MELE BAY AND ERAKOR LAGOON, VANUATU

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SUMMARY

This report describes coastal processes and a site inspection of Mele Bay beach erosion which was required to assist with a management plan for Mele Bay (SOPAC Task VA.6b.91). This report also describes current meter data which was collected in September 1991 under the Erakor Lagoon causeway bridge.

It is recommended that all beach mining on Mele Bay beach be stopped and that the sources of pollution in Erakor Lagoon be located and stopped.

ACKNOWLEDGEMENTS

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Acknowledgement is made of the assistance of Garry Armstrong and Colin Bottomley of the Royal Australian Navy, the crew of the survey ship Spia Laen and the many Vanuatu Government personnel who assisted with this work, in particular: Maurice Bollen, Willie Kalotuk, Cedric Mortimer, Willie Neuman, Siri Seoule, Martin Sokomanu, Stanallison Temakon, Judah Tingris and Captain Chris.

Acknowledgement is also made to Malcolm Greig of the New Zealand Oceanographic Institute and Ed Saphore of SOPAC for data processing.

OBJECTIVES

During September 1991 field work at Port Havannah, an inspection of the sand mining of Mele Bay Beach was carried out to assist with the preparation of a management plan for Mele Bay - SOPAC Work Plan Task 91 .VA.6b. This report discusses the natural coastal processes of Mele Bay and the effects of sand mining on the coastal processes.

Also during the September fieldwork, a current meter was suspended under the causeway bridge across Erakor Lagoon for nine days, to gather current data related to the flushing of the lagoon. This report presents and discusses these current meter data and some of their implications for the flushing of Erakor Lagoon.

MELE BAY

Introduction

Mele Bay (Lat 17' 44's, Long 168' 15'E) is a large, U-shaped bay on the southwest side of Efate Island, just west of Port Vila (Figures 1 & 2). The bay is about 8 km wide and is open and exposed to the southwest. The bay has no natural protective reef and deepens seaward to over 200 m in the middle of the bay. The shoreline of Mele Bay is characterised by a fine sand beach about 6 km long which is the most extensive stretch of volcanic sand beach on Efate. There is a small island and a rock outcrop just off the beach which have caused spits to form perpendicular to the beach face. There are four main rivers (Teae, Tepwukoa, La Colle, Tagabe) which flow across the beach face of Mele Bay and have sand spits at their mouths.

Various aspects of the coastal geology of Mele Bay have already been studied by others (Radford 1975, Ash et al 1978, Howorth 1983, Howorth 1985, Temakon et al 1988, Rearic 1990). A review of the geological literature indicates that Mele Bay has been a naturally stable beach, but there have been recent complaints of beach erosion. Excessive beach sand mining was suspected and the government of Vanuatu requested SOPAC to assist with the preparation of a management plan for Mele Bay. This request was been included in the SOPAC Work Programme as Task 91.VA.6b.

As part of the requirements of SOPAC Task 91.VA.6b, the nearshore bathymetry and seabed morphology were mapped by SOPAC in March 1990 (Smith 1991). A second part of the task was a baseline study of coastal erosion and the establishment and measurement of beach

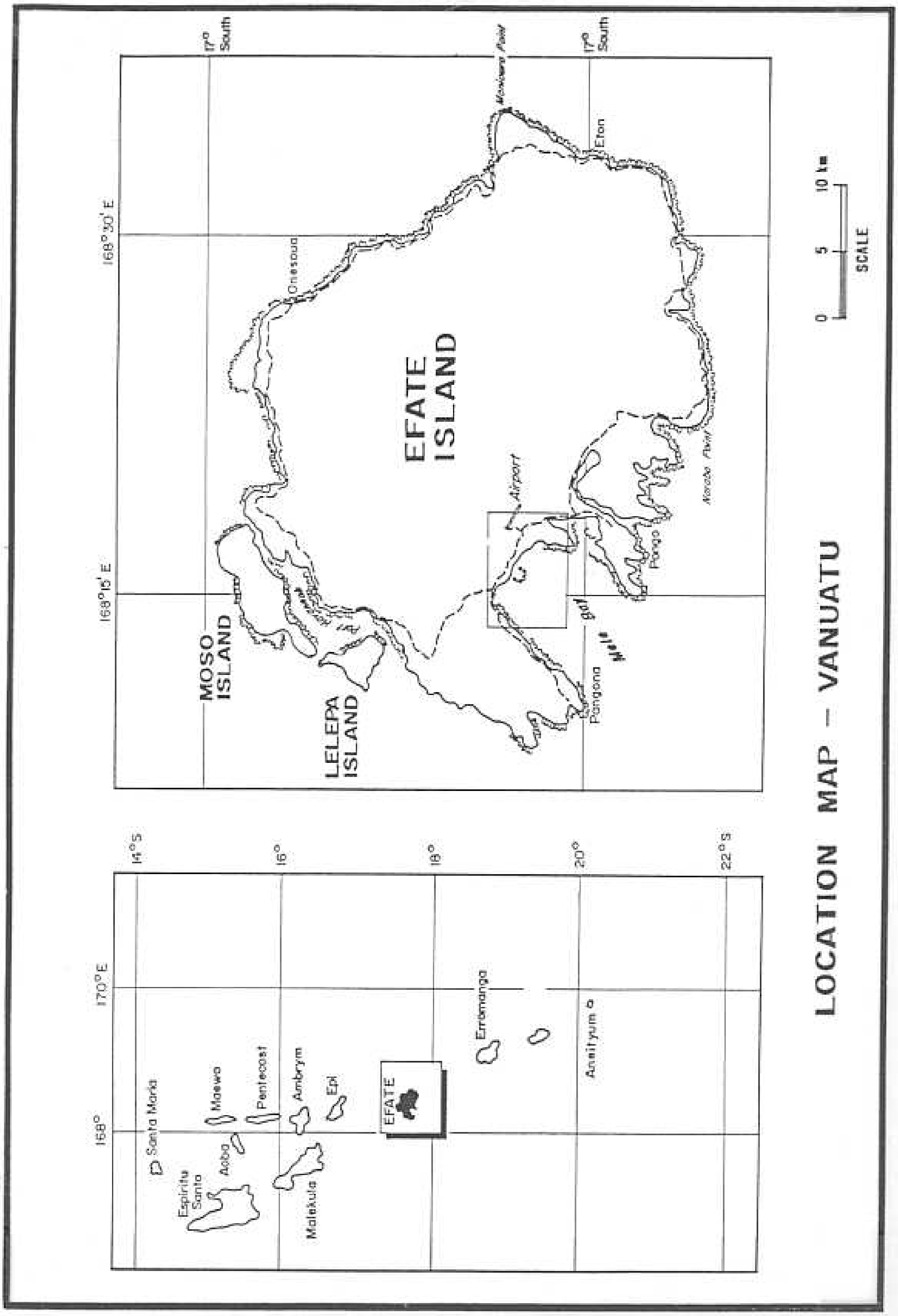

Figure 1. Location map - Vanuatu.

