COASTAL MANAGEMENT AND BEACH RESTORATION GUIDELINES: JAMAICA

WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

ACP-EU Natural Disaster Risk Reduction Program

An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR

Contributors

With financial support from the European Union (EU) in the framework of the ACP-EU Natural Disaster Risk Reduction Program, managed by the Global Facility for Disaster Reduction and Recovery

The Technical Working Group helped to shape the aims and objectives and the direction throughout the project. The Technical Working Group consisted of: National Environment and Planning Agency, Planning Institute of Jamaica, National Works Agency, Office of Disaster Preparedness and Emergency Management, and Jamaica Social Investment Fund.

The Consultants on this project were Mott MacDonald Ltd. and partners which included: Sustainable Seas, Smith Warner International and Clear Caribbean.

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A	10/02/17	B. Riley L. Eyres	J. McCue	P. Phipps	Draft for comment
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INFORMATION CLASS: STANDARD

Update of Guidelines

Further identified studies and associated research, required to update within these Guidelines has been recommended and presented in a separate report entitled "Beach Restoration and Coastal Management Guidelines: Further Recommendations for Research for Jamaica" (Mott MacDonald, 2017). The Guidelines should be updated every five years to include more recent case studies, updates in regulation and international best practice research. Additional interim reviews of national legislation or regulation is required every three years so that important policy or legal updates are incorporated.

Table of Contents

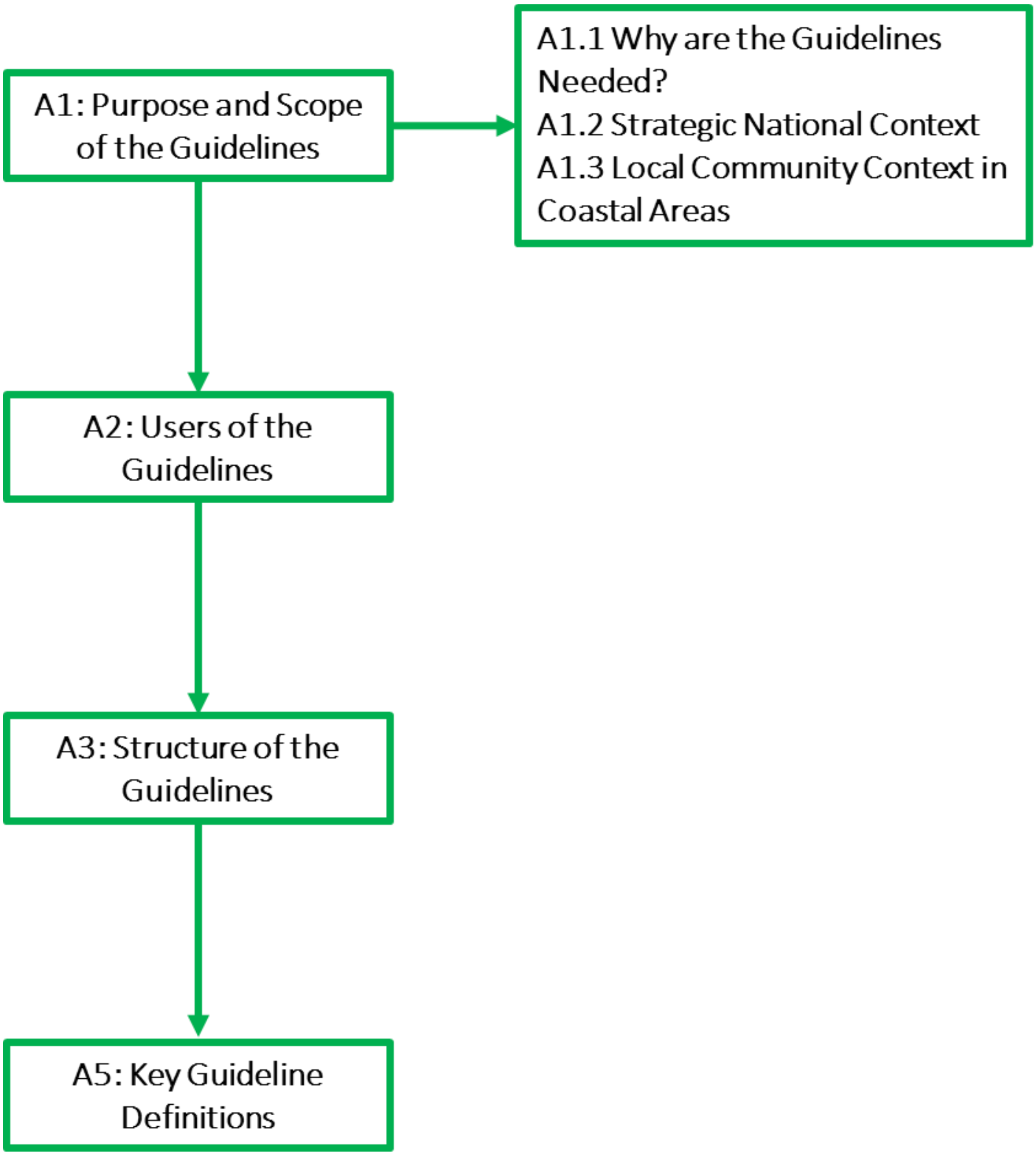
Glossary

Accretion	The accumulation of (beach) sediment, deposited by natural fluid flow processes. (CIRIA, 2010).
Beach management plan	A formal written plan for managing a beach (generally for coastal defence) involving a selection from a wide range of potential capital, maintenance and monitoring works. (CIRIA, 2010).
Beach Profile	A cross-section taken perpendicular to a given beach contour. The profile may include the face of a dune or seawall, extend over the backshore, across the foreshore, and seaward underwater into the nearshore zone (CIRIA, 2010).
Biodiversity	"biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (article 2, Convention on Biological Diversity).
Buildability	The simplicity (or complexity) of an intervention to construct.
Climate change resilience	Climate resilience is the capacity of a system to "anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (IPCC, 2014).
Coastal squeeze	Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers (such as resistant cliffs or a seawall) (CIRIA, 2010).
Coral Bleaching	The paling in colour which results if a coral loses its symbiotic, energy-providing, organisms (IPCC, 2000)
Design Life	The period for which an intervention will continue to function as it is designed to.
Downdrift	In the direction of the nett longshore transport of beach material (CIRIA, 2010).
Foreshore	The intertidal area below highest tide level and above lowest tide level (CIRIA, 2010).
Hard intervention	Typically used historically as coastal defences, hard interventions refer to engineered designed and built structures.
Hybrid intervention	This represents a combination of nature-based, hard and non-structural interventions that may be used to enhance coastal resilience by providing important storm and coastal flooding protection, while also providing other ecosystem service benefits.
Hydrodynamic	The study of the movement of a liquid.
Hydrology	Studies referring to the water cycle and the movement of water on Earth.
Intervention	These represent physical constructions that help to implement a Management Approach. Such interventions may include nature-based, hard and non-structural intervention measures to reduce erosion mitigation, to reduce coastal flooding, "quick fix" short term measures etc.
Longshore/ littoral drift	Movement of (beach) sediments about parallel to the coastline (CIRIA, 2010).
Management approach	A management approach refers to the broader adoption of a particular approach to coastal management along the coastline. This could include defending a section to a particular standard of protection as well as choosing not to do anything and to let the coastline naturally erode.
Natural Resources	Natural resources are natural assets (raw materials) occurring in nature that can be used for economic production or consumption (OECD, 2005).

Nature-based intervention	Intervention projects that are inspired and supported by nature. They provide habitat for plants and animals through careful consideration of the site and strategic placement of components along the entire ridge to reef profile. They are cost-effective and simultaneously provide environmental, social and economic benefits and help build resilience.
Non-structural intervention	An intervention which is focussed more on planning decisions rather than building or restoring ecosystems or structures.
Overtopping	Water carried over the top of a coastal defence due to wave run-up exceeding the crest height (CIRIA, 2010).
Resilient / Resilience	The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change (IPCC, 2007).
Ridge to reef (R2R)	Ridge to reef is the term used within these Guidelines to define the coastal zone to which the Guidelines are applicable. It is a term which is to be used to ensure rather than just simply the focussing on the shoreline, coastal management considers the cross sectional profile at the coast across different areas. This includes consideration of the hinterland, shoreline and nearshore profile.
Scour	Erosion resulting from shear forces associated with flowing water and wave actions (CIRIA, 2010).
Setback	A specified distance from a defined area – in this case the distance between the shoreline and where the developments can be built.
Small Island Developing State (SIDS)	Small Island Development States (SIDS) are a distinct group of developing countries facing specific social, economic, environmental vulnerabilities. There are 52 countries and territories presently classified as SIDS (United Nations, 2011).
Standard of protection	The flood event return period above which significant damage and possible failure of the flood defences could occur (CIRIA, 2010).
Updrift	The direction opposite to that of the predominant longshore movement of beach material (CIRIA, 2010).
User group	Anticipated users of these Guidelines. Groups are defined within Table 1: Users of the Guidelines.
Watershed	The land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge (USGS, 2017).

Part A: Introduction

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.



Contents

A1: Purpose and Scope of the Guidelines

A1.1: Why are the Guidelines Needed?

Currently in Jamaica there are two core guidelines which are used for coastal management **interventions** and beach restoration. These are:

- NRCA Guidelines for the Planning, Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines (Circa 1995); and
- Draft Guidelines for the Relocation and Restoration of Jamaica's Coastal Resources: Corals, Seagrasses & Mangroves, A Guide for Developers (2010).

There is now a need to integrate these guidelines with a focus on how to build **climate change resilience** into existing and future designs for coastal management or beach restoration. This includes the need to provide the tools to ensure Jamaican stakeholders can plan, manage and initiate **interventions** at the **ridge to reef** scale which includes considering **watershed** boundaries, intertidal areas, and nearshore coastal habitat rehabilitation in a holistic manner. These updated Coastal Management and Beach Restoration Guidelines (hereafter referred to as the "Guidelines") will therefore provide advice of how coastal management schemes and activities within Jamaica could be implemented along the coast.

Guidance is also needed on the implementation of existing planning regulatory advice in addition to management measures. This is because Environmental Impact Assessment (EIA) requirements and land use planning regulations in Jamaica are generic in terms of coastal activities and planning guidance advice provided on "climate proofing" **interventions** within the coastal zone.

More recently in Jamaica there has been an increase in the utilization of **nature-based interventions** with varying goals in mind. In most instances, though shoreline protection is not the main goal or objective of **nature-based interventions**, it may often be an indirect, long-term outcome. Such **nature-based interventions** include, though are not limited to, coastal habitat restoration, relocation, rehabilitation, vegetation replanting and beach nourishment schemes. There is now the requirement to provide integrated guidance to help support the introduction of more **nature-based interventions**, potentially as part of combined integrated systems using **nature-based** approaches alongside more traditional hard engineered structures (**hybrid interventions**).

The focus of these Guidelines will therefore be to identify ways to ensure that coastal flood and erosion adaptation techniques, as well as wider land use developments, can be made **resilient** against climate change threats in a more cost-effective and socially acceptable way. It provides guidance to ensure that current and future Jamaican coastal management schemes are planned appropriately and are adaptive to predicted **climatic change**.

A1.2: Strategic National Context

For Jamaica, as a **Small Island Developing State (SIDS)**, building **resilience** to the impacts of climate change is of the highest priority. Jamaica's location, geology, and geography make the island prone to several natural hazards including landslides, hurricanes, floods, droughts, and earthquakes. This susceptibility to natural disasters has proven to be a major threat to Jamaica's economic development, the **resilience** of human settlements, and associated critical infrastructural assets.

Jamaica's coastline is approximately 886 kilometres long and provides habitat for many of the Island's living **ecosystems** including sandy beaches, rocky shores, estuaries, wetlands, seagrass beds and coral reefs. It is also the location for most of the critical infrastructure, formal and informal housing, as well as a high percentage of the Island's economic activities, including tourism, mixed farming, fishing, shipping, and mining.

Storm surge events are expected to increase in frequency and size, and sea levels are predicted to rise, thus increasing the incidence of coastal flooding and coastal erosion. This will have a direct impact on infrastructure, homes, and livelihoods including the loss of beaches, mangroves, and breeding grounds for fish and other marine life. This has resounding economic implications that are likely to be observed at the local and national scale, affecting local communities, fisheries, tourism, and other sectors.

The removal and **degradation** of mangroves, seagrass beds, and coral reefs, often caused by the multiple use demands within the coastal zone, has increased Jamaica's vulnerability to hurricanes and storm surges and poses a threat to coastal **ecosystems** and marine wildlife. This vulnerability is not only manifested in terms of **natural resource** impacts but also with regards to changes in social and economic well-being, as sectors such as tourism, agriculture, fisheries, forestry, and water resources are all climate sensitive. In recognition of this, the Government of Jamaica (GoJ) has sought to incorporate climate change considerations into its development policies. Importantly, this remains one of the main objectives of the Climate Change Policy Framework for Jamaica completed in 2015 (GoJ, 2015) which is aligned to Vision 2030 Jamaica - National Development Plan (GoJ, 2009).

The overall vision laid out in the GoJ Climate Change Policy Framework and Action Plan (GoJ, 2015) is that: *"Jamaica achieves its goals of growth and prosperity for its people while meeting the challenges of climate change as a country with enhanced **resilience** and capacity to adapt to the impacts and to mitigate the causes in a coordinated, effective and sustainable manner."* Relevant objectives include: *"To improve communication of climate change impacts so that decision makers and the public will be better informed."*

These Guidelines will help Jamaica implement the Vision 2030 Jamaica (GoJ, 2009) through:

- protecting coastal ecosystems;
- encouraging the adoption of adaptation measures and **nature-based** and **hybrid** approaches; and
- enhancing fisheries.

These Guidelines are also aligned with national environmental policies and plans, the results and conclusions of the Second National Communication (SNC) presented to the United Nations Framework Convention on Climate Change (UNFCCC) (GoJ, 2011) and the recently developed Climate Change Policy Framework and Action Plan (GoJ, 2015).

A1.3: Local Community Context in Coastal Areas

At the community level, there are several factors which pose a challenge towards the successful mainstreaming of **climate change resilience** into coastal management and beach restoration practices. Some of the key challenges include:

- Climate change pressures: Climate change is expected to have adverse impacts on **biodiversity**, lifecycles of marine organisms, quality of habitats, ecosystems, and on socioeconomic services; ultimately increasing the vulnerability of marine-coastal ecosystems.
- Development pressures: Coastal and marine resources are essential components of Jamaica's economy and cultural diversity. Given that most the population rely heavily on coastal and marine ecosystems for their livelihood, the ecological impacts can be translated into significant financial losses. However, anthropogenic development also has significant impacts on coastal and marine resources.
- Impact of land based pollution: Land-based point sources of pollution such as inefficient or non-functioning wastewater treatment plants cause pollution of coastal waters, damage

fragile coastal resources and endanger the health and safety of the resident and tourist population.

The Planning Institute of Jamaica (PIOJ) approximates that 70 percent of the population of Jamaica resides in coastal areas (PIOJ, 2008). They further note that in the last decade, there is an increasing threat of poorly regulated development within the coastal zone which has increased the vulnerability of coastal communities. In 2009, 45.5% of households in Jamaica possessed a female as the head of the family, with 30% classified as being below the poverty line (PIOJ, 2012).

The majority of low income communities (61%) live in rural areas. Available data show the average poverty level at 20.4% in some of the communities linked to the Orange Bay Special Fisheries Conservation Area (PIOJ, 2012). Most employment opportunities fall within the agriculture, fisheries, and tourism sectors; however, unemployment levels remain high, especially among the youth. Many residents in coastal communities depend on fisheries as a source of protein and income, and are among the poorest in the country. One crucial issue faced is the low adaptive capacity of fishers who depend on highly vulnerable fisheries for their livelihoods. Thus, they may engage in unsustainable practices that further threatens their livelihood.

The tourism sector provides approximately US$1.9 billion annually to the foreign exchange earnings of the country (PIOJ, 2012). Of relevance to these Guidelines, the tourism economy in Jamaica is critically dominated by coastal tourism which remains reliant on a healthy coastal zone and associated coastal ecosystems. The important role of Marine Protected Areas (MPA) in the protection and restoration of coastal ecosystems, in addition to improving fish biomass is recognised as a key planning tool to assist the delivery of sustainable tourism not only in Jamaica, but throughout the Caribbean region.

Without alternative livelihood activities being readily available to embrace the need for climate adaptation at the community level, the expected net cost associated with climate-induced damage on coastal resources and people is therefore likely to increase substantively over time. To this end, GoJ agreed to define a goal within its Revised Draft Action Plan for Implementing the Programme of Work on Protected Areas of the Convention on Biological Diversity (Protected Areas Committee (PAC), 2012) which declares a goal to: *"identify and integrate climate change adaptation and mitigation measures in protected area planning and management strategies".*

A2: Users of the Guidelines

The Guidelines present strategic planning considerations and from this, clearly outline the process that should be followed when planning, designing and managing coastal management and beach restoration **interventions**. The Guidelines are therefore intended for:

- Technically competent persons from organisations or groups with responsibilities or a need to undertake planning, design, or monitoring/maintenance of technical **interventions**. Such users include asset managers, emergency and civil contingency planners and responders, appraisers and designers of shoreline management schemes, tourism developers, conservationists, and local community groups.
- Developers, designers, and contractors (and other organisations) involved with the development or improvement of management measures or **intervention** schemes.

A key theme in the development of these Guidelines is that integration of efforts across sectors and with various organizations is a prerequisite towards building climate **resilience**. The Guidelines therefore are prepared in a manner that allows all stakeholders to make informed choices concerning the selection, design, engineering, and construction of technical **interventions**. The anticipated users of these Guidelines (defined as "**User Groups**") and why the Guidelines are to be beneficial to them is set out below in Table A1.

Table A1: Users of the Guidelines

User Group Number	User Group Description	Benefit of the Guidelines to the User Group
User group 1	Government Ministers or Permanent Secretary	Helps to provide strategic advice on national development planning.
User group 2	Government technical managers (middle management practitioners)	Helps to provide technical guidance and advice on engineering best practice and environmental regulatory compliance to existing laws, regulations, and codes.
User group 3	Private sector (designers and contractors)	Helps to provide guidance on **nature-based interventions** and coastal **intervention** design using more "**hybrid**" approaches, achievability of contract standards and preparation of ecosystem service and climate **resilient** focused tender specifications.
User group 4	Private sector (international and national developers)	Helps to provide information on the regulatory requirements prior to the selection of locations for a development (including tourism development) whilst setting out a process for selecting and assessing coastal **intervention** options (**hard** or **nature-based interventions**).
User group 5	Local and District Councils	Helps to equip local councils (parish level) with the informed knowledge on "when and how" to make correct choices with respect to **management approach**/technical **intervention** adaptation and maintenance.
User group 6	Local Community Leaders	Helps to advise communities on self-help strategies to address coastal risks (e.g.: household flood plans etc.) and to inform communities on approaches for coastal change observations and monitoring (beaches/habitats etc.).

A3: Structure of the Guidelines

A summary of the purpose of each Part of the Guidelines, coupled with the likely intended **User Group** audience (as per Table A1) is set out below in Table A2. Appendices are included and referred to throughout this document to provide additional technical information and examples of proforma which can be used as tools in coastal management activities.

Table A2: Summary of each Part of the Guidelines and relevance to each User group

Guideline Content	User group Relevance
PART A – Introduction: This Part outlines the structure of the Guidelines and how to use them to ensure that it is accessible in an appropriate manner to the various **User Groups** who shall refer to its content.	All **User Groups**
PART B – Defining and Developing Resilience: This Part describes what is meant by climate **resilience** for Jamaica and the key risks for the coastal zone of Jamaica. It then presents the types of **management approaches** for coastal management and how to select the most appropriate **intervention** in different environments around Jamaica.	All **User Groups**
PART C – Selecting Approaches and Interventions: This Part looks at the decision making criteria for selecting coastal management **interventions** as well as key design considerations.	**User Group** 2: Government technical managers **User Group** 3: Private sector (designers and contractors) **User Group** 4: Private sector (international and national tourism developers) **User Group** 5: Local and District Councils
PART D – Designing Interventions: This Part outlines the criteria that should be considered to support the selection of coastal protection **interventions** (**hard**, **nature-based**, **hybrid** and **non-structural**) as well as pre-construction considerations. This Part is complemented with information on the material standards which are referenced throughout, as well as lessons learnt and examples from Jamaica and from other **SIDS**.	**User Group** 2: Government technical managers **User Group** 3: Private sector (engineering contractors) *NB: the term "construction" implies either engineering **interventions** or equally, preparing lands for **nature-based interventions**.*
PART E – Governance and Stakeholders: This Part outlines how the design and construction of climate **resilient interventions** can be linked to existing regulations (environmental and land-use planning) in addition to how local/national stakeholders should be involved in their design or implementation.	All **User Groups**
PART F – Monitoring and Maintenance: This Part provides recommended monitoring and inspection protocols, in addition to data collection and advice on scheme performance evaluation.	**User Group** 2: Government technical managers **User Group** 4: Private sector (international and national tourism developers) **User Group** 5: Local and District Councils **User Group** 6: Local Community Leaders

A4: Key Guideline Definitions

A full glossary is presented at the start of these Guidelines. However, a few key terms have been expanded upon below to provide a more detailed definition.

Climate Change Resilience (in the context of this project)

To implement coastal infrastructure and development adaptation measures that improve **resilience** to climate change by adhering to formal risk management procedures that are designed to "future proof" decision making in Jamaica.

Hybrid Interventions

This represents a combination of **nature-based**, **hard** and **non-structural interventions** that may be used to enhance coastal **resilience** by providing important storm and coastal flooding protection, while also providing other **ecosystem** service benefits.

Interventions

These represent physical constructions that help to implement a **management approach** (see below). Such **interventions** may include **nature-based**, **hard** and **non-structural intervention** measures to reduce erosion mitigation, to reduce coastal flooding, "quick fix" short term measures etc.

Management Approach

A **management approach** refers to the broader adoption of an approach to coastal management along the coastline. This could include defending a section to a particular **Standard of Protection** as well as choosing not to do anything and to let the coastline naturally erode.

Mitigation

Within these Guidelines, mitigation refers to risk mitigation. Mitigation of a risk is an action which is undertaken to reduce that risk (i.e. reduce either the likelihood of it occurring, or the impact if it were to occur).

Nature-based Interventions

Intervention projects that are inspired and supported by nature. They provide habitat for plants and animals through careful consideration of the site and strategic placement of components along the entire **ridge to reef** profile. They are cost-effective and simultaneously provide environmental, social, and economic benefits and help build **resilience**.

Ridge to Reef

Ridge to reef (R2R) is the term used within these Guidelines to define the coastal zone to which the Guidelines are applicable. It is a term which is to be used to ensure rather than just simply the focussing on the shoreline, coastal management considers the cross sectional profile at the coast across different areas. This includes consideration of the hinterland, shoreline, and nearshore profile.

Given the close inter-connections between land, water and coastal systems in Jamaica, the integration of **watershed** management with coastal area management is essential to foster effective cross-sectoral coordination in the planning and management of land, water, and coastal uses.

Inherent in the delivery of coastal management across the **R2R** profile is the philosophy of cross-sectoral coordination in the planning and management of freshwater use, sanitation, wastewater treatment and pollution control, sustainable land use and forestry practices, balancing coastal livelihoods and **biodiversity** conservation, hazard risk reduction, and climate variability and change.

Integration of Jamaican communities, stakeholders, and national governments within such a cross-sectoral planning framework builds on current international best practice towards improving engagement and participation of stakeholders.

A "whole of ecosystem" approach ensures that policies, multiple sectors, agencies, and community interests are properly considered and integrated in the planning and management of Jamaican coastal resources.

Standards

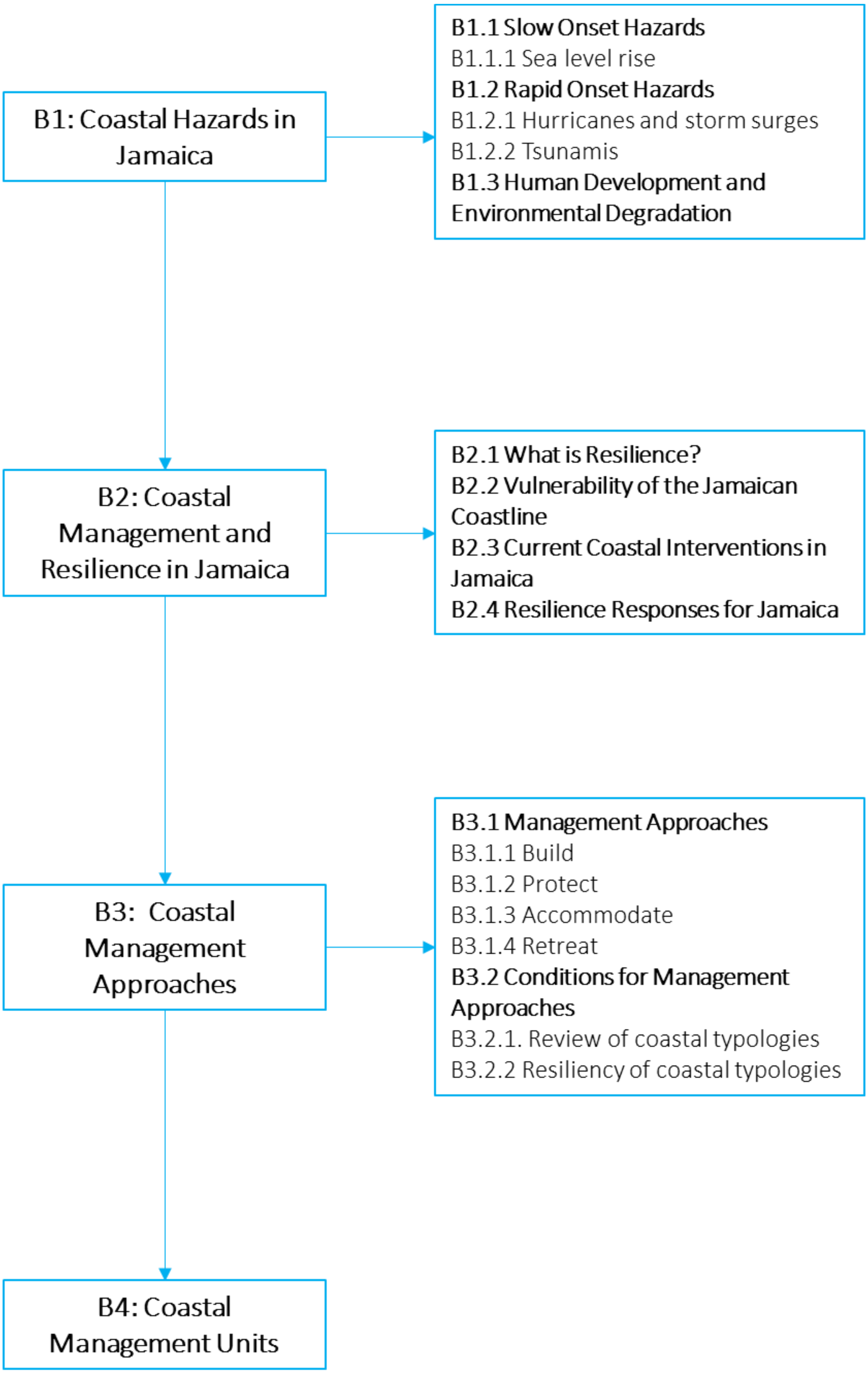
The term standard in this instance is defined as a legally enforceable guideline that incorporates two procedures, namely a) a design standard for coastal development protection that determines the type of technology or practice that should be adopted plus supporting construction detail parameters and b) a materials standard for the type of materials (rock, plantings, sand etc.) required to achieve the required design standard.

Summary

- These Guidelines are presented to provide a tool for coastal managers, developers, and planners.
- These Guidelines look to compliment Vision 2030 Jamaica.
- At the community level these Guidelines aim to provide advice on ensuring coastal management is undertaken in a sustainable way with consideration of wider impacts on the environment and communities.

Part B: Defining and Developing **Resilience**

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.



Contents

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B1: Coastal Hazards in Jamaica

The island of Jamaica is vulnerable to several coastal hazards. These can be split into three broad categories:

- Slow onset hazards;
- Rapid onset hazards; and
- Human development and environmental degradation.

The following sections consider these hazards in more detail.

B1.1: Slow Onset Hazards

A slow onset hazard is defined as a hazard whose impact may take decades to be felt. Climate change is, for example, a very slow onset event. It often contributes towards the effects of slow onset disasters that may be predicted in advance and unfold over a large temporal period. The key slow onset hazards in Jamaica which affect the coastal zone include sea level rise, coastal erosion, and environment degradation caused by changes in meteorological conditions or seasonal fluctuations. These are explored further below.

B1.1.1: Sea Level Rise

Sea level rise (SLR) can be defined as an increase in mean sea level. Throughout history, the earth has gone through periods of SLR and lowering, which are directly tied to climate change and global warming and cooling trends over both geologic and recent time periods (Pacific Centre for Environment and Sustainable Development, 2015). Sea level rise can further be caused by tectonic related alterations to topographic or bathymetric levels (land subsidence or uplift) which can impact significantly on relative sea level heights.

Based on analyses of observed SLR between 1950 and 2000 by Church *et al.,* (2004), SLR in the Caribbean appeared to be near the global mean (i.e. estimated to have been 0.17 ± 0.05 m during the 20th century). Satellite altimeter measurements suggest a higher rate of SLR of about 3 mm/year since the early 1990's (Bindoff, 2007).

Estimates of SLR in Jamaica

Predicted rise in sea level is between 0.28m to 0.98m over 100 years.

The CARIBSAVE Climate Change Risk Atlas (CARIBSAVE, 2011) suggests that these estimates may have been too conservative, and that the assumed rate of 3 mm/year may not appropriately represent future climate change scenarios. The approach by CARIBSAVE (2011) is supported by the Climate Change Policy Framework for Jamaica (GoJ, 2015) which states that predicted change in SLR is a rise of 0.28 to 0.98m by 2100 taken from climate model projections for Jamaica and the Caribbean region. More recent studies have indicated that these values may be too conservative and SLR could be up to 1.6m by the end of the century (Jamaica's Second National Communications to the UNFCCC; State of the Jamaican Climate 2012).

It is also important to note that SLR can be further caused on a seasonal scale by thermal expansion, which is a phenomenon that is experienced primarily between July and November, a period which unfortunately coincides with the hurricane season.

PIOJ and Mona Informatics have undertaken research which demonstrates that there will be critical loss of land in coastal areas of Jamaica under different sea level rise scenarios. If sea level rises by 0.18m

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the predicted loss of land area is 101.9 km^2 and 416.4 km^2 for a 1 m increase in sea level (Climate Studies Group, Mona, 2014).

SLR can be one of the dominant factors in beach erosion (alongside seasonal fluctuations due to storms, and environmental degradation such as deterioration of coral reef health which restricts sediment supply to beaches). The magnitude of beach retreat varies based on local conditions. For example, on a steeply rising intertidal shoreline the rate of retreat is relatively low, however on a topographically low elevation intertidal area, the rate of retreat can be very high. In some studies, preliminary estimates suggest that there will be at least a 30 metre retreat of some of the flatter lying Jamaican beaches by the end of the century due to SLR alone (Robinson, Rowe and Khan, 2006).

Beach erosion is prevalent in many locations along Jamaica's shoreline and is dependent on the nature of the beach and the sediment the beach is composed of. The white sand beaches of the north and west coast of Jamaica are made up of fragments of the skeletons of marine organisms, mainly algae. On the other hand, the beaches common along the south and northeast coasts are composed of sand and pebbles eroded and brought down by fluvial transportation from the various **watersheds** that drain into the coastal zone from the island's interior. Surveys of historical erosion show several places along the Jamaican coast where erosion rates are significant. 100 metres or more of beach have been lost over the past 60 years in some locations, whereas in other locations, no significant erosion has taken place over the same period (Robinson, Rowe and Khan, 2006). Whilst there are reports of seriously eroded beaches following storm events, the same reports often do not report whether these beaches recover, and if they do, by how much. Therefore, it remains a challenge to calculate how much erosion on a permanent basis is, on average, occurring. Formal beach monitoring programmes by the GoJ have only been in operation since 2006, with many locations only monitored since 2011.

Case Studies: Beach Erosion Estimates

NEPA (2013) has been conducting beach erosion monitoring on 36 monitoring sites in 7 locations since 2011. The erosion trends were as follows between 2011 and 2012. It is to be noted that erosion trends over only one year will provide varied results and previous studies have indicated general erosion trends of between 0.26m/year and 0.76 m/year.

Beach monitored	Erosion trends
Portland	Varies between erosion of 2.11 m/year and **accretion** of 1.54 m/year.
Palisadoes to Port Royal peninsular	Varies between erosion of 6.34 m/year and **accretion** of 7.64 m/year.
Burwood	Varies between erosion of 1.82 m/year and **accretion** of 0.39 m/year.
Bluefields	**Accretion** up to 2.16 m/year.
Font Hill	**Accretion** up to 0.95 m/year.
Jackson Bay	Varies between erosion of 3.34 m/year and **accretion** of 3.21 m/year.
Negril	Varies between erosion of 4.55 m/year and **accretion** of 5.39 m/year.

B1.2: Rapid Onset Hazards

Hazards that arise suddenly, or whose occurrence cannot be predicted far in advance, are referred to as rapid onset hazards which commonly include events such as earthquakes, hurricanes, landslides, floods, and storm surges. The warning time for such rapid onset hazards can range from seconds (or at best a few minutes in the case of earthquakes), to several days in the case of most hurricanes and floods. Jamaica is in the most likely path of tropical storms and hurricanes in the Caribbean (Ishemo, 2009). It is also geologically situated within a seismically active area of the Caribbean Plate.

The impact of rapid onset events on the coastline is predominantly through rapid erosion/landslide events (from very high wave energies and drainage causing landslides) and extreme coastal flooding (from short term rapid increases in sea levels and heavy rain).

B1.2.1: Hurricanes and storm surges

The most significant natural hazard that generates coastal risk in Jamaica is posed through hurricanes, particularly because of the large area which can be impacted by any single event (which then requires a large amount of disaster recovery resources at the same time). Storm surges can lead to coastal flooding in Jamaica, and can often occur in parallel with hurricanes. Storm surges are a rise in the water level due to the low pressure and wind impacts from the storm. Storm surges can lead to high volumes of coastal flooding through **overtopping** and breaching of the coastline.

Hurricanes and storm surges can cause a number of impacts on the coastal zone including:

- Low atmospheric pressure causing a rise in sea level which results in flooding/**overtopping**;
- High winds generating large waves which often results in increased beach erosion and subsequent flooding/**overtopping**;
- High winds causing increased wave energies which can cause damage to reefs, seagrasses and mangroves;
- Increased rapid onset precipitation causing river levels and sediment levels to increase within water courses which influence turbidity levels and the risk of sediment smothering onto mangrove forests, seagrasses and coral reefs.

Figure B1 presents tracks of Category 3, 4, and 5 storms that have impacted the region since 1851.

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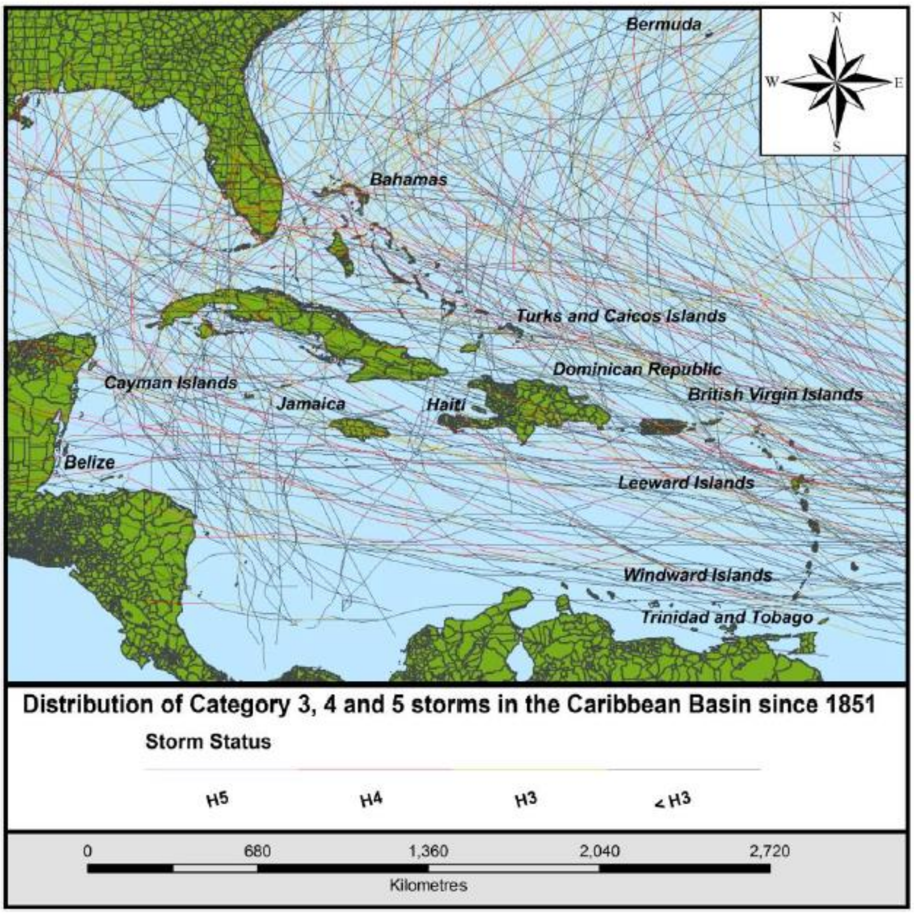
Figure B1 Category 3, 4 & 5 storms affecting the Caribbean since 1851.



Source: NOAA-NHC accessed by CCRIF, 2013

As stated within the Climate Change Policy Framework for Jamaica (GoJ, 2015) the severe weather events which have impacted the country over the years have affected the country's economic growth and development. Between 2001 and 2012, Jamaica experienced 11 storm events (including 5 major hurricanes) and several flood events. These events combined resulted in loss and damage amounting to approximately JM$128.54 billion (Climate Studies Group, Mona, 2012). Historic data suggests that in Jamaica, as well as for the wider Caribbean, the frequency of hurricanes has increased over the last 80 years (Climate Studies Group, Mona, 2014).

Case Studies: Economic Damages Caused by Hurricanes

Hurricane Ivan in 2004, the loss was equivalent to 8.0 % of GDP.

