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# BASELINE STUDY OF COASTAL EROSION AT MELE BAY, EFATE, VANUATU
**5 March to 19 March 1990**

by

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## SUMMARY

A coastal erosion survey was carried out at Mele Bay, Efate, Vanuatu between 5 March and 19 March 1990. The objective of the survey was to establish a series of beach profiles and collect baseline data with which future data acquired from the resurveying of the profiles could be compared. Twelve beach profiles were levelled from 11 Bench Marks, 10 of which were established by the survey team using Vanuatu Bench Mark 30 (BM 30) on Swango Point as a base reference mark. SOPAC has requested that the profiles be resurveyed at 6-month intervals and after major storms. The data are to be used to determine a quantitative estimate of coastal erosion in Mele Bay.

Coastal erosion has been a recurring problem at Mele Bay and in recent times has been linked to the unregulated mining of beach sand at two sites in the bay, one to the east of Swango Point and one to the west. Swango Point, a sand spit built over bedrock or older reef, divides the bay into two distinct areas. Both areas show signs of recent coastal erosion. The initial surveying has shown that the beaches of the two areas are relatively steep and narrow, with east Mele Bay having beaches that are lower and narrower. A unit volume of beach sediment between the head of the beach and Mean Sea Level (MSL) was calculated for each profile site. In east Mele Bay, the volume of sand on the beach near the sand mining site was 5 and 7.5 m per 1 m length of beach, whereas in areas away from the mining site the volume of beach sand was between 17.5 and 21.5 m. In west Mele Bay, the overall size of the beach is larger with beach volume near the sand mining site 13 and 22.5 m per 1 m length of beach. Sediment volume of the beaches away from the mining site ranges between 35 and 50 m. The extraction of sand at the mining sites is probably responsible for the differences noted in beach size.

Due to the narrow continental shelf and steep continental slope of the nearshore zone of Mele Bay, sand that is transported offshore during storms is probably permanently lost to the sediment budget system. When this sediment loss is added to the sand that is extracted by beach mining, an average of 450-500 m per month since 1985, the total amount is significant and the coast becomes even more susceptible to erosion. It is apparent that the rivers that discharge into the bay are unable to supply enough sediment to make up for the amount extracted by the mining operators.

One alternative to the mining of beach sand is to find other sources of commercial grade construction materials. The Mele Bay coastal plain is composed of "typical" Mele Bay beach sediment and suitable sources may be found away from the coastal zone.

## ACKNOWLEDGEMENTS

Major support for this project was provided by the United States Geological Survey. SOPAC gratefully acknowledges the help and cooperation of the Department of Geology, Mines and Rural Water Supply, Republic of Vanuatu and in particular Dr Cedric Mortimer, Department Director; Mr Stanley Temakon, Department Deputy Director; and Mr Colin Cheney, Hydrogeologist.

## OBJECTIVES

The objectives of the survey were to establish new bench marks, where necessary, for the surveying of beach profiles and to collect baseline data from the initial surveying of the beach profiles. These data are to be used as the reference for future resurveying of the profiles. The combined data will be used to determine the rate of coastline retreat in Mele Bay.

The survey was undertaken as part of Project VA.6, Baseline Studies of Inshore Areas in Vanuatu for Coastal Development and Task 90.VA.6b, Mele Bay Stability and Sediment Budget Study.

## INTRODUCTION

### Mele Bay Survey, 1990

A SOPAC coastal survey, No. VA9002, was conducted at Mele Bay, Efate, Vanuatu between 5 March and 19 March 1990 to establish a set of beach profiles that will be used to determine the rate of coastline retreat and the severity of coastal erosion in the area (Figure 1). The results of the present study are intended to complement a SOPAC nearshore bathymetry and subbottom survey performed during the same period, No. VA9001 (Smith and Saphore, 1990). A total of 12 beach profiles were established along the coast and 10 new bench marks were surveyed from Vanuatu Survey Bench Mark 30 (BM 30) located on Swango Point at UTM coordinates 14640.327E/15681.091N and VMG (Vanuatu Map Grid) coordinates 528311.749E/8043643.504N.

The survey was lead by a SOPAC Marine Geologist and ably assisted by a staff member of the Vanuatu Department of Geology, Mines and Rural Water Supply and a trainee from the Solomon Islands Geological Survey working under the Fellowship Scheme of the SOPAC Training Programme. The following people participated in the survey:

| | | |
|---|---|---|
| Douglas Rearic | - | SOPAC Marine Geologist (seconded from the United States Geological Survey) |
| Willie Harrison | - | Geological Assistant, Vanuatu Department of Geology, Mines and Rural Water Supply |
| Ivan Leanamae | - | Mines Assistant, Ministry of Natural Resources, Solomon Islands Geological Survey |

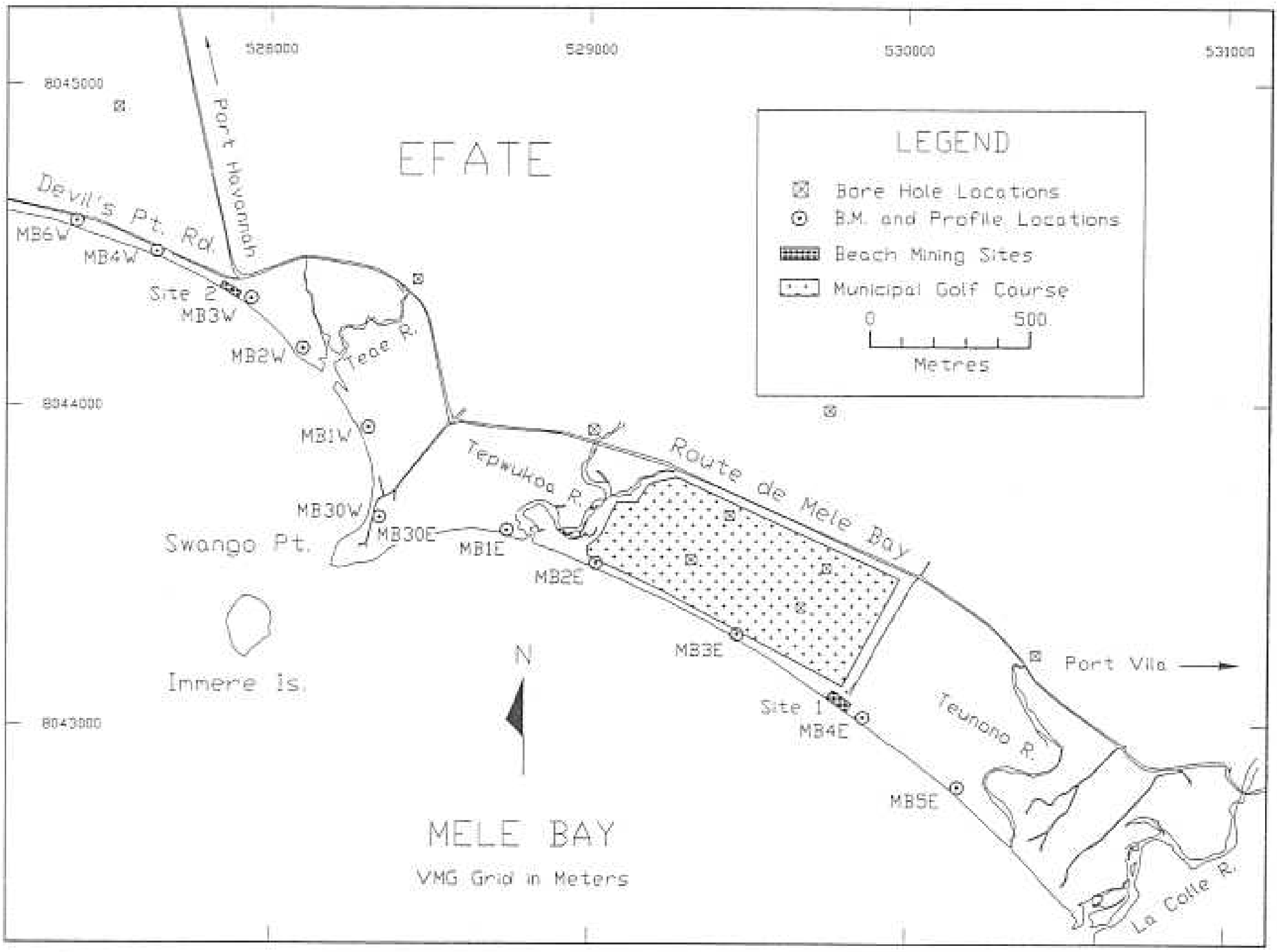


**Figure 1.** Location map of Mele Bay beach profiles. Included in the map are the locations of boreholes and wells for which the Department of Geology, Mines and Rural Water Supply have supplied data on sediment grain size and composition. Note the areas where the mining of beach sand is occurring.

## Techniques and Equipment

Twelve beach profiles were surveyed from a total of 11 bench marks, 10 of which are new bench marks surveyed in from Vanuatu Survey Bench Mark 30 (BM 30) on Swango Point (Figure 1). Metal rods of 1 m length were driven into the ground at each new bench mark site and about 10 cm was left above ground and painted orange for easy location at later dates (Figure 2). The surveys were performed using a Sokkisha level, Model C3E, and stadia rod. All data were reduced to MSL (Mean Sea Level) and are given in the Appendix.

## Geology of the Mele Bay Coastal Plain

The coastal plain at the head of Mele Bay is described by Howorth (1983) as an extensive coastal alluvial fan bounded by two main headlands, Devil's Point on the west and Pango on the southeast (Figure 3). The bay-headland morphology is controlled by faults and associated

**Figure 2.** Example of one of the new Bench Marks established in Mele Bay. The Bench Mark is VAW1 from which beach profile MB1W is being levelled.

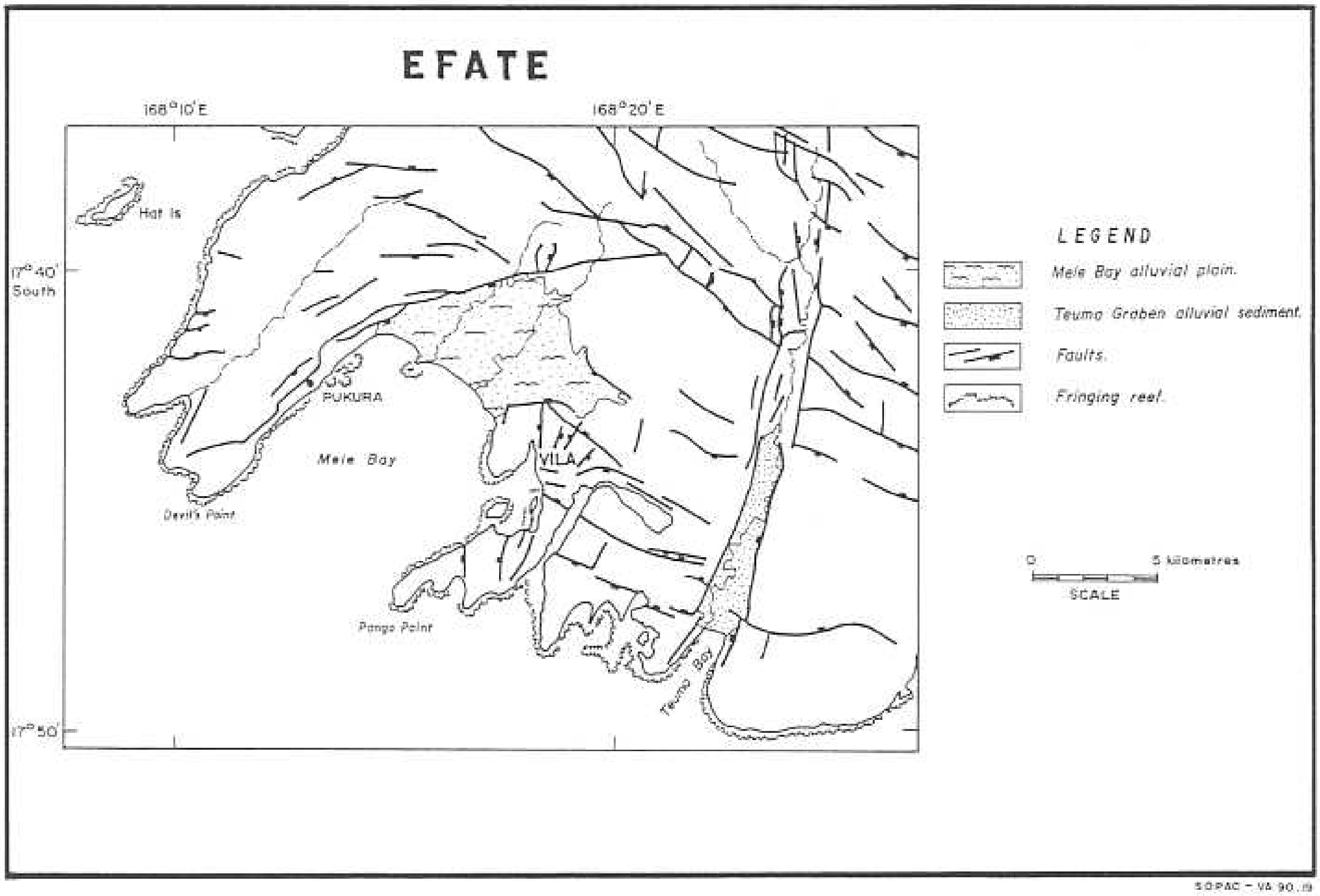


Figure 3. Location map of SW Efate showing Mele Bay coastal plain, major faults, and locations discussed in the text.

tilted blocks between them, which give a distinct northeast-southwest trend to the morphological structure of the coast. In most other areas of Efate, the structural trend of faulting is northwest-southeast, except for the north-south trending Teuma Graben to the east of Mele Bay (Ash et al., 1978).