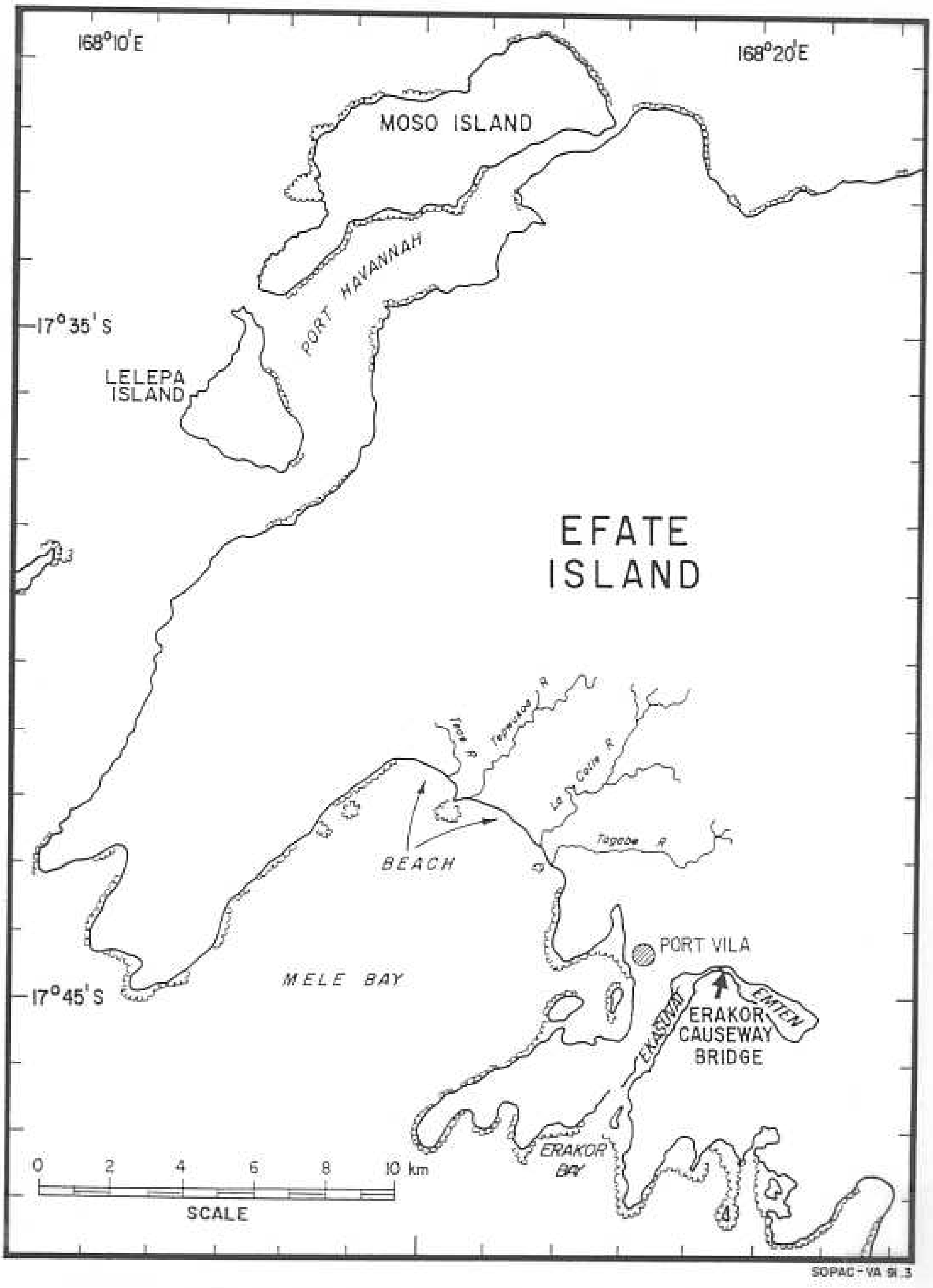

Figure 2. Efate Island.

profiles (Rearic 1990). The results of these two surveys were summarised in SOPAC Projects (2), reproduced here as Appendix 1. Rearic recommended that alternative sources for sand mining be found on the coastal plain. Following this study, the present writer was requested to inspect the Mele Bay beach and note any information or observations pertinent to the sand mining and the beach erosion problem. This present report, describing the beach inspection of September 1991 and discussing the effects of sand mining on the natural stability of Mele Bay beach, is an additional part of Task 91.VA.6b.

Methods

This first step in this study was to search and review all available literature on the geology, coastal process and oceanography of Mele Bay. Many reports were found on the geology of Efate and the beach area of Mele Bay (Ash et al 1978, Howorth, 1983, Howorth 1985, Howorth and Green 1987, Radford 1975, Rearic 1990, Smith 1991, Temakon and Harrison 1990). Wave data have been collected in the open ocean southeast of Efate since November 1990 (Barstow 1992, written communication).

The Mele Bay beach was inspected and photographed by the writer on 11/09/91. The beach inspection involved walking the full length of the beach and noting and photographing the natural features, any erosion sites, and particularly the sand mining locations. The outstanding features are noted and discussed in this report with an explanation of the natural beach processes of the bay.

Results

A Waverider buoy has been moored about 5 nautical miles southeast of Efate (Lat 17' 52.5'S, Long 168' 33'E) since 22 November 1990. The most common wave direction is east-southeast for wind seas and south southeast for swell. For the data collected to date, the average significant wave height is 1.8 m. The highest waves recorded over the period of record were cyclone generated waves of about 5 m significant height in November 1991. The maximum wave heights will be about 1.9 times the significant heights. The average mean period is 7.7 sec and the average peak period is 9.3 sec. The most frequent peak period is about 8 sec for wind waves and about 12 sec for swell waves. There does not appear to be any clear seasonality in the wave data collected to date (Barstow 1992, written communication, Appendix 2).

Because these wave data were collected southeast of Efate and the wave directions are predominantly from the southeasterly sector, the waves will not impact directly on Mele Bay beach. These southeasterly waves can be expected to refract into Mele Bay and hit the northwest shore and the beach at a reduced energy level. Mele Bay is directly exposed to waves from the southwest. Although southwesterly waves are not common, cyclone waves can come from that direction and Mele Bay beach can be impacted directly by cyclone waves and southerly swell from northwest of New Zealand. (Barstow 1992, written communication; Appendix 2)

Mele Bay beach is the most extensive volcanic sand beach on Efate. It represents the seaward limit of the alluvium - filled fault depression of the Mele Plain. The Mele Plain extends back about 4 km and rises to 40-50 m above sea level. The rivers crossing this region drain a large portion of central Efate, which is composed of submarine pumiceous breccias and tuffs of andesite to latite composition (Radford 1975).

In 1983 it was reported that "no part of Mele Beach was seen to be actively eroding", except for small areas on the northwest side of Mele Island and on the northwest side of Mele Bay (Howorth 1983). It was also noted that the river mouths changed very significantly after cyclones Ursula and Carlotta but no net long term changes were apparent. It appears that the additional fluvial material added to the beach by Ursula was repositioned by Carlotta and by waves during the next few months. It was concluded that the additional material was eventually redistributed over the bottom slope offshore. A bathymetric study of Mele Bay in March 1990 reported a steep bottom slope and a narrow shelf. This study also reported indications of sediment instability nearshore which suggest submarine slides and movement of material offshore (Smith 1991, Appendix 1).

Sand has been mined for construction purposes from Mele Bay beach for sometime but the amount of sand removed is difficult to determine. At a site near the Taea River mouth, sand mining has occurred since 1985 and it was estimated that about 23, 587 m was removed between 1985 and 1988. This estimate is about 655 m per month over three years. Sand extraction at a site in the middle of Mele Bay from May 1987 to August 1988 recorded removal of a total of 7056 m or an average of 440 m per month (Temakon and Harrison 1988). In addition, unrecorded amounts of sand are removed by individuals from other sites. It is estimated by the writer from these records that a total of well over 1100 m per month is being removed from Mele Bay beach.

Temakon and Harrison (1990) recognised serious beach erosion of Mele Bay beach and assumed that sand mining was a contributing factor. Sand mining is believed to have continued for about 10 years at a site west of Swango Point and at a site at the east end of the golf course (Rearic 1990). The continued erosion required a more detailed study; therefore, cross-section profiles of the beach were recorded at 12 sites in May 1990. These profiles indicated that the beach slope is relatively consistent throughout the bay except that beaches are narrower near sand mining sites. It was recommended that these profiles be resurveyed regularly and that alternative sources of construction sand be found on the Mele coastal plain (Rearic 1990). The collective results of these previous studies indicate that beach sand is currently being removed faster than it can be replaced by natural process.

Mele Bay beach is all sand except for the coral shores at the east and west ends. The four substantial rivers which flow across the beach into Mele Bay have formed small lagoons behind the beach berm and small spits where the rivers flow through the berm. Four active sand mining sites were noted on the inspection (Figures 3-6). Two of these sites had stockpiles of sand awaiting removal; one had a stockpile of sand and a parked bulldozer; and one site was an excavated pit.

Discussion

Beaches are basically shaped by waves. The particular shape of a beach is a result of the local wind and wave climate acting on the beach material over the local tidal range for a long period of time. A beach is dynamic and varies on a daily, monthly and yearly basis but is relatively stable on a long term basis. Most beaches have developed to their present state of equilibrium over the last several thousand years, since the last major sea level change. The natural slope and profile of a beach, from the beach berm to deep water, is a result of the wave climate acting over the range of water levels given by local tides and storm surges. Natural beach slopes are dynamically stable even though they may change considerably with the seasons and with major storm events. The following is a brief description of how beaches form and react to the wave climate.

Waves move any loose material on a shoreline up and down the foreshore with each successive wave impact. When waves impact the shore at an angle the up and down movement of material becomes a zig-zag motion with a net component along shore. In this manner any loose material on a beach is moved alongshore in the same direction that the waves are moving. This

Figure 3. Mele Bay beach - sand mining site near LaColle River mouth.

Figure 4. Mele Bay beach - sand mining site near Teunono River mouth.

Figure 5. Mele Bay beach - sand mining site near east end of golf course.

Figure 6. Mele Bay beach - sand mining site west of Swango Point.

longshore movement of material is called littoral drift or littoral transport. When the material moves into a sheltered area, such as a pocket in the shoreline or the back of a bay, the material gathers and a beach is formed. This is why there is a beach at the back of every bay.

Mele Bay is a relatively deep U-shaped bay which is open and exposed to the southwest. Only waves from the southwest can come unrefracted into Mele Bay and directly reach the beach at the back of the bay. Waves from the west can impact the southeast shore of Mele Bay and refract into the bay to reach the beach with reduced energy. Waves from the south and southeast can directly reach the northwest shore of the bay and also refract into the bay to reach the beach with reduced energy. All these waves move littoral material to the back of the bay where it is trapped because there are no waves from the northeasterly to move material out of the bay.

Waves also move beach material onshore and offshore with the variations in wave climate. Long crested low waves (shallow water waves) move material onshore and build a beach berm. Examples of shallow water waves are swell waves and the gravity waves that are formed when large swell waves break on the fringing reef. Short crested high waves (steep wind waves) which occur during strong winds and storms tend to move material offshore. If the bottom slope is not too steep, an underwater bar will be formed a short distance offshore and this bar will be returned back to the beach by shallow water waves. Thus the beach berm is built up during periods of quiet shallow waves and is eroded and moved to an offshore bar during periods of storm waves. This onshore-offshore beach movement is usually cyclic with season and storm events, and enables the beach to adjust to the particular wave conditions. If the bottom slope is steep like Mele Bay, however, the offshore bar may be reduced to a change in slope and the material lost to deeper water.

