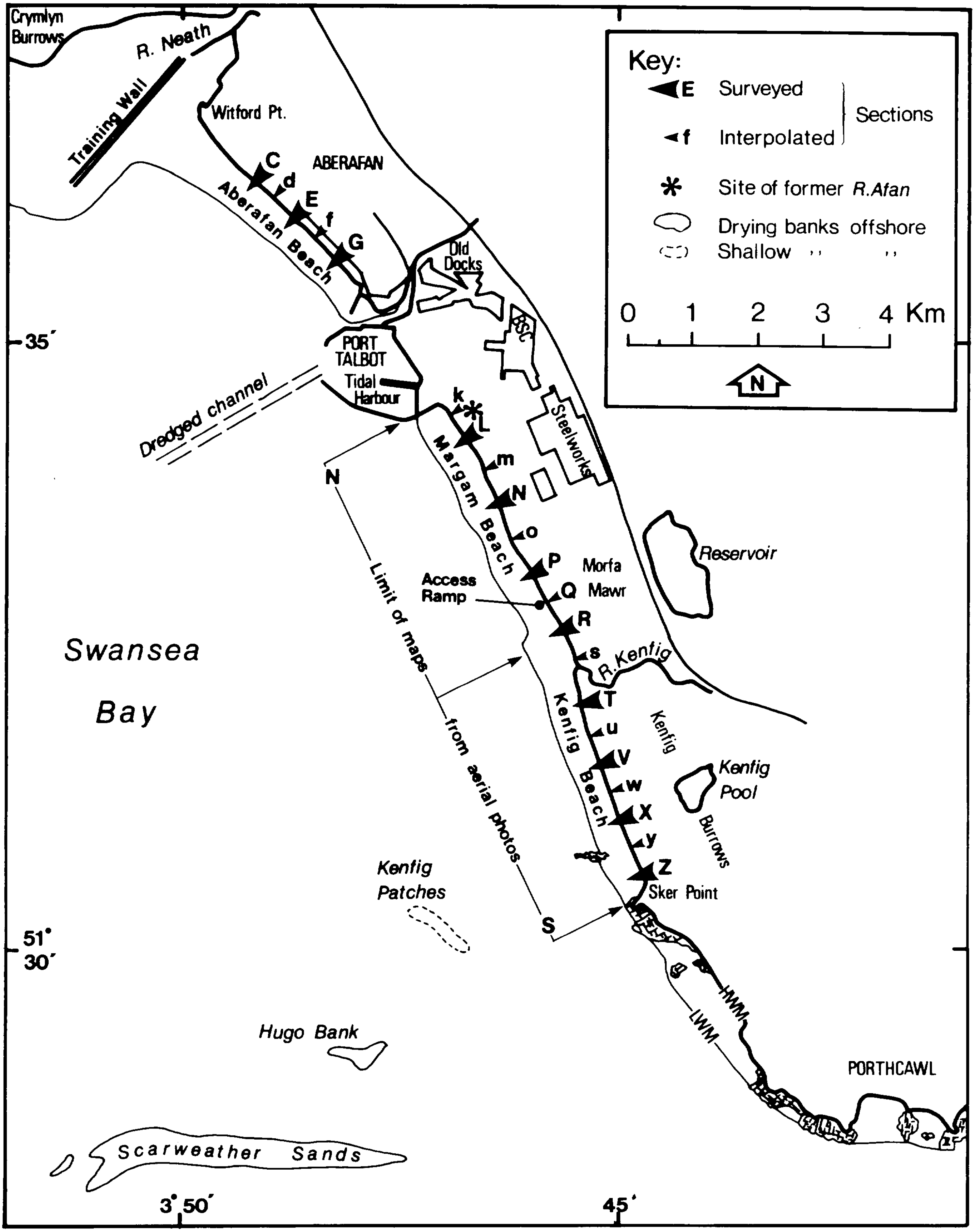
The Steel Company of Wales (SCOW) began their Margam development at a time soon after the Second World War when local medium and large scale maps and surveys were still based on OD (Liverpool). To avoid confusion the British Steel Corporation (SCOW's successors) have kept to this datum. Because much of the land survey control for the aerial photography was provided for IOS by BSC the maps derived from this information are also on Liverpool datum. However, in accordance with current practice, the beach levelling is based on OD (Newlyn).

For practical purposes there is little difference, OD (Newlyn) being 0.12m above the OD (Liverpool) in the Port Talbot/Swansea area. This compares with an accuracy of ± 0.15m for the maps produced from 1 : 6000 scale aerial photography.

Since data sets are never mixed the use of different datums has no effect on the volumes of beach material which have been calculated in this report.

## APPENDIX 5 ACKNOWLEDGEMENTS

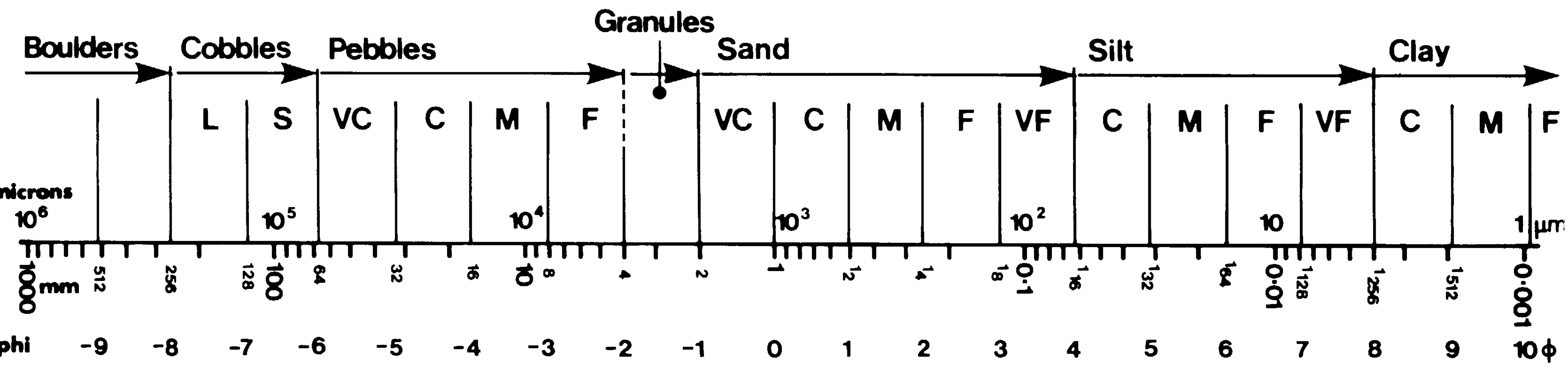
The Institute of Oceanographic Sciences wishes to express its thanks to the many organisations and individuals who have assisted in providing data and facilities for this Report. In particular, the whole-hearted co-operation of the British Transport Docks Board, who were instrumental in providing the aerial photography on which Section 2 is based, is much appreciated. So, too, is the help of the British Steel Corporation in supplying triangulation and bench mark information which played an important part in the photogrammetry.