The islands of Vanuatu are tectonically active due to their proximity to the New Hebrides Trench and are subject to numerous earthquakes. Uplifted Holocene reefs form a series of terraces along the coast of Efate (Ash et al., 1978). The upraising of the reefs to form terraces is believed to have accompanied earthquakes of magnitude M7.0 or greater during the Holocene (Howorth, 1985). An extensive list of previous work conducted on the coastal geomorphology of Efate is given by Howorth (1985).

The southern coast of Efate is surrounded by a fringing reef except for much of Mele Bay which is the only sandy beach environment in the Port Vila area (Howorth, 1985, Figure 3). Near the coastline in Mele Bay, between the Tepwukoa and Teunono Rivers, is a beach ridge given as 4 m above 1973 MSL (New Hebrides Map 2253, Series DOS 065, 1975). The Municipal Golf course lies behind this ridge and in the past has been protected from major storm damage by the ridge.

Borehole descriptions and well logs (Vanuatu Department of Geology, Mines and Rural Water Supply) from areas near the coast in Mele Bay (Figure 1) describe the sediment as mostly (up to 80 %) fine to coarse sand of volcanic origin. About 10 % of the coastal plain sediment is composed of limestone fragments. The sediment is described as "typical" Mele Bay beach sand and contains a small amount of magnetite which is estimated to have little commercial value (Temakon and Harrison, 1988). The volcanic sediment originated in the highlands to the north and east of Mele Bay, was eroded and transported to the plain by rivers and has been deposited as fluvial, beach, and nearshore marine deposits.

Rain gauge data for the years 1982-1984 show that Mele Bay receives between 800 and 2000 mm of rain per year with maximum rainfall in the highlands reaching over 3300 mm per year (Department of Geology, Mines and Rural Water Supply). River discharge data from 1982 to 1984 for the La Colle River in eastern Mele Bay show that discharge is generally greatest in February/March (maximum average 2.78 m/sec) and lowest in September/October (lowest average 1.07 m/sec). The greatest average daily river discharge during the 3 years was on 24 February 1982 where discharge averaged 9.38 m/sec.

**Background and Previous Work**

Coastal erosion has been observed at Mele Bay, Efate for a number of years (Temakon and Harrison, 1988) and in recent times has become a major concern to the residents, property owners and the operators and owners of the Municipal Golf Course. Land loss estimates vary but signs of coastal erosion are evident and include erosional scarps at the beach edge, exposed tree roots, fallen trees that litter portions of the beach, short and steep beach faces, and undercut building structures (Figures 4, 5, 6 and 7).

In April/May of 1983, H.G. Greene of the United States Geological Survey conducted the first CCOP/SOPAC Coastal Mapping Workshop in Vanuatu. The Workshop participants produced coastal geomorphology maps of the Mele Bay area. Soon after the completion of the Workshop, a study of the geology and coastal stability of the Port Vila area was completed by R. Howorth (1983), then a Marine Geologist for CCOP/SOPAC. Howorth established three beach profiles in Mele Bay, two of which were near areas of active sand mining. Unfortunately, the profiles have not been resurveyed and therefore documentation of actual beach loss is not available at this time. SOPAC has recently requested the Department of Geology, Mines, and Rural Water Supply to resurvey the profiles at their earliest convenience and to transmit the data to SOPAC so that comparisons of the past shoreline to the present can be made and estimates of coastal erosion calculated.

In 1984 and 1985, Howorth (1985) again visited Efate and studied the record of Holocene uplift by dating in situ corals from raised Holocene reef terraces. His data showed that, in Pukura in western Mele Bay, the coastal zone has been uplifting at rates of 1.28-2.13 mm/year during the Holocene. These rates are comparable to the rate of estimated global sea level rise over the last 100 years of 1-1.5 mm/year (Roy and Connell, 1989) and would indicate that this section of the Efate coast should not have been affected by rising sea level in recent times.

R. Smith and E. Saphore (1990) of SOPAC conducted a bathymetric survey of Mele Bay in February of 1990 (Figure 8). Preliminary interpretation of their data show that the continental shelf at Mele Bay is very narrow (about 50-350 m wide) and slopes at about 1.5. The continental slope at the edge of the shelf is steep (about 4.5) and incised by numerous channels off the river mouths. Water depth increases to as much as 120 m within 2 km of the coast. Evidence of recent downslope movement of sediment has been noted on the seismic records.

Figure 4. A short, steep beach near the sand mining operation on the east side of Swango Point. Note the fallen trees in the foreground and background that have been eroded by waves. During a cyclone this portion of the beach would be at severe risk to erosion from wave attack and the beach could be expected to retreat inland.

Figure 5. The club [illegible] of the Municipal Golf Course lies at the edge of the beach. Colin Cheney, a hydrogeologist recently of the Department of Geology, Mines, and Rural Water Supply, has estimated that 10 years ago the beach in this location was between 8 and 10 m farther seaward than its present location (oral communication). In the circle, there is a concrete platform which was the base pad of an outdoor shower once used by golf club members. To the left of the circle is the water line that once lead to the shower.

Figure 6. Close-up photo of Figure 5. Note the corner of the concrete base pad which has been undercut and now lies beneath the level of the club house and also the water line that once lead to the shower and is now lying on the beach. This area was once covered in grass and is now at high risk to erosion during a cyclone due to its nearness to the oceans edge.

Figure 7. Sand-mining Site 2 west of Swango Point. Mining operations were inactive at the site at the time the photograph was taken in October 1989. The beach originally sloped from the edge of the vegetation at the top of the scarp to the waters edge to the right of the photograph. This is an indication of the amount of sand that has been extracted. Storm waves can now reach at least to the base of the scarp and will eventually undercut the vegetation causing the beach to retreat farther inland.

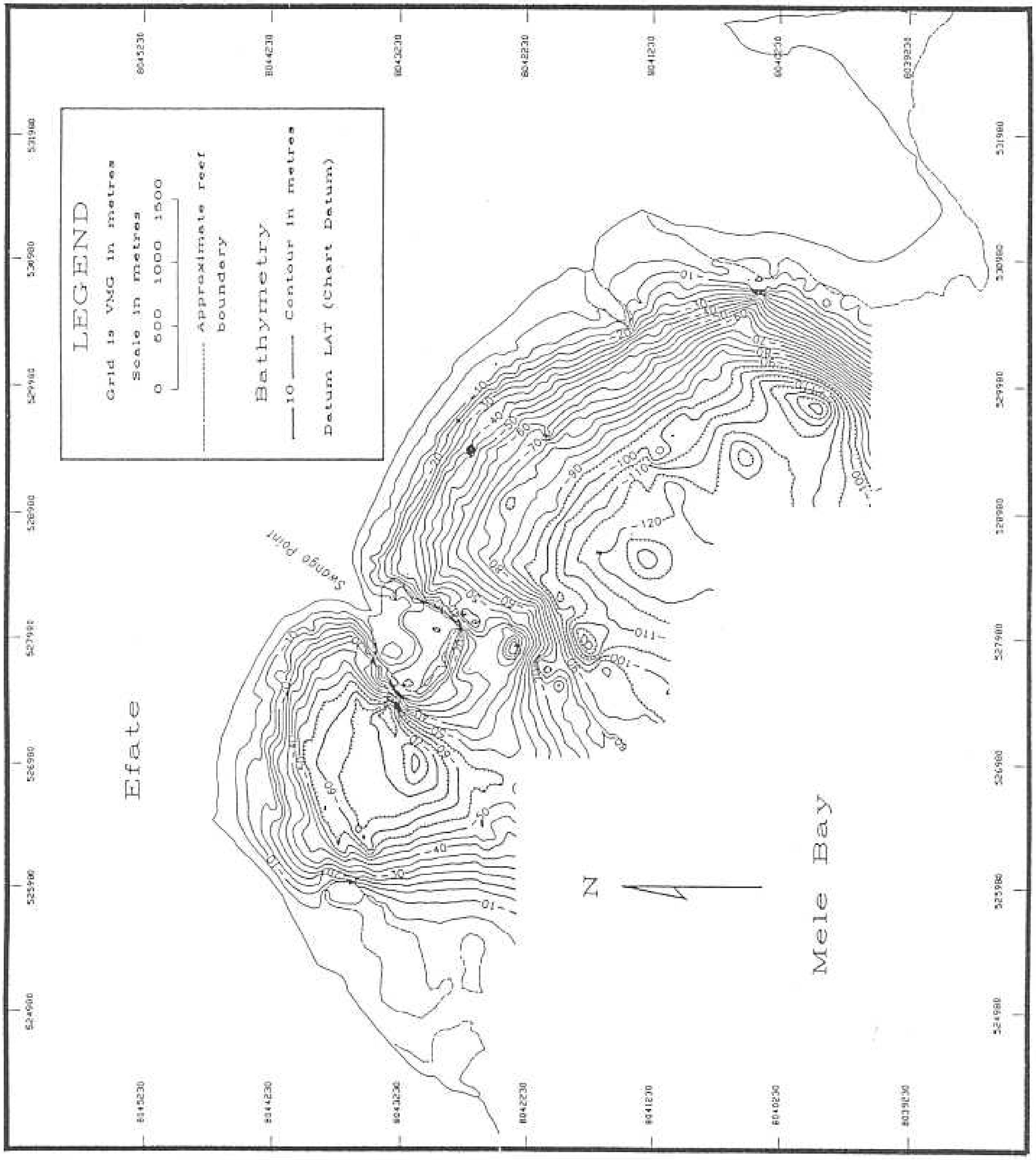


Figure 8. Bathymetry map from the SOPAC survey of Smith and Saphore (1990). Note the steepness of the slope and the narrowness of the shelf. Refer to the report of Smith and Saphore (1990) and the text for a more detailed description of the offshore bathymetry and geology.

## Sand Mining

The commercial mining of sand from the beaches of Mele Bay has continued for about 10 years from two sites, one east of Swango Point at the east end of the golf course, and the other west of Swango Point near the road junction for Klem Hill and Devil's Point (Figure 1). Recent data show that sand was extracted from these sites by commercial mining concerns (Temakon and Harrison, 1988) at an average rate of between 450-500 $m^3$ per month between the years of 1985 and 1988, although mining has not been continuous at either site. During a visit by D. Rearic in October 1989 (Rearic, 1989) only the eastern site was being actively mined (Figure 9) and during the present survey only the western site was being actively mined (Figure 10). Individuals have also taken sand from the beaches for their own use but the amount is minor when compared to that of commercial mining.

Temakon and Harrison (1988) speculate that sand extraction at Mele Bay has contributed to the erosion of the coastline. They report that between 1983 and 1988 the morphology and shape of the coastline of Mele Bay has changed considerably. They attribute this to the direct result of cyclones which create waves capable of removing large amounts of sand from the beach. They also suggest that the effect the mining of sand has on the coast, although not quantitatively known at this time, can reasonably be assumed to lessen the protection offered to the coast by the beaches.

**Figure 9.** Sand mining at Site 1 east of Swango Point. Note the steep scarp to the right of the photograph.

**Figure 10.** Sand mining at Site 2 west of Swango Point. The environmental effects of the mining can be seen by the undercut tree to the left in the photograph and by the shortness and steepness of the beach.

## RESULTS

Six beach profiles were established to either side of the sand spit (Swango Point) extending into Mele Bay (Figure 1). The numbering of the beach profiles began at the spit and extended to the east and west so that beach profile MB30W extended from BM 30 into the western part of the bay and profiles MB1W through MB5W continued consecutively to the west from Bench Marks VA1W through VA5W (Figure 1). The numbering for the beach profiles to the east follows the same pattern.

### Bench Mark Locations and Descriptions

A total of 11 bench marks, 10 of which are new, were used to survey the beach profiles in Mele Bay. BM 30 on Swango Point was used to survey two beach profiles, one on the east side of the spit (MB30E) and one on the west (MB30W). Five bench marks were established to either side of the spit from which the remaining profiles were surveyed. The bench marks to the east of the spit are numbered VAE1 to VAE5 and the bench marks to the west VAW1 to VAW5.

**BM 30 -** The bench mark is located on Swango Point (a sand spit built over bedrock or Holocene reef) to the southeast of a concrete pad that serves as a basketball court. The height of the bench mark is 2.090 m above MSL.

**VAE1 -** The bench mark is located about 450 m east of BM 30 and lies just east of the Tepwukoa River. The river in this area does not enter the bay directly as shown on New Hebrides Map 2253, but bends to the west and follows the coastline to enter the bay near the area of beach profile MB30E (Figure 1). The bench mark is 16.7 m back from the MSL elevation on the beach. The height of the bench mark is 2.792 m above MSL.

