Report

Shoreline Protection Guidelines

Prepared for Government of Kiribati (Client)

By Beca International Consultants Ltd (Beca)

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Revision History

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A	Lisa Hardwick	Draft for client review and comment	28 January 2010
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C	Lisa Hardwick	Revised draft guidelines for client comment and review	7 May 2010
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Document Acceptance

Action	Name	Signed	Date
Prepared by	Lisa Hardwick		18 June '10
Reviewed by	Stephen Priestley		18.6.10
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on behalf of	Beca International Consultants Ltd		

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Introduction

Kiribati is one of the most vulnerable countries in the world to the effects of climate change. To address the rising risks the Government of Kiribati is undertaking an adaptation programme, supported by the World Bank, the Global Environmental Facility, AusAID and NZAID, UNDP, and a parallel project by the EU.

The Kiribati Adaptation Programme is comprised of a number of components, one of which is aimed at reducing the vulnerability of the coastline through encouraging the implementation of proactive management techniques and a range of risk management solutions. As part of this component design guidelines are to be produced and applied to a sample of public assets that are at risk. This document constitutes the design guidelines for shoreline protection works in Kiribati.

Reason for a guideline

Historically shoreline protection works in Kiribati have relied solely upon one of two hard structural solutions. The two standard designs have been used are vertical coral rock walls and sandbag revetments. Both of these are known as "seawalls" in Kiribati. Other walls are built by landowners in wide variety of informal methods. Many examples of failed walls can be observed. The existing guideline currently used in Kiribati is limited to the Development Consent application process for seawalls and considers only these standard solutions.

A wider range of options for managing the shoreline is required to provide Kiribati with better tools to adapt to climate change. Improvements to the existing "one size fits all" hard structural solutions are also required.

This guideline is intended to update the existing two page guideline and provide some alternatives to the current default solution. The scope of the guideline is set out on the Terms of Reference for this project.

Terms of Reference

The relevant sections of the terms of reference for this commission are as follows:

> *Work closely with staff from MPWU, MELAD and other relevant GoK agencies as required to finalise the draft seawall design guidelines (2007). There are currently two model cross sections for seawalls – a sloping concrete bag design and a vertical coral rubble design. These model designs will require review and integration into the seawall guidelines. Operational officers in the consent granting agencies, responsible for providing advice to seawall construction applicants, use the seawall guidelines as a basis for their recommendations.*
>
> *The consultant is required to develop or revise existing guidelines which will typically have the following features:*
>
> 1. *Set out the general principles of approach, thinking and steps required using simple language covering all project phases from concept development to construction.*
> 2. *Use diagram aids, flow-charts, stand-alone [laminated] cheat-sheets and wall posters.*
> 3. *Incorporate standard drawings and simple specifications for certain types of construction.*

Provide training to GoK staff on the application of the shoreline protection guidelines, including training on where seawall construction is not appropriate (as emerges in the development of Adaptation Strategies for specific sites) and the use and maintenance of the condition assessment and complementary profile. Where appropriate these Workshops will build on and complement the inter-ministerial working groups set up by Dr. Robert Kay.

A note about flooding

Coastal hazards in Kiribati comprise coastal erosion and flooding.

Flooding of land occurs when the sea levels rise above the land levels, often made worse by waves overtopping the coastline. While structures can reduce wave overtopping they must be very high to prevent it altogether. Also because the coastal structures are designed over a certain length, they cannot prevent flooding from high water levels – sea water will simply go around the wall.

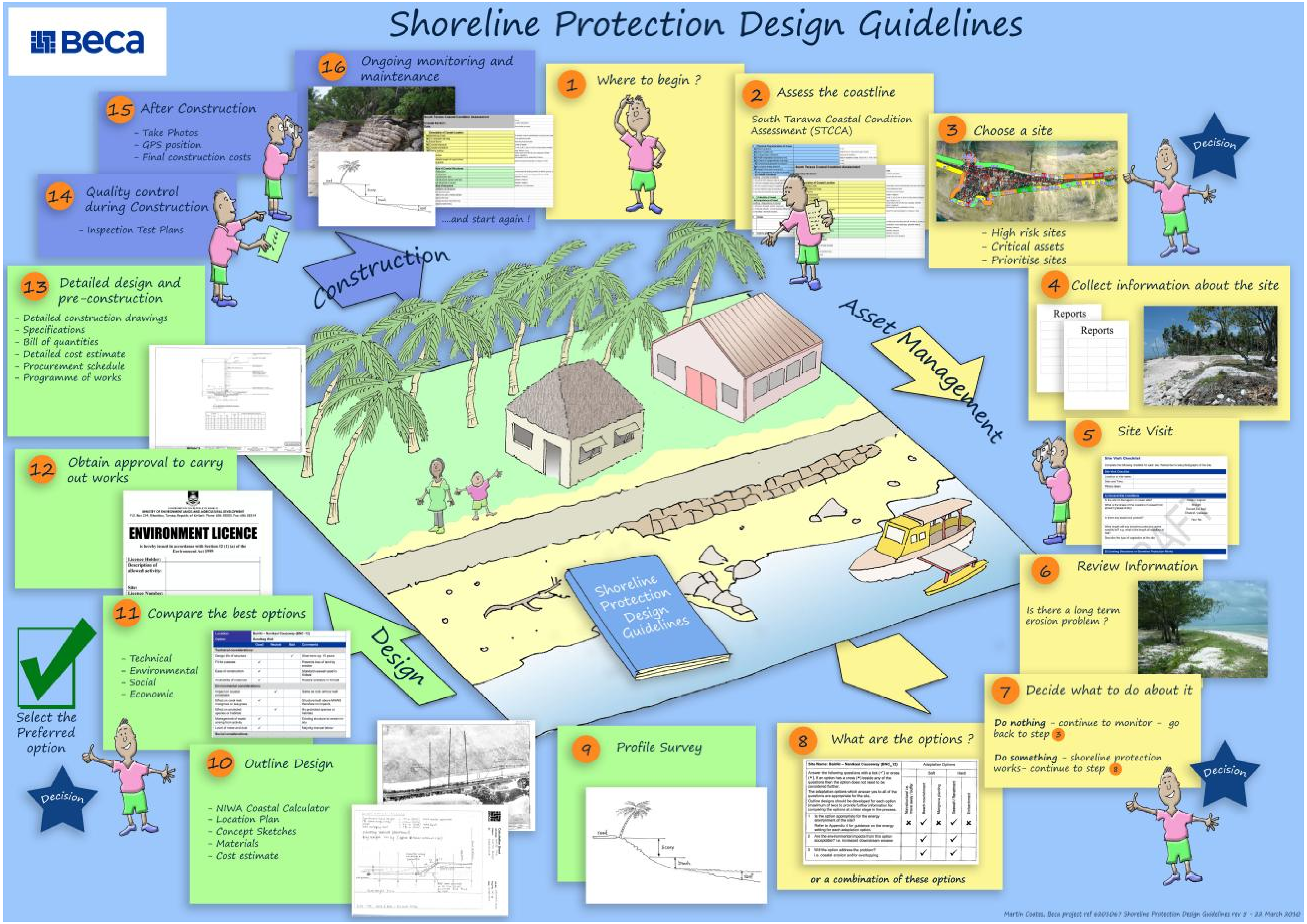
It is important to understand that use of this guideline can address erosion and reduce overtopping, but it cannot prevent flooding from high water levels.

