ASSESSMENT OF COMMUNITY ASSETS (INFRASTRUCTURE AND ECOSYSTEMS) VULNERABLE TO COASTAL STORMS AND SEA LEVEL RISE

in

HAMILTON, LAKKA, TOMBO, CONAKRI-DEE, SHENGE & TURTLE ISLAND

Assessment Report Submitted to UNDP

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Table of Contents

List of Tables

List of Figures

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Executive Summary

This study was commissioned by the Environment Protection Agency Sierra Leone (EPA-SL) as part of activities of Component II of the project "Adapting to Climate Change ~~i~~Induced Cc~~e~~oastal R~~r~~isk M~~m~~anagement in Sierra Leone". It aimes~~d~~ to assess community assets/infrastructure that are at risk to sea level rise and coastal storm in six pilot project sites, namely, Lakka, Hamilton, Conakri-Dee, Tombo, Shenge and Turtle Island.

The changes in shoreline positions of the pilot sites over Thirteen years (13) period were investigated using multi-dated satellite images and topographic maps. In addition, an inventory of assets/infrastructure was ~~also~~ undertaken in these pilot sites so as to determine those assets most vulnerable to sea level rise and coastal storm impact. The methodology also involved review of pertinent documents and published articles, interviews and field studies.

The assessment also quantified shoreline changes over thirteen years period with the aim to produce a baseline data which could be used in predicting shoreline positions needed to determine what assets/infrastructure could be at risk to sea level rise and coastal storm. Thus the assessment concludeds the following:

- That the shoreline change in all pilot sites was evidently high and the magnitude of the resulting impact to communities, assets/infrastructure as well as ecology was significant.
- According to the data collected, all pilot sites were highly vulnerable to climate change and sea-level rise as manifested in the increased rates of coastal erosion with severe consequences of persistent coastal recession.
- The assessment confirms that coastal vulnerabilities, such as shoreline changes affect the pilot sites and these are accountable for destruction of property and infrastructure~~s~~.
- Whilst the assessment concludes that without proper adaptation measure, the physical, human and financial impacts would be significant, it further infers that human interventions play a vital role in shoreline changes in addition to natural processes.

1 Section One

1.1 Context

Accelerated Sea Level Rise (SLR) is usually regarded as the most certain consequence of global warming. It has serious physical impacts on coastal areas, mainly characterized by inundation risk and displacement of lowlands and wetlands (Ghaleb et al. 2013).

Ghaleb et al. (2013) note that the increasing coastal inundation vulnerability may lead to substantial socio-economic losses such as the loss of coastal structures, damage to buildings and settlements, dislocation of the population and the loss of the agricultural production.

According to McGranahan et al. (2007), Ten per cent of the world's population resides in coastal areas that are less than 10 meters above sea level, and two-thirds of the world's cities with over five million people are located in low-lying coastal areas. McLean (2018) has also shown that the rising seas cause direct risk (flooding of unprotected coastal infrastructures) and indirect threats of increased storm surges. Similarly, a study by IPCC (1996) had revealed that the main challenges likely to face African populations will emanate from the effects of extreme events such as tropical storms, floods, landslides, wind, cold, waves, droughts and abnormal sea-level rises that are expected as a result of climate change; and that coastal nations of West and Central Africa (e.g., Senegal, The Gambia, Sierra Leone, Nigeria, Cameroon, Gabon and Angola) with low-lying lagoonal coasts are susceptible to erosion and are threatened by sea-level rise. Other studies had proven that inundation of coastal areas could be a significant concern from sea level rise and storm surge (Awosika et al., 1992; Dennis et al., 1995; French et al., 1995; ICST, 1996; Jallow et al., 1996).

Some physical evidence of inundation of low-lying areas, shoreline erosion, coastal wetland loss and coastal flooding in coastal areas in Sierra Leone have been documented (GoSL, 2015; NBSAP, 2015). The State of Marine Environment report for Sierra Leone (2015) has also revealed that human-induced pressures on coastal zones (e.g. habitat degradation) has over the years contributed to the increasing effects of sea-level rise. Therefore, proper mitigation actions to address these issues with a view to protecting lives and property from the effects of coastal storms and sea level rise must be of priority.

1.2 Introduction

The Global Environment Facility (GEF) through the Least Developed Countries Fund (LDCF) funded the Project titled "Adapting to Climate Change Induced Coastal Risks Management in Sierra Leone". The project is one of the key frameworks for implementing the adaptation priorities identified in the National Adaptation Programme of Action (NAPA). It also aims at strengthening the ability of coastal communities to systematically manage and adapt to climate change risks and impacts on physical infrastructures and economic livelihoods as well as strengthening government institutions and local coastal communities' resilience to climate change impacts.

Component II of the project is implemented by the Environment Protection Agency. This Component focuses on internalizing climate information into coastal development policy and plans. As an outcome of this component, it is expected that appropriate protection measures, policy, budgeting and legal tools and integrated coordination mechanisms would have been developed to improve and support policy design and implementation in dealing with current and long-term coastal challenges.

Under output 2.1, one of the project activities is the assessment of coastal assets and ecosystem vulnerable to sea level rise and coastal storm. Six pilot coastal sites namely:

i. Lakka;
ii. Hamilton;
iii. Shenge,
iv. Tombo;
v. Conakri-Dee and
vi. Turtle Island,

known to have been significantly altered by adverse environmental as well as human impacts are selected for this assessment. It is important to note that there is also lack of comprehensive baseline information on the type of assets found in these locations which increases the potential for uncertainties in future.

The assessment therefore involved analyzing the shoreline change in order to determine the extent of risks on assets (infrastructure and ecology) in a given area from coastal storm surge or sea level rise. This report will therefore provide data and information on the extent of exposure of coastal assets to risks from sea level rise and storm surge in the selected project sites.

1.3 Purpose and Objectives of the assessment

1.3.1 Purpose

The purpose of the assessment is to strengthen preparedness for future climate change induced hazards such as sea level rise and coastal storm surge based on the baseline established by this assessment especially the rate of rise in sea level in the pilot locations. As a result, policy and decision makers will become aware of the exposure of the various assets and infrastructures that are at risk to sea level rise and storms. The type of assets inventoried in the assessment includes the following:

- Public infrastructure
  - Roads
  - Jetties/Fish landing sites
  - Ports
  - Power stations
  - Schools
- Housing
- Industries
- Hospitality and entertainment (Hotels, Restaurants, Night clubs)
- Harbours
- Ecological assets (vegetation, shores and sediment types).
- Utilities (water & power)
- Physical coastal protection infrastructure

1.3.2 Objectives

The assessment aimed to determine the estimated geographic extent of sea level rise and inventory of assets that are at risk and most vulnerable to sea level rise and coastal storm in the pilot project locations. The specific objectives of the assessment include:

- To provide an overview of infrastructure or assets and coastal ecosystems exposed to sea level rise and coastal storms;
- To determine the extent of exposure and risk to coastal assets under different sea level rise and storm surge scenarios.

The assessment was meant to address the following questions:

i. What types of assets are there in the coastal zones of the pilot sites?
ii. What could be the current threat on the assets from sea-level rise?
iii. How much impact could such a threat cause on the ecological, social and economic systems in the pilot sites?
iv. What could be the possible rate at which the shoreline is changing in the coastal zones of the various pilot sites? What could possibly be accelerating this change in the pilot sites?
v. Which sites are of greater risks to sea-level rise?
vi. What are the various sea-level rise coping or adaptation strategies instituted by inhabitants?

1.4 Scope of the assessment

The scope of this assessment covered the six pilot sites, Namely; Lakka, Hamilton, Tombo, Conakri-Dee, Shenge and Turtle Island. The assessment was designed to;

i. Provide an inventory of infrastructure or assets and coastal ecosystems exposed to sea level rise and coastal storms;
ii. Determine the extent of exposure to coastal hazards and risks from sea level rise and coastal storm impacts;
iii. Assess the current threats to the shoreline of the various sites.