Hurricane Sandy (2012) accounted for JM$9.7 billion or 0.8% of 2011 GDP in direct and indirect damage (JM$9.4 billion in damage and JM$0.3 billion in losses) as well as increased expenditure by private and Government entities. The health, housing and education sectors experienced the greatest impact accounting for 48% of the total costs in damages. One death and 291 injuries resulted from Hurricane Sandy (Economic and Social Survey Jamaica, 2012).

Image of destruction after Hurricane Sandy (PIOJ, 2013)

Increased sea levels and future climate changes are likely to result in changes to the frequency or magnitude of storm surges on Jamaica's coast. The likelihood of more severe hurricanes will increase, although the overall frequency of hurricanes remains uncertain. While there may be an overall decrease in the frequency of tropical cyclones, there may be an increase in category 4 and 5 of such storms by the end of the 21st century (Climate Change Risk Atlas, 2011 – Jamaica (CARIBSAVE); Climate Studies Group, Mona, 2012). Whilst the National Building Code for Jamaica has been developed to provide guidelines for the construction of hurricane resistant buildings and **setbacks**, further measures and **interventions** can be implemented to increase the **resiliency** of the infrastructure to hurricanes.

B1.2.2: Tsunamis

A tsunami is a series of ocean waves generated in the sea by the sudden vertical displacement of a column of seawater, typically generated by an underwater earthquake (however they may also be generated by landslides and volcanic activity). A tsunami wave may be small in deep ocean settings yet upon approaching the shoreline as a fast-moving wall of turbulent water, the result is often a total inundation of low-lying coastal areas causing significant destruction of both natural and human environments within the immediate hinterland. There are two types of tsunamis: distant and local. A distant tsunami travels long distances from the event that triggers it to impact the coast hours later. Alternatively, a local tsunami can impact the coast within minutes after the triggering event, allowing little to no time for warning and evacuation (U.S. Indian Ocean Tsunami Warning System Program, 2007).

In the past 300 years there have been at least two tsunami events in Jamaica; in 1962 the sinking of a part of Port Royal caused a wave of 1.8m to cross the Harbour with a withdrawal of 274m, and in 1907 waves of 1.8-2.4m were reported along the north coast between Portland and St. Ann, accompanied by withdrawal of the sea by 70-90m, with waves of 2.5m being observed in Kingston Harbour. Both events followed local earthquakes which vertically displaced land vertically into the sea at Port Royal and along parts of the north coast (Wiggins-Grandison, 2005).

The Earthquake Unit (EQU), a department of the University of the West Indies funded by the Government of Jamaica, is responsible for the monitoring of earthquakes and seismic activity in Jamaica. The EQU operates a network of analogue short period seismograph stations installed across the island as well as a network of accelographs installed across the island to record ground shaking for larger earthquakes (UWI at Mona, Jamaica, 2007). Recently, the EQU received at least 6 additional broadband linked pieces of equipment to help assist with early warning predictions (ODPEM *pers comm* 2017).

B1.3: Human Development and Environmental Degradation

Environmental degradation is the deterioration of the environment through depletion of **natural resources**, the destruction of ecosystems, habitat destruction, the extinction of wildlife, and pollution. Environmental degradation is closely coupled with human development, with both impacting each other to increase the overall vulnerability of coastal communities within Jamaica.

Coastal communities in Jamaica are experiencing a high rate of change due to population growth, human-induced vulnerability, and climate change. In addition, the impacts from natural disasters have also increased in number, scale and intensity due to the settlement patterns of coastal communities thus increasing their overall vulnerability. Based on the 2001 population census, Jamaica's population was approximately 2.7 million of which approximately 82% live in towns and villages along the coast, making these settlements highly vulnerable (Ishemo, 2009). Over 50 percent of economic assets, including air and sea port facilities and tourism infrastructure, are also concentrated in coastal areas (PIOJ, 2008). It is this combination of the intensification of natural events due to climate change, environmental degradation, and the number of persons, structures and infrastructure that are located within vulnerable locations that has increased the overall vulnerability of Jamaica's coastal settlements (Ishemo, 2009). Where large scale land reclamation is undertaken, if adequate consideration for future change in not considered this can cause the coastline to become out of equilibrium and increases the impact of hazards on that section of the coastline.

A reduction in the health of coral reefs and seagrass meadows (either from natural cycles or human induced impacts) has influenced how **resilient** this ecosystem can prove to climate change and as an important natural coastal defence. The anatomical structure of many coral reefs often allows them to withstand and dissipate strong wave action, thus reducing wave energy arriving at the shoreline and thus protecting land, islands, and beaches from shoreline erosion. Parameters influencing coral reef **resilience** and health that are jeopardising its ability to provide this natural protection include hurricane induced damage; **coral bleaching** (occurring because of a rise in seawater temperature); and die-off of the sea urchin *(Diadema antillarium*) populations which are important in controlling turf (brown) algal growth on reefs. Jamaica's coral reefs also continue to suffer from human-induced stresses. In Jamaican waters, overfishing affects approximately two-thirds of reefs. Limited alternative employment opportunities, densely populated coastal zones, and easy access to the narrow shelf areas mean that the reef resources have been and continue to be heavily used to provide livelihood security.

> **Case Studies: Impact of Sea Urchin on Coral Reefs**
>
> in 1983 there was mass mortality due to an unknown disease, and the sea urchin population has not recovered (NEPA, 2010).

Seagrass meadows further provide additional resilience to a coastal ecosystem through processes such as nutrient uptake and particle deposition. The coastal protection provided by seagrass meadows is highest when plants occupy the entire water column (Barbier *et al.,* 2011).

If further reef or seagrass degradation occurs, shoreline erosion rates could increase significantly above the current observed rates. It has been found that over a ten-year period, the erosion rates could increase by more than 50% at Montego Bay, 70% at Ocho Rios and by more than 100% at Negril (WRI, 2012). As stated by Kushner *et al.,* (2011), the loss of beach due to coral degradation is projected to reduce tourist visitation by 9,000 – 18,000 visitors annually, costing an estimated US$23 million per year to the Jamaican economy. Further to reef degradation, reducing health coupled with the removal of mangrove and seagrass areas is becoming prevalent in Jamaica. This is reducing the natural erosion resistance and flood defence of the coastline thus increasing the overall coastal flood and erosion risk in these areas.

Agriculture is one of the primary economic activities of the country, and land clearing and poor agricultural practices have led to increased soil erosion within many **watershed** catchments. Where this is occurring (often near the mouths of rivers), increased turbidity and suspended sediment levels caused by soil erosion, is smothering nearby reefs, mangroves, and seagrass areas (NEPA,2010). Removing seagrasses from coastal areas, which is perhaps most prevalent in tourist areas, contributes to the destabilization of the intertidal beach and degradation of the broader coastal marine ecosystem (World Bank, 2016). This is due to their function in stabilizing the seabed and their ability to trap sediments and filter nutrients, effectively acting as a sediment barrier.

Human development can impact the coastal zone through pollution and inappropriate and unregulated land development. There are various ways in which pollution can impact coastal areas. Primary sources include industrial effluent from industries based in the coastal zone. These sources include brewing and bottling, agro-processing (including sugar and rum production), paints and chemicals, oil spills, particulates from quarrying and aggregates, improperly treated sewage by direct discharge or leaching through soak-away pits, pesticides and fertilizers, and solid waste dumped in gullies and rivers which eventually wash out to sea and then is deposited on beaches (GoJ, Ministry of Land, Water, Environment and Climate Change, 2013). Spills can be in the form of oil spills from ships, toxic materials released from storage tanks, petroleum releases from severed pipelines, etc. These events can have devastating effects on coastal environments.

Light and noise pollution is another consequence of human developments. Continuous coastal development has resulted in modification of the shoreline by buildings and their facilities for lighting. Bright lights on beaches and other coastal areas not only affect aesthetic value of an area but also have ecological consequences. Artificial lighting overrides natural lighting and results in disorientation, which can result in significant loss of turtles. Main issues related to coastal light pollution are coastal developments and improper beach lighting and signage. Increased use of motorized watersports equipment results in increased levels of noise that affect both the aesthetic value of a recreational area and disrupt fish populations. Fish populations and important marine mammals such as turtles may be fragmented and stressed by the noise created from jet skis and motorboats. Main issues related to noise pollution are conflict in zoning watersports and fisheries areas, and the lack of carrying capacity limits for motorized watersports (GoJ, Ministry of Land, Water, Environment and Climate Change, 2013).

B2: Coastal Management and Resilience in Jamaica

B2.1: What is **Resilience**?

Put simply coastal **resilience** can be defined as a community's ability (including its infrastructure and developments) to "bounce back" after a hazardous event, rather than just reacting to the event's impacts. Hazardous events can range from mild flooding to high category hurricanes, and the ability of a community to rebound quickly can reduce negative impacts and subsequent vulnerability upon human health, the environment, and the economy. Having a more informed and prepared community will create a greater opportunity for coastal areas to rebound quickly to such events. The ability of a community to successfully recover is related to the strengths and capacities of individuals, families, business, schools, hospitals, and all other aspects of the community. Yet, more people are moving to high risk areas along the coast, further increasing the risk to homes, business, and infrastructure. Incorporating coastal **resilience** into coastal management plans is therefore highly important to prevent a short-term hazard event from turning into a long-term community-wide disaster. When implementing coastal **resilience**, several different aspects can be assessed:

- ***Engineering resilience****:* '**Resilient** design' fosters an innovative approach to the design, construction and operation of infrastructure (US National Institute of Building Sciences, NIBS, 2010; Bosher *et al*, 2007). This can help ensure an acceptable level of performance is maintained when infrastructure is exposed to events more severe than anticipated.

- ***Ecosystem resilience:*** The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker *et al*. 2004). In general, changes must be gradual for successful adaptation of the ecosystem.

- ***Community resilience****:* Capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of change. In general, communities have a significant capacity to act autonomously to change.

In order to ensure a **resilient** coastal zone, the implementation of coastal management in Jamaica must generally look to address all three aspects of resiliency where appropriate.

B2.2: Vulnerability of the Jamaican Coastline

> Vulnerability is defined by the IPCC as: *"the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".*

In Jamaica, the recently produced work by the Climate Studies Group, Mona (CSGM), entitled "Near-Term Climate Scenarios for Jamaica (Technical Report)" (Climate Studies Group, Mona, 2014) declared some key climate predictions of relevance to these Guidelines as follows:

- Maximum, minimum and mean temperatures are to increase from present up to 2040 for Jamaica. Mean temperature increases by 1.3°C by the 2020s and 1.6°C by the 2030s. Minimum and maximum temperature show increases of similar magnitudes.

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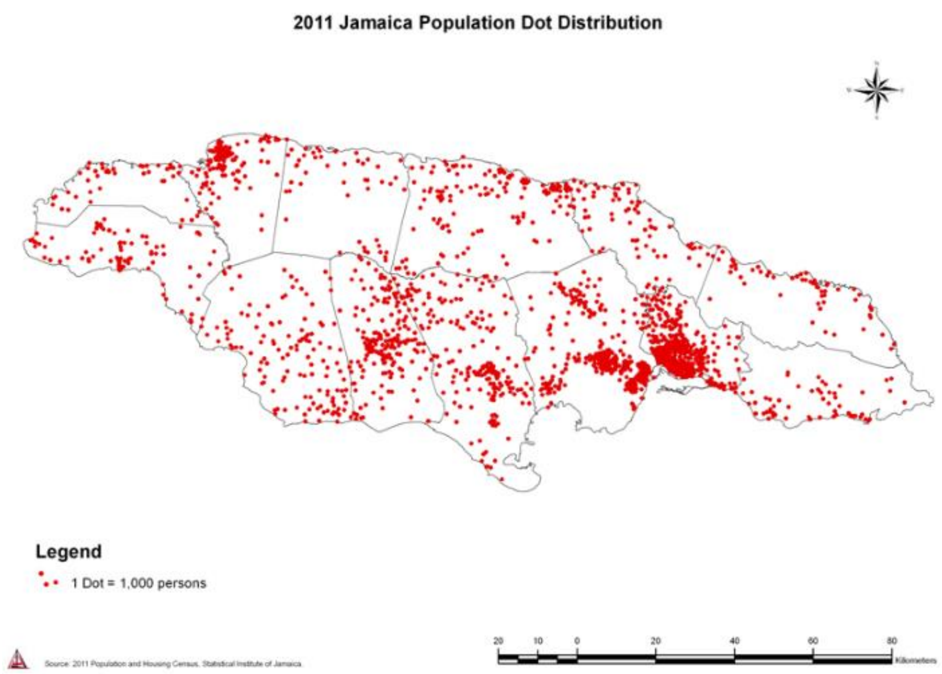
- There is a greater warming projected across the central and eastern interior of the island. This is likely related to topography. There is the suggestion that warming is occurring at a slightly higher rate for inland areas of greater altitude than for coastal regions.
- Mean annual rainfall in the near term does not show significant change for the island as a whole. The ensemble mean shows an annual mean change of -0.81% for the 2020s (-21% to +33%) and 1.84% for the 2030s (-21% to +14%).
- If sea level rises by 0.18m the predicted loss of Jamaican land area is 101.9 km2 and 416.4 km2 for a 1m increase. Areas forecasted to be inundated are fast growing urban areas such as Old Harbour Bay and Portmore.

Jamaica's coastline is where most of the critical infrastructure, formal and informal housing, and a high percentage of economic activities (including tourism, mixed farming, fishing, shipping, and mining) are located. The population density of Jamaica is distributed such that much of the population is focussed within coastal areas (Figure B2). This places an increased strain and an increased importance on Jamaica's coastline. There is further a current urbanisation trend that can be seen within Jamaica (Statistical Institute of Jamaica, 2016).

Figure B2: Population density map for Jamaica, 2011.



Source: Statistical Institute of Jamaica, 2011

The tourism sector provides approximately US$1.9 billion annually to the foreign exchange earnings of the country (Planning Institute of Jamaica (PIOJ), 2012). In 2015, it was reported that tourism contributed 7.8% of Total Gross Domestic Product (GDP) and employs 24.8% of the work force of Jamaica (Statistical Institute of Jamaica). The local tourism product is dominated mainly by resort tourism which is in coastal areas such as Montego Bay, Ocho Rios, and Negril. Montego Bay is Jamaica's principal resort area and contributes 33 % of Jamaica's room stock (Commonwealth Secretariat, 2002). Tourism remains one of the most important sectors to the nation's development given the substantial linkages with other sectors (agricultural production: as a local market for local farmers; water sector;

coastal and marine resources; fisheries). Hurricanes, storm surges and tropical storms have posed one of the greatest threat to this sector in recent times.

For Jamaica, building **resilience** to the impacts of climate change is of the highest priority. Jamaica's susceptibility to natural disasters has proven to be a major threat to economic development, the stability of human settlements and infrastructure. It is imperative that Jamaica adopts the necessary policies and actions to ensure that adaptation strategies are mainstreamed into key economic and climate sensitive sectors, particularly those related to natural resource use, physical infrastructure, land use, coastal zone planning and management. The dependence on **natural resources** (by sectors such as tourism whose GDP contribution is 8.4% and forestry, agriculture, and fisheries whose GDP contribution is 7.4%) (PIOJ 2012), means that climate change is a major threat to the nation's overall development.

B2.3: Current Coastal **Interventions** in Jamaica

Coastal management **interventions** typically consist of interposing a static structure between the sea and the land to prevent erosion and or flooding. In Jamaica, the general practice has been to commonly use **hard interventions** to protect against beach erosion or storm damages. These **interventions** usually involved the use of coastal armouring techniques such as seawalls and revetments or sand-trapping structures such as groynes.

Throughout Jamaican history, there have been several instances where local coastal communities could not afford to build formalised or **resilient** structures and instead, used easily accessible materials in their own attempt to protect their property. The types of less **resilient** (robust) materials often used may have included old tyres and river stones. Typically, these rudimentary defence materials were used and **interventions** 'constructed' without any consultation with official authorities, nor were the **interventions** "designed" in any professional or considered manner to reflect neighbouring coastal population or broader natural environments. The result was that **interventions** often failed quickly, or if they did withstand storm events, impacted deleteriously on adjacent coastlines. Conversely, larger developments such as hotels and guest houses would have more often selected to adopt more significant engineered structures such as breakwaters and groynes or combinations of the two. Several large private developments have also had engineering structures built to create quieter swimmable beach areas for guests.

Case Studies: Unregulated interventions

Unregulated property defence using (a) tyres at Hope Bay Beach, Portland; and (b) packed river stone at Copacabana Beach, St. Andrew

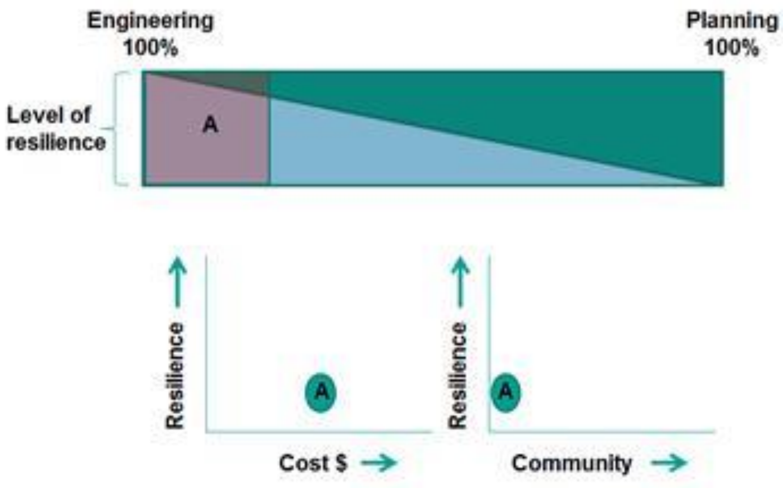
The obtrusiveness and cost of these **hard interventions**, in addition to increased environmental awareness of more sustainable "nature based **interventions**", has recently (within the last 20-30 years) resulted in a move toward more naturally **resilient interventions**.

Techniques have been developed to better replicate or "mimic" the protective characteristics of natural habitats (coral reefs etc.) and beach systems. For example, the use of artificial reefs and artificially nourished beaches as an engineering approach is proving to be a more environmentally friendly method for dissipating wave energy to protect coastal developments. The resulting accreted beach sands are also aesthetically appealing for tourism developments whilst providing new beach areas for fishing boat landing and for new turtle nesting sites. For this reason, beach nourishment, has become far more common (especially with larger hotel developments) in Jamaica.

Over the years, consultants and government agencies alike have become more informed about the effects of coastal **interventions** on the environment and as such greater thought has been given to environmental impact mitigation. In particularly sensitive marine environments, agencies may denounce a project from concept stage.

Despite the production of local plans in areas of Jamaica, and an increasing focus on environmental impact mitigation, the present position of Jamaica appears to be more focused on engineering rather than planning (Figure B3).

Figure B3 The position of Jamaica on the engineering-planning continuum (A) and the present position in relation to coast and community involvement.



B2.4: **Resilience** Responses for Jamaica

Any approach towards improving climate **resilience** for Jamaica needs to use coastal protection in a selective and efficient way to maximise benefits at minimum cost. To facilitate this, there is also the need to develop appropriate policy and decision-making processes. As stated by UNDP: "*This means that action must begin today, before climate risks materialize, to protect critical socio-economic infrastructure, and to manage the risks associated with the impacts of climate change expected to occur by the middle of this century. There is a need to grow investments in infrastructure in the coming years to proactively prepare for the future*". Thus, optimal use of coastal **interventions** means that they need to be well planned as well as well-built. This means that **ridge to reef** (**R2R**) **resiliency** sits in both the planning and engineering domains. Chapter B3 looks in more detail at the possible engineering **approaches** that can be adhered to for building **R2R resiliency** into existing and newly designed schemes.

B

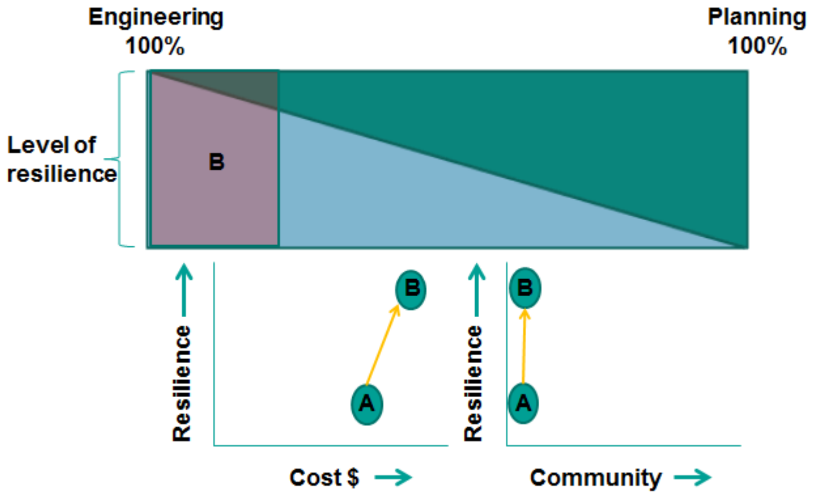
Different Responses: Engineering Versus Planning

Response 1 – Build Better ***Interventions***

With climate change pressures, there is a probability that the **resilience** provided at present in Jamaica will be reduced. One option is to increase the investment, or "buy and build" more **resilience** (i.e.: more **interventions** (covering both **nature-based** and **hard interventions**) placed along the coast). However, this can be a very costly approach.

An alternative approach is to identify the weaknesses in the present system and to take a structured approach to enhancing **resilience** and building more **resilience** per unit $. One aspect where improvements can be made is in the quality of construction of coastal protection **interventions**. Better feasibility assessment and design, wider involvement of Local Councils and local people in consideration of options, adhering to international construction standards, effective sign-off and post-construction inspection and planned maintenance can swiftly and significantly improve the level of **R2R resilience**. Furthermore, by increasing the amount of **nature-based intervention** approaches or **hybrid approaches**, these can increase the overall resiliency of the wider coastal ecosystem and economy. This option to "build better **interventions**" is visualised below (Figure B4).

Figure B4 "Build better interventions" approach (denoted by B) involves improving engineering construction standards and provides an overall higher level of coastal protection resilience at a minimal increase in cost and with possibilities for improved community involvement



Response 2 – More Robust Planning

Whilst the "build better **interventions**" approach can provide systematic improvements in the protection afforded by a majority of the ongoing coastal works and provide better value-for-money, it is still an expensive route for developing **resilience** in Jamaica. However, it is proposed that further gains can be made from strengthening the planning dimension through a "more robust planning" response.

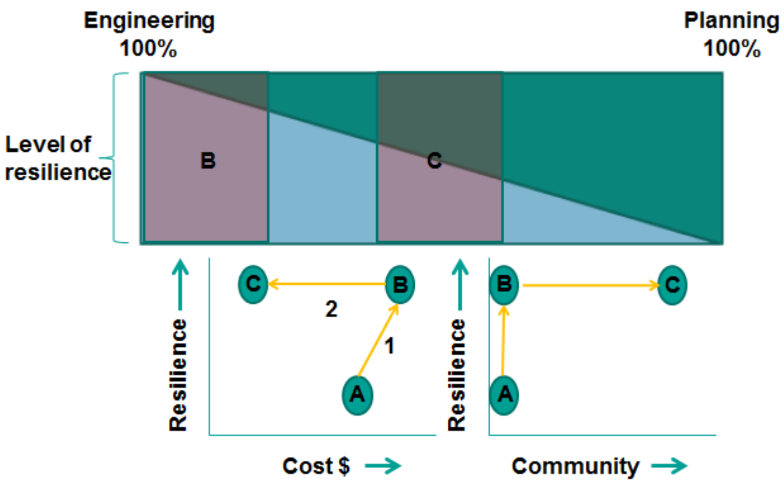
In this "more robust planning" response, a more coherent and comprehensive approach is taken to efficient and effective utilisation of coastal hinterland. For example:

- Land use planning: Positioning of new development away from eroding shoreline as much as possible. New reclamation areas are developed which are not in high erosion areas and do not flood existing households and infrastructure.

- Building codes: Infrastructure in vulnerable areas are made more **resilient** through raising floor levels (e.g. houses) and raising key installations (generators in powerhouses);
- Environmental assessments: New developments do not cause erosion or environmental degradation elsewhere on the island and thus necessitate further **R2R intervention**.
- Coastal and beach **interventions**: Only used in a sparse and deliberate way when alternative planning **approaches** have been considered and concluded not to be viable. In this situation, all viable defences should be considered to offer the required protection performance, including **nature-based interventions** such as beach recharge and ecosystem replanting or rehabilitation.

The consequence of the "more robust planning" approach is shown below (Figure B5). The response means a move away from a reliance on engineering resistance and a wider use of coherent planning. The consequences are that the cost per unit of **resilience** dramatically reduces compared to the "build better **interventions**" approach, and the opportunities for community involvement increase (through consultation and consensus planning in the various planning instruments).

Figure B5 "More robust planning" response (denoted by C) provide a similar level of resilience as the "build better interventions" response (B) (but more than the present situation A) but at less cost and with more possibilities for community involvement.



Whilst the vulnerability of Jamaican shorelines is clear and apparent, the existing approach of relying predominately on **hard interventions** is expensive. This approach also raises the possibility that just resisting or "manipulating" the external forces will lead to a progressive decay in adaptive capacity to meet the uncertain future and thus decrease **resilience**.

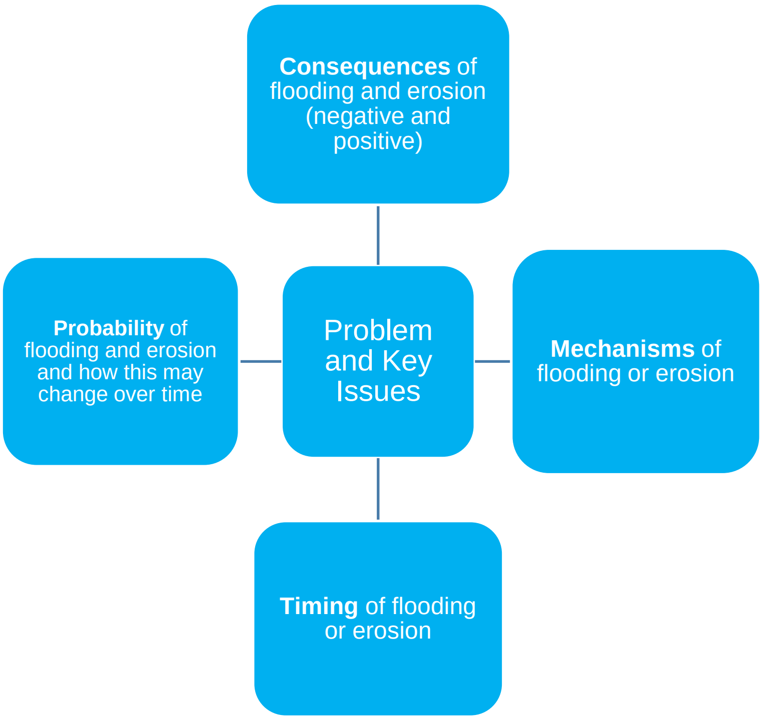
The "build better **interventions**" response (Response 1 above) provides better value for money and can be implemented rapidly; as such this is a highly available and controllable response. The "more robust planning" response (Response 2 above) is certainly more long term, but it can be used in combination the "build better **interventions**" approach, to provide a more cost effective medium- to long-term planning response. Coastal management within the **R2R** profile must involve a mix planning and construction. The planning aspects determine where critical infrastructure, or domestic developments, are positioned (land use planning), what type of building and infrastructure they use (building codes) and what design causes minimal environmental impacts (EIA Regulations). There are currently projects underway which are developing the National Spatial Plan which will provide tools towards implementing a more planning response. The technical aspects determine the appropriate type of **intervention** required, its final design, material used, the build-quality and the inspection and maintenance procedures. The additional benefit of this response is that Local Parish Councils and local communities can be more involved in the process which will help raise adaptive capacity and build a more multi-dimensional form of **resilience**.

B3: Coastal Management Approaches

B3.1: Management Approaches

A **management approach** describes the over-arching policy or approach towards "managing" a section of coastline. These should be defined following a careful consideration of the problem and key coastal issues to be addressed (Figure B6). It is recommended that these **management approaches** are defined within strategic level studies, such as Parish Plans, so that an integrated and coordinated approach is undertaken. Future considerations of land use and development at the coastline can then be compared with the **management approach** set out within the Parish Plan (or similar) to ensure that the proposed works compliment the strategic long term management of a section of coastline.

Figure B6 Consideration of what management approach should be taken should involve a clear definition of the problem at that site and what the key issues. From this, an appropriate response can be defined.



There are several different **management approaches** that can be delivered. Delivering **resilient interventions** is much more involved than simply reducing the chance of damage through the provision of defined **interventions** at the coast, and adaptive management is much more involved than simply "wait and see". Both are purposeful **approaches** towards effective planning, design and management that are inherently risk based and importantly, seek to actively manage uncertainty. For these guidelines, four "**management approaches**" are presented for consideration for coastal managers, developers, and planners in Jamaica.

B

Management approaches

Build: The intent of this is to maintain the current position of the coast and maintain or increase the level of protection using **nature-based**, **hybrid** or **hard interventions**;

Protect: The intent of this is that existing **interventions** are used to provide the protection rather than building or implementing new **interventions**;

Accommodate: The intent of this is to modify or retrofit existing or adjacent **interventions** that are already in situ to improve overall scheme performance; and

Retreat: The intent of this to review and/or adopt new planning tools to enable the coast to accommodate sea level rise and storm surge inundation events.

The four **management approaches** are expanded below in more detail. Technical **interventions** are not considered here for each approach, though Part D is designed to present each coastal **intervention** option and to identify their appropriateness for different coastal typology situations etc.

B3.1.1: Build

The intent here is to "build" new **interventions** into order to maintain the current position of the coast and maintain or increase the **standard of protection** required for a stretch of coast (using either **nature-based** or **hard interventions**). There may also be the opportunity to combine **nature-based** and **hard interventions** to undertake a **hybrid intervention** (see Part D1). There may be a need to construct a new local alignment of a new structure. Alternatively, an existing structure design may be upgraded (through adding sub-component parts) etc. to increase structure resiliency.

This **management approach** option relates to the ability to "engineer" performance improvements (at the design stage) to better address climate **resilience**. As part of the definition of this approach, it would be important to clearly set out a series of Standards of Protection (SoP) (see Part C2) that should be adhered to that reflect the assets at risk behind the **intervention** being implemented.

B3.1.2: Protect

The intent here is similar to the 'build' approach, however existing **interventions** are used to provide the protection rather than the construction ("building") of new **interventions**. This often therefore has a lower upfront capital cost compared to a 'build' approach, however, it can command higher costs associated with long term maintenance.

Nature-based interventions are particularly successful within this approach, especially where habitats naturally occur or have previously existed. The overall **resiliency** of the area can thereby be increased by maintaining and improving the current ecosystems to provide wider benefits such as fisheries, tourism, and recreation.

Probably the most common adjustments to any **hard intervention** at the shoreline involves remedial works such as underpinning, encasement, or addition of an apron to the wall. Such works are often not a permanent solution to the problem and hence they may have to be repeated later, either extending the level of protection further along the coastline. However, they do make maximum use of the existing **interventions** which are often still appropriate, or can be repaired without great expense.

This **management approach** can also relate to "retrofitting" adjacent **interventions** that maybe located close by to the proposed "footprint" of the new scheme. Various examples exist that relate to adapting designs. These may include (for example) the re-positioning of a groyne field to better improve sediment drift to new locations. Further examples of this type of approach may include modification of a structure due to the impact it is having on erosion (through mechanisms such as sediment by-passing – see D2.3).

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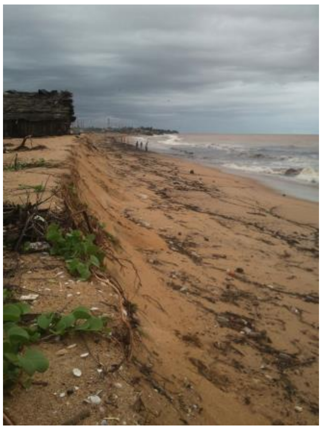
Case Studies: Adapting breakwaters in India to reduce erosion downdrift

Structures that are developed perpendicular to dominant net sediment transport systems can have a major impact in disrupting natural sediment source to sink transport mechanisms. In Managlore, India, major accumulation has occurred on River Training Breakwaters owing to strong **littoral drift** and available mobile sediments. Down drift of the breakwaters has experienced significant erosion:

- River mouth training breakwaters were constructed in the 1990s at Mangalore to assist in keeping the Gurupura River mouth open and navigable.
- However, the structures led to rapid accumulation of sand to the north at Bengre where the original sand spit grew 500m seawards.
- Sand started to accumulate in the river mouth between the two training breakwaters, and has to be dredged every year. The sand is deposited offshore.
- To the south at Ullal major starvation of sand occurred, leading to breakthrough on the Ullal spit and increased erosion in front of the Ullal village.



Erosion has become a big issue south of the Ullal breakwaters

The solution:

- At Ullal the solution was to develop a scheme that included large offshore sub-merged breakwaters up to 400m offshore to assist in dampening the monsoon wave conditions and to provide an initial large input of sand re-charge in front of the Ullal spit and community, and assist in controlling further longshore drift with the provision of geo-textile groyne structures.

- Alternate solutions that have been developed in similar locations include the provision of sand bypass systems, that try and keep a semblance of natural sand movement even where structures have been developed on shorelines with mobile sediments.

B3.1.3: Accommodate

An 'accommodate' approach refers to the modification or retrofitting of existing infrastructure that are already in situ to improve overall scheme performance. This can include building permit control, raising property or transport links (e.g.: road levels), "climate proofing" households or commercial property, early warning systems installation and evacuation route construction.

Examples may include purchasing land in the lee of an embankment to facilitate future raising or widening, or designing foundations that anticipate a heightened embankment in the future. This approach often provides a more asset-specific solution and can be useful where there are limited vulnerable assets at risk or limited wider **biodiversity** benefits within an area as it allows the capital investment to be focussed on the asset.

B3.1.4: Retreat

The intent of this **management approach** is to review and/or adopt new planning tools (such as "buffer zone" creation or the use of development **setback** techniques) to enable the coast to accommodate sea level rise and storm surge inundation events. This could include realigning or re-locating vulnerable assets and coastal defences. This approach represents **non-structural** solutions to help coastal communities adapt to climate change. This could also partly include taking the decision to not invest in coastal defences or operations and let the coast erode and develop naturally.

Case Studies: Adaptation of road at Bluefields Bay Beach

Bluefields Beach park is an area in the south-east of Westmoreland. The beach itself is very narrow and is roughly 1km in length and is often used by community members, especially on weekends and public holidays. The major roadway was previously separated from the beach by only by a low stone wall. However, this has now been changed and the major roadway has been relocated slightly inland, creating a larger park area to be used for vehicular parking and approach as well as reducing the risk to the road. This can be easily observed in the images below, where 1991 is compared to 1998.

Bluefields Beach Park in 1991

Bluefields Beach Park in 1998

B3.2: Conditions for **Management Approaches**

There are several coastal features and "typologies" in Jamaica and these respond differently to coastal processes. As a result of this variance, there are a range of possible **intervention** measures spanning the conceptual cross section of most situations in Jamaica that may need to be considered. Therefore, appropriate **management approaches** for sections of coastline, as well as the appropriate **intervention** required to implement it will be dependent on the physical and environmental characteristics of the coastal zone.

B3.2.1: Review of coastal typologies

The classification of the coastal zone in Jamaica is presented in Figure B7 and explained in Table B1. Typically, the south has larger areas of coastal fans and plains compared to the north which has more bays/small inlets and gentle slopes adjacent to the coastline. There is a large area of coastal reefs, which extend 10-15km off shore, in the south near to Kingston compared to the majority of the rest of the coastline which has smaller pockets of reefs which typically extend only 1-2km offshore. The classification of the Jamaican coastal zone into these typologies is presented in Appendix B. These maps should be used to determine the relevant sheets to refer to in Section B4.