Who is this guideline for?

The guideline has been prepared for use by people familiar with design and construction processes in Kiribati. It has been assumed that the user will be technically proficient and able to apply objective reasoning to the process of design and use of this document.

List of Acronyms and Abbreviations

AusAID	Australia Agency for International Development
CEU	Civil Engineering Unit – MPWU
ECD	Environment and Conservation Department
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EU	European Community
FMC	Foreshore Management Committee
GoK	Government of Kiribati
GIS	Global Positioning System
KAP	Kiribati Adaptation Programme
MELAD	Ministry of Environment, Lands and Agriculture Development
MFMRD	Ministry of Fisheries and Marine Resources Development
MISA	Ministry of Internal and Social Affairs
MPWU	Ministry of Public Works and Utilities
PPE	Personal Protective Equipment
NASC	National Adaptation Steering Committee
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NZAID	New Zealand Agency for International Development
PMU	Project Management Unit
SOPAC	South Pacific Applied Geoscience Commission
STCCA	South Tarawa Coastal Condition Assessment
ToR	Terms of Reference
UNDP	United Nation Development Programme
UoH	University of Hawaii Datum


Beca
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....and start again !
Construction
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Design
Shoreline Protection Design Guidelines
Martin Coates, Beca project ref 6201067 Shoreline Protection Design Guidelines rev 3 - 22 March 2010

1 Where to begin?

This guideline provides an overview of the process to be carried out in order to protect the coastline and public assets. The protection of the coastline is an ongoing process. The steps in this guideline should be followed in a systematic process. Firstly it is important to define what the coastal hazards are and secondly understand the processes which create them.

1.1 What are coastal hazards?

Coastal erosion is the wearing away of land by the action of natural forces such as wind and waves. Short term coastal erosion occurs as a result of the dynamic beach system. A beach will fluctuate between seasonal erosion and accretion trends, such as erosion after a storm event and build up of sediment during normal weather conditions. Long term erosion is shown by trends over many years. If the erosion is short term then it is likely no action is needed, so it is important to try to determine whether erosion is short or long term.

Overtopping is water which passes over the top of a structure as a result of wave action. There are two main types of overtopping: (i) overtopping can occur as a result of waves running up the face of a structure or (ii) when waves break on the seaward face of a structure and produce significant volumes of splash which may then be carried over the structure.

Coastal flooding is caused either by overtopping or high tide levels where land is low lying.

1.2 What are the Coastal Processes in South Tarawa?

Coastal processes is the name given to the systems that move water and sediment around the coastlines. Coastal processes include winds, wave action, currents and the behaviour of the coastline in response to these actions.

A discussion of the coastal processes in South Tarawa is contained in Appendix 1.

2 Assess the coastline

The first step is to assess the current condition of the coastline. The South Tarawa Coastal Condition Assessment (STCCA) provides a simple and consistent methodology for assessing the condition of the coastline in South Tarawa. It is a point in time assessment which can be used as the initial baseline and can be regularly updated to document changes in coastal condition through time.

The methodology described in the STCCA involves dividing the coastline up into sections depending on the location of the public asset which is being protected. A site visit is carried out, photos taken and STCCA form completed for each site.

Based on the information collected during the site visit an assessment is made of the condition of any existing structures or the physical condition of the coastline and a condition grading is assigned to the site.

The results of the STCCA are displayed in a GIS database which can be viewed using MapInfo ProViewer software. A simple colour-coded condition grading, where 1 is low risk (green) and 5 is high risk (red), has been used to rate the condition of the structure or coastline. Copies of the GIS database and STCCA report are held by the KAPII PMU, MPWU, MELAD and MFMRD. Over time this tool can be improved by adding more updated information.

3 Choose a site

The STCCA can be used to identify the public assets which are at highest risk of damage due to coastal erosion. As it is not always practical or economic to carry out works at all high risk sites, the STCCA process provides guidance on the areas where shoreline protection works should be focussed. Generally high risk equals high priority.

A list of high risk sites can be extracted from the STCCA and prioritized to assist with the decision making process. The sites are prioritized based on the following criteria:

- Condition of the structure or coastline (as determined by the width between vegetation and asset), and
- Importance of the asset.

Decision point – Select one site from the list of high risk sites which is to be considered for potential shoreline protection works and continue through the next steps in this process.

4 Collect information

It is important to collect as much information as possible about a site to understand what has been happening at a site over time. It is usually more cost effective to undertake a detailed desktop study first rather than incurring costs for more expensive fieldwork.

Start by gathering existing information about the site from a range of sources such as:

- Government records (MPWU, MELAD. MFMRD and Department of Land records)
- Monitoring records
- Survey data (e.g. beach profiles, field measurements, land survey boundaries)
- Aerial photographs (older photos will need to be rectified[1])
- Site photos (e.g. STCCA records[2])
- Anecdotal evidence (e.g. discussions with government ministries, local people)
- Maps
- As-built drawings and construction information for previously built structures
- Location of nearest reliable survey marks.

[1] Only rectified aerial photos should be used to measure erosion. Rectification removes the distortion that occurs in camera lenses when taking the pictures.

[2] Note that the accuracy of the aerial photos and GPS used in the STCCA is approximately 5m, so if coastal erosion appears less than this, it is not possible to prove there is long term erosion occurring, using this method alone.

5 Site visit walkover

The site will have been visited during the STCCA, however a site visit should be carried out to investigate and understand the context, surrounding environment and gather further information for the site. A site visit checklist is included as Appendix 2 which can be completed in the field for each site visited. Things to consider when undertaking a site visit include:

5.1 General Site Conditions

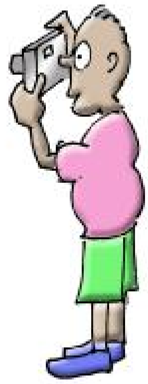
- Is the site located on the lagoon or ocean side?
- Where is the high water mark?
- Take photographs
- How long will any structure need to be?

5.2 Existing Structures

- Are there any existing structures or shoreline protection works at the site?
- If yes, what condition are they in? What materials are they made from? Are there any signs of damage or failure?
- Is the land behind the structure showing any signs of regular overtopping?

5.3 Coastal Environment

- What is the coastline type e.g. hard rock/coral, sandy beach?
- What are the coastal processes like e.g. large waves, strong currents?
- Is sediment built up on one side of the structure or coastline, indicating the direction of longshore sediment transport?
- Is there visual evidence of erosion e.g. erosion scarp?
- Is the beach steep or flat?
- Large or small sand grain size?
- Is there any beach rock? If yes, where is it?
- What is the type and extent of vegetation?
- What is the local drainage pattern from natural runoff or stormwater?



5.4 Asset

- Is the asset at risk if flooding/erosion continues?
- What is the condition of the asset?
- How important is the asset?
- How close is the asset to the potential risk?
- Is the asset new or near the end of its useful life? (e.g. an old building)

5.5 Land Use

- What is the main use for the site?
- Have there been any recent changes in the use? Consider the land use beyond the top of the beach e.g. reclamation, commercial.
- Are there any important areas at the site with environmental, ecological, natural character or cultural significance?