**Site Map**

Fig.1

Key
**L** Large
**S** Small
**V** Very
**C** Coarse
**M** Medium
**F** Fine




Particle size grading terminology.

Fig. 2


1968
Metres
100 50 0 100 200 300 400
N
KEY
Area of Lag deposits.
Area of Clay/Peat outcrops.
P Patches of material only.
Contour values in metres (O.D. Liverpool)
Centre point of Aerial photograph.
Line of section.
Low Water at time of flight.
National Grid coordinates are shown.
TIDAL HARBOUR
Wreckage
Weighbridge
276000
277000
278000
187000
186000
185000
184000



Fig. 3a


1968
Metres
100 50 0 100 200 300 400
KEY Contour values in metres (O.D. Liverpool)
Area of Lag deposits.
184000
278000
183000
182000
181000
279000
180000
277000
278000
Bridge
Course of River
Pillbox
Wreckage
T
V
X
Z
182
183
184
185
186
187
188
189
SKER
POINT
Rock
Rock



Fig. 3b


1970
Metres
100 50 0 100 200 300 400
N
KEY
Area of Clay/Peat outcrops.
P Patches of material only.
Contour values in metres (O.D. Liverpool)
187000
186000
185000
184000
276000
277000
278000
Morfa Farmhouse
Weighbridge
Rocket Post
TIDAL HARBOUR
Wreckage
146
147
148
149
150
151
152
153



Fig. 4a

1970
Metres
100 50 0 100 200 300 400
KEY Contour values in metres (O.D. Liverpool)
Area of Lag deposits.
Area of Clay/Peat outcrops.
Bridge
Course of River
Pillbox
Wreckage
SKER
POINT
Rock
Rock




Fig. 4b


1975
Metres
100 50 0 100 200 300 400
N
KEY
Area of Lag deposits.
Area of Clay/Peat outcrops.
P Patches of material only.
Contour values in metres (O.D. Liverpool)
277000
278000
276000
187000
186000
185000
184000
189
190
191
192
193
194
195
196
219
220
221
222
223
224
225
226
227
L
N
P
R
7A
Morfa Farmhouse
Weighbridge
Rocket Post
TIDAL HARBOUR
Wreckage
Wreckage
10
5
4
3
2
1
0
-1
-2
-3