1.5 Limitations

i. The lack of comprehensive baseline information on Sierra Leone related to the study was a challenge. There has been no study done to analyze the trend of coastal erosion and rate of shoreline change. These could have provided insight of the issues investigated and would serve as a baseline for this and any other studies of this nature.

ii. Cost of damage from potential coastal hazards could not be appraised in this assessment. Most coastal assets are not insured, thus it makes it rather difficult or even impossible to estimate the true value of these assets to represent cost of damage from impact of potential sea level rise and or coastal storms.

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1.6 Assumptions

Through a transect walk of 300m distance along shoreline of the pilot sites, assessments were made on assets located at the beach front in an attempt to determine risk and vulnerabilities of these assets and infrastructure to SLR and/or coastal Storm. Analyzing risk factors was on the one hand based on the assumption that the shorter the distance between High Water mark (HWM) and the nearest asset/infrastructure, the higher the risk and impact of Sea level rise and coastal storms, and on the other hand the multiple indirect contributing factors such as human influences and the natural settings of the pilot sites. By this, the analysis utilized the average distance between mean HWM and the nearest asset as parameter for consideration in the potential hazard analysis.

2 Section Two

2.1 Assessment methodology

2.1.1 Description of the pilot sites

The pilot sites comprised of six coastal settlements along the Sierra Leone Coastline and include, Tombo, Shenge, Lakka, Hamilton, Conakri-Dee and Turtle Island.

The coastal fishing villages of Tombo (Figure 1) and Shenge are the highly populated settlements situate along the Yawri Bay. Whilst Tombo is a major fishing settlement with very high population, Shenge (Figure 2) remains historically important with very low fishing activities. Fishing, boat building and repairing and fish processing form the major socio-economic activities in these communities. Boat building and repair is much more pronounced in Tombo.

Figure 1: Map Showing Tombo pilot site

Lakka and Hamilton are small settlements in the Freetown Peninsular. Owing to the location of these coastal settlements and the nature of the coastline (entirely sandy beaches) these two communities have been known as popular tourist and recreational areas along the Western Peninsular. Fishing is also an active activity but on a very low scale.

Figure 2: Map showing pilot sites: Coastal stretch of Lakka, Hamilton & Shenge

Tourism development often influence development and planning decisions, as tourism and recreation constitute the major sources of income for the inhabitants of both Lakka and Hamilton. Most of the housing units on the seaward side are standard and sanitation aspect is quite improved when compared with the other project sites.

Conakri-Dee (Figure 3) on the other hand is situated on the Northern Coastline in the Port Loko District about 10.9 Km from the International airport. This settlement is widely known for its fishing activities. The community has been seriously affected by coastal erosion, where many structures have collapsed as a result of coastal recession. Access to this community can be by road or by sea.

Bumpe-Tok is a small fishing village in Turtle Island (Figure 3). Most of the housing units are substandard, built up of mud and thatch with no concrete floors. As the name implies, Turtle Island can only be accessed by water, and this is one and only means of travel from and to other Island settlements. The turtle island has been known as major habitats of sea turtles. For this reason Reptiles and Amphibian, conservation NGO, together with the Conservation Society Sierra Leone had implemented a number of livelihood and marine and coastal conservation projects in these communities. The major source of income in this village is fishing activity.

Figure 3: Map of Conakri-Dee community and its environs (left) and Turtle Island (Right) pilot sites

2.1.2 Assessment of ecosystem vulnerable to coastal storm and sea level rise

As part of the assessment, the methodology for this aspect involved:

i. Physical site survey to be able to describe the ecosystem ~~interms~~in terms of vegetation types, geology, topography, elevation;
ii. Provide description of the physical features of the selected pilot sites: sandy/muddy/rocky shoreline;
iii. Assess the Current threats from coastal (natural and man induced) and to assess loss of ecosystem from effects of sea level rise and coastal storms.

2.1.3 Inventory of coastal assets and current threats

The method involved systematic transect walk for a 300m distance along shoreline of each pilot sites. Interviews with local people also formed aspect of this inventory. Observations were also made on the physical features and/or current state of the environment including natural and pressures from humans. The coastal adaptation practices were also assessed at all pilot sites, evaluating their effectiveness and how these have contributed to reducing impact on coastal assets.

However, the inventory did not take into account survey of all infrastructure/assets within the coastal zone of the pilot sites; else it focused on those assets found closest to the High water mark in the assessment area. No standard procedures were used to estimate the area covered at each pilot site.

2.1.4 Potential sea level rise and coastal storm hazard assessment

- **Determining the significance of impacts/hazards of potential Coastal storm and sea level rise**

The potential sea level rise and coastal storm hazard assessment were based on the data collected in the field and especially the analysis of the rate of shoreline changes over the thirteen years period (2005 – 2018).

This was complemented by expert's professional judgement, the actual current state of the pilot sites from the data collected, the observations during field studies and the threat facing these sites. Thus the hazard assessment adopted a systematic approach using preset criteria which was completed by the projections drawn for the shoreline change scenarios and the experience and knowledge of the team. Obvious factors such as wave action and tidal fluctuations served as supporting argument in the potential hazard assessment.

The hazard assessment also involved identifying receptors (i.e. coastal assets/infrastructure) potentially at risk from predicted hazards. Baseline data and information in addition to local knowledge provided a detailed understanding associated with any key risk factors. Further, the assessment used the projected rate of shoreline change (practical scenarios in determining the level of effect of the hazards on the receptors) based on the GIS data analyzed.

Here a systematic scoring system to establish the significance of impacts or hazards was used. Thus the level of hazard significance was determined by using the guidelines set out in Table 1, which provides a platform for impact/hazard decision-making.

The classification of coastal hazards on the above scale was dependent upon the detailed understanding of the size of impact and the scale on which this impact will be noted for the receptor being considered (see Table 1 below).

The magnitude of impact was assigned by taking into account the combination of importance/value, sensitivity, and the resistance ability of receptors. In this context, resistance relates to Climate change adaptation capacity and natural features which offer protection to not only the coastline but assets/infrastructure located at the beach front.

As per the assessment of size and severity, magnitude was determined on the scales of high, medium and low for importance and value and sensitivity; short term, medium term and long term for timeframe; and High, Moderate and Low for Resistance and Adaptive capacity of community assets.

In determining the significance of potential hazard, '***Magnitude***' is assessed against the '***Severity /Scale'*** of hazard to provide a range of significance.