5.6 Anecdotal Evidence

- Are there any local people who you can interview to get a better knowledge of any problems occurring at the site?
- How long has there been a problem?
- What do they think is causing the problem?
- Have there been any changes which may have contributed to the problem e.g. sand mining, discharges of stormwater?

6 Review information

Information collected in steps four and five can be used to assess what is occurring at the site. Compare information between the present and the past; look at what changes have occurred and what the impacts are.

6.1 Is there a coastal erosion problem?

It is important to determine whether the coastal erosion is occurring over the short or long term as erosion over the short term is not likely to require any action whereas long term erosion will require some action.

Compare aerial photos, survey data and site visit information collected to determine the changes in the shoreline over time. It is suggested that historical data that is at least 10 years old should be used to determine long term trends in coastal erosion. Figure 1 provides an example of the changes in beach profile which can occur over the short (seasonal fluctuations) and long term (erosion or accretion). You may be only able to plot two or three points on this graph, due to lack of data or measurement.

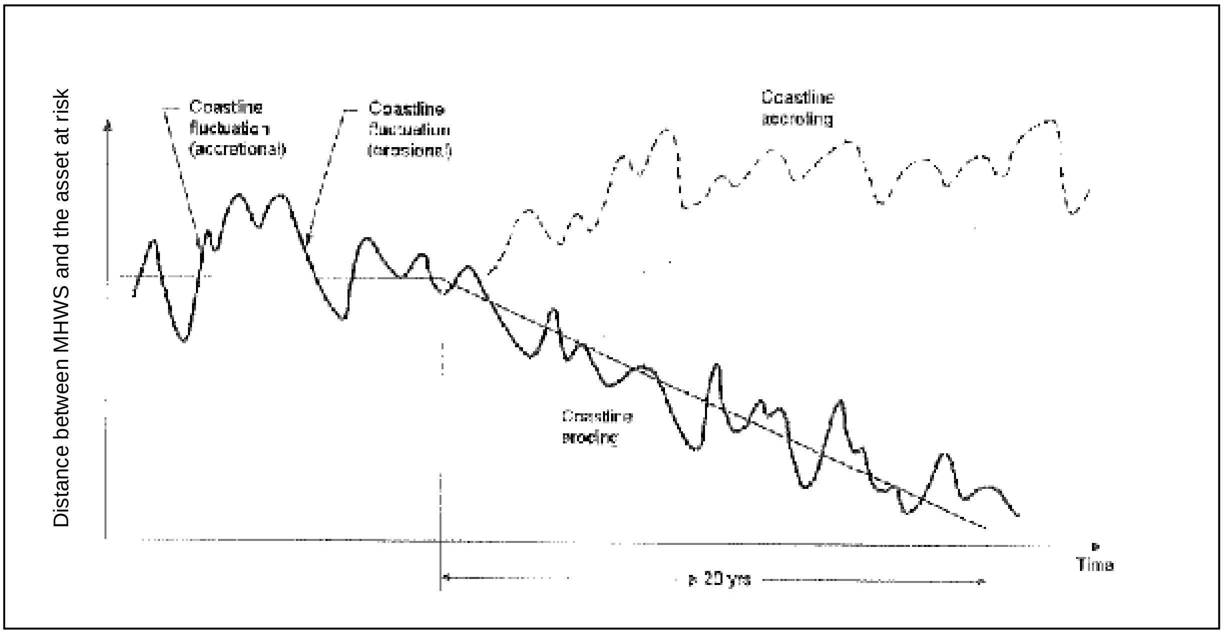


Figure 1 – Short and long term erosion trends

Look at the information collected for the site and assess:

- Where was the coastline in the past? (aerial photos, historical monitoring or survey records)
- Where is the coastline now? (site visit data, recent site photos)
- How has the position of the coastline changed over time?

If the position of the shoreline has remained relatively similar over the last 10 years (minor seasonal changes are expected, ± 5m horizontal movement) then it is likely that any coastal erosion is relatively short term and action may not be required.

However, if the shoreline has retreated landwards more than 5m, compared with information from 10 years ago, then it is likely that coastal erosion is occurring in the long term and this may need to be managed if an asset is threatened.

6.2 Determine the rate of erosion

The rate of erosion can be estimated by comparing historical data with recent information, as outlined in the previous section, and quantifying the quantity of change that has occurred over the time period between the two sets of information.

One way of doing this is to measure the distance between the past shoreline and the present shoreline by overlaying aerial photos or survey data and dividing this by the number of years between the two data sets. This will give an estimate of the rate of erosion per year.

Alternatively if regular monitoring and profile surveys of the beach have been carried out at the same location these can be compared. A common reference point in the beach profile surveys, such as the centreline of the road, is required to allow meaningful comparisons to be made.

6.3 Causes of Erosion

The cause of erosion needs to be determined in order to identify the most appropriate management response. Likely causes of erosion include:

- Reclamations which restrict the supply of sediment to and along the coast.
- Clearing of vegetation which previously helped to bind sediment.
- Construction of seawalls, revetments, groynes which change the coastal processes.
- Dredging of material offshore which can alter sediment transport, wave and current conditions.
- Human activities such as sand mining which remove sediment from the system.

6.4 Assess the impacts

Coastal erosion can affect existing structures or shoreline protection works, the assets adjacent to the coastline, the environment, the economy and society in different ways.

6.4.1 Existing structures

- How is coastal erosion affecting the existing structures?
- Are there visible signs of deterioration such as flanking at the ends of structures, undermining at the toe, loss of backfill material etc.

6.4.2 Asset

- How is the asset currently being affected by coastal erosion? Is the problem high water levels or overtopping by waves?
- What is the likely impact if the asset is damaged?
- When was the asset built? When is it due to be replaced?
- The remaining life of asset can be determined by calculating the number of years until the asset will be replaced.
- Compare the remaining life of the asset with the rate of erosion. Is coastal erosion likely to undermine the asset before the asset is replaced?
- Could the asset be rebuilt in another location? (eg a building = yes, a causeway = no)

6.4.3 Environment

- Are there areas of environmental importance or significance which will be adversely affected by coastal erosion?
- Are there any environmental benefits as a result of coastal erosion?
- How can the potential impacts be avoided or mitigated?

6.4.4 Economic

- What are the likely impacts of coastal erosion on the economy? For example if the airport runway was affected by coastal erosion there are likely to be major impacts on the economy as access into and out of Tarawa would be restricted. Alternatively if a local school was affected the impacts on the economy are likely to be smaller as the impacts are limited to a small proportion of the island.

6.4.5 Social

- What is the current land use and how is this likely to change in the future?
- What impact will coastal erosion have on the way the land is currently used?
- Can the land use be changed to avoid or mitigate the impacts?

7 Decide what to do

Reviewing information collected for a site will enable an informed decision to be made about whether there is a problem and if so, whether something should be done to address the problem.

If the asset is likely to be replaced in the near future then it may not be a high priority to protect the asset. Think about the following questions when deciding whether to carry out shoreline protection works for a site:

- Are shoreline protection works required to be carried out now or could they be carried out in the future?
- What is the future use of the land and how would this change the level of acceptable risk for the site?