Figure B7 Diagram presenting the R2R profile for Jamaica and the different typology zones, as described in Table B1

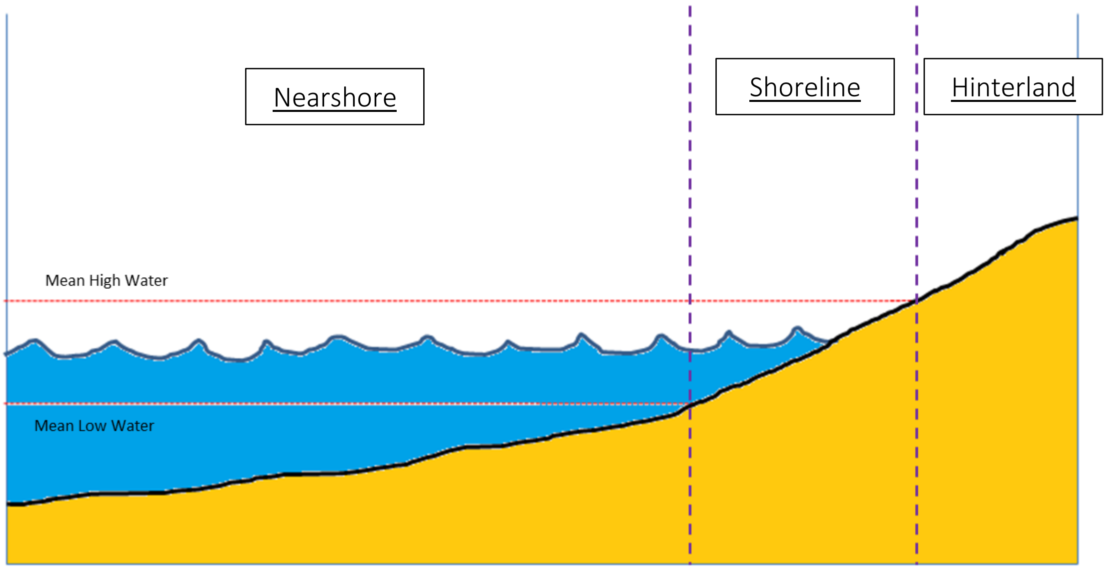
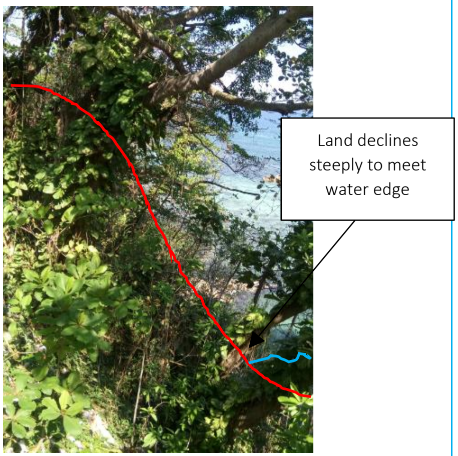
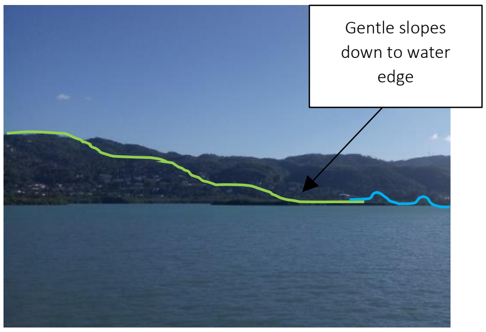
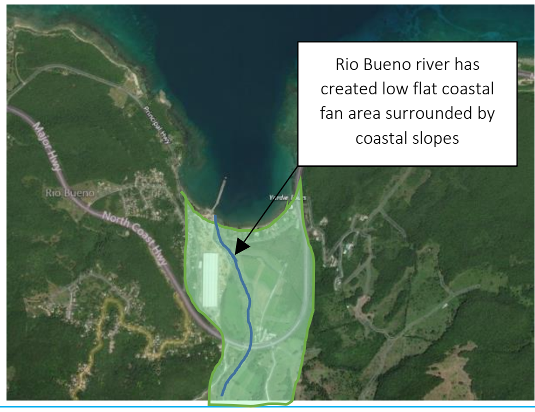
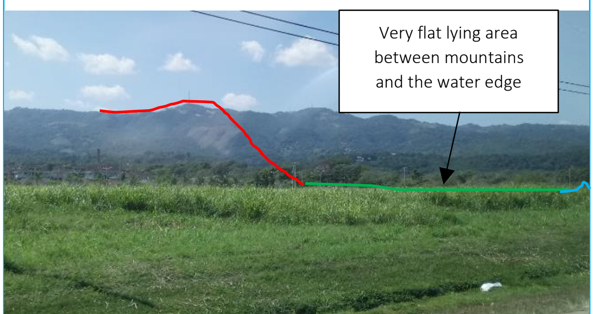
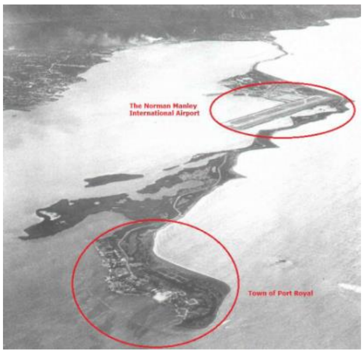
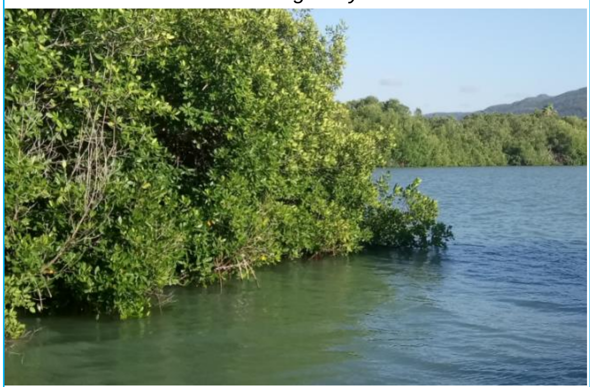


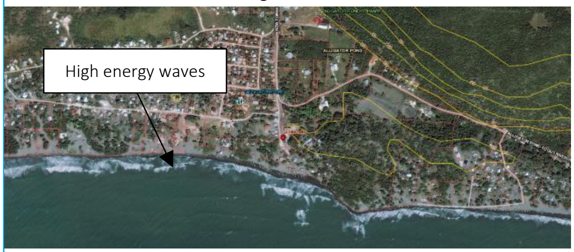
Table B1 Table displaying the categories used to classify the R2R profile for Jamaica.

<table>
<tr><th>Location</th><th>Name</th><th>Short Description</th><th>Example Photograph</th></tr>
<tr><td rowspan="4">Hinterland</td><td>Steep mountain front</td><td>Typified by steep mountainous area, rising up to ~200m adjacent the coastline.</td><td>West of Ocho Rios

</td></tr>
<tr><td>Coastal slopes/ foothills</td><td>Gentle, undulating sloping lowlands.</td><td>Montego Bay

</td></tr>
<tr><td>Coastal fan</td><td>Located where rivers enter the sea and typically include an area of flat land around the river.</td><td>Rio Bueno

</td></tr>
<tr><td>Coastal plains</td><td>Flat land adjacent to the coast, but not linked to any fluvial system. Also includes swamp / morass areas.</td><td>Between Discovery Bay and St Anne's Bay

</td></tr>
</table>

B

<table>
<tr><th>Location</th><th>Name</th><th>Short Description</th><th>Example Photograph</th></tr>
<tr><td></td><td>Barrier</td><td>A small section of land border by a coastline on both sides.</td><td>Palisadoes, Kingston
</td></tr>
<tr><td rowspan="3">Shoreline</td><td>Beach</td><td>Sloping ground which is composed of sand and gravel in varying amounts depending on the wave energy at these locations.</td><td>Long Bay Beach, Negril
</td></tr>
<tr><td>Cliffs</td><td>Vertical or near vertical section of bedrock, high energy environment at the base of the cliff.</td><td>South of Negril
</td></tr>
<tr><td>Mangrove or swamp</td><td>Area of coastline covered in mangrove or wetland vegetation. These areas often extend to a greater extent cross-shore compared to other shoreline classifications.</td><td>Montego Bay
</td></tr>
</table>

<table>
<tr><th>Location</th><th>Name</th><th>Short Description</th><th>Example Photograph</th></tr>
<tr><td></td><td>Low rocky shore</td><td>Section of coast line characterised by shallow rocky strata, normally irregular shaped coastline</td><td>Black River
</td></tr>
<tr><td rowspan="4">Nearshore</td><td>Pavement (rock or uplifted dead coral)</td><td>This is an inter tidal bedrock platform which is formed from horizontal or near horizontal bedded bedrock and a high wave energy environment.</td><td>White Horses Region
</td></tr>
<tr><td>Fringing coral reef</td><td>Shallow water environment with barrier or island reefs. Often find seagrass located within these nearshore environments.</td><td>East of Falmouth

</td></tr>
<tr><td>Open coast</td><td>Open coastline with no distinguishing features.</td><td>Alligator Pond

</td></tr>
<tr><td>Shallow enclosed waters</td><td>Enclosed bay or natural harbours with shallow water. Often find seagrass located within these nearshore environments.</td><td>Bowden Harbour

</td></tr>
</table>

B

Nearshore and offshore islands and cays

In Jamaica, there are several islands and cays present within the nearshore and offshore environment. Although many of these are positioned outside of the nearshore zone being considered above, they are an important consideration in coastal management studies. Due to the scale of the typology assessment as presented in Appendix B, offshore islands and cays have not been specifically identified as a typology. However, it is important that they are considered at three different levels:

- In strategic planning – although many of the islands and cays are unpopulated, there are a number which are populated such as the Pedro Cays. The population is dominantly fishing based communities and are very vulnerable to hazards such as storms and hurricanes, in addition to longer term sea level rise and environmental degradation. Longer term adaptation plans are required on the strategic level to ensure the protection to these communities.
- In conservation planning – Many of the cays and islands are extremely important in terms of environmental and ecological significance to the country. The Pedro Bank became Jamaica's first offshore Marine Protected Area. The Goat Islands are another example of areas rich of **biodiversity** and habitat in Jamaica. Conservation of these areas through designated Protected Areas is critical for the overall protection of Jamaica's coastal and marine environments.
- Direct impact on wave climate at shoreline – The islands and cays of Jamaica are positioned both nearshore (such as the Goat Islands which are about 1 mile from the shoreline) and offshore (such as the Pedro Cays which are about 50 miles from the shoreline). The islands and cays will interact with incoming waves and cause diffraction and dampening of wave energies. Particularly those close to the shore are likely to provide protection to the shoreline from wave energies and therefore erosion and **overtopping**. This provides a good natural defence for the coastline. However, with many of these islands being low lying, the impact of sea level rise may not just impact the island itself, but also the mainland coastline through increasing wave energies and erosion. This should be considered when planning **management approaches** or **interventions** in terms of potential future changes and impacts.

B3.2.2: Resiliency of coastal typologies

In general, the resiliency of the coastline depends on the cross-section of typologies which extend from the highest point of a **watershed** (i.e. a "ridge") down to the submerged reef flat or offshore deep waters (i.e. the combination of hinterland, shoreline, and nearshore environments). Depending on the combination of typologies, the overall hinterland-shoreline-nearshore combination has been termed a Coastal Management Unit (CMU). Section B4 below presents each combination found within the Jamaican coastal zone and comments on the key risks, its **resilience** to climate change and coastal hazards, and presents the appropriate potential engineering solutions which could be implemented at this type of location.

B4: Coastal Management Units

Depending on the combination of typologies, the overall hinterland-shoreline-nearshore combination has been termed a Coastal Management Unit (CMU). Each CMU has been given a reference ID which relates to the hinterland environment (A-E) and the combinations of other typologies (noted by a number ID). These IDs have been used to allow easy cross referencing and referral to different CMUs.

Each CMU has a range of processes and features that are relevant to that CMU and key issues which should be considered. Therefore, it is important to consider what **interventions** are appropriate in each CMU. It is recommended that one of the first stages of choosing a coastal **intervention**, is to look up the applicable CMU in the following pages, consider the key issues, and the list of applicable **interventions** to be used to form the initial long list of potential applicable **interventions** (see Part C1 for further details on this process).

The CMUs presented are those which are found on the Jamaican Coastline and have been written to be specific to Jamaica. Appendix B presents maps showing the classification of the coastline of Jamaica into these CMUs. Table B3 presents the index for the following pages. Within the following section, each CMU has a description of the CMU, key considerations and then has a table associated with it which relates to the possible **interventions**. All the core **interventions** are presented in Section D of these Guidelines.

Within these tables, the **interventions** have been given a "**resiliency**" score which is applicable specifically to that environment. The term **resiliency** has been defined in B2.1 and in summary represents the ability of a community, infrastructure or ecosystem to recover following impact in addition being able to adapt to future changes.

The general suite of characteristics which have been used to enable the assessment is presented in Table B2. This scoring is to be recognised as being indicative to enable demonstration of the overall resiliency rather than providing a full quantitative assessment.

Table B2 Resiliency scoring

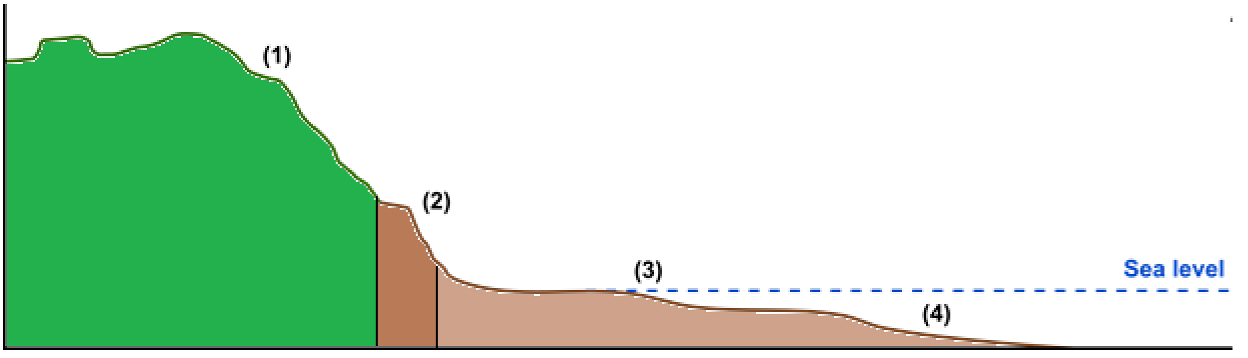
Score	Protection offered against coastal flood and erosion risk	Ability to recover from coastal hazards	Long term adaptability to climate change
1	Only some protection offered	Very low - likely to lose integrity	Limited
2	Protection offered to smaller events	Would need a lot of work to recover after event	Some small adaptation potential
3	Protection offered to medium size events	Will recover to maintain some of its functions	Could be modified to provide some level of adaptation
4	Provides protection to most hazards	Will recover to maintain most of its functions	Can be modified to provide adaptive approach
5	Provides high **standard of protection**	High ability to accommodate and recover	Provides flexibility and adaptability

B

Table B3 Index for CMU information presented below.

COASTAL MANAGEMENT UNIT A1

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Cliff	Pavement



KEY FEATURES

- Where main Jamaican mountain chains meet the coastline. Elevations from ridges at >2,000mAOD can reach sea level in less than 20km **(1)**. Typically steep (>30 degree) slopes with high gradient water courses.
- Often sub-vertical cliffs at coastline **(2)**, up to 20m high in Jamaica. Form dependent on local geology and geomorphology.
- Rocky pavements in nearshore are formed as wave cut platforms typically not more than 200m wide in Jamaica **(3)**, and may be associated with a fringing non-living reef, prior to descent into shelf seas **(4)**.
- Generally low population density in hinterland owing to access difficulty and limited development terrain.

KEY PROCESSES

- Hinterland effected by ongoing **weathering**, and dominantly **erosional** processes in the form of soil erosion on poorly vegetated slopes. Landslides are often driven by **basal undercutting** in river systems, or triggered by seismic, hurricane or storm events.
- Bed-load in rivers is mainly limited in **incised valleys** and is predominantly undergoing transportation.
- Cliffs are prone to **erosion** and landsliding mechanisms, leading to retreat of the coastline. The dominant process is dependent on the geomorphology and geology at the coastline, and often the **hardness** of the rock formations and their structure.
- Cliff retreat can occur from wave impacts, but also from associated groundwater conditions and changes. Debris collects in nearshore and moves into the coastal system.
- Platform lowering can change overall water depths and wave conditions nearshore.

KEY ISSUES

- Modifications to drainage and land-use in mountain catchments can lead to significant changes distances away at the coastline.
- Where cliff recession is impacting assets in Jamaica, often the solution is to try and fix the coastline in place through coastal protection works in the form of revetments, walls, and cliff works. In the face of sea level rise this can lead to **coastal squeeze** in front of the cliff lines, with combined platform lowering, providing more and more aggressive wave event conditions.
- The Health and Safety of people and communities around coastal cliffs must be considered carefully. Cliffs can fail with sometimes metres of land lost in one event. Combined with cliff height, this can provide a real hazard both upslope, and below the cliffs on the foreshore.

CASE STUDY

White Horses is an area of cliffs to the east of Kingston. The cliffs are approximately 14m high above sea level.

The general environment is of chalky limestone cliffs that are sub-vertical, and undergoing cliff falls predominately through coastal undermining.

There is currently no coastal management in place at this location.

Whilst the main road diverts in land here, access roads and properties are located very near the cliff edge in places and the current rate of retreat should be used to assess potential risk to the erosion of the road.

Likely responses in this location would be concentrated on cliff monitoring and planning responses such as set-back regulations from the cliff edge. To prevent erosion major toe protection and cliff stabilisation works would be required.

COASTAL MANAGEMENT UNIT A1

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Cliff	Pavement

FUTURE CHANGES

Rapid Onset Hazards:

- Key events (in particular large storms and hurricanes in the east of the Island) in steep mountain systems in Jamaica provide high magnitude rainfall, in quickly **responsive catchments**, that have effects distances away at the coastline. Mobilised debris can affect coastline watercourses, and flows themselves may be very high providing a real hazard in watercourses.
- Short term storms and storm surges, can provide significant triggers to the development of **erosion** and coastal landslides, bringing about rapid recession changes in sensitive coastal cliffs, that can quickly affect assets.

Slow Onset Hazards:

- Slow erosion of coastal cliffs can start to approach properties and highways, until such time that they become unsafe (if not protected in time) and should be abandoned or the assets moved.
- Changes in groundwater regimes through climate change variations may assist in modifying the overall conditions for catchment processes and cliff **erosion** events at the coastline.

Human Development:

- Provision for development in mountain systems should be carefully considered for locations and access to the developments. Assessments should be undertaken on the natural soil and ground conditions, erosion and landslide potential, and drainage issues. Provision of a development can detrimentally change the existing equilibrium, and engineering or other management solutions may be required to ensure the development and accesses are safe.
- Planning for Jamaican coastal communities around cliffs should be carefully considered. Developments, highways, and other infrastructure near cliffs can become vulnerable to recession and then require reactive measures for protection, lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.

Summary

- Often a harsh environment with limited access and high wave energies.
- Key considerations in these environments is related to **erosion** and **weathering** of the cliffs and hinterland.
- Ongoing **erosion** of cliffs is one of the key future risks to consider in the future, which may increase due to sea level rise.
- Furthermore these areas are very prone to sudden collapse after extreme rainfall/storm events.

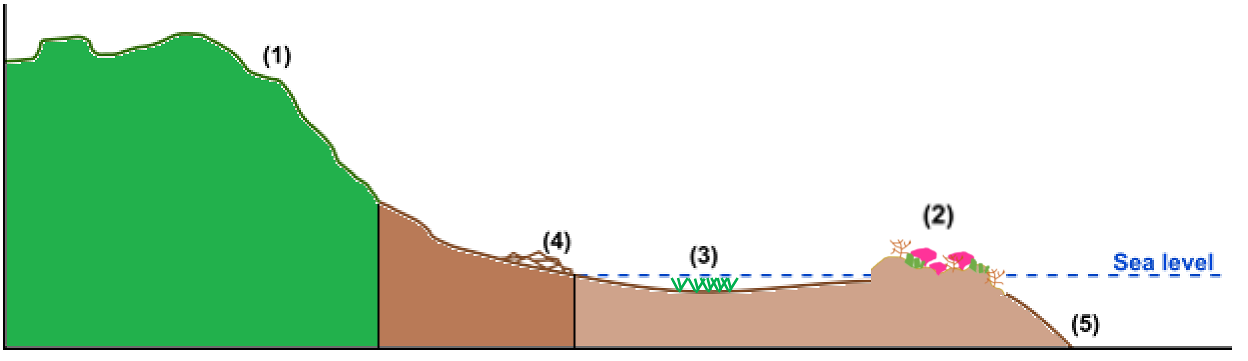
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Basal Undercutting:** Erosion of material at the base of the cliff.
- **Weathering:** The process of the breakdown in material and particles by the action of wind, flowing water or waves. Differs to erosion as the sediments are not removed or transported elsewhere.
- **Coastal Squeeze:** Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers (such as resistant cliffs or a seawall) (CIRIA, 2010).
- **Incised Valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.
- **Hardness:** Used to characterise rock types and is a measure of the resistance of the material to abrasion.
- **Responsive Catchments:** Watercourses which can rise and fall in levels very quickly and give little or no warning prior to flooding.

CMU A1						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	May have some limited impact in reducing toe erosion of cliff.	3
Revetments	√	√	x	x	May have some limited impact in reducing toe erosion of cliff.	2
Sea Walls	√	√	x	√	May have some limited impact in reducing toe erosion of cliff. Depending on design overtopping can cause scour of cliff behind sea wall.	1
Groynes	x	x	x	x		
Land Reclamation	√	x	√	x	Would not be advised in high energy environment.	2
Gabions	√	√	x	x	Not likely to be very effective in the high energy environment.	1
Flood Barriers	x	x	x	x		
Embankments	x	x	x	x		
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	Moving assets and infrastructure away from the cliff edge and erosion one can be very helpful.	5
Watershed Planning	x	x	√	x	Reducing run off and cliff saturation from the hinterland can be very effective in reducing risk of collapse and landslides in cliffs.	3
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates of cliffs.	4
Building Codes	x	x	x	x		
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT A2

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Rocky Shore	Fringing Reef



KEY FEATURES

- Hummocky or moderately steep mountainous/hilly terrain close to coastline (< approx. 700m) **(1).**
- Development of a near-shore fringing reef system **(2)** in Jamaica is sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(3)**. Fringing reef may extend further than 1.5km from shore.
- Rock exposed along shoreline or fringing reef continues up to top of shore **(4).**
- Seafloor falls to shelf depths beyond outer limit of fringing reef **(5).**
- Fringing reefs can provide good natural protection to the Jamaican coastline from wave energies along coastline.
- Steeper mountain fronts often appear to have forced construction of roads very close to coastline in Jamaica.

KEY PROCESSES

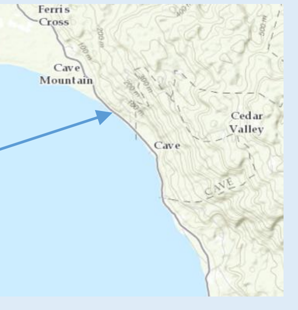
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills and formation of red **residual soils**.
- Active **erosion** of upland areas, often enhanced by tropical storms. Possible **undercutting** in river channels.
- Increasing depth of fringing reef exposes rocky shore to waves in Jamaica, increasing potential **erosion** rates. This may be caused by coral removal or due to higher relative sea levels (e.g. during storm surges).
- Sensitivity of rocky shore to **erosion** closely linked to its geology in Jamaica (such as structural features and **lithology**).
- Seagrasses and coral reefs can contribute to sand production where present.

KEY ISSUES

- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; systems particularly sensitive to human activity in Jamaica.
- Shallow fringing reef system provides erosion protection to shoreline, but can easily be subject to inundation (e.g. from rising sea levels, tropical storm surges).
- Rocky shore does not provide significant protection to wave energy, so the usually low energy environment can become high energy during storm events, potentially permitting significant erosion.

CASE STUDY

Topographic lines show steep slope down into the coastline where the coastal road is sited.



North of Bluefields Bay on the south west coast of Jamaica, the Bluefields mountains drop straight down into the rocky shoreline. A coastal road follows the shoreline closely and there is very limited space for any other key assets due to the steep slopes.

A fringing reef and seagrass beds do, however, provide some protection to the shoreline and assets along the shoreline from wave energies. Reduction in the extent or health of these ecosystems could increase the risk of flooding and erosion of the road and other assets along the shoreline.

There is currently limited management required along this part of the shoreline as it is partly sheltered from wave energies due to the incidence of the shoreline, presence of coral reefs and seagrasses. However, with increasing sea level rise, the risk of erosion and overtopping will increase and additional interventions may be required.

COASTAL MANAGEMENT UNIT A2

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Rocky Shore	Fringing Reef

FUTURE CHANGES

Rapid Onset Hazards:

- Key events (in particular large storms and hurricanes in the east of the Island) in steep mountain systems in Jamaica can provide high magnitude rainfall, in quickly **responsive catchments**, that can then have effects distances away at the coastline. Mobilised debris can affect coastline watercourses, and flows themselves may be very high providing a real hazard in watercourses.
- Storm surges can quickly inundate usually sheltered fringing reef systems. This can expose the shore/coastline to unusually large waves, where vastly increased wave energy along the shoreline may lead to rapid rates of **erosion** and quickly threaten coastline infrastructure.

Slow Onset Hazards:

- Gradual increase in sea level relative to fringing reefs induced by climate change. Jamaican coastline more exposed to typical wave conditions and increases vulnerability to erosion during larger storm events.
- Rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to coastline property and infrastructure.
- Inland pollution, ocean acidification, overfishing, climate change and coastal developments are all threats to the fringing reef system of Jamaica and therefore threatens the condition of the coastline's natural protection against erosion and shoreline retreat.

Human Development:

- Provision for development in mountain systems should be carefully considered for locations and access to the developments. Assessments should be undertaken on the natural soil and ground conditions, erosion and landslide potential, and drainage issues. Provision of a development can detrimentally change the existing equilibrium, and engineering or other management solutions may be required to ensure the development and accesses are safe.
- Planning for Jamaican coastal communities around cliffs should be carefully considered. Developments, highways, and other infrastructure near cliffs can become vulnerable to recession and then require reactive measures for protection, lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- The ecological condition of fringing reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system in Jamaica threatens to increase rates of **erosion** with consequences for coastal communities and infrastructure.

Summary

- Often a harsh environment with limited access and high wave energies.
- Key considerations in these environments is related to **erosion** and **weathering** of the rocky shore and hinterland.
- The fringing reefs are very important in providing erosion protection, as well as wider ecosystem benefits, however are extremely vulnerable to climate change and human development.

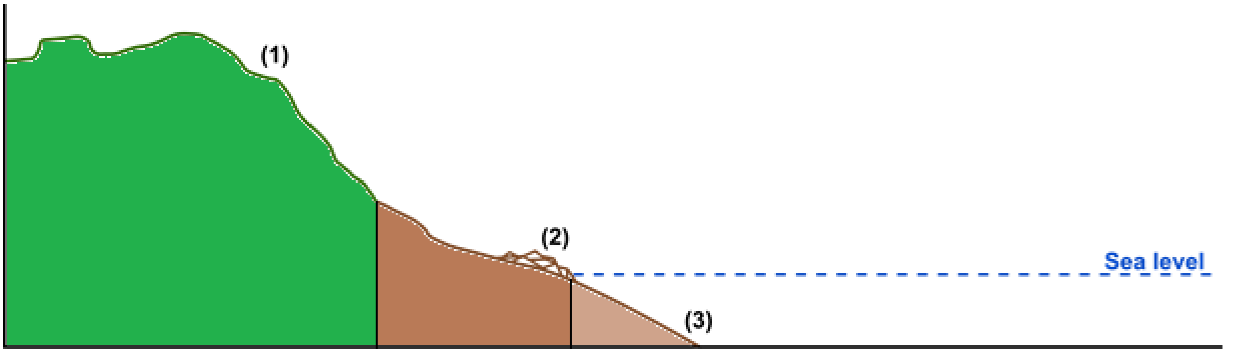
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Responsive Catchments:** Watercourses which can rise and fall in levels very quickly and give little or no warning prior to flooding.
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Undercutting:** Erosion of the base of a structure or rock forming caves or nooks, causing the structure or rock to become unstable.
- **Lithology:** The physical characteristics of a rock including colour, texture, grain size and composition.

CMU A2						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can bring wider tourism and fishery benefits as well as ecology benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Potentially however seagrasses are not likely to exist in these higher energy environments.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	x	x	x	x		
Land Reclamation	√	x	√	x	If considering land reclamation, must consider impacts on the coral reefs.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	In particular agricultural practices can cause increases in suspended sediment in the water and cause degradation of coral reefs.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates of the shoreline.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT A3

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Rocky Shore	Open Coast



KEY FEATURES

- Hummocky or moderately steep mountainous/hilly terrain close to coastline (< approx. 700m in Jamaica) **(1).**
- Rock exposed along shoreline, possibly with development of a narrow wave cut platform **(2).**
- Seafloor generally increases quickly in depth away from the Jamaican coastline **(3).**

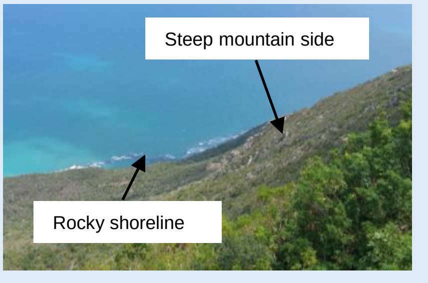
KEY PROCESSES

- Ongoing inland **Karst** formation in extensive limestone areas across Jamaica: sinkholes, caves, hummocky hills, formation of red **residual soils**.
- Active erosion of upland areas, often enhanced by tropical storm events. Possibly **undercutting** in the river channels.
- Coastline openly exposed to incident waves and therefore undergoing active **erosion**. Erosion rates are controlled by the nature of the processes operating along the Jamaican coastline and its geology (such as structural features and **lithology**).
- Higher rates of **erosion** may be expected during storm events, for example due to increased runoff and higher energy waves along the coastline.
- Lowering of the rocky shore or platform can change overall water depth and wave conditions near the shore in Jamaica.

KEY ISSUES

- Modifications to drainage and land-use in mountain catchments can ultimately lead to significant response scenarios distances away at the coastline within Jamaican watersheds.
- Most energy from incident waves is directed straight at the coastline in these environments in Jamaica. This is a particular problem during storm events when wave energy and sea levels are higher, leading to increased potential for **erosion** and coastal retreat.

CASE STUDY



Lover's Leap is located on the Santa Cruz Mountains that exposes a 520 metres (1,700 ft) drop to Cutlass Bay at the shoreline.

The area is part of a terrestrial and marine protected area (designated in 2002) for natural and cultural resources and is part of the Lovers' Leap Forest Reserve. The interaction between erosional features and erosional risk and the forestry and hinterland management is important here.

The assets along the section of coastline at Lover's Leap are set back from the shoreline at a higher altitude. The reduces the risk from erosion and flooding on these assets.

Further along the coast however, Port Kaiser is located between Lover's Leap and Alligator Pond, and is built out from the shoreline. Bauxite is exported from Port Kaiser and it is an important asset for Jamaica. However it is located in a high energy environment and therefore could be at increasing risk with sea level rise.

COASTAL MANAGEMENT UNIT A3

HINTERLAND	SHORELINE	NEARSHORE
Mountain Front	Rocky Shore	Open Coast

FUTURE CHANGES

Rapid Onset Hazards:

- Key events in Jamaica (in particular large storms and hurricanes in the east of the Island) in steep mountain systems can provide high magnitude rainfall, in quickly **responsive catchments**, that can then have effects distances away at the coastline. Mobilised debris can affect coastline watercourses, and flows themselves may be very high providing a real hazard in watercourses.
- The increased wave energy associated with storm surges has the potential to cause rapid **erosion** at the coastline in the absence of any natural defence along the coastline.

Slow Onset Hazards:

- Increased sea level through climate change may reduce wave energy absorption that might be offered by the presence of a platform along rocky shores.
- Rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to Jamaican property and infrastructure.
- Changes in groundwater regimes through climate change variations may assist in modifying the overall conditions for catchment processes and erosion events at the coastline.

Human Development:

- Provision for development in mountain systems should be carefully considered for locations and access to the developments. Assessments should be undertaken on the natural soil and ground conditions, **erosion** and landslide potential, and drainage issues. Provision of a development can detrimentally change the existing equilibrium, and engineering or other management solutions may be required to ensure the development and accesses are safe.
- Planning for Jamaican coastal communities around cliffs should be carefully considered. Developments, highways, and other infrastructure near cliffs can become vulnerable to recession and then require reactive measures for protection, lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.

Summary

- Often a harsh environment with some restricted access and high wave energies.
- Key considerations in these environments is related to **erosion** and **weathering** of the rocky shore and hinterland.
- Open coast environment increases risks associated with high incident waves.
- Future consideration must be made when planning intervention works regarding sea level rise and the impact sea level rise could have on future erosion rates.

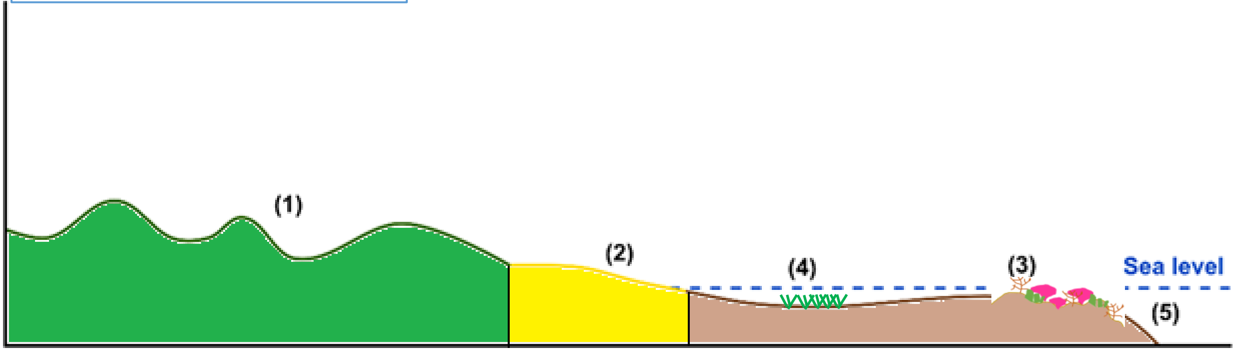
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Responsive Catchments:** Watercourses which can rise and fall in levels very quickly and give little or no warning prior to flooding.
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Undercutting:** Erosion of the base of a structure or rock forming caves or nooks, causing the structure or rock to become unstable.
- **Lithology:** The physical characteristics of a rock including colour, texture, grain size and composition.

CMU A3						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	x	x	x	x		
Land Reclamation	√	x	√	x	If considering land reclamation, must consider the impacts of the high energy waves often found in these environments.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can be very effective in reducing risk of collapse and landslides.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates of the shoreline.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B1

HINTERLAND Coastal Slopes/ Foothills	SHORELINE Beach	NEARSHORE Fringing Reef



KEY FEATURES

- Gentle undulating sloping lowland areas that connect the Jamaican steep mountain ranges to the coastline **(1)**.
- Shoreline consists of shallow slopes with short exposed section of beach at the high water level.
- Beaches comprise sloping ground composed of sand and gravel in varying amounts depending on the wave energy at these locations around Jamaica **(2)**.
- The nearshore has a shallow sea area which may be likely to support seagrasses **(4)** with a fringing reef **(3)**, prior to descent into shelf seas **(5)**. Fringing reefs grow near the Jamaican coastline, and are separated from the shore by narrow, shallow lagoons. Coral (fringing) reefs act as a buffer against wave action, storms and hurricanes.
- Shoreline is generally a populated area in Jamaica.
- Seagrass meadows often present in the shallow lagoon area **(4).**

KEY PROCESSES

- Hinterland effected by shallow slope movements and **soil creep**.
- White sand beaches can be found along the north coast of Jamaica comprising sediments eroded from the offshore coral reefs.
- **Erosion** of the hinterland produces sediment which nourishes the southern beaches. This sediment tends to be darker than the sediment produced from offshore coral reef which typify the north coast.
- Beach **erosion** and **longshore** and offshore **sediment transport** can provide **erosion** problems at the shoreline.
- Seagrasses and coral reefs can contribute to sand production where present.

KEY ISSUES

- Soil **erosion** and slope failures on coastal slope/foothill surfaces.
- Natural and man-made factors which influence the erosion of the beaches may cause the beaches to shrink and disappear.
- Damage to the fringing coral reefs as a result of natural processes (i.e. hurricane damage; increase in temperature; siltation and excess nutrients) and man-made influences (i.e. loss of herbivores through extreme over-fishing, in addition to sewage pollution).

CASE STUDY

Priory Bay Public Beach is located on the north coast of Jamaica west of Ocho Rios. It is a large beach which is located at the bottom of the coastal slopes along the north coastline.

The main north coast highway A1 passes to within 100m of the coastline at this location. The bay itself forms a junction between low foothills to the south and east, with very dominant south to north drainage with low relative relief interfluves, and a quite flat coastal slope on which the Richmond Estate and Plantation Village are located.

The bay provides not only a focus for amenity in the sheltered waters here, but is also a location, where the hinterland drainage also converges. The increasing and relatively recent development here, and the potential opening up of new lands in this attractive areas, may give rise to significant changes in surface water run-off, and water quality control issues for the drainage discharges into the sea.

COASTAL MANAGEMENT UNIT B1

HINTERLAND	SHORELINE	NEARSHORE
Coastal Foothills/ Slopes	Beach	Fringing Reef

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes in Jamaica (particularly for the east of the Island) can provide high magnitude rainfall which may lead to slope failures on coastal slopes/foothills.
- Flooding from coastal slopes/foothills during intense rainfall events.
- **Erosion** of beaches may also occur during hurricanes and storm events in Jamaica.

Slow Onset Hazards:

- The supply of sediment from the coastal slopes/foothills to the beaches on the south coast may be altered by a change in climatic conditions.
- Beaches in Jamaica are vulnerable to sea-level rise. An increase in wave action, tides and currents may change beach **erosion** patterns.
- Climate change in Jamaica is expected to cause a significant impact to coral (fringing) reefs due to their sensitivity to temperature changes. Coral (fringing) reefs are vulnerable to sea-level rise.

Human Development:

- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed through human development that would usually provide important interception and storage of rainfall.
- The ecological condition of fringing reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of **erosion** with consequences for Jamaican coastal communities and infrastructure.
- Increasing demands for land along the coast in Jamaica for housing construction will encroach on beach areas.
- An increase in agricultural activities, and poor agricultural practices has led to an increase in soil **erosion**. Near the mouths of rivers, sedimentation is damaging nearby reefs.

Summary

- Beaches provide **erosion** protection to the hinterland and reduce likelihood of flooding.
- However beaches are also very prone to wave **erosion** and sediment movement.
- The fringing reefs are very important in providing **erosion** protection, as well as wider ecosystem benefits, however are extremely vulnerable to climate change and human development.
- Future climate change and human development are required to be assessed to ensure a suitable solution, particularly in consideration of how the fringing reef may function following further depletion of the system.
- Depletion of seagrass meadows through construction activities can further increase the vulnerability in these locations.

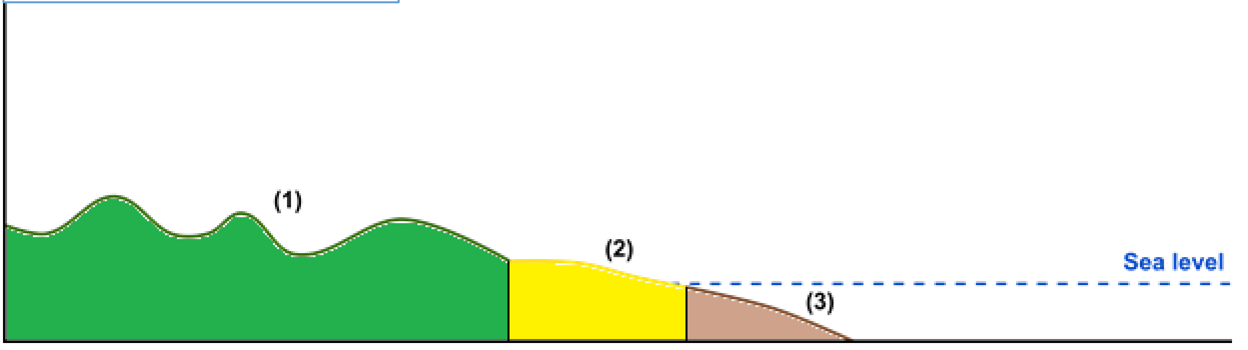
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Soil creep:** The slow gradual movement of rock or soil down a slope
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

CMU B1						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	X	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide additional sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can be very effective in reducing risk of collapse and landslides.	5
Set Back Zones	√	x	√	x	Should be calculated using erosion estimates of the shoreline.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B2

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Beach	Open Coast



KEY FEATURES

- Gentle undulating sloping lowland areas that connect the Jamaican steep mountain ranges to the coastline **(1)**.
- Shoreline consists of shallow slopes with short exposed section of beach at the high water level **(2)**.
- Beaches comprise sloping ground composed of sand and gravel in varying amounts depending on the wave energy at these locations in Jamaica.
- The sea level typically falls to shelf depths beyond the beach **(3).**
- Larger areas of shallow seas covering landscapes can be found in the south (due to subsidence in the south) whilst deep seas can be found to the north.