Significance = Size and Severity of Impact x Magnitude (Importance and Value + Sensitivity + Timeframe + Resistance and Adaptive capacity)

Table 1: Evaluating the component of impacts/hazards significance

Potential Impact /Hazards to Receptors	Component of Significance	Understanding potential hazards and their interaction with baseline environmental conditions and current threat levels in various pilot sites	Guidelines for determining the level of potential Hazards
Coastal communities and Beachfront assets/infrastructures	Size and Severity	➢ What scale of impact will sea level rise and coastal storm have on different assets and ecology in pilot sites? ➢ At what scale will the sea level rise and coastal storm affect coastal communities, assets and infrastructures? ➢ How does this change (shoreline change) relate to the existing baseline situation and current threats level? ➢ Is the extent of the potential impacts solely related to sea level rise and coastal storm or indirectly on human related effects?	**High:** The potential impact/hazards will lead to loss of assets, fragmentation of coastal habitat due to erosion and coastal recession. It will lead to adverse effect on socio-economic (employment) activities such as damage to hotels, fishery facilities and other assets **Medium**: The potential sea level rise or coastal storm will lead to a loss of lesser important habitat and less fragmentation of habitats. This will inflict a moderate to adverse change to the ecology and to the beachfront assets. **Low**: The sea level rise or coastal storm will not have any adverse impact on important habitat or infrastructure and shoreline ecologies.
	Importance/Value	➢ Are the coastline in the pilot site truly natural, i.e. not modified by man? ➢ What is the size of the shoreline to be affected? ➢ How diverse is the area affected ~~interms~~in terms of economic activities? ➢ What is the conservation value / status of the habitats and species at the site that will be affected by the impact of sea level rise? ➢ What is the level of importance associated with the scale of shoreline change?	**High**: A natural/pristine area with high economic importance and ecological value. e.g. touristic attraction area. The site is very important ~~interms~~in terms of socio-economic livelihood supports as it hosts important infrastructure which contribute to nation development and livelihoods of a number of people. **Moderate:** Impact will be somehow mitigated or the adaptation mechanism can lesson any unforeseen impact. The extent of impact will not be so adverse due to the less dependency of people on these assets. **Low**: An area which also support diverse livelihood activities but not as threatened as other areas to the extent that it may lead to severe economic loss and damage to properties. Impact could be localized and does not undermine socio-economic activities and survival of people.

Potential Impact /Hazards to Receptors	Component of Significance	Understanding potential hazards and their interaction with baseline environmental conditions and current threat levels in various pilot sites	Guidelines for determining the level of potential Hazards
	Sensitivity	➢ What are the key physical environmental factors such as coastal erosion, salt water intrusion etc.? ➢ Is this area currently stressed? What is causing this stress? ➢ What are the thresholds of sensitivity or limits of acceptable ecological change that are affected? ➢ What is the level of sensitivity of the local community to change? ➢ What aspects of community life, livelihoods, cultural are particularly vulnerable to shoreline change?	**High**: The site is highly dependent upon physical factors such as natural accretion of sand that may be affected by the sea level rise and resultant coastal recession with communities that are unlikely to adapt to the changes that may result. **Medium**: Coastal communities can adapt to physical changes that may result from the impact of sea level rise and storms, but this may increase stress and vulnerability. **Low**: Coastal communities can readily adapt to physical changes that may result from sea level rise and storms and this will not increase stress and vulnerability.
	Timeframe	➢ Over what frequency will impacts occur? Will they be persistent, short term or catastrophic impacts? ➢ How long will it take communities to adapt or recover from any loss or damage? ➢ Over what time period communities would be affected by the change?	**Short-term**: A temporary impact resulting from any shoreline change or effects from sea level rise and coastal storm. **Medium-term**: A resultant impact that occurs relatively infrequently, but has the potential to disrupt economic activities to such a great extent. **Long-term**: A Constant or intermittent and permanent impact that goes beyond a limit that allows communities to easily adapt or recover loss and damages and this can have long lasting negative consequences on population/coastal communities.
	Resistance and adaptive capacity	➢ Will the shoreline communities and assets/infrastructures be able to resist any effect of sea level rise or coastal storms? ➢ What capability does the site possess to resist impact of sea level rise and coastal storms? ➢ Once an impact has occurred can the community be susceptible or be adapted to the resulting change?	**High:** the community and its assets/infrastructure possess high resistance and adaptive capacity through natural forms and/or through man's intervention to adapt and prevent in whole any effects of sea level rise and storm hazards. **Moderate:** The degree to which the coastal community and its assets can resist or prevent adverse impact of sea level rise and storm is adequate to offset adverse impacts. **Low:** the adaptive capacity is low to withstand any effects of sea level rise and storms, with ultimate adverse impact to community and assets.

➢ Scoring system for determining hazards significance

In this context, a systematic approach was utilized to assess hazard potentials of both sea level rise and coastal storms taking into account the current threats (both natural and human induced) and the sea level rise induced shoreline change over a thirteen years' period (See Table 2E).

Consistent with similar impact assessment (e.g. Brown et al., 2011) this hazard assessment took into account all components of magnitude, separately, including time frame and shoreline/ assets resistance and adaptive capacity. The assessment allows for a combined scoring approach that draws together all of the elements of impact/hazard significance so that one level of significance is assigned dependent upon the combination of these factors.

The following Tables (Table 2A- E) present the scoring system that has been adopted for scoring the significance of potential hazards. Significance is determined by identifying the size and severity of hazard in combination with all of the components of magnitude as follows:

Significance = Size and Severity of Potential hazard x Magnitude (Importance and Value + Sensitivity + Timeframe + Resistance and adaptive capacity)

Table 2: Scoring of potential hazard significance for each component of magnitude

Table 2A- Importance/Value

Size and Severity	Importance/Value		
	Low	Medium	High
High	2	3	4
Medium	1	2	3
Low	0	1	2

Table 2 B - Sensitivity

Size and Severity	Sensitivity		
	Low	Medium	High
High	2	3	4
Medium	1	2	3
Low	0	1	2

Table 2 C - Timeframe

Size and Severity	Timeframe		
	Short	Medium	Long
High	2	3	4
Medium	1	2	3
Low	0	1	2

Table 2 D - Resistance and Adaptive Capacity

Size and Severity	Resistance and adaptive capacity		
	Low	Moderate	High
High	4	3	2
Medium	3	2	1
Low	2	1	0

Table 2 E - Levels of Significance of Potential Hazards

Hazard Category	**Score**
Slight	0
Minor/Low	1 - 4
Low /Moderate	5 - 6
Moderate	7 - 8
Moderate/Major or High	9 - 10
Major/High	11 - 16

2.1.5 Assessment of current threats on coastal zone

As part of the broader assessment, the team also evaluated the current human activities at the various pilot sites in an attempt to determining the level at which human activities are contributing to the cumulative impact of sea level rise and coastal storms. This aspect was intended to cross examine whether human activities actually posed a threat to the coastal environment and what linkages exist between these and the sea level rise and coastal storm impact.

It is important to note that the threat assessment did not involve indebt analysis of quantifiable data on such activities such that the extent of impact resulting from one activity could be evaluated in terms of its scale and magnitude.

2.1.6 Coastal assets exposure analysis – Shoreline change analysis

With the use of GIS technique, satellite images over time were collated for the purpose of determining the shoreline change over thirteen years period (2005 – 2018), and the geographic areas to be inundated from sea level rise through modelling a vertical increase in water levels over existing terrain. This analysis produced evidences of shoreline change at a 5 year interval, from which the rate of shoreline change were estimated for the six pilot sites.

3 Section Three

3.1 Assessment findings

3.1.1 Coastal assets

Table 3 gives brief description of the assets inventoried at the various pilot sites. As spelt out in the assessment methodology, the scope didn't involve taking stock of every assets or infrastructure in the pilot sites. It concentrated on those specific assets that are located closest to the high water mark in anticipation that risk or vulnerability assessment could easily be done taking into consideration the assumptions and the potential hazard analysis done in this report.

Table 3: Description of major assets types

No	Asset Type	Descriptions
1	Fish processing facility	These are well established fish processing complexes constructed by the Government of Sierra Leone under the ADB funded project. In the pilot sites, these facilities exist in Tombo and Shenge.
2	Bridge	A foot path bridge, made of wooden base, supported by concrete pillars connecting the settlement and the beach area.
3	Shower room	This is hospitality asset originally designed for shower purposes beach users. Found in Hamilton.
4	Restaurant	A restaurant is a very important facility for relaxation. These were found located along beaches of Lakka and Hamilton. Lakka, being a well-established place for tourism, it hosts large number of restaurants. A single restaurant was recorded for Hamilton
5	Hotel	Many Hotels were not found in the pilot areas except for Lakkah where there were quite a few guest houses and hotels currently under construction, whilst others have already being destroyed.
6	Road	Roads were considered public infrastructure in this study. The inventory did not capture roads in the area of interest as far as this assessment is concerned.
7	Naval office	This office regulates or man affairs related to the marine environment (Sea transport, IUU fishing, etc.). It is situated in Tombo.
8	Slip way	Sleep way is part of the fish processing facility meant to support boat/Vessel repairs activities.
9	Jetty	Jetties are fish landing platforms constructed to aid local fishermen to land their catch onshore where it is either sold or taken for processing.
10	Residential Houses	Residential homes were the assets found almost in all pilot sites.