**VAE2 -** The bench mark is located about 290 m east of BM VAE1 and lies at the edge of the golf course fairway east of the club house. The bench mark is 16.9 m back from the MSL elevation on the beach. The height of the bench mark is 3.604 m above MSL.

**VAE3 -** The bench mark is located about 500 m east of BM VAE2 and lies near the eastern end of the golf course. Mining of beach sand at Site 1 (Figure 1) is occurring to the east of the site. The bench mark is about 11.9 m back from the MSL elevation on the beach. The height of the bench mark is 2.858 m above MSL.

**VAE4 -** The bench mark is located about 394 m east of VAE3 and lies just east of the sand mining operation at Site 1 (Figure 1). The bench mark is 15 m back from the MSL elevation on the beach. The height of the bench mark is 3.183 m above MSL.

**VAE5 -** The bench mark is located about 348 m to the east of VAE4 and lies west of the La Colle River. The bench mark is 17 m back from the MSL elevation on the beach. The height of the bench mark is 3.247 m above MSL.

**VAW1 -** The bench mark is located about 263 m west of BM 30 and lies near the end of a dirt track that parallels the beach inland. The bench mark is 33.2 m back from the MSL elevation on the beach. The height of the bench mark is 2.442 m above MSL.

**VAW2 -** The bench mark is located about 325 m west of VAW1 and lies just west of the Teae River. The bench mark is 30.6 m back from the MSL elevation on the beach. The height of the bench mark is 2.993 m above MSL.

**VAW3 -** The bench mark is located about 222 m west of VAW2 and lies about 30 m east of the sand mining operation at Site 2 (Figure 1). The bench mark is 25.4 m back from the MSL elevation on the beach. The height of the bench mark is 4.092 m above MSL.

**VAW4 -** The bench mark is located about 325 m west of VAW3 and lies to the west of the sand mining operation at Site 2 (Figure 1) on a berm on the ocean side of Devil's Point Road. The bench mark is 14.7 m back from the MSL elevation on the beach. The height of the bench mark is 3.041 m above MSL.

**VAW5 -** The bench mark is located about 265 m west of VAW4 and lies at the upper edge of the beach. The bench mark is 22.5 m back from the MSL elevation on the beach. The height of the bench mark is 4.035 m above MSL.

**Beach Profile Locations and Descriptions**

In the following descriptions, the width of the beach is taken as the horizontal distance between the shoreward margin of the beach (generally taken as the end of permanent vegetation or an erosional scarp) and the interaction of the profile with MSL. This allows comparison of the profiles within a set of equal parameters. The profiles obtained from the eastern area of Mele Bay all extend below MSL and the beach width can be readily calculated. However, in the western part of the bay, because some of the profiles were levelled during high tide, only two of the six profiles extend below MSL. In these cases, the beach profile is extended to MSL using the slope of the last two available elevation points. From observation of the trends of all the profiles, it is believed that this will be within any reasonable error that could be produced by this method. The width of estimated beach added to the profiles is from 1 to 3 m for three of the profiles. Profile MB30W, on Mele Spit has an estimated 9 m added to the beach, however the profiles from the spit area are of a less critical nature in considering the problems associated with coastal erosion.

The location maps of the Bench Marks and beach profiles (Figures 11A to 22A) are modified from the New Hebrides Map Series DOS 065, 1975 Edition, Scale 1:2500. The projection is Cassini. The grid is Efate Cassini and each tick mark represents 100 m of distance. The beach profile graphs (Figures 11B to 22B) are plotted at a vertical exaggeration (VE) of 8:1.

(For Figures 11 to 22 see pages 22 to 33 after the profile descriptions.)

**Profile MB30E -** Beach profile MB30E was levelled from Swango Point at a bearing of 164 T from BM 30 into the eastern part of Mele Bay (Figure 11). During the survey, the Tepwukoa River ran parallel to the beach before discharging into the bay. During times of high river discharge the sand bar forming the beach can be breached further to the east and the river then drains directly into the bay rather than running its present course. New Hebrides Map 2253 shows the river discharging directly into the bay (Figure 1).

The beach profile crosses the river before reaching a sand bar that extends from the beach further to the east. The shape of the bar suggests that longshore transport is towards the west, building the spit on an area of rock foundation that extends out to Immere (Mele) Island. Because the river provides an almost constant supply of sand and the spit interrupts the transport of sand, the beach in this area is relatively wide (over 50 m) when compared to the rest of the beaches in the bay.

**Profile MB1E -** Beach profile MB1E was levelled from BM VAE1 at a bearing of 198 T (Figure 12). The beach, which is just east of the Tepwukoa River, is 13.7 m wide. There is a small beach ridge at a height of 1.7 m above MSL that may be either a storm ridge or related to high tide level.

**Profile MB2E -** Beach profile MB2E was levelled from BM VAE2 at a bearing of 204 T (Figure 13). The beach, which lies off the western end of the golf course, is 12.8 m wide. The slope of the beach is almost constant for the entire length of the profile.

**Profile MB3E -** Beach profile MB3E was levelled from BM VAE3 at a bearing of 210 T (Figure 14). The beach, which lies off the eastern end of the golf course and west of the sand mining operation at Site 1, is 8.7 m wide. There is a 0.8 m erosional scarp at the upper edge of the beach. The slope of the beach is constant from the base of the scarp to the end of the profile.

**Profile MB4E -** Beach profile MB4E was levelled from BM VAE4 at a bearing of 222 T (Figure 15). The beach, which lies just to the east of the sand mining operation at Site 1, is 8.1 m wide. There is a 1.4 m erosional scarp at the upper edge of the beach and the beach slope is almost constant from the base of the slope to the end of the profile, similar to site MB3E.

**Profile MB5E -** Beach profile MB5E was levelled from BM VAE5 at a bearing of 222 T (Figure 16). The beach, which lies to the west of the Teunono River, is 14.9 m wide. The slope of the beach is almost constant for the entire length of the profile.

**Profile MB30W -** Beach profile MB30W was levelled from BM 30 at a bearing of 263 T (Figure 17). The beach, which lies on the western side of Swango Point, is 34.7 m wide.

**Profile MB1W -** Beach profile MB1W was levelled from BM VAW1 at a bearing of 251 T (Figure 18). The beach is 23.2 m wide. There is a storm or high-tide ridge on the beach which lies 2.4 m above MSL.

**Profile MB2W -** Beach profile MB2W was levelled from BM VAW2 at a bearing of 223 T (Figure 19). The beach, which lies just west of the Teae River, is 21.6 m wide. The slope of the beach is relatively constant for its entire length.

**Profile MB3W -** Beach profile MB3W was levelled from BM VAW3 at a bearing of 215 T (Figure 20). The beach, which lies about 30 m east of the sand mining operation at Site 2, is 17.0 m wide. There is a 1.7 m erosional scarp at the upper edge of the beach and a storm or high-tide ridge at 2 m above MSL.

**Profile MB4W -** Beach profile MB4W was levelled from BM VAW4 at a bearing of 215 T (Figure 21). The beach, which lies to the west of the sand mining operation at Site 2, is 12.4 m wide. There is a 0.9 m erosional scarp at the upper edge of the beach and a storm or high-tide ridge at 1.1 m above MSL, similar to site MB3W.

**Profile MB5W -** Beach profile MB5W was levelled from BM VAW5 at a bearing of 013 T (Figure 22). The beach is 22.5 m wide. There is a small break in slope at 1.7 m above MSL, otherwise the slope of the beach is almost constant.

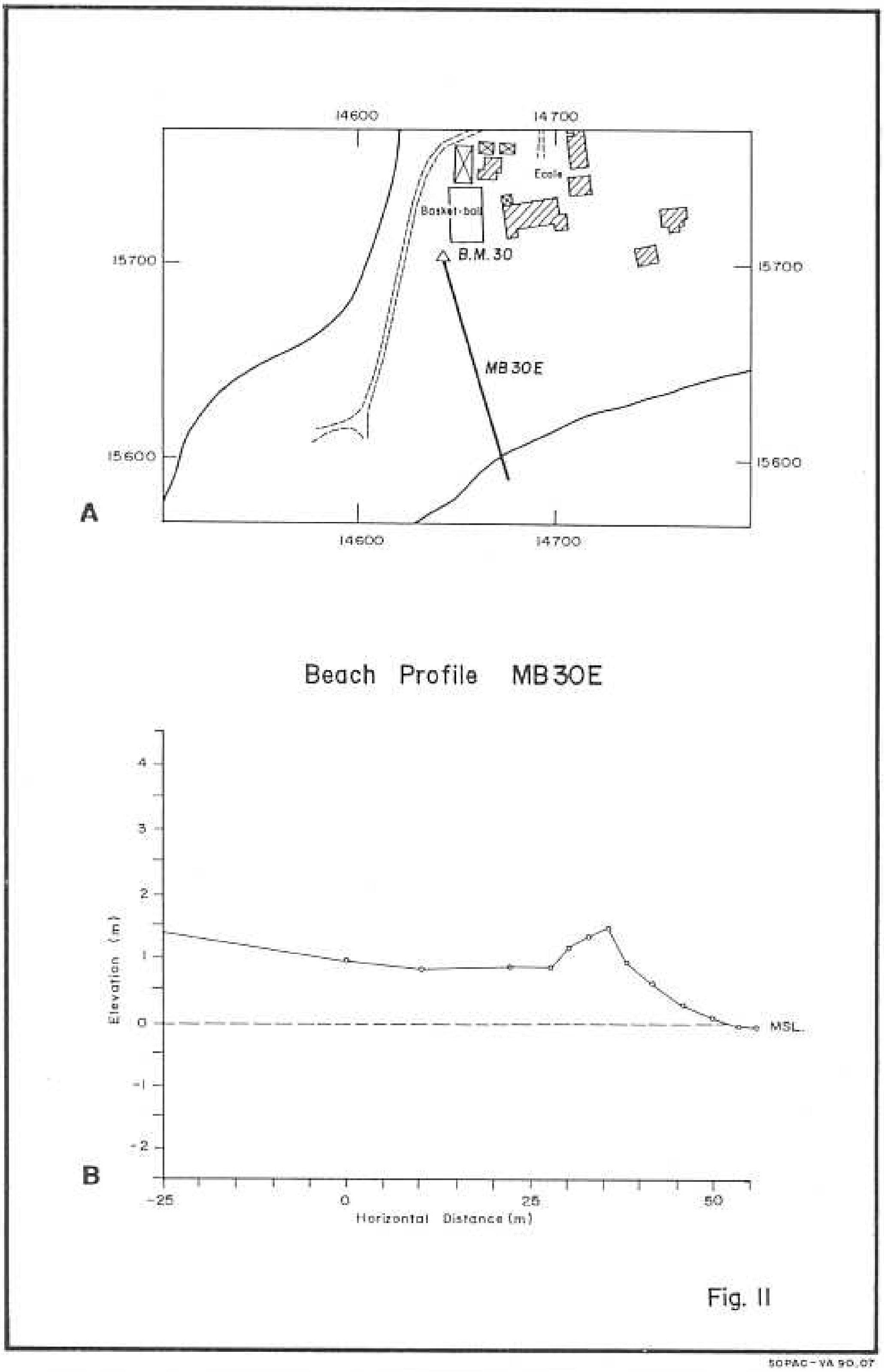


**Figure 11.** Location (A) and plot (B) of BM 30 and beach profile MB30E. Location map is taken from New Hebrides Map 2153, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to fluctuation of river discharge pattern and erosion.