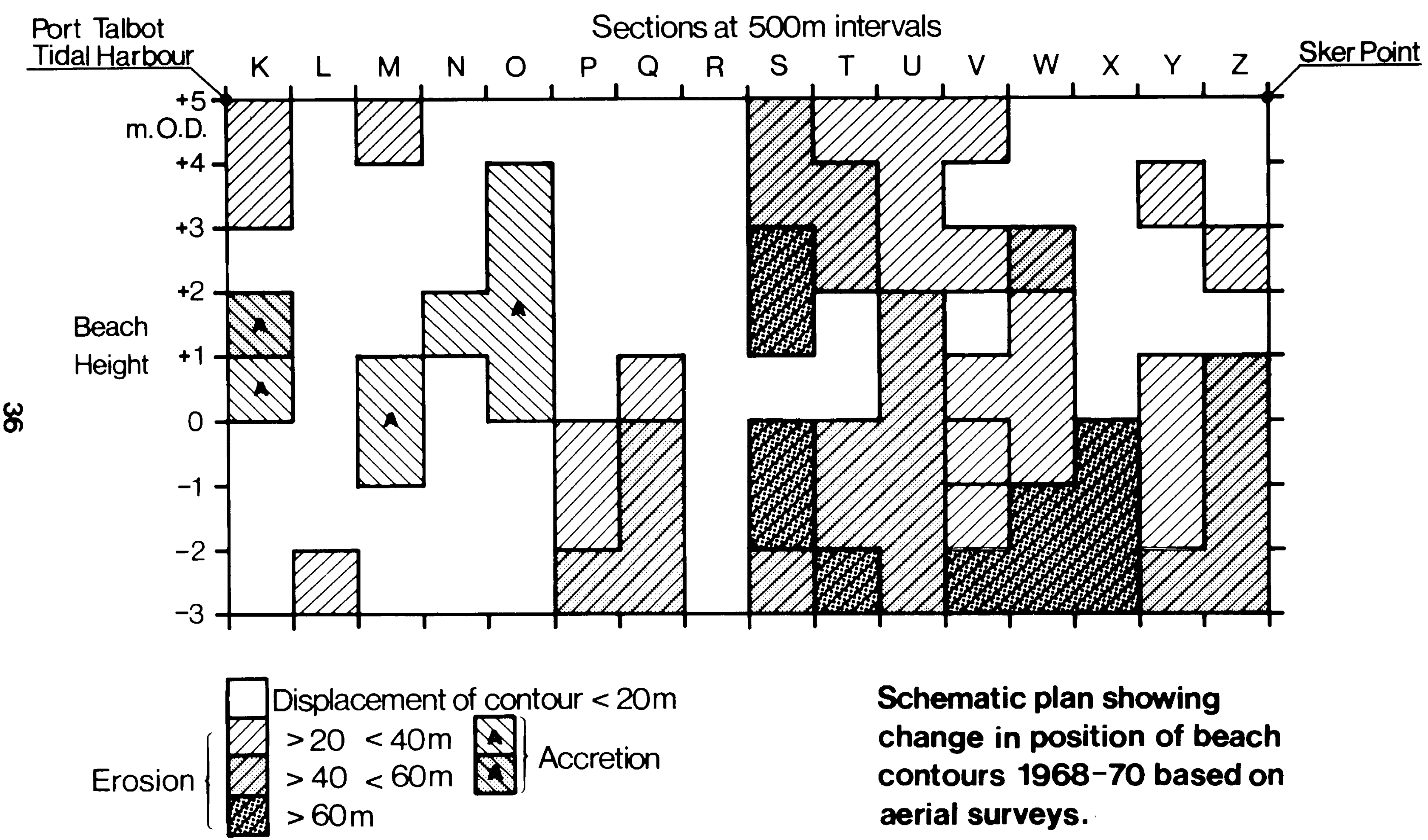


Fig. 5a


1975
Metres
100 50 0 100 200 300 400
N
KEY Contour values in metres (O.D. Liverpool)
Area of Lag deposits.
Area of Clay/Peat outcrops.
P Patches of material only.
Course of River
Pillbox
Wreckage
SKER POINT
Rock

