ENVIRONMENTAL IMPACT ASSESSMENT

PROPOSED ROCK REVETMENT TO REPLACE SEAWALL FROM PALACE TO WHARF AT LIFUKA, HA’APAI, KINGDOM OF TONGA

by

Talanoa Fuka Kitekei’aho

This report has been prepared to analyze potential environmental effects associated with the construction of a Rock Revetment to replace the seawall from the Palace to the southern end of the new wharf at Lifuka, Ha’apai. Mitigation measures are suggested on potentially significant impacts together with discussions on two other alternatives to solve the chronic coastal erosion on the western coastline of Lifuka.
SUMMARY

ENVIRONMENTAL IMPACT ASSESSMENT

FOR

PROPOSED REPLACEMENT CAUSEWAY FOR FOA ISLAND, KINGDOM OF TONGA

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Type of Action

To construct a rock revetment structure to replace the existing worn out sea wall in front of the Palace at Lifuka, Ha’apai.

Description of the Proposed Action

The purpose of the action is to protect the Palace from continuing coastal erosion by replacing the existing worn out seawall structure with a rock revetment structure. It is anticipated that this would immediately stop further coastal erosion in this area. The rock revetment is designed similarly to the Nuku’alofa rock revetment with some upgrade engineering. The crest of the structure would be 4m above mean sea level and width of the crest at 8m wide to further dissipate wave energy and reduce overtopping by waves. The slope of the structure is set at 1V:2H and toe must be buried into the coral substrate at low tide. The structure is finally covered with sand from toe to upper crest level to encourage formation of beach. The structure is estimated to cost about TOP$1 million.

Environmental Effects

Environmental effects requiring specific analysis are limited to the followings;

- Possible effect of the structure on coastal erosion
- Fine sediment dispersion from the construction site and its possible effects on fauna and flora in the nearby marine areas.

Other effects considered in the analysis include social issues on remittances, fisheries, tourism and health issues.

Mitigation Measures

The effect of fine sediment plume is unavoidable but can be minimized by avoiding transportation of fine sediment to site during loading and deliveries of large coral boulders from the quarries. Secondly is to restrict all construction to low tide and use sediment net to contain dispersion of any sediment.
plume. The sediment plume would affect mostly the marine ecosystem close to shore. The effect on coastal erosion can be mitigated by having two groyne fields position at either end of the structure.

**Alternatives to the Proposed Action**

The alternative 2 of Wharf Reconstruction and Sand Replenishment with groyne field is an ideal option which requires the shoreward part of the wharf to be reconstructed into an open piling structure. This is necessary to allow sediment trapped on the northern side of the wharf to be transported across to the rest of the southern coastline which is currently suffering from chronic erosion. This option offers the most natural approach to solving the coastal issue in the long run, especially if the correct rock sizes prescribed to Alternative 1 is not available locally. Although this option does not stop coastal erosion immediately, it has minimum impact on the environment. The cost of this alternative could be much cheaper than the proposed action. Alternative 3 of do nothing is considered too expensive as coastal erosion is threatening properties, infrastructures and lives of people along this coastline.

**Monitoring**

The use of the Environmental Management Programme (EMP) during construction stage to ensure compliance and Safety, Health and Environment practices are adopted is necessary for the success of the project.

Data collected on biodiversity and beach profiles need to be collected repetitively to monitor any impact of the structure on adjacent environment. It is therefore recommended that monitoring of the reef flat and conducting beach profiles must be carried out within 3-6 months after construction and 6 months thereafter for a period of 18 months to determine any detrimental effect of the structure on the environment.

**Public Hearing**

A public scoping meeting was held between 29th April to 3rd May 2013 with the 5 communities of Lifuka Island to determine their preferred choice amongst three options and their preferred choice was a rock revetment, similar to that at the Nuku’alofa coastline. Oral and written comments are incorporated in this report and recorded in Appendix II.
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**Figure 1**: Typical cross section of a Rock Revetment

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ACKNOWLEDGEMENT

I would like to thank the proponent, Ministry of Infrastructure and Transport for having confidence in our company in conducting this Environmental Impact Assessment (EIA). I am also grateful to Ministry of Fisheries for accommodating the survey team while at Ha’apai, especially Mr. Sailosi ‘Alofi and his dear wife ‘Ana who continuously provided us with fresh raw fish for a Ha’apai breakfast.

I would also like to thank Poasi Nguluafe of Ministry of Fisheries for his contribution on the habitat map and social issues. Apai Moala of Geological Section of Ministry of Lands and Survey for resurveying the beach profiles.
ENVIRONMENTAL IMPACT ASSESSMENT
FOR
CONSTRUCTION OF A ROCK REVETMENT TO REPLACE THE SEAWALL IN FRONT OF THE PALACE AT LIFUKA, HA’APAI, KINGDOM OF TONGA

I. BACKGROUND AND PURPOSE OF PROPOSED ACTION

Project Overview
Tonga’s Joint National Action Plan (JNAP) on Climate Change and Disaster Risk Management, 2010, identified priority adaptation needs for Tonga. One of these priority areas is the western coastline of Lifuka Island at the Ha’apai Group. The low lying island is a home for 5 communities of Hihifo, Ha’ato’u, Pangai, Holopeka and Koulo. The low lying area of the western coastline is vulnerable to frequent attacks by storm surges and recently by tsunami waves, causing coastal erosion and inundation that requires immediate concrete actions.

In 2011, the Pacific Adaptation Strategy Assistance Program (PASAP) project, ‘Assessing vulnerability and adaptation to sea-level rise: Lifuka Island, Ha’apai, Tonga’, was developed in conjunction with the Secretariat of the Pacific Community (SPC), Tonga’s Ministry of Environment and Climate Change (MECC) and Australia’s Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE).

The primary objective of PASAP is to: ‘enhance the capacity of partner countries to assess key vulnerabilities and risks, formulate adaptation strategies and plans, and mainstream adaptation into decision making’. SPC and MECC were tasked to assess and provide ‘evidence-based strategies for adaption to sea-level rise’ in Lifuka.

Some of the objectives were:

1. to assess the impacts of seismic subsidence on the coastal zone and people of Lifuka;
2. to assess the vulnerability of the coastal zone and people of Lifuka to future rises in sea level;
3. to propose and assess a range of adaptation strategies for adapting to sea-level rise on Lifuka;
In objective 3, the study proposed a range of options which varied from managed retreat to higher ground inland, raising houses at vulnerable zone above storm surge level and finally to coastal protection. The preferred choice of the communities was coastal protection and it was rock revetment, similar to that at Nuku’alofa coastline. The detail of this option and its construction is discussed in Worley Parsons Report (2013) on Coastal Rehabilitation of Lifuka Island, Tonga. The report is attached as PART II of this report.

In February 2015, the Minister of Infrastructure and Transport Hon Lavulavu, visited Lifuka Island. He recognised the coastal erosion on the coastline in front of the Palace, required urgent rehabilitation works. The coastline was protected by a seawall which is now suffering from wave overtopping due to sea level rise and concrete slab are falling down. It is proposed that this section would be replaced by a rock revetment using coral boulders from local quarries.

**Proposed Action**

The main purpose of this action is to protect the Palace by minimizing coastal inundation and erosion on this 200m coastline with a rock revetment. The proposed design of is similar to Fig 1 shown below and discussed extensively in Worley Parsons Report, 2013 (attached).

**Figure 1: Typical cross section of a Rock Revetment**

This action will further act as a pilot project for protecting the western coastline of Lifuka from further erosion in future.
Study Area

The study area is the coastline in front of the Palace property which is located on the western coastline of Lifuka Island in an area south of the main wharf (Fig 2).

EIA Study

The EIA report is required under the Environmental Act 2003 for major project. It is aimed at identifying potential environmental impacts due to the construction of the rock revetment to replace the existing seawall at the coastline in front of the Palace and to the north towards the wharf, which is necessary for the designing and construction of the replacement structure.

Environmental Act 2003

The recent enacted Environmental Impact Assessment Act 2003 provided for an effective enforcement and administrative framework for the Department of Environment. This act requires all major development projects to be supported by an appropriate environmental impact assessment (EIA).

The proposed coastal protection works is classified as major project due to its potential impact on the environmental along this coastline. No project would be allowed to proceed without the appropriate impact assessment required under this Act and approved in the prescribed form.

Funding

The funding of this project is through the Disaster Fund of the Government of Tonga.

Project Proponent

The proponent is Ministry of Infrastructure and Transport of the Government of Tonga.
Project Scope and Objectives

The scope of the study is to determine the potential environmental impacts emanating from the construction and operation of a rock revetment proposed to replace the seawall in front of the Palace at Lifuka, Ha’apai.

The Terms of References (TOR) is attached as Appendix 1 of the report.

Work Plan

<table>
<thead>
<tr>
<th>TITLE</th>
<th>EIA STUDY: CONSTRUCTION OF A ROCK REVETMENT TO REPLACE THE EXISTING SEAWALL INFRONT OF PALACE AT LIFUKA, HA’APAI</th>
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<tr>
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<th>Field Studies</th>
<th>Biological &amp; Marine</th>
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EIA Study Team

The proponent contracted GEOcare & Petroleum Consult Ltd of Tonga to conduct this study. The project Team and their task designations are set out below in Table 2.

Table 1: Study Team.

<table>
<thead>
<tr>
<th>NAME</th>
<th>POSITION</th>
<th>QUALIFICATION</th>
<th>ROLE IN THE EIA STUDY</th>
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</thead>
<tbody>
<tr>
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<td>MSc in Marine biology</td>
<td>Marine Biologist/ Diver</td>
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<td>Field Scientist</td>
<td>Certificate in Marine and Earth Science, USP, Fiji</td>
<td>Beach profiling</td>
</tr>
</tbody>
</table>
The Terms of Reference was accepted and arrangements were made to commence the study on 23rd March 2015 with a site visit and field studies 30th and 31st March 2015.

**Methodology**

Usually this type of study follows the following steps in investigating potential impacts on social and natural environment during design, construction and operation phases of the project.

1. Record baseline information about the site and its surrounding environment utilizing existing and secondary information as well from a reconnaissance site visit.
2. Conduct a scoping process to determine potential impacts from member of the communities, Interested and Affected Parties (I & APs) and to make sure that their views, comments and opinions are recorded and addressed in the EIA report.
3. Conduct communities’ household survey to ensure all voices are heard and concerns addressed.

However, considering that steps 2 & 3 were carried out satisfactory during the PASAP studies, it is proposed to forego these steps to avoid community frustration and focus only on step 1 since rock revetment was the communities’ preferred choice during the Scoping Meeting. A report on the final consultation of the PASAP studies is attached as Appendix II of this report.

The field works began on 27th to 30th of March with beach profiling and followed by biological survey on marine organisms and habitat mapping on areas in front of the structure between 30th and 1st of April 2015.
II. ALTERNATIVES INCLUDING THE PROPOSED ACTION

This section defines the proposed course of action in more detail and examines two other alternatives in this Environmental Assessment.

Alternative 1: Proposed Action-Rock Revetment

This option refers to the proposed action of constructing a rock revetment to protect the Palace and stop further coastal erosion at this part of the western coastline of Lifuka. The concept design of the options is based on an analysis of the coastal processes occurring at and near the site as well as the provision of design parameters for all the aspects of the proposed option.

As determined in the last public consultation carried in Pangai, Lifuka, in May 2013, the rock revetment should resemble that built on northern coastline of Nuku’alofa. See Figure 3 below.

Figure 3: Nuku’alofa rock revetment.

Material Properties

The design of the rock revetment was done through desktop investigation into coastal processes and the conceptual design conducted by WorleyParsons, 2013.

It is envisaged that coral limestone available locally would be used to construct the revetment. A more ideal rock would be igneous rock but it is understood that there is no viable igneous rock at Lifuka. An igneous rock has much higher bulk density than coral rock and would be more resistant to wave attrition. Therefore, to achieve the same level of protection against wave attack, a revetment constructed of coral rock armour would need to include much larger primary armour stones than one constructed using igneous rock (WorleyParsons, 2013).

Ha’apai coral rocks have an average density of around 2.0g/cm³. In contrast, igneous rock typically used for revetments (including basalt or granite) has a bulk density of 2.65-2.7g/cm³. It is therefore recommended that in order to use coral rock with highest density, coral rock samples from different
Quarries in Lifuka and Foa should be tested in accordance with International Standard during the
detailed design stage.