Decision point – Decide whether or not something should be done now to protect the asset.

Do Minimum: This means leaving the site in it's current condition and not undertaking any shoreline protection works at this stage. The site should continue to be monitored and assessed as the situation may change in the future. Return to step 1 and select another site. Periodic repairs and maintenance are likely to be required.

Do Something: Deciding to do something requires carrying out shoreline protection works. Continue through the process and complete the following steps.

Figure 2 summarises the design process that is further explained in steps 8 – 13 of this guideline.

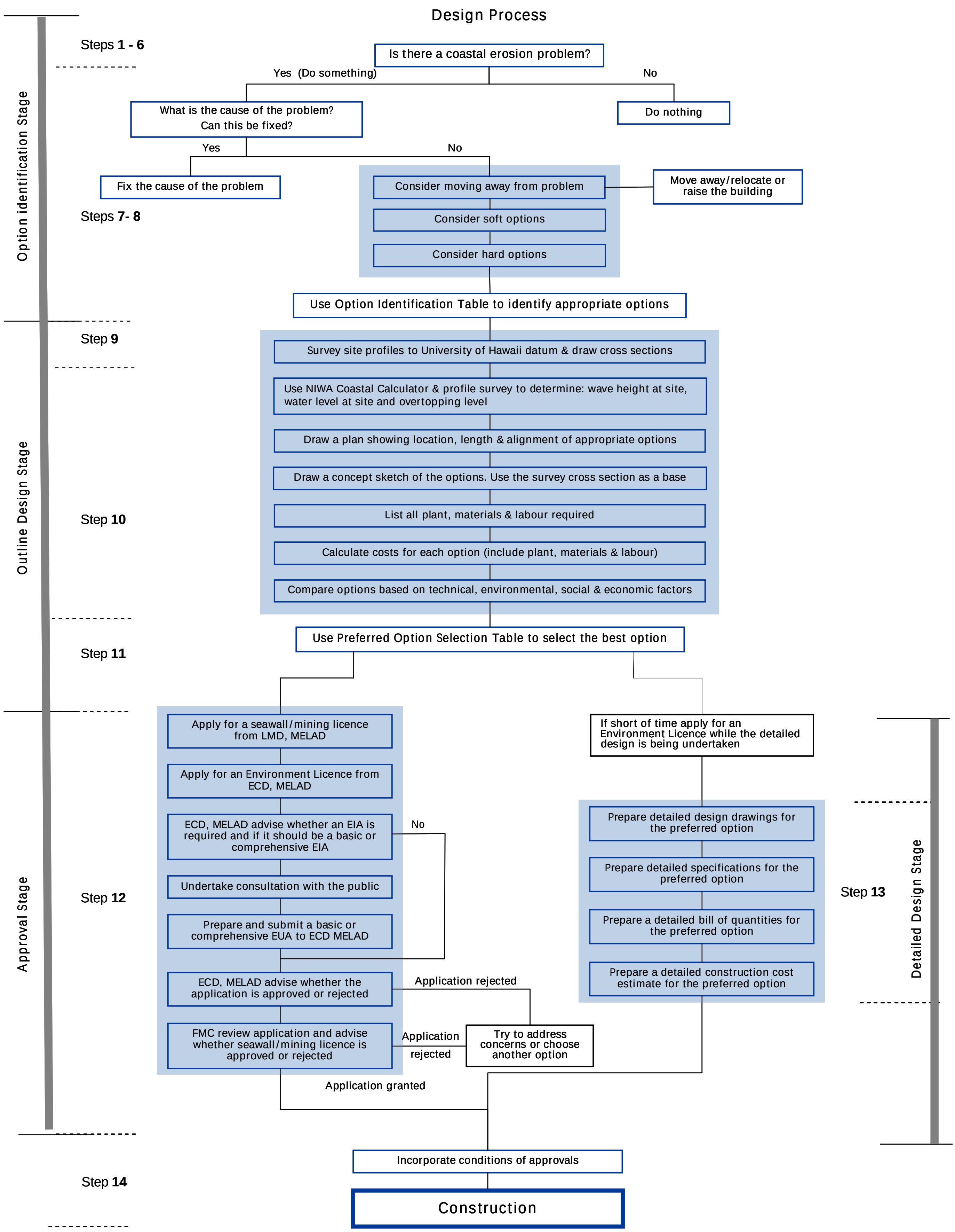


Figure 2 – Design Process Flowchart

8 What are the options?

Different options available for protecting the shoreline can be grouped into three main categories: non-structural, soft-structural and hard-structural.

Non-structural options aim to remove the asset from the coastal erosion hazard. They are more likely to be implemented on a strategic level and relate to the management of land uses above MHWS.

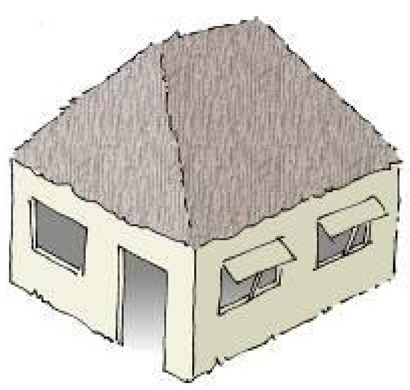
Structural options aim to protect coastal development and activities by managing the physical processes causing coastal erosion. These options involve physical works and require a relatively high level of investigation and design to be successfully implemented.

8.1 Non-Structural Options

A wide range of non-structural options for adapting to climate change in Kiribati have been identified by Coastal Zone Management Pty through the Integrated Coastal Hazard Risk Diagnosis and Planning project. In addition to the options provided by Coastal Zone Management Pty the following are suggested as specific options relating to the protection of the shoreline (refer to Appendix 3 for further details):

- Relocation of people or the asset away from high risk areas to create buffers or set-back zones between the shoreline and the asset at risk
- Elevated floor levels

8.1.1 Relocation and Creation of Buffer or Set-back Zones



Relocation involves the planned retreat away from a coastal erosion hazard. Relocation can sometimes involve moving people and assets back from the shoreline to create a buffer or moving to a different location that is not at risk from erosion.

Buffers or set-back zones are a pro-active management technique that involves determining the rate of erosion and limiting the use of the land in the set back area.

8.1.2 Elevated Floor Levels

This involves raising the floor level of buildings to create a floodable space below the building while reducing the flood damage to the building itself. Traditional thatched huts in Kiribati, where the floor is built on posts approximately 1m above ground level, are examples of buildings with elevated floor levels.

8.2 Soft Structural Options

Soft (and hard) structural options aim to protect the asset from the coastal erosion hazard.

The purpose of soft structural options is to re-establish or maintain the natural form of the coastline. These options tend to use naturally occurring materials such as sand and vegetation, and are more in keeping with natural characteristics of the surrounding environment.

Soft structural options for adapting to climate change in Kiribati, as identified in Appendix 3, are:

- Beach nourishment
- Planting mangroves

8.2.1 Beach Nourishment

a. Purpose

Beach nourishment involves the artificial placement of material on a beach to increase the volume of sediment (Figure 2). Beach nourishment does not prevent erosion or short term fluctuations in beach profile but provides a natural buffer between the erosion hazard and the asset. Once the initial design life is exceeded further nourishment is likely to be required, unless headland structures are used to prevent the loss of sediment along the shoreline.