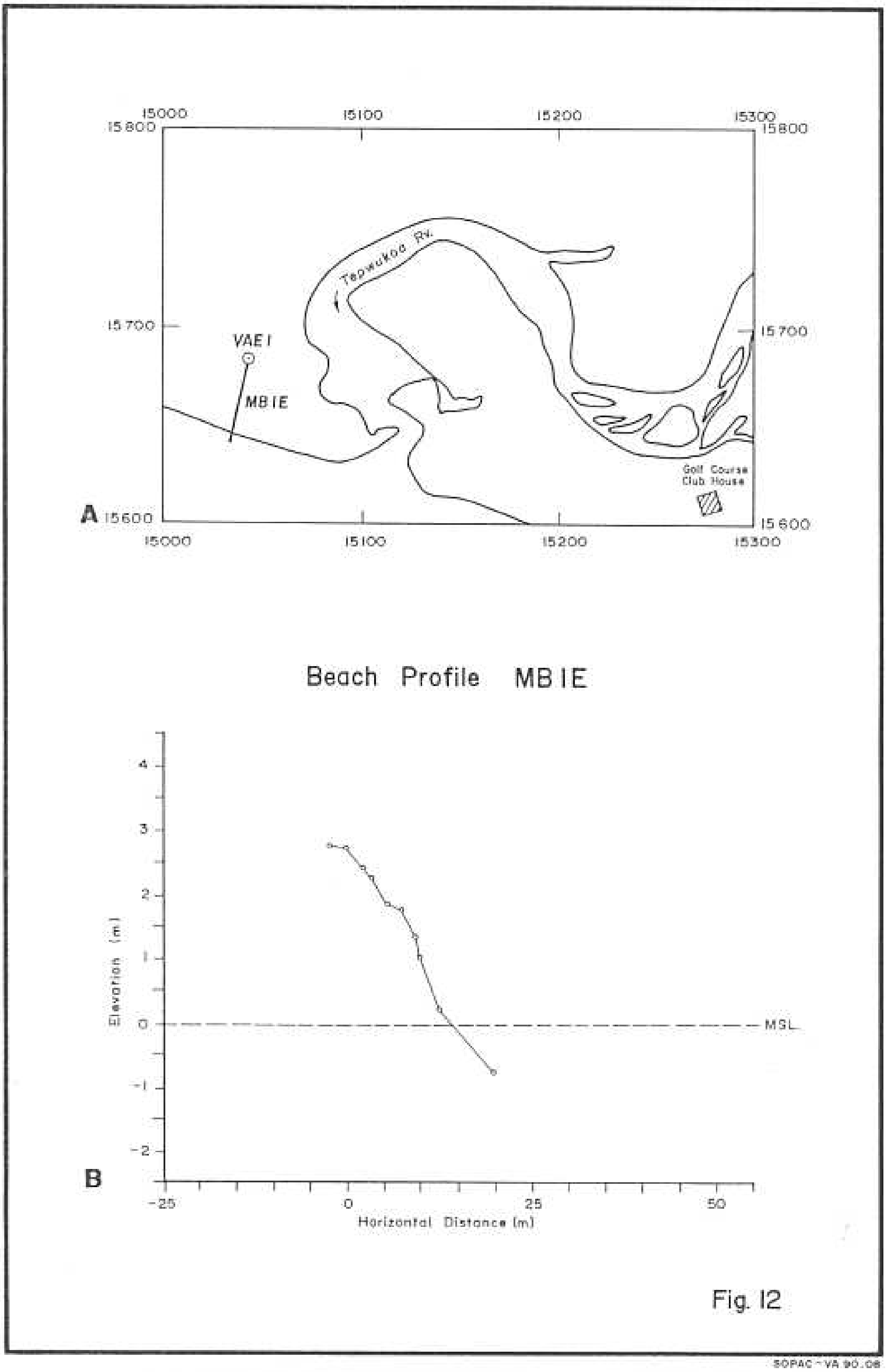


Figure 12. Location (A) and plot (B) of BM VAE1 and beach profile MB1E. Location map is taken from New Hebrides Map 2253, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to fluctuation of river discharge pattern and erosion.

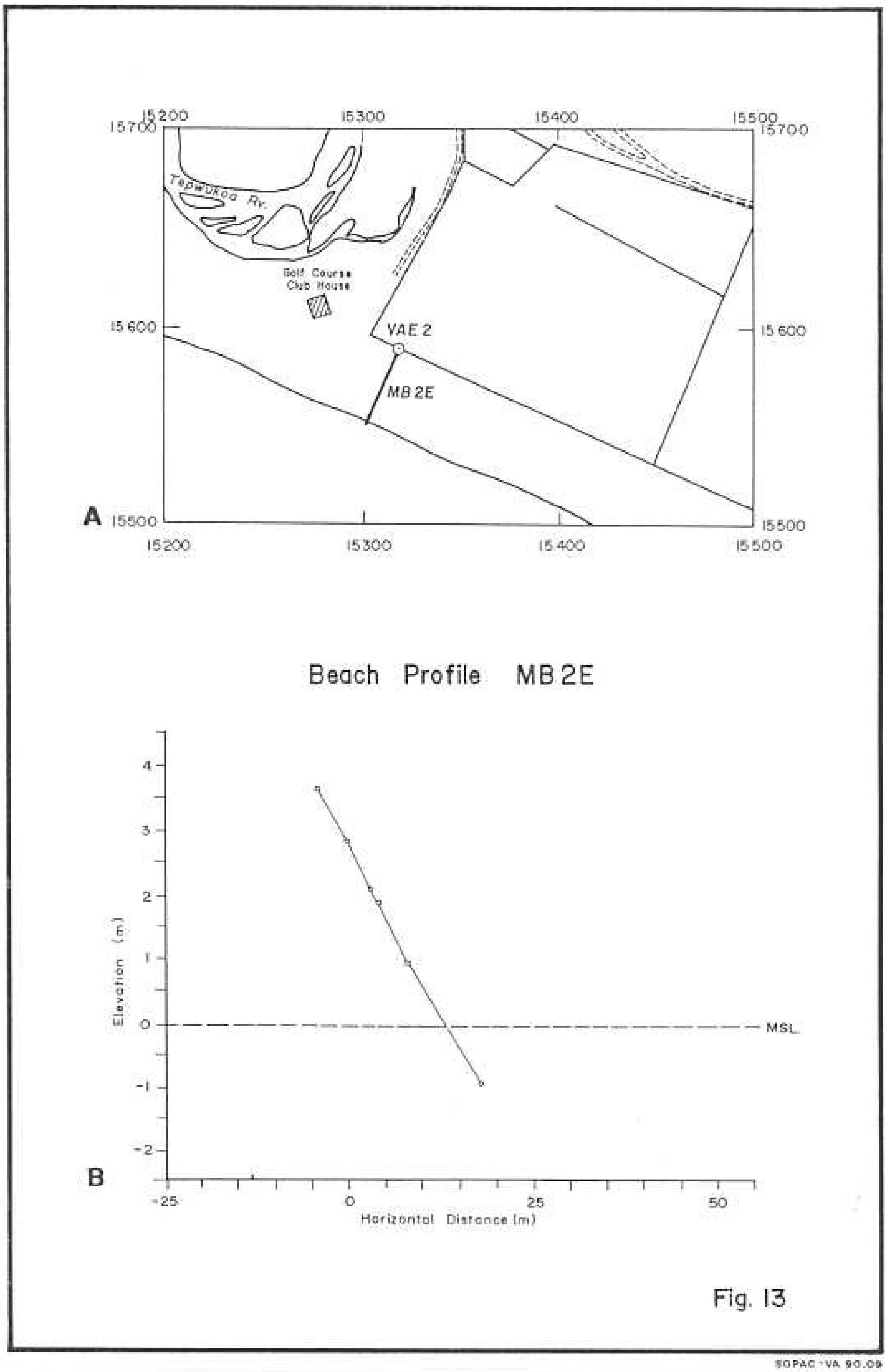


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Figure 13. Location (A) and plot (B) of BM VAE2 and beach profile MB2E. Location map is taken from New Hebrides Map 2253, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

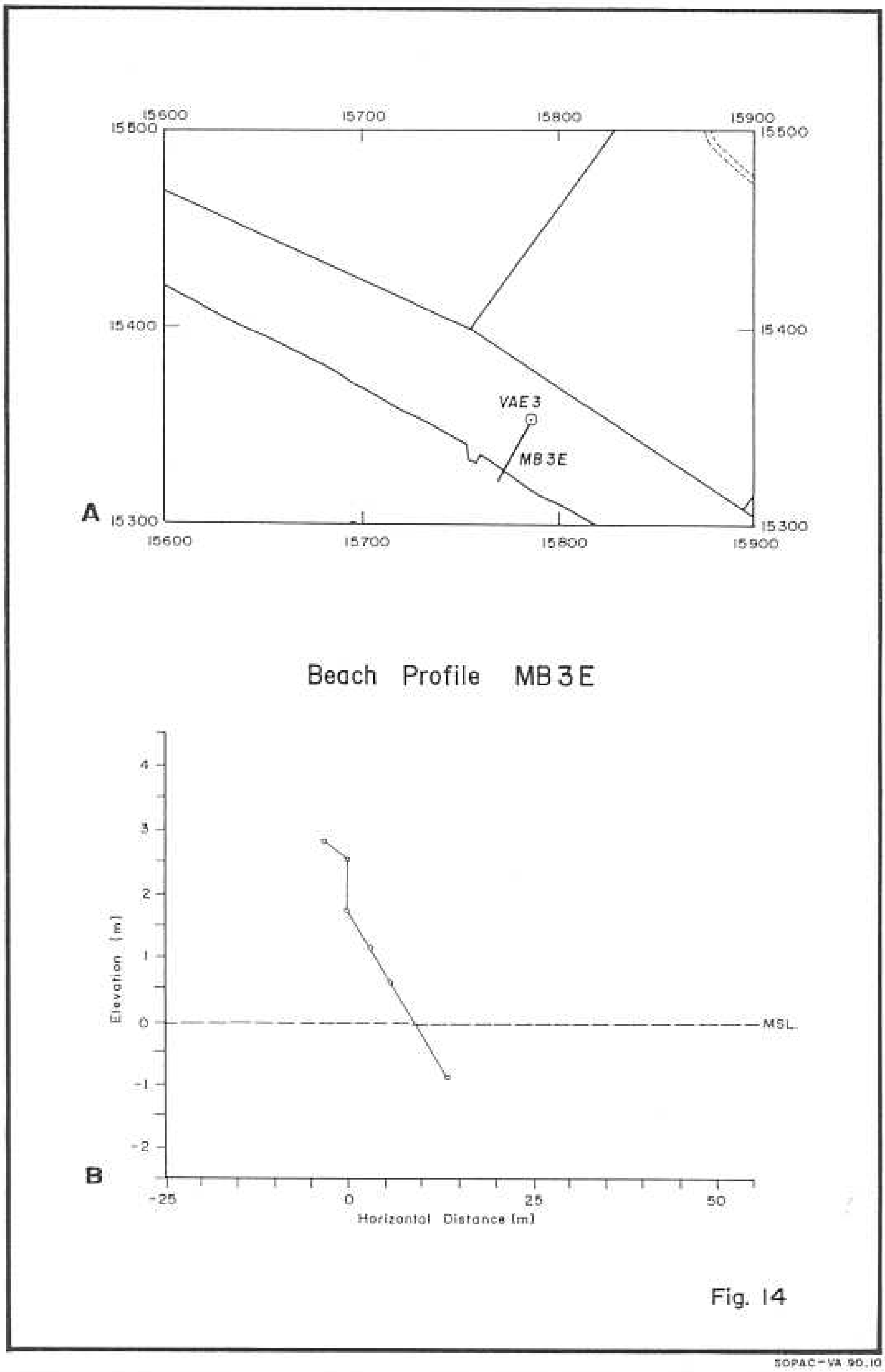


Figure 14. Location (A) and plot (B) of BM VAE3 and beach profile MB3E. Location map is taken from New Hebrides Map 2253, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

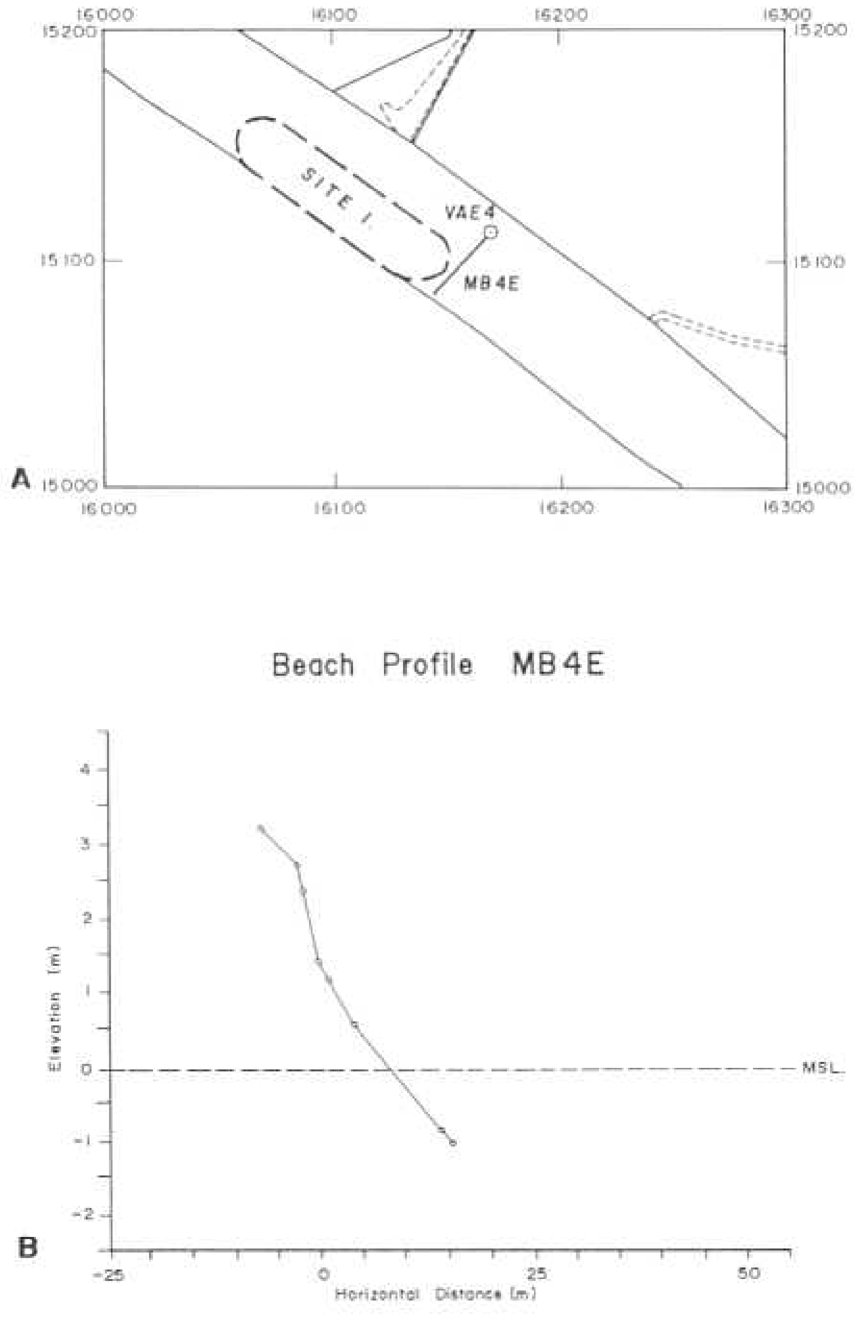


Fig. 15

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Figure 15. Location (A) and plot (B) of BM VAE4 and beach profile MB4E. Location map is taken from New Hebrides Map 2253, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion and beach-sand mining.

