COASTAL PROTECTION
TEBUNGINAKO VILLAGE, ABAIANG
KIRIBATI

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SUMMARY

For several years, there have been reports of erosion on the lagoon shore of Tebunginako and other villages on Abaiang, Kiribati. This report describes SOPAC Task 91.KI.4e: Development of a Coastal Protection Plan for the lagoon shore of Tebunginako Village.

This task involved a study of previous work, bathymetric charts, weather data and a detailed site inspection. Discussions were held with the Kiribati Ministry of Works Chief Engineer, with respect to the locally available construction materials and equipment.

This report discusses natural coastal processes and the effects of El Ninos and associated westerly winds on natural features, the effectiveness of existing coastal structures, and gives some alternatives for protection for Tebunginako.

It is concluded that the net long term littoral drift is definitely toward the northwest. There are no substantial man made structures which could cause the erosion; therefore, the problem is probably a natural cycle of westerly wind wave erosion associated with recent severe El Ninos. A shoal to the west of Tebunginako Village is a significant natural feature influencing natural processes.

The existing attempts at coastal protection are largely ineffective. Several coastal protection alternatives are discussed; however, the limitations of local construction make most of these impractical. A coastal protection alternative is provided for expensive buildings which are not relocatable, and it is recommended that buildings be setback 15 metres from the natural boundary of the sea.

ACKNOWLEDGEMENTS

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Acknowledgment is made of the Kiribati Government personnel who assisted with this work Norman Watts and Tapetulu Merang of the Ministry of Works, Erene Nikora of the Lands and Surveys Branch, and Tarawa Natava of the Library Archives.

OBJECTIVES

This work was carried out to fulfill the requirements of SOPAC 1991 Work Plan Task 91.KI.4e: Development of a Coastal Protection Plan for the lagoon shore at Tebunginako, Abaiang. The first part of this task was a field trip and detailed site inspection carried out in April 1991 (Holden 1991). The objective of this report is to combine the field trip information (Field Survey Number KI9102) with other information and previous work to develop a coastal protection plan for Tebunginako. This report also discusses the erosion problem and some alternatives for coastal protection or mitigation of the erosion at Tebunginako.

INTRODUCTION

Abaiang Atoll (Lat 1' 52'N, Long 172" 56'E) is situated north of Tarawa Atoll, Kiribati (Figures 1 and 2)'. Abaiang is a rectangular shaped atoll, about 33 km long and 9 km wide, with a northwest - southeast orientation. The shoreline on the long northeast facing side and the short southeast facing end is continuous with no gaps. The other two sides are essentially a chain of reefs with some gaps and some islands. Tebunginako Village is on the lagoon shore of the northeast side of Abaiang and is only exposed directly to wind and waves from between south and northwest.

Coastal erosion is threatening buildings along the lagoon shoreline of Tebunginako and other villages on Abaiang Atoll. This erosion was initially investigated and documented by an earlier SOPAC survey (Harper 1989), Which made the following noteworthy observations and conclusions. "Tebunginako Village is on an old natural coastal spit which was formed by the dominant littoral drift from the south. Although this spit formed naturally, the present erosion may have been partially caused by land fill and shore protection structures. In the short term, some protection may be warranted; however, the recommended long term objective should be to relocate houses from the critical areas." Harper recommended that a coastal engineer conduct a detailed site investigation and recommend a comprehensive protection plan.

A site inspection of the shore of Tebunginako and other villages was carried out by a SOPAC coastal engineer in April 1991. At the same time, discussions were held with the Chief Engineer Kiribati Public Works to ascertain the nature and availability of local materials and equipment (Holden 1991). That information is used in this report which describes a coastal protection plan for Tebunginako.

Remainder of figures, 3 to 11 can be found together after page 26.

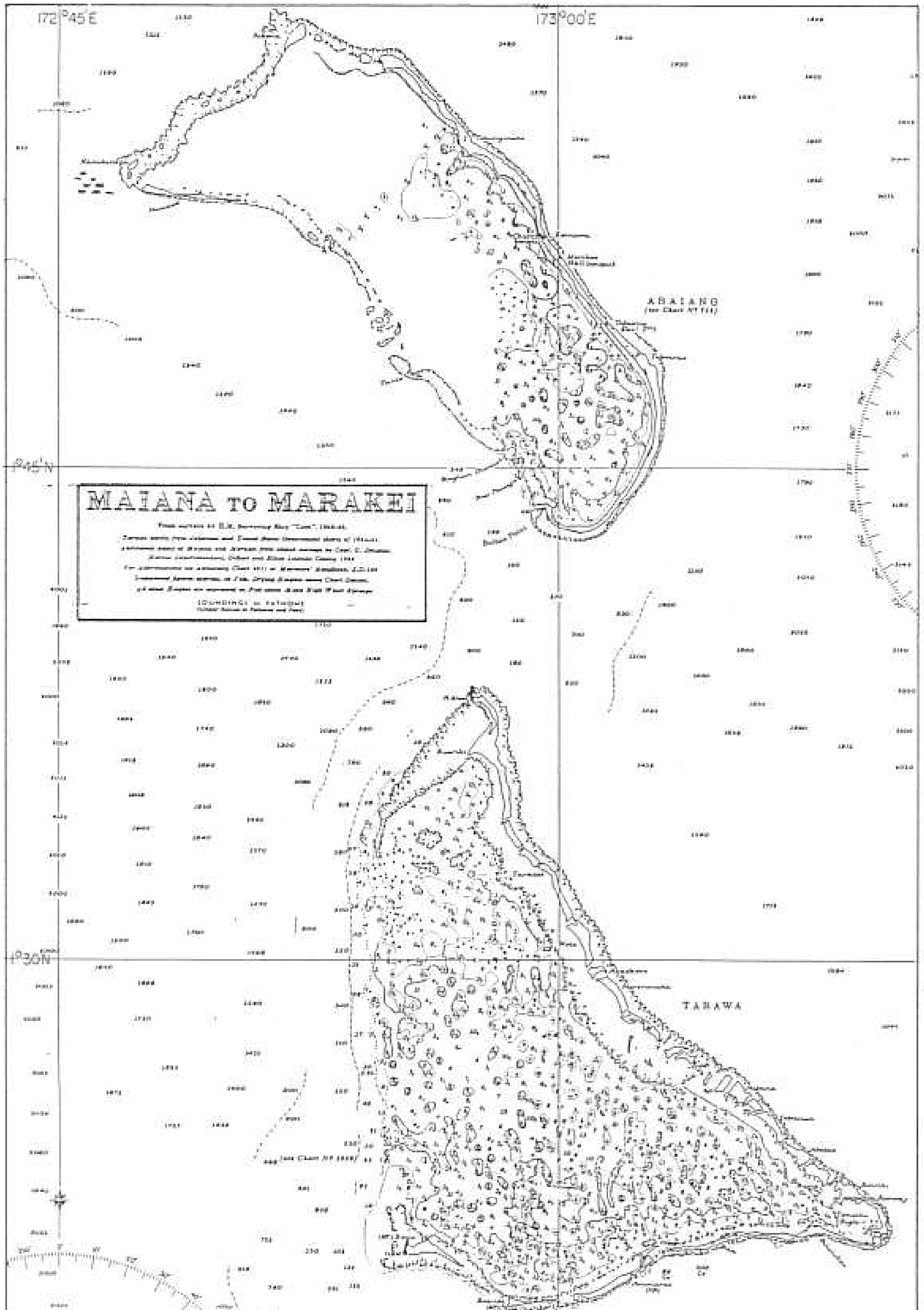

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Figure 1. Abaiang and Tarawa site map.