The time period until further nourishment is required depends on the rate of erosion at the site and the volume of material added. Typically volumes of material are much larger than would be used to build a hard structure.

Figure 2 – Beach Nourishment

b. Effect on Coastal Processes

Beach nourishment on its own does not change the overall coastal processes and long term erosion will continue. Therefore a nourished beach is susceptible to the same coastal processes which caused the erosion problem in the first place.

Beaches are generally much less reflective than a wall which is good for dissipating wave energy and reducing overtopping.

Often there is a rapid redistribution of sediment during and immediately after placement (ARC, 2000). Addition of sediment to the beach can potentially increase the movement of sediment both windborne and waterborne. This may cause increased accretion in other areas as the sediment "settles in" and is transported away from the site.

Beach nourishment is most suitable on beaches where sand already exists (or used to exist) and where structures or coastal land forms exist to retain the new beach material.

c. Materials

A readily available supply of sediment is required in order to nourish the beach and a suitable means of transporting the sediment to the site.

Beach material of preferably the same or larger, grain size and density as the natural beach material is required. The volume of material placed should be sufficient to allow for losses due to:

- ongoing erosion (including coastal and windborne);
- adjustments between nourished profile and equilibrium profile;
- differences between the borrow sediment characteristics and those of the native sediment;
- handling losses during transport and placement.

d. Seasonal Variations in Beach Profile

Seasonal variations in the beach profile are an important design consideration. The seasonal extent of beach profile variations at a location can be estimated from historical profile data or with periodic site inspections over several years. However reliability of the data will depend on the frequency of profile surveys, the number of years over which they have been collected and the accuracy of the survey data (Maharaj, 2000). Using a few isolated profiles is not likely to produce a meaningful result.

8.2.2 Planting Mangroves

a. Purpose

Mangroves can be planted to help dissipate wave and tidal energy and in doing so trap littoral sediments. They are a soft structural option which in time provides some protection against coastal erosion but no protection against coastal flooding (Figure 3).

Figure 3 – Mangrove Planting

b. Effect on Coastal Processes

Mangroves dissipate wave energy and trap sediment by interrupting the flow water. It has been found that mangroves grow best in sheltered lagoons, on low energy coastlines (Baba *et al*., 2009).

On the island of Tarawa the most suited environment for Mangroves is along the Ananau Causeway (main road to Bonriki Airport on the lagoon shoreline). Areas where mangroves occur naturally are good sites for further planting.

c. Planting Requirements

Most mangrove species produce propagules that are relatively easy to collect and plant. Thus Mangrove planting needs to be planned when propagules are in-season. Once propagules have been collected, care must be taken to ensure they are kept in moist plastic bags out of direct sunlight. Replanting of the seedlings must be done within three days of collection.

Propagules of the mangrove species Rhizophora stylosa can be collected from local plants and replanted in groups of three at close spacing of 0.5m x 0.5m. Due to the coral gravel foundations, steel rods are required to dig planting holes. In order to increase the chance of survival seedlings need to be planted between mean water level (MWL) and mean high water level (MHWL). This generally results in plantations of long narrow belts with 3 to 6 rows of seedlings.

Seedlings should not be planted in locations where there is a chance of:

- Poor drainage during low tide (forming stagnant water in shallow puddles)
- Barnacle infestation
- Poor soil nutrients
- Seaweed entanglement

Monitoring of the mangroves after planting is necessary to evaluate whether the location is adequate for their survival. Seedlings can be expected to grow to 20cm in height after the first year, 50cm after the second and up to 1.2m after the third year in the right environment (Baba *et al*., 2009).

8.3 Hard Structural Options

Hard structural options prevent shoreline sediment contributing to coastal processes by locking the material into the land. This can alter the coastal sediment transport process and have down drift effects (usually erosion). They are typically constructed of materials such as rock, gabions, concrete or timber and modify the visual character of the area in which they are constructed. These options will impact on coastal processes as they fix the position of the coastline and prevent the natural migration of the shoreline. These effects need to be carefully considered.

Hard structural options for adapting to climate change in Kiribati, as identified in Appendix 3, are:

- Seawalls (rock or concrete)
- Revetments (sandbags, concrete, rock, gabion baskets)
- Embankments (soil or granular materials)

8.3.1 Seawalls

A self-supporting structure built along the coast to prevent erosion by wave action or currents, e.g. reinforced concrete wall, (Figure 4), rock armour or bund wall, mass block wall and reinforced earth structure. They are typically able to withstand greater wave forces than revetments. They sometimes have armour units or rock in front of the structural wall, such as at Betio port.

Figure 4 – Seawall in Kiribati

a. Purpose

The purpose of a seawall is to protect the land from wave and current action. They are constructed parallel to the shoreline and provide a physical barrier between the land and the sea.

b. Effect on Coastal Processes

Erosion will occur regardless of whether there is a seawall or not. Seawalls can sometimes increase the rate of erosion in front of the seawall due to wave reflection and at the ends of the structure caused by wave focussing.

When all available sediment has been removed in front of the wall, down drift areas will no longer receive sediment and erosion may be accelerated as a result of building the wall.

8.3.2 Revetments

A sloping facing of stone / concrete, supported by the land behind it, to protect an embankment or shore structure from erosion e.g. sandbag walls, coral rock walls (Figure 5).

Figure 5 – Typical Revetment in Kiribati

a. Purpose

A revetment is similar to a seawall in that it is designed to protect the land from erosion by providing a physical barrier between the land and the sea. The main difference between a seawall and a revetment arises from their structural support. Revetments rely on the land behind for structural support, whereas a seawall is self-supporting. Because of this revetments are less costly.

b. Effect on Coastal Processes

A sloping revetment will have a reduced effect on the rate of erosion compared to a vertical seawall, due to wave run up on the slope dissipating a proportion of the wave energy which reduces the amount of coastal erosion caused by wave reflection. However as for seawalls they ‘lock up’ the shoreline sediments and can cause down drift erosion problems.

8.3.3 Embankments

An embankment is an onshore structure aimed at protecting low-lying areas against wave overtopping (Figure 6). It is normally an artificially raised bank or mound made of fine materials like sand, gravel and soil with a gentle seaward slope in order to reduce the wave run-up and the erodible effect of waves.

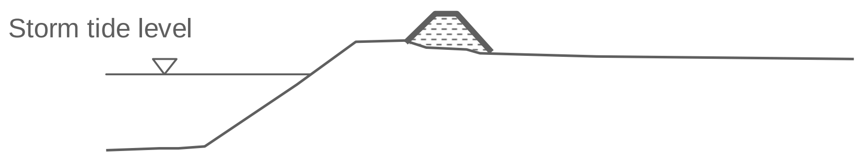


Figure 6 – Typical Earth Embankment (diagrammatic)

a. Purpose

The main purpose of an earth embankment is to reduce the wave run-up and overtopping volumes. They give limited protection against erosion as they are generally constructed from material which can be easily eroded by wave action. Short structures will do little to prevent flooding.

b. Effect on Coastal Processes

Embankments are constructed where they will not impact on the coastal processes. They are not appropriate where active erosion is occurring.