The survey shows that the type and number of assets and infrastructure at the different pilot sites vary. There are many reasons to this; principally based on the different socio-economic activities these communities engage in. In areas close to the capital city i.e. Lakka and Hamilton, touristic asset are more common with minimal fishing activities. Tombo and Conakri- Dee are well renowned fishing communities and the assets found in these areas are more fisheries related than tourism.

In terms of value of the assets, financial value of residential houses or huts varied from place to place. In remote areas such as Bumpe-tok in the Turtle Island, there are hardly any concrete structures and this was believed to have resulted from the awareness amongst the inhabitant on the risk of coastal storm impact.

What the assessment gathered was that people had deliberately embarked on constructing very simple units of dwelling houses made up of mud which cost very little. So in time of damage from storms, the cost of rebuilding could be low and affordable.

Assets and infrastructures in the pilot sites can be categorized into three;

1. Those owned by private individuals,
2. Government and
3. Community.

From the assessment, it was noted that private properties are given considerable attention ~~interms~~in terms of care and protecting it from damage, whereas, Government owned infrastructures are given lesser care.

Similarly, Tables **4a-4f** show the various assets recorded and their current state at each pilot site. These also include some analysis of potential risk to the assets. The risks were scaled as either very low, low, medium or high

Table 4: Inventory of community assets and their current state in six pilot sites

Table 4a: Inventory of community assets and their current state - Lakka

Name of Site	**Type of asset**	**Current state**	**Analysis of Potential risk (Very Low Low; Medium; High/Critical)**	**Notes**
Lakka	Restaurant	in good form	Very Low	The distances to HWM make the impact lesser; as well as the adaptation measures used.
	Swimming pool	Some cracks in the wall on the seaward part	High	Inappropriate defense/protection
	Hotels	Some Fence walls damaged and some collapsed; Whilst Some hotels have collapsed, some are in poor state;	High	Inappropriate coastal defense applied
	Dwelling/Residential Houses	Intact, not many affected	Medium	Considerable distances from HWM
	Guest Houses	Foundation walls been leached leaving some cracks at some points on the wall.	Medium	Not too close to the beach

Photo showing destructions to Hotels along Lakka beach

Table 4b: Inventory of community assets and their current state-Hamilton

Name of Site	Type of asset	Current state	Analysis of Potential risk (very low Low; Medium; High/Critical)	Notes
Hamilton	Bridge	Collapsed	High	Exposed to wave actions and increase in water level
	Public Shower and bath rooms	Not functioning, All damaged	High	The construction didn't consider long tem effects from sea level rise
	Restaurant	In perfect condition	Medium	Current position closer to high tide zone
	Residential houses	Fences are under serious threat from erosion; Foundation walls are being eaten up slowly	High	This indicate coastal recession is rapid

Coastal erosion effects on Shoreline and Coastal assets in Hamilton

The effect of coastal erosion was visible and the study shows that coastal assets along the shoreline in Hamilton could be at high risk to sea level rise and storm in the near future (see photos above).

Table 4 c: Inventory of community assets and their current state – Conakri-Dee

Name of Site	Type of asset	Current state	Analysis of Potential risk (Very Low; Low; Medium; High/Critical)	Notes
Conakri-Dee	Cinema	In good condition	High	Elevations are below sea level. At high tide water would hit the walls of the building.
	Residential houses	Some have already been destroyed as seawater invades inland	High	Currently located in high tide zone
	Fish smoking huts	Still in working condition	High	Currently located in high tide zone and under serious threat as the area becomes inundated at high tide
	Fuel sales outlet	Still in working condition.	High	Currently located in high tide zone. Threat level is also high as the area becomes inundated at high tide
	Market sheds/mini shops	Some have collapsed, whilst some are partly destroyed.	High	Asset now found in high tide zone

Given the rapid shoreline recession, some property owners have constructed some form of non-mechanical coastal defense by placing a number of sand bags at the beach front with the aim to reduce the rapid erosion as a means to protect their properties.

Shoreline erosion and effects of houses in Conakri-Dee

Table 4d: Inventory of community assets and their current state - Tombo

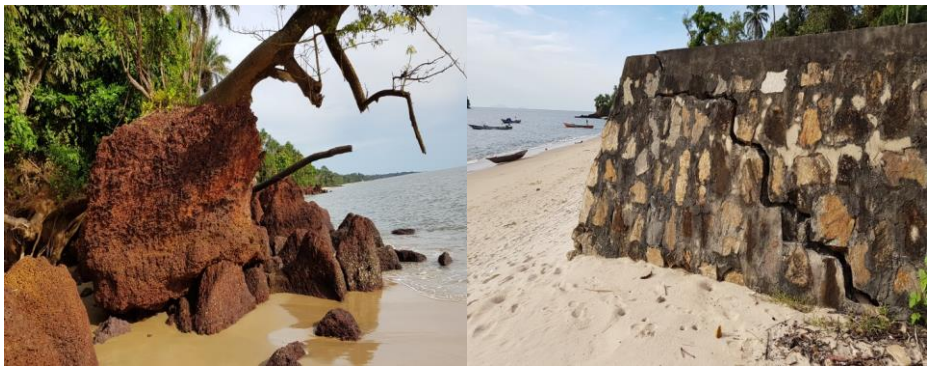
Name of Site	Type of asset	Current state	Analysis of Potential risk (Very Low; Low; Medium; High)	Notes
Tombo	Modern Fish processing facility of Government of Sierra Leone	Functional but there are several cracks in the Concrete Sea wall which has left leaching of the concrete wall and foundation.	High	Constant pressure from wave actions. This will slowly make the facility unstable
	Jetty	Currently in good shape	High	Risk of being damaged is probable
	Facilities of Private fishing companies	In good conditions	High	For one (Korea Fishing Company), water levels now reach the height of fence wall, while for the other (Brother Fishing Company) the fence wall under pressure from wave actions
	Slipway	Still in working condition	High	Not impacted to the level that raises concern

	Market sheds	Currently stable Not impacted to a level that raises concern	Medium	Human interventions have reduced the impact considerably through Artificial protection (boulders) which has rendered these areas with a sustained protection against waves, sea level rise ad storms.
	Naval office	Stable at relocated position	Medium	Located in market area close to shoreline. Has protection from rock piles placed by inhabitants
	Boat building workshop	In stable condition	Medium	There is considerable distance from high tide zone
	Residential houses	No evidence of destruction/damage	Medium/Moderate	There is considerable distance from the high water mark.

Effect of erosion on the walls of the Fish processing facility in Tombo

Table 4e: Inventory of community assets and their current state - Shenge

Name of Site	Type of asset	Current state	Analysis of Potential risk (Very Low; Low; Medium; High/Critical)	Notes
Shenge	Modern Fish processing facility	Generally in good condition but there leaching of the Foundation of the sea wall and cracks were observed.	High	Considering the cost of this infrastructure, the potential risk is very high.
	Residential houses	Not affected	very Low	Highly elevated area (Cliff). Additional protection by natural means such as vegetation and rocks: Cliffs show some amount of stability.
	Old jetty	Collapsed	High	Located below high tide zone, it becomes inundated at high tide.
	New jetty	In perfect condition	High	Constant pressure from wave actions during high tide



Rocks serving as natural protection (Left); Cracks if the seawall in Shenge

Table 4f: Inventory of community assets and their current state – Bumpe – Tok (Turtle Island)

Name of Site	Type of asset	Current state	Analysis of Potential risk (Very Low; Low; Medium; High/Critical)	Notes
Bumpe tok (Turtle Island)	Dwelling houses/huts	There were evidence of collapsed structures. Some others are partly destroyed.	High	The vegetation (coconut) had served as natural barrier to shoreline erosion. However, all the natural protection are gone, thereby leaving houses/shed exposed.
	Hand Pump	Not functional in use as the salt water intrusion has made it impure for drinking purposes.	Very high	The salt water intrusion has made it impure for drinking purposes. This asset is beyond any form of protection.