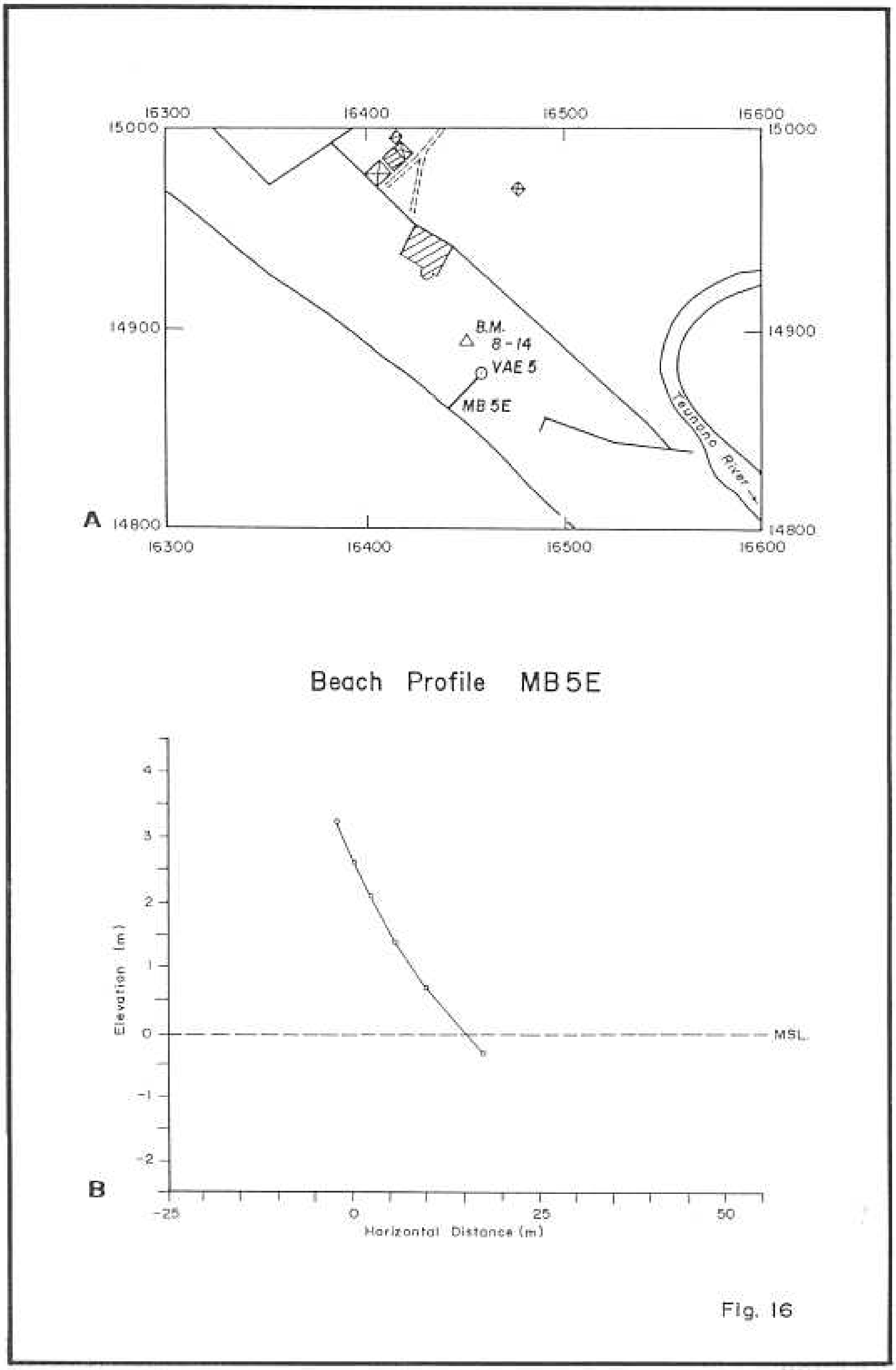


Figure 16. Location (A) and plot (B) of BM VAE5 and beach profile MB5E. Location map is taken from New Hebrides Map 2254, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

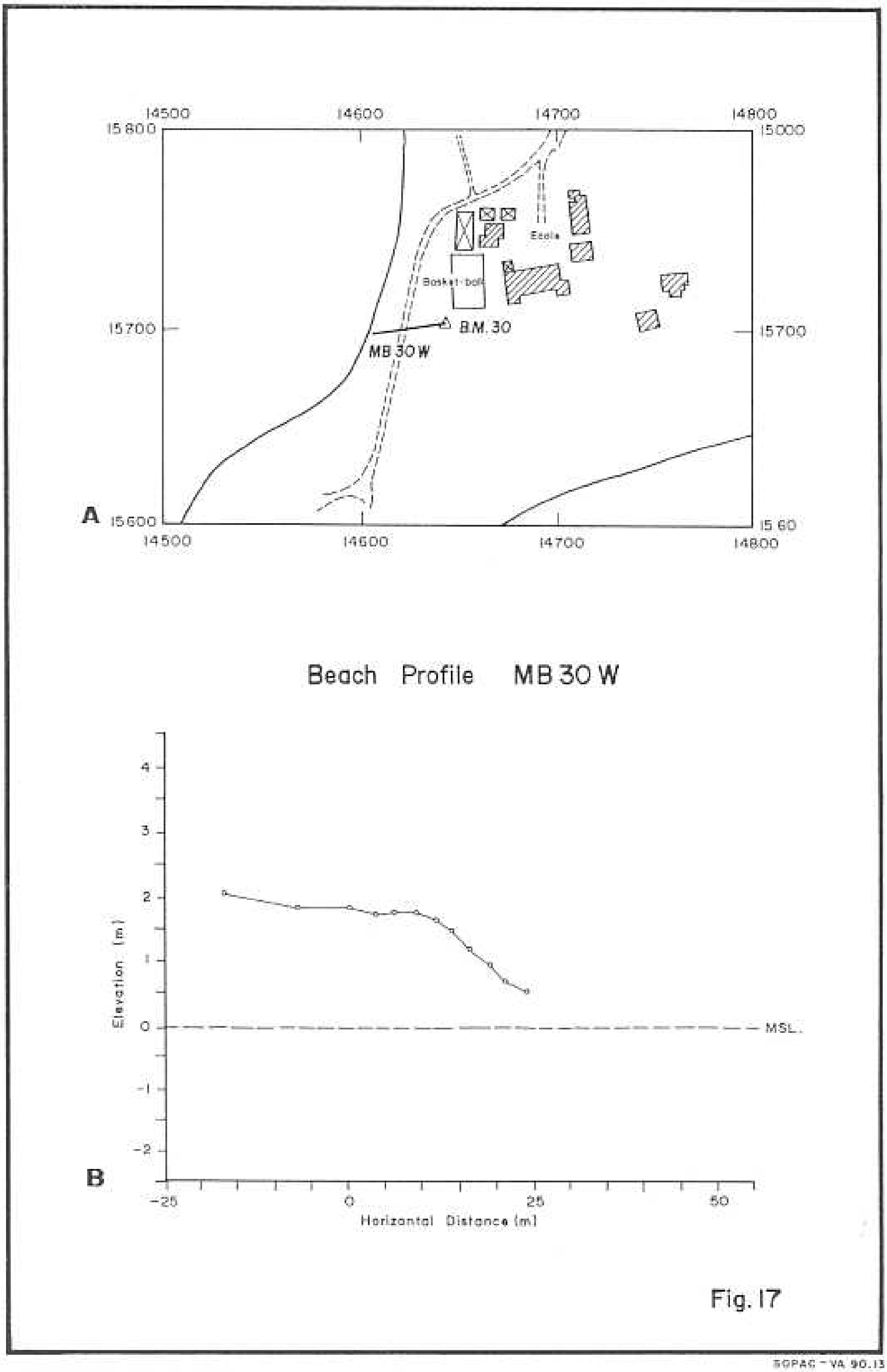


Figure 17. Location (A) and plot (B) of BM 30 and beach profile MB30W. Location map is taken from New Hebrides Map 2153, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to fluctuation of river discharge pattern and erosion.

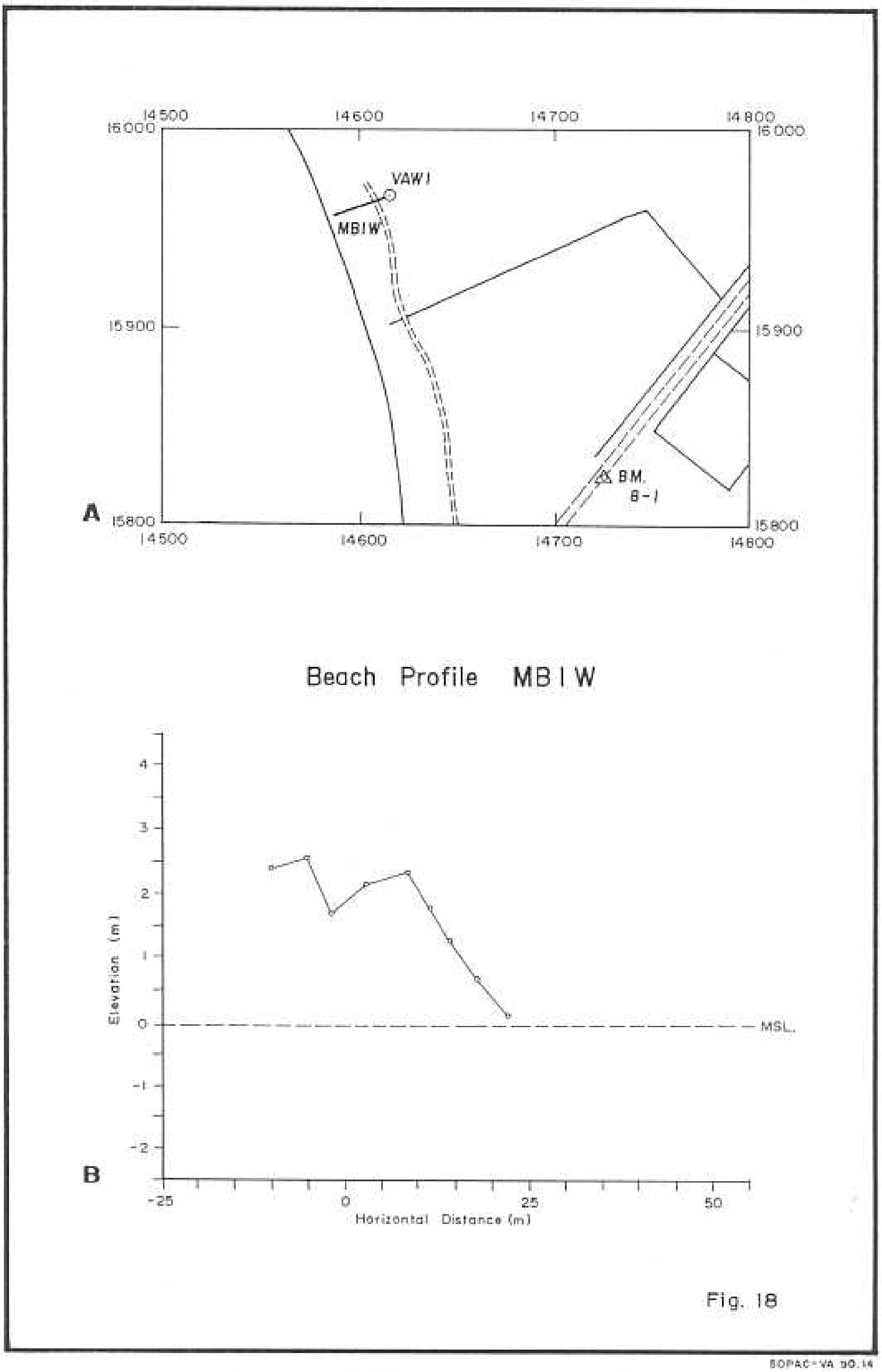


Figure 18. Location (A) and plot (B) of BM VAW1 and beach profile MB1W. Location map is taken from New Hebrides Map 2153, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