KEY PROCESSES

- Hinterland effected by shallow slope movements and **soil creep**. Possible debris flows and **deeper seated slope movements,** particularly in locally over-steepened areas such as **incised valleys**.
- **Erosion** of the hinterland produces sediment which nourishes the beaches. This sediment tends to be darker than the sediment produced from offshore coral reef which typify more of the beaches on the north coast.
- The open coast means that the beaches are generally exposed to more extreme wave action and will therefore likely to be steeper and with coarser sediments compared to beaches protected by land or reefs.
- Beach erosion and **longshore** and offshore **sediment transport** can provide **erosion** problems at the shoreline.

KEY ISSUES

- Soil erosion and slope failures on coastal slope/foothill surfaces.
- Natural and man-made factors influence the **erosion** of the beaches and may cause the width of the Jamaican beach to decrease.
- Beaches are exposed to an increase in wave energy during storm events and particularly where there are no coastal protection measures in place in Jamaica this can cause increased **erosion**.

CASE STUDY

The Font Hill Beach Park is located in the parish of St. Elizabeth towards the western boundary.

During its operation, it was a small but well-maintained stretch of sandy beach, however it was closed to the public in 2013, for reasons unknown.

The beach park was a part of the Font Hill Wildlife Sanctuary, which is rich in natural assets including scrubby acacia, logwood thickets and, closer to the shore, a maze of connected lagoons and swamps. Although the beach appears very exposed to wave energy and passing storms, it seems as if erosion was not a serious problem on the beach, with few problems being reported during its operation.

COASTAL MANAGEMENT UNIT B2

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	**Beach**	**Open Coast**

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes in Jamaica (particularly for the east of the Island) can provide high magnitude rainfall which may lead to slope failures on coastal slopes/foothills.
- Flooding from coastal slopes/foothills during intense rainfall events.
- **Erosion** of beaches may also occur during hurricanes and storm events in Jamaica.

Slow Onset Hazards:

- The supply of sediment from the coastal slopes/foothills to the beaches on the south coast may be altered by a change in climatic conditions.
- Beaches are vulnerable to sea-level rise. An increase in wave action, tides and currents may change beach **erosion** patterns.

Human Development:

- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events in Jamaica, particularly if vegetation is removed through human development that would usually provide important interception and storage of rainfall.
- Increasing demands for land along the Jamaican coast for housing construction will encroach on beach areas.
- Beaches may be susceptible to polluted surface water run-off from land based sources.

Summary

- Beaches provide **erosion** protection to the hinterland and reduce likelihood of flooding by providing a buffer between the open coast and the hinterland.
- However beaches are also very prone to wave **erosion** and sediment movement which can reduce the effectiveness of the beach in protection.
- Beaches in open coasts environments can be more susceptible to high energy waves as well as the hinterland watershed management.

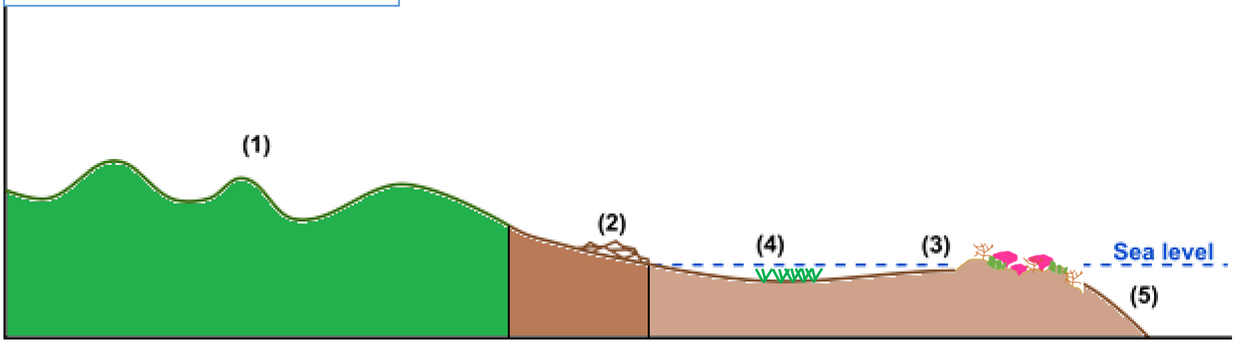
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Soil creep:** The slow gradual movement of rock or soil down a slope
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Incised valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.

CMU B2						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	X	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	If considering land reclamation, must consider the impacts of the high energy waves often found in these environments.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	3
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can be very effective in reducing risk of collapse and landslides.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates of the shoreline.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Fringing Reef



KEY FEATURES

- Shallow-gradient sloping, occasionally hummocky, lowland areas in Jamaica **(1)** that connect steep mountain ranges further inland to the coastline. Typically well-vegetated.
- Development of a near-shore fringing reef system **(3)** sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(4)**. Fringing reef may extend further than 1.5km from shore in Jamaica.
- Rock exposed along shoreline or fringing reef continues up to top of shore **(2).**
- Seafloor falls to shelf depths beyond outer limit of fringing reef **(5).**
- Fringing reefs can provide natural protection to **erosion** and wave energies along the coastline.

KEY PROCESSES

- Coastal slopes/foothills in Jamaica are affected by shallow slope movements and **soil creep**. Possible debris flows and **deeper seated slope movements**, particularly in locally over-steepened areas such as **incised valleys**.
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills, and formation of red **residual soils.**
- Increasing depth of fringing reef exposes rocky shore to waves, increasing potential **erosion** rates. This may be caused by coral removal or due to higher relative sea levels (e.g. during storm surges).
- Sensitivity of rocky shore to erosion is closely linked to its geology (such as structural features and **lithology**).
- Seagrasses and coral reefs can contribute to sand production where present.

KEY ISSUES

- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; system is particularly sensitive therefore to human activity.
- Shallow fringing reef system provides **erosion** protection to Jamaican shoreline, but can easily be subject to inundation (e.g. from rising sea levels, tropical storm surges).
- Rocky shore does not provide significant protection for absorbing wave energy, so the usually low energy environment can become high energy during storm events, potentially permitting significant **erosion**.

CASE STUDY

Hopewell, on the west coast of Jamaica, is approximately 15km west of Montego Bay. The coastal slopes in this area run from Montego Bay and further landwards and typically represent the hinterland along this long section of coastline down to Negril.

Much of the coastline is rocky which provides a very narrow shoreline space and limits the space for development and tourist recreation on this section of coastline.

Seawalls along some of section separate the shoreline and the main coastal road which runs from Negril to Montego Bay. However, in others there is no separation which could cause a flood risk, particularly when considering sea level rise and erosion risk. Properties are generally in this area located further back on the coastal slopes which reduces the potential flood risk as they are on elevated ground.

COASTAL MANAGEMENT UNIT B3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Fringing Reef

FUTURE CHANGES

Rapid Onset Hazards:

- Gently sloping surfaces of the coastal slope/foothill may promote more rapid run-off, especially over impermeable or saturated soil/bedrock, which may increase the likelihood of flooding during storm events in Jamaica.
- Storm surges can quickly inundate usually sheltered fringing reef systems in Jamaica. This can expose the shore/coastline to unusually large waves, where vastly increased wave energy along the shoreline may lead to rapid rates of **erosion** and quickly threaten coastline infrastructure.

Slow Onset Hazards:

- Gradual increase in sea level relative to fringing reefs induced by climate change. Coastline more exposed to typical wave conditions and increases vulnerability to erosion during larger storm events.
- Rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to coastline property and infrastructure in Jamaica.
- Inland pollution, **ocean acidification**, overfishing, climate change and Jamaican coastal developments are all threats to the fringing reef system and therefore threats to the condition of the coastline's natural protection against erosion and shoreline retreat.

Human Development:

- Planning for Jamaican coastal communities around rocky shores should be carefully considered. Developments, highways, and other infrastructure near cliffs can become vulnerable to recession and then require reactive measures for protection, lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed through human development that would usually provide important interception and storage of rainfall.
- The ecological condition of Jamaican reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of erosion with consequences for coastal communities and infrastructure.

Summary

- Key considerations in these environments is related to **erosion** and **weathering** of the rocky shore and hinterland.
- The fringing reefs are very important in providing erosion protection, as well as wider ecosystem benefits, however are extremely vulnerable to climate change and human development.
- Future climate change and human development are required to be assessed to ensure a suitable solution, particularly in consideration of how the fringing reef may function following further depletion of the system.

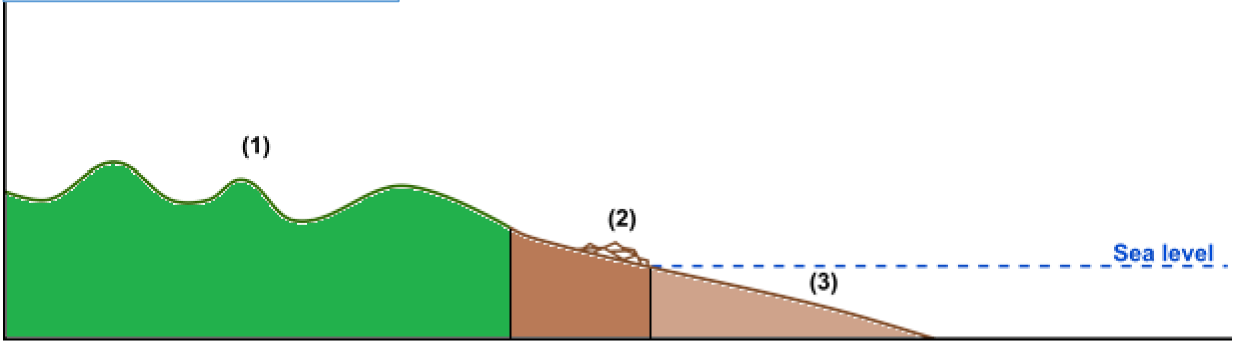
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Incised valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.
- **Lithology:** The physical characteristics of a rock including colour, texture, grain size and composition.
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.

CMU B3						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can bring wider tourism and fishery benefits as well as ecology benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	√	√	x	x	Only applicable if creating an artificial beach.	2
Land Reclamation	√	x	√	x	If considering land reclamation, must consider impacts on the coral reefs.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	In particular agricultural practices can cause increases in suspended sediment in the water and cause degradation of coral reefs.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates of the shoreline.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Open Coast



KEY FEATURES

- Shallow-gradient sloping, occasionally hummocky, lowland areas **(1)** that connect steep mountain ranges in Jamaica further inland to the coastline. Typically well-vegetated.
- Rock exposed along shoreline, possibly with development of a narrow wave cut platform **(2).**
- Seafloor generally increases quickly in depth away from coastline **(3).**

KEY PROCESSES

- Coastal slopes/foothills affected by shallow slope movements and **soil creep** in Jamaica. Possible debris flows and **deeper seated slope movements**, particularly in locally over-steepened areas such as incised valleys.
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills, formation of red residual soils
- Coastline openly exposed to incident waves and therefore undergoing active **erosion**. **Erosion** rate controlled by nature of the processes operating along the coastline and its geology (such as structural features and **lithology**) in Jamaica.
- Higher rates of **erosion** may be expected during storm events, for example due to increased runoff and higher energy waves along coastline.
- Lowering of the rocky shore or platform can change overall water depth and wave conditions near the shore.

KEY ISSUES

- Most energy from incident waves is directed straight at the coastline. This is a particular problem during storm events when wave energy and sea levels are higher in Jamaica, leading to increased potential for **erosion** and coastal retreat.
- Gently sloping surfaces of the coastal slope/foothill may promote more rapid run-off, especially over impermeable or saturated soil/bedrock, which may increase the likelihood of flooding during storm events.

CASE STUDY

Satellite image showing rocky exposed coastline with properties and road close to the shoreline in many places.

North of Oracabessa, the headland here has a rocky shore with little or no offshore reefs to provide protection to waves. Despite this, the road in many places is still located close to the shoreline and a number of properties are built along the shoreline edge.

Although the road appears to be stable at the moment, future erosion, particularly considering sea level rise, could be a cause for concern here. Historic erosion rates are unknown, but would help to determine future risk to properties and infrastructure in the area.

COASTAL MANAGEMENT UNIT B4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Open Coast

FUTURE CHANGES

Rapid Onset Hazards:

- The increased wave energy associated with storm surges in Jamaica has the potential to cause rapid erosion at the coastline in the absence of any natural defence along the coastline.
- Potential for increased severity and quantity of extreme events in the future with climate change in Jamaica.

Slow Onset Hazards:

- Increased sea level through climate change in Jamaica may reduce wave energy absorption that might be offered by the presence of a narrow wave-cut platform along rocky shores.
- Rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to coastline property and infrastructure.
- Changes in groundwater regimes through climate change variations may assist in modifying the overall conditions for catchment processes and erosion events at the coastline.

Human Development:

- Planning for Jamaican coastal communities around rocky shores and open coastline should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed that usually provides important interception and storage of rainfall.

Summary

- An open coast means that the rocky shore is very exposed to wave energies and storms.
- Both **erosion** and flooding can be hazards experienced here.
- Future changes in storminess and sea level rise will potentially increase the current risks in these environments.

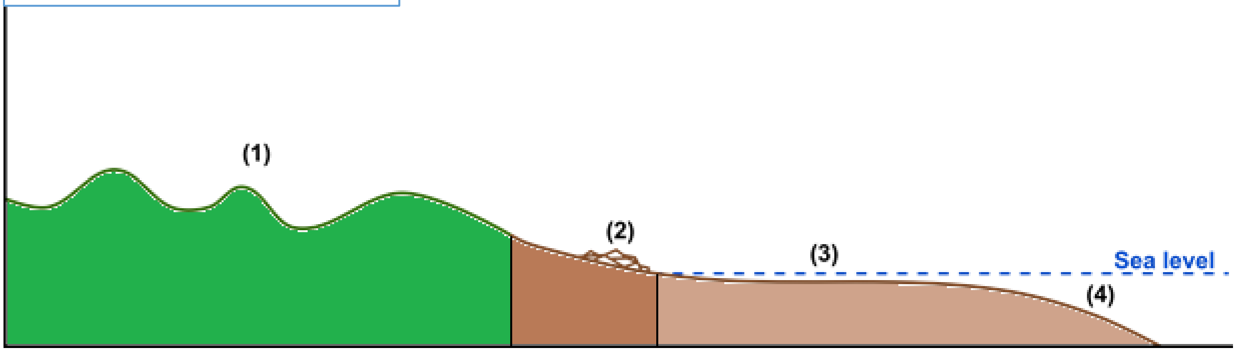
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Lithology:** The physical characteristics of a rock including colour, texture, grain size and composition.
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Soil creep:** the slow gradual movement of rock or soil down a slope.

CMU B4						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	√	√	x	x	Only applicable if creating an artificial beach.	2
Land Reclamation	√	x	√	x	If considering land reclamation, must consider the impacts of the high energy waves often found in these environments.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can be very effective in reducing risk of collapse and landslides.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B5

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Pavement



KEY FEATURES

- Shallow-gradient sloping, occasionally hummocky, lowland areas **(1)** that connect steep mountain ranges in Jamaica further inland to the coastline. Typically well-vegetated.
- Rock exposed along the shoreline **(2).**
- Rocky wave-cut **erosional** platform in Jamaica typically not more than 200m wide extends away from the shore-line **(3)**, usually associated with large areas of shallow water in the tidal zone.
- Water depths increase to shelf levels beyond the furthest extent of the pavement **(4).**

KEY PROCESSES

- Coastal slopes/foothills in Jamaica affected by shallow slope movement
- s and **soil creep**. Possible debris flows and **deeper seated slope movements,** particularly in locally over-steepened areas such as **incised valleys**.
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills, formation of red **residual soils.**
- Wave-cut platform generally provides an area where some wave energy is absorbed before reaching the coastline, although its presence is an indicator of ongoing coastal retreat.
- Higher rates of **erosion** may be expected during storm events, for example due to increased runoff and higher energy waves along coastline.
- Lowering of the rocky shore or platform can change overall water depth and wave conditions near the Jamaican shore.

KEY ISSUES

- Most energy from incident waves is directed straight at the coastline, including the rocky shore and wave-cut platform. This is a particular problem during storm events when wave energy and sea levels are higher in Jamaica, leading to increased potential for **erosion** and coastal retreat, particularly because the protection offered by the platform is somewhat reduced.
- Gently sloping surfaces of the coastal slope/foothill in Jamaica may promote more rapid run-off, especially over impermeable or saturated soil/bedrock, which may increase the likelihood of flooding during storm events.

CASE STUDY

White Horses is a community in the parish of St. Thomas, some 36km east of Kingston.

The coastline borders the roadway and is quite rocky and exposed to high wave energy due to it being exposed to the open coast, which limits its recreational use and introduces health and safety concerns.

Fisherman do use the coastline for both recreational and commercial use.

There has been some history of damage to the road, located very close to the shoreline. Large waves have inundated the road often with rocks and debris, and in some cases have made it impassable. In an attempt to safeguard the road, some rocks were placed to form a makeshift revetment along the road. This revetment features both stones natural to the area and larger stones which were brought in to aid in construction. However, there have still been instances of surge flooding the roadway in significant storm events.

COASTAL MANAGEMENT UNIT B5

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Pavement

FUTURE CHANGES

Rapid Onset Hazards:

- The increased wave energy associated with storm surges in Jamaica has the potential to cause rapid **erosion** at the coastline in the absence of any natural defence along the coastline.
- Climate change in Jamaica has the potential to increase the frequency and severity of extreme events such as hurricanes (particularly for the east of the Island) .

Slow Onset Hazards:

- Increased sea level rise through climate change in Jamaica may reduce wave energy absorption that might be offered by the presence of the wave-cut platform along rocky shores.
- A rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to Jamaican property and infrastructure.
- Changes in groundwater regimes through climate change variations may assist in modifying the overall conditions for catchment processes and erosion events at the coastline.

Human Development:

- Planning for Jamaican coastal communities around rocky shores and open coastline should be carefully considered. Developments, highways, and other infrastructure near the coastline in Jamaica can become vulnerable to recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure
- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed that usually provides important interception and storage of rainfall.

Summary

- Key considerations in these environments is related to **erosion** and **weathering** of the rocky shore and hinterland.
- The rocky platform can provide some reduction in wave energies however has only limited effect, particularly under high water levels.
- Future climate change in terms of sea level rise and increased storminess is likely to increase the risk of flooding and **erosion** in these areas.

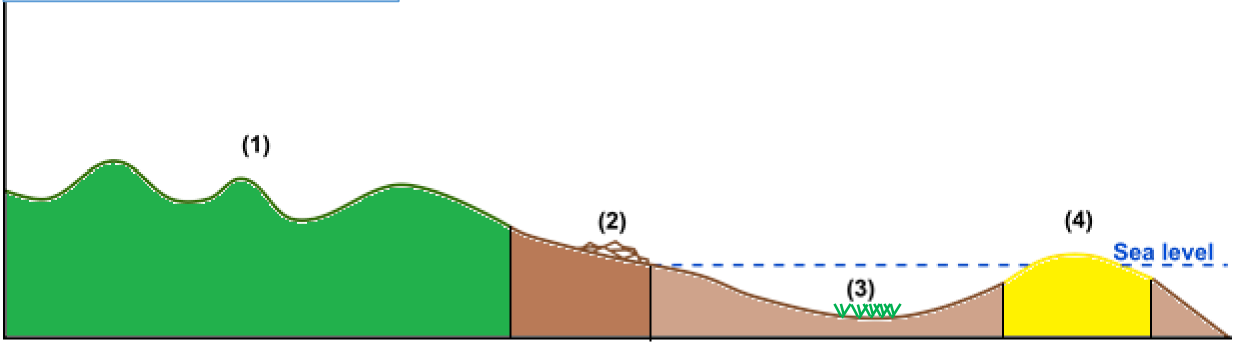
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Incised valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Soil creep:** the slow gradual movement of rock or soil down a slope.

CMU B5						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	X	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	√	√	x	x	Only applicable if creating an artificial beach.	2
Land Reclamation	√	x	√	x	Appropriate ground conditions must be considered for use.	3
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	X	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can be very effective in reducing risk of collapse and landslides.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B6

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Enclosed Water



KEY FEATURES

- Shallow-gradient sloping, occasionally hummocky, lowland areas **(1)** that connect steep mountain ranges in Jamaica further inland to the coastline. Typically well-vegetated.
- Rock exposed along shoreline, possibly with development of a narrow wave cut platform **(2).**
- Sheltered enclosed water area **(3)** (for example by a natural or man-made spit **(4)**) protects shore from wave energy and may be likely to support seagrasses.
- Sea-front infrastructure in Jamaica often built up to enclosed water.
- There may often be seagrass meadows present within the sheltered enclosed area **(3)**.

KEY PROCESSES

- Coastal slopes/foothills in Jamaica affected by shallow slope movements and **soil creep**. Possible debris flows and **deeper seated slope movements**, particularly in locally over-steepened areas such as **incised valleys**.
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills, formation of red **residual soils.**
- Spit provides significant protection from incoming waves to the enclosed area of water and land behind it reducing likelihood of **erosion** and flooding.
- Higher rates of **erosion** in Jamaica may be expected during storm events, for example due to increased runoff and higher energy waves along coastline.
- Lowering of the rocky shore or platform can change overall water depth and wave conditions near the shore.
- Presence of sea grasses can further reduce wave energies.
- Seagrasses can contribute to sand production where present.

KEY ISSUES

- Geometry of spits are likely to change through time in response to wave patterns. This will ultimately control the amount of **erosion** and flood protection offered to enclosed water bodies and un-protected rocky shorelines.
- Gently sloping surfaces of the coastal slope/foothill may promote more rapid run-off, especially over impermeable or saturated soil/bedrock, which may increase the likelihood of flooding during storm events.

CASE STUDY

Bowden Bay is directly offshore the town of Port Morant, in the south-east section of the Island.

Historically used as a commercial harbour, it is only privately used now although the Coast Guard still have a base here.

The enclosed area of Bowden Bay is very shallow and protected. There is a government-run oyster programme in the Bowden Bay area whereby oyster harvesters supply oysters to local hotels and other businesses.

Both sides of Bowden Bay are flanked by coastal slopes and hence the coastal road and communities are located close to the coastline.

Due to the calm water environment, there is less need for management of the shoreline compared to elsewhere in Jamaica.

COASTAL MANAGEMENT UNIT B6

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Rocky Shore	Enclosed Water

FUTURE CHANGES

Rapid Onset Hazards:

- Storm surges and storm waves in Jamaica are likely to affect the ability of spits to protect enclosed water bodies from **erosion** and flooding to the rocky shores/coastal infrastructure behind them.
- The increased wave energy associated with storm surges has the potential to cause rapid **erosion** at the coastline in the absence of any natural defence along the coastline, especially if the effectiveness of protection offered by spits is reduced.

Slow Onset Hazards:

- Gradual increase in sea level rise induced by climate change in Jamaica is likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions.
- The extent of spits protecting enclosed waters will evolve through time in response to factors such as wave incidence angle and the direction/quantity of sediment transport.
- A rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to Jamaican coastline property and infrastructure.
- Changes in groundwater regimes through climate change variations may assist in modifying the overall conditions for catchment processes and erosion events at the coastline.
- Destruction of vegetation in Jamaica can make spits that protect enclosed waters from wave energies more sensitive to **erosion**.

Human Development:

- Development on Jamaican coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed that usually provides important interception and storage of rainfall.
- Engineering measures to protect spits may reduce the severity of consequences from rapid and slow onset hazards.
- Planning for Jamaican communities should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to coastal recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- Removal of the seagrasses in the sheltered/enclosed waters can reduce the natural protection to wave energies offered by the system and increase flood risk to the hinterland.

Summary

- An enclosed area is likely to be a low energy wave environment and may often have seagrass meadows located in the nearshore area.
- If the enclosed area is protected by a spit, or barrier island type formation, the system will be affected by the constant movement over time of the spit.
- Removal of seagrasses through coastal developments and construction can significantly reduce the resilience of the system.

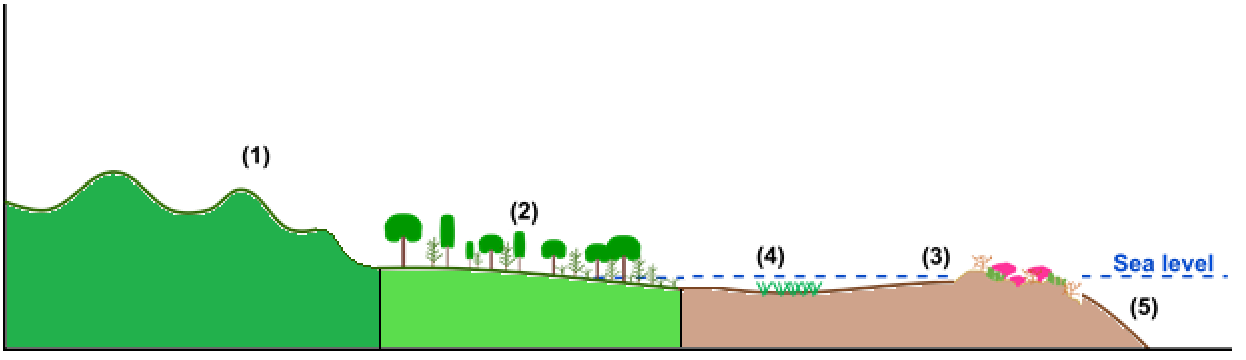
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Lithology:** The physical characteristics of a rock including colour, texture, grain size and composition.
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Soil creep:** the slow gradual movement of rock or soil down a slope.
- **Incised valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.

CMU B6						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	X	x	x	x		
Beach Vegetation Protection	X	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	x	x	x	x		
Revetments	√	√	x	x	Can be quite effective; drainage from overtopping should be considered.	3
Sea Walls	√	√	x	√	Can be quite effective; drainage from overtopping should be considered.	2
Groynes	√	√	x	x	Only applicable if creating an artificial beach.	2
Land Reclamation	√	x	√	x	Would need to consider whether would encroach on any sensitive habitat such as seagrasses.	3
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Limited use in some low lying areas but mostly erosion risk in these areas.	2
Embankments	√	√	x	√	Could be used to reduce overtopping and the limited flood risk.	2
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	In particular agricultural practices can cause increases in suspended sediment in the water and cause degradation of coral reefs.	5
Set Back Zones	√	x	√	x	Set back zones and coastal zones should be calculated using erosion estimates.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT B7

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	Mangrove/Swamp	Fringing Reef



KEY FEATURES

- Shallow-gradient sloping, occasionally hummocky, lowland areas in Jamaica **(1)** that connect steep mountain ranges further inland to the coastline. Typically well-vegetated.
- Mangrove/swamp area between inland coastal plain and fringing reef **(2)**; water salinity varies from brackish to sea water. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas
- Development of a near-shore fringing reef system **(3)** sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(4)**. Fringing reef may extend further than 1.5km from shore in Jamaica.
- Seafloor falls to shelf depths beyond outer limit of fringing reef **(5).**

KEY PROCESSES

- Coastal slopes/foothills in Jamaica are affected by shallow slope movements and **soil creep**. Possible debris flows and **deeper seated slope movements**, particularly in locally over-steepened areas such as **incised valleys**.
- Ongoing inland **Karst** formation in extensive limestone areas: sinkholes, caves, hummocky hills, and formation of red **residual soils.**
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Mangrove swamps provide crucial natural defence against wind and waves. Roots of trees trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.
- Seagrasses and coral reefs can contribute to sand production where present.
- Fringing reefs provide natural protection to **erosion** and wave energies along the coastline.

KEY ISSUES

- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; system is particularly sensitive therefore to human activity.
- Mangrove swamp provides a crucial buffer to inland areas against wind and waves during storm events along exposed open coast, but may easily become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.
- Shallow fringing reef system provides **erosion** protection to Jamaican shoreline, but can easily be subject to inundation (e.g. from rising sea levels, tropical storm surges).

CASE STUDY

Image sourced from marinas.com

Just to the east of Discovery Bay on the north coast of Jamaica is a very low lying foothills which are set in front of steeper mountains. Along this length of coastline there is a mix of low rocky shores, beaches and mangrove sections.

In general, in areas with mangroves, the main coastal road is set back from the shoreline edge, as the mangroves occupy a larger space compared to other sections. However there also tends to be less seawall or other hard engineered structures and this probably partly to do with the natural protection and reduction in wave energies and therefore scour, overtopping and erosion of the hinterland.

Some areas of mangroves have clearly been removed for development, however it is important to maintain sections to increase the biodiversity and maintain some of the natural protection of the coastline.

COASTAL MANAGEMENT UNIT B7

HINTERLAND	SHORELINE	NEARSHORE
Coastal Slopes/ Foothills	**Mangrove/Swamp**	**Fringing Reef**

FUTURE CHANGES

Rapid Onset Hazards:

- Gently sloping surfaces of the coastal slope/foothill may promote more rapid run-off, especially over impermeable or saturated soil/bedrock, which may increase the likelihood of flooding during storm events in Jamaica.
- Storm surges can quickly inundate usually sheltered fringing reef systems in Jamaica. This can expose the shore/coastline to unusually large waves, where vastly increased wave energy along the shoreline may lead to rapid rates of **erosion** and quickly threaten coastline infrastructure.

Slow Onset Hazards:

- Gradual increase in sea level relative to fringing reefs induced by climate change. Coastline more exposed to typical wave conditions and increases vulnerability during larger storm events.
- Inland pollution, **ocean acidification**, overfishing, climate change and Jamaican coastal developments are all threats to the fringing reef system and therefore threats to the condition of the coastline's natural protection against erosion and shoreline retreat.

Human Development:

- Development on coastal slopes/foothills may lead to a more responsive hydraulic system during storm events, particularly if vegetation is removed through human development that would usually provide important interception and storage of rainfall.
- Steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.
- While coastal protection measures along the open coast may help to provide short-term defence for mangrove swamps, they may not be sustainable in the long-term and might result in more focussed **erosion** elsewhere or affect the mangrove ecosystems by changing the sediment budget and the ability of seawater to reach the swamps. Mangrove ecosystems are not necessarily able to adapt rapidly to sudden changes in their environment, with implications for the health of the system.
- The ecological condition of Jamaican reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of **erosion** with consequences for coastal communities and infrastructure.

Summary

- Having mangrove/swamp areas can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of mangroves. However, mangrove ecosystems are more likely to adapt and respond positively to climate change impacts (depending on human development in the hinterland).
- The fringing reefs are very important in providing erosion protection, as well as wider ecosystem benefits, however are extremely vulnerable to climate change and human development.
- Future climate change and human development are required to be assessed to ensure a suitable solution, particularly in consideration of how the fringing reef may function following further depletion of the system.

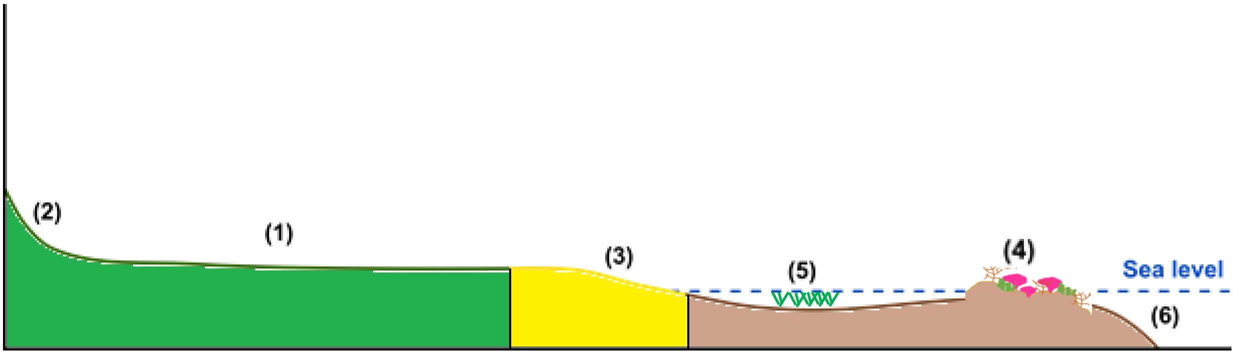
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Deep seated slope movement:** A slope failure that extends beyond near-surface superficial deposits, often with a circular slip surface.
- **Incised valley:** Occurs when a river has cut down into the bedrock creating a steep sided valley.
- **Karst:** A topography which has been formed through the dissolution of underlying soluble rocks by surface water or ground water (USGS, 2016).
- **Soil Creep**: The slow gradual movement of rock or soil down a slope.
- **Residual soils:** The sediments that remain following rock decay and removal of the soluble elements of the soil.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.

CMU B7						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C1

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Beach**	**Fringing Reef**



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas **(1)** separate the coastline from higher relief inland areas of Jamaica **(2).**
- High sinuosity meandering river channels, with abandoned channels, ox-bow lakes, and flood terraces.
- Shoreline partly protected from wave energy by beach **(3).**
- Development of a near-shore fringing reef system **(4)** sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(5)**. Fringing reef may extend further than 1.5km from shore.
- Seafloor falls to shelf depths beyond outer limit of fringing reef in Jamaica **(6).**

KEY PROCESSES

- Meandering fluvial systems likely to be actively migrating across fluvial/coastal plain.
- Deposition **of unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains
- Increasing depth of fringing reef exposes beach to waves, increasing potential **erosion** rates.
- Seagrasses and coral reefs can contribute to sand production where present.
- Fringing reefs can provide good natural protection along coastline to flooding and **erosion**.

KEY ISSUES

- Low-lying coastal plain may be subject to both fluvial and coastal flood events, or potentially of both during tropical storms.
- Fluvial deposits on the coastal plain are likely to be loose/soft unconsolidated sediments which can be poor foundation material for buildings.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Beaches and the protection they offer to the coastline are subject to temporal changes. Beach gradients become steeper during storm events. **Longshore sediment transport** along a beach is controlled by incident angle of incoming waves.
- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; systems particularly sensitive therefore to human activity.
- Shallow fringing reef system provides erosion protection to shoreline, but can easily be subject to inundation (e.g. from rising sea levels, tropical storm surges).

CASE STUDY

Negril's Long Bay Beach is a long stretch of sandy beach which had stimulated growth of the tourist industry in the area.

However, Negril has seen a huge amount of erosion over the last few decades. Work assessing the cause of erosion has suggested the following causes:

1. The primary source of sand for the Negril beach is as a result of coralline algae within the nearshore seagrass beds. Degradation of these seagrass beds has led to a reduction in the volumes of sand being supplied to the beach areas.

2. Over the past five (5) years, the actual volume of sand on the beach has reduced. To some degree, this erosion problem has been exacerbated by a series of damaging hurricanes and severe swell events.

3. There are believed to be several other factors that have contributed to the severity of the problem, such as the construction of seawalls and tourism-based infrastructure close to, or at, the water's edge.

COASTAL MANAGEMENT UNIT C1

HINTERLAND Coastal Plain	SHORELINE Beach	NEARSHORE Fringing Reef

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- Liquefaction of loose, near-saturated sandy soils during high magnitude seismic events.
- Storm surges can quickly inundate usually sheltered fringing reef systems. This can expose the shore/coastline to unusually large waves, where vastly increased wave energy along shoreline may lead to rapid rates of erosion and quickly threaten coastline infrastructure.
- Increased sea levels during storm surges can make the low-lying coastal plain areas more susceptible to flooding.

Slow Onset Hazards:

- Very gradual migration of non-engineered river channels across the flood plain.
- Frequency, magnitude and severity of fluvial flooding events on coastal plain may increase with climate change.
- Destruction of vegetation can make the beach more sensitive to erosion.
- Gradual increase in sea level relative to fringing reefs induced by climate change. Coastline more exposed to typical wave conditions and increases vulnerability to erosion during larger storm events. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.
- Inland pollution, ocean acidification, overfishing, climate change and Jamaican coastal developments all might threaten the fringing reef system and therefore the condition of the coastline's natural protection against erosion and retreat.

Human Development:

- Developments on coastal plains in Jamaica may lead to more rapid run-off which can increase the severity of flooding at the shoreline.
- Construction of coastal infrastructure or sea defences can lead to a disequilibrium scenario, for example with focussing of erosion elsewhere along the coast and alteration of sediment transport mechanisms.
- Planning for Jamaican communities should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to coastal recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- The ecological condition of fringing reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of retreat with consequences for coastal communities and infrastructure.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- The fringing coral reefs can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments including impacts on beach sediments and deterioration of coral reefs.

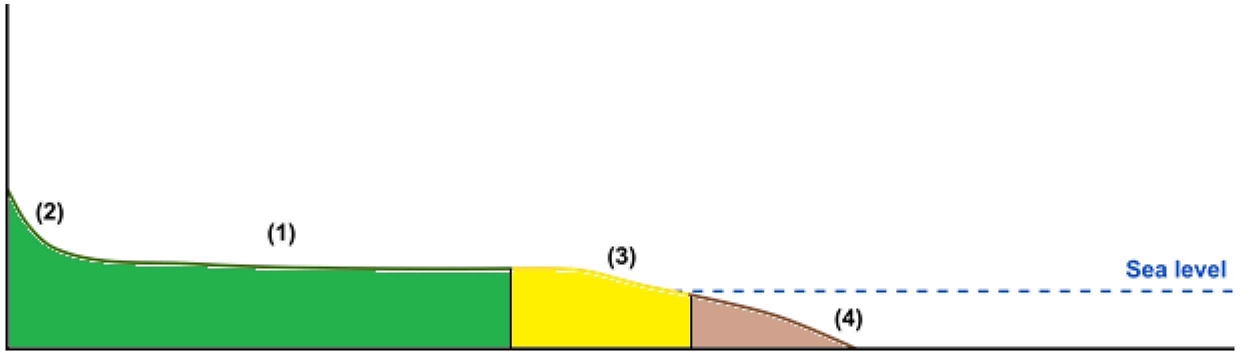
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

CMU C1						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide additional sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C2

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Beach	Open water



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2)**.
- High sinuosity meandering river channels, with abandoned channels, ox-bow lakes, flood terraces.
- Shoreline partly protected from incoming wave energy by beach **(3)**.
- Sea depth increases into open water beyond extent of beach **(4).**

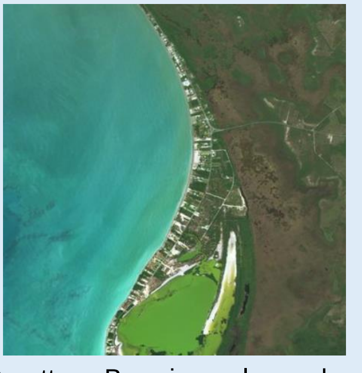
KEY PROCESSES

- Meandering fluvial systems likely to be actively migrating across fluvial/coastal plain.
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains.
- Beach changes through time in response to nature of incoming waves, e.g. angle of incidence, energy.