3.1.2 Potential impacts from Sea level rise and Coastal Storm

~~Eventhough~~Even though estimating shoreline change projections is outside the scope of this assessment, the rate of shoreline change between 2005 an d 2018 (Table 9) suggests that most areas on the beachfront in the pilot sites are at high risk to coastal hazards.

From the analysis, the potential hazards Lakka and its surrounding community will be prone to consists of alteration of the shoreline morphology and damage to assets/infrastructure. Such impacts are exacerbated by human activities, i.e. sand mining. The hydro dynamics at some areas in Lakka shows that structural defense/coastal protection systems on the shoreline can only offer better protection when the appropriate one is applied.

The situation is more serious in Conakri-Dee, where six out eight hazards categories (Table 5) will severely affect the shoreline as well as the assets with a resultant effect on socio-economic and livelihoods. The shoreline of Conakri-Dee does not have any structural protection and even in places where rocks are found, the impact of coastal erosion is still high.

Left: Erosion of Shoreline in Shenge: Right: Shoreline protection initiative by Locals of Tombo

Table 5: Significance of potential hazards on coastal communities

Potential hazard type	Significance of Potential hazards on coastal communities					
	Lakka	Hamilton	Conakri-Dee	Tombo	Shenge	Turtle Island
Destruction to coastal vegetation						
Coastal/Shoreline erosion						
Coastal recession						
Damage to assets/Infrastructure						
Coastal Inundation/Flooding						
Salt water intrusions						
Coastal wetland loss						
Change in shoreline morphology						

As it may be anticipated (From Table 5) above, Turtle Island could be seen as a place not critically vulnerable to impact of sea level rise and coastal storm as the hazard assessment does not show such level of hazard severity when compared with the other places. This is probably because all the assets surveyed in the Island were shafts and fish smoking sheds of lower monetary value, and which construction does not require huge capital. Besides, the inhabitants have exercised some adaptive strategies in limiting construction to the use of local and low cost materials only.

Unlike Lakka and Hamilton where sand mining is more intense and is believed to have contributed to the severe coastal erosion, the Shoreline of Shenge is in part protected by large boulders which have slowed down the rate of erosion in some areas. In other places where the shoreline is sandy, the erosion is very intense and no initiative has been devised by the community to halt the loss of coastland. Table 6 provides the significance of potential hazards on coastal assets.

Table 6 below further shows the significance of potential hazards on coastal assets/infrastructure of the various pilot sites. Various colour schemes are used to indicate how prone a particular asset is to potential coastal hazard from SLR or coastal storm in each of the sites. The colour red indicates high significance of threat on an asset while green indicates low significance.

Table 6: Significance of potential hazards on assets/infrastructure

Site	Significance of Potential hazards on assets/infrastructure																	
	Bridge	Hotels	Restaurants	Dwelling/Residential houses	Jetty	Fish processing facility	Swimming Pool	Guest Houses	Public Shower and Bath room	Cinema	Fish Smoking huts	Fuel Sales Outlets	Market shed/ mini shops	Slipway	Offices (Naval Post)	Hand pump	Boat building/repair yard	Ecology
Lakka																		
Hamilton																		
Conakri-Dee																		
Tombo																		
Shenge																		
Turtle Island																		

Various coping or adaptive measures have been instituted by some property owners to reduce the impact of coastal erosion and to reduce the degree at which properties are affected as noted in Table 7 below. Pictures below show some infrastructure that has either collapse or at high risk in Hamilton. Recognizing the rapid shoreline erosion which has affected many infrastructures along the Hamilton beach, some property owners have erected non-structural beach face embankment to reduce the impact of coastal erosion and to reduce the degree at which properties are affected.

Left: In Hamilton, coconut trees planted on the beachfront have been exposed to coastal erosion and many uprooted; Right: Public shower ruined as a result of storm and erosion

The vast wetland area covered by mangrove vegetation is connected to the sea through an inlet which is occasionally flooded during high tide and receives fresh water from surface run off during rains.

3.1.3 Coastal infrastructure and assets protection strategy

From interviews with community representatives, about 120 coconut trees were planted along Hamilton-Lakka beach to serve as natural barriers to wave action and storm. At the time of the assessment, observation shows that these coconut trees have suffered massive destruction from coastal erosion impact leaving only about ten surviving trees with some of the coconut trunks having their root now exposed.

Photos showing adaptive strategy by Tombo and Lakka Communities

Table 7: Coastal protection measures present at pilot sites

Name of site	*Shoreline protection measure applied*
Lakka	*Natural defense (sustained); Structural defense (some destroyed); Some building mounted on concrete pillars; some have sea walls as protection means; bags-contained sand used as wave breakers*
Hamilton	*Natural protection at some points with natural rock outcrops. Structural (All buildings have* defense walls. These are to further strengthen property perimeter fence walls and prevent damage from wave actions at high tide .
Tombo	*Structural (concrete Walls, human induced protection – Embankment by piling boulders at the seafront)*
Conakri-Dee	*Partly rocky (natural induced protection)*
Shenge	*Natural (cliffs, sandy, rocky shoreline).*
Turtle Island	*Mainly natural (vegetation, e.g. coconut). Temporal dwelling units are constructed in the vicinity of the shoreline. Inhabitants highly adapted to retreating as sea water invades inland.*

Approximately some 35% of the shoreline area in Hamilton is rocky whilst 65% is sandy, and these are not much littered when compared with other places. Apart from the walls of concrete fences constructed around many houses, there is no physical coastal defense in this area. Because of high wave action exacerbated by the sand mining in some areas, serious impact of erosion has already been felt as many structures have collapsed and some fence walls are at high risk and at the verge of collapsing.

In Lakka, restaurants are now built with a design to absorb shocks from sea level rise or wave and storm surges. This is an impressive local adaptation strategy. The assessment also reveals that some structural defense

***Left**: The banks of Monkey-island in Shenge has been sustained by the presence of rocks; **Right:** The presence of Cliffs in Shenge town has reduced the risk of damage to houses*

The peculiar nature of the shoreline in Shenge presents unique features of the coastal erosion threats and the cumulative resulting impacts. Some areas with high cliff have outcrop of boulders and these present natural coastal protection and have over the years reduced the rate at which the land is taken up by the water. Observations show the indentation of the shoreline geomorphology indicating the different rate of the erosion in areas with natural protection and those without protection. In Shenge the only assets protected by mechanical defense structure is the fishery processing complex, but this facility is now facing serious threat from erosion resulting to damage to the asset.

There are a number of the huge cracks in the walls constructed to provide means of protection to the facility and some areas have already been damaged. Some of the observations indicate the following:

- Natural barriers through rocks and boulders have offered some amount of shoreline protection by providing resistance thereby reducing the intensity of the pressure;
- The geomorphology of the Shenge township offers great tendencies to slow down the coastal erosion impacts to the community;
- From historical account, the small Island called "Monkey Island" was cut off from the main land some 15 years ago but the presence of rocks have offered great resistance to erosion and recession.