**Concept Design of Rock Armor**

The major features of revetments are a stable armour layer, underlayer, filter layer and toe protection (USACE, 2011). The filter and the underlayer supporting the armour allow the passage of water through the structure. Toe protection prevents undercutting and provides support for all the layer materials.

A general schematic diagram of a flexible sloping revetment, illustrating the main features, is shown in Figure 4 below.

![Figure 4: Typical Structure showing main features](image.png)

The concept design of the primary armour against wave attack has been assessed using a static approach with the Hudson equation (WorleyParsons, 2013). The static approach does not allow movement or deformation of the armour layers over the design life, and the structure appearance will not change appreciably over time.

**Filter Layer**

A geotextile or graded rock filter layer would be required to prevent loss of fines through the structure. However, use of a geotextile layer between the underlayer and core layer would reduce the interface shear strength significantly. In addition, a geotextile layer would reduce the permeability of the armour which would decrease its stability under wave action.

For this reason, a **graded filter layer** would be recommended rather than a geotextile to prevent fines from the core washing through the armour layer. A geotextile could be used, however, if the slope of the revetment was made flatter than 1V:3H.

An engineering drawing for the rock revetment is shown in Figure 5 below.

The following design criteria have been applied based on the derived design parameters above:

- Design wave height $H_{10} = 2.3$ m
- Design wave period $T = 10$ s
- Design still water level = $3.6$ m above mean sea level (MSL)
- Design wave run up level = $6.6$ m above MSL.

**Slope**

With reference to the LiDAR data at the site, the existing foreshore slope is around 1V:10H. To obtain a stable slope with an acceptable Factor of Safety against geotechnical sliding failure it is recommended that the wall be designed with a maximum slope of 1V:2H. Slopes steeper than this would risk failure due to sliding of the armour layer over the underlying geotextile, due to the low friction angle between the geotextile and overlying armour stones. The cost of the seawall would increase if slopes are much flatter than this, due to the increase in excavation and volume of fill required.

**Armour layer Size**

For a slope of 1V:2H using specially placed coral rock boulders with an assumed bulk density of 2000 kg/m$^3$, the following armour dimensions are required:

$W_{50} = 2512$kg; $D_{50} = 1140$mm for primary armour;
$W_{50} = 251$kg; $D_{50} = 530$mm for secondary armour.

**Crest Level**

According to the LiDAR data, the crest of the existing embankment is typically around 2-2.5 m above mean sea level, though it is lower in some areas. The embankment would be subject to major inundation. Crest level of the revetment should be selected such that major wave overtopping is excluded during cyclone event. It is noted that the nearshore water level is expected to reach 3.6m above mean sea level during a cyclone event according to the SBEACH modelling, which currently results in the inundation of much of the infrastructure on the west coast of Lifuka. To protect against the inundation (without allowing for the effects of waves or percolation through the structure), the crest of the structure would need to be at least 4m above mean sea level, which allows for 0.4m freeboard above the still water level. There would also need to be an allowance made for the crest level to be increased in the future to account for sea level rise due to climate change, depending on the structure design life. However, waves will run up onto the structure and overtop the structure unless the crest is made higher still.

To design a structure to exclude wave overtopping would, therefore, require a structure 5m higher than the elevation of the surrounding land. To allow a reduction in crest level and reduce wave overtopping
to a level that would improve pedestrian and vehicle safety, one or more of the following measures could be put into place:

- Increase crest width – a wider crest is able to absorb wave overtopping back into the revetment armour;

- A more practical approach may be to construct the crest level to around 4m above sea level which would allow wave overtopping but to mitigate against this by increasing the width of the crest to about 8 meters, such that the wave overtopping can be absorbed back into the structure. This is a similar approach to that used for the coral rock revetment at Nuku’alofa.

**Toe Details**

Toe scouring due to wave breaking at low tide is a common cause of seawall failure generally. However, it is understood that the base of the embankment consists of hardpan coral reef material. It is recommended that the toe be keyed into (or trenched into) the basement coral reef material which is assumed to be around 1 m below mean sea level.

**Horizontal Wall Alignment**

The revetment should be aligned to match the existing adjacent shoreline and maintain as smooth a finish as possible, while minimising the volume of excavation and fill required. As the rock revetment would have a large footprint and its landward position would be constrained by the presence of development on the landward side, the rock revetment would encroach onto the beach.

**Material Quantities**

Based on the LIDAR data and the length of foreshore to be protected of about 200 m, the following quantities of materials are estimated for the seawall at the site:

- Primary armour stone (coral rock boulders D50 = 910mm): 200m x 31.35m3/m = 6270m3
- Secondary armour stone (coral rock boulders D50 = 420mm) 200m x 14.25m3/m = 2850m3
- Geotextile or Graded filter layer: 200m x 20m = 4000m2
- Excavation and removal of material from site to be determined at detailed design stage.

**Cost Estimate**

An indicative cost of the rock revetment for the 2.2 kms of coastline at Lifuka was calculated to be about **$12.34 million**, or **$5,600** pa’anga per meter (Worley parsons, 2013) based on rates used for supply of rock and fill material. This figure therefore can be varied according to the rates of supply at the time.

It is likely that maintenance of the structure would be required, following major storm events. This would involve regular inspection of the structure, particularly after storm events or stormy periods. The likely net present value maintenance cost, based on an allowance of 0.2% of the capital cost per year (based on a 1% probability that the design storm event could be exceeded in any one year, and that the revetment would suffer 20% damage in such an event) is estimated to be around **$25,000**.
pa’anga per annum, not including the cost of inspection of the structure. The maintenance costs would be higher as a proportion of the total structure cost, should the revetment be designed for a more frequent event.

The estimated cost for this 200m proposed rock revetment is based on the above estimate to be approximately TOP$1.12 million based on TOP$5,600/meter.

The most appropriate design adopted in the WorleyParsons (2013) report has a reduced height and extended width of crest. This is shown in Fig 5 below.

Figure 5: Configuration of a rock revetment for Western Coastline of Lifuka. The slope is a drop of 1m for every 2m horizontal.

Alternative 2: Wharf Reconstruction and Sand Replenishment with groyne field

This alternative may become important if the supply of primary and secondary rocks within Lifuka is unattainable.

In this alternative it is envisaged that part of the landward side of the new wharf would be removed and reconstruct with an open piling structure to allow for longshore current to carry sediment, currently blocked at the northern side of the wharf to flow southward to rest of the western coastline. Such an alternative would complement the three openings already created at the Foa Causeway at northern end of lifuka, and would assist in the resumption of the natural process of sediment distribution in this coastline.
The EIA study carried by Geocare & Petroleum Consult (2010) revealed that the sand movement on the island of Lifuka is anticlockwise due to the dominant south easterly wind direction. According to the study the wind direction generates waves that approach the shores at an angle to the coastline from the southeasterly direction. These waves in turn generate longshore current that drives sediment northward towards the Foa Causeway. Since the Foa Causeway was like a block of concrete with no culverts for sand to pass through to the westward side of the causeway, most of the sand is therefore driven towards southern coastline of Foa Island. Occasionally during strong winds the sand accumulation at the southern end of Foa Island is large that it occasionally overflowed onto the road disrupting vehicle movement between the two islands of Foa and Lifuka. Frontend loaders were occasionally called in to clear the road to allow traffic to flow between the two islands. As a result, the original Foa Causeway has acted to join the two independent processes of sediment distribution along the two coastlines of Foa and Lifuka into one large cell. The EIA study made recommendations to create large openings on the Causeway during the rehabilitation work on the Causeway in 2011, to isolate the two processes and allow each island to receive its own supply of sediment. The recommendation was adopted and three large openings were added to the design and reconstruction of the Causeway.

The EIA study also noticed that the recent construction of the wharf at the western coastline of Lifuka at Pangai has further blocked sediment from reaching the coastline south of the wharf. The starving of this coastline of sediment led to the chronic coastal erosion witnessed at this coastline today.

This alternative therefore seeks to encourage resumption of the natural process that has been operating in the past. It seeks to reconstruct the landward part of the wharf to an open piling structure to complement the three openings already created at the Foa Causeway and to assist the resumption of the natural process and flowing of sediment to the coastline south of the wharf during the northwesterly winds. The rest of the coastline then can be protected with sand replenishment and alternating groyne field and series of short rock revetments, at possibly much lesser cost than Alternative 1. This alternative may not stop sea inundation at short term but the adaptation measure is environmentally friendly and maybe sustainable in the long term.

**Costing**

The relevant section of the wharf to be rehabilitated is shown below in Fig 6.

*Figure 6: The main Wharf at Pangai, Lifuka. The section to be rehabilitated is shown in the red box.*
The cost for rehabilitating of the wharf is estimated at $7 million pa’anga. The cost of the groyne field and sand replenishment is estimated at $600,000 pa’anga. The total cost for this option is therefore estimated at **$7.6 million pa’anga**. Refer to Appendix III for the detail calculation.

**Alternative 3: Do Nothing**

This alternative assumed that no protection works would be carried out and coastal erosion and sea inundation is allowed to continue. According to previous studies (PASAP Study (2013), Geocare (2010)) the damaged to the coastline of Lifuka, especially in area south of the main wharf is chronic with large amount of land and properties at high risk.

It is evident from the above studies that the cost of doing nothing would be too high and therefore not the best alternative and has not been considered further by the consultants.
III. DESCRIPTION OF THE AFFECTED ENVIRONMENT

The following passages describe the most important aspects about wind, ocean currents, geological and bathymetry setting, biological communities, and social systems as they relate to the potential for environmental impacts. Only those topics which relate directly to potential environmental impacts are considered in detail.

Physical Consideration

The islands of the Ha’apai Group are situated north of Tongatapu, the main island in the Tonga Group of Islands. Lifuka Island is the main island of the Ha’apai group and the host for the administrative centre of the Ha’apai Group of islands, which consisted of 60 small low lying islands. The town of Pangai on the western coast of Lifuka contains about 40% of the population of the Ha’apai group of islands (Fig 7).

Figure 7: The Ha’apai Group of islands showing the island of Lifuka.

Topography

The topography of Lifuka Island exhibits an island tilted to the west. The highest point is at 17m at the eastern coastline at Hihifo village and the lowest point at the western coastline. Refer to Figure 8 below.
Figure 8: Coastal terrain model of Lifuka showing LiDAR bathymetry and topography collected under the PASAP project. The map also shows the location of major infrastructure such as houses, roads and the airport. Note that the majority of buildings are located on the low-lying western coastline.

**Tectonic Setting**

The Kingdom of Tonga lies at the edge of the Australian Pacific Plate and in direct collision with the Pacific Plate at the east (Packham, 1978). This type of plate boundary is commonly referred to as a “Subduction Zone” where the Pacific Plate is subducted or thrust underneath the Australian Plate travelling which is travelling eastward. This type of boundary is also commonly known as the “Ring of Fire” due to high violent volcanic activities associated with this type of Plate boundary (Fig 9). Drilling in the 70s and early 80s for petroleum occurrences due to oil seepages found on Tongatapu, revealed the basement rocks to consist of volcanic origin. An effect of the underthrusting or subduction of the Pacific Plate underneath the Australian Plate is to cause a tilt in the islands formation to the west. The topography of ‘Eua, Tongatapu and the Lifuka Islands exhibit this tilt.

Figure 9: Tonga Tectonic Setting. The Pacific Plate to the east is subducted beneath the Indo-Australian Plate to the west.
The prevailing winds in Tonga consist mainly of the southeasterly winds, but cyclones pass through the area, generally from the northeast. Under ambient condition the wind speed is between 2.6 m/s and 7.5 m/s (Figure 10). In extreme wind condition the wind has been recorded to reach 26.3 m/s from the northeast direction in previous cyclones.

Tropical cyclones are seasonal phenomenon (November to April in the SW Pacific) with a frequency of 1 cyclone per season for Tonga. The average number of tropical cyclone that affected the SW Pacific per season varies between 8 and 10. The Ha’apai Group tends to suffer the most as some of these cyclones passed through the Tonga Group.

Figure 10: Wind Speed by return period. Source: NIWA, New Zealand
The study area is on the western coastline of Lifuka and is shadowed from the prevailing SE winds. However, the island is exposed to occasional cyclones that come from the northerlies direction (NE-NW). High velocity cyclone and other storm winds do occasionally impact the islands from the north, along with associated large breaking waves. These waves have been recorded to cause large damages to the islands. Tropical Cyclone Ian destroyed about 80% of houses in the island and killed one person.

Figure 11 shows the number of cyclone occurred in the Southwest Pacific, in the period 1969 - 2007. The graph is suggesting decrease in frequency of tropical cyclone and a corresponding increase in intensity.