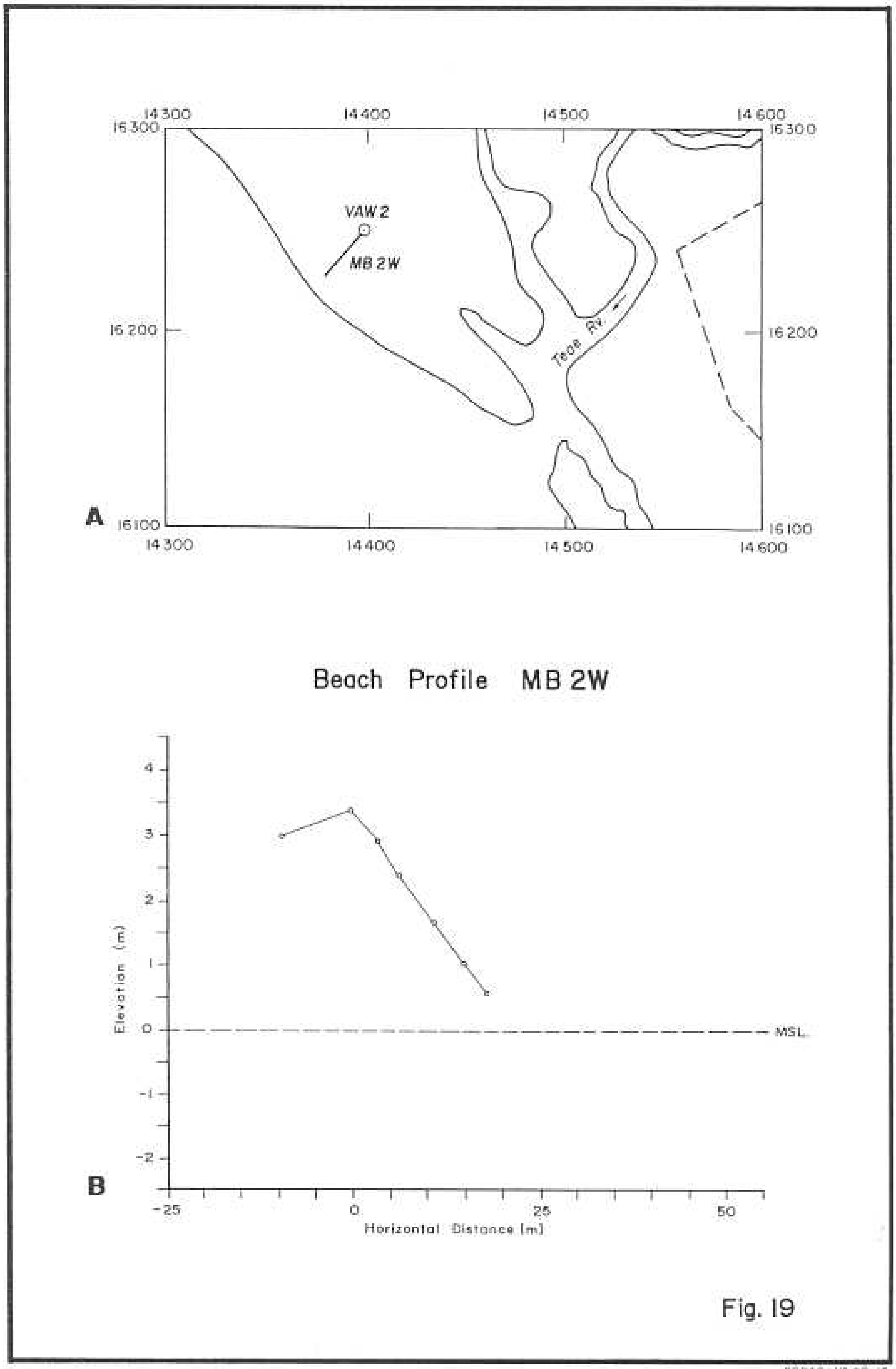


Figure 19. Location (A) and plot (B) of BM VAW2 and beach profile MB2W. Location map is taken from New Hebrides Map 2152, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to fluctuation of river discharge pattern and erosion.

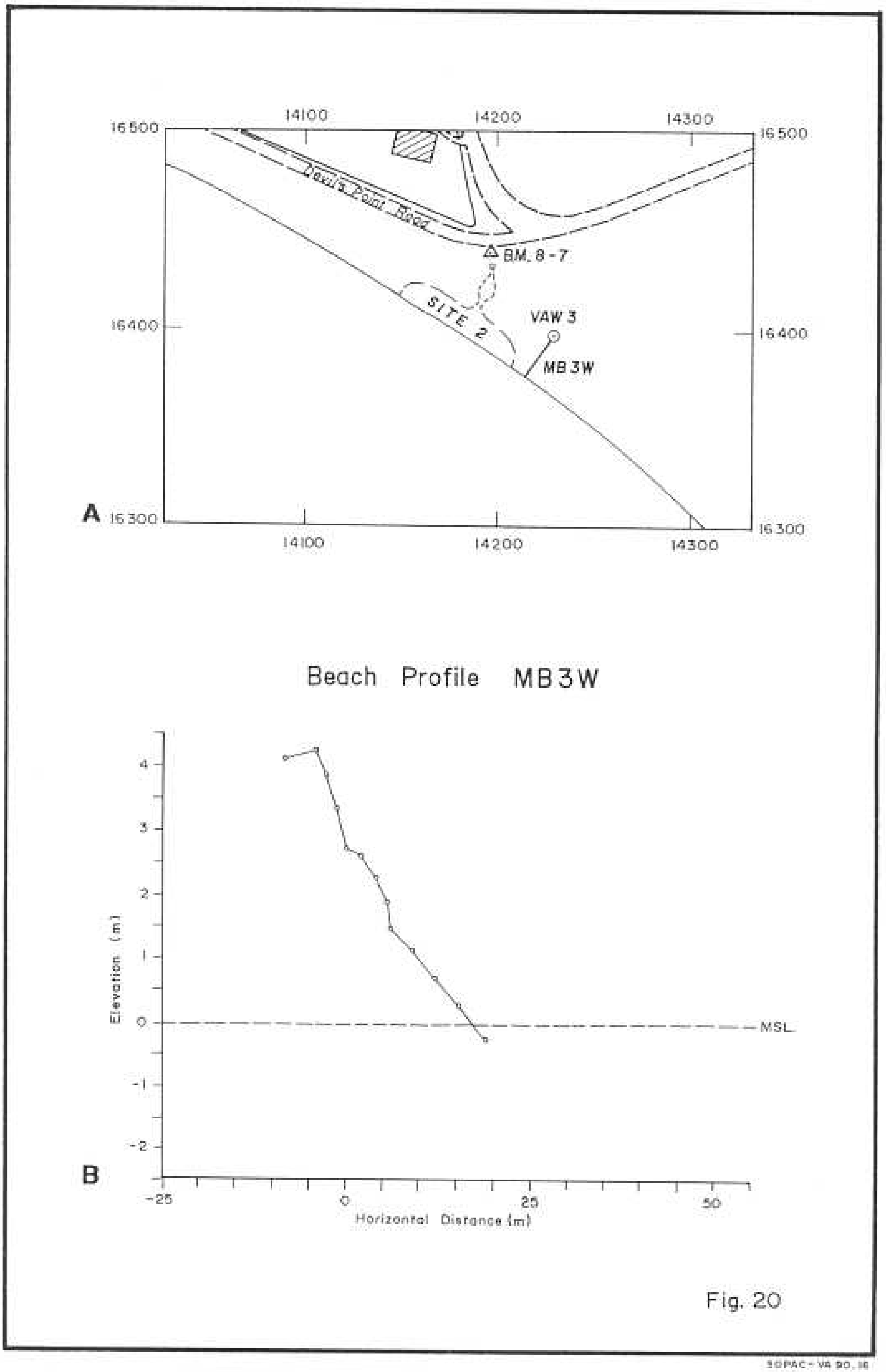


Figure 20. Location (A) and plot (B) of BM VAW3 and beach profile MB3W. Location map is taken from New Hebrides Map 2152, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion and beach-sand mining.

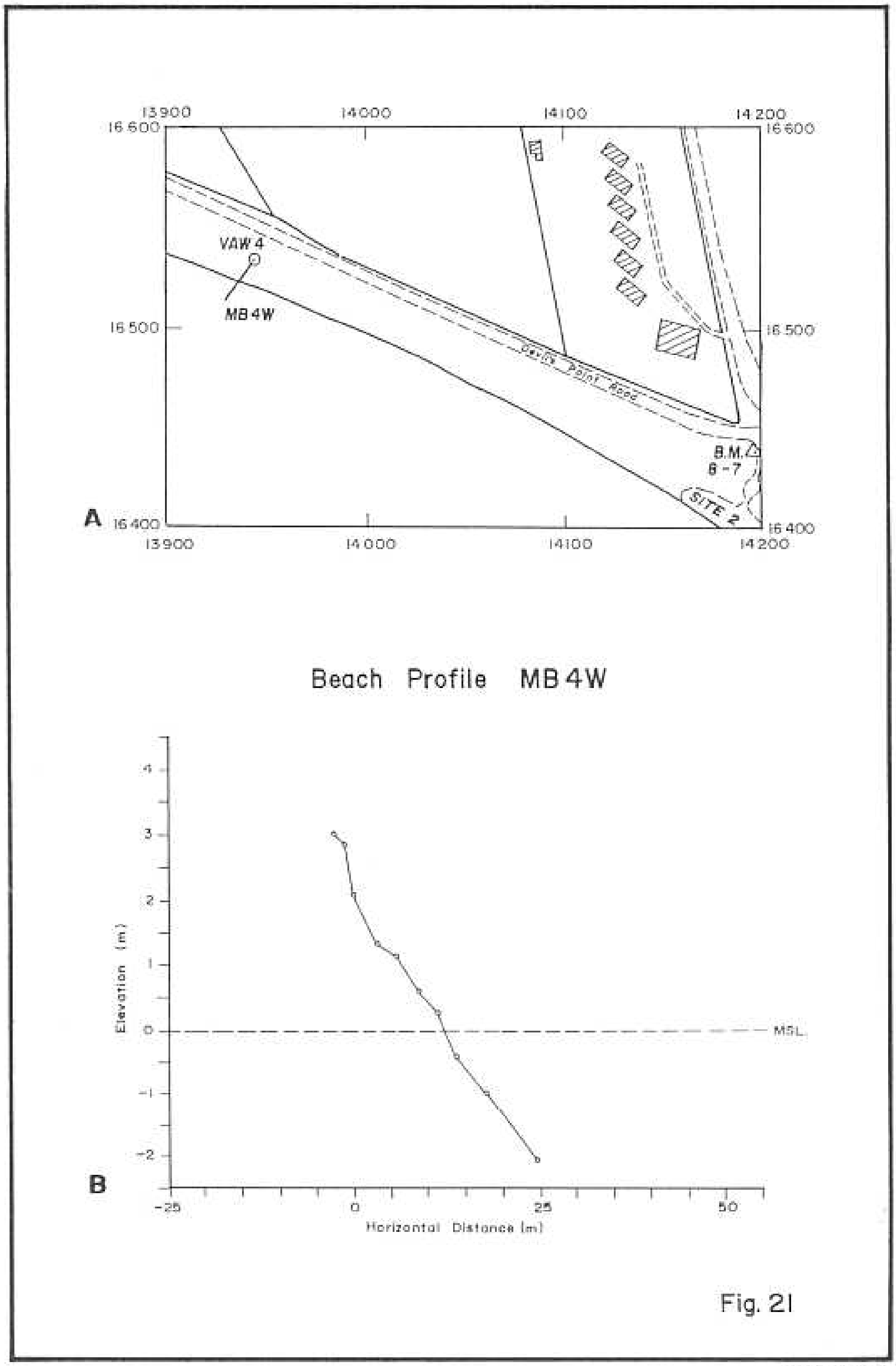


Figure 21. Location (A) and plot (B) of BM VAW4 and beach profile MB4W. Location map is taken from New Hebrides Map 2152, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