Some material could also be moved and lost offshore by very severe storms, earthquake induced submarine slides or density flows. (Smith **1991)** while these are rare events, the amount of material involved may be very large, and has to be replaced either by beach erosion or natural sediment supply.

The major source of beach material for Mele Bay is the fluvial material transported to the beach system by the rivers flowing across the Mele Plain. These rivers have been transporting eroded material from the land to the shoreline for several thousand years and have built out the Mele Plain about **4** km seaward. These rivers have a small lagoon behind the beach berm and a spit on the beach at the mouth. These rivers will break through the spits and flow directly to the sea at times of high river flow. During times of low river flow, waves will reshape the spits. These river mouths and spits are expected to change several times a year, with variations in river flow and wave climate. Any material eroded from the shoreline or produced on the reefs of Mele Bay has also contributed to the supply of material on the beach. While the Mele Plain has been accreting, the wave climate has been shaping the edge of the plain as a beach. Thus Mele Bay beach has been built and has achieved dynamic equilibrium over the last several thousands years.

If material is removed from a beach by mining, or material is added for land reclamation, the beach will be reshaped by the wave climate rather than maintain a man-made artificial shape. It is not possible to mine material from a beach and not have some effect on the beach and or the adjacent land. If material is mined from a beach, the waves will attempt to re-establish the original natural slope by eroding the land until the removed volume of material is replaced. On an erodible shoreline, mining material from a beach is essentially mining from the adjacent land. Even if beach mining removes material at a slower rate than the natural source replenishes it, there will still be local site specific erosion as the beach readjusts and reshapes. Beaches and beach berms should not be mined or disturbed because they are the natural storm protection for the adjacent land. Although there may appear to be plenty of material on a beach berm, this material is that part of the beach which is moved offshore during storms. When the berm is mined, storms then erode the land and move the material offshore and the same beach slope is established further landward.

Once erosion has taken place, there is not much that can be done except replace the material artificially or wait until the natural source replaces the material. Replacing material artificially on Mele Bay beach is unlikely to be financially unfeasible, since there are no expensive structures in danger. This beach could be left to re-adjust to a new natural beach profile, although this may take up to several decades. On the beach of Mele Bay, it is recommended that no beach mining or permanent construction be permitted within 30 m landward of the high water mark (Holden 1987).

Conclusions

1. The shoreline of Mele Bay is eroding because sand is being removed from the beach at a faster rate than it can be replenished by natural processes.

2. Beach mining is a major cause of sand loss from Mele Bay, and therefore a cause of coastal erosion.

Recommendations

1. That all beach mining be stopped immediately.

2. That no mining or permanent construction be permitted within 30 m landward of the high water mark.

ERAKOR LAGOON

Introduction

Erakor Lagoon (Lat 17' 45'S, Long 168' 19'E) is just east of Port Vila and is made up of two water bodies or lagoons: Ekasuvat and Emten (Figures 1 & 2). Ekasuvat lagoon extends northeastward about 6 km from the sea, then turns eastward through a narrow channel and opens to Emten lagoon which is about 3 km long. These two lagoons are over 500 m wide and the connecting channel is only about 100 m wide. This connecting channel is a natural constriction to the tidal flow and it is now further constricted by a causeway and small road bridge. There are no substantial rivers or sources of fresh water flowing into the lagoons; hence, the circulation and flushing is by tidal action only.

Because of increased population and subsequent sewage discharges in the area, the water quality of Erakor Lagoon has suffered in recent years. The water quality has been checked several times (Carter 1983, Wallis 1988, Abbott 1990, Carter 1990, Naidu et al 1990) and has been found to be worsening in recent years principally as a result of increased sewage contamination.

The flushing of Erakor Lagoon has been studied previously and current and water level data have previously been collected. It has been determined that the flushing rate of Emten Lagoon can be increased by replacing all or part of the causeway with a bridge (Carter 1983). It has since been recommended that the causeway be removed and replaced by a full bridge (Carter 1990). Based on this recommendation, the Government of Vanuatu requested that a current meter be placed under the causeway bridge to get more current data between Emten and Ekasuvat lagoons. This report presents and discusses those data.

Methods

While SOPAC was conducting the physical oceanographic study of Port Havannah in September 1991, an Aanderaa RCM 4 current meter was suspended below the causeway bridge (Figure 7) from 14/09/91 to 23/09/91. This meter had sensors for salinity temperature, pressure speed and direction. These current meter data were processed, analysed and plotted, and are presented here as Figure 8.

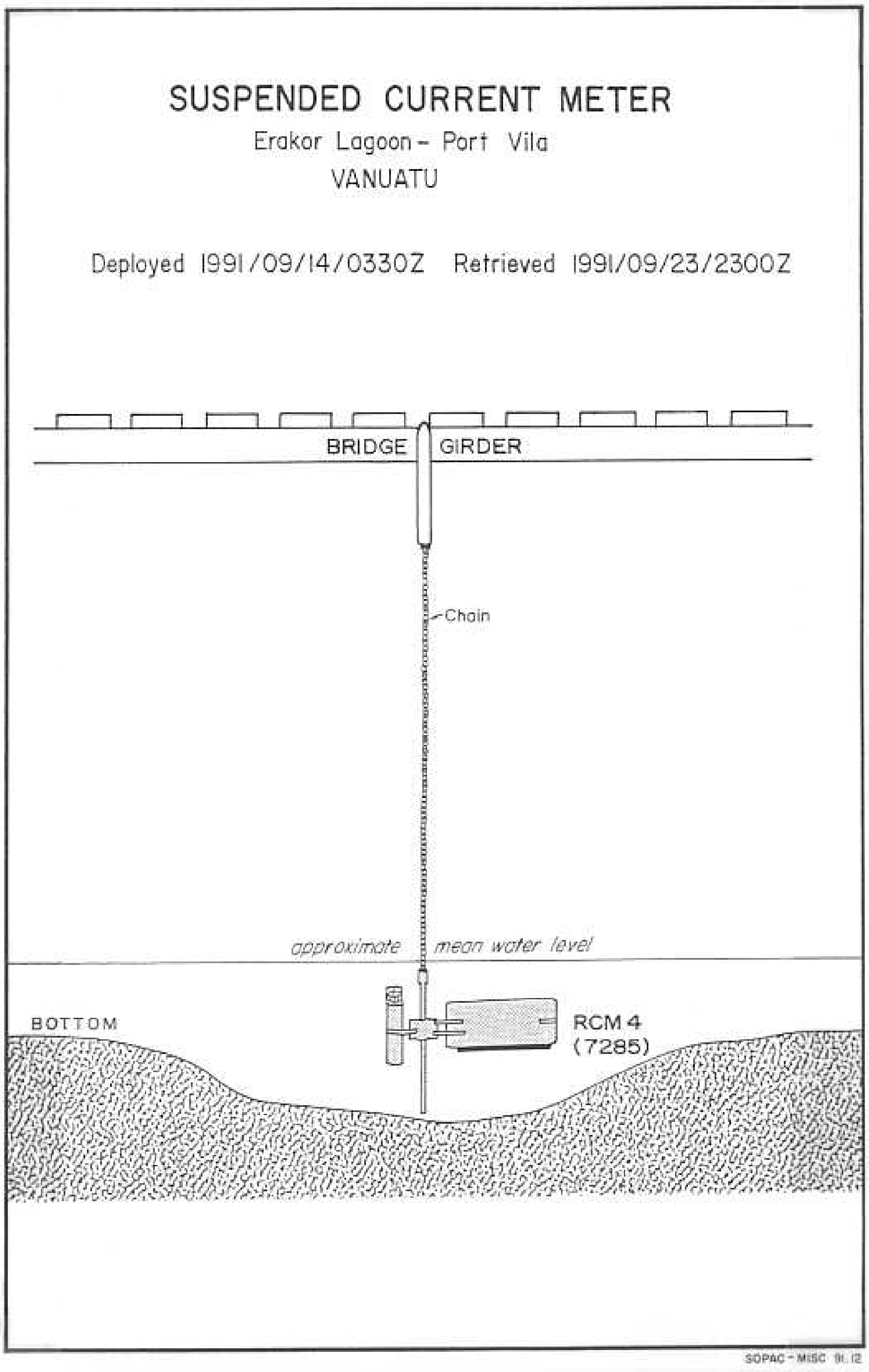

Figure 7. Erakor Lagoon - suspended current meter.