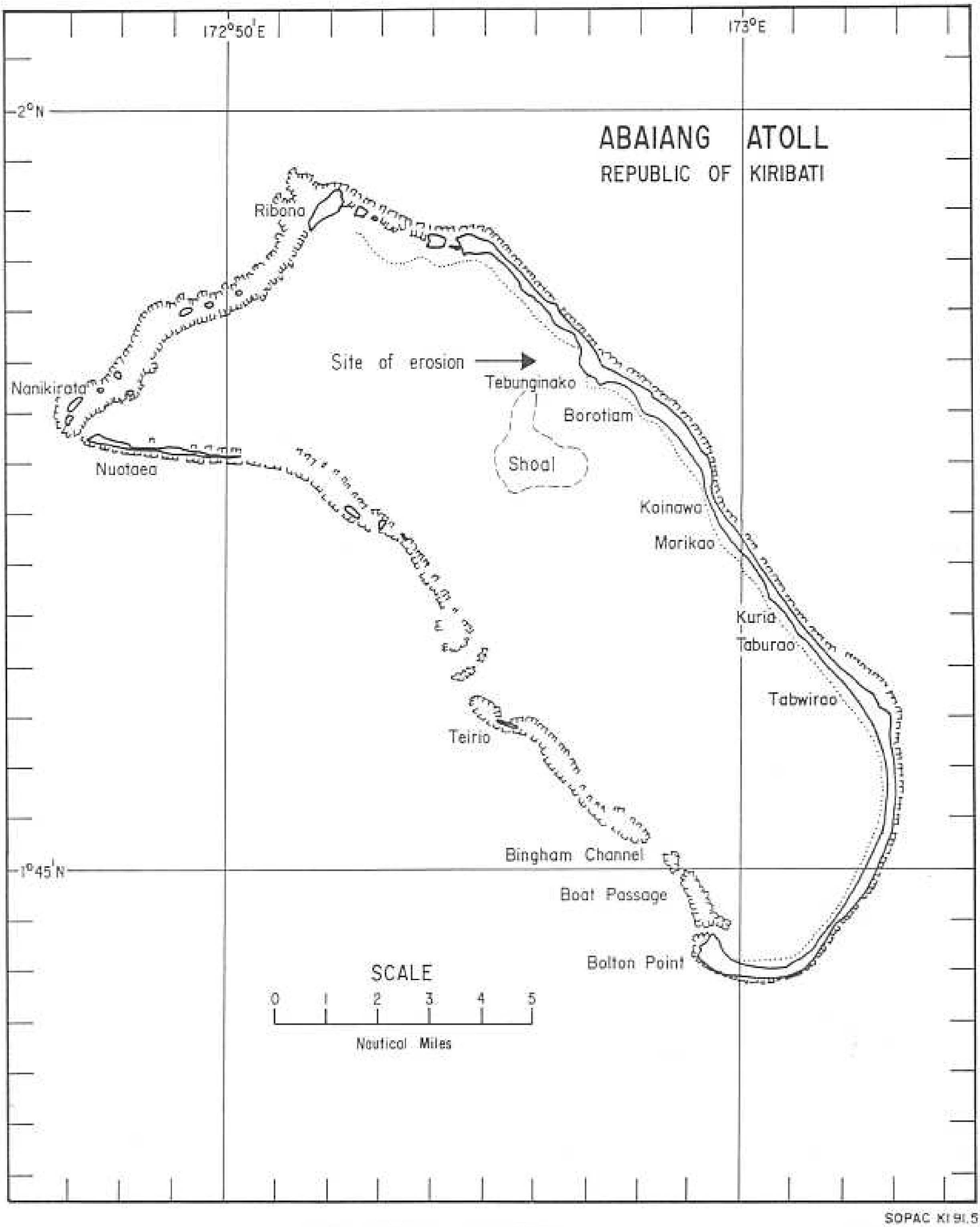


Figure 2. Abaiang site map.

METHODS

A study of coastal erosion usually involves researching existing information, making a site inspection visit and then combining both the existing information and the information from the site visit into a final report.

The procedure for conducting a study of coastal erosion generally begins with collecting and studying existing data related to the site. The existing information used in this study was wind data, bathymetric maps, topographic maps and air photos. The site visit is necessary to verify the real problem and the nature of the beach as shown on the maps.

A site inspection of the erosion at Tebunginako and other villages was made on 27 April 1991 by the writer and Tapetulu Merang of the Kiribati Ministry of Works. The purpose of the site inspection was to search for indicators of littoral drift, to inspect old protection works, and to ascertain the nature and composition of the beach. This involved walking the lagoon beach at Tebunginako, taking photographs of particular features and making notes. The inspection area extended updrift and downdrift of the specific erosion sites to look for causes and effects of the erosion on adjacent shorelines.

Any construction project is dependent on the locally available material and equipment that which can be transported to the construction site. To determine this local information, discussions were held with Norman Watts, the Kiribati Ministry of Works Chief Engineer. Discussions were also held on the natural coastal processes and the positive and negative effects of some coastal protection alternatives. There was also some discussion on the methods of construction, construction supervision and the local financial benefits of the works in Kiribati.

All the information collected from existing data, reports and the site inspection was used to develop a coastal protection plan. The alternatives and final recommendations are cognizant of limitations of locally available material and equipment.

The coastal engineering terms used in this report are defined in Appendix 1: Glossary of Terms. The principles of coastal and oceanographic engineering used and discussed in this report can be found in Wiegel (1964) and US Army Corps of Engineers (1975).

RESULTS

Charts/maps

The best available bathymetric chart of Abaiang is the Admiralty chart MAIANA TO MARAKEI (Figure 1). This chart is not complete throughout Abaiang Lagoon but it does show a very significant shoal area in front of Tebunginako village. This shoal will cause wave attenuation and refraction in front of Tebunginako. This shoal area is less than one fathom below chart datum and, as a submerged breakwater, provides some shelter from westerly waves.

The only available topographic map of Abaiang is Series XO42 (DOS 367P) (Figure 3), published by the Government of the United Kingdom for the Government of Kiribati. This map is a 1980 edition and does not show much shoreline detail.

The only available air photos of Abaiang are from 1968 and 1969 flights. The best stereo pair in the Kiribati archives was No. 61 and 62 of flight 68-239. An older air photo is required to ascertain changes prior to 1968 and a new air photo is required to ascertain changes since 1968. It is recommended that the 1940's air photos be obtained and that Abaiang be flown again at the same scale as the 1968 photos. A copy of photo no. 62 (Figure 4) is included with the ground photos taken at the site inspection (Figures 5, 6, 7, 8).

Wind

There are no wind data available for Abaiang; however, there are data for Tarawa, which is the only climatological station in Kiribati to have an anemometer (Burgess 1987). Tarawa Airport (Bonriki) is about thirty five nautical miles from Tebunginako (Figure 1) and the wind is taken to be similar in strength and frequency by direction.

The wind roses for Tarawa (Figure 9) show very clearly that the area is dominated by wind from the easterly sector. The winds are predominantly from the east and northeast for December to May and predominantly from the east and southeast for June to November. These easterly winds do not directly impact the lagoon shore at Tebunginako as severely as westerly winds. The southeasterly winds generate lagoon waves from the southeast, which move littoral material toward the northwest on the lagoon shore at Tebunginako. The westerly winds generate waves which directly impact and erode the lagoon shoreline.

Although winds from the west are not frequent in Tarawa, they do occur occasionally and can be severe. Winds from the southwest through to northwest are infrequent and irregular and accompanied by heavier and prolonged rainfall. These winds and rains appear to be associated with El Nino events and also with the northwest monsoon (Burgess 1987). There were moderate to strong El Nino events in 1972, 1977-8, 1982-3, 1987, and in 1991. The Tarawa wind roses (Figure 10) (Wallingford 1976) show the direction variation between a typical year (1970) and an El Nino year (1972)

Since the coriolis force is negligible near the equator, tropical cyclones rarely occur within five degrees latitude of the equator. There are no records of tropical cyclones in Kiribati; however, when a cyclone is developing to the south or north gale force winds do sometimes occur from the west to northwest (Burgess 1987).

Winds from the northwest to southwest have an average frequency of 7% to 11%. The mean wind speed is 5.7 kn from June to August and 7-10 kn from December to February. Winds near gale force (at least 28 kn) occur on average only one day per year. The maximurn gust recorded on the anemometer at Tarawa was 52 kn from 280' on 18 November 1982 (Burgess 1987).

Waves

A wind speed of 40 kn from the west is used here to hindcast waves from the west at Tebunginako The hindcasting method is that described in the US Corps of Engineers Shore Protection Manual (1975). A 40 kn wind over a fetch of 5 nautical miles can generate wind waves with a period T = 4.5 seconds, a deep water wavelength L = 32 m and a significant height Hs = 1.4 m. This wave will begin to feel bottom and refract in 16 m water depth. This wave is used as the design wave for coastal protection structures on the lagoon shore of Tebunginako.

Tides

The astronomical tides at Abaiang are based on the standard tidal reference port of Puerto Montt, Chile. These tides are mainly semidiurnal, with two high and two low tides each day. The maximum astronomical tidal range, which occurs over the 18.6 year tidal cycle, is 3.3 m. Tide levels will be close to this astronomical maximum a few days each year; however, this maximum astronomical tide will occur only a few times during the 18.6 year cycle, when the total gravitational pull of the sun and moon is maximum. The mean spring tidal range is 1.6 m and this range occurs a few times every fortnight at the new and full moon (syzygy). These tide heights and ranges are referenced to chart datum (Admiralty Tide Tables 1990).

Site Description

The site inspection commenced north of Tebunginako village at the indentation in the shoreline (Figure 4). This is an accreting area which has a wide sandy beach (Figures 4,5,6) and has been planted with coconut trees as the land accreted. The trees range in height from about 1.5 m near the shore to mature trees at about 300 m back from the shore. The range of tree sizes indicates that this accretion and the tree planting project has been on-going for some years. Local residents said that this area was the tip of a spit with a small lagoon entrance until about 20 years ago and the accretion began when the gap at the tip of the spit was artificially closed. The 1968 airphoto (Figure 4) does not show a gap at the tip of a spit; hence, there is some doubt about the existence of a spit with a gap opening to the swamp behind and or the time of closure of such a gap.