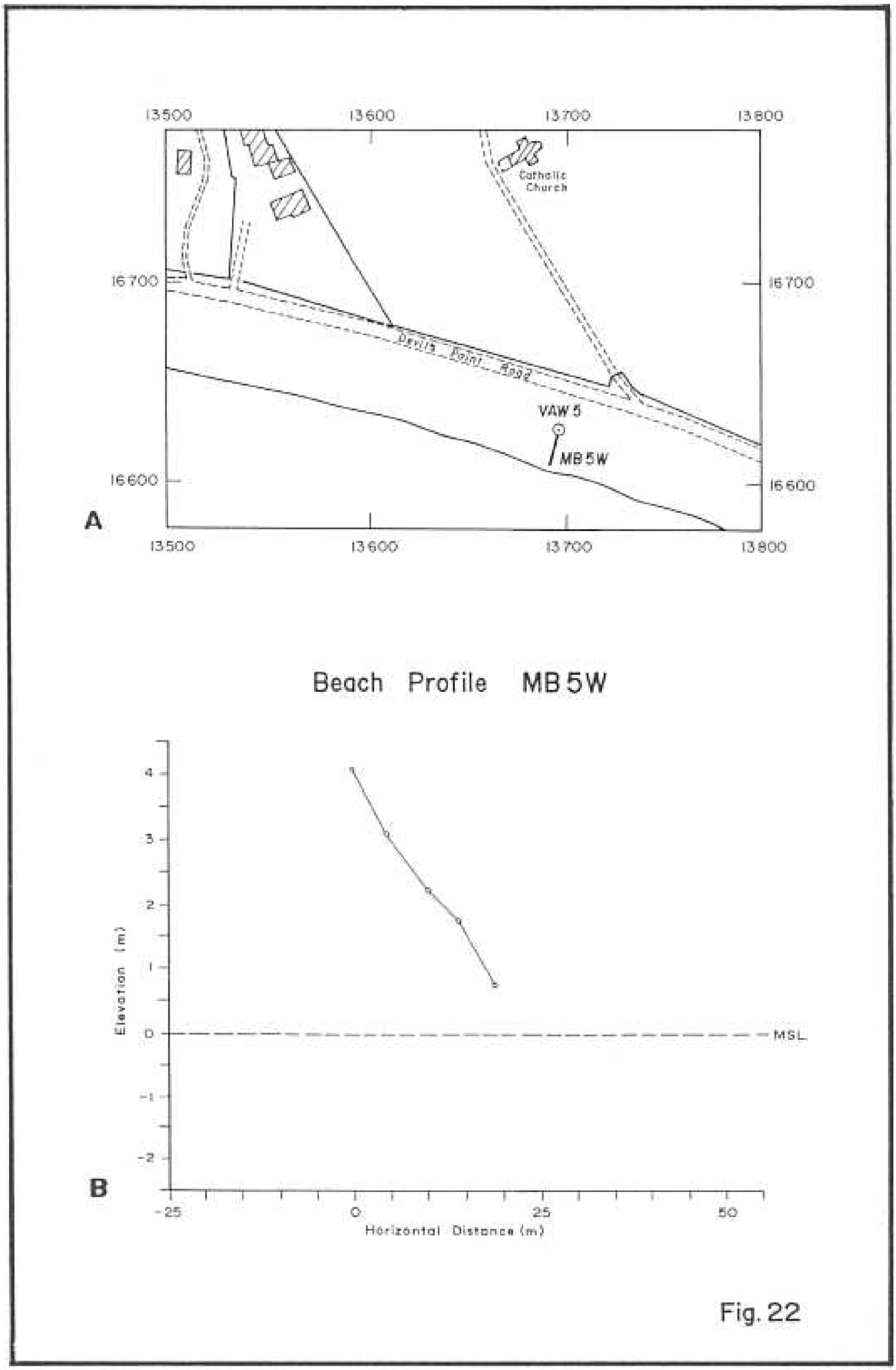


Figure 22. Location (A) and plot (B) of BM VAW5 and beach profile MB5W. Location map is taken from New Hebrides Map 2152, DOS 065, Edition 1-DOS 1975. Note that current coastline has changed due to erosion.

**Preliminary Analysis of Data**

An initial set of 12 beach profiles has been surveyed in Mele Bay. Until more data are collected, a quantitative estimate of the rate of coastal erosion cannot be made. It has been recommended to the Department of Geology, Mines and Rural Water Supply that the beach profiles be resurveyed at 6-month intervals and after major storm events. It is estimated that 2-3 years of data need to be analyzed before reliable information can be obtained on any erosion occurring at Mele Bay.

From the initial data collected and the observations of the survey party it is apparent that beach mining is having a detrimental effect on the coastline. Erosional scarps at the beach edge, exposed tree roots, fallen trees littering portions of the beach, short and steep beach faces, and undercut building structures (Figures 4, 5, 6 and 7) all attest to the ongoing erosion of the coast. These signs of erosion are particularly severe near the two areas of beach-sand mining and extend well along the coast. From the work of Howorth (1985), it can be shown that this is not a consequence of global sea level rise since uplift of the coastal zone has at the least kept pace with sea level rise in the past.

When the initial set of beach profiles is plotted it can be seen that the beaches near the beach-sand mining sites are significantly narrower than those further away from the sites (Figures 23 and 24). On Figures 23 and 24 it can be seen that the slope of the beach is consistent for the entire bay. This is a function of the wave regime and the beach sediment will lie at an angle of repose that corresponds to the average intensity of reworking. However, it is evident from the profiles that the beaches closer to the beach-sand mining (profiles 3 and 4 in both figures) are lower and narrower than those in other areas of the bay.

These differences have been quantified by computing a unit volume for each beach profile (Figures 25 and 26). The calculations were made by using the computer program AutoCad to calculate the area of the polygons created by the beach profiles, the head of the beach (highest elevation), MSL (elevation of 0), and the horizontal distance at MSL. The area of each profile polygon was calculated and the result multiplied by 1 m to give a unit volume, or essentially the volume of beach sediment for each 1m length of beach.

In the eastern section of Mele Bay, the beaches contain less sand than the beaches in the western section. Beaches near beach-sand mining Site 1 contain about 5 and 7.5 m of sand for every 1 m of beach length, whereas beaches further away from Site 1 in either direction contain between about 17.5 and 21.5 m of sand per 1 m of beach length. Although the

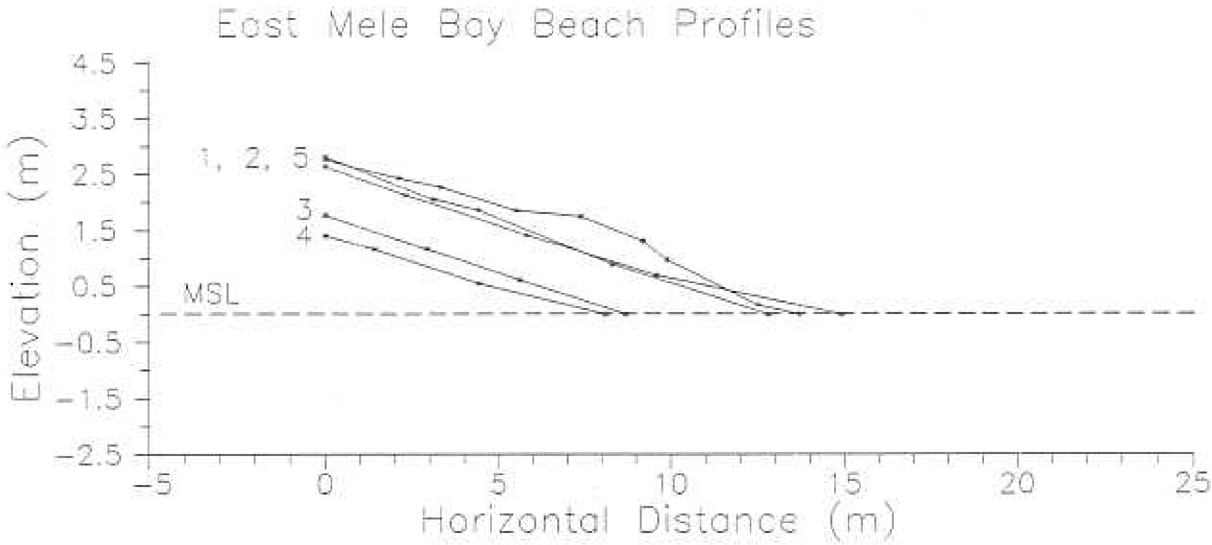


Figure 23. Graph of east Mele Bay beach profiles (VE = 1.7:1). The graph includes only the area between the beginning of the beach and MSL. Note the difference in beach height between the profiles near beach-sand mining Site 1 (profiles 3 and 4) and those away from the site (1, 2 and 5).

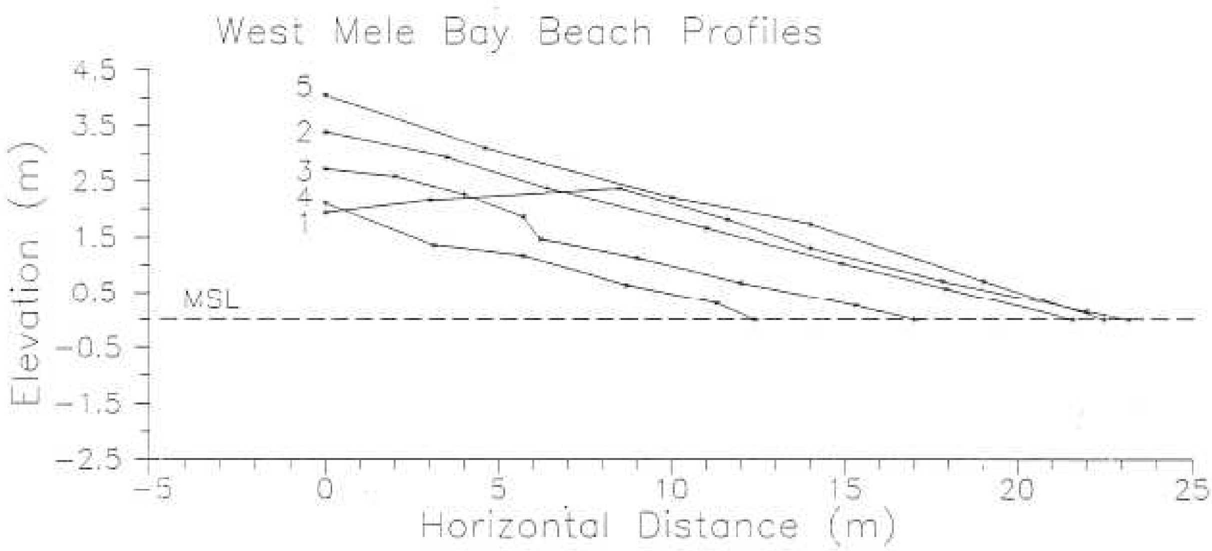


Figure 24. Graph of west Mele Bay beach profiles (VE = 1.7:1). The graph includes only the area between the beginning of the beach and MSL. Note the difference in beach height between the profiles near beach-sand mining Site 2 (profiles 3 and 4) and those away from the site (1, 2 and 5).

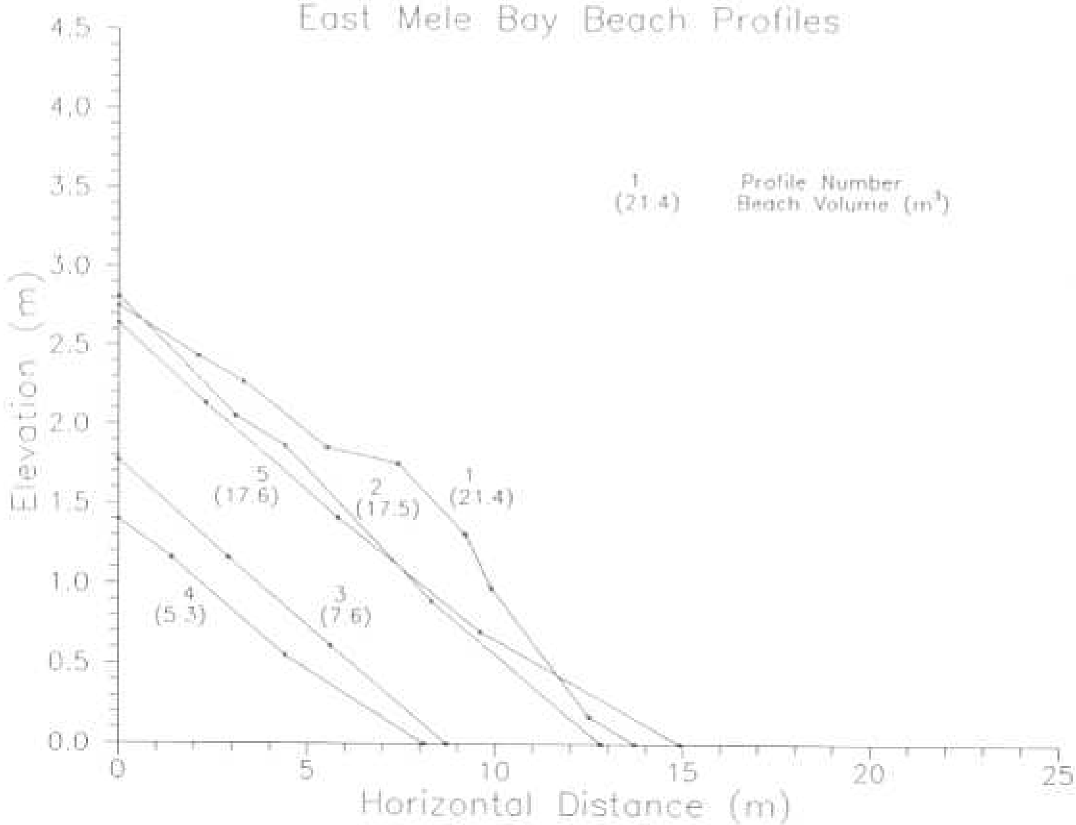


**Figure 25.** Graph of the polygons created by the east Mele Bay beach profiles, the head of the beach (highest elevation), MSL (elevation of 0), and the horizontal distance at MSL. The area of each profile polygon was calculated and the result multiplied by 1 m to give a unit volume, or essentially the volume of beach sediment for each 1 m length of beach. VE of the graph is 4:1.