8.4 Combination of options

In some cases it may be appropriate to consider a combination of structural and non-structural options. A combination of options can provide a balance between construction costs and the environmental impacts.

Non-structural options are considered preferable to structural options. In addition, options which include the removal of existing ineffective works or the extension of existing effective works are preferred to new types of works at a site. If structural works are required it is always preferable to implement soft options which allow the natural coastal processes to continue rather than hard structural options which will modify the costal processes.

8.5 Identify appropriate options

Complete the Option Identification Table in Appendix 4 to determine what options are applicable at the site. Table 1 shows a completed example. As a minimum the option of “Do Nothing” should be considered to provide justification for undertaking shoreline protection works. Options which have the least impact on coastal processes are preferable, in which case non-structural options should be considered first, then soft options and lastly hard options.

Table 1 – Option Identification Table Example

Site Name: Bairiki – Nanikai Causeway (BNC_12)	Adaptation Options				
Answer the following questions with a tick (ü) or cross (û). If an option has a cross (û) beside any of the questions then the option does not need to be considered further. The adaptation options which answer yes to all of the questions are appropriate for the site. Outline designs should be developed for each option (maximum of two) to provide further information for comparing the options at a later stage in the process.		Soft		Hard	
	Non-structural i.e. move away / buffer	Beach nourishment	Mangrove planting	Seawall / Revetment	Embankment
1 Is the option appropriate for the energy setting of the site? Refer to Appendix 3 for guidance on the energy setting for each adaptation option.	û	ü	û	ü	û
2 Are the environmental impacts from this option acceptable? i.e. increased downstream erosion		ü		ü	
3 Will the option address the problem? i.e. coastal erosion and/or overtopping		ü		ü	

9 Profile Survey

Accurate survey data is critical to the design of any shoreline protection works. Having decided the most appropriate options for a site a profile survey should be carried out to determine the existing levels of the land or structures, slope of beach, toe of beach and reef flat. Levels should be relative to a known datum. Excavation by hand or with a machine should also be undertaken to determine the depth to the reef foundations below the beach. Cross sections of the site can then be developed using the survey data.

Because Kiribati is very flat using the correct datum for the profile survey is critical. All survey profiles must correctly identify the datum used so that the relative water levels can be correctly plotted and understood.

The standard survey datum for Kiribati is the University of Hawaii datum defined as 3.553 m below benchmark KIR1 on the Betio Harbour wharf.

An example of the information which needs to be captured in the survey is provided in the guidelines contained in Appendix 5.

10 Outline design

10.1 What to design for?

The design criteria which need to be considered in the outline design of shoreline protection works are:

- Main function: Erosion and/or overtopping.
- Design event: The extreme wave or storm event which the option is required to withstand in terms of structural integrity. Often described in terms of the probability of the event occurring in any one year (i.e. Annual Exceedence Probability or AEP). Refer to Section 10.2 for details of the AEP selected by the Foreshore Management Committee (FMC) for all shoreline protection works.

- Design life: The length of time the option is required to function for to manage the erosion (i.e. timeframe). Refer to Section 10.2 for guidance on the design life recommended by the FMC.
- IPCC emission scenario: The Intergovernmental Panel for Climate Change's (IPCC) predicted increase in sea level rise based on a scenario for carbon emissions and ice sheet discharge. Refer to Section 10.2 for the FMC's recommendation on the emission scenario to be used for design. (Check what the current status is as this will change over time).
- Acceptable overtopping discharge: The level of overtopping which is considered acceptable. Described as the mean overtopping discharge which would cause a certain level of damage. Refer to Section 10.2 for acceptable level of overtopping recommended by the FMC.

10.2 Selection of Design Criteria

Australian Standard 4997 (AS4997) provides guidelines for the design of maritime structures. The FMC has selected the following design criteria, based on AS4997:

- Structures are category 2 and 3 (normal to high property value or risk to people) and should have a design life of at least 25 years.
- Annual exceedence probability (AEP) of 1/100 (1%) which is based on the best currently available data.
- Intergovernmental Panel for Climate Change A1F1 high emission scenario for sea level rise projections.
- Acceptable level of overtopping discharge for the main road should be damage to vehicles and for Bonriki airport should be damage to vehicles and pavement.

The design criteria in Table 2 have been used as the basis for the shoreline protection works covered by this guideline.

Table 2 – Design Criteria

Design event or annual exceedence probability (AEP)	1% (1 in 100 year event)
Design life	Minimum 25 years
IPCC emission scenario	A1F1 upper limit (including 0.2m ice sheet discharge)
Acceptable overtopping discharge	Damage to vehicles

10.3 Timeframe

Coastal protection measures can be designed for a range of timeframes depending on the level of "climate proofing" which is preferred. Outcomes of the GoK national consultation determined the timeframes for climate change which should be considered in the design of shoreline protection works. These are shown in Table 3 below. Standard designs covered by this guideline are designed for the long term using the 2070s.

Table 3 - Timeframes for Climate Change

	GC* (short term)	GGC* (medium term)	GGGC* (long term)
GoK defined date range	2012 – 2036	2036 – 2060	2060 – 2084
Coastal Calculator range	2030 – 2039	2050 – 2059	2070 – 2079

*GC – Grand Children, GGC – Great Grand Children, GGGC – Great Great Grand Children

10.4 Sea Level Rise

Allowance for sea level rise is based on the Intergovernmental Panel for Climate Change (IPCC) predictions for various green house gas emission scenarios. The Foreshore Management Committee (FMC) has recommended the IPCC A1F1 high emission scenario upper limit, including an allowance for 0.2m ice sheet discharge, should be adopted for shoreline protection works in Kiribati.

For the timeframe 2070-2079 this equates to a 0.55m rise in sea level, which is the value that has been used in this guideline.

Table 4 - Tide Levels (including future sea level rise)[3]

Tide Levels (m)	IPCC Baseline (1980 – 1999)	2050s (2050 – 2059)	2070s (2070 – 2079)
Mean Level Of the Sea	1.62	1.97	2.17
Mean High Water Springs	2.51	2.86	3.06
Storm Tide	3.03	3.39	3.59
Storm Tide + Wave Set-up (ocean side only)	3.31	3.61	3.80

*All water levels relative to SEAFRAME datum.

NIWA's Coastal Calculator was used to determine the predicted future water levels including an allowance for climate change and sea level rise. There is a discrepancy between the tide gauge datum and the land survey datum which significantly impacts on the design of shoreline protection works.

The NIWA Coastal Calculator assumes that there is a discrepancy of 0.419m between the SEAFRAME tide gauge datum and the University of Hawaii datum. Depending on which is selected, different tide levels are predicted.

Observations of water levels in Kiribati lead us to conclude that the discrepancy noted by NIWA probably means the datum was previously 0.419m out and is now correct.

Therefore, we recommend that until such time as the status of the tide gauge and Coastal Calculator is confirmed, the Calculator is set to SEAFRAME datum and land levels to University of Hawaii datum are used. This results in more conservative values and this method has been used to derive the predicted future water levels used in these guidelines.