**Figure 11: Number of Tropical Cyclones occurred in the Southwest Pacific (1969-2007)**

![Graph showing the number of tropical cyclones in the Southwest Pacific from 1969 to 2007.](image)

In 2014 cyclone Ian hit the Ha’apai group as category 5, killing 1 person and destroying crops and properties. In March 2015 cyclone Pam hit Vanuatu as a category 5, killing about 8 people and lots of properties.

**Coastal Morphology and Processes**

Study of the coastal morphologies and processes acting on the coastlines of Foa and Lifuka suggested a delicate balance between east facing beaches and those on the western side. The eastern coastlines of Foa and Lifuka face the dominant SE wind direction and waves it generated. Current determinations along the coasts of Foa and Lifuka Islands suggest strongly that the beaches on the western coastlines are being fed from sediment derived at the eastern coastline (Figures 12 & 13). Observations of littoral current acting in the channel areas (Nukunamo-Foa; Lifuka- Uoleva), showed a dominant east to west flow at both low and high tides.

**Figure 12: Current pattern determined along Foa, the Foa-Nukunamo and Lifuka-Foa channels.**
The above pattern suggests that the channels act as a link in balancing sediment generated at the eastern coastline and the beaches on the western coastline. Refer to Appendix C for GPS locations of sites for current determinations.

**Figure 13: Current flow regime around Lifuka’s coastline.**

With wind from the easterly direction, the pattern of currents at Lifuka–Uoleva channel was determined to be similar to that at Foa-Nukunamo channel. The flow direction of water in the channel remained from east to west at both low and high tides. At the SW corner of Lifuka Island, the flow converged to build a sand spit. The overall flow pattern on Lifuka suggests an anticlockwise pattern of sediment distribution which is also similar to that determined for Foa Island. The distribution pattern also demonstrates the influence of coastal geomorphology on wave pattern and final littoral current flow directions.

The two current patterns recorded on Foa and Lifuka have acted independently of each other for centuries. The building of the causeway in 1978-1979 connected these two processes into one cell,
leading to a shift in the current pattern timing and distribution pathway of sediment along the shores of the two islands.

Climate Change and Coastal Erosion

Sea level rising is threatening the coastline of small Pacific Islands in the Pacific through inundation, coastal erosion, freshwater contamination and changing marine habitat. Most of the low lying islands of the Pacific, including Lifuka need to be prepared to adapt to this new challenge (Fig 14).

Figure 14: Lifuka Island. The photos exhibit severe coastal erosion in areas near wharf and at the Palace coastline (western coastline). The right photo shows the seawall in front of the Palace is being overtopped during high water tide.

The island of Lifuka in the Kingdom of Tonga is low lying with its highest elevation at about 17m was identified through its JNAP program (2010) as one of the most vulnerable areas in its group of islands, due to inundation and coastal erosion caused by sea level rise. It was noted from recent studies (Kitekei’aho, 2010 and PASAP Report, 2015) that onset of coastal erosion at Lifuka may have been initiated by introduction of manmade structures to its coastline in 70s and 90s. The earlier structure consisted of the Foa Causeway and the latter was the construction of the new wharf at Pangai. In 2006, an earthquake equal to about 7.9 magnitudes caused a downthrown of the western coastline of Lifuka by about 23cm (Cummins et al. 2006). Subsequently, the western coastline of the island of Lifuka was immediately exposed to an accelerated rise in sea level of the same amount. The impact of these events on the western coastline of Lifuka resulted in a loss of coastline up to 40m (PASAP studies, 2013) in some parts due to coastal erosion. See Figure 15 below.

Figure 15: Estimate of coastal erosion on western coast of Lifuka using satellite photos and GPs Positioning.
The current sea level rise is about 3mm/yr worldwide. According to the US National Oceanic and Atmospheric Administration (NOAA), this rate is significantly larger than the averaged sea level rise in the last thousand years and the rate may be increasing. In Ha’apai, the rising sea level is estimated to be much higher than 3mm/yr probably due to combine effects of tectonic tilting, sea level rise and interference of manmade structures on sediment distribution along the western coastlines.

The western coastlines of Foa and Lifuka islands are showing sign of severe coastal erosion (Figure 16 & 17) in some areas. On Lifuka, coastal erosion and sea water transgression is ruining the coastline and properties on the village of Hihifo, while Foa Island is experiencing thinning of sand on its western beaches and totally removed in some areas towards the southern end of the island near the causeway.

Figure 16: Coastal erosion at village of Hihifo, Lifuka Island.
Coastal Protections along Western Coastline

Attempts to minimize the impact of coastal erosion on the western coastline of Lifuka through coastal protection have been practiced in the past. Going from north to south, the first coastal protection is a cement bags revetment to protect the road from being eroded at Holopeka was built in 2013. The second coastal protection is the seawall at the southern side of the wharf to southern end of the Palace, was possibly built in 1980s. The third attempt is another sandbag revetment to protect the hospital at Hihifo and was built in 2013. Refer Figure 18 for locations of these coastal protection structures.

Figure 17: Severe coastal erosion at southwestern end of Foa Island, near the Causeway.

Figure 18: The island of Lifuka showing position of three existing coastal protection structures along the western coastline.
**Holopeka Cement Bag Revetment**

This structure is positioned adjacent to a deep water channel near the toe of the structure. The deep water offers waves with longer wave length (cyclone) to recharge itself as it attacks the structure.

Figure 19 shows the condition of the structure at 30th March 2015. The northern end of the structure has acted like a groyne and trapped sediment from migrating southward to build a beach (left photo), resulting in sediment starvation at the southern end of the structure. Continuous attacking of waves at this end of the structure resulted in collapse of the structure and erosion at this end (right photo).

**Figure 19: Holopeka Cement bag revetment breaking down. There is sand accumulation on northern end while erosion is pervasive on southern end of the revetment.**

The above scenario confirms that sediment distribution along this coastline is from north to south.

**Palace Sea Wall**

This is a vertical structure compared to a revetment that extended from the new wharf southward to the end of the Palace. The structure’s usefulness appeared to have expired with high water level frequently topping the structure and attempt to undercut the structure from both front and back. As a result the structure has begun to collapse in places (Fig 20).

**Figure 20: Left photo shows Old Seawall is broken down and overtopped at High tide. Middle photo shows the Palace. Right photograph shows old seawall broken down in front of palace.**
The proposed action is to replace the sea wall at this length of coastline with a rock revetment.

Hospital Cement Bag Revetment

This cement bag revetment has passed the test after cyclone Ian a category 5 cyclone hit the Ha’apai Group in January 2, 2014.

The cement bag revetment was built as community project at a cost of about $700,000 pa’anga. Figure 21 shows the condition of the coastal protection on 30th March 2015. About 80% of the structure is still in reasonably good condition.

Figure 21: Hospital Cement Bag revetment. The northern end is showing sand accumulation while the southern end is showing collapsed tower structure due to erosion.

As seen on the Holopeka structure, the northern end of the Hospital structure has acted to trap most of the sediment brought southward by the by the littoral current to build a beach. On the southern end though the structure is breaking up with part of the TCC tower being severely damaged and its vertical wall collapsed.

Coastal Geomorphology

Determination of coastal line variability was carried out between 27th and 28th of March by re surveying of beach profile lines set up during the PASAP study.

The variation on shape of the profiles can be interpreted as caused by seasonal changes due to wave and wind directions, beach mining, cyclone, earthquake and finally by interference of man-made structure on coastal processes. The earthquake in 2010 recorded a 23cm vertical drop of the western coastline relative to land on the east. This resulted in a sudden sea level rise which allowed natural
processes and wave energy to re shape and re configure the coastline of Lifuka. This is on top of a coastline that is suffering from rising sea level and sediment starvation.

The changes in the shape of the beach profiles would provide clue whether the coastline is retreating or growing in width. Figure 22 shows locations of bench marks (BM) on Lifuka’s western coastline.

*Figure 22: Showing the locations of the Bench Mark (BM) for the beach profiles.*

![Figure 22](image)

The following Figures (23a to 23f) shows the repeated surveys conducted on these lines (Zulfikar, 2014).

*Figure 23a: Benchmark 1*
Most of the changes observed at BM 1 resulted from land reclamation and construction of a sandbag revetment. During the first phase of the survey, erosion and inundation were evident in the hospital compound, mainly in front of the ward section. During high tide, seawater was seen to be reaching the vegetation line, and the two water tanks nearest to the lagoon were undercut by erosion. This prompted action from the government and reclamation was initiated, with temporary protection using cement mix sandbags. With regard to beach morphology, minimal change was observed. The structures has caused collapsed to TCC wall at the southern end of the revetment.

**Figure 23b: Benchmark 2**

![Repeated beach profiling BM2](image)

Changes in beach morphology were observed for benchmark 2, at the old store in Ha'ato'u. Data from the survey show that the width of the beach decreased over the survey period. The decrease was observed after TC Cyril in February, 2012. Waves from the cyclone may have washed the sand away, probably southwards. As a result, waves now frequently reach the vegetation line during high tides. This also affects nearby homes.

**Figure 23c: Benchmark 3**

![Repeated beach profiling BM3](image)
Benchmark 3, located at the King’s Palace, shows some changes to the morphology of the profile line. Noted was an increase in height resulting probably from soil and aggregates accumulating after TC Cyril. Minor erosion was observed on the scarp. A few palm trees were observed to have fallen over in that area as a result of the erosion.

**Figure 23d: Benchmark 4**

![Repeated beach profiling BM4](image)

Only three phases of survey were completed for benchmark 4 at the police station. The reference point was removed due to extension of the police building; therefore, surveys could not be repeated. It can be noted that there were minimal changes to the morphology of the profile. Boulders and concrete slabs have been placed on the beach face and there is sea-wall protection, which shelters the beach and land from high-energy waves.

**Figure 23e: Benchmark 5**

![Repeated beach profiling BM5](image)
The survey on this Benchmark did not show much change in morphology. An increase in height during phase 4 was a result of disturbance due to overgrown vegetation. With regard to erosion, beach size did not alter but the scarp next to the vegetation seemed to be increasing. This was evident after TC Cyril.

Figure 23f: Benchmark 6

In BM 6, some changes were observed on the third phase of the survey. Large amounts of sand were piled up on the beach face, probably during TC Cyril. In later parts of the survey, the area seemed to normalising. Beach size remained consistent. Minor or minimal changes in the morphology were noted.

**BIOLOGICAL RESOURCES**

The main biological resources considered in this analysis include the coral reefs and the reef organisms that live in them.

**Coral Reef Habitats**

Coral reefs serve at least four major functions to island communities. First they form physical barrier to protect islands from rapid erosion due to ocean waves, secondly they provide habitat for large biological communities, act as sediment supply and thirdly they provide tourist attraction for island economies.

Figure 24 below showed the LIDAR bathymetry map of western coastline of Lifuka. The map depicted a large reef flat on this coastline with a break which was dredged as a channel to the main wharf.
In order to fulfill its four main functions mentioned above reefs need to be healthy. The status of the reef and other habitats within the Lifuka lagoon were determined from previous study conducted under PASAP (2010) program which used underwater photographs, satellite images and visual interpretation of two WorldView images, and the current study.

The PASAP (2010) study found the marine environment to consist of about eight zones (counting land as defined by NOAA) and seven structures (Fig 25). The biological cover types (corals, seagrasses and algae) on the other hand, were extracted through unsupervised classification of the satellite image, with the three broad categories further separated into three density classes for mapping purposes.

Figure 24: Map showing the LiDAR bathymetry used in conjunction with the WV2 satellite image to derive the habitat maps.

Figure 25: Habitat map of zone classes, Lifuka Island, Tonga
The major benthic categories are portrayed in Figure 25 below which was based on analysis of underwater photos and under water diving.

![Major Benthic Categories (%) n=607](image)

**Figure 26**: Major benthic categories resulting from analysis of 607 photos. Substrate includes sand, rock, rubble and dead coral.

Figure 26 indicates that substrate which is consisted mainly of sand, dead coral and rubbles is the most abundance. This is followed by seagrass at about 23%, live coral at about 15% and algae formed the least abundance at about 10%.