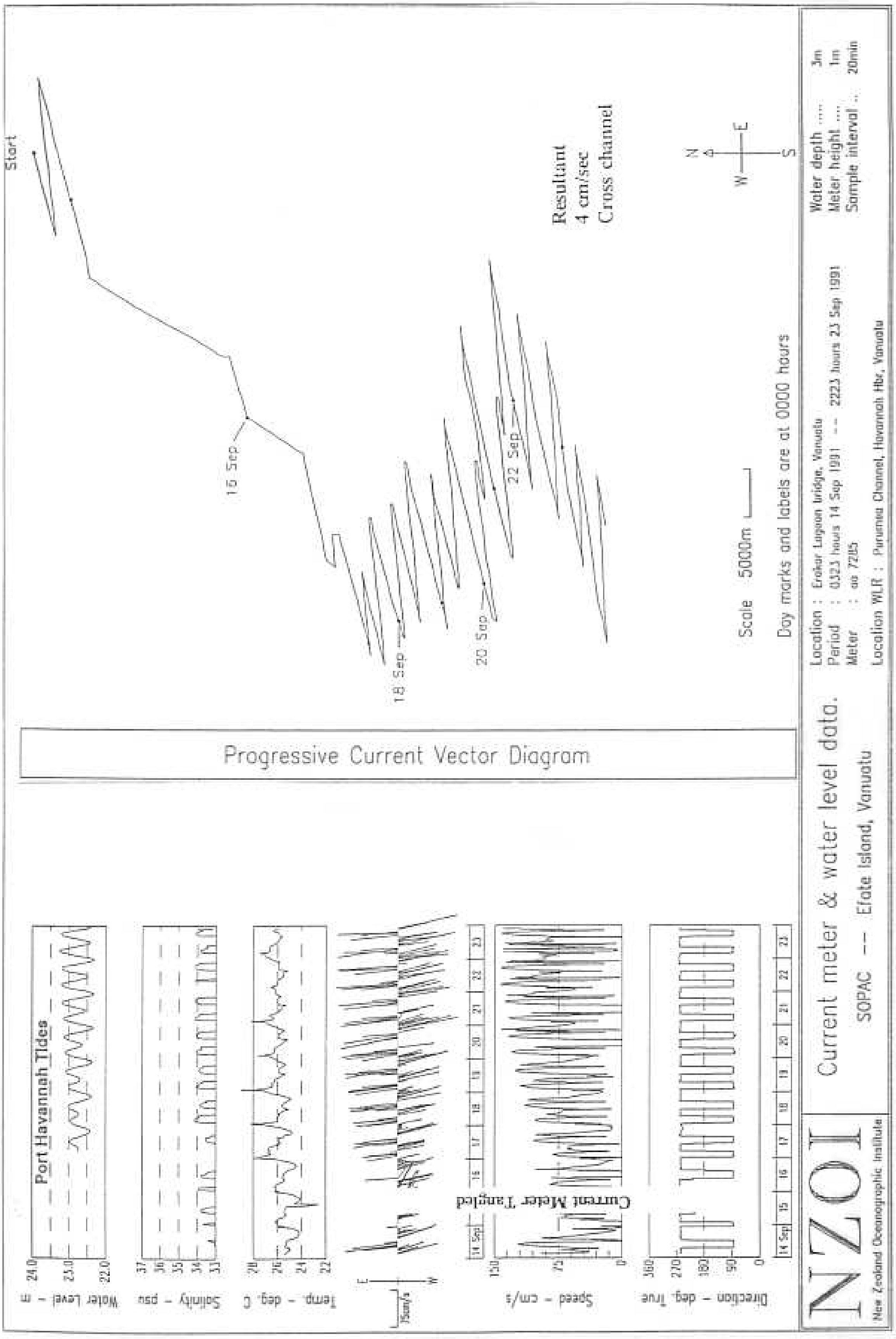

Figure 8. Erakor Lagoon - current meter data and progressive vector.

Results

Although this meter was suspended from the Erakor causeway bridge from 14/09/91 to 23/09/91, the meter had become entangled during 15 and 16/09/91 and continuous useful data was collected only for about seven days from 17/09/91 to 23/09/91. Although this current meter was suspended as low as possible, the water depth at low tide was not always sufficient to cover the sensors and rotor. The occurrence of this low water problem can be observed when the salinity and current speed drop suddenly. The current direction is still valid because the large fin was still submerged. Although these data have gaps they are still useful.

Salinity was about 34'/ 00 throughout the period of record but the readings dropped abruptly whenever the sensor was not completely submerged at low tide. This salinity of34'/00 confirms that there is negligible freshwater in Erakor Lagoon. The water temperature data ranged between 24' C and 26' C at the beginning of the record and between 25'C and 27' C at the end of the record. These data indicated diurnal heating and cooling and possibly a seasonal or weather change warming effect. The spikes on the temperature plot (Figure 8) are the heating effect of sunlight when the sensor was out of the water at low tide.

The current speeds were about the same in both directions, and ranged up to about 100 cm/sec (1.9 kts) during neap tides and up to about 140 cm/sec during spring tides. For the seven days of useful data the progressive vector (Figure 8) shows the current flowing in and out (easterly and westerly) but with no significant net movement. The resultant net vector for the last 7 days was only 4 cm/sec (0.08kts) across the channel - not in or out.

Discussion

Ideally a current meter should be moored for about one month to get a record of currents over a complete lunar cycle. Because the Erakor Lagoon current meter was destined for the Port Havannah study it could be placed in the Lagoon only for about 10 days. Even though the data collection period was short this meter gave a good sample for the current speeds, between Ekasuvat and Emten lagoons because it was moored for the transition period from neap fides to springs.

The salinity of 34'/ 00 confirms the reports of others that there is negligible fresh water inflow to these lagoons. Without fresh water inflow, there is no additional volume to force a net flow outward. The diurnal heating and cooling also indicates that the tide is having a negligible effect on the water temperature.

Current speeds were up to about 140 cm/sec in both directions (75' and 250' true). It is expected that the current speeds would reach about 150 cm/sec during high spring tides. That these currents are almost equal in both directions indicates that the net flushing effect is negligible. Carter (1983) estimated that the flushing time of Ekasuvat and Emten lagoons were 19 and 91 days respectively and these current data (Figure 8) do not make the flushing situation look any better. These data could be used to check and refine these flushing estimates but the exercise would be largely academic. The flushing of Emten Lagoon is by tidal action only and the rate is very slow.

Removing the causeway will enable more water to flow through the channel in a tidal cycle (Carter 1983, 1990), but the exchange will still be tidal only and largely the same water mass will move in and out which each tide. The larger volume of water moving in and out should reduce the flushing time of Emten Lagoon from the 91 days estimate of Carter (1983). The channel should also be deepened to enable more of the deeper water to be exchanged and flushed.

Removal of the causeway and deepening of the channel will improve the flushing of Emten Lagoon and the mixing of Emtem with Ekasuvat lagoons. This will still leave the unsatisfactory water quality problem unless the pollutant sources are eliminated. Even if the causeway is removed and the channel deepened it will be essential to stop the sources of pollution, whether sewage or otherwise if the water quality is to be improved.

Conclusion

1. Ekasuvat and Ernten lagoons have very slow flushing rates, because there are no substantial fresh water inflows to cause a net outflow to the sea.

2. Removal of the causeway and deepening of the channel will improve the flushing of Ernten lagoon and the mixing of Emten with Ekasuvat lagoons.

3. The poor water quality in the lagoons is not caused by the road causeway and bridge - it is caused by pollutants being discharged into the lagoons.

Recommendations

1. That all sources of pollution to the lagoons be located and stopped.

2. That the causeway be removed and replaced by an open pile bridge and the channel deepened to increase the natural water exchange and flushing rate.

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APPENDIX 1

Coastal Erosion at Mele Bay
Efate, Vanuatu

SOPAC Projects No. 2

Coastal erosion at Mele Bay, Efate, Vanuatu

Mele Bay is a large embayment formed in the southwest of Efate Island, Vanuatu. Coastal erosion has been a recurring problem and has recently become a major concern to the residents and property owners. Signs of coastal erosion 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. The erosion has recently been linked to the unregulated mining of beach sand at two sites in the bay.

Sand mining at Mele Bay has resulted in narrower, steeper beaches near the mining sites. Although sand extraction contributes to beach erosion, a SOPAC survey of the nearshore zone of Mele Bay indicates that natural sedimentary processes operating on the shelf slope may be causing cyclic erosion and build up of the beach.

To understand the sedimentary processes affecting Mele Bay so that recommendations could be made to the Government of Vanuatu on management of the erosion problem, SOPAC carried out two surveys under their Coastal and Nearshore Programme. One was a coastal erosion survey to establish a series of beach profiles that accurately describe the morpholgy of the beach and provide baseline information against which any future changes to the beach could be measured. The other was a geophysical survey to map the bathymetry and seabed morphology in Mele Bay, because processes operating beyond the beach itself could be significant. In fact, the results indicate that these less obvious processes are probably the key to fully understanding the beach erosion problem.

The initial data and observations from the erosion survey demonstrate that beach mining is having a detrimental effect on the coastline. Not only is erosion damage most severe near the mining sites, but the beach profiles near these sites are lower and narrower than those further away, reflecting the change to the shape of the beach due to the mining. By allowing large waves with the capacity to remove considerable quantities of sand to reach further up the beach, the beach is consequently vulnerable to erosion during major storms. With no fringing reef around Mele Bay to dissipate the effects of storm waves on the beach, and only a very narrow shelf below the littoral zone, large quantities of sediment can be moved offshore during storms and lost to the beach system. Erosion was particularly severe during Cyclone Uma in 1986.

It has been recommended to the Department of Geology, Mines and Rural Water Supply in Vanuatu that the beach profiles be resurveyed at 6-monthly intervals and after major storm events. This will enable quantitative estimates to be made of the rates of beach erosion.

The geophysical survey carried out in the nearshore zone of Mele Bay reveals that other sedimentary processes can contribute to the erosion of the beach. Thirty two bathymetric and seismic profiles totalling some 50 kilometres in length were surveyed and interpreted.