10.5 Concept Sketches

Using the cross sections developed in step 9 concept sketches for each of the options identified in step 8 can be developed. A copy of the standard designs printed on a transparent piece of paper at the same scale as the cross section is useful for this.

There are different design aspects to consider depending on the type of option identified. Appendix 6 contains guidance on the design considerations for each of the options recommended in these guidelines.

10.6 Minimum Crest Elevation

The GIS database from the STCCA provides an indication of the minimum crest elevation for seawalls and revetments. This can be used as the basis for the outline design as a minimum however it is recommended that for more accurate minimum crest elevations the Coastal Calculator should be run for each site using the results of the profile surveys in step 9. Guidelines for using the Coastal Calculator are contained in Appendix 7.

[3] Tide levels were derived from NIWA's Coastal Calculator, version 4.5.

10.7 Plant and Materials

Consideration should be given to the type of material which is available in Kiribati as the cost of importing materials to Kiribati will have a large impact on the overall construction costs. Calculate the volume or quantity of each material that is required.

Remember to include the volume of any excavation or back fill material that will result from the construction works. Refer to Appendix 8 for an example bill of quantities.

10.8 Preliminary Construction Cost Estimate

A preliminary construction cost estimate can be developed at this stage in the design process using the estimate of the quantity and volume of material required. This will provide an indication of the likely costs of each option and allow comparisons between them to be made.

An example preliminary construction cost estimate is contained in Appendix 8.

11 Compare the options

Following the outline design work, sufficient information is available to compare the options and select the preferred option. Careful consideration should be given to choosing an option that:

- is capable of managing the identified cause of the erosion; (Technical)
- has acceptable environmental effects associated with it; (Environmental)
- has acceptable social effects associated with it; (Social) and
- has reasonable and practicable costs associated with it (Economic).

Decision point – Complete the Preferred Option Selection table in Appendix 9 for each option. Table 5 below shows a completed example. Compare the options with each other and rate them as either “good”, “neutral” or “bad” by placing a tick in the appropriate box under each of the four categories (technical, environmental, social and economic). Select the best option which will generally have the most ticks under the “good” column.

Table 5 – Preferred Option Selection Table Example

Location:	**Bairiki – Nanikaai Causeway (BNC -12)**			
Option:	**Rock Armour Revetment**			
	Good	**Neutral**	**Poor**	**Comments**
Technical considerations:				
Design life of structure	ü			Long term eg:50+ years
Fit for purpose	ü			Prevents loss of land by erosion
Ease of construction			ü	Requires plant not available in Kiribati
Availability of materials			ü	Imported material
Environmental considerations:				
Impact on coastal processes		ü		Same as sand bag wall
Effect on coral reef, mangrove or sea grass	ü			Structure built above MHWS therefore no impacts
Effect on protected species or habitats		ü		No protected species or habitats
Management of waste arising from activity	ü			Existing structure to remain in-situ
Level of noise and dust			ü	Noise generated by plant placing rock armour
Social considerations:				
Access to and along the beach		ü		No change to existing access
Impact on neighbouring land owners		ü		Causeway with no neighbouring landowners
Impact on current & future land use		ü		No impacts, same land use proposed
Impact on areas of cultural or historical significance		ü		No areas of cultural or historical significance
Outcome of consultation with community				Yet to be undertaken
Economic considerations:				
Capital costs			ü	Expensive to import materials
Maintenance costs	ü			Last longer therefore reduced maintenance costs.
Efficient use of funds	ü			Long term life of structure requires few replacements
Impacts on local population & employment			ü	Mechanical construction therefore fewer labouring jobs

12 Obtain approval to carry out works

Before any shoreline protection works can be carried out the appropriate approvals need to be obtained. This includes an Environment Licence, to comply with existing environmental legislation in Kiribati and obtaining budget approval from the relevant ministry.

12.1 Budget Approval

Budget approval should be sought through the existing GoK procurement procedures for the relevant ministries (refer Appendix 10).

It is usual to add a 20 to 30% contingency to any cost estimate at this stage, before any detailed site information is available and before detailed design has been completed. After detail design the contingency can be reduced to 15%, but this should be maintained through the construction phase.

12.2 Seawall Application

When undertaking construction of seawalls or mining activities a seawall application form should be obtained from the Land Management Division of the Ministry of Environment, Lands and Agriculture Development (MELAD).

12.3 Environment Licence

All shoreline protection works covered by this guideline should comply with the Environment (Amendment) Act 2007 and the Environment (General) Regulations 2008.

The Environment (Amendment) Act 2007 states that an Environment Licence is required for any proposed activity. An Environment Licence application form must be completed, along with the payment of applicable fees as stipulated in part 3 of the Environment (General) Regulations 2008.

12.3.1 Environmental Impact Assessment

The Principal Environmental Officer reviewing the application will advise whether an Environmental Impact Assessment (EIA) report is required to supplement the application. There are two types of EIA reports which may be required under the Environment (General) Regulations 2008: a basic environmental impact assessment report or a comprehensive environmental impact assessment report. Refer to Appendix 11 for guidance on preparing an Environmental Impact Assessment Report.

12.3.2 Consultation with Public

One of the requirements for an EIA is for the applicant to undertake consultation with communities which are likely to be affected by the works.

Further details on the consultation requirements can be obtained from the Environment and Conservation Department (ECD) of MELAD.

13 Detailed design and pre-construction

Detailed design is the process of taking the preliminary or outline design used to decide what type of action is being taken, to the point where costs can be accurately estimated and it can be built. This requires time and effort to match the detail of the site with the standard solutions. The process is the same regardless of what option has been selected.

13.1 Design Process

Before detailed design can be done some basic information must be gathered: surveyed profiles, the elevation of the reef conglomerate rock at each cross section and an accurate plan of the site.

For ease of the following description, we will assume that a structure of some sort is being built, as non-structural options usually do not need detailed design drawings.

1. For each cross section, decide where the structure will be relative to the road or asset under threat. Choose the place that gives the best economy in terms of excavation and filling. A copy of the standard design printed on a transparent piece of paper at the same scale as the cross section is useful for this.

2. Plot the position of the top and bottom of the structure on the plan for each cross section. Decide whether the structure should be straight or curved. Don't just join up the dots – that won't look good when it is built. Select a final alignment.

3. Once the alignment is decided, re-plot the position of the structure on each cross section.

4. Determine the depth to the reef conglomerate rock or reef mud at each cross section and confirm where the structure needs to be founded. Decide whether the structure will have the same foundation level along the whole length of whether it should vary. Use the Scala Penetrometer to probe foundations. Mark location of probes on the plan.

5. Pay close attention to the ends of any option selected. A sudden stop to the structure will result in a turbulent wave environment and increase risk of localized erosion. It should either be tied into adjacent structures or be turned back into the backshore at the appropriate point.

6. Work out the quantities of excavation and filling that will be required.

7. Work out the quantities of structural materials required

8. Determine the estimated cost of the structure using the standard spreadsheet and check that you are still within the budget. If not, check that you have not been too conservative or whether you can economise by relocating the wall.