KEY ISSUES

- Low-lying coastal plain may be subject to both fluvial and coastal flood events in Jamaica, or potentially a combination of both during tropical storms, particularly to the east of the Island.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which is poor foundation material for infrastructure and buildings.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Beaches and the protection they offer to the coastline are subject to temporal changes. For example, beach gradients tend to become steeper during storm events, direction of **longshore sediment transport** along a beach is controlled by incident angle of incoming waves.
- Very little natural protection from incoming wave energy, beach can quickly **erode** and coastline may be subject to sudden and rapid retreat.

CASE STUDY



Parottee Bay is a large bay located south of Black River on Jamaica's south coast. Both private homes and hotel properties mean this area is used both by the community and by tourists.

The coastal plain behind the beach is characterised by wetlands. These are part of the southeastern reaches of the Black River that runs between Walla Wash Pond and the sea.

The community in this location have been experiencing increased issues of flooding, potentially partly as a result of the increased development the area has seen, but dominantly due to the vulnerability of this flat area from flooding both from the land and the coast.

Effective management in this location is required but will need to be integrated across both fluvial/surface water flooding and coastal flooding.

COASTAL MANAGEMENT UNIT C2

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Beach**	**Open water**

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Storm surges mean that waves break higher up the shore, meaning less of the incoming energy is absorbed by the beach. This can expose the upper shore/coastline to unusually large waves, where vastly increased wave energy along shoreline may lead to rapid rates of **erosion** and quickly threaten coastline infrastructure.
- Increased sea levels during storm surges can make the low-lying coastal plain areas more susceptible to coastal flooding.

Slow Onset Hazards:

- Very gradual migration of non-engineered river channels across the flood plain.
- Beaches will change over time in response to gradual changes in **longshore sediment transport**, for example due to changes in wave incidence angle.
- Destruction of vegetation can make the beach more sensitive to erosion.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline. Decreased ground permeability in developed areas may also mean flooding affects a wider area.
- Construction of coastal infrastructure or sea defences can lead to a disequilibrium scenario, for example with focussing of **erosion** elsewhere along the coast and alteration of sediment transport mechanisms and directions along beaches.
- Planning for Jamaican communities should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to coastal recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- Beaches positioned at an open coast can be exposed to higher wave energies and tend to have steeper slopes and coarser sediment.
- There are high future risks associated with the impacts of human development on these environments, particularly with the future risk of sea level rise which could decrease the beach width and increase the risk of flooding to the low lying, already vulnerable, hinterland.

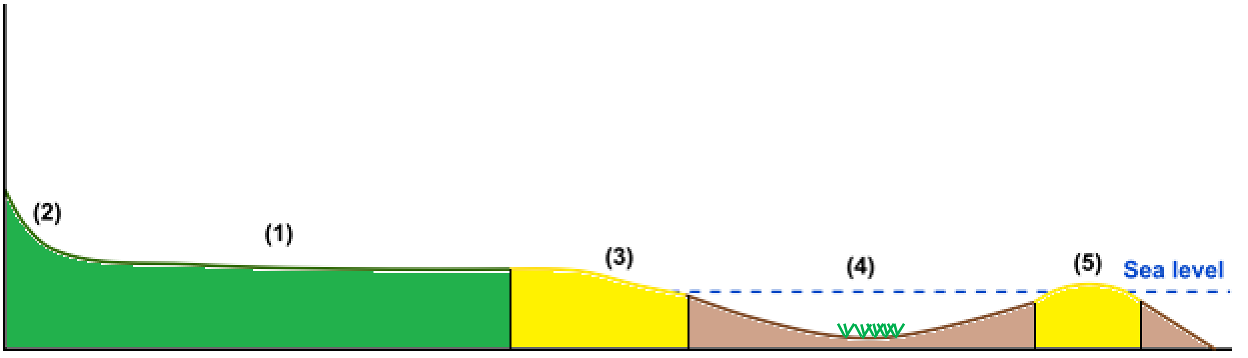
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

CMU C2						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Beach	Enclosed Water



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2).**
- Channelisation of rivers in the central Kingston area.
- High sinuosity meandering river channels, with abandoned channels, ox-bow lakes, flood terraces.
- Sheltered enclosed water area **(4)** (for example by a natural or man-made spit **(5)**) protects beach **(3)** from wave energy and may be likely to support seagrasses.
- Sea-front infrastructure often built up to enclosed water.

KEY PROCESSES

- Natural meandering fluvial systems likely to be actively migrating across fluvial/coastal plain.
- Channelised rivers in the Kingston area respond rapidly to high rainfall events.
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains.
- Beach changes through time in response to nature of incoming waves; e.g. angle of incidence, energy.
- Spit provides significant protection from incoming waves to the enclosed area of water and land behind it.
- Seagrasses can contribute to sand production where present.

KEY ISSUES

- Low-lying coastal plain may be subject to both fluvial and coastal flood events, or potentially a combination of both during tropical storms.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which can be poor foundation material.
- Beaches and the protection they offer to the coastline are subject to temporal changes. Direction of **longshore sediment transport** along a beach controlled by incident angle of incoming waves.
- Geometry of spits are likely to change through time in response to wave patterns; this will ultimately control the amount of protection offered to enclosed water bodies.

CASE STUDY

Port Morant is located at the head of enclosed water called Bowden Bay, in the south-east section of the Island.

Historically used as a commercial harbour, it is only privately used now although the Coast Guard still have a base here.

The enclosed area of Bowden Bay is very shallow and protected. There is a government-run oyster programme in the Bowden Bay area whereby oyster harvesters supply oysters to local hotels and other businesses.

At the head of Bowden Bay is located the mouth of the Beating River and an area of flat land which allows for more agriculture in this area.

COASTAL MANAGEMENT UNIT C3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Beach**	**Enclosed Water**

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Particularly rapid responses are likely in channelised river sections in central Kingston. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Storm surges mean that waves break higher up the shore, meaning less of the incoming energy is absorbed by the beach. This can expose the shoreline to unusually large waves, and may lead to rapid rates of **erosion**. Storm surges and storm waves are further likely to affect the ability of spits to protect enclosed water bodies and the coastal infrastructure behind them.
- Increased sea levels during storm surges can make the low-lying coastal plain areas more susceptible to coastal flooding.

Slow Onset Hazards:

- Very gradual migration of non-engineered river channels across the flood plain.
- Beaches will change over time in response to gradual changes in **longshore sediment transport**, for example due to changes in wave incidence angle. Similarly, the extent of spits protecting enclosed waters will also evolve through time in response to similar factors.
- Destruction of vegetation in Jamaica can make beaches/spits more sensitive to **erosion**.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline.
- Construction of coastal infrastructure or sea defences can lead to a disequilibrium scenario, for example with focussing of erosion elsewhere along the coast and alteration of **longshore sediment transport** mechanisms and directions along beaches.
- Planning for coastal communities should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to coastal recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- Removal of seagrass meadows can increase the vulnerability of the coastline and decrease the wider ecosystem benefits achieved in these areas.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- Beaches positioned in enclosed waters tend to be better protected from erosion and often have seagrass meadows featured which can further reduce erosion at the shoreline and increase the biodiversity in the area.
- Certain designs of coastal defences, or removal of seagrass meadows, can both increase the **erosion** risk in certain areas of the shoreline.
- Sea level rise may start to reduce the amount of coastline which is enclosed as spits/barriers may be engulfed by the water level.

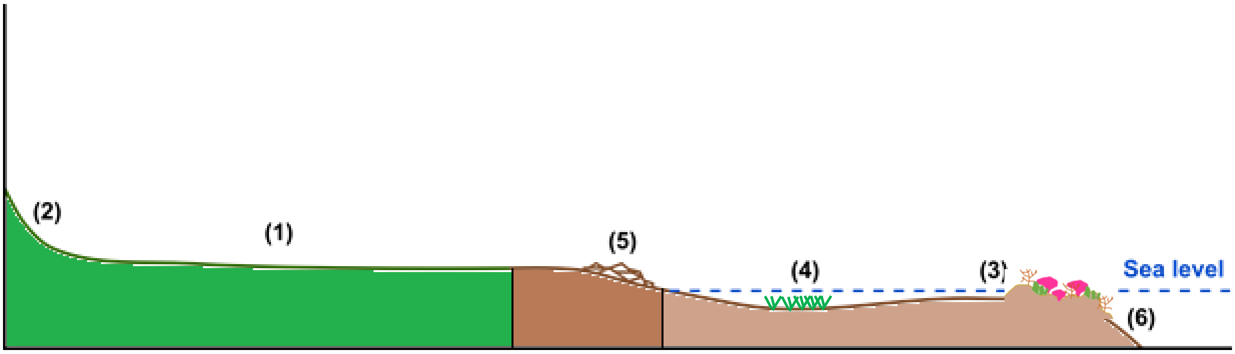
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Unconsolidated sediments are loose materials and grains through which water can flow.
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

CMU C3						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Rocky Shore	Fringing Reef



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2).**
- Development of a near-shore fringing reef system **(3)** sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(4)**. Fringing reef may extend further than 1.5km from shore.
- Rock exposed along shoreline or fringing reef continues up to top of shore **(5).**
- Seafloor falls to shelf depths beyond outer limit of fringing reef **(6).**

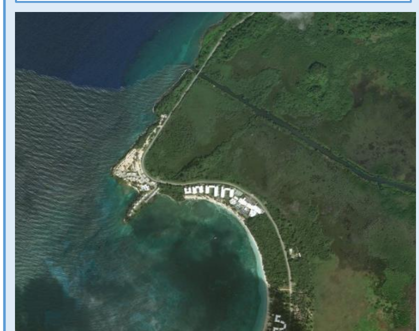
KEY PROCESSES

- Natural meandering fluvial systems likely to be actively migrating across fluvial/coastal plain
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains
- Increasing depth of fringing reef exposes rocky shore to waves, increasing potential **erosion** rates. This may be caused by coral removal or due to higher relative sea levels (e.g. during storm surges)
- Sensitivity of rocky shore to **erosion** closely linked to its geology (such as structural features and lithology)
- Seagrasses and coral reefs can contribute to sand production where present.
- Fringing reefs can provide good natural protection along coastline to wave energies

KEY ISSUES

- Low-lying coastal plain may be subject to both fluvial and coastal flood events.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which can be poor foundation material.
- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; reefs sensitive therefore to human activity.
- Shallow fringing reef system provides **erosion** protection to shoreline, but can easily be subject to inundation.
- Rocky shore does not provide significant **erosion** or flood protection.

CASE STUDY



Negril is characterised by Long Bay Beach, however north of Negril, towards Lucea, features a section of the coastal plain that Negril is located on, but with a more rocky shoreline.

This has likely been formed due to the changes in shoreline orientation and therefore sediment supply. The Norman Manley Boulevard runs adjacent to the coastline along this section.

Although the offshore reefs and seagrasses present here will provide some protection to incoming wave energies, with the erosion problems that have been evident at Long Bay Beach further south, erosion is likely to pose a risk in the future to the main road and set-back requirements for assets and developments need to be carefully considered.

COASTAL MANAGEMENT UNIT C4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Rocky Shore**	**Fringing Reef**

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Increased sea levels during storm surges can make the low-lying coastal plain areas more susceptible to coastal flooding, particular in areas with a rock shore which offers less protection to the shoreline compared to a beach.
- Storm surges can quickly inundate usually sheltered fringing reef systems. This can expose the shore/coastline to unusually large waves, where vastly increased wave energy along shoreline may lead to rapid rates of erosion and quickly threaten coastline infrastructure.

Slow Onset Hazards:

- Gradual increase in sea level in Jamaica induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level. Increase in sea level relative to fringing reef will mean that coastline is more exposed to typical wave conditions and also increases vulnerability to **erosion** during larger storm events.
- Inland pollution, **ocean acidification**, overfishing, climate change and coastal developments all might threaten the fringing reef system and therefore the condition of the coastline's natural protection against **erosion** and retreat.
- Rocky shore is subject to an ongoing process of **erosion**; gradual retreat without intervention is a general hazard to coastline property and infrastructure. A rocky shore has limited ability to adapt to sea level rise.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline. Decreased ground permeability in developed areas may also mean flooding affects a wider area.
- Planning for coastal communities around rocky shores should be carefully considered. Developments, highways, and other infrastructure near the coastline can become vulnerable to recession and then require reactive measures for protection, or lead to loss of valuable assets, or require significant adaptation and re-location of communities or infrastructure.
- The ecological condition of fringing reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of retreat with consequences for coastal communities and infrastructure.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- The fringing coral reefs can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- However rocky coastlines tend to provide less protection to the hinterland from flooding compared to beaches.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of coral reefs.

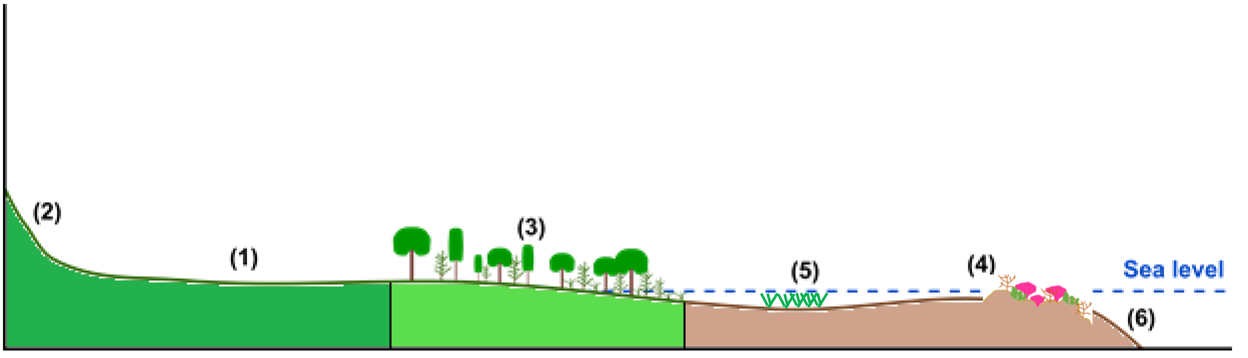
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.

CMU C4						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	√	√	x	√	Would likely need hybrid approach with a hard intervention such as a breakwater or groynes to reduce sediment loss.	2
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide additional sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Only applicable if creating an artificial beach.	2
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly seagrasses and coral reefs.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes used to ensure resilient infrastructure is built appropriately n vulnerable areas .	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C5

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Mangrove/Swamp	Fringing Reef



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2).**
- Mangrove/swamp area between inland coastal plain and fringing reef **(3)**; water salinity varies from brackish to concentrated relative to normal seawater. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas.
- Development of a near-shore fringing reef system **(4)** sometimes separated from the shore by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(5)**.
- Seafloor falls to shelf depths beyond limit of fringing reef **(6).**

KEY PROCESSES

- Natural meandering fluvial systems likely to be actively migrating across fluvial/coastal plain.
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Increased depth of water on fringing reef increases potential **erosion** rates. This may be caused by coral removal or due to higher relative sea levels (e.g. during storm surges).
- Mangrove swamps provide crucial natural defence against wind and waves, particularly during tropical storms. Roots of trees also trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.
- Seagrasses and coral reefs can contribute to sand production where present.

KEY ISSUES

- Low-lying coastal plain and mangrove swamp may be subject to both flood events, or potentially a combination of both during tropical storms.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which can provide poor foundation material. Near-saturated sandy deposits may also experience **liquefaction** during high magnitude seismic events.
- No deep intervening lagoon between reef and coast to buffer runoff, pollution, sedimentation etc.; systems particularly sensitive therefore to human activity.
- Shallow fringing reef system and mangrove swamp provides a crucial buffer against wind and waves during storm events, but may become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.

CASE STUDY

‘Portland Bight’ refers to the body of water between Portland Ridge and Hellshire Hills. The Portland Bight is located on the southern coast of Jamaica falls within the Portland Bight Protected Area (PBPA), which is the largest protected area in Jamaica.

In addition to several healthy mangrove forests and salt marshes, particularly along the Salt Island Creek (shown below), the area also features 3 fish sanctuaries and is seen as highly beneficial to the south coast population for this reason. The Old Harbour Bay fishing community is the site of one of the south coast’s largest fish markets. The seafloor around the Goat Islands features large areas of sea grass. Further it is reported that the Portland Bight is home to numerous endemic reptiles and amphibians.

Conservation of this area and management through nature-based techniques is crucial to maintain the ecological importance of the area.

COASTAL MANAGEMENT UNIT C5

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Mangrove/Swamp**	**Fringing Reef**

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Increased sea levels during storm surges can make the areas more susceptible to flooding.
- Storm surges can quickly inundate usually sheltered fringing reef systems. This can expose the shoreline to unusually large waves, where vastly increased wave energy along shorelines may lead to rapid rates of **erosion** and quickly threaten coastline infrastructure.
- Frequency, magnitude and severity of fluvial flooding events may increase with climate change.

Slow Onset Hazards:

- Very gradual migration of non-engineered river channels across the flood plain.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level. Increase in sea level relative to fringing reef will mean that coastline is more exposed to typical wave conditions and also increases vulnerability to **erosion** during larger storm events.
- Inland pollution, **ocean acidification**, overfishing, climate change and coastal developments all might threaten the fringing reef system and fauna in mangrove swamps and therefore the condition of the coastline's natural protection against erosion. Mangrove ecosystems are sensitive to changes in the sediment budget, which may be induced by river channel engineering.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline. Similarly, while fluvial engineering can reduce the extent of flooding, channelisation and decreasing river sinuosity can also increase flood severity and have impacts on the ecology of coastal plain fauna and flora, particularly in mangrove swamps.
- The ecological condition of fringing reefs should be monitored closely, particularly on coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or disease.
- Steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.

Summary

- Coastal plains tend to consist of low lying land which is at risk from flooding.
- Having both mangrove/swamp areas and a fringing coral reef can provide increased protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of coral reefs and mangroves. However this environment is more likely to adapt and respond positively to climate change.

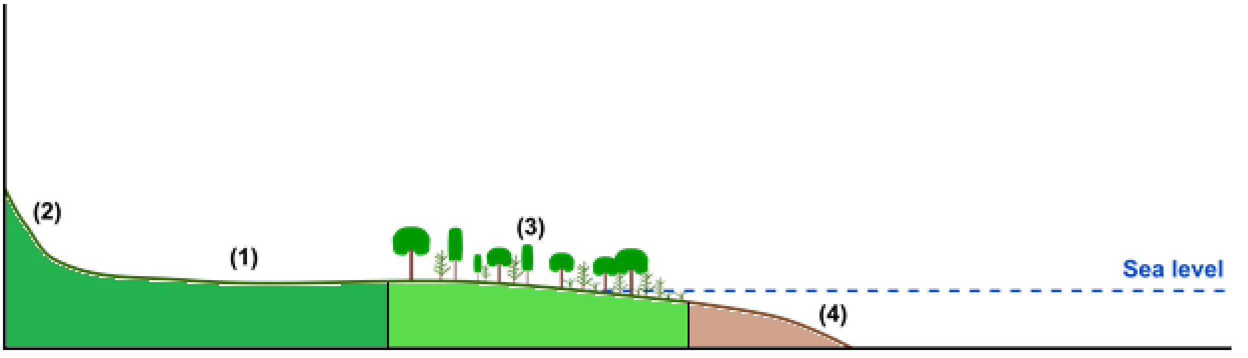
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.

CMU C5						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C6

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Mangrove/Swamp	Open Coast



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2).**
- Mangrove/swamp area between inland coastal plain and fringing reef **(3)**; water salinity varies from brackish to sea water. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas
- Seafloor falls to shelf depths beyond furthest extent of coastline/mangrove swamp **(4).**

KEY PROCESSES

- Natural meandering fluvial systems likely to be actively migrating across fluvial/coastal plain.
- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Mangrove swamps provide crucial natural defence- especially for areas of exposed open coast- against wind and waves. Roots of trees trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.

KEY ISSUES

- Low-lying coastal plain and mangrove swamp may be subject to both fluvial and coastal flood events.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which is often poor foundation material. Near-saturated sandy deposits may also experience **liquefaction** during high magnitude seismic events.
- Mangrove swamp provides a crucial buffer to inland areas against wind and waves during storm events along exposed open coast, but may easily become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.

CASE STUDY

The Black River is one of the longest rivers in Jamaica, at 33 miles, and is located in the parishes of Manchester and St Elizabeth.

The river is known for the dense vegetation that surrounds it and the humid mangrove swamps. The sediment in the river is very dark due to the high organic content.

Prior to reaching the sea, the river flows through the Great Morass and therefore the influence of vegetation, both wetlands on the coastal plain and the mangroves, heavily influences the processes and ecosystems here.

Source: jamaicablackriver..com

COASTAL MANAGEMENT UNIT C6

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	**Mangrove/Swamp**	**Open Coast**

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Increased sea levels during storm surges can make the low-lying coastal plain areas and mangrove swamps more susceptible to coastal flooding.
- No protection from open sea at coastline meaning the majority of wave energy is dissipated here and shoreline may be subject to sudden retreat events during storms.

Slow Onset Hazards:

- Frequency, magnitude and severity of fluvial flooding events on coastal plain may increase with climate change. This may lead to a positive feedback loop by damaging mangrove trees, reducing their capacity to provide a buffer at the coast for storm winds and waves.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.
- Inland pollution and coastal developments might threaten the fauna in mangrove swamps and therefore the condition of the coastline's natural protection against **erosion** and retreat. Mangrove ecosystems are also sensitive to changes in the sediment budget, which may be induced by factors such as changes to flood return period and river channel engineering.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline. Similarly, while fluvial engineering can reduce the extent of flooding, channelisation and decreasing river sinuosity can also increase flood severity and have impacts on the ecology of coastal plain fauna and flora, particularly in mangrove swamps.
- Furthermore, steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.
- While coastal protection measures along the open coast may help to provide short-term defence for mangrove swamps, they may not be sustainable in the long-term and might result in more focussed **erosion** elsewhere or affect the mangrove ecosystems by changing the sediment budget and the ability of seawater to reach the swamps. Furthermore, mangrove ecosystems are not necessarily able to adapt rapidly to sudden changes in their environment, with implications for the health of the system.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- Having mangrove/swamp areas can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of mangroves. However, mangrove ecosystems are more likely to adapt and respond positively to climate change impacts (depending on human development in the hinterland).

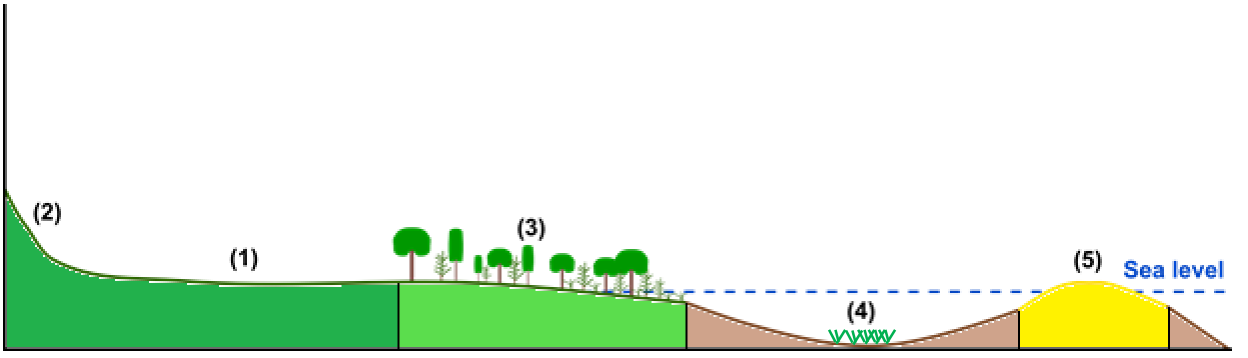
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.

CMU C6						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	X	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT C7

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Mangrove/Swamp	Enclosed Water



KEY FEATURES

- Large (10s-100s km^2), flat, low-lying areas in Jamaica **(1)** separate the coastline from higher relief inland areas **(2).**
- Mangrove/swamp area between inland coastal plain and fringing reef **(3)**; water salinity varies from brackish to seawater. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas.
- Sheltered enclosed water area **(4)** (for example by a natural or man-made spit **(5)**) protects shore from wave energy and may be likely to support seagrasses.
- Sea-front infrastructure often built up to enclosed water.

KEY PROCESSES

- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Mangrove swamps provide crucial natural against wind and waves, particularly during tropical storms. Roots of trees also trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.
- Spit provides significant protection from incoming waves to the enclosed area of water and land behind it.
- Seagrasses can contribute to sand production where present.

KEY ISSUES

- Low-lying coastal plain and mangrove swamp may be subject to both fluvial and coastal flood events.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments**; these provide poor foundation material. Near-saturated sandy deposits may also experience **liquefaction** during high magnitude seismic events.
- Mangrove swamps and enclosed waters provide a crucial buffer to inland areas against wind and waves during storm events, but may easily become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.
- Geometry of spits are likely to change through time in response to wave patterns; this will ultimately control the amount of protection offered to enclosed water bodies and the mangrove swamps along the coast.

CASE STUDY

Source: NEPA (2013)

The Portland Bight Protected Area is the island's largest protected area and has a number of enclosed water areas which are characterised by mangroves and seagrass.

Due to the importance of the mangroves in this area for ecosystem health and coastal resilience, this area was selected as the targeted restoration site for mangrove restoration and planting as part of the GOJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction Project in 2012.

5.04 ha of a degraded mangrove Restorative activities began in April 2012 and were completed in August 2012. This was enhanced by planting 4,920 red and black mangrove seedlings that were common to the area prior to the forest being disturbed.

COASTAL MANAGEMENT UNIT C7

HINTERLAND	SHORELINE	NEARSHORE
Coastal Plain	Mangrove/Swamp	Enclosed Water

FUTURE CHANGES

Rapid Onset Hazards:

- High intensity rainfall events in Jamaica can quickly lead to increased discharge and subsequent flooding of the coastal plains. Permeable bedrock in limestone areas may help to reduce this effect by allowing rapid transfer of surface water to groundwater.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Storm surges and storm waves likely to affect the ability of spits to protect enclosed water bodies and the mangrove swamps/coastal infrastructure behind them.

Slow Onset Hazards:

- Frequency, magnitude and severity of fluvial flooding events on coastal plain may increase with climate change in Jamaica. This may lead to a positive feedback loop by damaging mangrove trees, reducing their capacity to provide a buffer at the coast for storm winds and waves.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.
- The extent of spits protecting enclosed waters will evolve through time in response to factors such as wave incidence angle and the direction/quantity of sediment transport.
- Destruction of vegetation can make spits that protect enclosed waters more sensitive to **erosion**.

Human Development:

- Jamaican developments on coastal plains may lead to more rapid run-off which can increase the severity of flooding at the shoreline. Decreased ground permeability in developed areas may also mean flooding affects a wider area.
- Steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.
- Mangrove ecosystems are not necessarily able to adapt rapidly to sudden changes in their environment, with implications for the health of the system and therefore their ability to provide effective coastal protection.

Summary

- Coastal plains tend to consist of low lying land which is at risk from fluvial and coastal flooding.
- Having mangrove/swamp areas can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- Mangrove swamps situated next to enclosed waters will be more protected from storms and wave energies.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of mangroves. However, mangrove ecosystems are more likely to adapt and respond positively to climate change impacts (depending on human development in the hinterland).

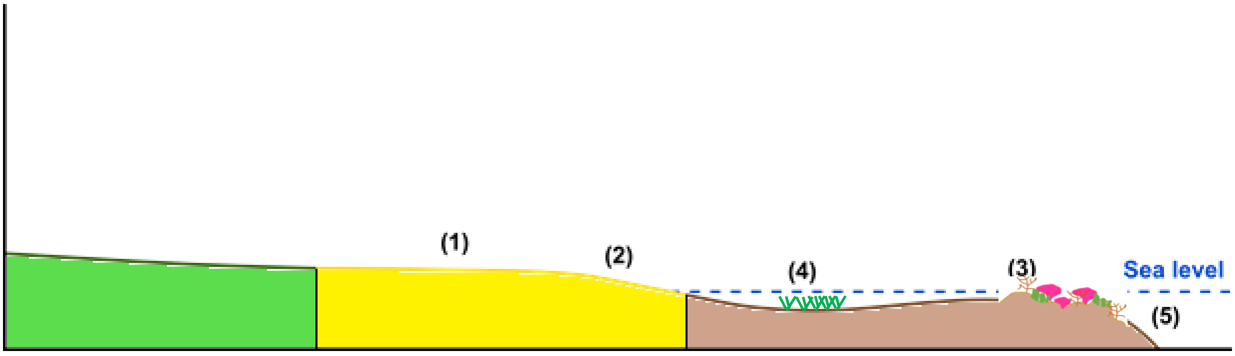
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.

CMU C7						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT D1

HINTERLAND **Coastal Fan** | SHORELINE **Beach** | NEARSHORE **Fringing Reef**



KEY FEATURES

- Coastal fans are typically flat areas located landwards of the shoreline where rivers enter the sea **(1)**. The coastal fans comprise poorly sorted sedimentary deposits in Jamaica.
- Beaches **(2)** comprise sloping ground composed of sand or gravel in varying amounts depending on the wave energies.
- Fringing reefs grow near the coastline **(3)**, and are separated from the shore by narrow, shallow lagoons which may be likely to support seagrasses **(4)**. The depth of the sea typically falls to shelf depths beyond the furthest extent of the fringing reef **(5)**.

KEY PROCESSES

- Catchment characteristics (drainage area, relief, and geology) control supply of water and sediment and influence the morphology. Generally, the supply area of sediment for the south coast is greater than the north due to larger catchments.
- **Erosion** on the beaches at the shoreline of coastal fans can cause fan profile shortening and steepening which may trigger **erosion** on the coastal fans.
- White sand beaches can be found along the north coast of Jamaica comprising sediments eroded from the offshore coral reefs. The beaches located on the south typically comprise black sand supplied by river sediments.
- Seagrasses and coral reefs can contribute to sand production where present. Fringing reefs act as a buffer against wave action, storms and hurricanes.

KEY ISSUES

- Flooding of coastal fans during extreme storms. Due to the topography, peak flows resulting from storms are difficult to contain as they generally tend to spread widely.
- A rise in sea level can result in **erosion** of the coastal fan at a distance from the coastline. This may have implications for the stability of slopes within the river valley from which the coastal fan emerges.
- Natural and man-made factors which influence the **erosion** of the beaches may cause the beaches to shrink and disappear.
- Damage to the fringing reefs as a result of natural (hurricane damage; increase in temperature; siltation and excess nutrients) and man-made influences (loss of herbivores through over-fishing, sewage pollution) reduced the overall resilience of the system.

CASE STUDY

The beach at St. Margaret's Bay is bordered by the Caribbean Sea to the north, the Rio Grande to the east, the main road to the south and the bluff to the west.

The entire bay is approximately 1.5km long. The width of the beach varies along its length, starting at 8m – 10m at the south-easterly end through a mid-range of 18m - 20m in the middle and ending at an approximate beach width of 25m in the northwest. The entire area of the beach is roughly 3 hectares.

There are small patches of sea grass beds about 7m offshore, the patches are not consistent but appear at various points along the entire bay. Historically there has been some erosion evident on St. Margaret's bay beach.

It is presumed that due to its exposed alignment and lack of protective reef, steady wave action on the beach would cause erosion. It is clear also that hurricanes impact the beach, and several trees have exposed roots and several areas along the beach have erosion scarps.

COASTAL MANAGEMENT UNIT D1

Coastal Fan	Beach	Fringing Reef

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes (particularly for the east of the Island) can provide high magnitude rainfall, which can result in flooding and **debris flow** activity within the low lying coastal fan areas.
- **Erosion** of beaches may also occur during hurricanes and storm event. Usually following storm events a beach may recover and accrete back to the previous slope however if there are a number of storm events in a row this may reduce the ability of the beach to recover.

Slow Onset Hazards:

- Beaches in Jamaica are vulnerable to sea-level rise. An increase in wave action, tides and currents may change beach **erosion** patterns.
- Coastal fan morphology as well as sedimentary styles may be influenced by climate change.
- Climate change is expected to cause a significant impact to coral (fringing) reefs due to their sensitivity to temperature changes. Coral (fringing) reefs are vulnerable to sea-level rise.
- Inland pollution, **ocean acidification**, overfishing, climate change and coastal developments all might threaten the fringing reef system and therefore the condition of the coastline's natural protection against erosion and retreat.

Human Development:

- Coastal fans and beaches Jamaica may be susceptible to polluted surface water run-off from land based sources.
- Increasing demands in Jamaica for land along the coast for housing construction will encroach on beach areas.
- An increase in agricultural activities, and poor agricultural practices has led to an increase in soil erosion. Near the mouths of rivers, sedimentation is damaging nearby reefs.

Summary

- Coastal fans are very low lying land and very susceptible to flooding.
- Beaches and fringing reefs both provide protection to wave energies and therefore flooding and **erosion** of the coastal fan.
- However, both beaches and fringing reefs can be damaged by frequent storms which can reduce the resilience of the hinterland to flooding and erosion.
- One of the largest threats is the impact of human development and climate change on the health of the reef systems and beaches.

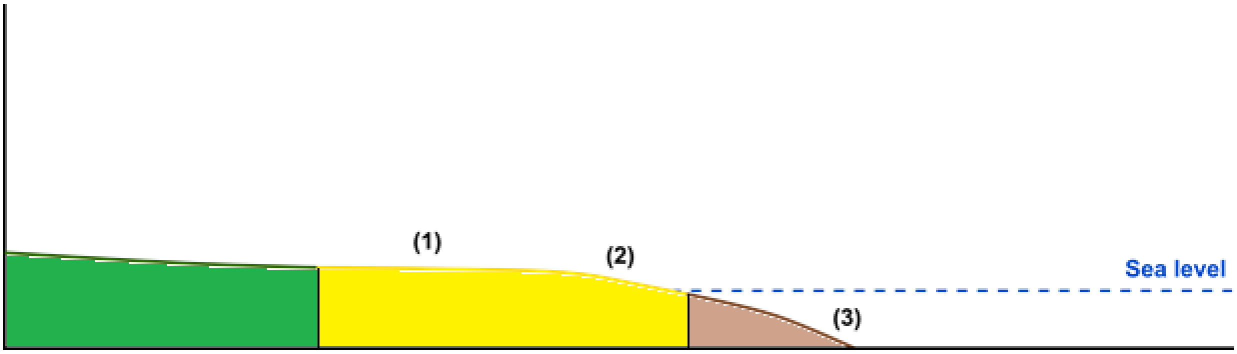
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.
- **Debris Flow:** Sediment becomes water logged and starts to flow downhill as a mass.

CMU D1						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide additional sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT D2

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	**Beach**	**Open Coast**



KEY FEATURES

- Coastal fans are typically flat areas located landwards of the shoreline where rivers enter the sea **(1)**. The coastal fans comprise poorly sorted sedimentary deposits in Jamaica.
- Beaches **(2)** comprise sloping ground composed of sand or gravel in varying amounts depending on the wave energy at these locations.
- The sea level typically falls to shelf depths beyond the beach **(3)**.
- Larger areas of shallow seas covering landscapes can be found in the south (due to subsidence in the south) whilst deep seas can be found to the north.

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KEY PROCESSES

- Catchment characteristics (drainage area, relief, and geology) control supply of water and sediment and influence the morphology. Generally, the supply area of sediment for the south coast is greater than the north due to larger catchments.
- **Erosion** on the beaches at the shoreline of coastal fans can cause fan profile shortening and steepening which may trigger **erosion** on the coastal fans.
- White sand beaches can be found along the north coast of Jamaica comprising sediments eroded from the offshore coral reefs. The beaches located on the south typically comprise black sand supplied by river sediments.

KEY ISSUES

- Flooding of coastal fans during extreme storms. Due to the topography, peak flows resulting from storms are difficult to contain as they generally tend to spread widely.
- A rise in sea level can result in **erosion** of the coastal fan at a distance from the coastline. This may have implications for the stability of slopes within the river valley from which the coastal fan emerges.
- Natural and man-made factors which influence the **erosion** of the beaches may cause the beaches to shrink and disappear.
- Damage to the fringing reefs as a result of natural (hurricane damage; increase in temperature; siltation and excess nutrients) and man-made influences (loss of herbivores through over-fishing, sewage pollution) reduced the overall resilience of the system.

CASE STUDY

Alligator Pond is a fishing community on the south coast of Manchester, the main beach there is located along the Alligator Pond main road (close to the border with St. Elizabeth).

The beach has suffered damage with the passing of hurricanes. With each storm more sand has been washed out and community members have noticed a significant decrease in beach width over the years. However, they tend to link the beach erosion to storm activity and not persistent wave action on the beach, which they say is typically low energy.

All along the beach are sand dunes, which appear to be the only environmental feature of note on the beach. In some cases, the dunes are stable and vegetated, however in some instances, the brush has been cleared and the health and stability of the dunes is questionable.

COASTAL MANAGEMENT UNIT D1

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	Beach	Open Coast

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes (particularly for the east of the Island) can provide high magnitude rainfall, which can result in flooding and **debris flow** activity within the low lying coastal fan areas.
- **Erosion** of beaches may also occur during hurricanes and storm event. Usually following storm events a beach may recover and accrete back to the previous slope however if there are a number of storm events in a row this may reduce the ability of the beach to recover.

Slow Onset Hazards:

- Beaches are vulnerable to sea-level rise in Jamaica. An increase in wave action, tides and currents may change beach **erosion** patterns.
- Coastal fan morphology as well as sedimentary styles may be influenced by climate change.

Human Development:

- Coastal fans and beaches in Jamaica may be susceptible to polluted surface water run-off from land based sources.
- Increasing demands for land along the coast for housing construction will encroach on beach areas.
- An increase in agricultural activities, and poor agricultural practices in Jamaica has led to an increase in soil erosion.