Seismic profiling and precision echo sounding reveal a variety of seafloor landforms which appear to indicate a significant amount of instability of bottom sediments on the shelf slope. This instability is indicated by hummocky topography, internally chaotic sub-surface reflections, extensive submarine channelling of the shelf slopes, step-faulting and deformed bedding.

The rapid accumulation of sediments during a catastrophic event such as a cyclone can generate large quantities of sediment which are transported by rivers offshore and deposited on the slopes. The extensive channel network developed on the shelf slope provides conduits for the rapid transportation of the sediment offshore which is then lost to the beach system.

Bathymetric data show that off the beach is a very narrow shelf, beyond which is a steep shelf slope, ranging from 7 to 15 degrees in its upper part. A slope of much less than 1 degree can be sufficient to cause sliding or slumping when a high sediment accumulation rate has resulted in under-consolidation and high pore pressure. Earthquakes or cyclone waves, both common events in the area, could trigger sliding or slumping. On the shelf slopes off one of the river deltas supplying sediment to Mele Bay, seismic profiles show a block slide estimated to represent 90,000 -180,000 cubic metres of sediment removed from the upper shelf slope. Slumping of this scale has the potential to generate localised tsunami in Mele Bay.

Sediment instability in the nearshore has implications for coastal erosion on Mele Beach. Any sediment lost on the upper slopes must be replaced to maintain equilibrium. An event such as a mudslide removes large volumes of sediment from the nearshore zone. Replacement of this sediment must be from either the rivers or the shoreline or a combination of both. Under present conditions, sediment replenishment from the rivers draining Mele Plain is unable to keep pace with the total amount being removed from the beach sediment system, including that being removed by beach mining.

If sediment is removed from the shelf by slumping of unstable sediments, a period of coastal erosion must occur to regain sediment lost by shelf slope instability, followed by a period of coastal stability or even beach build up for a time until slope failure occurs again to repeat the cycle.

Because nearshore sediment instability is a naturally occurring phenomenon, the implications are that significant coastal erosion may take place in cycles directly influenced by the effects of slumping and sediment creep on the shelf slope which in turn are influenced by natural events as cyclones and earthquakes. Present data are insufficient to predict the time span of these cycles.

Towing the seismic sub-bottom profiler in Mele Bay alongside the Vanuatu Department of Lands Survey Hydrographic Branch vessel *Spia Laen* with SOPAC Electronics Engineer Ed Saphore supervising.

SOPAC's studies show that while sand mining is certainly contributing to the erosion problem, the dynamic nature of the geological processes at work in Mele Bay means that periods of erosion as the result of natural phenomena may be inevitable. Studies of several years duration may be necessary to understand and monitor the changes that result and to predict future events.

Original SOPAC reports: Rearic, D.M. 1990. Baseline study of coastal erosion at Mele Bay, Efate, Vanuatu. SOPAC Technical Report 116; Smith, R. 1991. Nearshore bathymetry and seabed morphology, Mele Bay, Efate, Vanuatu. SOPAC Technical Report 126.

APPENDIX 2

Waverider Data Southeast of

Efate Island

November 1990 - December 1991

OCEANOR

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Received: 24 APR 1992

File Reference: DON 11/14/1-7

Action: Brendan.
& Jim Eade ✓

Acknowledged:

Dato/Date April 23, 1992

Antall sider (denne inkl.)/
Number of pages (this one incl.) 9

Vår ref./
Our ref. 1514/28400/esk

Please call if any pages are missing.

Brendan,

Egil passed on your fax concerning the Vanuatu measurements. There follows some comments on the wave climate off Efate.

First, I should point out that it is uncertain how representative the Waverider data are for Mele Bay. With reference to the map (Fig. 1) one can see that the buoy is exposed to waves coming from a wide sector. The only information we have on wave directions comes from the U.K. Met. Office wave model (open ocean model, islands are ignored). Frequency distributions for wave and wind directions are shown in Fig. 2. The most common wave direction is east - south east (wind seas) with south - south east also relatively common (swell). Fig. 3 shows that north easterlies are relatively common in the summer. South westerlies (axis of Mele Bay) are uncommon all year round with high waves occurring only as a result of cyclones (Hs = 10 m from south west would be possible). There is also a possibility for swell from the south when strong southerlies occur off the west coast of North Island New Zealand. There is however only a relatively narrow "window" between New Caledonia and Vanuatu for such swell.

The wave conditions in Mele Bay are therefore likely to be much lower than at the Waverider location, although extremes are not likely to be any different as there is probably no preferred wave direction from cyclones.

Time series of various wave parameters from the Waverider are given in Figs. 4 - 6.

Unfortunately, no data is available during the cyclones earlier this year as the Waverider stopped transmitting and may be lost.

The average significant wave height for all the data is 1.8 m, average mean period (Tm02) is 7.7 s and average peak period (Tp) is 9.3 s. The frequency distribution of peak period (Tp) is shown in Fig. 7 and has a double peaked form according to wind seas (most frequent peak at about 8 secs.) and swell (12 secs.).

The seasonal variation in wave heights and periods is shown in Figs. 8 and 9. There does not seem to be any clear seasonality in wave heights in the data so far. The highest wave heights occurred in the November 1991 cyclone.

Maximum wave heights will be approximately 1.9 times the significant heights.

I hope this will be sufficient for your purposes.

Best regards,

Stephen Barstow

Stephen Barstow

P.S. I have sent 2 faxes to SOPAC asking them to check on the whereabouts of my aluminium trunk which has not arrived here. Could you ask Litia if anybody has checked this for me and to give me some kind of response (by fax) today - regardless of whether it is good or bad news.

Thanks.

2 Measuring Programme

2.1 Overview of Measuring Sites

Wave measurements started offshore Vanuatu in 1989. On November 22nd a Waverider buoy was moored 5 nautical miles southeast of Efate.

Figure 2.1 shows the measurement location. Position: 17°52.5'S, 168°33.0'E. Water depth: 285 m.