3.1.4 Shoreline movement

Overall, the assessment shows evidence or shoreline retreat and massive coastal erosion in the six pilot sites. The rate of the shoreline change as given in Table 9 varies from site to site. Apparently this indicates the level of some other external pressures as well as the geology of the coastline.

According to interviews with local inhabitants, the rise in sea level has become very prominent over the past 10 years. In this study, a GIS tool was applied to track the shoreline change over 13 year's period of the various pilot sites. It is no doubt that low lying areas have been more affected by the rising sea level coupled with coastal erosion, making coastal assets very vulnerable.

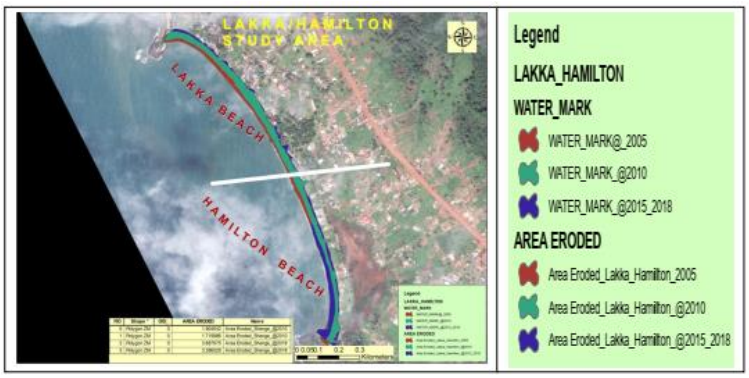


Figure 4: Shoreline change in Lakka-Hamilton beach area

As shown from this studies (Table 9), the cumulative change in shoreline is remarkably high for Hamilton and Lakka (see also Figure 4) with distance of 42m over the 13 years period. Figures (4 – 8) give a pictorial presentation of the rate of movement of the shoreline overtime

Notwithstanding this, however, Conakri-Dee which gives the second highest in the distance of shoreline change (Figure 5) show even more aggressive impact. At the wharf area, the entire settlement becomes inundated during high tide.

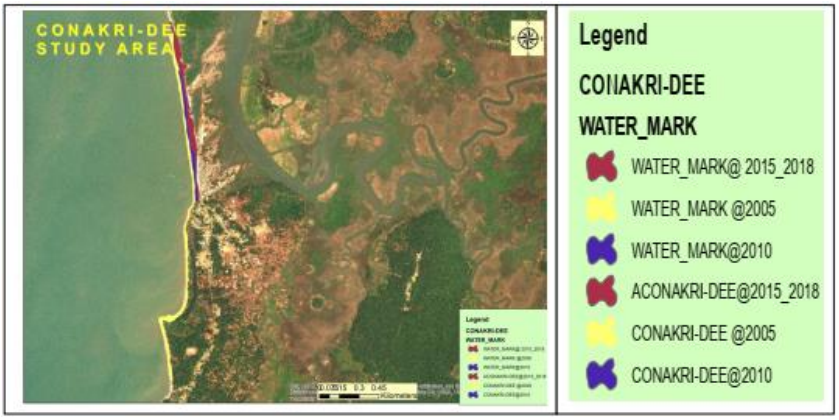


Figure 5: Shoreline change in Conakri-Dee area

In Turtle Island, the coastal recession show the least when compared with other sites giving the difference between the water mark in 2005 (baseline) and 2018 as 29.0m.

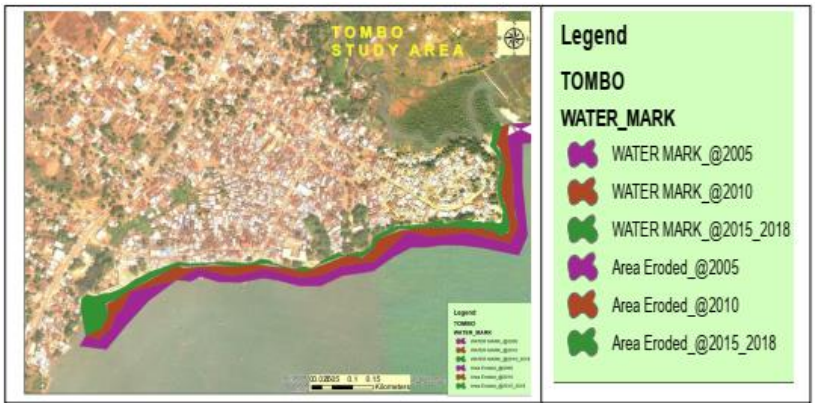


Figure 6: Shoreline change in Tombo area

What is most evident is that even though the difference in the rate of shoreline change amongst the six sites is high, yet the impact or effects on assets are almost very similar but the intensities are exacerbated by human activities. Table 8 gives the vertical distance between Low water mark (at low tide) and High Water mark (during high tide). Owing to the different coastal morphologies and the coastal development of the pilot sites, the mean distance varies from one pilot site to another.

Table 8: Tracking sea level change

Pilot site	Distance of immediate assets from HWM (m)	Distance between LWM & HWM (m)	Mean distance (M)
Lakka	30m	75m	53
Hamilton	20m	30m	25
Tombo	<1m	40m	20
Conakri-Dee	<1m	40m	20
Shenge	<1m	50m	25
Bumpe Tok (Turtle Island)	10m	30m	20

Photo showing the impact of shoreline erosion in Turtle Island

For the stretch of coastline spanning from Lakka to Hamilton, the analysis shows a steady rate of shoreline change over five years intervals (2005 – 2010 and 2010 – 2015 (Table 9). The rate calculated can be misinterpreted to be even for both Lakka and Hamilton, however this could not be true as the external pressures in these two locations are not the same.

Table 9: The rate of shoreline changes (Mean rate of shoreline change (m/year) (rates are used in the prediction of future shoreline positions)

Name of site	Cumulative Change in shoreline position (m)	Rate of shoreline change - Coastal recession (m/year)
Lakka & Hamilton	2005 – 2010 = 15	3.00
	2005 – 2015 = 30	3.00
	2005 – 2018 = 42 (cumulative)	3.23
Tombo	35	2.69
Conakri-Dee	41.9	3.22
Shenge	38	2.92
Turtle Island	29.0	2.23

The current threats at these locations indicate that Lakka is under high pressure than Hamilton and it has experienced devastating impacts than any of the sites assessed.

In Shenge (Figure 7), unlike the other pilot sites, coastal erosion is massive and the rate is very rapid but not with uniform intensity across the length of the shoreline due to multiple factors.

The current threats to the coastal assets range from damage to infrastructure due to rise in sea level and coastal storms and land degradation. From historical accounts, the rate at which the sea is eating up the land is very glaring and resulting impacts of destruction to the ecology cannot be over exaggerated. The features of the shoreline in Shenge present unique characteristics of how the shoreline responds to pressures and resulting impacts and risks. In areas with clayey or muddy soils on the shoreline, the areas impacted are vast and the potential risk remains very high.

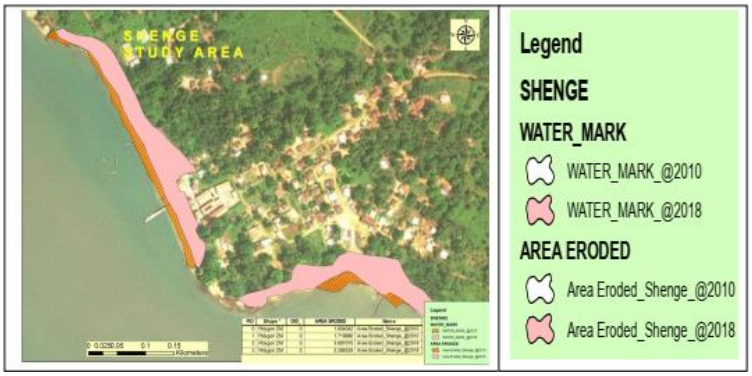


Figure 7: Shoreline change in Shenge area

In Turtles Islands, one of the noticeable indications showing the relative speed at which the sea is advancing is the current location of the water tap which was constructed in the middle of the Bumpe-Tok village over 5 years ago.