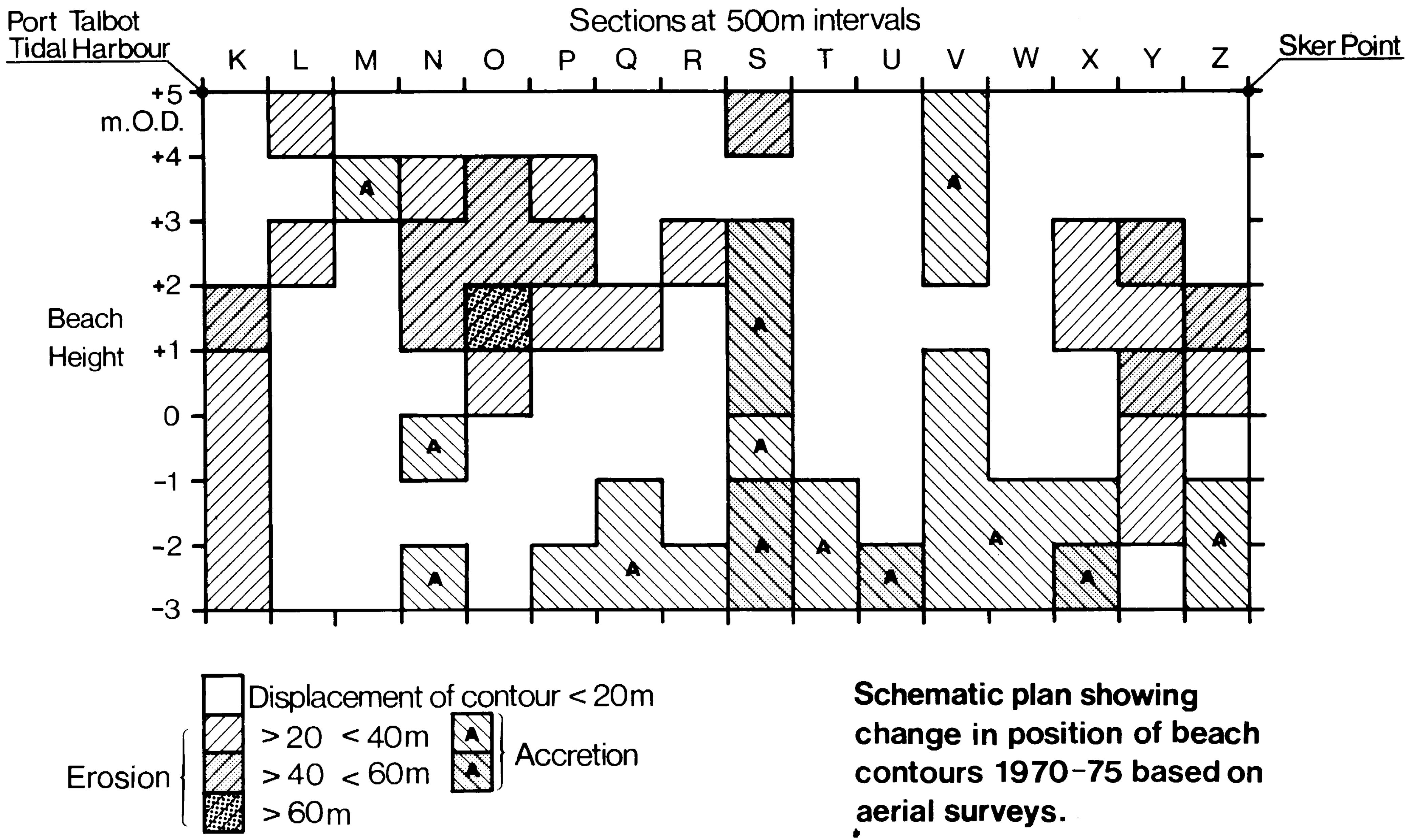



Fig. 5b



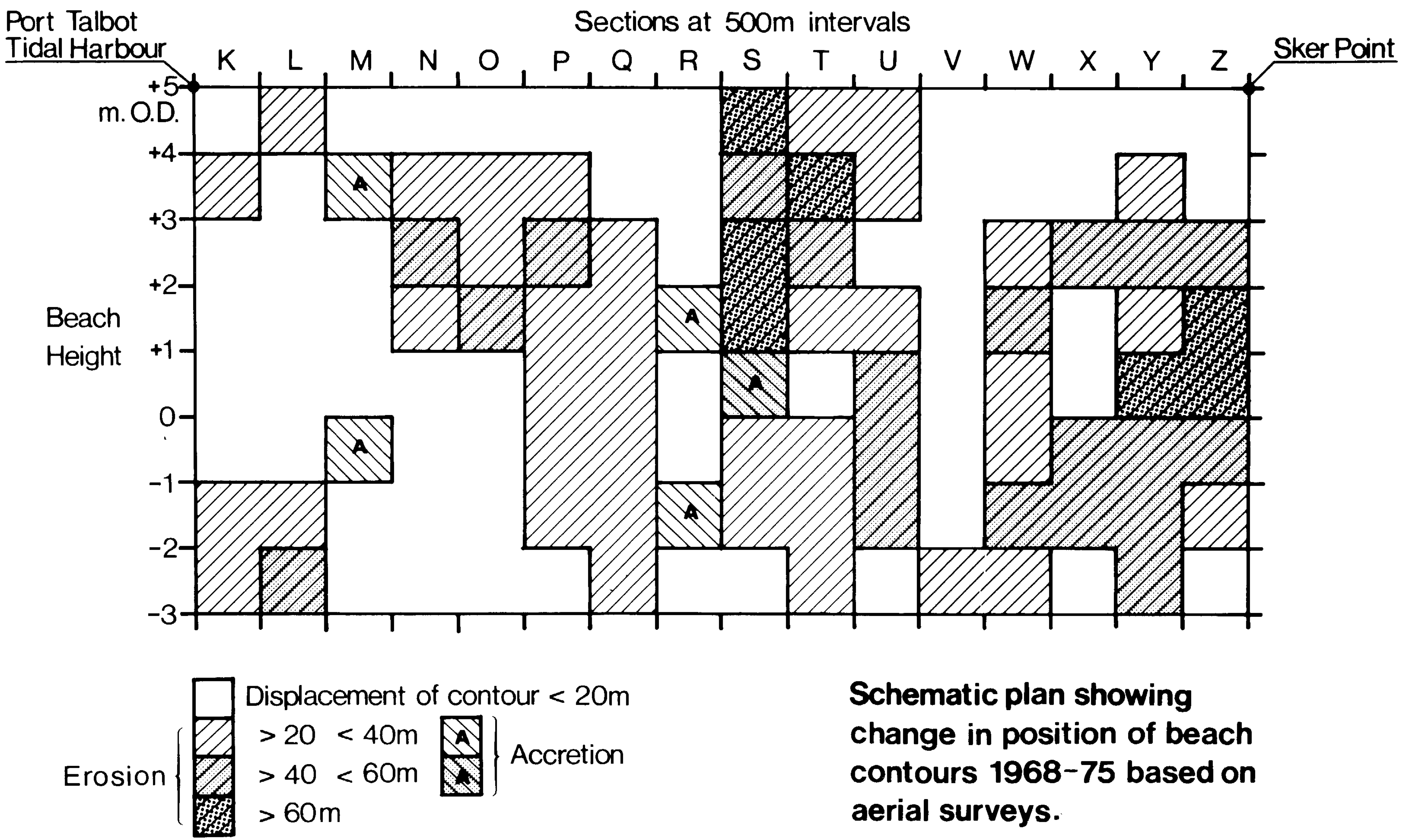

**Schematic plan showing change in position of beach contours 1968–70 based on aerial surveys.**

Fig.6




**Schematic plan showing change in position of beach contours 1970–75 based on aerial surveys.**

Fig. 7




**Schematic plan showing change in position of beach contours 1968–75 based on aerial surveys.**

Fig. 8

Figs 9-12: Profiles showing maximum range during period OCT 1975-APR 1977.

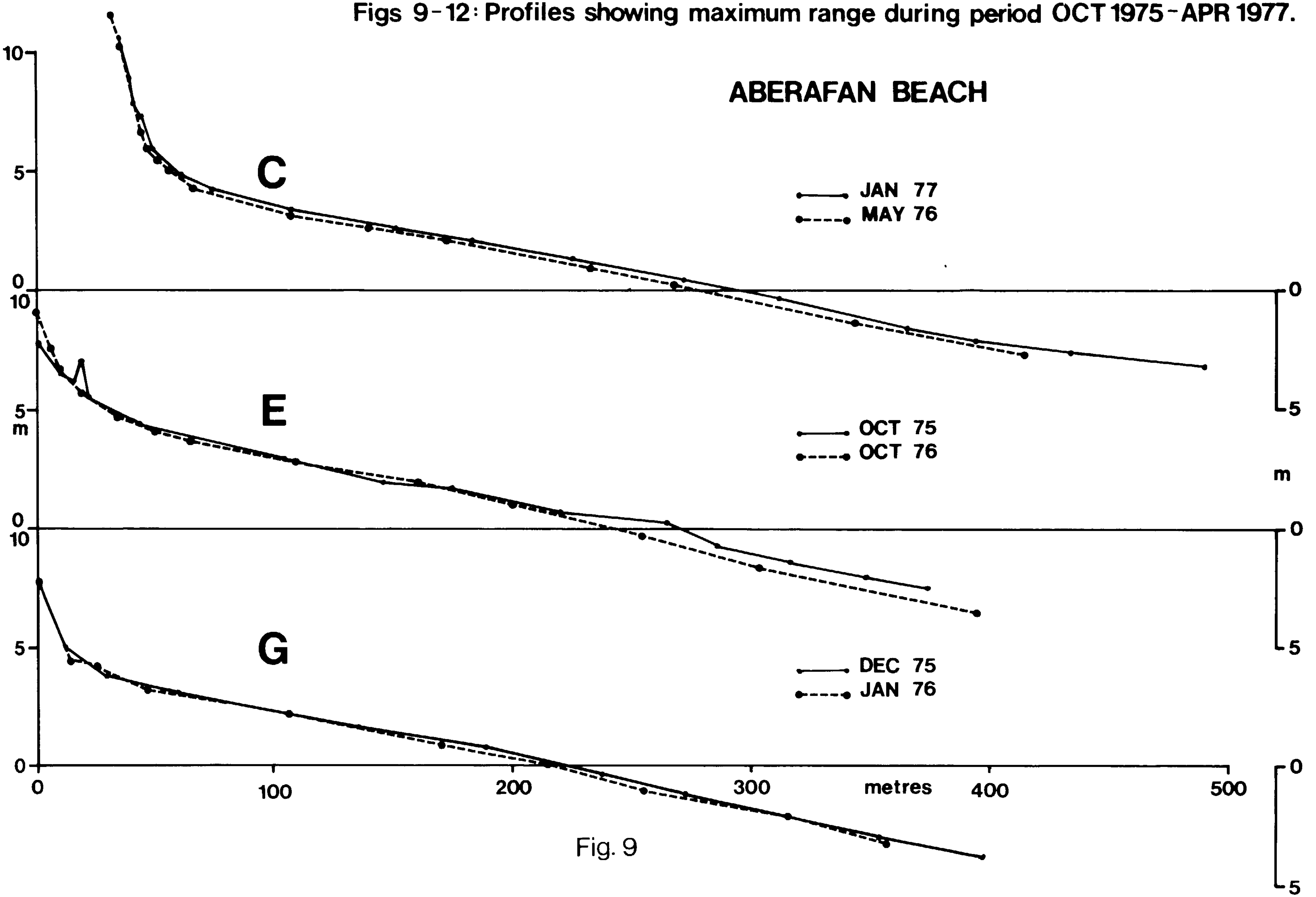



Fig. 9

Figs 9-12: Profilès showing maximum range during period OCT 1975 - APR 1977.