The beach accretion area north of Tebunginako is composed entirely of fine sand (Figure 5 & 6). The beach fronting the village is composed of a mixture of sand and cobbles. The cobbles are generally small and sizes range only up to a maximum diameter of about 0.3 m (Figures 4 & 8). There are some sections of large flat-lying beachrock on the beach or just below the surface (Figure 8). Some sections of these flat beachrock slabs have been cut out and removed. To the south of Tebunginako the beach again is generally sandy and there are many seaweed plantations in the shallow water near shore.

The beach fronting Tebunginako and other nearby villages has wave cut banks and numerous fallen coconut trees as evidence of erosion. There are remnants or relics of several coastal protection devices. These are rock groynes, rock seawalls, vertical log seawalls and gabion seawalls. Most of these structures are in a dilapidated state and have no positive effect on the beach (Figures 4, 7 and 8).

There are small groynes on the beach at Tebunginako, with a build-up of material on the southeast side and erosion on the northwest side. One groyne is directly in front of the maneaba (Figures 4 & 7). These groynes indicate that littoral drift is northward at Tebunginako.

The rock filled gabion seawall which was reported and photographed in 1989 (Harper 1989) has been demolished. All that remains of this seawall is a scattered pile of rocks on the beach and some twisted gabion wire (Figures 4 & 8). The effect that this seawall had on the shoreline appears to have been negligible. It is not known if the gabions were broken by wave action or the wire was cut.

Local Materials and Equipment

During the April field trip, Norman Watts (Kiribati Ministry of Works Chief Engineer) was consulted regarding the materials available, the methods of construction, the available equipment and local financial benefit of works in Kiribati. From these discussions the following points were noted.

a. Abaiang Atoll has no mechanical equipment for construction purposes. If a project requires earth moving equipment (trucks or loaders) they will have to be shipped to the atoll at considerable expense.

b. The only locally available materials for construction on Abaiang are sand and some beach rock from the reef flat. There are only a few large rocks which would be suitable as armour stones. The breaking and removal of beachrock slabs from the beach to build protection works is not beneficial because their removal will accelerate erosion.

c. A general limitation for any construction project on Abaiang is that it must be done with manual labour; hence, the size and quantity of rock is limited to that which can be moved by hand.

d. Sand bags or cement and sand (grout) filled bags are an option which can be handled by manual labor, and may be a suitable substitute for small armour stone.

e. There is a shortage of knowledgeable people for the supervision of construction projects in remote areas. Since the placement of coastal protection works is a precise operation, Mr Watts inquired whether SOPAC could provide a construction supervisor.

f. If mechanical equipment is brought in from outside Abaiang, the aid money is essentially being spent outside the area and there will be no direct benefit to the local population. The same principle applies to bringing in construction materials such as steel or concrete from outside. It is preferred that local material and local labour be used, so that the project can have local economic benefits. This preference for local building materials and local labour force was also stated in a recent report on causeways (AIDAB 1988).

DISCUSSION

Littoral drift

The wind roses (Figures 9 and 10) clearly show a dominant wind direction from the northeast to southeast. Although wind from the northeast and east does not affect the lagoon shore at Tebunginako, the wind from the southeast generates waves moving toward the northwest in the lagoon. These winds and the resulting waves are dominant for several months of most years. These wind waves refract toward the shore and move beach material toward the northwest.

The shoreline erosion at the village and the accretion to the north of the village indicate northward littoral drift (Figures 4 to 8). Sand is eroding from the village beach and is accumulating north of the village. There is no accumulation of sand to the south. There is also erosion at several other villages to the south of Tebunginako.

There are several groynes on the beach at Tebunginako, with a buildup of material on the south side and a lack of beach material on the north side (Figure 7). There are also other items, like fallen trees and points of land which show the same effects as groynes. The effect of a groyne is to block littoral drift as a dam blocks a river. Buildup occurs on the updrift side of the groyne and the downdrift side suffers erosion. Since the buildup is on the south side of these groynes, and there is erosion on the north side, the littoral drift is moving toward the north.

The site inspection confirmed that littoral drift is toward the northwest on the lagoon side of Tebunginako, in agreement with Harper (1989).

The Shoreline Bulge

The Tebunginako site is characterised by a bulge on the shoreline of Abaiang and a shallow water area (shoal) offshore of the bulge (Figures 1 & 2). This shoal is believed to be the cause of the bulge on the shoreline. The shoal is effectively a submerged breakwater which provides shelter against large waves and causes refraction of most waves.

The ratio of wave height to water depth at breaking is $H_b/D_b = 0.78$. Since the chart water depth over this shoal is under 1.8 m, any waves over 1.4 m. in height must break on this shoal at low tide. At higher tide levels, these waves may not break but would be refracted and diffracted around this shoal and the energy dissipated.

Waves feel bottom and begin to refract when water depth is about half the wave length. The water depth over this shoal will cause any waves with a period over 2 seconds to feel bottom and refract around the shoal. The effect of this refraction is that the wave energy is greatly reduced between the shoal and the shoreline.

This means that this area has much less wave energy available to move beach material; hence, the material gathers to form a bulge on the shoreline. It is essential for the stability of Tebunginako that this natural offshore shoal is never dredged, mined or disturbed in any way.

The lagoon wind waves described previously will start to feel bottom and refract in 16 m water depth. This means that these waves can move bottom sediments at water depths less than about 16 m. It follows that a sandy bottom out to this depth is part of the littoral system and any disturbance may affect the state of the beach at the shoreline. It is recommended that no dredging be allowed in water depths less than about 16 m in the lagoon.

Coastal Erosion

The shoreline erosion at Tebunginako has several possible explanations. The erosion may be caused by some of man's activities and structures, or by natural processes and storm events.

Structure Induced Erosion

The present erosion at Tebunginako may have been partially caused by previous attempts at coastal protection as was stated by Harper (1989). Improperly designed or placed coastal structures are often useless for protection and may actually cause more erosion damage. Erosion near human habitations implies that one should consider the cause might be human induced.

It is well known that groynes cause an accumulation of material on the updrift side. What is also true but not so well known, is that groynes cause erosion on the downdrift side. This is the expected effect of all groynes, unless they are filled with beach material at the time of construction. Even when groynes are filled at construction, they may still cause erosion. Groynes do not reduce the wave energy striking the shore. Groynes force littoral drift offshore around the groyne and this may cause or accelerate the loss of beach material to the offshore deepwater zone. Material which is lost to the offshore deepwater will not return to the beach. This effect of groynes makes them detrimental to beaches even when they are filled at the time of construction. It is now generally realised that groynes have a negative effect on beaches and are not generally favoured for coastal protection.

There are several small groynes along the shoreline of Tebunginako. None would seriously disrupt littoral drift, although they exacerbrate the problem and cause localised erosion and scour. They are largely ineffective for coastal protection. That there are no major groynes south of Tebunginako indicates that the problem may be natural erosion exacerbated by the small structures.

Seawalls have also been criticised for causing erosion of the beaches fronting them, particularly in the case of vertical and/or smooth seawalls with high reflection coefficients. A smooth vertical seawall in deep water can reflect the incoming wave almost 100%. In this case, the reflected wave passes back through the incoming wave and where the two wave crests pass, the wave height is doubled as a standing wave. The effect of this is to increase the erosion potential in front of the wall. The result can be erosion of the beach in front of the wall by a depth roughly the same as the incident wave height.

Although all seawalls are not in deep water or perfect reflectors, they are still suspected to have negative effects on the beach. While some seawalls are suspected to have caused or accelerated erosion, other seawalls appear to have no discernable effect on the rate of shoreline changes (Basco 1991). The least damaging seawalls are non-reflective ones, (stepped or rough, porous, and sloped) which can absorb wave energy and are located out of the water. The various seawalls (rock walls, vertical log walls and gabion walls) at Tebunginako are not deemed to be helpfull and are suspected of exacerbating the erosion.

Previously built coastal protection structures have used rock locally gathered from the reef flat and the lagoon shore. The removal of rock from the beach leaves the finer material in a more easily erodible state. The large beachrock slabs on the lagoon shore are non erodible and are a natural protection against erosion. The breaking up and removal of these beachrock slabs will loosen unconsolidated material and enable it to erode faster than normal. The removal of beachrock slabs to build protection works is not deemed to have any net benefit.

Natural Erosion

Beaches often appear to be eroding and/or accreting for different time intervals and the process is completly natural. These natural beach fluctuations are often seen on a regular yearly basis, may occur over time intervals of several years or may be related to major storms or other events. After a major event the beach may take many years in the adjusting process.