Photos showing effects of sea level rise and coastal erosion in Turtle Island

The choice of the location was to have a sustained service, but during the assessment it was observed that the location of the tap is now almost about 30m from HWM and many houses surrounding the tap have already been destroyed. The tap is no longer useful as the sea level rise has led to decreasing the water table and the intrusion of salt water rendering the water unfit for drinking.

A Chi-square test (Table 10) was conducted to test if there was any significant difference in the rate at which the shoreline changes occurred in the pilot sites. From the analysis, the calculated value (0.234) was lower than the tabulated value (3.84) at 5% level of significance, implying that there is no significant difference in the rate of shoreline change among the six sites.

Figure 8: Shoreline change in Turtle Island

Table 10: Chi square test on the rate of shoreline change in the pilot sites (November, 2018)

Sites	Observed number (O)	Expected number (E)	O-E	$(O-E)^2$	$(O-E)^2/E$	$\sum (O-E)^2/E$	Calculated X^2	Tabulated X^2
Lakka & Hamilton	3.23	2.86	0.37	0.1369	0.0478	0.234	0.234	3.84
Tombo	2.69	2.86	0.17	0.0289	0.0101			
Conakri-Dee	3.22	2.86	0.36	0.1296	0.0453		No significant difference	
Shenge	2.92	2.86	0.06	0.0036	0.0013			
Bumpe Tok	2.23	2.86	0.61	0.3721	0.1301			
Total	14.31							

As the analysis indicates, coastal recession is prominent in every pilot site, but the rate at which sea water has moved inland over the past thirteen (13) years (i.e. 2005-2018) thereby changing the position of the shoreline varies from one place to another.

Despite the slight variations in the rate of change of the shoreline, a Chi-Square test conducted for this study (Table 10) shows with 95% confidence (ANOVA; P=0.05; df.1) that there is no significant difference in the rate at which water moves inland. Such a statistical outcome suggests that the drivers of change (Human and/or natural) could be similar for all the sites, under investigations. However, the gravity of the impact on the receptor from SLR could vary by sites.

3.1.5 Current threats to the coastal environment

Table 11 gives an indication of the Human induced as well as natural environmental pressure and the magnitude of such risks in the pilot sites. Threats from human activities are seen to be prevalent in all sites.

a. Lakka

Current threat visible in this area include shoreline erosion resulting to destruction of vegetation, damage caused to hotels, fences and guest houses by wave action during high tide. There is all indication that extreme weather conditions could exacerbate the threat particularly on recreational facilities (such as hotels, restaurants, and huts). Such effect from flood on infrastructures is reflected in the various coping strategies observed in this area including the construction of sea protection walls or beam, though inappropriate. Dwelling houses are the list affected probably because of the considerable distance away from the high water mark. However, evidence of sea defense mechanisms seen around residential houses makes it prudent that these are also at potential risk to flooding.

Table 11: Potential ecological and environmental risks

Name of site	Human induced /natural environmental pressure	Magnitude of resulting risks (High Moderate, Low)
Lakka	Sand Mining; rapid costal infrastructural development	High
Hamilton	Sand mining; Salt water intrusion; Wetland reclamation and embankment	High
Tombo	Logging	Moderate
Conakri-Dee	Mangrove logging	High
Shenge	None recorded	N/A
Turtle Island	None recorded	N/A

There is increased coastal erosion at some location in this area. The basement of some restaurants is heavily flooded during the rains, a phenomenon of the mean water spring tides. Construction of sea walls as adaptation strategies by owners of various assets was evident. These were however seen to be inadequate as the high water mark currently levels with the height of some defense walls.

b. Hamilton

Coastal erosion is evident and stand as one key threat at Hamilton. Coastal erosion effects on vegetation and infrastructures such as bridge and public shower or bath room were quite evident. The shoreline erosion in this area affects many residential houses located near the sea. Highest high water mark levels with the height of defense wall of houses. Salt water intrusion also affects the dynamics of the creek connecting the sea which in turn affects human settlement located far off the beach area by either destroying housing foundations or make construction work too difficult for the people. This effect is strongly felt during the months of July-August, according to interviews with residents.

c. Conakri-Dee

Intensive coastal erosion is a major environmental problem facing the Conakri-Dee coastal zone. Residential homes, entertainment and relaxation centers (Cinema) and market sheds/mini shops, fish smoking huts, fuel sales outlet are all now located in the high tide zone, and are being flooded or inundated during periods of highest high tides. There are evidences of abandoned and destroyed homes and other structures as a result of wave actions. As an adaptive strategy, the people surround their houses and entertainment centers with heaps of sand (Sand dunes) as defense against incoming flood water during high tide. Evidences of the effects of erosion on trees are also widespread.

d. Tombo

Currently, the defense wall of the government fishing facility is constantly being hit by coastal water during highest high tide (HHT), and collapsing at some point. Less than 1m difference exists between highest water mark and height of the defense wall of the facility. Also, about 80% of the length of the sleep-way is submerged during high tide.

Fishing companies recorded in Tombo included the Korean and Brother Fishing Companies. Adaptive measures are in place by building a coastal defense wall, but these are under threat from the rise in water level. At the HHT, the height of the sea (Highest Water Mark) currently levels with the height of the retaining wall (coastal protection) of the Korean fishing company facility and there is evidence of the effects of “splash flood” during the highest high tides. Notwithstanding, the defense wall by Brother fishing company is much elevated, but is also under continuous pressure during high tide, and it is possible that it may collapse over time if appropriate measures are not taken.

Residential houses and immediate vicinity of the Sierra Leone Artisanal Fisheries Union complex currently located within the high tide zone of the coastline are being affected by splash flood at periods of highest high tide. Also, the coastline is experiencing high levels of siltation, thus making navigation difficult especially at low tides.

e. Shenge

Just as in Tombo, the defense wall of the government fishing facility situated in Shenge is under high pressure from wave actions during high tide. Leaching and cracks on the Foundation of the sea wall of the facility from wave actions are so visible. Erosion of trees and jetty (old jetty) were very prominent. The old jetty is currently submerged under water even at mid high tidal level. Notwithstanding the topography of some shoreline areas in Shenge provide natural protection for residential houses.

Dwelling houses are situated on highly elevated areas (cliffs) above sea level and there was no records erosion effects on these properties. However, sea water is fast advancing in residential areas but with the presence of some boulders at the foot of the cliff the rate at which the land is taken up by the sea is moderate.

The impact of storm and sea level rise has had little effect on the new jetty and slipway constructed to service the fishery complex as the construction took into account adaptation phenomena. However, the coastal floodplain adjacent the fishery complex is also battling with some of the effect and risks posed by sea level rise and coastal storms. Destruction to vegetation on the shoreline is a clear indication of the growing pressure and risk the coastal zone is exposed to.

f. Bumpe-Tok (Turtle Island)

All houses on this island are built of mud with some having corrugated iron roof and many having thatches as main roofing material. There were physical evidences to show shoreline erosion and the destructions caused to trees which were planted by the community to serve as protection and barrier against storm and wave effects. In Bumpe tok village, a number of coconut tree trunks were spotted and debris of concrete houses destroyed by the advancing seawater. The coastline protection measures adopted here is the natural protection type. Hundreds of coconut trees were planted on the beachfront for the purpose of shoreline defense against storm and wave actions.