Summary

- Coastal fans are very low lying land and very susceptible to flooding.
- On areas of open coast, the beaches will likely be subject to larger wave energies.
- Beaches provide protection to wave energies and therefore flooding and **erosion** of the coastal fan.
- However, beaches can be damaged by frequent storms which can reduce the resilience of the hinterland to flooding and erosion.

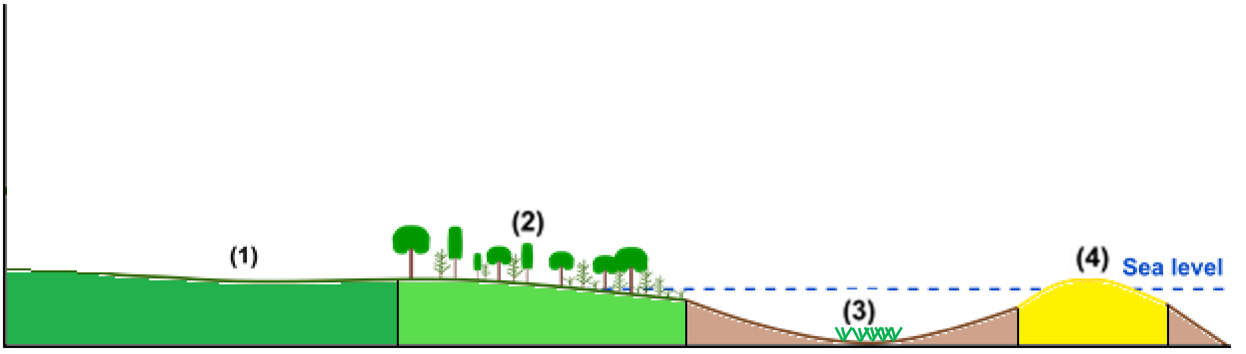
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.
- **Debris Flow:** Sediment becomes water logged and starts to flow downhill as a mass.

CMU D2						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	X	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	X	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	X	x	x	x		
Mangrove Restoration and Rehabilitation	X	x	x	x		
Sea Grass Restoration and Rehabilitation	X	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT D3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	Mangrove/Swamp	Enclosed Water



KEY FEATURES

- Coastal fans are typically flat areas located landwards of the shoreline where rivers enter the sea **(1).** The coastal fans comprise poorly sorted sediment deposits.
- Mangrove/swamp area between inland coastal plain and fringing reef **(2)**; water salinity varies from brackish to seawater. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas.
- Mangrove swamps provide good natural protection along coastline
- Sheltered enclosed water area **(3)** (for example by a natural or man-made spit **(4)** protects shore from wave energy and may be likely to support seagrasses

KEY PROCESSES

- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Mangrove swamps provide crucial natural against wind and waves, particularly during tropical storms. Roots of trees also trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.
- Spit provides significant protection from incoming waves to the enclosed area of water and land behind it.
- Seagrasses can contribute to sand production where present.
- Sea-front infrastructure often built up to enclosed water.

KEY ISSUES

- Flooding of coastal fans during extreme storms. Due to the topography, peak flows resulting from storms are difficult to contain as they generally tend to spread widely.
- A rise in sea level can result in **erosion** of the coastal fan at a distance from the coastline. This may have implications for the stability of slopes within the river valley from which the coastal fan emerges.
- Low-lying coastal fan and mangrove swamp may be subject to both fluvial and coastal flood events.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments**; these provide poor foundation material. Near-saturated sandy deposits may also experience **liquefaction** during high magnitude seismic events.
- Mangrove swamps and enclosed waters provide a crucial buffer to inland areas against wind and waves during storm events, but may easily become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.
- Geometry of spits are likely to change through time in response to wave patterns; this will ultimately control the amount of protection offered to enclosed water bodies and the mangrove swamps along the coast.

CASE STUDY

The mid and south sections of Montego Bay are lined with mangroves along the shoreline. The coastal slopes fall to the shore which is protected from high wave energies by offshore fringing reefs.

The mangroves will provide important protection from high energy storm events to the town of Montego Bay as their root systems act to dampen the wave energies.

Although in the north section of Montego Bay there have been a number of coastal management interventions, in the area by the mangroves (to the south and west of Montego Bay) there is little need for coastal intervention structures.

COASTAL MANAGEMENT UNIT D3

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	Mangrove/Swamp	Enclosed Water

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes (particularly for the east of the Island) can provide high magnitude rainfall, which can result in flooding and **debris flow** activity within the low lying coastal fan areas.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Storm surges and storm waves likely to affect the ability of spits to protect enclosed water bodies and the mangrove swamps/coastal infrastructure behind them.

Slow Onset Hazards:

- Coastal fan morphology as well as sedimentary styles may be influenced by climate change.
- The extent of spits protecting enclosed waters will evolve through time in response to factors such as wave incidence angle and the direction/quantity of sediment transport.
- Destruction of vegetation can make spits that protect enclosed waters more sensitive to **erosion**.

Human Development:

- Coastal fans and beaches Jamaica may be susceptible to polluted surface water run-off from land based sources.
- Steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.
- Mangrove ecosystems are not necessarily able to adapt rapidly to sudden changes in their environment, with implications for the health of the system and therefore their ability to provide effective coastal protection.

Summary

- Coastal fans are very low lying land and very susceptible to flooding
- Having mangrove/swamp areas can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- Mangrove swamps situated next to enclosed waters will be more protected from storms and wave energies.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of mangroves. However, mangrove ecosystems are more likely to adapt and respond positively to climate change impacts (depending on human development in the hinterland).

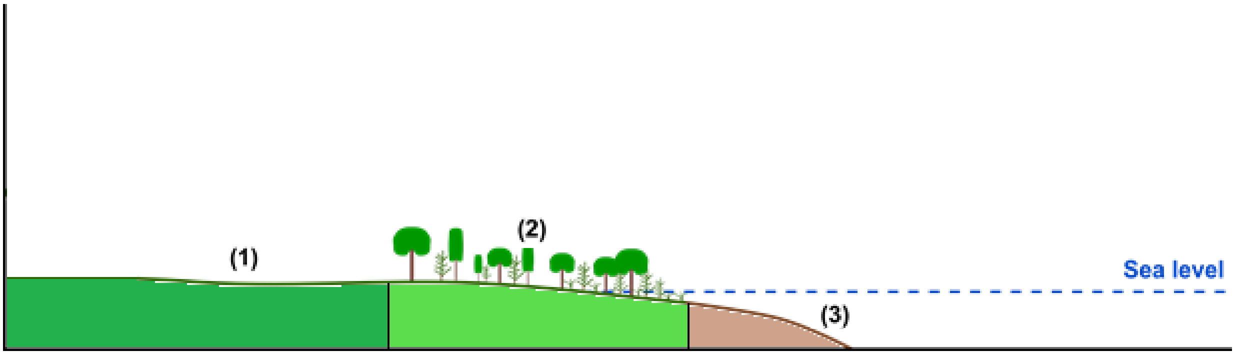
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Unconsolidated Sediment:** Loose materials and grains through which water can flow.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.
- **Debris Flow**: Sediment becomes water logged and starts to flow downhill as a mass.

CMU D3						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	x	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT D4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	Mangrove/Swamp	Open Coast



KEY FEATURES

- Coastal fans are typically flat areas located landwards of the shoreline where rivers enter the sea **(1).** The coastal fans comprise poorly sorted sediment deposits.
- Mangrove/swamp area between inland coastal plain and fringing reef **(2)**; water salinity varies from brackish to sea water. Form in areas that experience net deposition of fine grained typically organic sediments. Mangrove swamps also frequently cover large areas inland from coast.
- **Halophytic flora** grow in calm mangrove swamp areas
- Seafloor falls to shelf depths beyond furthest extent of coastline/mangrove swamp **(3).**

KEY PROCESSES

- Deposition of **unconsolidated alluvial sediment** from actively **eroding** upland areas inland on extensive flood plains and mangrove swamps.
- Mangrove swamps provide crucial natural defence- especially for areas of exposed open coast- against wind and waves. Roots of trees trap sediment and stabilise the shoreline to help reduce the effects of coastal **erosion**.

KEY ISSUES

- Flooding of coastal fans during extreme storms. Due to the topography, peak flows resulting from storms are difficult to contain as they generally tend to spread widely.
- A rise in sea level can result in **erosion** of the coastal fan at a distance from the coastline. This may have implications for the stability of slopes within the river valley from which the coastal fan emerges.
- Low-lying coastal fan and mangrove swamp may be subject to both fluvial and coastal flood events.
- High groundwater levels in low-lying areas, particularly if frequently flooded.
- Fluvial deposits on the coastal plain are likely to be loose/soft **unconsolidated sediments** which is often poor foundation material. Near-saturated sandy deposits may also experience **liquefaction** during high magnitude seismic events.
- Mangrove swamp provides a crucial buffer to inland areas against wind and waves during storm events along exposed open coast, but may easily become subject to inundation (particularly with rising sea levels).
- Storm events and human activity may damage the natural buffer provided by mangrove swamps, potentially compromising its ability to provide effective coastal protection.

CASE STUDY

The Milk River is located on the south coast of Jamaica, between Alligator Pond and Rocky Point.

Although the Milk River is most well known for the Milk River Spa which is located inland, the mouth of the river creates a coastal fan area which is lined with mangroves.

Landwards of the mangroves, the coastal fan has some agricultural activity, which likely benefits from the alluvial sediment deposits.

Erosion of the soft alluvial deposits will be slowed and mostly stopped by the presence of the mangroves at the shoreline, which particularly at this location, are critical for reducing wave energies and building up sediment at the shoreline.

COASTAL MANAGEMENT UNIT D4

HINTERLAND	SHORELINE	NEARSHORE
Coastal Fan	**Mangrove/Swamp**	**Open Coast**

FUTURE CHANGES

Rapid Onset Hazards:

- Storms and hurricanes (particularly for the east of the Island) can provide high magnitude rainfall, which can result in flooding and **debris flow** activity within the low lying coastal fan areas.
- **Liquefaction** of loose, near-saturated sandy soils during high magnitude seismic events.
- Increased sea levels during storm surges can make the low-lying coastal fan areas and mangrove swamps more susceptible to coastal flooding.
- No protection from open sea at coastline meaning the majority of wave energy is dissipated here and shoreline may be subject to sudden retreat events during storms.

Slow Onset Hazards:

- Coastal fan morphology as well as sedimentary styles may be influenced by climate change.
- Frequency, magnitude and severity of fluvial flooding events on coastal fan may increase with climate change. This may lead to a positive feedback loop by damaging mangrove trees, reducing their capacity to provide a buffer at the coast for storm winds and waves.
- Gradual increase in sea level induced by climate change. Likely to be accompanied by a gradual retreat of the coastline to reach equilibrium conditions. Additionally, low-lying coastal plain areas sensitive to coastal flooding events which will become more common with increased sea level.
- Inland pollution and coastal developments might threaten the fauna in mangrove swamps and therefore the condition of the coastline's natural protection against **erosion** and retreat. Mangrove ecosystems are also sensitive to changes in the sediment budget, which may be induced by factors such as changes to flood return period and river channel engineering.

Human Development:

- Coastal fans and beaches Jamaica may be susceptible to polluted surface water run-off from land based sources.
- Steps should be taken to conserve the mangrove swamp ecosystems to ensure that they continue to provide effective coastal protection in the future. Developments behind mangroves restrict the ability of the system to retreat back with sea level rise causing **coastal squeeze**.
- Deforestation is one of the largest threats to mangroves.
- While coastal protection measures along the open coast may help to provide short-term defence for mangrove swamps, they may not be sustainable in the long-term and might result in more focussed **erosion** elsewhere or affect the mangrove ecosystems by changing the sediment budget and the ability of seawater to reach the swamps. Furthermore, mangrove ecosystems are not necessarily able to adapt rapidly to sudden changes in their environment, with implications for the health of the system.

Summary

- Coastal fans are very low lying land and very susceptible to flooding.
- Having mangrove/swamp areas can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments particularly in relation to the deterioration of mangroves. However, mangrove ecosystems are more likely to adapt and respond positively to climate change impacts (depending on human development in the hinterland).

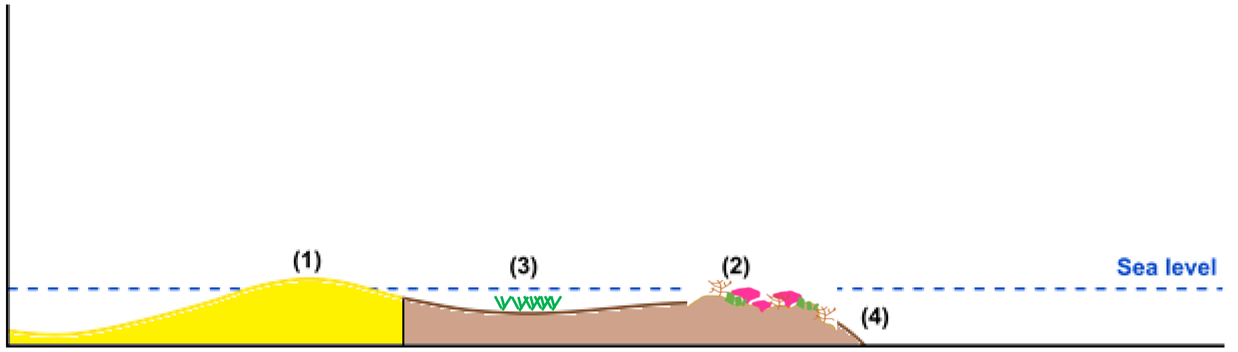
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Unconsolidated Sediment:** Unconsolidated sediments are loose materials and grains through which water can flow.
- **Halophytic fauna:** Plants which are adapted to grow and survive in saline conditions.
- **Coastal Squeeze**: Narrowing of the intertidal zone as sea level rises and natural retreat is prevented by natural or man-made barriers.
- **Debris Flow**: Sediment becomes water logged and starts to flow downhill as a mass.

CMU D4						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	x	x	x		
Beach Nourishment / Recharge	x	x	x	x		
Beach Recycling	x	x	x	x		
Beach Vegetation Protection	X	x	x	x		
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	√	√	x	x	Need to limit grazing and deforestation which damages mangroves and reduces the resiliency of the intervention.	3
Sea Grass Restoration and Rehabilitation	x	x	x	x		
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be effective used in front of the mangroves to facilitate growth of new plants..	3
Sea Walls	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	2
Groynes	x	x	x	x		
Land Reclamation	x	x	x	x		
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Limited impacts behind the mangroves in case of extreme event.	3
Sand Bag Structures	x	x	x	x		
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	√	x	Reducing run off and soil saturation from the hinterland can reduce pollution in the nearshore area, particularly the mangroves.	5
Set Back Zones	√	x	√	x	Should be calculated using projected flood risk maps.	4
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT E1

HINTERLAND	SHORELINE	NEARSHORE
Barrier	**Beach**	**Fringing Reef**



KEY FEATURES

- Narrow offshore barrier system runs sub-parallel to coastline **(1)**. Barrier likely to comprise loose sandy deposits.
- Development of a near-shore fringing reef system beyond barrier **(2)** sometimes separated by a shallow back-reef intertidal/sub-tidal lagoon area which may be likely to support seagrasses **(3)**. Fringing reef may extend further than 1.5km from barrier in Jamaica.
- Seafloor falls to shelf depths beyond outer limit of fringing reef **(4).**

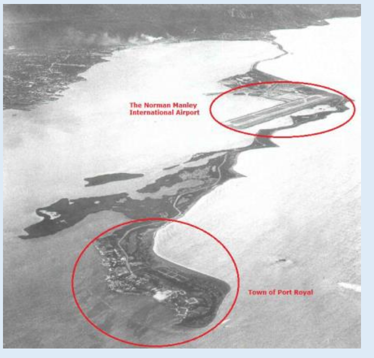
KEY PROCESSES

- Barrier most likely to have formed through a combination of **longshore drift** and sub-aerial/ aeolian sediment transport processes. May be related to emergence of fringing reef-system from shallow waters.
- Continued temporal evolution of the barrier system in response to ongoing environmental changes (e.g. wind and wave direction, sediment budget).
- Increasing depth of fringing reef exposes beach to waves, increasing potential erosion rates. This may be caused by coral removal or due to higher relative sea levels (e.g. during storm surges).
- Seagrasses and coral reefs can contribute to sand production where present. Fringing reefs can provide good natural protection along coastline.

KEY ISSUES

- Barrier forms part of a highly sensitive system subject to ongoing change. Implications not only for developments/infrastructure constructed on the barrier, but also for enclosed water bodies and land behind that they typically protect from wave energies.
- Sediments that barrier is formed of are typically loose sands.
- Shallow fringing reef system provides **erosion** protection to shoreline, but can easily be subject to inundation (e.g. from rising sea levels, tropical storm surges).

CASE STUDY



The Palisadoes Spit is a strip of land roughly 15km long, joining the town of Port Royal to the parish of Kingston, and that almost completely encloses the Kingston Harbour.

The spit provides critical protection from wave energies to Kingston Harbour, however important assets such as the airport and Port Royal are located on the strip and are very vulnerable to storm and wave damage.

To address this critical vulnerability of the road to passing storms and related wave action, the Government of Jamaica decided to undertake major roadworks. The roughly 5km strip of roadway recently underwent works (completed in 2013) which raised the original road by approximately 2m and added a boulder revetment over a four-kilometre stretch in order to buttress it against incoming wave action.

COASTAL MANAGEMENT UNIT E1

HINTERLAND **Barrier**	SHORELINE **Beach**	NEARSHORE **Fringing Reef**

FUTURE CHANGES

Rapid Onset Hazards:

- Storm surges can quickly inundate usually sheltered fringing reef systems. This can expose the barrier system to unusually large waves, where vastly increased wave energy along shoreline may lead to rapid rates of **erosion** and quickly threaten infrastructure built on the barrier, or on the coastline behind it.
- Barrier deposits in Jamaica mostly comprise loose sand with a high water table; these are particularly susceptible to **liquefaction** during seismic events. Potential for sudden and major earth settlement associated with almost complete loss of ground **bearing capacity/strength**.

Slow Onset Hazards:

- Gradual increase in sea level relative to fringing reefs induced by climate change. Coastline more exposed to typical wave conditions and also increases vulnerability to **erosion** during larger storm events.
- Barrier continues to evolve in response to changing environmental conditions in an unpredictable manner. Different conditions in the future might change its shape, size etc. and may completely breach it (i.e. creating a channel from the open sea to enclosed water behind it).
- Barrier systems usually respond relatively quickly to environmental conditions to restore an equilibrium state. Construction of sea defences may gradually lead to an in-balance between environmental conditions and the barrier system with implications for its long term stability.
- Inland pollution, **ocean acidification**, overfishing, climate change and coastal developments all might threaten the fringing reef system and therefore the condition of the coastline's natural protection against erosion and retreat.

Human Development:

- Jamaican developments on barrier systems should carefully consider the ground conditions and its **bearing capacity**. Furthermore, the possibility that the shape and size of the barrier will change in the future should be considered to design appropriate coastal protection measures. This may be particularly difficult to achieve adjacent to the sensitive fringing reef environment.
- Whilst coastal protection measures can be used to maintain the position of the barrier and improve its stability, caution should be exercised to ensure that conditions do not move too far from the natural equilibrium.
- The ecological condition of fringing reefs should be monitored closely. This may focus on reef resilience by studying factors such as coral/fish cover, abundance, diversity and richness to identify problems such as bleaching or coral disease. Depletion of the fringing reef system threatens to increase rates of retreat with consequences for coastal communities and infrastructure.

Summary

- Barriers as a hinterland tend to be small in size and susceptible to change over time in position.
- The fringing coral reefs can provide protection to incident wave energies, reducing the risk of **erosion** and flooding at the shoreline.
- There are high future risks associated with the impacts of human development on these environments including impacts on beach sediments and deterioration of coral reefs.

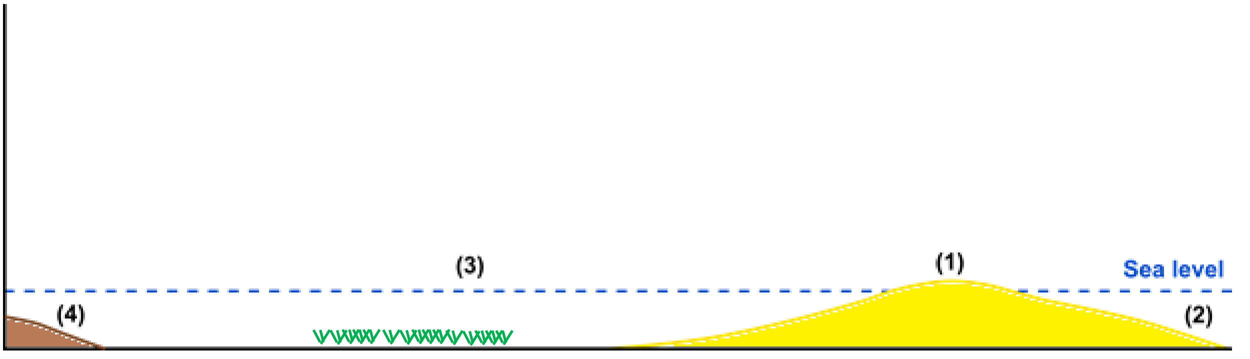
Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Ocean Acidification:** A decrease in the pH of the ocean due to the uptake of CO_2 by the atmosphere.
- **Bearing capacity / strength:** The ability of the soils to maintain loads applied to it.
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

CMU E1						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational tourism benefits.	3
Beach Recycling	x	√	x	√	Can provide additional recreational tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	√	√	x	x	Can provide additional sediment supply to the beach as well as wider tourism and fishery benefits.	3
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can be combined as a hybrid approach with artificial reefs.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach so the toe is protected.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state. Would likely involve moving off the barrier island.	4
Watershed Planning	x	x	x	x		
Set Back Zones	x	x	x	x		
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

COASTAL MANAGEMENT UNIT E2

HINTERLAND	SHORELINE	NEARSHORE
Barrier	Beach	Enclosed Water



KEY FEATURES

- Narrow offshore barrier system runs sub-parallel to coastline **(1)**. Barrier likely to comprise loose sandy deposits in Jamaica.
- Open water beyond the beaches of the barrier; sea depth typically falls to shelf elevations **(2).**
- Enclosed body of water **(3)** on the inland side of the barrier system may be likely to support seagrasses and separates the barrier from the main coastline **(4).** Typically a low energy environment which benefits from the shelter the barrier provides against incoming waves from the open ocean.
- Seagrass meadows likely to form in the sheltered enclosed waters **(3)**.

KEY PROCESSES

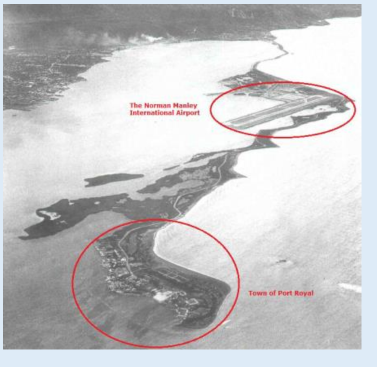
- Barrier most likely to have formed through a combination of longshore drift and sub-aerial/ aeolian sediment transport processes. Continued temporal evolution of the barrier system in response to ongoing environmental changes (e.g. wind and wave direction, sediment budget).
- Refraction of waves around, or overtopping of, the barrier during high energy storm events dramatically changes conditions in the enclosed water body.
- Lee of the barrier should be protected from most high energy waves and therefore beaches can form in protected areas.
- Seagrasses can contribute to sand production where present.

KEY ISSUES

- Barrier forms part of a highly sensitive system subject to ongoing change. Implications not only for developments/infrastructure constructed on the barrier, but also for enclosed water bodies and land behind that they typically protect.
- Sediments that barrier is formed of are typically loose sands.
- Little or no natural protection from open sea along seaward sections of the barrier shoreline, therefore highly sensitive to changing environmental conditions and **erosion**.
- Stagnant enclosed water bodies may be susceptible to pollution from run-off or waste disposal if proper controls are not in place.

CASE STUDY

The Palisadoes Spit is a strip of land roughly 15km long, joining the town of Port Royal to the parish of Kingston. It was formed many centuries ago by longshore sediment transport and eventually formed a spit that gradually extended itself westwards towards the various cays on the island shelf.



The sheltered enclosed waters on the north side of the Palisadoes Spit provide protection to Kingston Harbour as well as a number of industries located along the coastal strip at Kingston.

More recently, mangrove replanting has been undertaken on the inside of the barrier island and in some areas these mangroves appear to have survived well.

COASTAL MANAGEMENT UNIT E2

HINTERLAND	SHORELINE	NEARSHORE
Barrier	Beach	Enclosed Water

FUTURE CHANGES

Rapid Onset Hazards:

- Storm surges in Jamaica are likely to expose the barrier system to unusually large waves and strong winds; vastly increased wave energy along shoreline may lead to rapid rates of **erosion** and quickly threaten infrastructure built on the barrier, or on the coastline behind it. This is a particular problem if waves are able to refract around a barrier to reach the inland side, or if particularly large waves overtop it during storms.
- Barrier deposits most likely comprise loose sand with a high water table; these are particularly susceptible to **liquefaction** during seismic events. Potential for sudden and major earth settlement associated with almost complete loss of ground **bearing capacity/strength.**

Slow Onset Hazards:

- Gradual increase in sea level induced by climate change. Coastline more exposed to typical wave conditions and makes barrier more sensitive to **erosion** during storm events.
- Barrier continues to evolve in response to changing environmental conditions in an unpredictable manner. Different conditions in the future might change its shape, size etc. and may completely breach it (i.e. creating a channel from the open sea to enclosed water behind it). In this instance, the enclosed water body may offer significantly less protection to inland coastal areas during storm events.
- Barrier systems usually respond relatively quickly to environmental conditions to restore an equilibrium state. Construction of sea defences may gradually lead to an in-balance between environmental conditions and the barrier system with implications for its long term stability.

Human Development:

- Jamaican developments on barrier systems should carefully consider the ground conditions and its **bearing capacity**. Furthermore, the possibility that the shape and size of the barrier will change in the future should be considered to design appropriate coastal protection measures.
- Whilst coastal protection measures can be used to maintain the position of the barrier and improve its stability, caution should be exercised to ensure that conditions do not move too far from the natural equilibrium.
- Environmental conditions in enclosed water bodies should be carefully monitored to ensure that pollution does not threaten marine or terrestrial ecosystems. Pollution may also affect humans that live adjacent to enclosed water bodies or come into contact with them through work or leisure.

Summary

- Barriers as a hinterland tend to be small in size and susceptible to change over time in position.
- Future sea level rise at risk of submerging low lying areas of the barrier.
- Lee side of the barrier onto enclosed areas can be good environments for seagrass meadows, however construction activities threaten the benefits these bring.

Glossary

- **Erosion:** Process by which particles are removed by the action of wind, flowing water or waves (CIRIA, 2010).
- **Liquefaction:** A process by where saturated, or partially saturated soil looses strength due to a force or pressure applied to it such as during an earthquake.
- **Bearing capacity / strength:** The ability of the soils to maintain loads applied to it.
- **Longshore sediment transport:** Movement of beach material along the shoreline caused by the incident wave action.

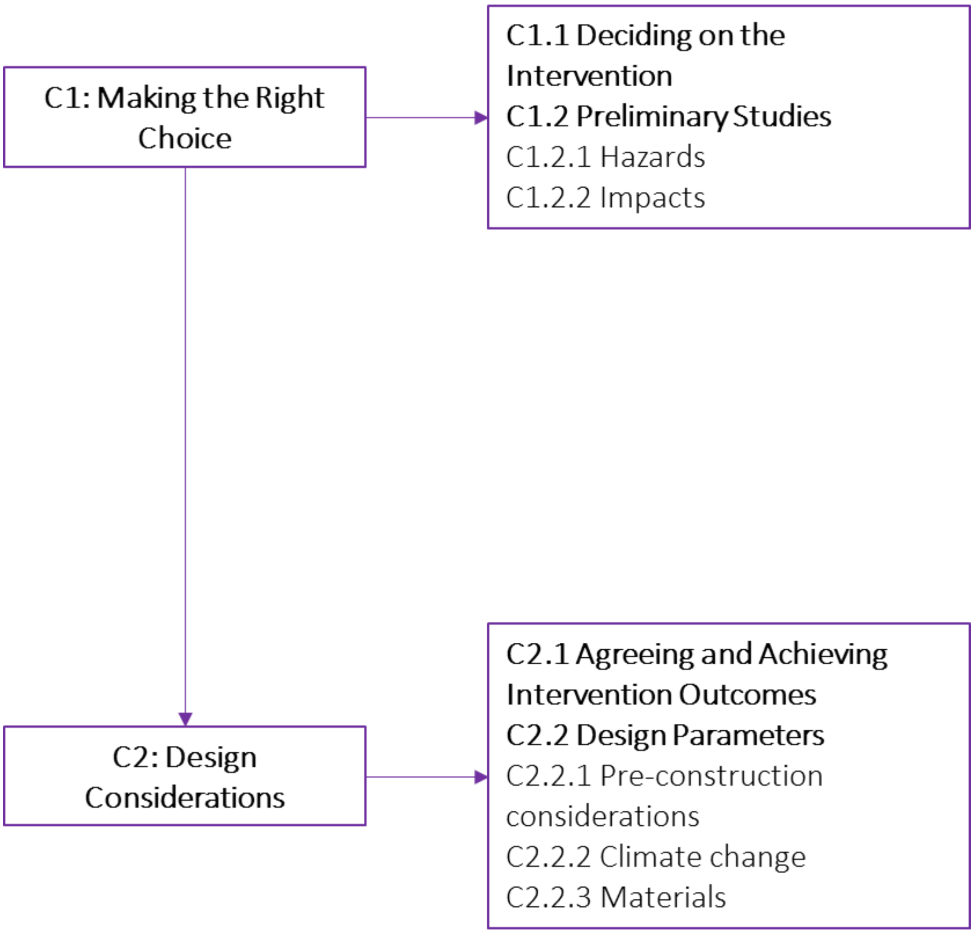
CMU E2						
Coastal Intervention	Appropriate Intervention?				Site Specific Considerations	Resiliency Score
	Build	Protect	Accommodate	Retreat		
Nature-based intervention						
Natural Beach Protection	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Nourishment / Recharge	√	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Recycling	x	√	x	√	Can provide additional recreational and tourism benefits.	3
Beach Vegetation Protection	x	√	x	√	Reduces area for typical tourist and recreational use so may depend on beach width.	2
Coral Reef Restoration and Rehabilitation	x	x	x	x		
Mangrove Restoration and Rehabilitation	x	x	x	x		
Sea Grass Restoration and Rehabilitation	√	√	x	x	Can contribute to sediment supply and help reduce wave energies.	2
Hard intervention						
Breakwaters	√	√	x	x	Can reduce wave energies before they reach the shore.	3
Revetments	√	√	x	x	Can be quite effective and can be positioned behind the beach.	3
Sea Walls	√	√	x	√	Can be quite effective and can be positioned behind the beach so the toe is protected.	2
Groynes	√	√	x	x	Can be effective alongside beach protection to keep the sediment in place.	3
Land Reclamation	√	x	√	x	May reduce the width of beach available.	2
Gabions	√	√	x	x	Can be used to help stabilise slopes but must be designed well and maintained. Are not very resilient to climate changes.	1
Flood Barriers	x	x	√	√	Particularly useful in areas with limited asset as is cheaper than big capital scheme.	4
Embankments	√	√	x	√	Could be used to reduce overtopping and limit flood risk.	3
Sand Bag Structures	√	√	x	x	Should be used only as short term or temporary interventions.	1
Non Structural intervention						
Managed Realignment	x	x	x	√	By removing assets away from the flood and erosion risk areas, the coastline can retreat to an equilibrium state.	4
Watershed Planning	x	x	x	x		
Set Back Zones	x	x	x	x		
Building Codes	√	√	√	√	Building codes can be used to ensure resilient infrastructure placed in vulnerable areas is built appropriately.	3
Stakeholder awareness, education and engagement	√	√	√	√	Stakeholder awareness and education is fundamental to compliment any management strategy. Should be used in conjunction with another intervention.	3

Summary

- Jamaica's coastline is at risk from several hazards due to the number of assets and reliance of the economy on the coastal zone, including those such as sea level rise, environmental degradation, and hurricanes.
- The risks associated with Jamaica's coastal zone is likely to increase in the future with climate change, increasing rates of sea level rise and increasing human developments on the coastline.
- In order to provide holistic management of the coastline, different **management approaches** should be considered for large sections of the coastline. These will then influence the **interventions** which are considered appropriate at a site.
- The coastline of Jamaica can be split into different typologies which form a Coastal Management Unit (CMU). The CMU further recommends which **interventions** are appropriate under different **management approaches** and should therefore be considered prior to looking at individual **interventions** in more detail (see Part D).

Part C: Selecting Approaches and Interventions

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.



Contents

C

C1: Making the Right Choice

C1.1: Deciding on the Intervention

There are several steps that should be taken before deciding on the preferred **intervention** for a project, whether that is a shoreline protection project or a development project within the coastal zone. Figures C1 to C6 provide flow diagrams to depict a best practice route to follow in determining a preferred coastal **intervention**. This process has been linked to the Jamaican planning process (see Part E) and through following the steps, the majority of the required evidence for planning may be considered and assessed. Figure C1 should be read first as it provides the overall structure of the decision making process. Figures C2 to C6 then provide more details in order to achieve the five key steps which are presented in Figure C1.

The following high level process may be applied to several different scenarios or projects. The level of detail and exact methodologies should be adapted on a project level that embraces local conditions that are specific to the local site, size of the project, requirements of the PIOJ and complexity of the project. Furthermore, some projects are undertaken under emergency situations, where a solution is required to be determined very quickly. Despite these situations, the majority of these steps should still be applied, however some steps may be undertaken at only a high level or using proxy data rather than gathering new data. There are some key themes throughout the process which should be applied to every project, however small/large or complex.

Community engagement

Including the local community in the decision making process (using appropriate communication programmes) is vital to the successful selection of a sustainable solution which provides wider benefits to the coastline. It is recommended that a Stakeholder Engagement Plan should be compiled at the start of a project and updated throughout the process. This should be in line with the Government of Jamaica Communication Policy (Government of Jamaica, 2015) where a Government of Jamaica institution is leading the project. A template which could be applied to form a Stakeholder Engagement Plan is provided in Appendix F.

Community knowledge must not be neglected as part of the preferred option decision making process. Furthermore, a detailed analysis of past flooding/erosion (or other climate related) events, will enable a decision maker to use local and site specific knowledge and learn from past experiences. Sharing data with other stakeholders, who may be engaged in monitoring or follow-up activities, is highly commendable and cost effective. In particular, the social dimension of **nature-based interventions** for coastal protection is increasingly seen as a critical component for the long-term success and resilience of coastal environments (UNEP, 2013 and 2016; Wicander et al., 2016; Day et al., 2015). In Jamaica, the need to engage local communities in coastal ecosystem restoration is particularly important because many of the local stressors are associated with bad practices, such as over-fishing and unsustainable harvesting of mangrove. Where possible, restoration **interventions** focusing on corals, seagrasses or mangroves should try and include a more holistic programme that involves the management of the entire ecosystem with the support and engagement of the community. More information on this aspect is included in Part E.

Case Study: Negril – importance of stakeholder engagement

The coastline of the town of Negril straddles two parishes: Westmoreland and Hanover, and stretches roughly 16km if Bloody Bay, Long Bay and the West End are included. While Bloody Bay and Long Bay are sandy beaches, the West End is quite different, featuring rock formations and seaside cliffs. It is separated from the bays by the Negril River.

Offshore the Negril coast are also coral reefs and some seagrass beds; these features, as well as the cliffs, river and mangrove swamp to the east of the coastline (the morass) all contribute to the diverse natural beauty of the Negril coastline.

Negril is not only rich in natural assets but several beachfront properties: hotels, villas and restaurants, contribute to the commercial assets of the Negril coastline. The tourism industry is currently one of the largest earners of foreign exchange to the Jamaican economy and the resources (both natural and commercial) of Negril form a significant part of Jamaica's tourism product, reportedly providing more than 25% of these earnings.

Negril has been experiencing erosion for the last few decades (see image above). Whilst there have been several studies undertaken here, there is not currently any proposed intervention or works which have funding and planning agreement. Although there are many factors influencing this, one of these are the issues that have arisen around potentially late / lack of community and public engagement. This has led to differences in ideas and perceptions around risks and solutions between the local community and the Government of Jamaica and other stakeholders. Although potentially not the entire solution to this, early stakeholder engagement with the community prior to plans being developed for funding applications would have allowed discussion around the key concerns and potential solutions developed which complimented the different concerns associated with the shoreline here.

Incorporating consideration of future change

Scenario analysis is a crucial first step in determining robust decisions when faced with significant climate uncertainty. By exploring different future scenarios, an understanding of what the future may look like (often referred to as "future-casting") and, importantly, of how different decisions play-out in those futures, can be developed. Designers and developers must think imaginatively about change and not simply project existing trends. A comprehensive view of the potential drivers that might influence future coastal change must be considered and discussed. It is through this process that the status quo can be challenged and space given for innovation. More information regarding incorporating SLR into design is provided in Part C2.2.2 and throughout Part D.

Assessing different **interventions** including **nature-based, hybrid, hard and non-structural interventions**

Rather than, as can be the case in more traditional schemes, assuming the best solution is what has historically been used or has worked somewhere else, these Guidelines should be used to ensure a wide range of **interventions** are assessed. This should include assessment of nature-based, hybrid and **non-structural intervention** options alongside more traditional **hard interventions** to achieve the wider benefits, provide longer-term sustainability and stability of the shoreline in addition to reducing the environmental impacts. Part D of these Guidelines presents different **interventions** for consideration.