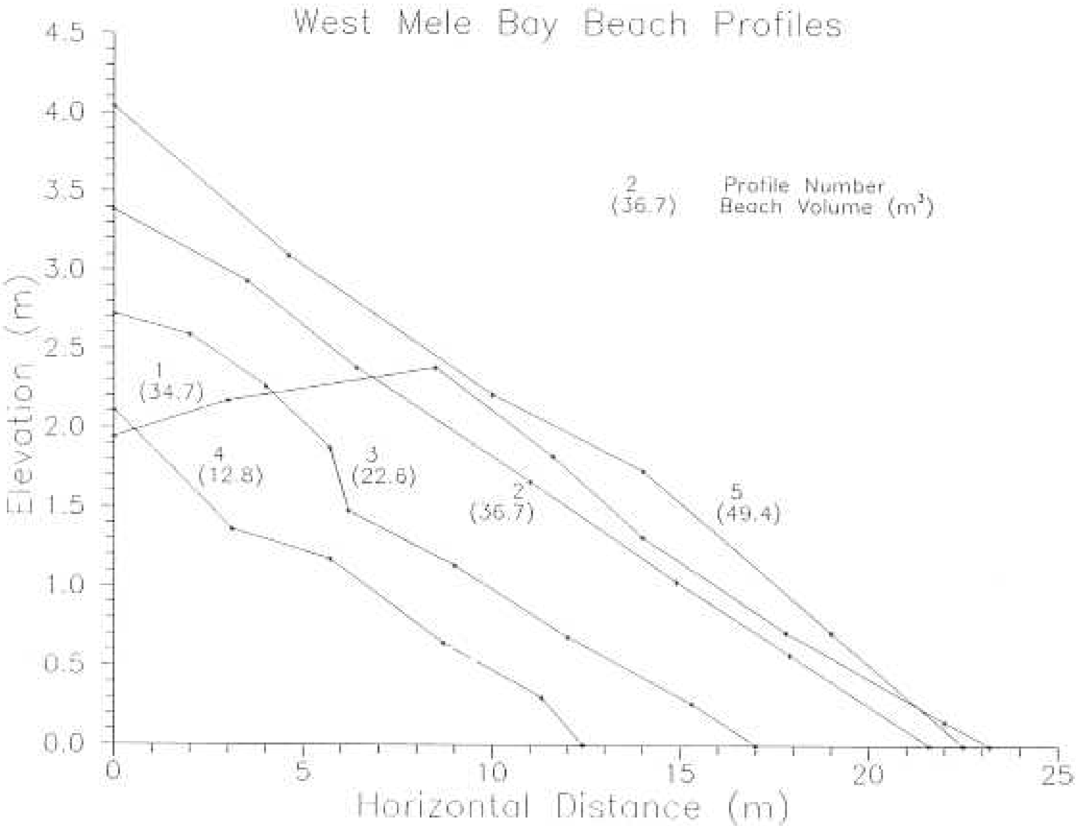


**Figure 26.** Graph of the polygons created by the west Mele Bay beach profiles, the head of the beach (highest elevation), MSL (elevation of 0), and the horizontal distance at MSL. The area of each profile polygon was calculated and the result multiplied by 1 m to give a unit volume, or essentially the volume of beach sediment for each 1 m length of beach. VE of the graph is 4:1.

beaches in the western section of Mele Bay contain more sand than the beaches in the eastern section, the beaches near beach-sand mining Site 2 still contain less sand than those away from the site. The volume of sand near Site 2 is about 13 and 22.5 m per 1 m of beach length compared to about 35 to 50 m per 1 m of beach length away from the site. In both sections of the bay, the beaches near the beach-sand mining sites contain only about 1/2 to 1/4 the volume of sand as the beaches away from the sites. The small volume of sand on the beaches near the sand-mining sites is significant and the consequences of mining large quantities of sand from the beach can be severe. Coastal erosion during major storms will be increased due to the ability of larger waves to reach further up the beach. This was noted during a 1987 cyclone (Temakon and Harrison, 1988) when erosion of the coast was extremely severe.

One of the problems with the loss of beach sediment in Mele Bay during storms results from the offshore bathymetry (Smith and Saphore, 1990; Figure 3). Where there is a wide shelf, sediment removed by storms is often deposited offshore as sand bars and is later returned to the beach during normal swell conditions. This process has been noted at many locations in the world and has been well documented by marine geologists. The shelf of Mele Bay is extremely narrow and the slope at the edge is steep. Typical slopes are 10' for the beaches, 1.5' for the shelf (between MSL and the 10 m contour), and 4.5' for the slope (between the 10 and 90 m contours). The consequences of a steep slope close to the beach are that sediment that is moved offshore may easily be transported over the shelf edge and is then permanently lost to the beach system. Rivers are the only source of sediment to make up for this loss and for the loss sustained by the sand mining operations. From the condition of the coastal zone, it is apparent that the sediment input from the rivers is unable to keep pace with the total amount of sand being removed.

One alternative to the mining of beach sand may be to mine sand away from the coastline. Borehole and well log data show that the sediment of the coastal plain is composed of "typical" Mele Bay beach sand. Areas could be investigated where the quarrying of sand would not interfere with private, industrial or governmental concerns. Leases similar to those obtained for the beach-sand mining could be negotiated so that the need for construction materials can continue to be met.

## CONCLUSIONS

Coastal erosion is evident along the coast of Mele Bay from erosional scarps at the beach edge, exposed tree roots, fallen trees littering portions of the beach, short and steep beach faces, and undercut building structures. The erosion is particularly severe near two areas of beach-sand mining.

Twelve beach profiles have been established along the Mele Bay coastline to monitor coastal erosion. With the addition of data from future surveys, a quantitative estimate of the rate of coastal erosion will be possible.

The initial set of beach profiles show that the beaches of Mele Bay are narrow and steep. Although beaches near the active sand mining sites have about the same angle of repose as those further away, they are smaller and therefore contain less sand, about 1/2 to 1/4 of that found in other areas along the coast.

The increasing loss of beach sand due to the mining operation may lead to very severe coastal erosion during major storm events. The narrowness of the Mele Bay continental shelf suggests that much, if not all, of the sediment removed from the coast during storms will be permanently lost to the sediment budget in the coastal zone. River input of sand to the sediment budget is apparently not keeping pace with the total amount of sediment being removed by the mining operation and lost through erosion during major storms.

Sufficient sand resources are available on the Mele Bay coastal plain to encourage local sand-mining companies to seek new sources of construction materials. Techniques could be developed to mine sand away from the coast. Environmental damage at the coastline could then be significantly reduced.

## RECOMMENDATIONS

The following recommendations are made with regard to resolving the problem of coastal erosion in Mele Bay:

1) In order to quantify the amount of coastal erosion occurring in Mele Bay it is recommended that the 12 beach profiles established along the coast be resurveyed at a minimum of every 6 months and immediately after major storms.

2) In order to establish limits for maximum sand extraction from the beaches without detriment to the coastal environment it is necessary to know the average amount of sediment being input to the beach system. It is recommended that the average amount of sediment discharged yearly into Mele Bay be determined by estimating the sediment load capability of the rivers using available rainfall data, stream discharge data, river profile data and catchment size.

3) Because there appears to be ample supplies of beach sand on the coastal plain of Mele Bay, it is recommended that the mining operators, in cooperation with the Government of Vanuatu, seek other areas from which to obtain sand. Assistance should be given to the operators for locating suitable sand reserves, lease negotiations, and appropriate extraction techniques.

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6) Smith, R. and Saphore, E., 1990, Geophysical Cruise Report for Mele Bay and Port Havannah, Vanuatu: SOPAC Preliminary Report 22.

7) Temakon, J.S. and Harrison, W., 1988, Nearshore and coastal mineral resources of Vanuatu: Manuscript presented at CCOP/SOPAC Nearshore Minerals Workshop, Savusavu, Fiji, September-October, 1988.

**APPENDIX**

Beach Profile Data in reduced format. The Horizontal Distance (HD) of 00.0 is the start of the beach. Negative values of the HD are distances back from the start of the beach.

**Profile MB30E (BM 30)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM 30 | 164 T | -60.3 | 2.09 |
| 1 | | -25.0 | 1.39 |
| 2 | | 00.0 | 0.96 |
| 3 | | 10.0 | 0.83 |
| 4 | | 22.2 | 0.90 |
| 5 | | 27.6 | 0.88 |
| 6 | | 30.3 | 1.21 |
| 7 | | 32.7 | 1.37 |
| 8 | | 35.7 | 1.51 |
| 9 | | 38.1 | 0.96 |
| 10 | | 41.7 | 0.63 |
| 11 | | 45.5 | 0.30 |
| 12 | | 49.8 | 0.09 |
| 13 | | 53.1 | -0.03 |
| 14 | | 55.8 | -0.07 |

**Profile MB1E (BM VAE1)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| **BM VAE1** | 198 T | -02.7 | 2.79 |
| 1 | | 00.0 | 2.75 |
| 2 | | 02.1 | 2.43 |
| 3 | | 03.3 | 2.27 |
| 4 | | 05.5 | 1.85 |
| 5 | | 07.4 | 1.75 |
| 6 | | 09.2 | 1.31 |
| 7 | | 09.9 | 0.97 |
| 8 | | 12.5 | 0.16 |
| 9 | | 19.8 | -0.83 |

**Profile MB2E (BM VAE2)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAE2 | 204 T | -04.4 | 3.60 |
| 1 | | 00.0 | 2.81 |
| 2 | | 03.1 | 2.05 |
| 3 | | 04.4 | 1.86 |

| | | | |
|---|---|---|---|
| 4 | | 08.3 | 0.89 |
| 5 | | 17.9 | -1.02 |

**Profile MB3E (BM VAE3)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAE3 | 210 T | -03.4 | 2.86 |
| 1 | | -00.2 | 2.56 |
| 2 | | 00.0 | 1.77 |
| 3 | | 02.9 | 1.16 |
| 4 | | 05.6 | 0.61 |
| 5 | | 13.4 | -0.93 |

**Profile MB4E (BM VAE4)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAE4 | 222 T | -07.0 | 3.18 |
| 1 | | -03.0 | 2.70 |
| 2 | | -02.1 | 2.35 |
| 3 | | 00.0 | 1.40 |
| 4 | | 01.4 | 1.16 |
| 5 | | 04.4 | 0.55 |
| 6 | | 14.3 | -0.88 |
| 7 | | 15.7 | -1.07 |

**Profile MB5E (BM VAE5)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAE5 | 222 T | -02.5 | 3.25 |
| 1 | | 00.0 | 2.64 |
| 2 | | 02.3 | 2.13 |
| 3 | | 05.8 | 1.41 |
| 4 | | 09.6 | 0.70 |
| 5 | | 17.4 | -0.34 |

**Profile MB30W (BM 30)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM 30 | 263 T | -1 7.2 | 2.09 |
| 1 | | -07.4 | 1.71 |
| 2 | | 00.0 | 1.86 |
| 3 | | 03.4 | 1.77 |
| 4 | | 06.0 | 1.79 |

| | | |
|---|---|---|
| 5 | 09.0 | 1.78 |
| 6 | 11.8 | 1.67 |
| 7 | 13.9 | 1.51 |
| 8 | 16.1 | 1.22 |
| 9 | 18.8 | 0.97 |
| 10 | 21.0 | 0.70 |
| 11 | 24.1 | 0.54 |

**Profile MB1W (BM VAW1)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAW1 | 251 T | -10.2 | 2.44 |
| 1 | | -05.5 | 2.60 |
| 2 | | -02.1 | 1.73 |
| 3 | | 00.0 | 1.94 |
| 4 | | 03.0 | 2.17 |
| 5 | | 08.5 | 2.38 |
| 6 | | 11.6 | 1.82 |
| 7 | | 14.0 | 1.31 |
| 8 | | 17.8 | 0.71 |
| 9 | | 22.0 | 0.15 |

**Profile MB2W (BM VAW2)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAW2 | 223 T | -09.1 | 2.99 |
| 1 | | 00.0 | 3.38 |
| 2 | | 03.5 | 2.93 |
| 3 | | 06.4 | 2.38 |
| 4 | | 11.0 | 1.66 |
| 5 | | 14.9 | 1.03 |
| 6 | | 17.9 | 0.57 |

**Profile MB3W (BM VAW3)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAW3 | 215 T | -08.4 | 4.09 |
| 1 | | -04.3 | 4.22 |
| 2 | | -02.8 | 3.86 |
| 3 | | -01.4 | 3.34 |
| 4 | | 00.0 | 2.72 |
| 5 | | 02.0 | 2.59 |
| 6 | | 04.0 | 2.26 |
| 7 | | 05.7 | 1.87 |
| 8 | | 06.2 | 1.47 |
| 9 | | 09.0 | 1.13 |
| 10 | | 12.0 | 0.68 |

| | | | |
|---|---|---|---|
| 11 | | 15.3 | 0.26 |
| 12 | | 18.8 | -0.27 |

**Profile MB4W (BM VAW4)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAW4 | 215 T | -02.7 | 3.04 |
| 1 | | -01.2 | 2.87 |
| 2 | | 00.0 | 2.11 |
| 3 | | 03.1 | 1.36 |
| 4 | | 05.7 | 1.17 |
| 5 | | 08.7 | 0.64 |
| 6 | | 11.3 | 0.30 |
| 7 | | 13.8 | -0.40 |
| a | | 17.8 | -0.98 |
| 9 | | 24.8 | -2.04 |

**Profile MB5W (BM VAW5)**

| Station | Bearing | Horizontal Distance (m) | Elevation Relative to MSL (m) |
|---|---|---|---|
| BM VAW5 | 193 T | 00.0 | 4.04 |
| 1 | | 04.6 | 3.09 |
| 2 | | 10.0 | 2.21 |
| 3 | | 14.0 | 1.73 |
| 4 | | 19.0 | 0.71 |