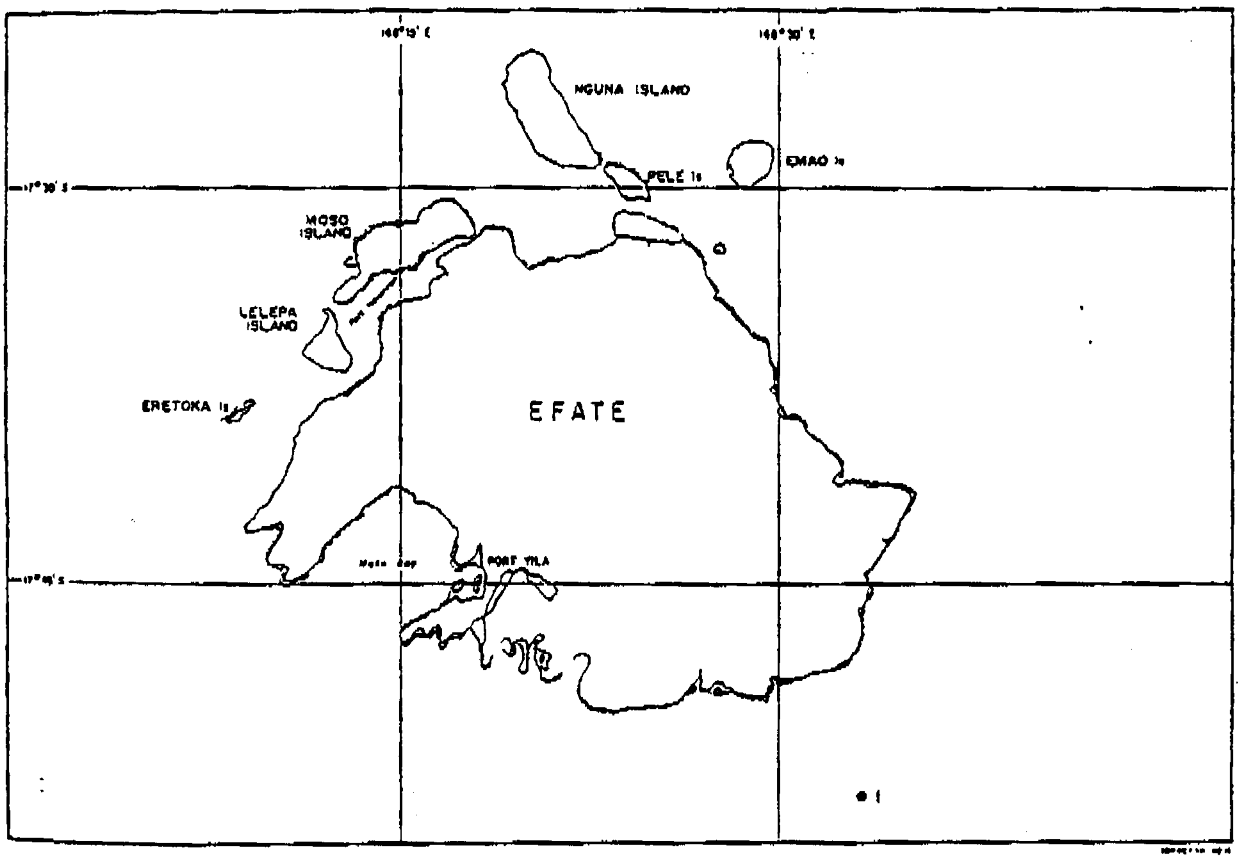
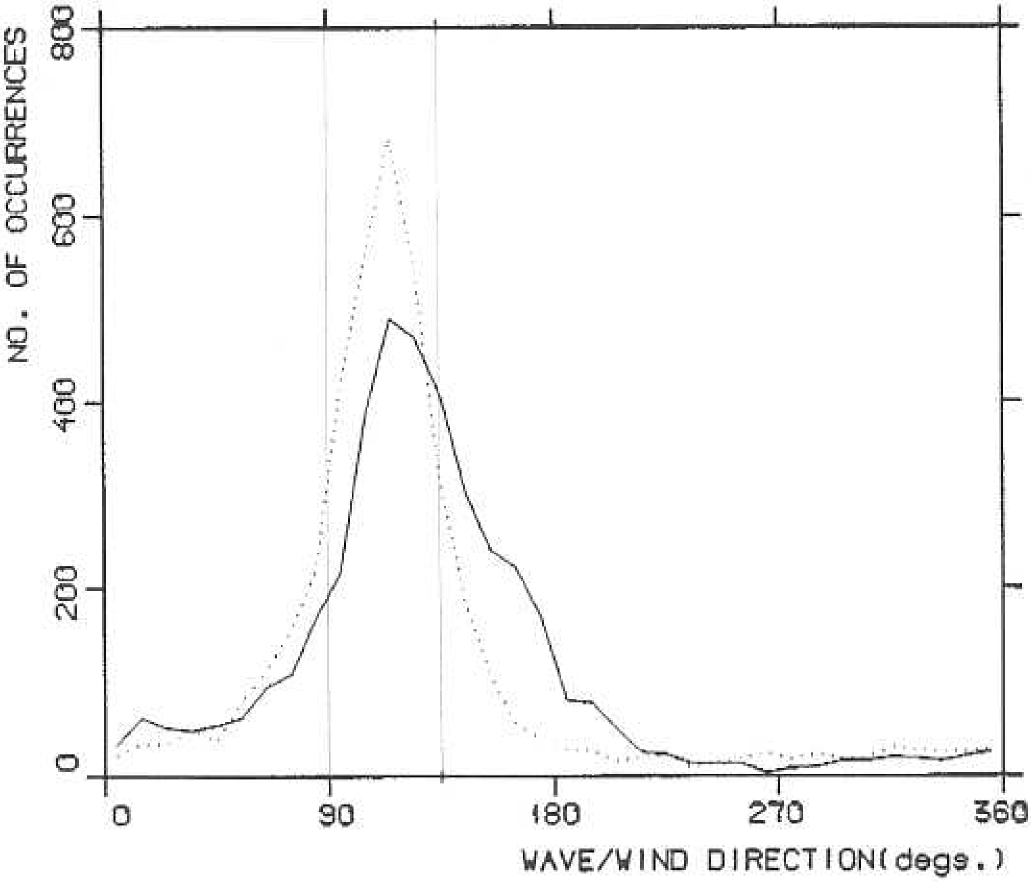
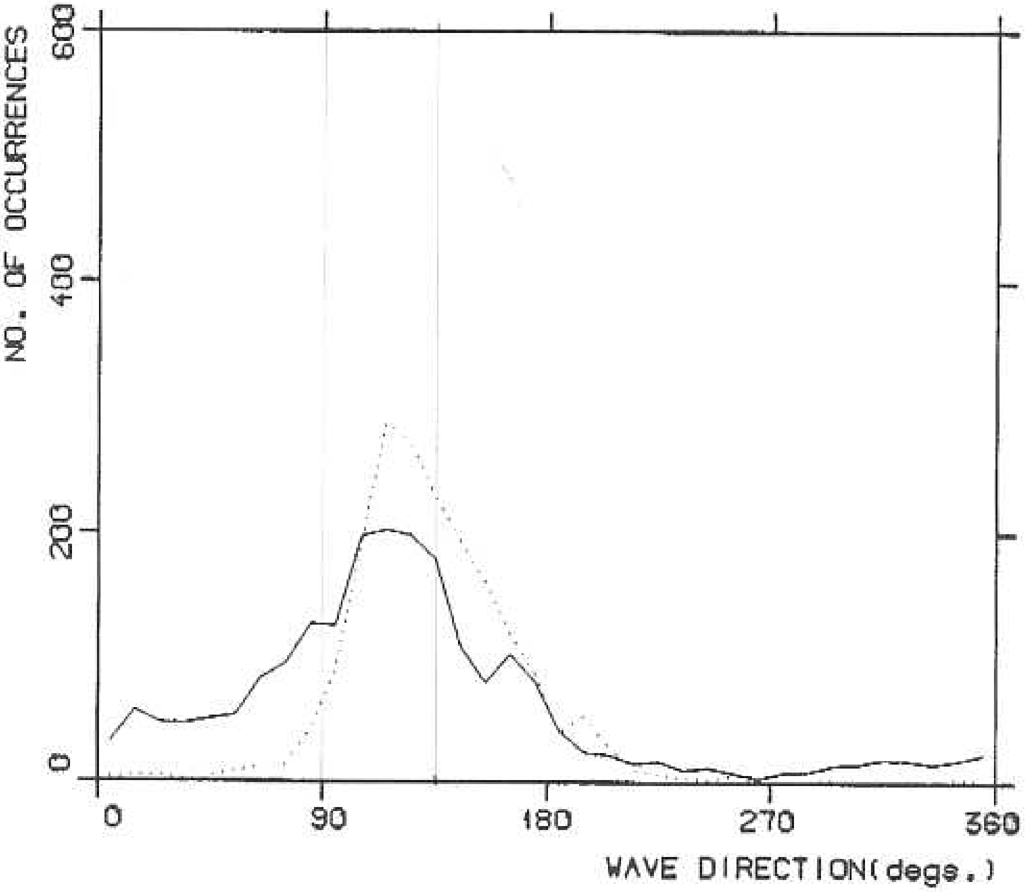


Figure 2.1 Location of the wave buoy southeast of Efate, Vanuatu.



WAVE(solid line) AND WIND DIRECTIONS (dotted line)