9. Once the structure location height and estimated cost have been confirmed, produce the cross sections and plans as construction drawings. Produce schedules of materials plant and labour necessary for the work.

10. Get someone else to check your decision process and arithmetic – mistakes are easy to fix at this point, but once you start building they can cost a lot more.

13.2 Common design and construction problems with coastal structures in Kiribati

The following common problems have been noted in a number of locations. Measures to overcome these problems are also discussed:

a) Walls are built that stop suddenly, usually just before they reach the adjacent structure or headland. The turbulence in the wave environment accelerates local erosion at either end of the structure. Also the processes that are causing the erosion problem are still able to affect the coastline where there is no wall, so the land edge "retreats" compared to the wall. This area then becomes the easiest place to walk from the foreshore to the beach, so a lot of foot traffic goes over this area, increasing erosion further. The end result is that although the structure is well away from the asset being protected, the erosion at the ends puts the asset under threat. Structures that allow access to the beach (steps) should be built at the centre of the structure and ends should be well tied in to adjacent structures or turned back onto the land gradually.

b) Where foundations of the wall are not on reef conglomerate, then the walls can be undermined or slumping can occur. This has happened on a number of the causeways. Structural foundation should always be taken down to the reef conglomerate where possible. Where this is not possible the scour toe should be built as shown on the standard drawings. Use the Scala Penetrometer to probe below the foundation to see if rock is close.

c) Mixing of sand and cement is sometimes not good quality and the sandbag walls fail once the hessian bag rots away and the uncemented sand mixture is washed out of the wall by wave action. Once the wall fails, the land behind and supporting the wall is washed out and the wall collapses. Mixing of sand and cement must be done thoroughly and hand mixing or mixing using the digger bucket is not reliable enough. A mechanical mixer is required. Mixing of the sand and cement should be checked by crushing test cubes or cylinders.

13.3 Detailed Construction Drawings

Detailed construction drawings will include:

- the standard cross section for the option selected,
- a detailed plan providing at least the following:
  - Location of the nearest reliable survey benchmarks (these should have been shown on the survey cross sections)
  - A reference line to which all the cross sections relate
  - Setting out information to enable the wall to be placed correctly on site.
  - Details of what happens at the ends of the structure
- the individual cross sections surveyed at the site showing:
  - the selected option overlain
  - tide levels
  - allowances for sea level rise and storm surge
  - elevations of the critical elements of the wall, land and reef

The construction drawings may also be accompanied by a standard specification, which covers the standard details and quality control and assurance requirements for the particular option being used. Wherever possible, specifications should be noted on the drawings.

Standard drawings for the options outlined in this guideline are included in Appendix 12.

13.4 Schedule of Quantities

A Schedule of Quantities must be produced for all projects.

The schedule of quantities will set out the main items and activities involved in the work. An example is included in Appendix 8. This can be used to generate the majority of the quantities and materials necessary.

The Designer needs to:

a) check that all items have been included and that the matters not calculated by the spreadsheet have been correctly measured and

b) Check whether other items particular to that project need to be added.

c) Check that rates in the spreadsheet have been updated with the latest costing information available from the MPWU quantity surveyors.

13.5 Procurement Schedule

A procurement schedule will be generated from the schedule of quantities using a spreadsheet template as shown in Appendix 13. As for the schedule of quantities, the Designer needs to check that any additional items for the project being considered, are included.

13.6 Programme of Works

The expected duration of the items of work listed in the schedule of quantities will be generated. The Designer needs to prepare the final construction programme to suit the availability of plant and equipment at the time the project is undertaken.

14 Quality control during construction

During construction, it is vital that the designs are followed correctly to ensure the shoreline protection works perform as intended. Unforeseen circumstances may arise during construction and changes to the design may be required. Design changes should be limited as much as possible. Take photos and record construction information on a daily basis as works progress. Example Inspection and Test Plans for each of the adaptation options are contained in Appendix 14.

14.1 Site Safety Management Plan

For each adaptation option, a site safety plan checklist has been prepared to assist the Designers to consider the health and safety of construction staff. A generic Site Safety Management Plan is included in Appendix 15.

The site safety plan needs to be prepared and communicated to the sites staff before the work on site commences.

The safe excavation of trenches is of great importance as accidents in trenches have led to fatalities. As a minimum, ground should be benched wherever excavations exceed 1.5m below ground level.

Staff on site should be equipped with basic personal protective equipment (PPE). The basic items should be:

- at all times:
    - Hard hat with sun flap to protect neck and shoulders
    - High visibility vest – long tail
    - Suitable footwear either steel capped boots or gum boots
- other specialist equipment when necessary:
    - Ear plugs
    - Safety glasses (when working with concrete to prevent cement splashes in eyes)
    - Gloves (when handling cement)

14.2 Environmental Management Plan

For each work site, a basic Environmental Management Plan should be prepared. A checklist is included at Appendix 16.

This should cover the basic issues where the environment may be damaged if proper care is not taken. The minimum EMP will cover:

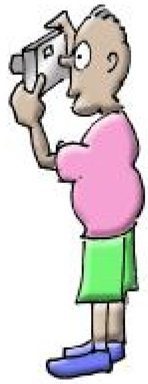
- Stockpiling of materials
- Storage of cement and hazardous materials
- Discharge of stormwater from the site
- Protection of vegetation
- Storage and fuelling of plant
- Traffic Management

15 After construction

Following the completion of the construction works it is important to record the following:

- Take photographs of the completed work. This provides a record against which comparisons can be made throughout the design life of the structure.
- Record the position of the works using GPS coordinates. This can be entered into the asset database to keep a record of assets.
- Final construction cost for the works. This will assist with estimating the construction costs for future works.

16 Ongoing Monitoring and Maintenance



After construction and throughout the design life of the works, ongoing monitoring and maintenance is required to assess the performance of the chosen option, prevent deterioration, assist with the design of future works and provide an understanding of the causes of coastal change over time.

The methodology and approached described in the STCCA is a good way of regularly monitoring the condition of shoreline protection works. Condition assessments can be carried out on a regular basis and the GIS database updated to provide records of the condition of the coastline and structures.

17 Glossary of Terms Used

Bay	An indentation in the shore forming an open bay.
Beach face	The section of the beach normally exposed to the action of the wave uprush. Also called the FORESHORE of the beach.
Beach rock	Cemented sand on the beach.
Erosion	The wearing away of land by the action of natural forces.
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 low-water mark, that is normally exposed to the uprush and backrush of the waves as the tides rise and fall. See BEACH FACE.
Groyne	Narrow structure built perpendicular to the coast to reduce longshore currents or trap sediments.
Headland	A high point of land projecting into a body of water.
Passage	Narrow gap between two islands or structures.
Revetment	A facing of stone / concrete, supported by the land behind it, to protect an embankment or shore structure from erosion e.g. sandbag walls, coral rock walls.
Scarp	An almost vertical slope along the beach caused by erosion by wave action. Its height may vary from a few cm to a metre or so, depending on wave action and the nature and composition of the beach.
Seawall (vertical or sloping)	A self-supporting structure built along the coast to prevent erosion by wave action or currents, e.g. reinforced concrete wall, rock armour, bund wall. Typically able to withstand greater wave forces than revetments.

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