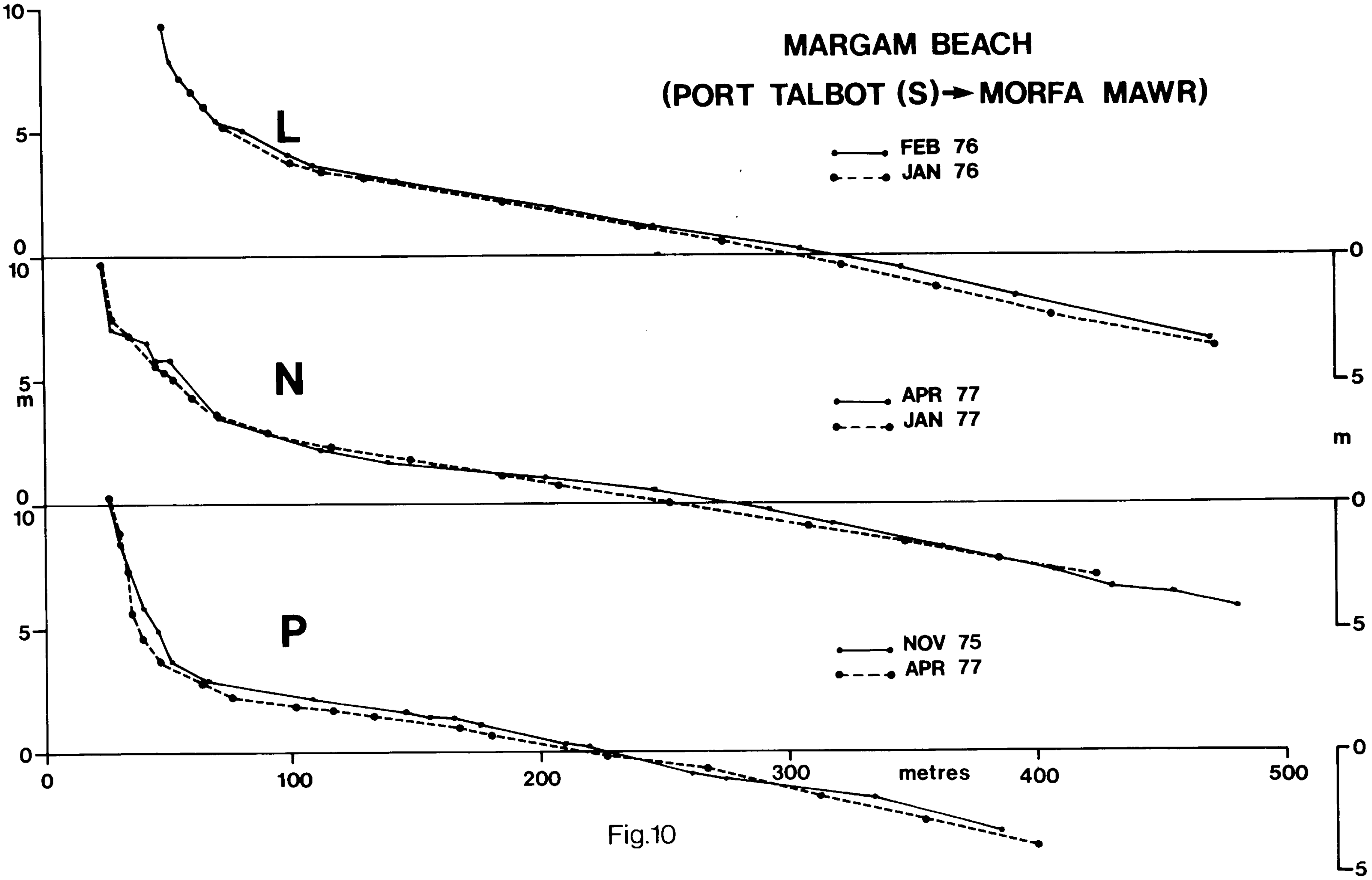



Fig.10

Figs 9-12: Profiles showing maximum range during period OCT 1975 - APR 1977.