Photo showing the old jetty in shenge in a dilapidated state

The inhabitants of this small island community gave an account of the advancing water level to have taken up landmass estimated at 150 m from its original position and the current high water mark over the last ten years. The vegetation (coconut) had served as barrier to shoreline erosion and flooding. Currently, the natural protection is almost all gone at most point of the shoreline leaving the huts/sheds exposed to the coastal storm and sea level rise impact.

All houses in Turtle are built up of mud as shown in this picture

4 Section Four

4.1 Coastline and asset/infrastructure vulnerability

This section tries to analyze the potential risks of sea level rise and coastal storm impact on assets/infrastructure and on the communities. The basis of this analysis rest on two key aspects already discussed above. The first one relate to the assumptions considered in this study, and also the historical evidences revealing the shoreline change through the GIS analysis done for a thirteen years' period.

Risks associated with shoreline change determine to a greater extent the vulnerability of the coastal assets. Where greater numbers of people in coastal communities rely on mainly fishing and tourism for their livelihoods, shoreline change can have greater adverse consequences on their businesses and in turn their livelihoods and wellbeing.

In the context of this study, the result indicates that all assets or facilities located on the beach front are at risk. The extent of these risks depends on the following:

i. Nature of shoreline;
ii. Type of assets/infrastructure;
iii. Adaptation strategy adopted in construction design, etc.

In the foregoing chapters, risks to various assets in the different pilot sites were elaborated. From those evaluations, it suggests that potential risk categories are understood based on the potential impact severity and magnitude.

Though this assessment could not further analyze this aspect, it is however obvious that all of the coastal assets surveyed are vulnerable to sea level rise and coastal storm surge impact but at different magnitudes. This is evidenced in the current damage caused to assets and the rapid advances of the water into the coastland. Where coastal protection or defense structures are adequate, there is high tendency that coastal erosion and coastal recession can be slowed down. In Conakri-Dee for instance where the coastal recession is very prominent, the vulnerability of these areas including its assets is unquestionable.

Meanwhile the application of coastal adaptation strategies through the installations of coastal defense system is another key determinant of how vulnerable assets could be to the impact of sea level rise. There are however inherent factors that can be considered in making judgement on vulnerability. Where the current state of the coastline show marked erosion as evident from data collected during this assessment, the vulnerability of the various sites could be depicted from these observations and the potential hazards ranking of the various sites.

Accordingly, the trend of shoreline change reported in this assessment would mean that all assets within the 5 to 7m range from the high water mark remains vulnerable to impacts of sea level rise and storm. Pictorial evidence has already confirmed this.

In low lying areas such as the Wharf of Conakri-Dee, the vulnerability is already expressly manifested in the rate of advance of the water and the resulting damage it has caused. For coastline with cliffs and outcrops of rocks, the assessment shows moderate vulnerability and such areas cannot be difficult to protect by human interventions.

4.2 Potential loss of assets and implications

The pilot sites are low lying with gentle slope in some areas. As erosion and flooding are key threats facing the pilot sites, indigenes have developed ways of responding to such threats which include retreating, accommodating and/or protecting. The erosion and flood effects could be some possible implications of climate change. As a consequence, social and economic activities including fishing, recreation and tourism-oriented economies are significantly impacted during periods of such occurrences. A number of studies allude that the coastal nations of west and central Africa (e.g., Senegal, The Gambia, Sierra Leone, Nigeria, Cameroon, Gabon, Angola) have low-lying coasts that are susceptible to erosion and hence are threatened by sea-level rise, and will increase an already existing physical, ecological/biological, and socioeconomic stresses on the African coastal zone (IPCC, 1996; Losado, et al., 2014). Other studies confirmed that the West Coast of Africa is often affected by storm surges and currently is at risk from erosion, inundation, and extreme storm events. (Awosika et al., 1992; Dennis et al., 1995; French et al., 1995; ICST, 1996; Jallow et al., 1996).

Owing to the rapid rate of sea level rise, the hand pump which was constructed few years ago at the then center of Bumpe tok village, Turtle Island to serve as potable drinking water source has been rendered unsuitable for drinking purposes due to the rise in water table causing salt water intrusion. Such situation could have both social and ecological consequences by dampening the livelihood of coastal inhabitants. According to Mitsch and Gosselink, (2000) coastal ecosystems provide a variety of services as well as the economic livelihoods of many communities. A similar study has shown that problems related to contaminated soils may occur when seawater reaches inland, and that climate change is expected to affect water quality; also, fish, birds, and coastal plants could lose parts of their habitat (Peters and Darling, 1985; Saunders and Hobbs, 1992; IPCC, 1996; Williams and Orr, 2002; Ward et al., 2003; Schwarz and Orme, 2005; Wolters et al., 2005; Koch et al., 2009; Kirwan and Temmerman, 2009; Stralberg et al., 2011; Parker et al., 2011; Lauren, 2016).

Further the study shows that the effect of erosion and flooding could be much intense during extreme weather conditions. This is confirmed by the 1995 and 1996 IPCC reports, which suggests that the potential damage to coastal settlements and infrastructure from more intense flooding events is a major concern in view of the magnitude of capital investment.

4.3 Conclusions

The pilot sites considered in this assessment were all observed to be in low-lying coastal areas, and are perceived to be particularly vulnerable to a meter rise in sea level and coastal storm surges. Current impacts include coastal erosion, flooding and salt water intrusion. These magnitude of these impacts are however not the same at the different coastal zones of the pilot sites. The findings of this assessment has also revealed that in some areas of the pilot sites, the position of the high water mark is now a meter or less closer to the shore than it was in about 10 to 15 years ago. A much higher tidal influence (mean water spring tides, locally known as Juxon spring) is felt during the rainy season (July-August) and has always caused serious flood issues on infrastructures located in the high tide zone of the coast

Meanwhile the results of this study can be used in quantifying shoreline changes and in predicting shoreline positions, which is sufficient to determine what assets/infrastructure could be at risk to sea level rise and storm. Thus the assessment concludes the following:

1) The Shoreline changes depend on the shoreline configuration;

2) That all pilots sites are under serious threats of coastal erosion and shoreline recession;

3) That the rate of change of shoreline position varies from place to place along the coast;

4) That human activities are inflicting serious threat to the coastal areas (sand mining, land reclamation/embankment, Coastal infrastructural development);

5) That only appropriate shoreline protection can reduce or limit the sea level rise and coastal storm impacts;

6) The assessment reports that the human interventions play vital role in regulating shoreline changes, in addition to natural processes (Tombo, Monkey Island);

7) The complex interaction of a number of processes and factors such as magnitude of wave energy reaching the shoreline, sediment supply and beach sediment budget, morphological properties (elevation) are responsible for recession of the shorelines.

4.4 Recommendations

1. A detailed study to cover wider areas of the pilot sites is necessary in providing further insight on the vulnerability of the coastal zones to climate change effects.

2. Environmental and conservation NGOs operating in these pilot sites to support communities in building their capacity through education and awareness programs on climate change risks and adaptation strategies;

3. Coastal infrastructural development projects in the tourism sector must take into account the level of risk such investment will be prone to;

4. Government regulatory Agencies such as the EPA, NPAA must formulate laws on coastal environmental protection to address unsustainable human practices;

5. Widen the scope of future assessment to be able to analyze and assess coastal erosion hotspots;

6. Coastal communities must be sensitized on best coastal protection adaptation methods;

7. Island communities in particular must endeavor to plant trees on the shoreline so as to lower the impact of destruction to assets along the shoreline;

8. Early warning systems should be strengthened at a national level and coastal communities capacitated to adapt to various forms of Climate impact;

9. Government, NGOs and INGOs must put measures in place for early warning as well as identifying suitable sites for relocation of coastal inhabitants should there be any future rise in sea level or coastal storm as predicted by the IPCC. Information on the extent of potential areas to be relocated is also important.

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4.6 Annexes

4.6.1 Terms of reference

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