This EIA study established three monitoring lines in the areas proposed for the rock revetment protection (Figure 27a & 27b). Locations of transects lines were located with GPS. Lines were extended from these locations seaward at 90° to the coastline with a length of about 100m. The main purpose is to record biological assemblages along the lines. Epiphytes coverage on seaweeds was recorded as indicative of level of sedimentation in the area and relative health of the habitats. These lines would be very useful in determining the impact of the proposed action on habitats and living organisms in areas immediate to the structure during the monitoring period.
TRANSECT LINE 1:

**Sediment type** – sandy-mud with rubbles

**Habitat** – Intertidal areas covered by seaweed and seagrass

**Depth** – average <1 meters (low tides)

*Sargassum spinuligerum* brown seaweed was found to be scattered around within 10m whereas seagrass (*Halodule sp & Thalassia testudinum*) and green (*Halimeda sp*) and brown (*Padina sp*) seaweed also found to be high density toward 100 m (Fig 26). Within 30 – 50 m transect, epiphytes were found to be totally 100% cover of the seaweed and seagrass bed with decreasing toward to the coastal areas (50 – 100 m). For edible marine organisms found at the site 1, ark shell and cockles were the main invertebrate able to collect during site assessment.

*Figure 28: Typical habitat found on Transect Line 1.*

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TRANSECT LINE 2

**Sediment type** – sandy & sandy-mud with rubbles

**Habitat** – Intertidal areas covered with seagrass & seaweed include scattered of coral boulders

**Depth** – average 1.5 m (low tides)

*Sargassum sp* seaweed dominant the first 50 m with scattering around of coral boulders whereas seagrass (*Halodule spp & Thalassia testudinum*) and other seaweed (*Padina spp & Halimeda spp*) found to be high abundance toward 100 m line (Fig 27). Epiphytes covered also found to be decreasing along the transect line toward the 100 m. None any of the cockles were found at transect 2.

*Figure 29: Typical Habitat on Transect Line 2.*
TRANSECT LINE 3

Sediment type – sandy with rubbles

Habitat – Intertidal areas covered with seagrass & seaweed and coral rubbles

Depth – average 2 m (low tides)

Within the first 40 m, dominant by sand with scattered around of seagrass bed (*Halodule spp* and *Halophila ovalis* but in low density. Toward 40 – 70 m transect, high density of Sargassum spp seaweed were located whereas coral rubbles dominated 70 – 100 m which also exposed during low tides. In term of edible marine organisms, only hard buried crab *Clappa spp* was found close to the beach within 0-10 m line.

**Figure 30: Typical Habitat for Line 3 is shown in below.**

<table>
<thead>
<tr>
<th>0 – 15 m</th>
<th>15 – 40 m</th>
<th>40 – 70 m</th>
<th>70 – 100 m</th>
</tr>
</thead>
</table>

Table 2: List of edible marine organisms found at the samples sites

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antique ark</td>
<td><em>Anadara antiquata</em></td>
<td>Kaloa’a</td>
</tr>
<tr>
<td>Re mussel</td>
<td><em>Modiolus spp</em></td>
<td>kuku</td>
</tr>
<tr>
<td>Elongate cockle</td>
<td><em>Acrosterigma elongatum</em></td>
<td>tuahi</td>
</tr>
<tr>
<td>Pacific tiger lucine</td>
<td><em>Codaakia tigerina</em></td>
<td>tulalo</td>
</tr>
<tr>
<td>Buried hard crab</td>
<td><em>Calappa spp</em></td>
<td>tafola</td>
</tr>
</tbody>
</table>

Reef Inhabitants

The lists of marine organisms were prepared with assistance from the previous meetings with the five communities of Lifuka. The flora and habitat were prepared from diving and photographs taken during the PASAP study and the EIA study on 30th to 31st March 2015.
Reef Fish

Reef fish is one of the major inhabitants of the coral reef ecosystem in Tonga. In the Ha’apai Group, the following species can be found;

Table 3: Finfish of Ha’apai Group

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Local names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon fish (5 species)</td>
<td>‘Ume, Pone, Manini</td>
<td>Acanthurus sp</td>
</tr>
<tr>
<td>Parrotfish (3 species)</td>
<td>Hohomo, Lalafi</td>
<td>Scarus sp</td>
</tr>
<tr>
<td>Goatfish (2 species)</td>
<td>Vete</td>
<td></td>
</tr>
<tr>
<td>Rabbit fish (3 species)</td>
<td>Oo</td>
<td>Siganus sp</td>
</tr>
</tbody>
</table>
### Table 4: Molluscs of Ha‘apai Group

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Local Names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bivalves</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant clams (4 species)</td>
<td>Vasuva</td>
<td>Tridacna sp</td>
</tr>
<tr>
<td>Oysters</td>
<td>Ufu</td>
<td>Atrina vexillum</td>
</tr>
<tr>
<td><strong>Gastropods</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trochus shell (2 species)</td>
<td>Takaniko</td>
<td>Trochus sp</td>
</tr>
<tr>
<td>Greensnail (2 species)</td>
<td>‘Elii</td>
<td>Turbo sp</td>
</tr>
<tr>
<td>Turbinella shell</td>
<td>Pule / Kele’a</td>
<td>Thais sp / Vasum sp</td>
</tr>
<tr>
<td><strong>Octobus</strong></td>
<td>Feke</td>
<td>Octobus sp</td>
</tr>
</tbody>
</table>

### Table 5: Crustaceans of Ha‘apai Group

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Local names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lobsters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banded lobster</td>
<td>‘Uo Tonga</td>
<td>Panulirus penicillatus</td>
</tr>
<tr>
<td>Painted rock lobster</td>
<td>‘Uo Fisi</td>
<td>P.versicolor</td>
</tr>
<tr>
<td>Coral lobster</td>
<td>‘Uo Tavake</td>
<td>P.longipes</td>
</tr>
<tr>
<td>Slipper lobster</td>
<td>Tapatapa</td>
<td>Parribacus sp</td>
</tr>
<tr>
<td><strong>Crabs</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Seven eleven crab  
  Pakatea  
  Arpilius maculatus

Table 6: Echinoderms of Ha’apai Group

These slow moving species are vulnerable to sediment plume. They are exclusively bottom dwellers.

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Local names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sea stars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Blue star</td>
<td>Mangamanga-‘a-tai</td>
<td>Linckia laevigata</td>
</tr>
<tr>
<td>• Featerstar</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sea urchin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Banded urchin</td>
<td>Vanamea</td>
<td><em>Echinotrix calamaris</em></td>
</tr>
<tr>
<td><strong>Sea cucumbers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lollyfish</td>
<td>Loli</td>
<td><em>Holothuria atra</em></td>
</tr>
<tr>
<td>• Greenfish</td>
<td>Holomumu</td>
<td><em>Stichopus chloronotus</em></td>
</tr>
<tr>
<td>• Tigerfish</td>
<td>Matamata</td>
<td><em>Bohadschia argus</em></td>
</tr>
<tr>
<td>• Surf redfish</td>
<td>Teleheka kula</td>
<td><em>Actinopyga mauritiana</em></td>
</tr>
<tr>
<td>• Deepwater surf redfish</td>
<td>Pulukalia</td>
<td><em>Theleona ananas</em></td>
</tr>
<tr>
<td>• White teatfish</td>
<td>Huhuvali hinehina</td>
<td><em>H. fuscogilva</em></td>
</tr>
<tr>
<td>• Black teatfish</td>
<td>Huhuvali ‘ui’uli</td>
<td><em>H. nobilis</em></td>
</tr>
<tr>
<td>• Stonefish</td>
<td>Mokohunu maka</td>
<td><em>Actinopyga miliaris</em></td>
</tr>
</tbody>
</table>

Aside from reef fishes and the class cephalopods which have high mobility, the rest of the phyla are bottom dwelling and less mobile. These invertebrates are most vulnerable to sudden change in their living environment and significant increase in sedimentation could be detrimental to some of them.

Table 7: Marine Plants and algae of Ha’apai Group

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Local names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seaweeds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Brown seaweed</td>
<td>Limu</td>
<td><em>Sargassum echinocarpum</em></td>
</tr>
<tr>
<td>• Fan-leaf seaweed</td>
<td>Limu</td>
<td><em>Padina japonicus</em></td>
</tr>
<tr>
<td>• Green turf-algae</td>
<td>Limu</td>
<td></td>
</tr>
<tr>
<td>Seagrasses</td>
<td>Limu</td>
<td>Halimeda sp</td>
</tr>
<tr>
<td>---------------------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>Turtle seagrass</td>
<td>Limu-'ae-fonu</td>
<td>Halodule sp/Thalassia sp</td>
</tr>
<tr>
<td>Spoon seagrass</td>
<td>Limu</td>
<td>Halophila ovalis</td>
</tr>
</tbody>
</table>

**Fishing activities and Potential aquaculture activities**

Based on the information provided by the local fishers, collecting ark shell and cockles were the main fishing activities carried-out at the study areas (Site 1 & 2) during low tide especially women. The cockle shell *Gafrium tumidum* know locally “To’oteka”, was originally reported to be abundant in the area were not found in this site assessment. Other species such as sea slugs known localy as “Mulione” also reported as one of the target invertebrates collecting during night for local consumption were also difficult to find during the site assessment. Apart from collecting invertebrates, gillnet fishing also exist especially during scud mackerel season (i.e. known locally “Otule”) which normally carry-out at site 3. Other target species especially Marbled parrotfish (known locally ‘Ufu) is also fished using gillnet at the seagrass bed around site 1 & 2 frequently.

![Photo 1: Edible marine organism found at the study areas (Transect Line 1 & Line 2).](image)

For Aquaculture activities, the study areas was also mapped as one of potential areas for aquaculture activities at Lifuka Island and is listed under Aquaculture Management Plan 2015 for farming of seaweed, *Euchema sp* (Photo 2). Based on the Aquaculture Research, Fisheries Division, pilot study result which currently carried out at Site 2, growth rate of seaweed was found to be very low due to high percentage covered of epiphytes. Epiphytes can also cause growth of high risk seaweed that cause disease known as “Iceice” is not favorable for seaweed farming in the future.

![Photo 2: Aquaculture activities on Transect Line 2](image)
Findings and Results at the study area for considerations

- Highly indication of sediment runoff due to the recognition of high percentage of epiphytes covered at the study areas and could be associated with the chronic land erosion in this coastline and slow moving current in the area.
- All the marine shellfish found at the study areas had filter feeding mechanisms which could be affected due to the sedimentation runoff activities.
- Finfishes would not be at risk due to their mobilization nature, which can be omitted bad condition during the development activities.
- Seaweed farming will not be recommended to the farmers due to high sedimentation problem, which will cause high risk for disease outbreak (i.e. Iceice disease).
- High density of seagrass bed and seaweed as an indication of high nutrient input at the study areas.

SOCIAL SYSTEM
The primary social systems of concern in this assessment include remittances, Tourism, fisheries, handicrafts and Human Health.

Remittances

Like Tongatapu, remittances play a major role in the lives of Lifuka people. Lifuka people received remittances from three types of migrants. Because the Ha’apai Group of islands is close to Tongatapu, most Ha’apai people have now reside on main island Tongatapu. Ha’apai people with jobs at Tongatapu send money back to their family at Ha’apai. The second type of remittance comes from Ha’apai people living overseas and the third type is from rugby players playing overseas. The communities of Koulo and Holopeka are having a partnership in sending rugby players to play in clubs in Europe.

According to the 2011 census the total population of Tonga was at 103,036 and about 7% of this live in Ha’apai Group. While Tongatapu’s was increasing at 0.8% the population fo Ha’apai was decreasing at 2.6% from last census. The threat of sea level rise might cause paranoia amongst the people and could trigger mass migration which would lead to downward spiral in the remittances to the group, causing further damages to the ailing economy of the Ha’apai group.

Tourism

The sandy beaches and pristine water of the Ha’apai Group of Islands offer the best attraction to tourists. The other attraction is offered by the large number of whales that migrated up north from the cold water of Antartica. As a result of climate change the changing water temperature has seen more whales in the Ha’apai water compared to Vava’u Group up north. According to members of the communities, Ha’apai’s economy can improve more on tourist arrivals if airport is extended for larger
plane to arrive safely and timetable is adhered to. They also think that unreliable scheduling of aircraft which led to lots of cancellation may affect Ha’apai’s tourism and its fragile economy.

**Fisheries**

Reef fishery is a common practice in the Ha’apai group which includes activities at commercial and subsistence level. Most of the fish sold at the wharf come from day or night spear diving. The variety includes parrot fish species, leather jacket, groupers, crayfish and snappers.