The present erosion of the Tebunginako bulge at the village centre and the accretion north of the village centre suggest a sand bulge migrating along the shoreline. Shoreline zones of accretion or erosion sometimes migrate along the shore with the littoral drift process. Although migration of the bulge is possible, it is not compatible with the existence of the offshore shoal near Tebunginako. The shoal should keep the bulge in the same general location as described previously. If the shoal has caused the bulge, then the shoal would have to move or be disturbed to cause the bulge to move. It is not known if the offshore shoal has been disturbed but it is unlikely since there is no heavy machinery known to be on Abaiang.

Although the lagoon shore of Abaiang is sheltered from the direct impact of the prevailing easterly winds, it is affected by occasional westerly winds associated with the occurrence of El Nino events (Burgess 1987). There have been notable El Nino events in 1972, 1977-78, 1982-83, 1987 and in 1991. It is possible that the westerly winds associated with these El Ninos have caused abnormal short-term erosion. Several severe El Ninos in succession could have caused more erosion than could be restored naturally in the interim.

Since El Nino events are natural and have always occurred, the westerly wind and waves are also natural events and the resulting beach fluctuations are part of the natural coastal process. These events can be expected from time to time and the beach should adjust naturally as it has in the past. It is not conclusive that the recent series of El Nino events caused this erosion, but there are no other known possible causes. In retrospect, one can see many natural disaster events which occurred in late 1982 and early 1983 and are now believed to be an effect of that El Nino. It may be that the present erosion is a natural event which will adjust itself without any coastal protection works.

Some coastal erosion is a natural process which supplies material for beaches and this erosion should not be prevented. Some erosion is caused by man’s interference with the natural beach processes by the use of groynes, seawalls, landfills or other structures. There is also some erosion which is cyclical such as seasonal beach changes or erosion/accretion waves migrating along the shoreline. These cycles of accretion and erosion or fluctuations occur on many beaches which are ‘stable’ but the term “dynamic stability" is more appropriate.

The possibility that this erosion is not a cyclic beach fluctuation is contradictory to the existence of Abaiang. If consistent long term erosion continued at any site on Abaiang and/or the updrift source of littoral material was somehow reduced, then there would in time be at least a gap in the island. It follows that the present erosion must be cyclic in nature. It is believed that Abaiang has existed in its present form for some millenia and is as dynamically stable as it ever was.

It is not known exactly what process or combination of processes is responsible for the apparent erosion at Tebunginako. It would require an extensive study of historical airphotos and records to determine exactly what is happening to the beach and what is causing the problem. Such a study would require considerable time in obtaining historical photos and may not be any more conclusive than the above discussions. At the end, the present erosion problems still have to be attended to.

The only accurate way to measure beach changes is by comparison of beach cross-section profile surveys done at the same time and same location over a period of years. Surveys must be done by qualified surveyors and referenced to permanent bench marks on land, so they can be repeated precisely. An initial baseline survey would have to be done if comparative surveys are to be made in the future. The beach surveys must be done at the same time each year to avoid seasonal effects and make the surveys comparable. If beach surveys are not done at the same time each year the comparisons are not necessarily valid and conclusions may be erroneous. It is recommended that beach surveys in Kiribati be conducted in August to record a stable beach and avoid the effects of the hurricane season in both hemispheres. To avoid the effects of major storms and other events, confident conclusions could only be drawn after periods of several years.

The best way to manage beach fluctuations and avoid losses is to leave the beach alone and let it fluctuate with the natural processes. This can only be done if all buildings are adequately setback to allow for erosion and natural beach fluctuations. Buildings can be setback a sufficient distance from the natural boundary of the sea to guard against erosion at least for the life of the building.

COASTAL PROTECTION ALTERNATIVES

Several of the most common alternatives for beach protection are discussed below with respect to their advantages, and disadvantages, their labor, equipment and materials requirements, and their maintenance problems. Some design specifications are given for each alternative, and comments are made on their feasibility for Tebunginako. This discussion provides a Comparative summary of some shore protection alternatives and indicates those appropriate for this particular site. A summary of these coastal alternatives is presented in Table 1 for ease of reference.

Table 1. Summary of Coastal Protection Alternatives

Structure	Advantage	Disadvantages	Appropriateness for Tebunginako
Groynes	Immediate buildup on updrift side. Easy to construct from local materials.	Immediate erosion on downdrift side. Beach obstruction. Littoral drift lost offshore.	Would cause downdrift erosion and possible offshore losses. Not recommended.
Offshore breakwater	Buildup of material inside the breakwater. No beach obstruction. No offshore loss.	Erosion downdrift of the structure. Require heavy equipment & construction supervision.	Rock and equipment not available. Not feasible.
Seawall	Protects land area only. Can be built on land by manual labour.	May cause beach erosion. Requires proper design and construction supervision.	Could be built of grout filled bags. Use only where property is valuable.
Artificial Nourishment	Preserves the natural beach. Does not disrupt natural processes.	Requires periodic replenishment. Requires heavy equipment and a supply of sand.	Equipment not available. Not feasible.
Setback/Relocation	Preserves the natural beach. Avoids future problems.	Requires government regulation and enforcement. Offers no protection for existing buildings.	Can be implemented at any time by enforcement of regulations. Recommended.

Groynes

A groyne is a structure placed approximately perpendicular to the shoreline on a beach. The groyne acts as a dam to the littoral drift process and accumulates material on the updriftside. The build up of the beach on the updrift side is an immediately apparent benefit, which makes the groyne initially look attractive. The major disadvantage is that while accretion is occurring on one side of the groyne, erosion is occurring on the downdrift side of the groyne. Since groynes cause erosion on the downdrift side, the net benefit is questionable unless the groyne is filled artificially when it is constructed. Groynes do not reduce the wave energy striking the shore. Groynes may also force littoral drift to move offshore around the groyne and thus beach material may be lost to the deep water offshore.

To mitigate the downdrift erosion, groynes must be filled artificially at the time of construction. Earth moving equipment (loader & truck) would have to be brought onto Abaiang to fill the groynes with a sufficient quantity of material. Material to fill the groynes would need to be hauled from the accreting area northwest of the village. A well constructed groyne which is artificially filled at the time of construction should not require maintenance,

Groynes can be built with manual labour from locally available material such as rocks or logs fixed perpendicular to the shoreline. A rock mound groyne must have the heaviest available stones placed on top to protect against wave action. Log groynes require some anchoring method to hold the logs in place.

Because of the downdrift erosion effects and the possibility that they will force material offshore, groynes are not recommended for Tebunginako.

Offshore Breakwater

An offshore breakwater is a breakwater structure which is located parallel to the shoreline a short distance offshore. An offshore breakwater causes the area behind the breakwater to be sheltered from wave action resulting in a build-up of beach material like a tombolo. An offshore breakwater will trap littoral drift and will also cause erosion on its downdrift side, like a groyne. Unlike a groyne, an offshore breakwater does reduce the wave energy striking the shore and will not force beach material offshore into deepwater.

An offshore breakwater should also be artificially filled with beach material at a time of construction to avoid downdrift erosion. If an offshore breakwater is properly constructed and artificially filled at the time of construction, it should require no further maintenance.

An offshore breakwater must be built from heavy rock which can withstand the design wave forces. Since an offshore breakwater requires armor stone weights of several hundred kilograms, and construction offshore in deeper water, it cannot be constructed by manual labor. Heavy equipment is required to move and place the large quantities of heavy rock and to fill behind the breakwater.

An offshore breakwater is a very expensive structure for which neither the rock nor the heavy equipment is available on Abaiang; therefore, it is not feasible.

Artificial Nourishment

Artificial nourishment refers to the dumping of sand on an eroding beach. This artificially supplied beach material will gradually move along the eroded area and will continue to move downdrift with the littoral process. The principal advantage of artificial nourishment is that it does not create an obstruction on the beach and it leaves the beach with a natural appearance. The principal disadvantage is that artificial nourishment is not maintenance free and it must be repeated from time to time as the material moves downdrift from the erosion area.

Artificial nourishment requires heavy machinery to transport and dump large amounts of beach material. The large amounts of material which must be transported cannot be handled by manual labor. There must be a readily available and suitable source of beach material. Material could only be borrowed and hauled from an area of accretion, such as the area northwest of the village and should be dumped southeast of Tebunginako. Littoral drift would eventually move the material toward the northwest and back to the accreting area. Attempts to claim or put buildings on the artificially nourished area would probably hasten its erosion and exacerbate the problem.

Since artificial nourishment needs heavy equipment and will need to be repeated periodically, it is not practical on Abaiang.

Seawalls

A seawall is a structure built along the land-sea boundary which only protects against erosion of land and does not protect or save the beach. Seawalls are constructed when valuable land or buildings have been built too close to the natural boundary of the sea, and are advantageous when land or buildings are more valuable than the cost of the seawall. A disadvantage of seawalls is that they often cause erosion in front of the wall. The amount of maintenance required for a seawall depends inversely on how well the wall has been built.