Fig. 2

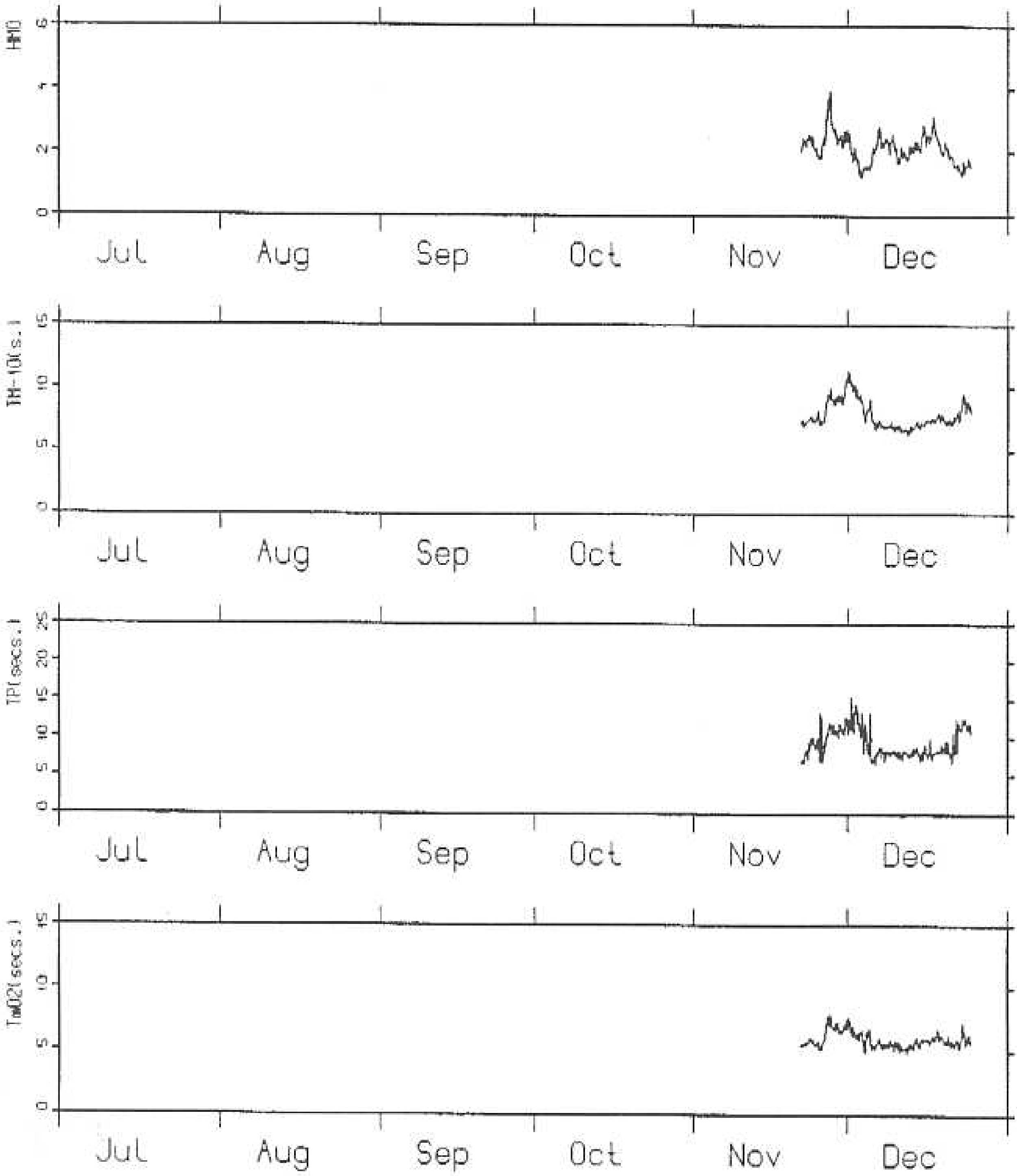


WAVE DIRECTION summer(solid) and winter~~(dotted)~~

Fig. 3

VANUATU WAVERIDER MEASUREMENTS:EFATE

PERIOD : 1 July 1990 - 31 December 1990

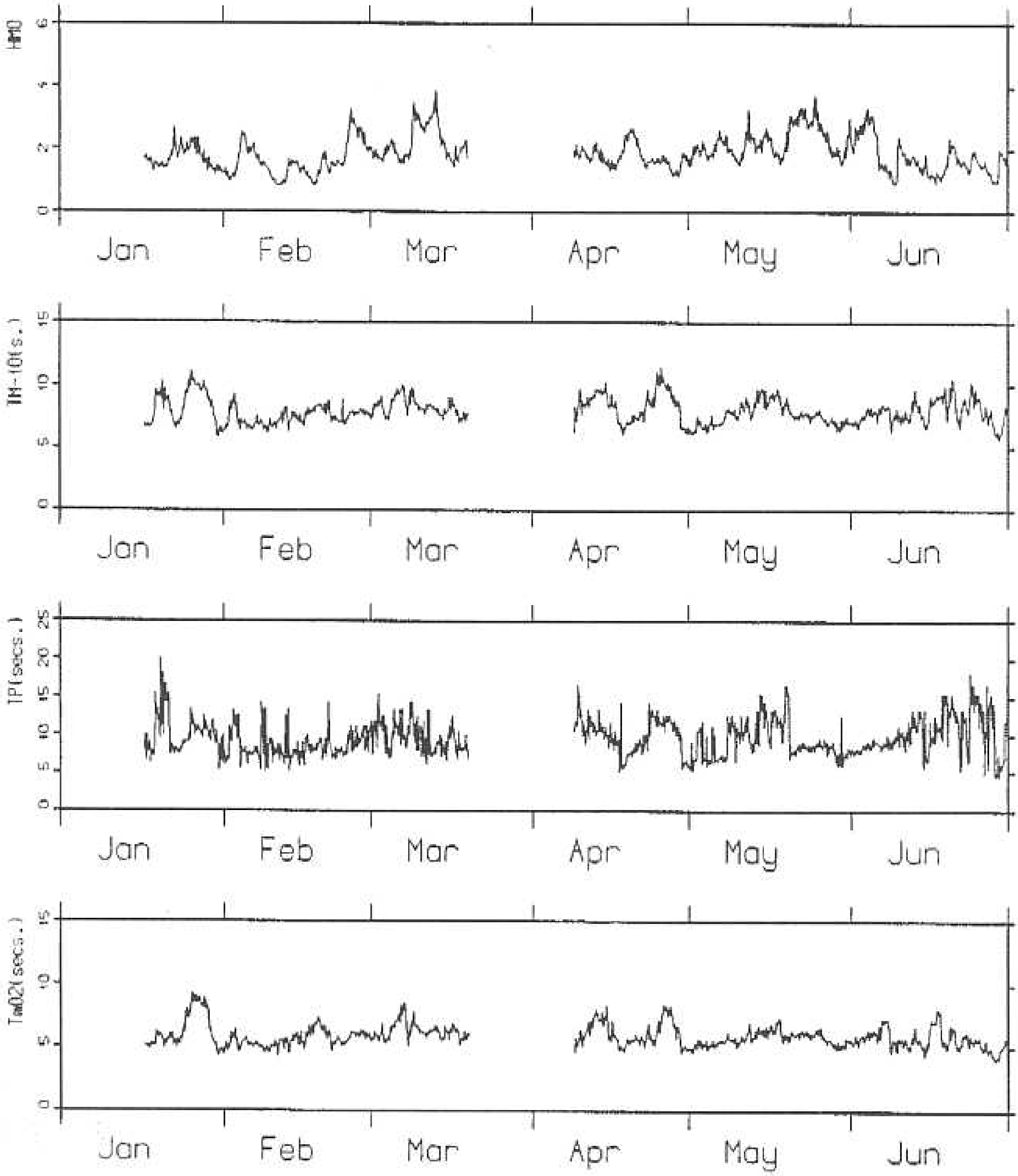


Program / Version : CURVPLOT V3.2
Parameter file : DUEUSERDS:ESFB.VRGDSDB]VAN.PV2

Fig. 4

VANUATU WAVERIDER MEASUREMENTS:EFATE

PERIOD : 1 January 1991 - 30 June 1991

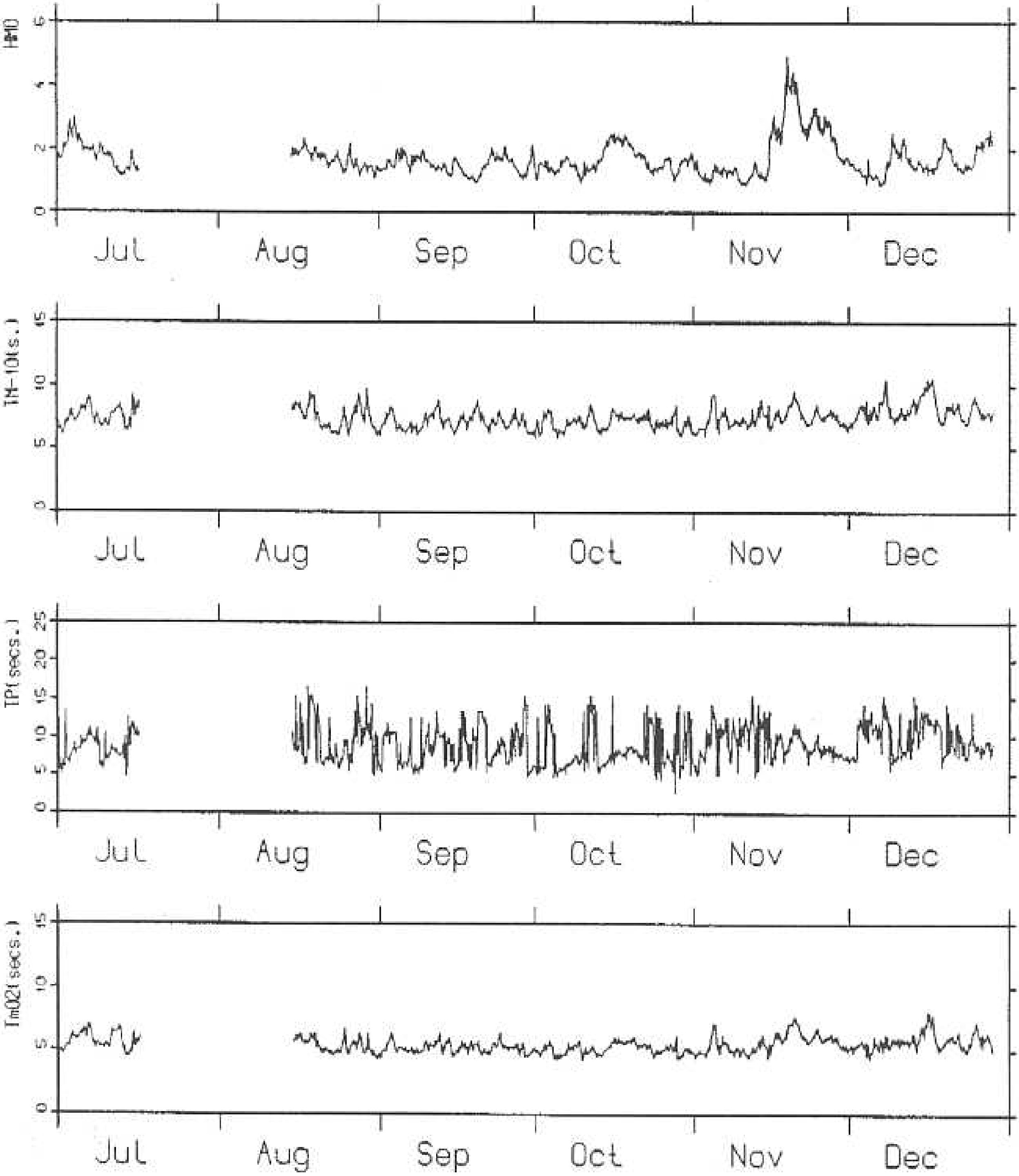


Program / Version : CURVPLOT V5.2
Parameter file : OCEUSERDS:ESFB.ARGOS03AVAN.PA2