Ha’apai inshore fishery methods include lobster diving, night or day spear diving, giant clam diving, net fishing and hand lines fishing. According to discussion during the Scoping Meeting most inshore fishery methods used in the reef included day or night spear diving, net fishing, hand lining and other forms of local fisheries on the reef flat including fakahe lomu, tufi loli (collecting sea cucumber), tuki hulihuli, a’afeke, and fangota kaloa’a, paki kuku, giant clam diving and so on. Fishing for Holothurian species is being a big business carried out by few divers when in season.

**Handicraft**

A recent trend identified in the PASAP study is a move towards weaving by ladies instead of going out reef fishing. This trend includes men abandoning agricultural activities and joined their partners in processing the leaves for weaving. This trend is driven by demand from Ha’apai migrants overseas on mats and other handicrafts which are paid reasonably well compared to traditional economic units like fishes and agricultural products. The overall impact of this trend is to discourage ladies from reef fisheries and men from going out farming. This is evident from observations made during the PASAP study on reef flat fishery. It was noted that number of people engaged in this type of fishery was very low. Furthermore, the market where agricultural products are on sale, were deficient of agricultural products leading to market being closed very early every day.

**Human Health**

There is no major endemic at Lifuka that this proposed action would assist in its spreading. However, fish related diseases such as ciguatera was reported by participants in the Scoping Meeting in Foa (Kitekei’aho, 2010) to have occurred in the surgeon fish species (pone) at areas near the causeway. The likely causes of this disease maybe many but one cause could be attributed to the toxic environment created on the western side of the causeway due to lack of channels for distribution of good nutrients and water circulation in this area. The proposed action is unlikely to cause such a condition on site and therefore not considered as threat on health.
IV. ENVIRONMENTAL CONSEQUENCES AND MITIGATION

The purpose of this Section is to identify and consider the most pertinent environmental impacts and to provide possible mitigation measures that are expected from the taking the proposed action. Should the structure be extended in the future to cover the whole coastline, an EIA will need to be conducted to deal with the associated changes in scale of the structure. The method for the risk analysis was adopted from Bosko et al (2014) and is summarized below.

Development of Mitigation Options

The flow adopted for developing this Chapter is as follows.

Figure 31: Identification, Evaluation and Development of Mitigation Options

Alternative 1: Proposed Action- Rock Revetment

This alternative reflects the outcome in the event that the Rock Revetment is built at the proposed site. Potential impacts of this event on the physical environment, biological and social systems are evaluated at this section according to the three phases of the project;
Impact Identification, Classification and Prioritization

For critical environmental impact assessment and timely mitigation of environmental issues, it is important that analysis of the project related activities along with anticipated environmental and social impacts, prior to construction.

Projects Timelines

The likely project timelines are given in Table 8. It gives the list of activities that are likely to take place at various stages of the project. The location and design phases are regarded to go hand in hand and as a result the impacts due to location and design have to be mitigated together.

Table 8: Project Timelines

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN ACTIVITIES</td>
<td>Site Preparation/ Delivery of correct sizes (1m-2m) rock to site</td>
<td>Tree Cutting or relocation/ digging shaping of slope/ laying of graded filter / laying of secondary armour/ bury toe 1m into coral substrate/laying of primary armour/development of 8m crest</td>
<td>Monitoring effectiveness/transect line/ beach profiling</td>
<td>6 monthly/ yearly/ 3 yearly/5 yearly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning/ Location</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phasing of Activities

Table 9: Phasing of Activities

<table>
<thead>
<tr>
<th>LIST OF ACTIVITIES</th>
<th>Location/Planning</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANNING/LOCATION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine availability of</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Impacts Due to Location/ Planning**

The activities to be carried out due to location of the site along with possible impacts are given below in Table 10.

**Table 10: Location - Activities and Impacts**

<table>
<thead>
<tr>
<th>Activities to be carried out</th>
<th>Description of Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Determining availability of correct rock sizes</td>
<td>Using coral rocks less than required sizes would reduce effectiveness of the structure and would generate fined sediment plume that would affect sea-grass and nearby habitat in the areas. Furthermore a damaged structure would cause an eye sore when the affected coastline would be covered with rock and boulders rather than</td>
</tr>
<tr>
<td>2  Tree Clearance/replanting</td>
<td>The site is covered with ironwood, ovava trees and other beach trees. The fauna and flora in this coastline will be loss permanently if they are in the way of the structure. Replanting will offer secondary protection to the rock revetment.</td>
</tr>
</tbody>
</table>

**Impacts during Construction Phase**
The activities to be carried out due to construction along with possible impacts are given below in Table 11.

**Table 11: Construction Phase- Activities and Impacts.**

<table>
<thead>
<tr>
<th>Activities to be carried out</th>
<th>Description of Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Restrict construction to low tide/compliance with EIA</td>
</tr>
<tr>
<td>2</td>
<td>Use of Heavy Machineries</td>
</tr>
<tr>
<td>3</td>
<td>Digging and sloping of the structure</td>
</tr>
<tr>
<td>4</td>
<td>Laying of secondary armour and toe of structure</td>
</tr>
<tr>
<td>5</td>
<td>Laying of secondary armour</td>
</tr>
<tr>
<td>6</td>
<td>Laying of 8m crest</td>
</tr>
<tr>
<td>7</td>
<td>Covering of Toe and Upper slope with sand</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities to be carried out</th>
<th>Description of Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monitoring</td>
</tr>
<tr>
<td>2</td>
<td>Coastal erosion on either ends of the structure</td>
</tr>
<tr>
<td>3</td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

**Impacts during Operation Phase**

The activities to be carried out due to operation along with possible impacts are given below in Table 12.

**Table 12: Operation Phase- Activities and Impacts.**

<table>
<thead>
<tr>
<th>Activities to be carried out</th>
<th>Description of Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monitoring</td>
</tr>
<tr>
<td>2</td>
<td>Coastal erosion on either ends of the structure</td>
</tr>
<tr>
<td>3</td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

**Evaluation and Classification of Impacts**
Prediction of impacts of the proposed project has been done by modified Leopold interaction matrix method. In the conventional Leopold matrix method, an interaction matrix is compiled with project action on the horizontal axis and environmental parameters on which impact can occur on the vertical axis. The modified Leopold matrix created for this project portrays anticipated intensity of positive and negative impacts for each activity. To estimate and prioritize severity of impacts a multi criteria analysis based on influences of the activity on the environment have been use. The various types of influences that have taken into consideration for the prediction are shown below on Figure 32.

**Project Activities – Influence & Impact Evaluation**

**Figure 32: Project Activities- Influences and Impact Evaluation.**

The following are the definitions of influences which have been used in impact evaluation.
### PROJECT ACTIVITIES INFLUENCES and WEIGHTAGES

#### Table 13: Details of Project Activities Influences

<table>
<thead>
<tr>
<th>INFLUENCE</th>
<th>DEFINITION</th>
<th>SYMBOL</th>
<th>WEIGHTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT</td>
<td>Direct impacts are those that are resultant directly due to the project activities</td>
<td>D</td>
<td>4</td>
</tr>
<tr>
<td>INDIRECT</td>
<td>Indirect impacts are those that arise not directly due to project activity, but alter the surrounding system which in turn affect the environment</td>
<td>ID</td>
<td>2</td>
</tr>
<tr>
<td>SYNERGISTIC</td>
<td>Impacts which have both direct and indirect impacts are called synergistic. These impacts are considered more serious</td>
<td>SYN</td>
<td>6</td>
</tr>
<tr>
<td>LOCAL</td>
<td>If the impacts are within the development zone, then it is termed as local</td>
<td>L</td>
<td>2</td>
</tr>
<tr>
<td>STRATEGIC</td>
<td>If the activities create an impact would affect the performance of the entire functional level of adopting areas, downstream/upstream areas, it is termed as strategic impact, irrespective or their intensity</td>
<td>S</td>
<td>4</td>
</tr>
<tr>
<td>SHORT TERM</td>
<td>Some of the activities carried out are of short duration. During the construction activities, there would be some amount of inconvenience that would not be there in the operation phase and are termed as short term.</td>
<td>ST</td>
<td>2</td>
</tr>
<tr>
<td>LONG TERM</td>
<td>During the operation stage there would be inconvenience and impacts that would be more of a regular nuisance to people in the surrounding area. These are terms as long term. Impacts in this phase could also be positive like in this case socio-economic development of the region. However, this case only the negative impacts are taken into account for counting.</td>
<td>LT</td>
<td>4</td>
</tr>
</tbody>
</table>

**NOTE:**

Each of these influences has been given a weight based on expert judgment (DEAT, 2006) and professional experience of the author. Most of the impacts have a probability of occurrence which has also been taken into account for this study. Where the probability of occurrence is very low then probability is 1, low probability is 2; medium probability is 4, high probability is 6 and extremely high (definite) the probability weight is 8.

The next step is the calculation of the ‘Overall Significance of Impact’ parameter, using the formula below:

\[
\text{Overall significance equal} = (\text{mode} + \text{duration} + \text{area} + \text{type}) \times \text{probability}
\]

52
### Overall Significance of Impact

#### Table 14: Evaluation - Overall Significance of Impact

<table>
<thead>
<tr>
<th>No</th>
<th>Action affecting Environmental Resources and Values</th>
<th>Possible effects on the Environment</th>
<th>Influences</th>
<th>Frequency/Probability of Occurrence</th>
<th>Overall Significance of impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mode</td>
<td>Duration</td>
<td>Area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D</td>
<td>ID</td>
<td>SYN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Determining availability of correct rock sizes</td>
<td>Causing sediment plumes &amp; rocky beach</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Tree clearance</td>
<td>Loss of trees and vegetation in project area</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Injuries and loss of lives</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Access to Palace land</td>
<td>May cause damages to other areas</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Use of Heavy machineries</td>
<td>Increase noise</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Injuries</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Air pollution</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Compliance</td>
<td>Flooding/inundation</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Digging and sloping for structure</td>
<td>Destroy &amp; disturbance of fauna and flora on site</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Laying of secondary armour</td>
<td>Injuries/loss of lives</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Laying of Primary armour</td>
<td>Injuries/loss of lives</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Laying of crest</td>
<td>Injuries/loss of lives</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Replanting</td>
<td>Offer secondary protection</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Coastal erosion at downstream end of structure</td>
<td>Construct groyne field at two ends of the structure with reducing length away from structure</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>Filling of toe and Upper area with sand</td>
<td>Injuries</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Compliance / Monitoring</td>
<td>Groundwater pollution</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Marine pollution</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Injuries</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Noise pollution</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Air pollution</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Prioritization of Impacts and Identification of Environmental Sectors**
Having evaluated the impacts, the impacts were prioritized into four different categories depending upon the numbers arrived at the evaluation of overall significance of impact for each of the impacts.

Here again the expert opinion/professional experience of similar projects which are already in operation was used to categorize the impacts. The four categories are given below.

<table>
<thead>
<tr>
<th>SEVERITY LEGEND</th>
<th>MASSIVE</th>
<th>SUBSTANTIAL</th>
<th>SIGNIFICANCE</th>
<th>TANGIBLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 70</td>
<td>41-70</td>
<td>16-40</td>
<td>5-15</td>
<td></td>
</tr>
</tbody>
</table>

This prioritization is necessary to gauge the severity of impacts so as to arrive at appropriate mitigation measures.

Table 15 to 17 identified possible effects on the environment have been arranged along with natural resources affected for the three phases namely location, construction and operation phases. The various natural resources (environmental components) which have been identified to be likely affected are biodiversity, groundwater, sea, energy, social-cultural noise, air and health & safety.