The most durable seawalls are rubble mound structures with armour stone rock sizes of several hundred kilograms and appropriate filter layers. A properly constructed rubble mound seawall can absorb wave energy and minimise wave reflection. A vertical concrete seawall, on the other hand, reflects wave energy and is susceptible to cracking and concrete failure.

Heavy equipment would be required to move and place the large quantities of heavy rock and armour stone. As with the offshore breakwater, this is an very expensive structure for which neither the rock nor the equipment is available on Abaiang; therefore, it is not feasible.

Some possible alternatives to rubble mound or vertical seawalls are stepped seawalls or sandbag seawalls, which may offer reasonable temporary protection against land erosion. Gabions (or rock-filled wire baskets) are another alternative form of seawall which are not long lasting and must be regarded as temporary structures only.

The only material which is abundantly available on Abaiang is sand and some rock from previous attempts at protection. A reasonable armouring could be made by filling sand bags with a cement and sand mix (grout). A seawall cross section using these grout filled sand bags is shown in Figure 11.

The grout bags are a compromise alternative for armour stone and are not as durable as the rubble mound seawall. Because the grout bags are much smaller than the normal armour stone sizes, certain precautions are necessary for the seawall to be viable. The grout mix must be rich enough to give good bonding between individual bags and the two layers of bags must be carefully placed to ensure 50% overlap in both horizontal directions to make a solid unit. The solid unit effect should compensate for the small size of the grout bags.

The toe depth of a seawall must be at least the design wave height (1.4 m) below the present natural beach level. Piling sand against the wall is not a substitute for this requirement. The present beach slope is 1/10 (Harper 1989) and the seawall is designed to be built with a side slope of 1/3. A steeper sloped wall would not be as durable. The crest elevation (top) of the seawall should be the height of the highest part of the land or the coastal berm. The crest width should be at least two bag lengths or 1.2 m wide. The under layer should be the best graded rock mix which can be found locally. There is rock from previous coastal protection structures which can be used for this under layer and the beach should not be disturbed to get additional rock. Ideally the under layer would be a graded mix of 12 cm minus stone and have a thickness of 0.3 m. The purpose of this layer is to prevent the sand from washing out between the grout bags.

This seawall must be built on land or as close to the land as possible so it does not extend into the water any more than necessary for the following reasons:

(i) The toe of the seawall must extend below the beach level and construction would be difficult under water.

(ii) If the structure is in water, it will likely cause some beach erosion in front of the seawall.

(iii) Any protrusion into the water will cause the build-up and erosion effects of a groyne.

The ends of the seawall must be rounded and the wall tied back into the land to avoid end scour. The closer the seawall is built into the land the better are its chances of survival.

This seawall should be built only to protect property which is valuable to the community and cannot be moved back from the seashore. If this wall is built as described above it should provide reliable protection for buildings at Tebunginako Village. The Same design can also be used at Borotiam, Koinawa and Kuria, because these villages have the same exposure to wind waves from the west. The design is not necessarily appropriate for other sites, which may have different wind and wave exposures.

Setbacks

Setback is the distance a building is built back from the natural boundary of the sea. By building permanent buildings at a safe setback distance, the beach and shoreline can be allowed to fluctuate and the buildings will not be lost or endangered. An advantage of setback of building is that the beach is left in its natural state and allowed to fluctuate naturally with no expensive structures being necessary to protect either the beach or the land. A disadvantage is that setbacks require government regulations and enforcement of these regulations. Some land owners perceive a disadvantage in being any distance from the shoreline with respect to loading and unloading of boats or fishing equipment.

The natural boundary is the high water "mark" as defined in the glossary. It is not the high water level because it also includes the effects of common and normal storms and wave runup. The natural boundary is the natural mark of the ocean on the land, made by the normal high tide plus the wave runup or the limit of the landwash. Since the natural boundary represents the combined effect of both high tides and wave runup, and is easily seen on the soil and vegetation, it is the best mark from which to measure setback distances or elevations of coastal structures (Holden 1987).

Considerable work has been done by Coastal Zone Management agencies to determine appropriate setback distances. The setback distance is usually chosen to save the structure from loss for a specific period of time. The time period is often based on one of the following: the estimated life of the structure, a human lifetime (70 yrs), the 100 yr erosion limit, the 200 yr storm event, etc. Setback distances have been recommended for various types of shorelines and exposures to wave energy (Holden 1987, Appendix B).

The setback distance should be appropriate for the cost and the intended life of the building or lifetime of the land owner. A setback of about 15 m from the natural boundary should be appropriate and adequate for the lagoon shoreline of Abaiang.

CONCLUSIONS

1. Littoral drift is toward the northwest on the lagoon shoreline near Tebunginako Village.

2. There is no significant coastal structure south of Tebunginako which would block littoral drift and cause the shoreline to erode.

3. The only wind waves which can erode the lagoon shoreline at Tebunginako are waves from the west which are usually associated with El Nino events.

4. The shallow water area (shoal) in front of Tebunginako Village provides partial shelter from westerly waves and is believed to have naturally caused the shoreline bulge at Tebunginako.

5. Since this shoal in front of Tebunginako provides natural shelter from westerly waves, it must never be dredged, mined or disturbed in any way.

6. The small seawalls and other coastal protection structures which have been constructed on the village shoreline are largely ineffective as protection structures, but are believed to have partially caused and exacerbated the erosion problems.

7. The very strong 1982-83 El Nino event is believed to have caused erosion and the natural processes did not have time to restore the beach before the 1987 El Nino occured.

8. If beach cross-section profiles are to be surveyed in Kiribati, they should be done by a qualified surveyor in the month of August.

RECOMMENDATIONS

1. The natural shoal in front of Tebunginako Village must never be mined, dredged or disturbed without a thorough study including a wave refraction study.

2. The shoreline should not be structurally protected, except in the case of interim protection for specific sites which are important and valuable to the community.

3. If a protective seawall is used for specific sites, it should utilise the grout filled sand bag seawall as shown and described in Figure 11.

4. No new buildings should be erected less than 15 m from the natural boundary of the sea.

5. The owners of existing buildings should be encouraged to relocate or setback at least 15 m from the natural boundary of the sea.

6. The setback area should be planted with as many trees as possible to help stabilise the land and mitigate erosion.

7. Good quality copies of the Abaiang air photos of 1968 and the 1940's should be obtained and the island should be flown again at the same scale as the 1968 photos.