Figure C1. HOW TO SELECT AN INTERVENTION

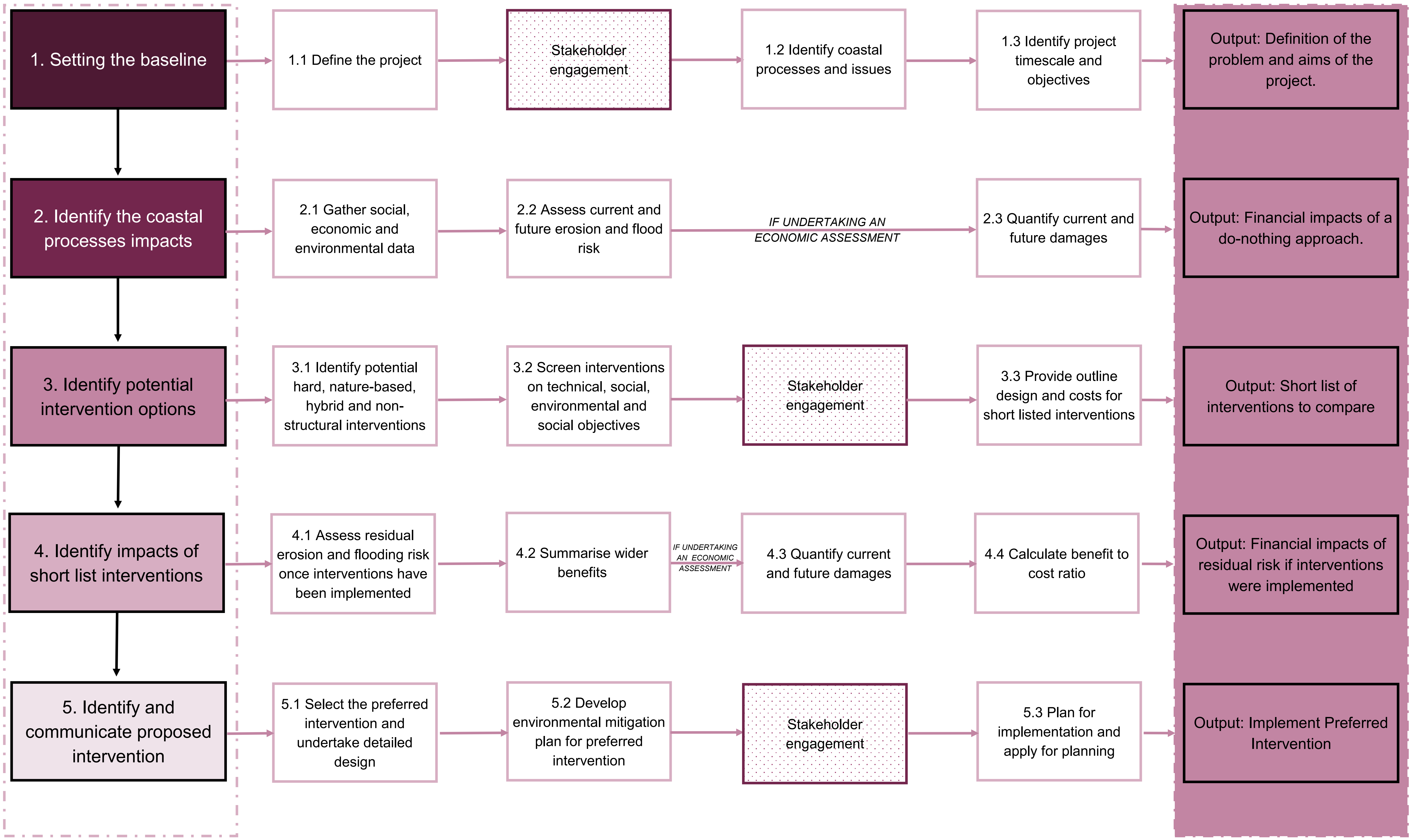


Figure C2. SETTING THE BASELINE

1.1 Define the project

→ Define the study area including the entire ridge to reef profile

Guidelines reference: A4; B4

→ Consider the potential impacts from adjacent shorelines

→ Consider the land ownership within the study area

1.2 Identify coastal processes and issues

→ Define the typical environments across the ridge to reef profile

Guidelines reference: B3; B4

→ Identify key assets in the area.

Assets to include:
- Properties
- Industry including water, sewerage, gas and electricity
- Transport infrastructure including roads, railways, ports, airports
- Critical infrastructure including hospitals, schools, government buildings etc.

→ Identify the key coastal ecosystems in the ridge to reef profile

Ecosystems to include as a minimum consideration of:
- Mangroves
- Coral reefs
- Seagrass meadows
- Beach/dune habitat

1.3 Identify project timescale and objectives

→ Define the key objective and the management approach for the study area

Guidelines reference: B3, C2.1

→ Define further objectives to provide wider benefits

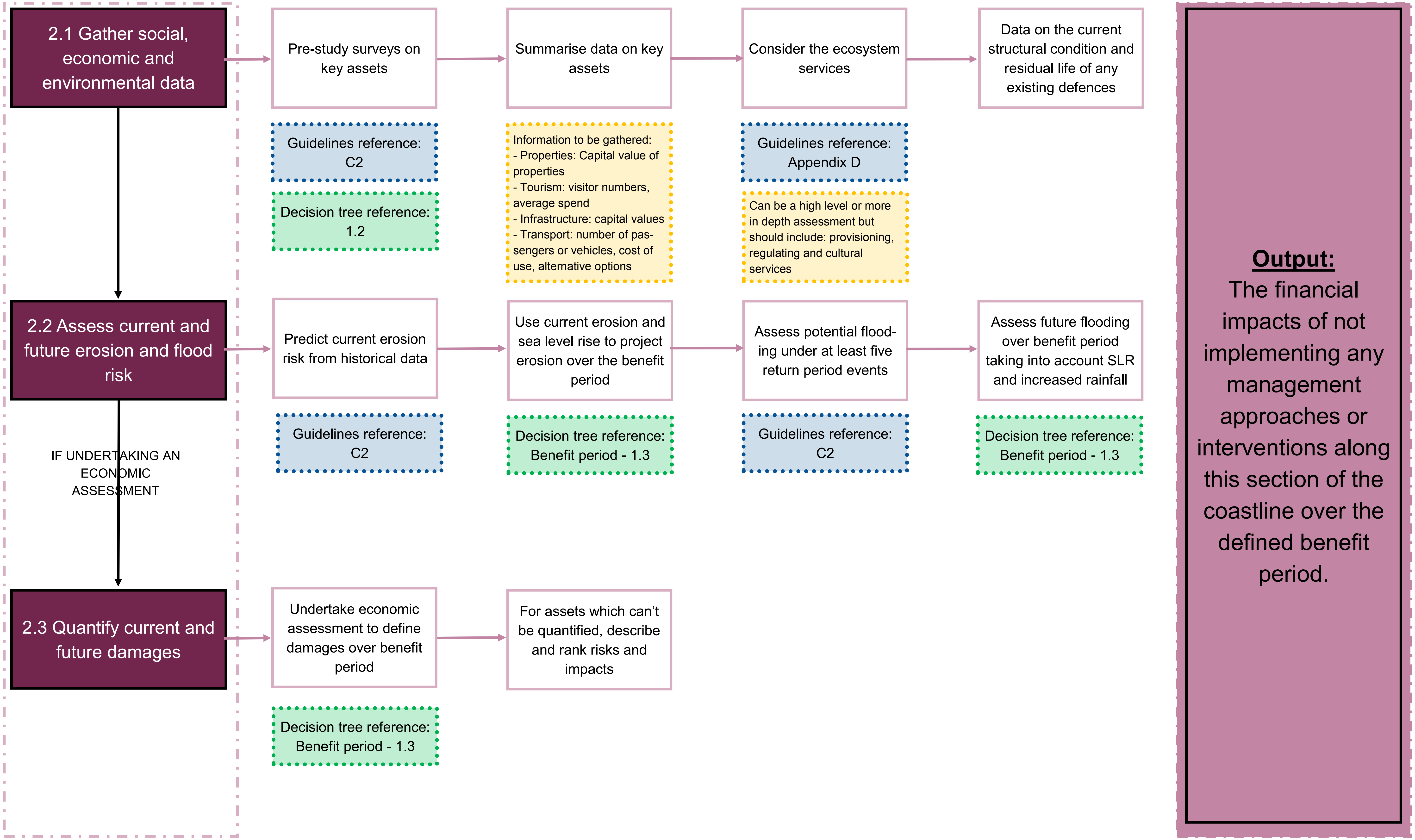
→ Identify timescale for assessment and define as the "benefit period"

Need to assess the whole life of a scheme but can assess over:
- short term (0-20 years)
- medium term (0-50 years)
- long term (0-100 years)

Output:
Presentation of a set of objectives which are within a defined benefit period and are tailored to the specific site environment. These objectives aim to provide flood or erosion protection as well as broader benefits to the communities and/or ecosystems and are supported by key stakeholders.

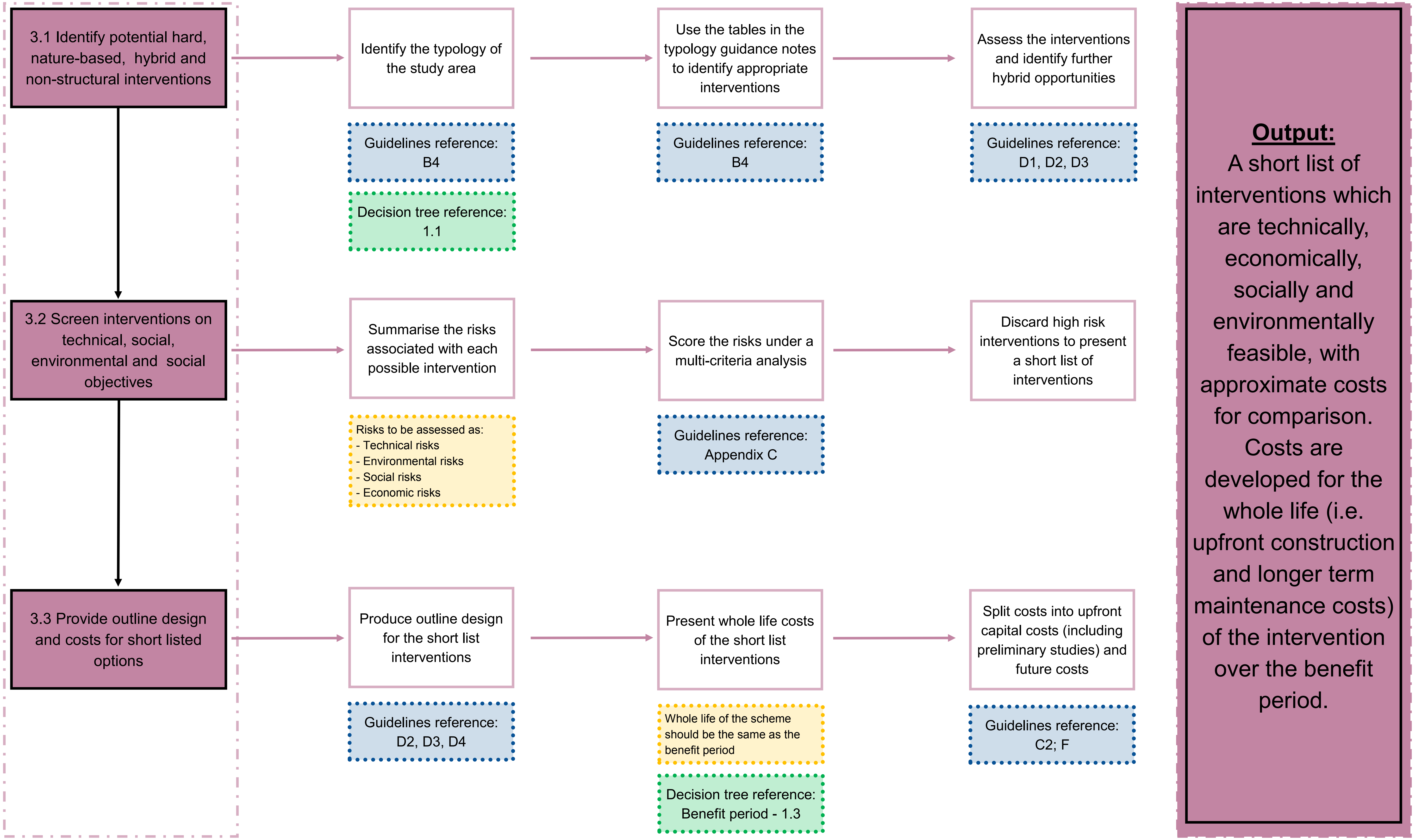
Stakeholder and community engagement: objectives of the project should aim to meet, where applicable, the wider aims and ambitions of the community and stakeholders in the surrounding area. Stakeholder Engagement Plan should be produced (Appendix F).

Figure C3. IDENTIFY THE COASTAL PROCESS IMPACTS



Stakeholder and community engagement: engagement with stakeholders should be undertaken to supplement the data gathering stage and ensure the best data available for the study area is used.

Figure C4. IDENTIFY POTENTIAL INTERVENTION OPTIONS



Stakeholder and community engagement: When undertaking a multi-criteria assessment, the opinions of the stakeholders and communities should be used to help determine the scoring.

Figure C5. ASSESS THE FLOOD AND EROSION RISK UNDER THE SHORT LIST OPTIONS

4.1 Assess residual erosion and flooding risk once interventions have been implemented
→ Predict reduction in erosion risk following implantation of intervention → Use sea level rise to project erosion over the benefit period → Assess potential flooding under at least five return period events under the intervention → Assess future flooding over benefit period taking into account SLR and increased rainfall

Decision tree reference: Erosion rates - 2.2

Decision tree reference: Baseline assessment - 2.2

4.2 Summarise wider benefits
→ Summarise the benefits for all short listed interventions

IF UNDERTAKING AN ECONOMIC ASSESSMENT

4.3 Quantify current and future damages
→ Undertake economic assessment for each shortlist intervention to define damages → For assets which can't be quantified, describe and rank risks and impacts → Discount damages to provide a present value damage for each short list intervention

Decision tree reference: Benefit period - 1.3 Economic data - 2.1

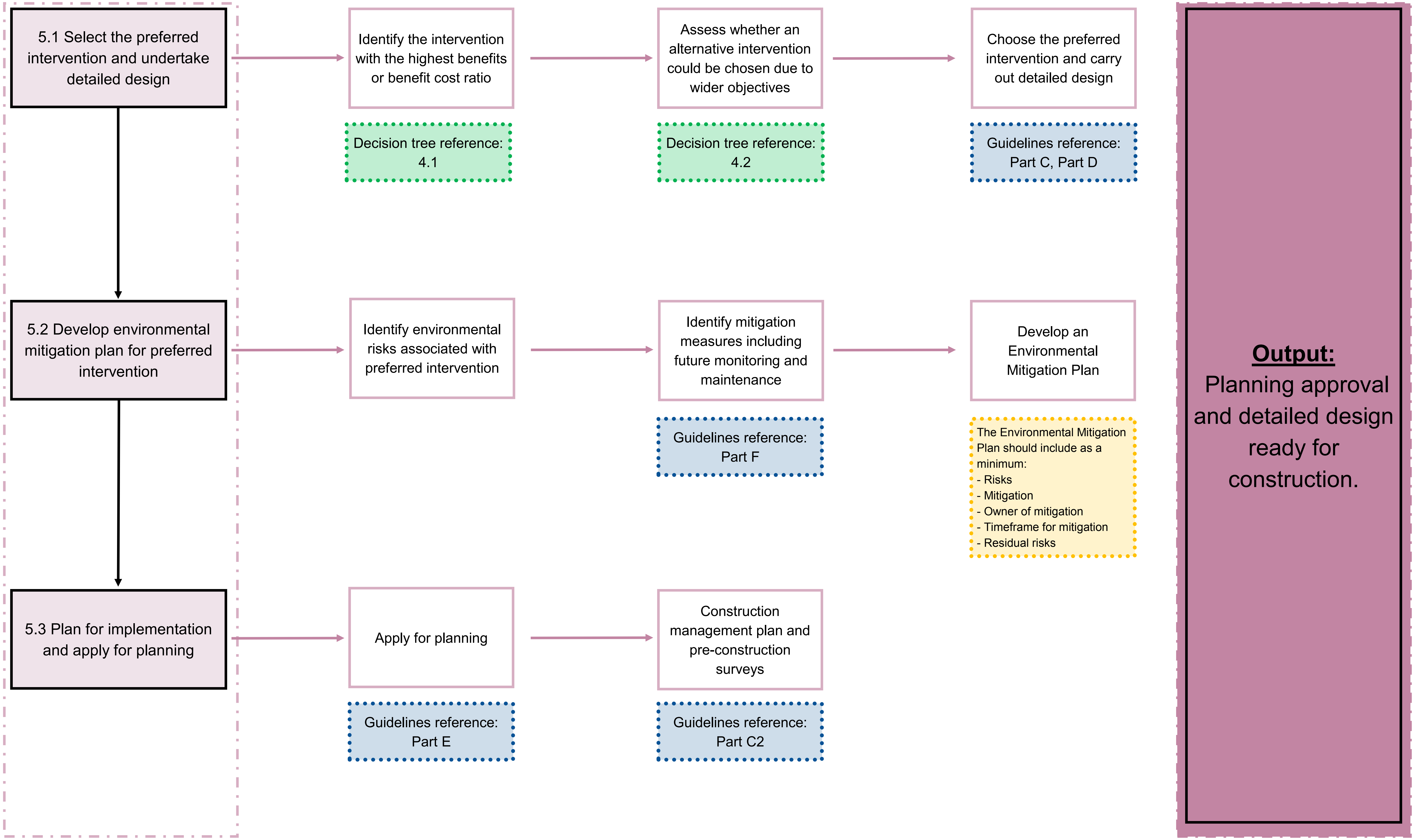
4.4 Calculate benefit to cost ratio
→ Calculate the benefit cost ratio for each short list intervention → Identify those with a benefit cost ratio below 1 as not economically justifiable → Order the short listed interventions from largest to smallest benefit cost ratio

Benefit Cost Ratio = PV Benefits ÷ PV Costs

Output:
The residual risk and therefore financial impacts following the implementation of each short list intervention. Values are discounted according to national guidance.

Stakeholder and community engagement: engagement with stakeholders should be undertaken to supplement the data gathering stage and ensure the best data available for the study area is used.

Figure C6. IDENTIFY AND COMMUNICATE PROPOSE D INTERVENTION



Stakeholder and community engagement: The preferred option needs to be communicated to stakeholders and planners. When planning construction, communication with the local community is important to reduce social and cultural impacts.

C1.2: Preliminary Studies

Risk =
Hazard × Impact

The choice of **interventions** for coastal **management approaches** partly depends on coastal risks which are prevalent within the study area. 'Risk' is expressed by multiplying the combination of hazards and impacts. Without both components there is no risk to a study area. The greater the hazard and impact, the greater the risk is.

To ensure that the most appropriate **intervention** is selected, it is important to understand the risks associated with the study area at the outset of the project or study. Preliminary studies will be required to inform the manager/designer about both the hazards and impacts in the study area and should incorporate social, economic, and environmental data.

The funder of the scheme should also be considered when identifying the appropriate **intervention**. A hotel owner may be more concerned with the **design life** of a scheme as opposed to the benefit-cost ratio, for example, compared to a Government funded scheme.

There are several different methods which can be employed when undertaking a disaster risk assessment and these vary in terms of complexity and data requirements. The information presented within this Part of the Guidelines demonstrates the general data requirements and considerations that should be included in a coastal management disaster risk assessment. The specific methods used to calculate the risk reduction and residual risks associated with the scheme will vary depending on the scheme size, location, and data availability.

Methods for disaster risk assessments:

Deterministic Assessment: Using event scenarios to provide the hazard data. A more simplistic approach as it does not require data on different levels of hazards associated with an event.

Probabilistic Assessment: Several different events of varying annual occurrence probability (such as a 1%, 0.5% and 0.01% Annual Exceedance Probability of coastal flooding) are assessed against potential losses to establish an Annual Average Damage (AAD).

C1.2.1: Hazards

There are a number of coastal hazards in Jamaica (see Part B1), however the main outcome of these hazards on the coastal zone is dominantly though erosion and coastal flooding. The erosion and coastal flood risk must be understood within the study area that is being assessed. There are several ways to assess erosion and coastal flooding including: assessing historical data, making use of previous studies, and numerical or physical modelling. Stakeholder involvement is also particularly important as the wider benefits to the coastline can be identified and local knowledge can be gained on past events that have occurred in the study area.

When calculating erosion rates for the study area past rates using historical data should be used where possible along with previous studies and photographs of the area. When predicting future rates both sea level rise and increased storminess should be incorporated. This can be done using either the Historical Trend Analysis or the Bruun Rule. Erosion rates should not only consider the impact of wave and water levels, but also whether sand mining or coral reef mining has impacted historic erosion rates and how this may change in the future.

When calculating flooding extents, **overtopping** volumes should be calculated, again incorporating sea level rise. Furthermore, extreme water levels including change in water levels in the short term (due to storms) and longer term (due to SLR) should be used to assess flood risk. Where further detail is required, numerical modelling should also be considered to identify the flood routes throughout the study area.

Historical Trend Analysis (HTA) = A tool which uses past erosion rates for the shoreline to quantify the rate of change and project that in the future, taking into account sea level rise. The following equation from SCOPAC (Bray, Carter and Hooke, 1992) should be used:

$$R2 = (R1/S1).S2$$

Where: S1 is the historical sea level rise; S2 is the future sea level rise; R1 is the historical retreat rate; and R2 is the future retreat rate.

Bruun Rule = More typically applied for beach recession than general shoreline recession, The Bruun Rule (1954) assumes that the beach retreats inland over time accounting for the relative cross-shore adjustment of sediment with sea level rise (Kamphuis, J., 2000).

$$R = xc.h / (dd + dc)$$

Where: R=recession; xc=distance out to closure; h=the water level rise; dd=height of beach; and dc= the closure depth.

C

Case Study: Palisadoes – critical infrastructure at risk from coastal hazards

The Palisadoes Spit is a strip of land roughly 15km long, joining the town of Port Royal to the parish of Kingston, and that almost completely encloses the Kingston Harbour. It was formed many centuries ago by alongshore sediment transport from waves that pushed river sediment coming down the Hope and Cane Rivers in a westward direction. This eventually formed a spit that gradually extended itself westwards towards the various cays on the island shelf, with one end attached to the shore and the other protruding into the Caribbean Sea.

For many years, Port Royal was only accessible by boat. This was until 1936, when the road along the Palisadoes, from Harbour Head to Port Royal, was completed by the Public Works Department. The criticality of this road is evident: (1) it is the only roadway link to the Norman Manley International Airport - the only international airport on the south coast of Jamaica, (2) it is the only roadway link to the town of Port Royal, which in addition to housing several residents and monuments is also home to the HMS Cagway – the only jetty of the country's coast guard.

Damage to the Palisadoes coastal area therefore severely impacts the country's economy by shutting down access to critical transportation hubs and a major import and commercial gateway into the island. To address this critical vulnerability of the road to passing storms and related wave action, the Government of Jamaica decided to undertake major roadworks after these storms. The roughly 5km strip of roadway from the Harbour View roundabout to the Airport roundabout recently underwent works (completed in 2013) which raised the original road by approximately 2m and added a boulder revetment over a four-kilometre stretch in order to buttress it against incoming wave action.

Various photos of the Palisadoes Roadway: (a) Before and (b) After the construction of the revetment; (c) right after Hurricane Ivan; and (d) after Hurricane Dean (road not shown as it is covered by washed up sand).

C1.2.2: Impacts

To assess the effectiveness of **interventions**, the assets or elements which are vulnerable to the hazards must be assessed. There are two main assessments which should be assessed:

- Socio-economic impacts; and
- Environmental impacts including preliminary studies of status of ecosystems.

<u>Socio-economic impacts</u>

Depending on the type and scale of the study, socio-economic impacts are often assessed by performing an economic assessment. The following factors should be considered at least at a high level, if not at a more detailed level as described in Table C1.

Table C1 Table summarising the socio-economic impacts that should be considered at the start of the study.

Asset	What should be assessed	How to assess under an economic assessment
Residential and commercial property	Assess whether residential and commercial properties are at threat from erosion and/or flooding.	If at threat from erosion, the year of failure should be calculated along with the present value of the property. If at threat from coastal flooding, the flood depths for each return period being assessed should be identified and the annual average damages calculated using information on cost of flood damage to properties. Costing of damages is often broken down into 6 components of damage; building structure and fabric, building services, moveable equipment, fixtures and fittings, stock/possessions, and clean-up costs.
Vehicles	Assessing how many vehicles may be damaged under a flood event.	Assessing exactly how many vehicles will be damaged during a flood event is difficult, however an assessment can be made by calculating the average number of vehicles damaged in previous events as a percentage of the number of properties in the area, and using this percentage to calculate the number of vehicles within the study area. Once the number of vehicles has been calculated, an average vehicle value can be used to calculate the overall value of vehicle damage in the study area.
Evacuation	Evacuation of flood affected properties should be considered in the short term to limit loss of life, injury and stress caused by the event.	Evacuation costs should incorporate average property rents, cost of temporary accommodation, food, additional transport costs and loss of earning.
Infrastructure	Losses to infrastructure should be considered in terms of the physical damage caused by flood waters and the wider economic impact to those	<u>Electricity and gas</u> – both direct damage to the supply and losses caused by disruption to the supply of services. <u>Water and waste water</u> – the costs imposed on households when water is cut-off.

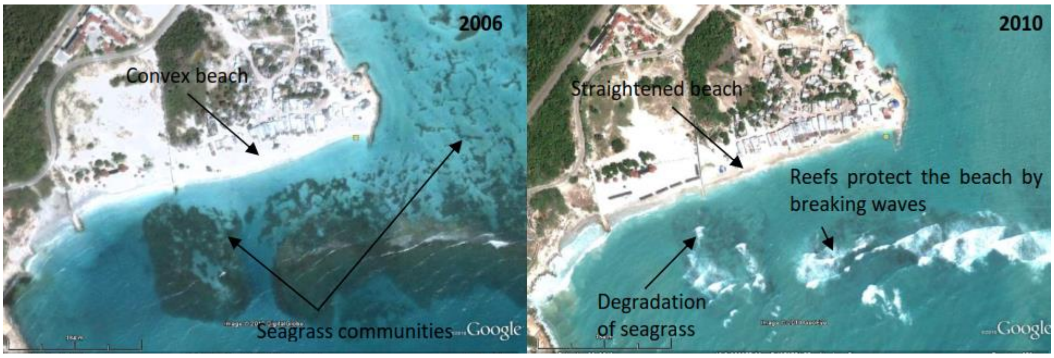
	both within and outside of the flood zone. Under erosion scenarios losses should be considered assuming permanent loss to infrastructure and will often consider the cost to re-build elsewhere.	Roads – the costs incurred due to damage of the road itself as well as the costs of disruption to both travellers and businesses due to road traffic disruption. Traffic disruption can be worked out by looking at length of diversions against fuel cost and vehicle numbers. Airport disruption – both direct damages to airport infrastructure itself and the cost to businesses affected by airport disruption. Telecommunications – consideration of repair costs, additional maintenance costs and extra operating costs during an emergency. Schools – direct damages occur due to the flooding of school buildings, the cost of temporary classroom accommodation and additional costs such as the cost of losses that may occur due to parents' absenteeism from work while they care for children who are unable to attend school. Hospitals – the flooding of hospitals can have social widespread impacts. Costs should incorporate the potential losses due to the direct impact of flooding on hospital buildings as well as due to the disruption and/or cancellation of hospital services. Emergency services and recovery costs – depending on the severity of the event, several emergency services may be involved in emergency works and clean-up operations, during and after the event. Costs would incur from the additional time and resources required for this.
Recreational gains and losses	Recreational benefits arise from the enjoyment of landscape, wildlife, natural amenities, and the enjoyment of recreational activities.	Costs are calculated by determining the number of visitors annually and multiplying by the value of a visit for recreational use.
Agriculture	Flooding of agricultural land can have a long term effect due to soil saturation and the effect on crops.	The cost of the land itself should be considered as well as the land use and potential loss of income.
Fisheries	Loss of income to local fishermen due to loss of port/harbour, environmental degradation or loss of access to area through erosion and therefore loss of customers. Further benefits can be deemed through improvement of marine habitat.	Potential loss if income should be calculated by looking at different scenarios of reduction in sales of fish. The coast of damages to boats and gears should also be considered when looking at impact of storms and hurricanes. Benefits of improving the marine environment should be calculated by looking at potentially increased stock and therefore sales, or increased quality which could lead to increased cost unit price.

Damage Functions for Economic Assessments

Research by Jongman, B., *et al.,* (2012) considers several different ways to value flood and erosional damages; assessing depth-damage functions and asset exposure valuations. They show the difference in outcomes depending on assumptions made and demonstrate the importance of clearly showing the assumptions and methods which are used to undertake the economic assessment. The guidance documents provided at the end of this section should be used to help provide consistency across Jamaican projects.

Case Study: Factors affecting erosion rates in Hellshire

Hellshire Beach in St. Catherine is a favourite location for many Jamaicans, drawing many fish-eaters, sunbathers and water-lovers from nearby Kingston and Portmore. However, aerial images taken over the last 5 years show that Hellshire beach has narrowed by up to 10 metres. The beach has also straightened and lost its convex shape. This erosion may be a result of one or a combination of the following: i) waves from extreme events such as Hurricane Dean in 2007; ii) degradation of the reef structure through natural or anthropogenic factors; and iii) other changes in the biological and physical marine environment, such as loss of seagrass communities or damage to existing groyne structures.



Assessment of the potential future erosion of the beach therefore needs to consider: i) climate change impacts on storms and sea level rise; ii) reef health and whether efforts to improve the reef health are going to be carried out; iii) seagrass health and seagrass restoration activities; and iv) maintenance that may (or may not) be undertaken to the groyne structures.

C

Environmental Impacts including Preliminary Studies of Status of Ecosystems

It is vital under every project that the environmental impacts that could arise from a project are understood, and where possible, mitigated. As such, required as part of a planning application for the works. There must always be an initial baseline assessment which uses existing data if possible, and if not looks to collect additional data. This needs to be undertaken and the health and extent of the current ecosystems in the area need to be defined. The potential reasons for any poor health or degradation of ecosystems that is observed at this stage, whether this is from storm damage, climate change or anthropogenic factors such as channel dredging for harbours and boat access and overfishing, should be identified at this stage.

However, as well as simply considering the potential impacts, the potential additional benefits that could be gained from an **intervention**, particularly when considering **nature-based or hybrid interventions**, should also be considered at the early stage of the study to maximise potential benefits as outcomes to the study.

As part of this process, a Strategic Environmental Assessment (SEA) of the scheme, including an assessment of the policies, regulations, institutional coordination mechanisms and procedures in places, should be undertaken to ensure the viability of the scheme during the lifetime, potential impacts and preventive and mitigation measures. Furthermore, an environmental analysis of the potential direct, indirect and cumulative impacts of the specific works and activities proposed for the public investment packages should be undertaken as required by national legislation, as well as the selection and costing of preventative and mitigation measures. An SEA further allows consideration of cumulative damages and impacts, which is a particularly important consideration when assessing the overall strategic management of the area.

In addition to a SEA being undertaken, in the development of a coastal management scheme, an ecosystem services approach to the assessment is now often considered as best practice. Ecosystem services are defined as the benefits that humankind gets from any type of ecosystem. Generally, they are split into different categories:

1. Provisioning: such as the production of food (including crops, fisheries, aquaculture, wild foods) and water, fuel (such as woodfuel/biomass), biochemical and medicine, fibre and genetic resources.
2. Regulating: such as the control of climate (local and global climate), flood and erosion protection and regulation, air quality regulation, soil quality regulation, water quality regulation, crop pollination, disease and pest control and noise regulation.
3. Cultural: such as tourism and recreational values, species diversity, cultural and spiritual values and scientific and knowledge values.

The key ecosystem services provided by the core coastal habitats in Jamaica are presented in Table C2.

C

Table C2 Ecosystem Services in Jamaica.

Ecosystem service	Beaches and Dunes	Seagrass	Coral Reefs	Mangroves
Provisioning				
Production of food (including crops, fisheries, aquaculture and wild foods) and water	Yes, but low importance – opportunity for agriculture on coastal dunes. Also, beaches and sand dunes store and filter water through the sand, and potentially raises the water table. There could be the potential for aquifers to develop in these areas.	Yes – provide habitats for scallops, shrimps, crabs, and juvenile fish. Also, seagrass crops in some areas can be used to provide fertilisers, but this is less widely practiced.	Yes – maintenance of fisheries by providing shelter space, reproductive habitat and nursery grounds, food sources for larger organisms. This can provide important income from commercial fisheries including tuna, mackerel, mahi—mahi, jacks, snappers, lobsters and crabs.	Yes – provide nursery and breeding habitats for offshore fisheries.
Fuel e.g. Wood fuel or Biomass				Yes – opportunity to use the mangroves to provide wood fuel.
Regulating				
Control of climate (local and global)	Yes – opportunity for carbon sequestration in the beaches/ dunes which could reduce the amount of Carbon Dioxide.	Yes – undertake carbon sequestration by using the carbon dissolved in sea water. This in turn reduces the amount of Carbon Dioxide.		Yes – undertake carbon sequestration by using the carbon dissolved in sea water. This in turn reduces the amount of Carbon Dioxide.
Flood and erosion protection and regulation	Yes – attenuate wave reducing the risk of coastal flooding. Also provides sediment stabilisation and soil retention in vegetation root structures to reduce risk of erosion.	Yes – seagrasses can attenuate waves, protecting the shoreline. Also provides sediment stabilisation which can control beach erosion.	Yes – coral reefs attenuate or dissipate waves which facilitates beach and shoreline retention.	Yes – attenuate waves and reduce storm surges. Also stabilise sedmiment and retain soil in their root structure to reduce shoreline erosion and deterioration.
Water quality		Yes – seagrasses remove sediments from the water column and decrease the	Yes – nutrient cycling provides biogeochemical activity, sedimentation and	Yes – water purification functions protect coral reefs, seagrass beds and

Ecosystem service	Beaches and Dunes	Seagrass	Coral Reefs	Mangroves
		concentration of suspended particles by increasing the rate of deposition.	biological productivity.	navigation waters against siltation and pollution.
Cultural				
Tourism and recreation	Yes – provide an important recreational benefit including boasting, fishing, swimming, scuba diving, walking, beachcombing and sunbathing.	Yes – provides unique and aesthetic submerged vegetated landscapes, which increase flora and fauna. Supports recreational activities SCUBA diving, snorkelling, island tours and sport fishing.	Yes – provides unique and aesthetic reefscapes which supports an abundance of recreational activities such as SCUBA diving, snorkelling, island tours and sport fishing.	
Species diversity	Yes – coastal dunes and beaches can provide maintenance of wildlife in the form of habitats for fish, shellfish and rodents.	Yes– seagrass provides a nursery habitat for many species including juvenile fish and crustaceans.	Yes – the sequestration of calcium carbonate is the primary reason for the high abundance and diversity of organisms.	Yes – mangroves provide a nursery habitat for many juvenile fish.
Scientific and knowledge values	Yes – beaches provide research opportunities for work that is essential to basic and applied science.	Yes – seagrass provides research opportunities for work that is essential to basic and applied science.	Yes – coral reefs provide research opportunities for work that is essential to basic and applied science.	Yes – mangroves provide research opportunities for work that is essential to basic and applied science.

** Ecosystem services based on paper by Barbier et al, 2011.*

There are two elements to an ecosystem services approach that are discussed below: scoping process including identifying high level mitigation and assessing the value of the ecosystem services provided under **interventions**.

<u>Scoping process including identifying mitigation:</u>

A project should start out by mapping the ecosystem services in the location. The mapping (derived from models/data/expert judgement) should combine to identify areas important for the provision of multiple ecosystem services. This exercise will allow the project to:

- Identify areas that are already providing/regulating multi-functional services or which represent opportunities for the enhancement of the ecosystem service; and

- Identify locations where high areas of importance/risk or opportunities in the individual services coincide. These locations can then be considered as important targets for measures to enhance the provision of multiple ecosystem services.

At the strategic level the project should then assess:

- *Multi-functional Service Provision Areas – Risk of Loss.* Where are services already being provided? These are areas at risk of degradation and where preservation, protection, and maintenance efforts should be focussed.
- *Multi-functional Services Opportunity Areas.* Where are the opportunities for the provision of multiple services to be enhanced?

It is recommended that at least a high level consideration of the above is undertaken, and the proforma presented in Appendix D can be used to do this. The results from this should then feed into assessing and developing the **interventions** for implementation.

Case Studies: Assessing beach interventions through an ecosystem services approach

In the case of an example of a beach, taking an 'ecosystem services' approach would look at restoring the ecological function of the beach, including the area at the back of the beach that could supply sand to the beach – and the near-shore area that appears to have no sand at all. This would involve consideration of the dynamics of the whole beach and the impacts that are currently affecting the sand erosion. There could be the potential to increase **biodiversity** in the area immediately adjacent to the beach (maybe through planting local species and landscaping the area) which would also improve tourism and recreation values as well as vegetating the back beach area to create beach stabilisation, reduce erosion and increase **biodiversity**.

<u>Assessing the value of damages and benefits.</u>

There are several different ways to value and quantify ecosystem services and the potential damages and benefits associated with an **intervention**. The World Bank WAVES programme (World Bank, 2016) recommends a process-resolving approach to assess damages and benefits using the Expected Damage Function. There are 5 core steps described:

1. Estimate offshore **hydrodynamics**;
2. Estimate nearshore **hydrodynamics**;
3. Estimate effect of coastal structure (habitats) on **hydrodynamics**;
4. Estimate flood or erosion; and
5. Assess expected and averted damages.

Further Sources of Information for Economic Assessments:

A detailed explanation of how to perform an economic assessment (using existing UK methodology) can be found within Penning-Rowsell *et al.,* 2005. *'The Benefits of Flood and Coastal Risk Management: A manual of Assessment Techniques'* and its accompanying Multi-Coloured Handbook.

Global Facility for Disaster Reduction and Recovery (2016). The making of a riskier future: How our decisions are shaping future disaster risk. Washington USA: GFDRR.

Sources of information for valuing ecosystems services include:

National Oceanic and Atmospheric Administration (NOAA), (2015). A guide to assessing green infrastructure costs and benefits for flood reduction. NOAA: Economics of Green Infrastructure.

World Bank. (2016). Managing coasts with natural solutions: Guidelines for measuring and valuing the coastal protection services of mangroves and coral reefs. Wealth Accounting and the Valuation of Ecosystem Services Partnership (WAVES), World Bank, Washington DC.

Yohe, G., *et al.,* (2010). On the economics of coastal adaptation solutions in an uncertain world. Climate Change 106: 71-92.

C2: Design Considerations

C2.1: Agreeing and Achieving Intervention Outcomes

In order to provide a sustainable **intervention** which meets the required objectives, **intervention** outcomes should be determined through assessing the required performance standards and design standards.

From a planning perspective, the design standards are likely to relate to the desired coastal **standard of** protection and the duration for which the protection should be provided to be compatible with the current and future land use and the surrounding environment.

The engineering design standards proposed for shoreline protection **interventions** (Part D) for Jamaica are based on those provided by British Standard, American Standard, EN Eurocodes and other Industry recognised relevant design manuals and guidelines. For **nature-based interventions** there are far less number of standards and guidelines available and several key guidelines have been referred to throughout Part D. They should be adapted to reflect Jamaican needs and situations (where possible or where available information allows this to be dictated). They ensure a uniform level of building quality to ensure consistency.