Location/Planning

Table 15: Location-Impact Matrix

<table>
<thead>
<tr>
<th>STAGE OF PROJECT</th>
<th>POSSIBLE EFFECT ON ENVIRONMENT</th>
<th>ENVIRONMENT COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION/PLANNING</td>
<td>Determining availability of correct rock sizes</td>
<td>Biodiversity</td>
</tr>
<tr>
<td></td>
<td>Loss of trees and fauna on project site</td>
<td>Biodiversity</td>
</tr>
<tr>
<td></td>
<td>Injuries/loss of lives</td>
<td>Health &amp; Safety</td>
</tr>
<tr>
<td></td>
<td>May cause damage to other areas</td>
<td>Socio-cultural</td>
</tr>
</tbody>
</table>

Construction Phase

Table 16: Construction Phase Impact Matrix

<table>
<thead>
<tr>
<th>STAGE OF PROJECT</th>
<th>POSSIBLE EFFECT ON ENVIRONMENT</th>
<th>ENVIRONMENT COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTRUCTION PHASE</td>
<td>Noise Pollution from heavy machineries</td>
<td>Noise</td>
</tr>
<tr>
<td></td>
<td>Injuries/loss of lives</td>
<td>HSE</td>
</tr>
<tr>
<td></td>
<td>Air pollution</td>
<td>Air</td>
</tr>
<tr>
<td></td>
<td>Flooding/inundation</td>
<td>Social/Groundwater</td>
</tr>
<tr>
<td></td>
<td>Disturb and destruction of fauna on</td>
<td>Biodiversity</td>
</tr>
</tbody>
</table>
Injuries due to laying of Secondary armour | Health & safety/Environment (HSE)
---|---
Injuries due to laying of Primary armour | HSE
Injuries due to laying of toes | HSE
Coastal erosion at ends of the structure | Physical
Offer secondary protection due to replanting | Biodiversity
Injuries due to laying of crest | HSE

### Operation Phase

#### Table 17: Operation Phase Impact Matrix

<table>
<thead>
<tr>
<th>STAGE OF PROJECT</th>
<th>POSSIBLE EFFECT ON ENVIRONMENT</th>
<th>ENVIRONMENT COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATION PHASE</td>
<td>Ground water pollution due to waves overtopping causing inundation</td>
<td>Ground water</td>
</tr>
<tr>
<td></td>
<td>Marine Pollution</td>
<td>Biodiversity</td>
</tr>
<tr>
<td></td>
<td>Injuries/loss of lives due to maintenance works</td>
<td>HSE</td>
</tr>
<tr>
<td></td>
<td>Noise Pollution due to maintenance works</td>
<td>Noise</td>
</tr>
<tr>
<td></td>
<td>Air Pollution due to maintenance works</td>
<td>Air</td>
</tr>
</tbody>
</table>

### Mitigation Measures

The severity of impacts identified to range from tangible to massive. The most probable issues identified in these sections for various activities have been found to originate from various sources like project location/planning, construction of project and project operation, and will depend on factors like awareness amongst personnel implementing the project and capacity of developmental and regulatory agencies. The evaluation and prioritization of environmental issues have been carried out as well as cross linkages with environmental components (Tables 18 to 24). With the help of these section outputs, the current section has been developed to show case the various mitigation steps that have been arrived at to minimize the environmental impacts.

#### Table 18: Environmental sector- Biodiversity
MITIGATION OPTIONS

1. This is the most important part of the project. The availability of correct size rock must be sought out. Large rock will reduce the amount of sediment plume generated and effectiveness of the structure is much improved. The structure must NOT be built with smaller rock size for it would litter the beach in the first cyclone.

2. Avoid removing any large tree if it is not in the way of the structure.

1. Digging and construction of toe of the structure must be restricted to low tide only to avoid generation of sediment plume and disperse by longshore current.

2. Replanting program must accompany the construction of the structure to act as secondary protection.

1. Restrict maintenance work to low tide and avoid delivering quarry dust to site and use correct rock sizes only to avoid generation of sediment plume.

Table 19: Environmental sector- Groundwater

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flooding/inundation</td>
<td>1. Ground water pollution due to waves overtopping causing inundation</td>
<td>1. If structure is at correct size then this would be irregular and contamination to groundwater will be</td>
</tr>
</tbody>
</table>

MITIGATION OPTIONS
not be regular.

Table 20: Environmental sector- Air

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pollution</td>
<td></td>
<td>Air Pollution due to maintenance works.</td>
</tr>
</tbody>
</table>

MITIGATION OPTIONS

1. Vehicles hired for the project must all pass annual test and smoke test. Must also be considered safe on the road.  
1. All vehicle used on site must passed annual test and smoke test

Table 21: Environmental sector-Noise

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Noise Pollution from heavy machineries</td>
<td></td>
<td>1. Noise Pollution due to maintenance works</td>
</tr>
</tbody>
</table>

MITIGATION OPTIONS

1. All trucks and heavy machineries to be used on the project must passed annual test and equipped with silencer to reduce unnecessary noise.  
2. All trucks and heavy machineries must be equipped with silencer to avoid unnecessary noise.

Table 22: Environmental sector- Health, Safety and Environment (HSE)

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Injuries/loss of lives</td>
<td>1. Injuries/loss of lives</td>
<td>1. Injuries/loss of lives due to maintenance works</td>
</tr>
<tr>
<td>2. Injuries due to laying of Secondary armour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Injuries due to laying of Primary armour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Injuries due to laying of toes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Injuries due to laying of crest</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MITIGATION OPTIONS

1. Workers to be involved on the construction must be aware of all safety procedures associated with using of heavy machineries on site. All drivers of heavy machineries and truck must attend a short training of HSE and a list and signatures must be kept by main contractor on site.

2. The operator of the digger must have reasonable experience on using the digger. People must be at safe distance from the arc covered by the arm of the digger. The sand must be dug up and store safely for re-use to cover slope and toe of the structure. Secondary

3. When laying Secondary, primary, toes and crest of the structure workers are required to be at safe distance from where the rock would be placed because they may slide or roll. The crane should do most of the work.

Table 23: Environmental sector- Social/Cultural

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>May cause damages to other areas due to lack of access to Palace</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MITIGATION OPTIONS

1. The operator must have reasonable experience with the machine to place rock safely. People must be kept at safe distance away from the arm of the digger or crane.

Table 24: Environmental sector- Physical Environment
Environmental Sector- Physical Environment

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coastal erosion at either ends of the structure</td>
<td></td>
</tr>
</tbody>
</table>

**MITIGATION OPTIONS**

<table>
<thead>
<tr>
<th>Location</th>
<th>Construction Phase</th>
<th>Operation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At least three groynes of similar design to that employed in Hahake coastal rehabilitation project but with reducing length away from the structure, must be laid at both ends to stop and accumulate sand.</td>
<td></td>
</tr>
</tbody>
</table>

**Alternative 2: Wharf Reconstruction with Sand Replenishment and groyne field**

This **alternative becomes attractive** and worth consideration if the correct sizes of rocks are not available locally for **Alternative 1**, as this will raise cost of the project The option will encourage natural distribution of sediment to resume and would leave behind a much less footprint. The environmental and social impacts are predicted to be at minimum. However, this option requires proper costing and can be considered as a long term solution versus construction of rock revetment for the 2.2 km of coastline once at hand.

**Alternative 3: No Action**

In this case no action will be taken and it is assumed that the present coastal erosion is allowed to continue.

This option does not offer security to the people living at the western coastline of Lifuka. The lack of land for a planned retreat as an option identified in the PASAP study, may lead to mass migration of people out of Lifuka as people are feeling hopeless. Such mass migration would affect the remittance to Ha’apai and could further hurt the ailing economy of the group.

The current coastal protection in critical areas of Lifuka are breaking down and already due for maintenance works. The cost would be too high when cost of eroded land and impact on the social systems are factored in making this alternative very expensive.

Diving in the area in front of the palace, revealed epiphytes to be extensive and covered most of the sea grass and coral in the area. The turbidity was recorded as high. The epiphytes are interpreted to be generated from coastal erosion in the area and therefore may have covered most of this coastline. Such condition would not be conducive to growth of marine organisms in the area. Further study is required.
in this area but it appears that this may contribute to drop in reef fishing on Lifuka’s large reef flat. The deteriorating status of reef ecosystem will also ensure that fisheries will be affected into the future.

It is due to the above that this Alternative is not considered a viable option.
V. ENVIRONMENTAL MANAGEMENT PROGRAM

This section details the environmental management plan (EMP) which will be adopted for the proposed rock revetment. It converses all activities to be carried on the three stages, location, construction phase and operation phase and their impacts on the environment. The EMP is based on existing environmental conditions and impacts assessed earlier in section 4.0. It enumerates set of measures to be taken during implementation and operation to eliminate or offset adverse environmental impacts or to reduce them to acceptable levels together with allocation of responsibility. All contractors and subcontractors taking part in the construction should be made aware of the requirement of the EMP. An EMP for the construction and operation phases of the fuel depot has been prepared and included as Appendix VII

Objectives
The objectives of the EMP are;

- To include all components of the development
- To prescribe the best control methods to lessen environmental impacts associated with different phases of the development.
- To monitor and audit performances of construction personnel in applying such controls
- To ensure that appropriate environmental training is provided to responsible construction personnel.

Key Players for Implementation of EMP

The responsibility for designing the mitigation measures are delegated to the project proponent with advices from Ministry of Environment and Climate Change (MECC). Other Ministries are included as follow;

- Ministry of Forestry or NGO to provide advices on the compensatory plantation
- Ministry of Lands and Survey to define boundary
- Construction Contractor to control issues arising out of construction site which include availability of correct rock sizes and work must be carried out only at low tide. Provide first aid facilities for workers and suitable environment that generates minimum noise and emission. Best work practices in executing work must be adopted at all times

Environmental Management Committee (EMC)

This is a body to be set up by MECC either within or from the private sector. Their main role is to implement the EMP effectively and closely supervise environmental monitoring programmes and to coordinate closely with proponent. EMC will undertake regular monitoring of the environment and conduct yearly audit of the environmental performance during the construction and operation phases
of the project. It will also check that the stipulated measures are being satisfactory implemented and operated.

EMC will manage all environmental related activities on the site. The organizational set-up of EMC is given in Fig 33 below;

Figure 33: EMC structure.

The roles and responsibilities of each EMC officers are given below;

1. **Assistant CEO**

   This will be the Head of the unit and perform following tasks:

   - Report to CEO of MECC
   - Planning and execution of monitoring programs
   - Review report submitted by the monitoring agency, checking the compliance of results with respect to the baseline environmental conditions
   - Procurement and testing of equipments
   - Overview training programs.

2. **Senior 1 (Geological Services)**

   - Report to Assistant CEO
   - Supervise the implementation of water pollution measures and water supply and sanitation
     - Noise and Air pollution
     - Report on site safety and safe workmanship
     - Monitoring Services
     - Training programs
     - Progress report

3. **Senior 2 (Engineering Services)**

   - Report to Assistant CEO
   - Report on compliance to design and HSE
   - Training programs
4. **Senior 3 (Scientist)**

- Report to Assistant CEO
- Laboratory services
- Health services
- Training programs
- Progress report

The EMC may recruit expertise on different component of the environment should there be a need to do so.

**Environmental Management Action Plan**

The detailed Environmental Management Action Plan is given as  *Appendix VII*. 
VI. CONCLUSIONS AND RECOMMENDATIONS

The study concludes that the proposed project would poise limited environmental and social risks. The proposed rock revetment would act as a pilot project to determine the true cost per meter for the structure and its environmental impact.

It is however critical that the correct rock sizes for primary and secondary armor are used and the structure is built to the recommended dimensions. If rocks of recommended sizes are not available then it is recommended that **Option 2** be considered as a viable option in this case.

All environmental risks can be minimized and managed by implementing preventive measures and sound management systems. It is recommended that environmental performances be monitored regularly to ensure compliance and that corrective measures be taken if necessary. It is also recommended that this information be made available to the community of Ha’apai at regular interval.

The workers must be experienced with this type of work especially in heavy machineries and positioning of the secondary and primary armors and toes. Contractor must adopt Health and safety requirement for safe workmanship during implementation of the project.

The EMP should be used as an on-site reference document during all phases of the proposed construction of the rock revetment, and auditing should take place in order to determine compliance with the EMP. Parties responsible for implementation of EMP should be held responsible for any rehabilitation that may need to be undertaken.

With future expansion of the structure to rest of the affected coastline, compliance with environmental, health and safety issue must again be checked and improve where necessary after an EIA study is completed.

**Monitoring Program**

There were two types of baseline data collected to monitor the impact of this project on the environment. First, are the beach profiles, their main purpose is to determine if structure is affecting the gaining and losing of sand downstream and upstream. The second set of data are the biological data collected along the transect lines in front of the site for the proposed structure. Again they would provide any negative impact of the structure on marine organisms and habitats in the nearby area. Such impacts will eventually affect the community’s livelihood if unattended to.

It is therefore recommended that monitoring of the reef flat and conducting beach profiles must be carried out within 3-6 months after construction and 6 months thereafter for a period of 18 months to determine any detrimental effect of the structure on the environment.
REFERENCES

1. Bosko Josimovic, Jasna Petric & Sasa Milijic. The Use of the Leopold Matrix in Carrying Out the EIA for Wind Farms in Serbia. Energy and Environment Research; Vol. 4, No. 1; 2014 ISSN 1927-0569 E-ISSN 1927-0577 Published by Canadian Center of Science and Education


APPENDIX I:

TERMS OF REFERENCE

Consultancy Title:
Consultancy to conduct the Environment Impact Assessment (EIA) for a Proposed Rock Revetment in front of the Palace at Lifuka, Pangai, Ha’apai.