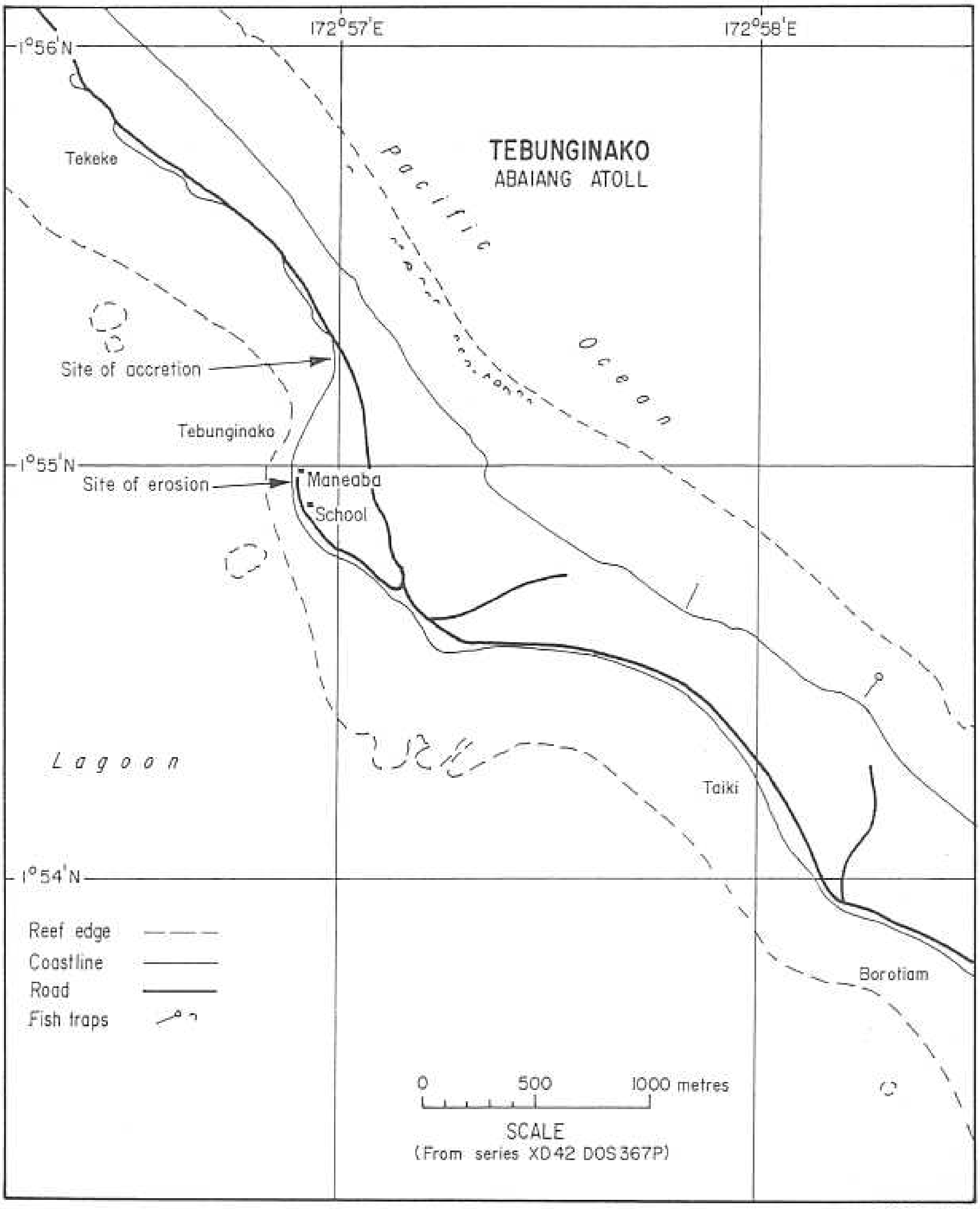


Figure 3. Tebunginako Village.

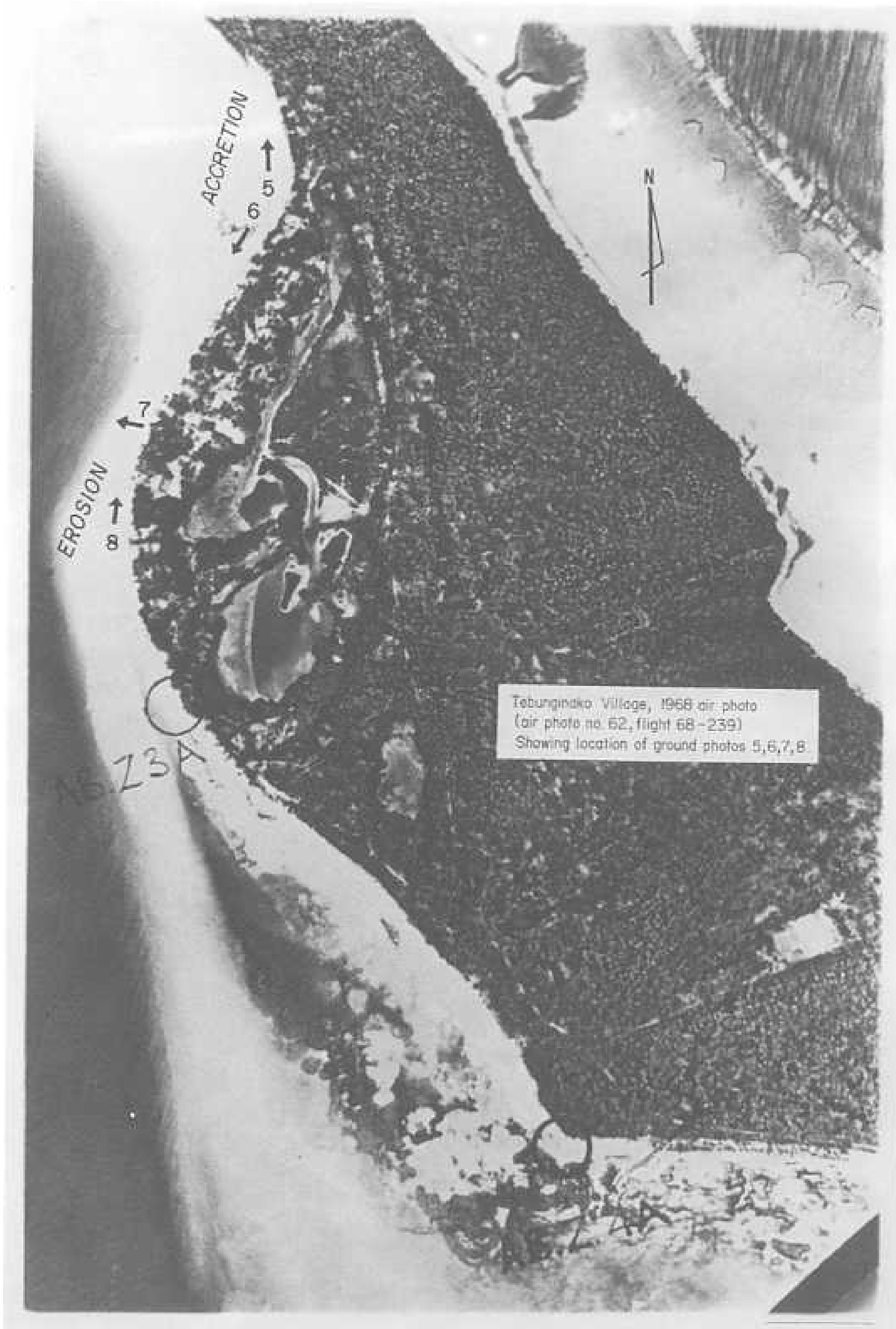


Figure 4. Tebunginako 1968 Air Photo #62.

Figure 5. Accreting area, north of Tebunginako, facing northwest.

Figure 6. Accreting area, north of Tebunginako, facing south.

Figure 7. Groyne in front of Tebunginako maneaba, facing west. Note accumulation of material on the left (south) side and depletion of material on the right (north) side.

Figure 8. Collapsed gabion seawall, south of Tebunginako maneaba. Shown as Figure 27 in Harper 1989.