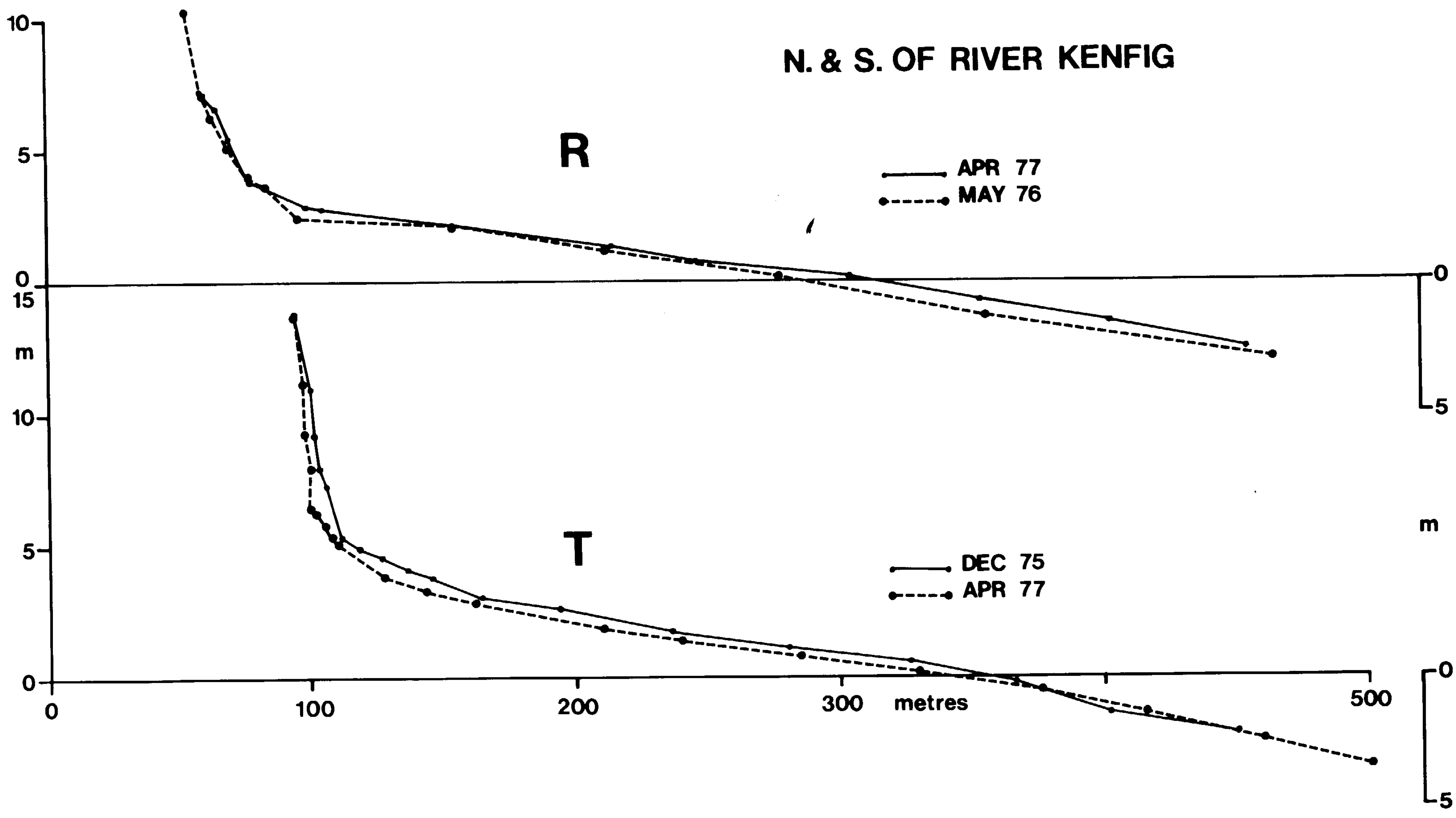



Fig.11

Figs 9-12: Profiles showing maximum range during period OCT 1975 - APR 1977.