Duration of Consultancy Service:
20 working days

Objective(s):
The Consultant is anticipated to successfully deliver the output(s) of the consultancy service under the direct supervision of the Interim CEO for Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) in close collaboration with government ministries, the Technical Team for the Joint National Action Plan on Climate Change and Disaster Risk Management and also with other relevant stakeholders.

Background:
In Lifuka/Pangai, Ha’apai, much of the socio-economic activities and critical infrastructures are concentrated on the low lying coastal areas which are highly vulnerable to the adverse impacts of climate change and natural disasters. In these areas, for several decades, residents have experienced historical inundation and land loss due to coastal erosion exacerbated by storm surges. Attempts to protect these areas have been piecemeal and inadequately engineered resulting in short-lived benefits.

Lifuka, Ha’apai was severely damaged by that Category 5, Tropical Cyclone Ian in January 2014. Coastal trees were uprooted and sea water not only flooded the roads but also to lower residential areas on the landward side of the main road.

Intervention in this coastal area has been prioritised under Tonga’s Joint National Action Plan (JNAP) for Climate Change Adaptation and Disaster Risk Management, 2010. A feasibility study, coastal design and costing for this coastal area were conducted by the Pacific Adaptation and Strategy Assistance Program which was funded by the Government of Australia under its International Climate Change Adaptation Initiative.. It was implemented by the Secretariat of the Pacific Community under the direction of MEIDECC (former, Ministry of Lands, Environment, Climate Change and Natural Resources, MLECCNR)

An environmental impact assessment (EIA) has not been conducted.

Cabinet has approved funding to build a seashore foreshore in Pangai. On 27 February, 2015, Cabinet has also endorsed that a consultant be hired and approved by MEIDECC to conduct EIA before the actual construction of the foreshore. It was also decided that Ministry of Finance and National Planning will secure funding for this consultancy service.

Scope of work/Expected Outputs/:
The consultant will undertake the consultancy work in close collaboration with MEIDECCCC, government ministries, Technical Team for the Joint National Action Plan on Climate Change and
Disaster Risk Management for the Joint National Action Plan on Climate Change and Disaster Risk Management and other relevant stakeholders.

The major output of the consultancy service will be:

1. Environment Impact Assessment Report

**Specific Tasks and Timelines:**
The Consultant will conduct the Environment Impact Assessment and tasks to be carried out are specifically detailed hereunder;

**Output : Environment Impact Assessment Report**

- Conduct EIA literature research & review including the PASAP Report, 2014
- Justify the need for the project
- Assess alternatives for achieving the aim of the project
- Prepare EIA on the proposed coastal adaptation structures/techniques (PASAP and proposed seashore foreshore design)
- Conduct meetings with relevant stakeholders including local communities in Lifuka/Pangai, Ha’apai
- Prepare Environmental Management/Monitoring Plan for Lifuka/Pangai, Ha’apai
- Prepare the EIA Report according to the EIA Guidelines provided for Form 3 as it is attached.
- Submit EIA Report.

**Timeline:** 20 days

**Targetted Starting Date:** 9 March 2015

**Completion Date:** 27 March 2015

**Fee Proposal/Quotation:**
The Consultant is required to provide a proposal or quotation of the fees/cost for the consultancy service that will be conducted. The fee proposal/quotation should include the following;

1. Total budget for the Consultancy Service which will be conducted.

**Competencies:**

- Good understanding and knowledge of climate change, disaster risks and development issues in Tonga;
- Experience in coastal adaptation, protection measures & coastal infrastructure planning;
- Strong interpersonal skills with ability to work under pressure and to establish and maintain effective work relationships with people of different backgrounds;
  - Excellent communication skills, reporting with ability to express ideas clearly, concisely & effectively both orally and writing;
  - Computer literacy n full Microsoft Office Package and web browser capability and;
  - Ability to take initiative and to work independently, as well as part of a team.

**Required Skills and Experience:**

- Master Degree in environmental management, integrated coastal management or field relevant to the expected outputs of the consultancy service;
- Practical research experience in coral island geomorphology and coastal processes is also highly desired.
• At least 5 years of experience in coastal management or environmental fields;
• A good understanding of climate change, coastal management, environmental issues and community development in Tonga;
• Fluent both oral & written English.

Inputs from the Consultancy Limited:
The Consultant is required to have its own computer for the consultancy service that will be undertaken.
BACKGROUND
On April 26th I flew from Tongatapu to Lifuka Ha’apai to conduct the last public consultation with five communities of Lifuka. Mrs Soana ‘Otuafi and rest of the team joined me on Monday 28th and Tuesday 29th of the following week. The weather was fine on Monday but it got a bit windy on Tuesday with some of the flights being cancelled and even delayed.

I took advantage of my early arrival to organise transport for the team, had meetings with District Officers and all town Officers and organise accommodations for the team.

PURPOSE
The main purpose of this public consultation is to take back to the communities the proposed mitigation measures, discuss their advantages and disadvantages and then let then choose their preferred option.

ALTERNATIVES
- Alternative 1: Sand Replenishment with groynes (Using Waikiki Beach in Hawaii as example)
• Alternative 2: Planned Retreat
• Alternative 3: Rock Revetment similar to Nuku’alofa

We originally planned the presentation to start with option 3 then followed by 2 and 1. However, after the presentation in Hihifo, we decided to rearrange the order because the community appeared to lose interest, after the Rock Revetment option is discussed.

PRESENTATIONS

All presentations, except the Governor’s one were given in the evening from 6-8pm during the week of 29th April to 3rd May 2013. Each presentation was started with a prayer followed by a presentation of the results of both water and marine studies which led to the proposed mitigation measures. Questions were taken during and after the presentation. After the main presentation, the group was divided into three groups of women, men and youth to discuss their preferred option and present it back with their reasons for choosing it.

Monday 28th

The Team from Tonga arrived. In the afternoon, I assisted Steve and Kelepi on taking photographic shots around Lifuka by driving them around to places Steve wanted to take photos from. I also took them to places where erosion is quite severe for them to take few shots.

The presentation was planned to start off with Pangai but a funeral occurred and disrupt the plan. So we immediately notified Hihifo’s town Officer if we could start with Hihifo to be followed by Holopeka and Koula. Pangai Ha’ato’u and Pangai –Navea were pushed to Friday 3rd May.

Tuesday 29th

Hihifo.

My day time was spent with Steve and Kelepi. In the evening I presented the results of the studies to community of Hihifo.
The presentation took place at the SDA hall and was attended by about 30 people consisted of women, men and mixed youth. At the end of the presentation, the community were divided into three groups and were asked to pick their preferred option(s) and explain their reasons for their choice.

The three groups all agreed that rock revetment is their preferred choice. This will give government time to source land for planned retreat to occur. However, the men preferred that the revetment be built 10m offshore to reclaim some of the land already lost to sea.

**Wednesday 1st**

**Governor’s Presentation.**

We did a presentation to the Governor, District Officer and all town officers and interested government officials and some church leaders in the morning. There were about 20 people attended this presentation. Discussion was mainly on land availability which is an issue to planned retreat. Other topic of discussion was on issue of the Sand Replenishment Option which requires sand removal and constant monitoring. Furthermore this option requires consistent availability of funds for continuing replenishment over the years.

The Governor had few questions as listed below;

**What does the program wants from his people and him to do in order for the options to be implemented?**

He was encouraged to lobby through the Ha’apai Development Committee which he is a Chairman and try to influence Government’s prioritisation list.

**Is it possible to resize (lower height & width of slope) the proposed revetment?**

He was advised that by lowering the length of the revetment would allow for more overtopping due to wave setup and it may led to continuing inundation and flooding from high waves.

**Is fund available for the option (s)? How long will it take to build a revetment?**

He was advised that funds are available through Climate Change and Climate adaptation programs but they need to persuade Government to put priority on their issues and funding would be available between 1-2 years.

**GOVERNOR’S OPTION**

At the end of his inquiries the Governor recommended the option of rock revetment with similar design and size as the one in Nuku’alofa.

**Evening 1st**

Holpeka and Koulo.
The presentation took place at the Free Wesleyan Hall of Koulo for these two Communities. There were about 40 people attending the presentation. We also had problems with my computer which was unable to transfer power-point slides to the projector. This caused a ten minute delay to the presentation, as we had to run back to Hihifo to borrow another computer that is able to transfer data to projector.

At the end of the presentation, the communities were divided into three groups of men, women and youth. Each group presented their decision and reasons for their choices at the end.

The youth preferred beach replenishment because they value their existing beaches and also to minimize impact to their natural coastal environment. However, both men and women groups opted for a rock revetment. Their main reasons for picking this choice is that the land is narrower at Holopeka and Planned Retreat is therefore not ideal. Sand replenishment has been unproven in Tonga and remained problematic.

**Thursday 2**nd

Pangai – Ha’ato’u

I spent the day with Steve and Kelepi. I also took an interview for the video documentary on this day

In the evening, we presented for Pangai Ha’ato’u. The presentation took place at the National Youth Centre with about 30 people attending the session in groups of men, women and youth.
After the presentation the communities were divided into three groups to discuss their best options.

The youth preferred a rock revetment and their reason was to give time for the shortage of land to be sorted out. The women opted for a combination of rock revetment and managed retreat while the men opted for rock revetment. They said that what is important is the safety and security of the people and protection of land from being lost to sea.

**Friday 3rd**

**Pangai- Navea**

This presentation also took place at the National Youth Centre at Pangai. It was attended by about 30 people consisting of men, women and mixed youth.

The three groups had the following comments in regard to their choices for coastal protection;

The youth preferred a rock revetment with their reason that planned retreat does not guarantee not getting any sea sprays, storm surges etc. At least a rock revetment will minimise these impacts. Furthermore, building a rock revetment would offer job opportunities for communities.

The women also opted for rock revetment as well saying that there is no available land for the people to be relocated to. Furthermore, financial stress of relocating would be unbearable to some people.

Men opted for rock revetment, saying that it is cheaper than managed retreat. They would also like for the rock revetment to reclaim some of the lost land by building further offshore.

**CONCLUSION**

All throughout the presentation, it was obvious that rock revetment was the preferred choice. It was also appeared that youth and women are more concern about environmental impacts and their livelihood than men. The sand replenishment was negatively look upon due its requirements for continuous maintenance and regular replenishment in the future would require funds to be
guaranteed. The option also does not guarantee it would stop storm surges. The presentation put in by
the youth of Koulo and Holopeka was interesting because they think that Sand Replenishment would
be more appropriate for their area because erosion is not severe and they have beautiful beaches.
Constructing a Rock Revetment in this area is likely to affect this natural and pristine environment. The
mens' opinions appeared to be influenced by lack of finance and lack of lands.