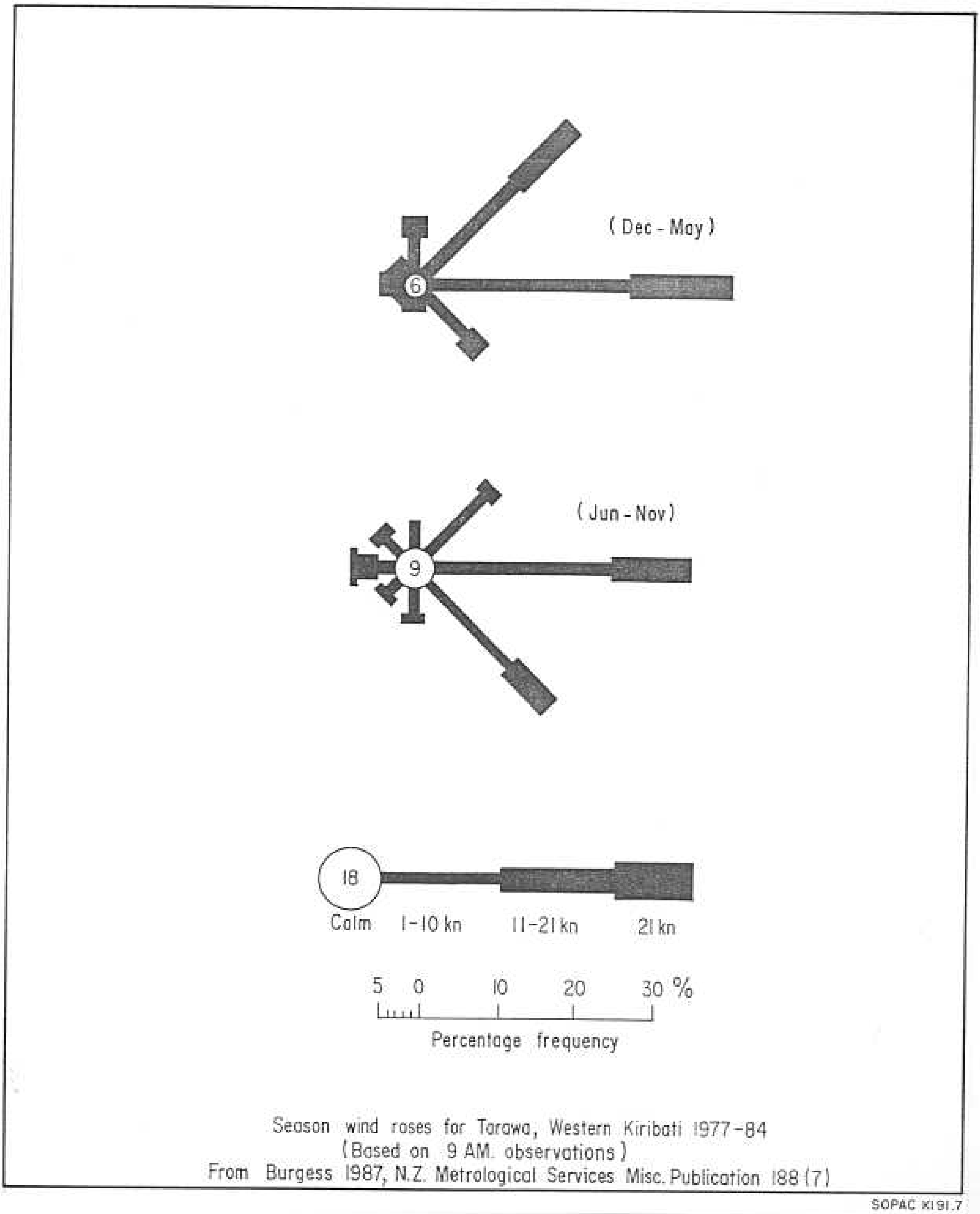
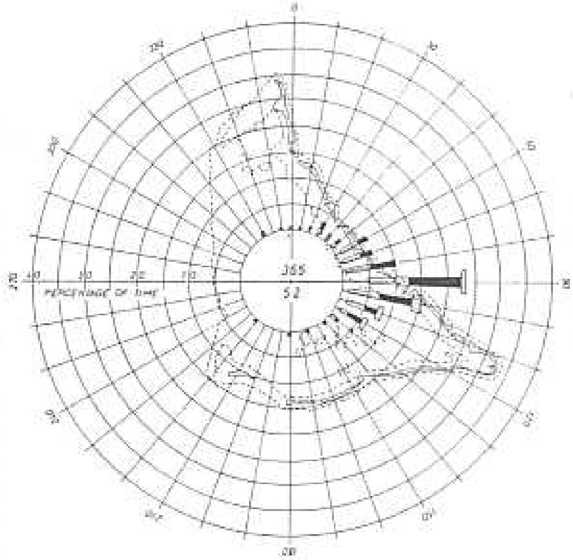
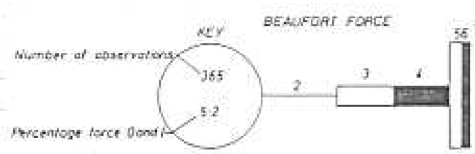
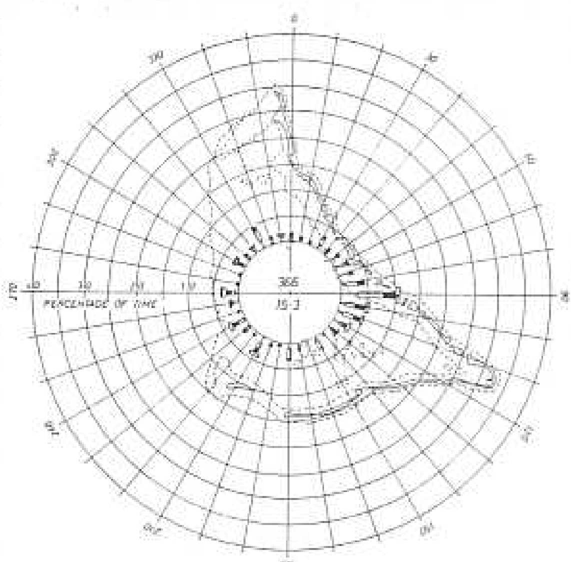


Figure 9. Wind Roses - Tarawa.



TARAWA 1970





TARAWA 1972

WIND ROSES

(From Wallingford 1976, Hydraulic Research Station Report No.727)

Figure 10. Wind Roses - Tarawa.

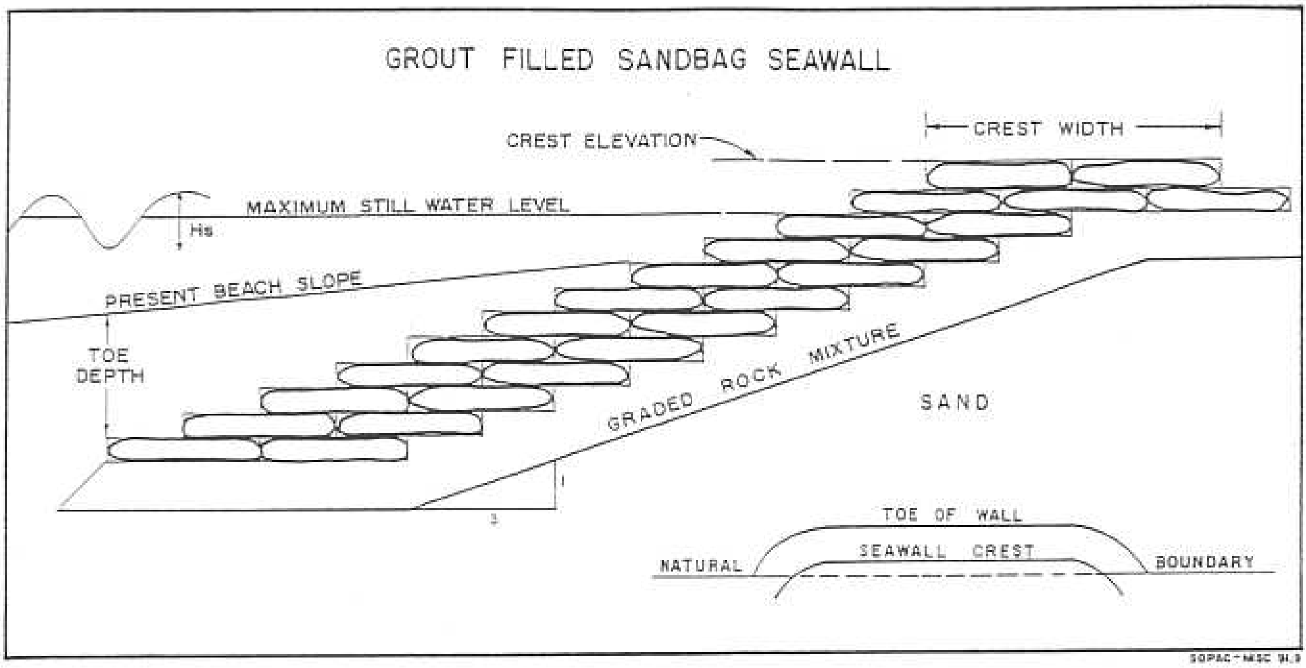


Figure 11. Seawall - Grout bag section.

Crest Elevation = highest level of the natural boundary

Crest Width = 2 bag lengths = 1.2 m

Hs = significant wave height = 1.4 m

Present Beach Slope = 1/10 (Harper 1989)

Toe Depth = at least 1.4 m below the present natural beach level, in anticipation of structure induced scour.

Weight of individual grout filled sand bags in the primary cover layer (10cm x 30cm x 60cm) = 45 kg. The primary cover layer must be at least two bags thick and all bags must be overlapped 50% in both horizontal directions. The underlying graded rock mixture (filter layer) should be as close to 12cm minus as possible.

Seawall ends should be rounded and built back into the land until the toe of the wall is in line with the natural boundary. This is to prevent the anticipated end scour.

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APPENDIX 1

GLOSSARY

(From Shore Protection Manual (SPM 1975)
(unless otherwise noted)

ACCRETION - May be either NATURAL or ARTIFICIAL Natural accretion is the buildup of land, solely by the action of the forces of nature, on a BEACH, by deposition of waterborne material. Artificial accretion is similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or a beach fill deposited by mechanical means. Also AGGRADATION.

ARTIFICIAL NOURISHMENT - The process of replenishing a beach with material (usually sand) obtained from another location.

BATHYMETRY - The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.

BEACH - The zone of unconsolidated material that extents landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach - unless otherwise specified - is the mean low water line. A beach includes FORESHORE AND BACKSHORE.

BEACH BERM - A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have several.

BEACHROCK - (beach-rock) A friable to well-cemented sedimentary rock, formed in the intertidal zone in a tropical or subtropical region, consisting of sand or gravel (detrital and/or skeletal) cemented with calsium cabonate; e.g. a thin, clearly stratified, seawarddipping calcarenite found on a sandy coral beach. Also spelled: beach rock. Syn: beach sandstone Glossary of Geology 1987.

BEDROCK - A general term for the rock, ususally solid, that underlies soil or other unconsolidated, superficial material. A British syn. of the adjectival form is solid, as in solid geology. Glossary of Geology 1987.

BENCH MARK - A permanently fixed point of known elevation. A primary bench mark is one close to a tide station to which the tide staff and tidal datum originally are referenced.

BLUFF - A high steep bank or cliff (of erodible material).

BREAKWATER - A structure protecting a shore area, harbour, anchorage, or basin from waves.

CELERITY - Wave speed.

CHART DATUM - The plane or level to which soundings or elevations or tide heights are referenced (usually LOW WATER DATUM). The surface is called a tidal datum when referred to a certain phase of tide. To provide a safety factor for navigation, some level lower than MEAN SEA LEVEL is generally selected for hydrographic charts such as MEAN LOW WATER or MEAN LOWER LOW WATER. **Chart datum is, by international agreement, a plane below which the tide will seldom fall,** i.e. LOWEST NORMAL TIDES.