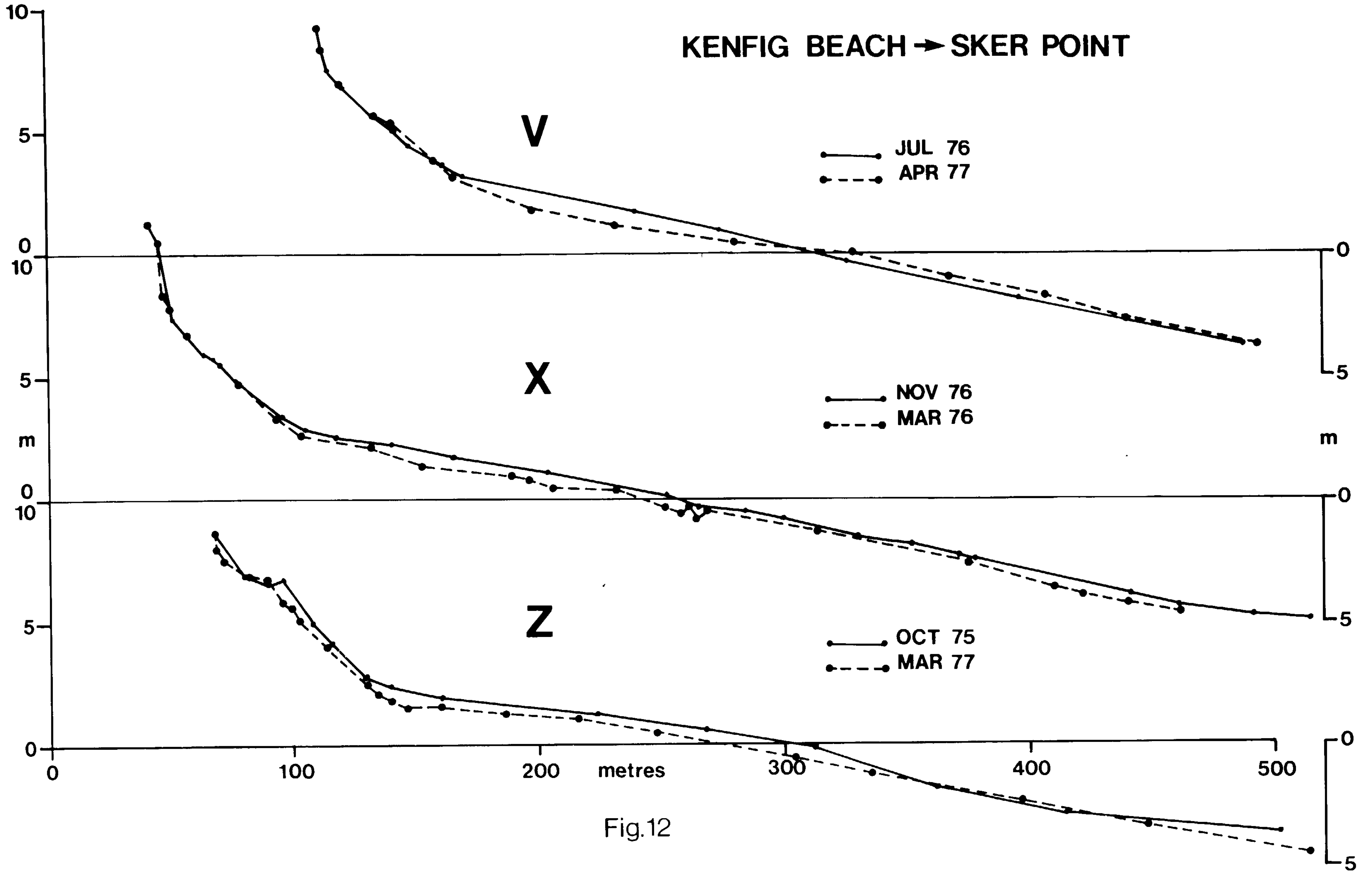
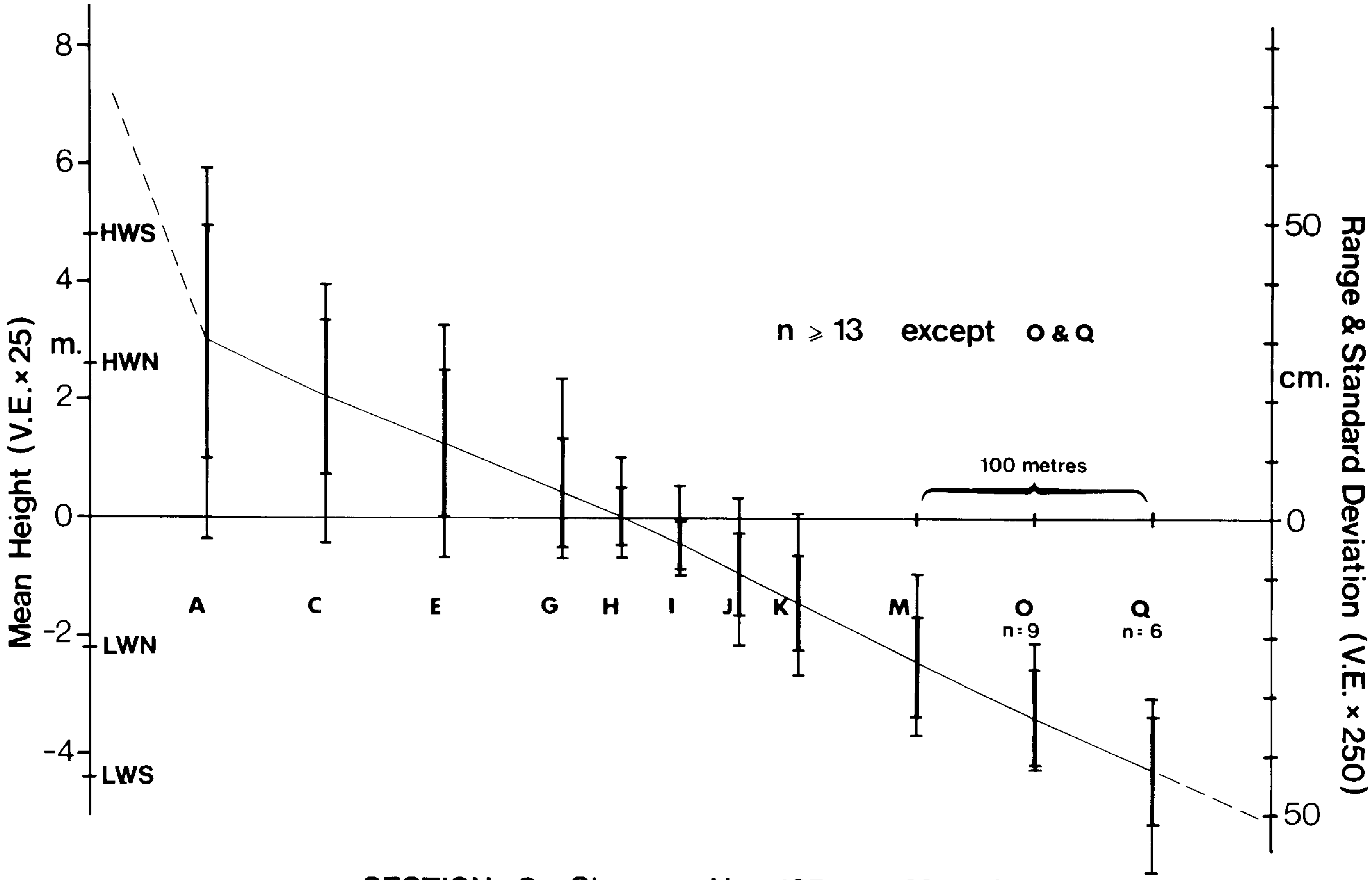
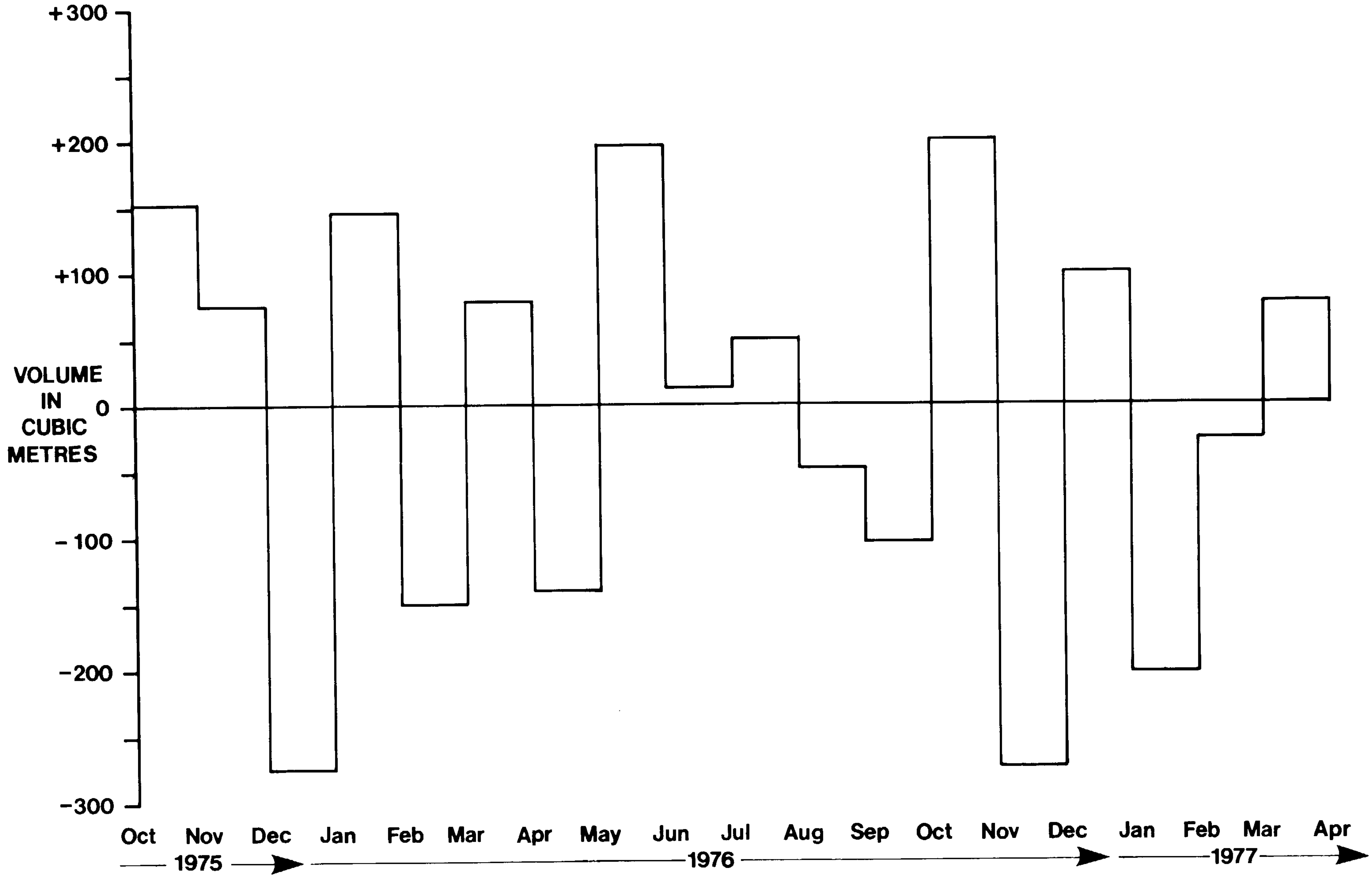