Fig. 5

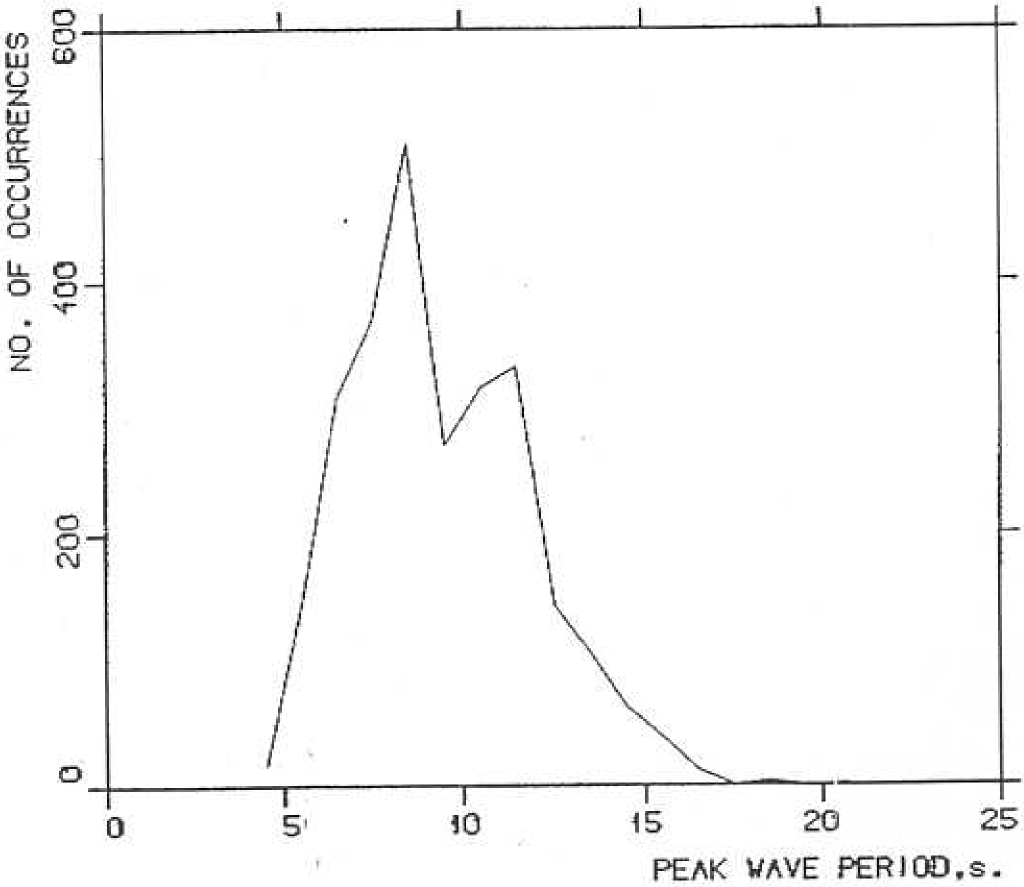
VANUATU WAVERIDER MEASUREMENTS:EFATE

PERIOD : 1 July 1991 - 31 December 1991



Program / Version : CURVPLOT V3.2
Parameter file : OCEUSERDB:[SF3.APGOSOO]VAN.PA2

Fig. 6.



FREQUENCY DISTRIBUTION FOR TP;VANUATU

Fig. 7

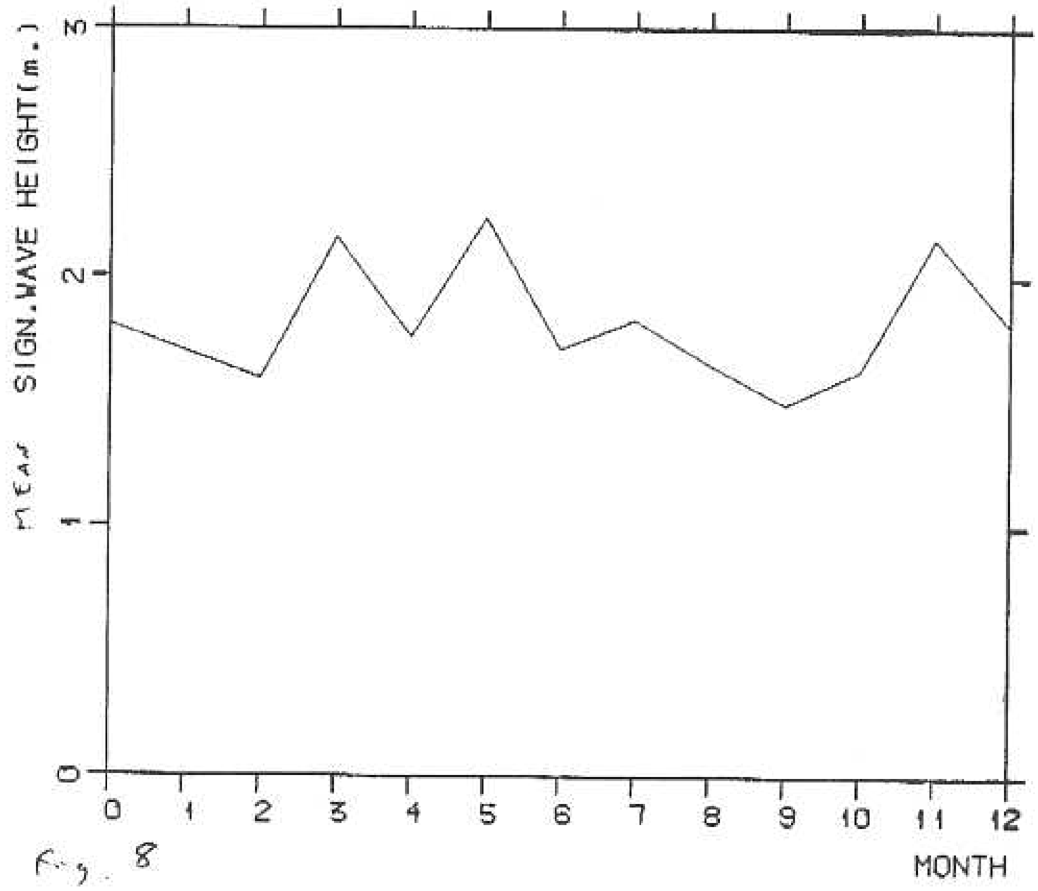


Fig. 8

VANUATU WAVERIDER STATISTICS

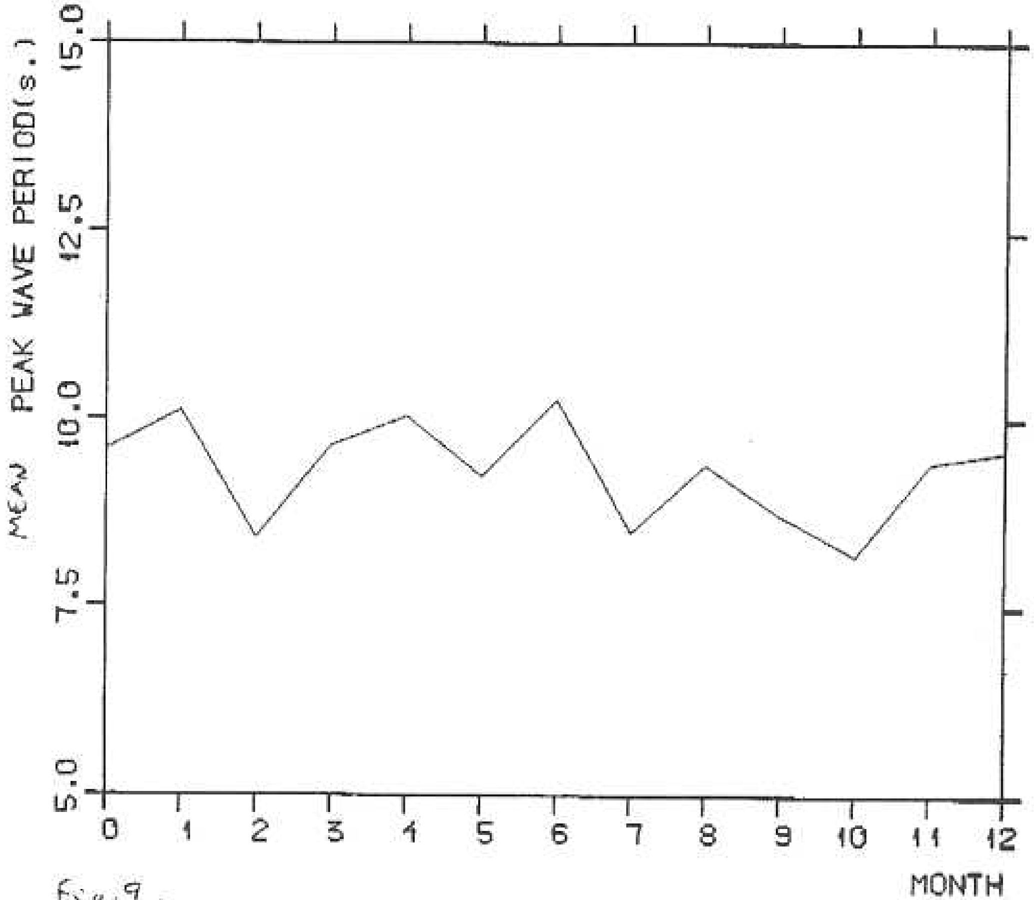


Fig. 9.

VANUATU WAVERIDER STATISTICS