COAST - A strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.

CORIOLIS FORCE - The effect of the earths rotation that deflects a moving particle to the right in the northern hemisphere and to the left in the southern hemisphere. Wiegel 1964.

CUSP - One of a series of low mounds of beach material separated by crescent-shaped troughs spaced at, more or less, regular intervals along the beach face. Also BEACH CUSP.

DEEP WATER - Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water.

DIFFRACTION (of water waves) - The phenomenon by which energy is transmitted laterally along a wave crest. When a part of a train of waves is interrupted by a barrier, such as a breakwater. the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

DIURNAL TIDE - A tide with one high water and one low water in a tidal day.

DOWNDRIFT - The direction of predominant movement of littoral materials.

EROSION - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

FETCH - The area in which SEAS are generated by a wind having a rather constant direction and speed. Sometimes used synonymously with FETCH LENGTH. Also GENERATING AREA.

FORESHORE - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall. See BEACH FACE.

GROYNE - A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

HURRICANE - An intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 75 mph (65 knots) for several minutes or longer at some points. TROPICAL STORM is the term applied if maximum winds are less than 75 mph.

LITTORAL DRIFT - The sedimentary material moved in the littoral zone under the influence of waves and currents.

NATURAL BOUNDARY - (Adapted from Land Act, Section 1 B.C. Canada). means the visible high water mark of any ocean lake, river, stream or other body of water where the presence and action of the water is so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the ocean lake, river, stream, or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself. In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas, and includes the effects of normal wave runup above the high tide level.

OFFSHORE - (1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf. (2) A direction seaward from the shore.

OVERTOPPING - Passing of water over the top of a structure as a result of wave runup or surge action.

PROBABLE MAXIMUM LEVEL - A hypothetical water level (exclusive of wave runup from normal wind-generated waves) that might result from the most severe combination of hydrometeorological, geoseismic and other geophysical factors that is considered reasonably possible in the region involved, with each of these factors considered as affecting the locality in a maximum manner. This level represents the physical response of a body of water to a maximum applied phenomena such as hurricanes, moving squall lines, other cyclonic meteorological events, tsunamis and astronomical tide combined with maximum probable ambient hydrological conditions such as wave set-up, rainfall, runoff, and river flow. It is a water level with virtually no risk of being exceeded.

PROFILE, BEACH - The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

RECESSION (of a beach) - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time. Also RETROGRESSION.

REFERENCE STATION - A place for which tidal constants have previously been determined and which is used as a standard for the comparison of simultaneous observations at a second station; also a station for which independent daily predictions are given in the tide or current tables from which corresponding predictions are obtained for other stations by means of differences or factors.

REFRACTION (OF WATER WAVES) - (1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours. (2) The bending of wave crests by currents.

RUNUP - The rush of water up a structure or beach on the breaking of a wave. Also UPRUSH. The amount of runup is the vertical height above stillwater level that the rush of water reaches.

SEAWALL - A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. Also BULKHEAD.

SEISMIC SEA WAVE (TSUNAMI) - A long-period wave caused by an underwater seismic disturbance or volcanic eruption. Commonly misnamed “tidal wave”.

SETBACK - (BC, CANADA) means a withdrawal of a building or landfill from the natural boundary or other reference line to maintain a floodway and to allow for potential land erosion.

SETUP, WAVE - Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

SHORE - The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

SIGNIFICANT WAVE HEIGHT - The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one third of a selected number of waves, this number being determined by dividing the time of record by the significant period.

SPIT - A small point of land or a narrow shoal projecting into a body of water from the shore.

SPRING TIDE - A tide that occurs at or near the time of new or full moon (syzygy), and which rises highest and falls lowest from the mean sea level.

STORM SURGE- A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. See WIND SETUP.

SWELL - Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular and longer period, and has flatter crests than waves within their fetch (SEAS).

SYZYGY - The two points in the moon’s orbit when the moon is in conjunction or opposition to the sun relative to the earth; time of new or full moon in the cycle of phases.

TIDE - The periodic rising and falling of the water that results from gravitational attraction of the moon and sun and other astronomical bodies acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the vertical movement.

TIDAL DAY - The time of the rotation of the earth with respect to the moon, or the interval between two successive upper transits of the moon over the meridian of a place, approximately 24.84 solar hours (24 hours and 50 minutes) or 1.035 times the mean solar day. Also called lunar day.

TIDAL PERIOD - The interval of time between two consecutive like phases of the tide.

TIDAL RANGE - The difference in height between consecutive high and low (or higher high and lower low) waters.

TIDE STATION - A place at which tide observations are being taken. It is called a primary tide station when continuous observations are to be taken over a number of years to obtain basic tidal data for the locality. A secondary tide station is one operated over a short period of time to obtain data for a specific purpose.

TOMBOLO - A bar or spit that connects or "ties" an island to the mainland or to another island.

TSUNAMI - A long period wave caused by an underwater disturbance such as a volcanic eruption or earthquake. Commonly miscalled "tidal wave".

UPDRIFT - The direction opposite that of the predominant movement of littoral materials.

WIND WAVES - (1) Waves being formed and built up by the wind. (2) Loosely, any wave generated by wind. (as opposed to swell waves or seismic sea waves)

WIND SETUP - (1) The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water. (2) The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. (3) Synonymous with WIND TIDE and STORM SURGE. STORM SURGE is usually reserved for use on the ocean and large bodies of water. WIND SETUP is usually reserved for use on reservoirs and smaller bodies of water.

APPENDIX 2

COASTAL ENVIRONMENT AND COASTAL CONSTRUCTION

(Summary of Recommendations from the discussion paper by B.J. Holden)

Province of B.C.
Ministry of Environment & Parks
Water Management Branch

COASTAL ENVIRONMENT

AND

COASTAL CONSTRUCTION

A DISCUSSION PAPER

Elevations and Setbacks
for
Flood and Erosion Prone Areas

by
B.J. Holden, P.Eng.
Coastal Engineer
Special Projects Section

Victoria, B.C.
1987

6. Summary of Recommendations

1) It is recommended that Coastal Flood Construction Elevations be based on the Natural Boundary at the particular site, with an additional allowance for extreme storm surges and waves. The present formula (A): (Coastal FCL = Natural Boundary + 1.5 m) should be retained; however, the allowance of 1.5 m should be checked and verified or refined as described in Section 4.3. In addition, the definition of Natural Boundary must be qualified to ensure that it is interpreted as truly representing the natural limit of permanent terrestrial vegetation.

   At sites exposed to the Pacific and at all coastal sites where the intended use is critical, the possibility of Tsunami damage must be considered.

2) It is recommended for all future construction that the Coastal Construction Setback be based on the principle of protecting the structure from flood and erosion for a period of 100 years from the date of construction. On shallow lots or special sites an appeal for relaxation can always be considered. Based on the principle of 100 years safety, the following setbacks are recommended:

   a) On bedrock shores: the setback shall be at least the designated Municipal setback (7.5 m) from the Natural Boundary.

   b) On sheltered beaches: (less than 2 km effective fetch) the setback for coastal construction shall be a minimum of 15 m from the Natural Boundary.

c) On exposed beaches: (greater than 2 km effective fetch) the setback for coastal construction shall be:

(i) a minimum of 30 m from the Natural Boundary, or

(ii) 15 m inland from the 100-year erosion limit as estimated from long term historical evidence by a coastal geotechnical engineer.

d) On coastal bluffs: the setback for coastal construction shall be:

(i) the greater of; 30 m from the crest of the bluff, or 3 times the vertical height of the bluff measured from the Natural Boundary, or

(ii) 30 m inland from the 100-year erosion limit, as estimated from long term historical evidence by a coastal geotechnical engineer.

In addition, it is recommended that provision be made to safeguard the natural vegetation, forest cover and the groundwater drainage on bluffs.

3. The present Floodplain Development Control Policy is based primarily on river floodplains. Although there are coastal plains, there are also the other coastal features: spits, beaches, berms and coastal marshes which are subject to flooding and possible erosion; and coastal bluffs which continually erode but are not subject to ocean flooding. The variety of coastal features and erosion problems indicate that a policy based on floodplain only is inadequate and restrictive.

Summary of Recommendations

To include erosion of coastal features, it is recommended that the existing policy be broadened to Flood and Erosion Prone Lands or Hazard Lands as defined by Ontario.

An alternative recommendation to broadening the existing policy would be to develop a new Coastal Zone Development Policy. Such a new Policy should accommodate all shoreline lands: oceans, lakes and rivers. This policy should also ensure management of coastal features such as plains, berms, swales, estuaries, lagoons, marshes, bluff plateaus, slopes, and any other shoreline feature which is either flood or erosion prone.