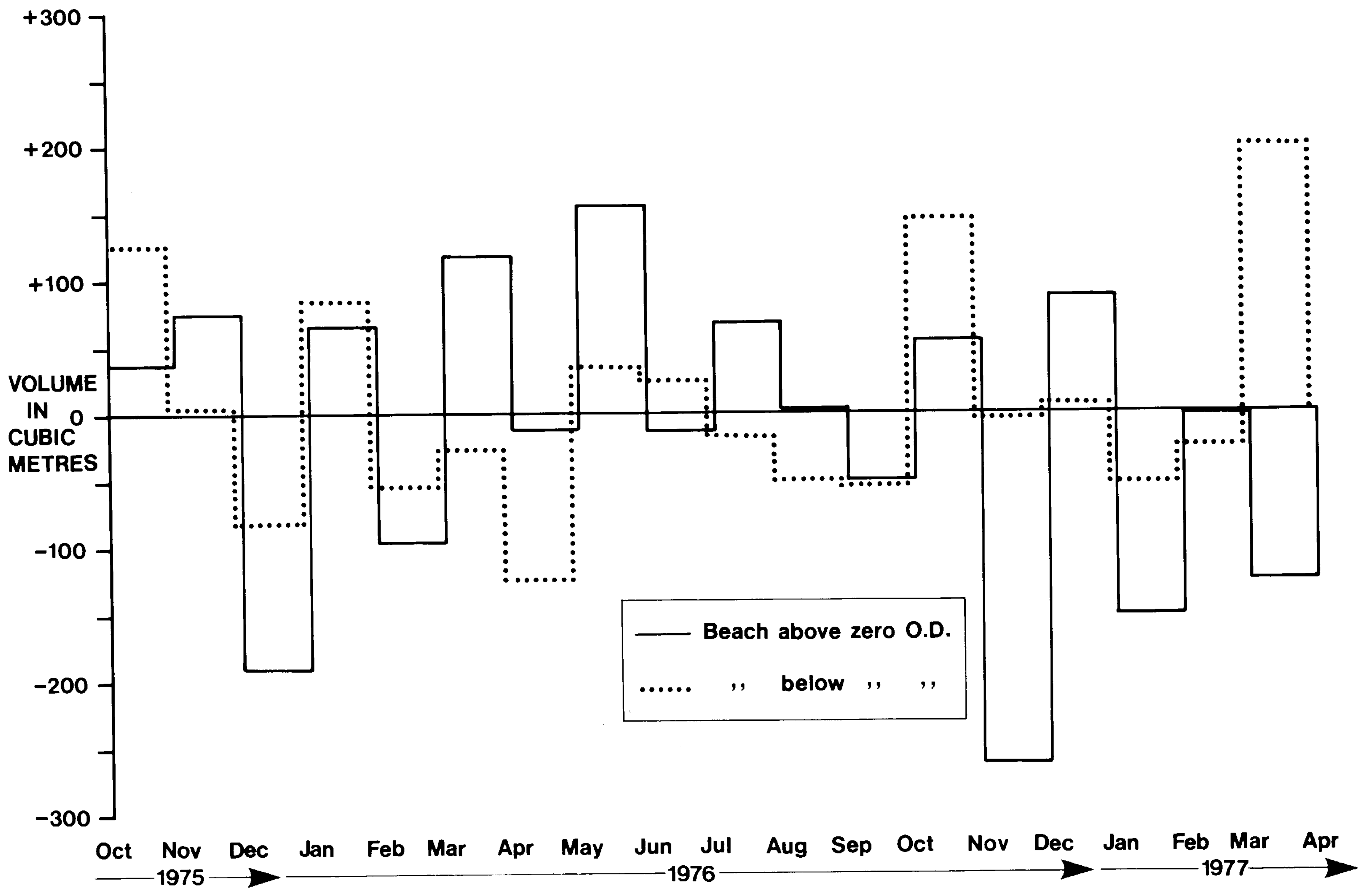

Fig.12




SECTION Q. Changes Nov 1976 to May 1977.
Fig.13



Overall change in volume along Sections between successive months.
Entire section.
Fig. 14a




Overall change in volume along Sections between successive months.
Upper and lower halves (above and below zero O.D.)

Fig.14b