FLIGHT BACK HOME

We had to take the Monday flight back to Tonga due to backlog in the flights caused by the bad
weather that was hanging almost all week.
### APPENDIX III: Cost Calculation for Option 2

#### MINISTRY OF INFRASTRUCTURES  
CIVIL ENGINEERING DIVISION

**Description:** Concrete Piling and Slabs of Shore End, Taufa'ahau Wharf  
**PROJECT:**  
**Date:** April, 2015  
**Prepared by:** PFT

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Qty</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 establishment</td>
<td>item</td>
<td>1</td>
<td>210,030.00</td>
<td></td>
</tr>
<tr>
<td>2 setout, site clearing</td>
<td>m²</td>
<td>5000</td>
<td>12</td>
<td>60,000.00</td>
</tr>
<tr>
<td>3 supply backfill material</td>
<td>load-3.8m³</td>
<td>3775</td>
<td>110</td>
<td>415,250.00</td>
</tr>
<tr>
<td>4 supply armored rocks</td>
<td>m³</td>
<td>7200</td>
<td>65</td>
<td>468,000.00</td>
</tr>
<tr>
<td>5 supply and placing filter material</td>
<td>m²</td>
<td>3500</td>
<td>16</td>
<td>56,000.00</td>
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<td>6 placing backfill material</td>
<td>m³</td>
<td>3775</td>
<td>25</td>
<td>94,375.00</td>
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<td>7 concrete works</td>
<td>m³</td>
<td>5213</td>
<td>426</td>
<td>2,220,738.00</td>
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<tr>
<td>8 steel works</td>
<td>length</td>
<td>5132</td>
<td>196</td>
<td>1,005,872.00</td>
</tr>
<tr>
<td>9 timber works</td>
<td>length</td>
<td>4552</td>
<td>137</td>
<td>623,624.00</td>
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<tr>
<td>10 design and supervision etc.</td>
<td>item</td>
<td>1</td>
<td>70,000.00</td>
<td></td>
</tr>
<tr>
<td>11 clean up the site</td>
<td>item</td>
<td>1</td>
<td>288,000.00</td>
<td></td>
</tr>
<tr>
<td>12 boat - ramp, access and drainage, foot path and walkway, etc</td>
<td>item</td>
<td>1</td>
<td>521,000.00</td>
<td></td>
</tr>
<tr>
<td>13 contingencies</td>
<td>item</td>
<td>1</td>
<td>924,374.00</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL ESTIMATION =** $7,086,863.00

#### MINISTRY OF INFRASTRUCTURES  
CIVIL ENGINEERING DIVISION

**Description:** Groynes and Sand Replenishment  
**PROJECT:**  
**Date:** April, 2015  
**Prepared by:** PFT

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Qty</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sand</td>
<td>t/load</td>
<td>1000</td>
<td>200</td>
<td>200,000.00</td>
</tr>
<tr>
<td>2 groynes manufacture</td>
<td>No</td>
<td>200</td>
<td>600</td>
<td>120,000.00</td>
</tr>
<tr>
<td>3 groynes base</td>
<td>No</td>
<td>40</td>
<td>1200</td>
<td>48,000.00</td>
</tr>
<tr>
<td>4 groynes construction</td>
<td>No</td>
<td>240</td>
<td>250</td>
<td>60,000.00</td>
</tr>
<tr>
<td>5 placement of sand</td>
<td>m³</td>
<td>3800</td>
<td>25</td>
<td>95,000.00</td>
</tr>
<tr>
<td>8 contingencies</td>
<td>item</td>
<td>1</td>
<td>78,450.00</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL ESTIMATION =** $601,450.00
APPENDIX IV: Current Determination Sites
APPENDIX V:
Photos showing coastal erosion at the western coastline of Lifuka island.

South of the Palace at Pangai. Showing an attempt to protect the coastline from further erosion.

Southern end of the Palace. Showing a failed seawall structure with the high water mark now above and behind the structure.

Hihifo village. Coastal erosion is widespread along this coastline. The tree line used to be above storm level is now at High tide level.
APPENDIX VI:

MONITORING REEF FLAT SITES

Introduction

The western coastline of Lifuka is suffering from chronic coastal erosion due to construction of the new wharf in early 1980s, an earthquake that resulted in a drop of 23cm in the western coastline and sea level rise (Kiteke’aho,T, 2010; PASAP study, 2012). The combination of these events have made Lifuka a priority in the list identified under Tonga’s JNAP (2010) as the most vulnerable community in the Tonga Group.

In February 2015, the Minister of Infrastructure and Transport Hon Lavulavu, visited Lifuka Island. He recognised the coastal erosion on the coastline in front of the Palace, required urgent rehabilitation works. The coastline was protected by a seawall which is now suffering from wave overtopping due to sea level rise and concrete slab are falling down. It is proposed that this section would be replaced by a rock revetment. However, prior to any major works and in accordance with the EIA Act 2003, MOW requires an Environmental Impact Assessment (EIA) to determine likely impacts this work may cause to the environment and to propose mitigation measures to alleviate these impacts.

Objectives

This study is aimed at collecting baseline data on biological communities and reef ecosystem as a basis for monitoring of the site after the construction.

Equipments

The following equipments were used for the study.

- 50m tape
- 1 meter square quadrat
- Underwater Video Camera
- GPS and Note Book

Methods

Three sites were selected along each side of the proposed structure. A 100m transect line was extended seaward towards the reef. The starting point was recorded with a portable GPS. Each line is studied using a meter square quadrat, placed at every 5 meter interval, starting at the 0m point at beach, to record types of substrates, fauna and flora inside the quadrat. Also inside the quadrat, the coverage of epiphytes on seaweeds, seagrasses and substrates are estimated as indicative of sedimentation. The study was accompanied by underwater photography to record significant findings along each transect line.

RESULTS
**TRANSCIT LINE 1:**

**Sediment type** – sandy-mud with rubbles

**Habitat** – Intertidal areas covered by seaweed and seagrass

**Depth** – average <1 meters (low tides)

*Sargassum spinuligerum* brown seaweed was found to be scattered around within 10m whereas seagrass (*Halodule sp & Thalassia testudinum*) and green (*Halimeda sp*) and brown (*Padina sp*) seaweed also found to be high density toward 100 m. Within 30 – 50 m transect, epiphytes were found to be totally 100% cover of the seaweed and seagrass bed with decreasing toward to the coastal areas (50 – 100 m). For edible marine organisms found at the site 1, ark shell and cockles were the main invertebrate able to collect during site assessment.

**Transect Line 2**

**Sediment type** – sandy & sandy-mud with rubbles

**Habitat** – Intertidal areas covered with seagrass & seaweed include scattered of coral boulders

**Depth** – average 1.5 m (low tides)

*Sargassum sp* seaweed dominant the first 50 m with scattering around of coral boulders whereas seagrass (*Halodule spp & Thalassia testudinum*) and other seaweed (*Padina spp & Halimeda spp*) found to be high abundance toward 100 m line. Epiphytes covered also found to be decreasing along the transect line toward the 100 m. None any of the cockles were found at transect 2.

**Transect Line 3**

**Sediment type** – sandy with rubbles
**Habitat** – Intertidal areas covered with seagrass & seaweed and coral rubbles

**Depth** – average 2 m (low tides)

Within the first 40 m, dominant by sand with scattered around of seagrass bed (*Halodule spp* and *Halophila ovalis* but in low density. Toward 40 – 70 m transect, high density of Sargassum spp seaweed were located whereas coral rubbles dominated 70 – 100 m which also exposed during low tides. In term of edible marine organisms, only hard buried crab *Clappa spp* was found close to the beach within 0-10 m line.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 15 m</td>
<td>Antique ark</td>
<td><em>Anadara antiquata</em></td>
<td>Kaloa’a</td>
</tr>
<tr>
<td>15 – 40 m</td>
<td>Re mussel</td>
<td><em>Modiolus spp</em></td>
<td>kuku</td>
</tr>
<tr>
<td>40 – 70 m</td>
<td>Elongate cockle</td>
<td><em>Acrosterigma elongatum</em></td>
<td>tuahi</td>
</tr>
<tr>
<td>70 – 100 m</td>
<td>Pacific tiger lucine</td>
<td><em>Codaakia tigerina</em></td>
<td>tulalo</td>
</tr>
<tr>
<td></td>
<td>Buried hard crab</td>
<td><em>Calappa spp</em></td>
<td>tafola</td>
</tr>
</tbody>
</table>
## ENVIRONMENTAL MANAGEMENT PLAN - EMP

<table>
<thead>
<tr>
<th>REF NO.</th>
<th>OBJECTIVES</th>
<th>ACTION</th>
<th>TARGET</th>
<th>RESPONSIBILITY</th>
<th>TOTAL BUDGET</th>
<th>MONITORING COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Ensure the mitigation measure are adhered to</td>
<td>The works unit/contractors should be briefed prior to commencement of works to ensure each individual is clear about the measures being taken. It is recommended that all construction activity should follow good practice advices and guidelines.</td>
<td>Evidence that appropriate training has taken place</td>
<td>PROJECT MANAGER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NATURE CONSERVATION

<table>
<thead>
<tr>
<th>2</th>
<th>ENVIRONMENTAL ISSUES/IMPAIRMENTS</th>
<th>MITIGATION MEASURES</th>
<th>MANAGEMENT ACTION</th>
<th>RESPONSIBILITY</th>
<th>BUDGET</th>
<th>MONITORING COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3</strong></td>
<td>Identify that correct rock sizes are available locally</td>
<td>This is the most critical part of the project. The sizes of the boulders were determined according to waves energy impacted on this coastline and to ensure that there is no movement in the structure after cyclone. Less rock sizes and finer material will cause more environmental issues with sediment plume being generated to affect marine organisms in nearby areas and small boulders could be a hazard to people and properties.</td>
<td>Ensure that the correct rock can be accessed locally</td>
<td>EMC/Proponent</td>
<td><strong>$2000</strong></td>
<td></td>
</tr>
</tbody>
</table>

### LOCATION/PLANNING

<p>| 4 | Loss of Habitat due to change land use | Though the change in land use is permanent there must be an attempt to improve the site resulting in better landscape then what it is at present. | Assess plan for landscaping ideas | EMC/Proponent | <strong>$1500</strong> | |</p>
<table>
<thead>
<tr>
<th>5</th>
<th>Loss of trees and Vegetation due to tree cuttings</th>
<th>Compensatory plantation to replace all trees removed must be carried out. The species of trees for replanting should be similar with those removed. Focus should be at fast establishing trees.</th>
<th>Confirm re planting plan in place. Cost of replanting to be borne by proponent. Monitoring of this activity is necessary.</th>
<th>MECC/EMC/Proponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Loss of trees and fauna due to landscaping</td>
<td>Replanting. The continuity of the coastal ecosystem on this coastline will ensure that displaced fauna and flora will re establish themselves on site and in the adjacent areas once construction ends.</td>
<td>EMC to monitor</td>
<td>Proponent/Forestry Ha'apai</td>
</tr>
<tr>
<td>7</td>
<td>Increase number of trees on coastline</td>
<td>Avoid planting fruit trees due to bird nuisance. Plant some iron wood trees (Toa) if possible.</td>
<td>EMC to monitor</td>
<td>Proponent/Forestry Ha'apai</td>
</tr>
<tr>
<td>8</td>
<td>Water and Marine pollution due flooding/inundation</td>
<td>Compliance with design of the structure is paramount</td>
<td>EMC to monitor</td>
<td>Contractor/proponent</td>
</tr>
</tbody>
</table>
| 9 | Injuries/loss of lives | • Workers are required to have thorough knowledge of safety, equipments used on site including control of heavy machineries. Proper attire of hard hat and safety shoes must be worn at all times on site.  
• Workers must be insured | EMC to monitor | Contractor / Proponent |
| 10 | Noise pollution from heavy machineries | • Need to negotiate with Government Ministries nearby on working hours. Ear puff must be worn while heavy machineries are working.  
• Vehicle must be equipped with silencer to reduce noise | EMC to monitor | Contractor/proponent |
<p>| 11 | Air pollution | Vehicle working on site with internal combustion are required to be maintained for effective combustion to lower pollution. | EMC to monitor | Proponent/Contractor |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Operation Phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Destroy fauna and flora</td>
<td>Disturbance of flora and fauna due to digging can be mitigated by reusing all sand to cover toe and upper slope of the structure.</td>
<td>EMC to monitor</td>
<td>Contractor/proponent</td>
</tr>
</tbody>
</table>
| 13 | Generation of Sediment plume due to digging and laying of boulders | • Ensure that all works are carried out at low tide  
• Ensure that sediment net is used to contain any sediment plume generated from the working area | EMC to monitor | Contractor/proponent |
| 14 | Loss of habitat and trees | • Ensure that trees are avoided from being cut down if possible.  
• A program for planting trees as secondary protection must be in place as soon as structure is laid. | EMC to monitor | Contractor/Proponent |
| 15 | Injuries due to heavy machineries | • Safe distance must be kept at all times while machineries are in used. Hard hat and safety boots must be worn at work site.  
• Workers must be insured. | EMC to monitor | Contractor/proponent |
| 16 | Air pollution due to maintenance works | This is not a permanent impact but can be minimised by ensuring that machineries to be used have passed annual test. | EMC to monitor | Proponent/Contractor |
| 17 | Injuries/loss of lives due work accident | Safe distance must be adhered to. Experience staffs are required to operate machineries. | EMC to monitor | Proponent/Contractor |
| 18 | Monitoring of structure and impacts | This must be adhered to. Transect lines for biological monitoring and beach profiling must be done during and after construction to ensure timely intervention before impacts is too large to correct. | EMC/Geocare | Proponent |

**OPERATION PHASE**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>16</td>
<td>Air pollution due to maintenance works</td>
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</tr>
<tr>
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</tr>
<tr>
<td>18</td>
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<td>This must be adhered to. Transect lines for biological monitoring and beach profiling must be done during and after construction to ensure timely intervention before impacts is too large to correct.</td>
<td>EMC/Geocare</td>
<td>Proponent</td>
</tr>
</tbody>
</table>

**$30,000**

**$3500**