The design standards to be used should be considered at the start of the project when defining the aims and objectives of the project, and for large projects or developments, agreement of these outcomes and standards should be made with the PIOJ through an initial technical review meeting (see Part E3).

Intervention outcomes are likely to cover a wide range of topics and the following elements in Table C3 should be included, where applicable. It is important to stress that these performance outcomes are designed to ensure that resiliency (see Chapter B) is incorporated directly into the structure of all future coastal developments. The performance outcomes will need to be assessed within all Environmental Management Plans prepared and all mitigation measure assessments. This is to ensure that the following aspects are addressed:

- **Intervention** design conditions account for climate change effects;
- There is an assessment of the adequacy of the design of **interventions**;
- Consideration is always given to building resilience into **intervention** design (to optimise performance); and
- There are basic assessments of how flood risk (e.g.: **overtopping** of existing coastal defence **interventions**) and erosion risk may change and how this relates increasing risk to vulnerable populations and assets.

Table C3 Table listing outcomes which should be considered when designing coastal interventions and how to achieve those outcomes.

Outcome	Steps to achieve the outcome
Works shall be consistent with the current and envisaged future land use plan prepared for the area to protect existing assets and planned coastal dependent development.	• Flooding/erosion threats are reduced to an acceptable level consistent with the planning horizon of facilities requiring protection; and • Where flooding/erosion protection **interventions** are necessary, maintaining physical coastal processes outside the area subject to the coast protection work is required to avoid adverse impacts on adjacent coastline and associated ecosystem.

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Works are to mitigate any increase in risk to people and property from flooding/coastal erosion considering climate change and future planning needs.	• Installing and maintaining on-site flood/erosion control **interventions** (see Part D); • The practical **design life** of the **intervention** in the context of future flood/erosion threat; • Designing **interventions** which can be adapted in the future to become more **resilient** to environmental changes; and • Installation and maintenance of coastal protection **interventions** to mitigate adverse impacts to people and property from coastal flooding and erosion at the location.
Works do not impact adjacent coastlines.	• Maintain sediment volumes in beaches and the nearshore coastal landforms and where this cannot be avoided entirely or in part, any resulting coastal flooding or erosion of the development area is mitigated by the choice of location, development of the design and construction and the application of appropriate operation/performance standards; • Ensure that the physical coastal processes outside the development footprint are maintained or enhanced where possible including alongshore sediment transport; • Ensure there is no risk of shoreline erosion for adjacent areas to the development footprint unless suitable shoreline/beach control **interventions** are incorporated in the development; and • Ensure there is no risk to near-shore ecosystems and the services that near-shore ecosystems provide.
Works do not impact or remove seagrass meadows, or where necessary undertake relocation of the seagrass.	• Ensure that there will be no change to the suspended sediment concentrations in the nearshore; • Ensure that the construction footprint does not encroach into the seagrass areas; and • If impacts cannot be avoided (should be a last resort) undertake translocation of the seagrass with appropriate monitoring and maintenance undertaken.
The preference to the adoption of **nature-based or hybrid interventions** as presented in Part D.	• When considering an **intervention** consider all relevant **interventions** for the Coastal Management Unit as presented in Part B4. • Refer to Part D for possible hybrid solutions.
If beach nourishment or beach recycling are proposed, then it is a requirement to ensure that the sediment transport processes are not impacted.	• Confirm that such works are suitable for the location; • Ensure that the material sourced is of suitable quality and grading which matches that of the material found at the location of recharge; • Adopt methods and procedures suitable to the location and do not interfere with the long term use of the locality or environmental values within the location or neighbouring areas; and • Ensure that the material supply source has sufficient material to maintain the longshore littoral process and coastal landforms in the recharged area.
Shoreline protection **interventions** built in areas of high ecological significance shall not adversely impact on the	• Retain vegetation in the areas to the extent possible to stabilise land and prevent soil erosion and water quality impacts off the development area; • Rehabilitation of undeveloped areas of the site following completion of development;

natural function of those areas.	• Ensuring alterations to natural landforms, **hydrology** and drainage patterns on the development site do not have significant impact on the adjacent areas; and • Where impacts outlined above cannot be avoided these shall be minimised and environmental offsets with appropriate monitoring and maintenance are provided for any residual impacts.

C2.2: Design Parameters

Following the consideration of the site, potential hazards and impacts influencing the design (C1.2), and the expected outcomes of the project (C2.1), the technical information required for the detailed design must be considered. Several elements should be considered and are discussed below:

- Pre-construction considerations: surveys and data required to influence the detailed design of the **intervention**;
- Consideration of climate change, ensuring that the design suitably accounts for future change as well as present day conditions; and
- The materials which will be used in the design of the **intervention**.

C2.2.1: Pre-construction considerations

In order to progress the design of any **intervention** (**nature-based and hard interventions**) it is paramount that existing site data such as previous study reports, drawings, surveys, and maps are collected from archives and institutions and reviewed to identify the adequacy and appropriateness for the design works to be carried out in that location. A list of additional design data required to assist with the design should be drawn up. Relevant study specification should be prepared and procured from relevant industry recognised institutions such as coastal research organisations, universities, governments, and private institutions involved in collection and storage of meteorological and geological/geotechnical data and their analysis.

This information should include (but is not limited to) the below which is summarised in Table C4.

Geological/Geotechnical Conditions

- Geological data from maps and reports to get an understanding of coastal evolution and sub-sea geology.
- Geotechnical data from results of previous borehole and trial pit investigations to determine the structure and composition of seabed overlying material and underlying material strata including depth to bed rock, type and quality/strength of rock and assist with the structure design.

Surveys

- Topographic survey of **foreshore**, structures and hinterland extending down to mean low water of springs – to supplement existing data.
- Bathymetric survey of near shore area extending from seaward from mean low water springs (MLWS) (if possible depending on available draft for survey vessel) down to sufficient water depth offshore where wave breaking is not pronounced.
- Survey of existing coastal **interventions** (seawalls, revetments, embankments, beach control structures, navigation aids etc.) and adjacent coastline and hinterland survey comprising visual inspection of their condition, form of construction and dimensions.

- Ecological mapping of existing coral reefs, seagrass meadows and mangroves to map the extent, health, and species/**biodiversity**.

Met. Ocean data

Existing data should be reviewed and supplemented by additional field studies involving the installation and collection of oceanographic data and analysis as outlined below:

Water Levels

- *Astronomical tides* shall be obtained from relevant tide tables where possible from the predictions for standard port and the specified corrections for non-standard port in close proximity to the development site. In the absence of suitable non-standard port tidal data correction in the tide tables, tidal measurements are made by installing a tidal gauge in a nearby sheltered location (minimise wave influence) and the results are analysed to determine the harmonic constants for the tides at the site and the necessary corrections applied to the standard port data to determine the astronomical tide levels at the site.
- *Surges and Still Water Levels* – Obtained by the purchase and use of long-term tidal records and subsequent analysis of this data. The tidal data could be obtained by access to previous study reports and/or from the nearby port authorities or oceanographic research and meteorological institutions. From the measured and predicted tidal data the surge component is isolated and analysed by different methods to determine extreme values of surges and still water levels and by using appropriate statistical distribution. The extreme still water level for different return periods can also be determined using the annual maximum water level values directly if sufficiently long data set is available for statistical analysis.

Offshore and Inshore Waves

- *Offshore Waves* – Obtained by the purchase and use of long-term wave records including hurricanes and subsequent analysis of this data. The data can be sourced from previous study reports for the site or nearby developments or by access to oceanographic and meteorological research institutions global wave model data. The global wave model is an atmospheric driven model (barometric pressure and wind) and calibrated using measured data The offshore data is obtained from the model grid point nearest to the site and analysed to determine the monthly, seasonal, and annual offshore directional wave height distribution. This information is then used to determine the normal and extreme offshore wave heights using appropriate statistical distribution. If the wave model point location is too far offshore and does not accurately represent the sea bed features offshore of the site, the offshore data could be refined, by carrying out wave measurements at a location in deep-water offshore of the development site, say 15 to 20m seabed contour as appropriate and located near the boundary of the numerical inshore wave model which would later be used for the inshore wave translation to determine the wave height at the structure.
- *Inshore waves* are determined by translating the offshore waves inshore to the location of the structure by numerical modelling using industry standard modelling suites (MIKE 21, SWAN etc.). The model input must include the offshore wave height/direction and periods (in the form of time series or directional distribution) and seabed bathymetry. The model is calibrated using short-term measured data by installing a wave recorder in near shore

C

location, say at 5 to 8m seabed contour for a period of minimum of 4 to 6 months, preferably longer capturing seasonal variations in storms.

Wind - The directional mean wind speed and gusts can be obtained by access to the long-term records available to the local and international meteorological stations and institutions and local airport authorities. The wind data (mean wind speed and gust) are analysed to determine the directional monthly, seasonal, and annual distributions. The extreme wind speeds (mean hourly and gusts) are then derived using appropriate statistical distribution.

Current data are, in general, obtained from on-site measurements using current meter. The data so collated are then analysed to determine the tidal currents and direction. The wave-induced currents, which are used in the assessment of longshore littoral movement of beach material and resulting shoreline erosion/**accretion** are generated by inputting the near-shore waves and wind information derived from data analysis into a **hydrodynamic** numerical model (tidal model).

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Case Studies: Collecting sea temperature data as part of Portland mangrove restoration project (part of GOJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction Project)

NEPA deployed HOBO pendant temperature/light data loggers to assess temperature within the water columns with a purpose to track trends and changes in sea temperature. Rotations were to occur at 60 day intervals. Project was carried out November 2011 – October 2013 with total of 27 loggers.

The installation process involved a team of divers locating a suitable area of reef at a depth not exceeding thirty feet for sites that had been pre-selected. Once the ideal site had been identified, a length of steel roughly a foot and a half in long was driven into the hard substrate using a 7 pound sledge hammer. Once the steel was secure, the logger was strapped to the rebar using standard plastic cable ties. This position was marked using GPS.

<u>Lessons learnt (taken from NEPA, 2013b):</u>

Theft of data loggers: Issues with theft of data loggers/ removal from installation sites were experienced. Prior to the installation of data loggers in an area, sensitization meetings were attempted to inform the public of the purpose of the device to reduce the number of incidences of data logger theft. In addition during interactions with fellow divers, snorkelers and hotel water sports operators, information was relayed. From this point forward, community and resource user sensitization became an important and ongoing process.

Flooding and Corrosion: Flooding of the data loggers was another unforeseen situation that occurred with some of the units. Once the logger seal is breached, the logger takes in sea water which corrupts and erases all data that would have been captured prior to flooding. The salt water led to corrosion of the loggers which were no logger functional. Flooding occurred with Negril (Orange Bay) data logger on two occasions. A possible solution to this was to use silicone gel to seal the caps (o-rings) of the loggers before deployment.

Table C4 Summary of potential data requirements for design.

Type of data	Data	Source of data
Geological / Geotechnical Conditions	Geological environment, including sub-sea geology	• Geological maps • Previous reports
	Geotechnical including depth to bed rock and type and quality of rock	• Ground investigations including borehole and trial pit investigations
Surveys	Topographic information	• Topography survey or LiDAR
	Bathymetric information	• Bathymetric survey
	Condition and residual life of defences	• Asset inventory • Condition survey
	Ecological features and baseline	• Previous reports • Ongoing monitoring • Ecological mapping
Met. Ocean – Water Levels	Astronomical tide data	• Tide tables • Corrected for specific site if possible • Tide gauge installation and monitoring
	Surge and still water levels	• Analysis of long term tidal records from previous study reports, port authorities or oceanographic/meteorological institutions
Met. Ocean – Offshore and Inshore Waves	Offshore waves	• Long term wave records from previous study reports, nearby developments or oceanographic/meteorological institutions • Global wave models
	Inshore waves	• Using **hydrodynamic** models to translate offshore waves to the location of the structure
Met. Ocean - Wind	Directional mean wind speed and gusts	• Long term records from local and international meteorological stations and institutions • Local airport authorities
Met. Ocean - Currents	Wave-induced currents	• On-site measurements using a current meter

C2.2.2: Climate change

The impacts of climate change due to global warming on coastal communities, developments, and assets (such as increased coastal flooding and erosion) are addressed by the provision of both **nature-based and hard interventions**. These are designed to which would withstand the effects of SLR and increased storminess during the **design life** of the **interventions**. The latest recent Inter-Governmental Panel on Climate Change (IPCC) guidelines sixth edition (dated 2013) is now recommended as an accepted document in the industry for the design of coastal **interventions** to varying SLR scenarios. The IPCC document provides information on SLR allowances for different scenarios of harmful gas emissions and melting of ice cap and areas around the world. The recommended SLR allowance is added to the derived still water level to determine the design water level. Sensitivities can be undertaken using different scenarios to present best and worst case conditions.

There is currently no standard approach to designing for SLR in Jamaica. There is no set rate which is used, neither is there any set design period over which the rate of increase should be applied (e.g. a 25-year life versus 50-year or 100-year). Furthermore, there is no set design scenario that has been agreed on by the engineering professionals in Jamaica (e.g. IPCC's B2 scenario).

Taking into consideration SLR

A recommended way of assessing SLR is to develop a design period particular to the project and then estimate the future mean sea level at that time, incorporating the global SLR for the projected year based on the IPCC scenarios or the sources below. This can then be integrated into the assessment of water level, the highest astronomical tide and inverse barometric rise for the hurricane being modelled so as to establish a design water level. The combined design water level (deep water) is then incorporated into a numerical (wave transformation and/or **hydrodynamic**) model, the results of which further guide the design at the shoreline of interest. In some situations, based on analyses of tide signals at several stations in the northern Caribbean adjacent to Jamaica, it may be appropriate to incorporate an allowance for thermal expansion, a phenomenon that is experienced primarily between July and November, a period which unfortunately coincides with the hurricane season.

SLR Sources

IPCC - global SLR projections for a number of emissions scenarios - https://www.ipcc.ch/index.htm

In 2018 the IPCC are scheduled to issue a paper assessing the impact of a 1.5 degree rise in global temperatures - https://www.ipcc.ch/report/sr15/

PRECIS Caribbean Initiative Project - There is currently research being undertaken looking at more regional models that could help develop the IPCC projections. PRECIS utilizes Regional Climate Models to give better projections by downscaling climate scenarios to provide higher resolutions over smaller areas.

For further consultation and data on:

- Long-term sea level rise – contact the Climate Studies Unit at UWI MONA - https://www.mona.uwi.edu/physics/csgm/home
- Storm surge related sea level rise – contact the Mines & Geology Division (Ministry of Transport and Mining) who carry out post-storm data collection surveys - http://mgd.gov.jm/

C2.2.3: Materials

The type of material to be used within the construction of a coastal **intervention** depends on:

- The type of **intervention**;
- The exposure of the site to environmental loads such as wind, waves, current, water level, etc.;
- Land use (current and future);
- Type and condition of **foreshore**;
- Geotechnical issues such as depth and type of founding material, and its susceptibility to erosion;
- Environmental status of the site and its surroundings; and
- The availability of material supply in Jamaica.

Materials used in coast protection works vary depending on whether **nature-based or hard interventions** are proposed and would typically be one or more of the following:

Nature-based interventions:

- Sediment (used for beach recharge/re-profiling and also used within sand bags);
- Timber (used in picket fencing, thatching, footpath management and general fencing);
- Vegetation (beach vegetation used to stabilise a beach in addition to sea grasses and mangroves);
- Artificial and natural substrate for corals; and
- Mangrove and seagrass plants.

Hard interventions:

- Concrete (in sloping and vertical sea walls, groynes, **scour** mattresses (fabriform, etc.) but highly reflective);
- Rock (as armour in revetments/embankments/ groynes/ **scour** protection at toe of cliffs and sea walls/ infill to gabions and **scour** mattresses);
- Masonry in seawalls and sloping revetments (dry or mortared);
- Timber (hardwood) used in groynes, piling, breastwork, cribwork;
- Steel used in seawalls as foundations and retaining walls;
- Geotextile (geotextile bags used for sand bag structures as well as in rock structures); and
- Asphalt mastic used in combination with sand/aggregate as coverlayer protection to sloping revetments (as open stone asphalt and lean sand asphalt).

Part D of these Guidelines goes on to look at each **intervention** in more detail, including referencing design parameters and materials specific to that **intervention**.

Case Studies: Material Source – Old Harbour Bay Wave Attenuation Units (part of GOJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction Project)

At Old Harbour Bay, the GOJ worked with local fishing community to develop wave attenuation devices to reduce erosion risk whilst facilitating boat access and fishing needs. During the construction, there were problems with the concrete supplier not fulfilling his duty. A secondary supplier had to be found and this caused delayed progress on several days which had been designated for concrete pouring. Having secondary or back-up suppliers can reduce the risk of incurring delays during construction if there is an issue with the material supply.

Summary

- This Part of the Guidelines sets out suggested processes and methods to follow as steps from starting a project within the coastal zone to designing and obtaining planning permission for the **intervention**.
- Preliminary studies are important to define the current and future risks within the **R2R profile** at the study location, in addition to facilitating assessment how this may change once the intervention is implemented.
- A number of design outcomes are required to be assessed to ensure that the **intervention** does not adversely effect the environment, is designed to be **resilient** and does not impact other sites along the coastal zone.
- This Part further presents key design considerations including: technical data and design parameters, consideration of **climate change** and materials.

Part D: Designing **Interventions**

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.

D1: Hard interventions, Nature-based Interventions and Hybrid Interventions

D2: Nature-based Interventions

D3: Hard infrastructure measures

D4: Non-structural solutions

Contents

D

D1: Hard interventions, Nature-based interventions, and Hybrid Interventions

D1.1: Types of Interventions

Generally, the type of shoreline or flood protection **intervention** can be split into different types:

- **Nature-based interventions** - projects that are inspired and supported by nature. They provide habitat for plants and animals through careful consideration of the site and strategic placement of components along the entire **R2R** profile. Within the wider literature, these types of interventions are also sometimes referred to as green infrastructure, natural infrastructure, living shorelines, and soft engineering.
- **Hard interventions** – describes engineered, structural solutions such as sea walls, breakwaters, levees etc. Within the wider literature, these types of interventions are also sometimes referred to as grey infrastructure.
- **Non-structural interventions** - relates directly to planning for a change and is often applied in situations where there are no immediate benefits in investing in **hard or nature-based interventions.**

Parts D2 to D4 of these guidelines look at specific measures within each of these categories in further detail.

D1.2: Importance of Nature-Based Interventions

Corals reefs, seagrass meadows and mangrove forests are very important marine ecosystems which provide invaluable ecosystem services such as natural shoreline protection from storm events, nurseries and feeding grounds for marine life, fisheries (food security), potential sources for pharmaceuticals, carbon storage, and habitat for **biodiversity** conservation among many other things (Chatenoux and Wolf 2013; European Commission, 2015; Guannel *et al.,* 2016; Monty, 2016; Narayan *et al.,* 2016; Sutton-Grier *et al.,* 2015). For multiple reasons (natural and man-made), these critical ecosystems have seen a decline in cover and thereby function. For example, shallow water Caribbean reef-building corals (Acroporid sp.) have declined 80-99% (Smithsonian Institution, 2009) from their historical population levels. This dramatic decline is negatively impacting the structure and function of reefs throughout their range, and has reduced their ability to carry out ecosystem services such as shoreline protection, sediment supply and habitat for fish and shellfish.

Corals reefs, seagrass meadows, mangrove forests, beaches, sand dunes, and sand bars/barriers retain water and dissipate wave energy, acting as a buffer against tidal waves, storms, and coastal flooding. Restoration activities can promote these natural functions such as mangrove regeneration and dune naturalisation. A key benefit of **nature-based interventions** over **hard interventions** is that they often increase the **resilience** of existing ecosystems and provide a wide range of benefits for other sectors, such as tourism, fisheries and coastal protection.

In the past decade, our understanding of the value of ecosystem services has gained traction with policy-makers and become more mainstreamed into coastal management and policy making. A large amount of research now exists to assess the important role ecosystems can have on disaster risk reduction and to highlight the importance of reducing ecosystem degradation to increase **resilience.** It is generally accepted (e.g. European Commission, 2015; Guannel *et al.,* 2016; Monty, 2016; Sutton-Grier *et al.,* 2015) that environmental management is required as part of any comprehensive disaster management plan, as it helps reduce exposure to hazards (e.g. extreme weather events, tsunamis) and promotes rapid recovery and reconstruction of natural coastal infrastructure. Good practice in environmental management can increase the **resilience** of coastal ecosystems and therefore decrease vulnerability of coastal communities and coastal infrastructure. Species and genetic diversity within ecosystems can contribute to the **resilience** of the ecosystem to disturbances, enhance the protective services they provide and contribute to the social **resilience** (Monty, 2016). Part C and Appendix D looks at integrating ecosystem services into coastal management decisions in Jamaica in further detail.

Furthermore, research suggests that it is important to look beyond a single habitat, and that the best approaches consider the entire seascape. For example, seagrasses and corals can reduce coastal erosion by dissipating wave energy and in so doing, increase the stability of the shoreline for mangroves, which in turn offer better protection during larger storm events: *"we find that together, these habitats substantially moderate incoming wave energy, inundation levels and loss of mud sediment, and ultimately protect the coast better than any one habitat alone"* (Guannel *et al.,* 2016).

The use of **nature-based interventions**, despite the overwhelming evidence of their potential to provide multiple benefits, is often not considered in detail due to the perceived risks around costs, potential for success, requirements for immediate protection/improvement and uncertainties regarding future change. Thus, when considering **nature-based interventions**, the following key questions must be assessed and answered to provide greater confidence in this option (European Commission, 2015):

1. Is the proposed measure effective in addressing the problem?
2. What are the most effective means of establishing and maintaining the green solution?
3. How does the effectiveness change with local conditions?

D1.3: Nature-based interventions in Jamaica

The majority of Jamaica's population is situated on or near the coastline and for decades, **hard interventions** or engineering structures have been used to provide coastal protection and safety for its people and infrastructure. Jamaica's approach to utilizing **nature-based interventions** as a tool for shoreline protection and coastal management is decentralised and commonly arises as a secondary consequence of conservation activities.

One of the more historic **nature-based interventions** that has been used in Jamaica are Jamaica's beaches. Beaches are a natural coastal defence that offer protection to the hinterland from erosion, flooding and encroachment by the sea. Beaches act as a natural buffer as they efficiently dissipate wave energy. This reduces damages to hard landforms at the back of the beach, and assets in the hinterland due to **overtopping**, flooding, erosion, or direct wave action. Additionally, beaches provide an amenity values for the local residents and help to support the local tourism economy. Historically, management of beaches as a coastal defence has included protection and conservation of natural beaches, beach nourishment/recharge, beach recycling and the creation of artificial beaches.

More recently there has been a surge in the use of **nature-based interventions** with varying goals in mind. In most instances shoreline protection is not the primary goal or objective, and often an indirect, long-term outcome. **Nature-based interventions** in Jamaica are mostly implemented by non-government organisations, including private and academic entities, with guidance and requisite permits from relevant government authorities. They are often the result of a conservation programme or mitigation activities associated with construction works.

> Port Royal Marine Lab and Discovery Bay Marine Lab (UWI) are undertaking research on different seeds which can be used in **nature-based interventions.** This research will help determine the most effective species to use in different Jamaican environments.

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It is reasonable to assume that the absence of **nature-based interventions** specifically targeted toward shoreline protection is associated with the difficulty in precisely assigning and quantifying the benefits of these approaches. Additionally, shoreline protection from **nature-based interventions** is often a long-term outcome that is coupled with the generally slow growth of coastal vegetation and corals. It can therefore take time for a **nature-based intervention** to fully function as an ecosystem and provide the full range of ecosystem services. Long term monitoring (see Part F of the guidelines) must become a key element to improve the use of **nature-based interventions** in the future.

Case Studies: Portland Bight – importance of coastal ecosystems

'Portland Bight' refers to the body of water between Portland Ridge and Hellshire Hills. The Portland Bight is located on the southern coast of Jamaica and spans southern sections of the parishes of St. Catherine, on its eastern side, and Clarendon towards the west. The area falls within the Portland Bight Protected Area (PBPA), which is the largest protected area in Jamaica. Its terrestrial area is 520 km^2 and represents 4.7% of Jamaica's land mass. Its marine space is 1356 km2 which is 47.6% of the island's shelf. The Caribbean Coastal Area Management Foundation (C-CAM) has been charged with managing zones within the protected area and produced the relief image shown here.

The largest town in Portland Bight is Old Harbour Bay. That settlement is largely residential with a population of 8,537 as of 2009. It should be noted that this figure may be under-reported as squatting is a serious issue for the area, and one which continues to worsen and increase in numbers. Major infrastructure in the surrounding area includes ports (e.g. Port Esquivel), railways, a section of highway 2000, factories and two power stations at Old Harbour Bay.

The Portland Bight is rich with **natural resources**. In addition to several healthy mangrove forests and salt marshes, particularly along the Salt Island Creek (shown below), the area also features 3 fish sanctuaries and is seen as highly beneficial to the south coast population for this reason. The Old Harbour Bay fishing community is the site of one of the south coast's largest fish markets. The seafloor around the Goat Islands features large areas of sea grass. Further it is reported that the Portland Bight is home to numerous endemic reptiles and amphibians - sea turtles, slider turtles, crocodiles, iguanas, galliwasps, anoles, polly lizards, ground lizards, boas, and frogs.

D

D1.4: Hybrid Interventions

Hybrid interventions use a combination of **nature-based and hard interventions** in order to provide immediate shoreline protection solutions while at the same time also providing wider benefits. A focus on **nature-based interventions** does not negate the need for physical infrastructure, as **nature-based and hard interventions** can often complement one another. Harnessing opportunities for reducing flood risk through natural processes can extend the life of structural defences and in addition reap multiple other benefits due to the synergies among different ecosystem services. Moreover, **nature-based interventions** generally require less investment and maintenance than **hard interventions**, thus providing a cost-efficient method of reducing the need for major structural projects. There are also growing concerns about the ability of 'fixed' engineered infrastructure to cope with impacts of climate change and thus a hybrid approach can be seen to be more adaptable to future uncertainties including climate change. For instance, it is known that healthy coral reefs can grow vertically at rates well in excess of the projections of SLR.

While there is still a lack of quantitative information regarding the use of hybrid approaches, particularly in terms of the storm protection benefits they can offer, it is also important to recognise that these approaches can bring wider benefits from diverse ecosystem services and increase the long-term adaptive capacity and **resilience** of wider coastal areas. Table D1 summarises the strengths and weaknesses relating to **hard, nature-based and hybrid interventions**. It is clear from Table D1, in addition to many reports and peer-reviews papers that **hybrid interventions** have the potential to enhance and strengthen the social, economic, and ecological **resilience** of coastal zones (European Commission, 2015; Guannel *et al.,* 2016; Monty, 2016; Sutton-Grier *et al.,* 2015). There is further evidence that over the long term, **hybrid interventions** may be more cost effective in comparison to **hard interventions** (European Commission, 2015; Sutton-Grier *et al.,* 2015).

Table D1 Strengths and weaknesses of hard, nature-based and hybrid interventions (adopted from Sutton-Grier et al., 2015).

Intervention	Strengths	Weaknesses
Hard interventions (such as sea walls, breakwaters)	▪ There is a lot of experience in undertaking these **interventions.** ▪ Expertise and guidance already exists. ▪ Will provide protection as soon as they are built. ▪ Detailed understanding regarding the design standards and protection that the **intervention** will offer.	▪ New structures required or structures must be modified to adapt to environmental change. ▪ Has a residual life which weakens over time. ▪ Can have negative impacts on coastal ecosystems and cause reduction in ecosystem services provided by the coastal zone. ▪ Generally, have limited wider benefits apart from storm/ erosion protection. ▪ Can experience more damage from ongoing small storm events compared to **nature-based interventions.**
Nature-based interventions (such as	▪ Can provide a wide range of benefits as well as shoreline	▪ There is less guidance and best practice available

coral reef or mangrove restoration)	protection including: fishery habitat, water quality, carbon sequestration, tourism enhancement, and recreation. ▪ If ecosystems are restored or replanted they often get stronger and more **resilient** over time. ▪ Have the potential to self-recover or repair after both small and larger storm events. ▪ Has the potential to naturally adapt and keep pace with environmental change and sea level rise. ▪ Can be cheaper compared to **hard interventions**. ▪ Has the potential to engage the local community and stakeholders in protecting, restoring, and enhancing coastal ecosystems that support their livelihood. In the long-term, this builds the adaptive capacity and **resilience** of coastal communities and ecosystems.	▪ Hard to predict the level of protection that will be provided ▪ Can provide varying levels of protection geographically ▪ Can take longer for the ecosystem to establish. ▪ Generally require more space for implementation compared to **hard interventions**. ▪ Limited data to allow quantification of benefits and comparison of benefit-cost ratios. ▪ Can be more difficult to gain planning approvals for these projects.
Hybrid intervention (combination of **hard and nature-based interventions**)	▪ Capitalises on the strengths of both hard and nature-based solutions. ▪ Provides opportunities for innovation. ▪ Can be used to provide wider benefits but where there is little space or there is a requirement for immediate protection. ▪ Has the potential to engage the local community and stakeholders in protecting, restoring, and enhancing coastal ecosystems that support their livelihood. In the long-term, this builds the adaptive capacity and **resilience** of coastal communities and ecosystems.	▪ Does not provide as many wider benefits as a **nature-based intervention.** ▪ Requires more research for best practice examples. ▪ Can still have some negative environmental impact.

D1.4.1: Examples of **Hybrid Interventions**

A number of different **hybrid interventions** can be undertaken:

- Temporary hard infrastructure - Natural approach can take a much longer time to establish and therefore hard infrastructure can be used to temporarily reduce disturbances with natural more long term.
- Protection of hard infrastructure - Natural infrastructure can be used to protect built infrastructure e.g. managed realignment – using salt marshes to reduce wave energies before they hit the hard infrastructure.
- Inspired by nature - Using designs inspired by nature to enhance the benefits provided by built infrastructure – such as adding rock pools to seawalls that mimic intertidal habitat. This includes submerged breakwaters which are designed to protect shorelines but also encourage **biodiversity**, in particular fish and lobster populations.
- Multiple lines of defence - Involves using environmental features (barrier islands, marshes) to complement hard infrastructure (levees and flood gates) as well as non-structural measures (raised homes and evacuation routes).

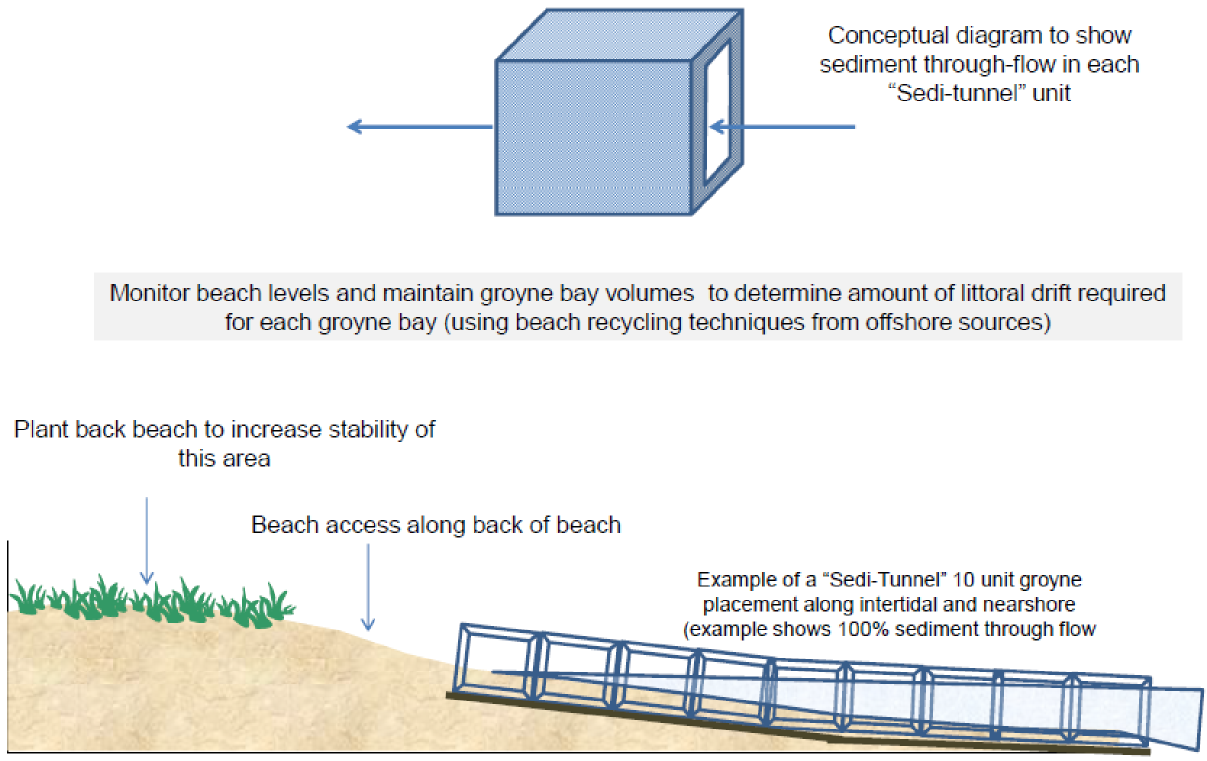
Examples of each type of infrastructure are provided below.

Temporary **hard interventions** – temporary groynes

Groynes are often used to contribute to **up-drift** sand deposition and beach consolidation, usually at the expense of **down drift** erosion problems. They can also lead to further complications especially if the constructions are poorly designed. Problems often arise if no consideration is given to their spacing, composition and height. As a result, significant alterations to the sediment regime can result around an island and importantly, may affect the quantity of material naturally passing by an island to neighbouring ones that maybe dependent upon these sediment supplies.

Engineering a **resilient** approach to this problem is important and the following technique has been piloted in Tonga. It combines sediment recycling with the construction of innovative concrete "unit" groynes ("Sedi-Tunnel groynes") to help maintain sediment dynamics and to create sand filled groyne bays in front of vulnerable areas. The philosophy behind the concept is that in areas where baseline data on sediment dynamics and budgets is lacking, a modular "pilot" approach to capturing enough mobile littoral sediment is preferred. This is an advantageous approach where **littoral drift** rates and the subsequent timing and amount of groyne bay "filling" can be managed to provide the necessary fronting beach protection required to protect hinterland assets and improve beach amenity. It can also be easily re-designed to ensure **down drift** erosion is kept to a minimum.

Figure D1 Example of "Sedi-tunnel" units



For this option, each groyne can be designed to be any length that is deemed appropriate. It is modular in its design and comprises of several units. Each unit shall rest on a purposely designed base unit that is buried to ensure the units remain secured in place. With each unit being placed on a base, the opportunity to re-orientate each unit by 90 degrees is presented in the design. This enables different rates of **littoral drift** to be experienced through the groyne structure and makes the approach more environmentally friendly than any other design of groyne (i.e.: existing rock structures are designed to block 100% of sediment movement between groyne bays). The design life of each unit (when exposed to salt water and encrusted with algae and marine crustaceans) is estimated to be circa 5 years. Thus, continued maintenance and "ownership" of such a scheme by the local communities is needed to ensure the scheme is a success and that unit replacements can be planned.

Protection of hard infrastructure – coral reefs

Coral reef functions similarly to a submerged breakwater (NRC,2014); a reef crest and reef flat have been found to reduce 97% of wave energy (Ferrario et al., 2014). This means that hard infrastructure at the shoreline will be partly protected from wave erosion and **scour**. In comparison to unhealthy reefs, live corals dissipate waves more and grow and accrete with SLR (Guannel, 2016), therefore providing a long term solution. Restoration of existing corals can therefore provide long term benefits.

Protection of hard infrastructure – seagrass meadows

Seagrass canopies have been found to modulate water flow and currents, contribute to wave attenuation, and retain and stabilise sediment in coastal areas (NRC,2007). In simulations it has been shown that seagrass meadows provided more protection than coral reefs alone by reducing the mean wave height and reducing bed shear stresses (Guannel, 2015).

In Negril, beach areas were found to experience less erosion when shielded by coral reefs and thick seagrasses than those that weren't (UNEP,2010).

Seagrass beds are more effective for small scale, high frequency events and not effective during storm surge flooding as frictional forces would quickly be reduced with higher water levels associated (NRC, 2014). It is also for this reason that SLR can make seagrass ineffective in reducing wave energies.

Protection of hard infrastructure – Mangroves

Mangroves could be used to protect hard infrastructure as they decrease wave energy as well as having additional benefits of stabilising the shoreline and retaining soil. The effectiveness of mangroves reducing wave energies is not limited by water levels and they can alleviate the impact of moderate tsunami waves as well as storm surges. In addition, they will also be more adaptable to rising sea-levels. In comparison to seagrass and corals, mangroves have been found to be the most effective habitat alone. However, in combination with seagrass and corals they can further help reduce the risk of shoreline erosion and sediment stability in the nearshore zone (Guannel, 2015).

Inspired by nature – using shoreline protection structures to also stimulate oyster growth

The primary goal of a coastal management project may be to prevent shoreline erosion along a coastal fringe marsh. The products used to protect the shoreline can be assessed not only against their ability to reduce wave energy and resist damage from the wave environment, but also to stimulate oyster growth and thereby increase the **biodiversity** in the immediate area. Through the use of an Oysterbreak™ System, both the shoreline protection and environmental goals can be obtained (this has been done in Louisiana to achieve said goals (Mott MacDonald, 2013)). Using this system, the shoreline protection units have been designed to not only attenuate waves and reduce erosion of sediment, but also to encourage oyster growth (Figure D2).

Figure D2 Example of use of shoreline protection structure which has been adapted to provide wider natural benefits. Picture shows installation of the concrete pods.

Inspired by nature – artificial reefs

Artificial reefs are submerged breakwaters which reduce wave energy reaching the shore as well as providing environmental, recreational and aquaculture benefits. In addition, they can contribute to the stability of beaches by reducing sediment transport and the loss of sand in an area (Harris, 2009). Depending on the artificial reef material, live coral can be moved away from areas at risk of being damaged and attached to the artificial reef (Harris, 2009), improving the structures ability to dissipate

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waves (Guannel, 2015). Artificial reefs provide habitat for benthic and pelagic flora and fauna which can be utilised for aquaculture of fish and lobster, providing diving and snorkelling amenity, and providing environmental mitigation and enhancement.

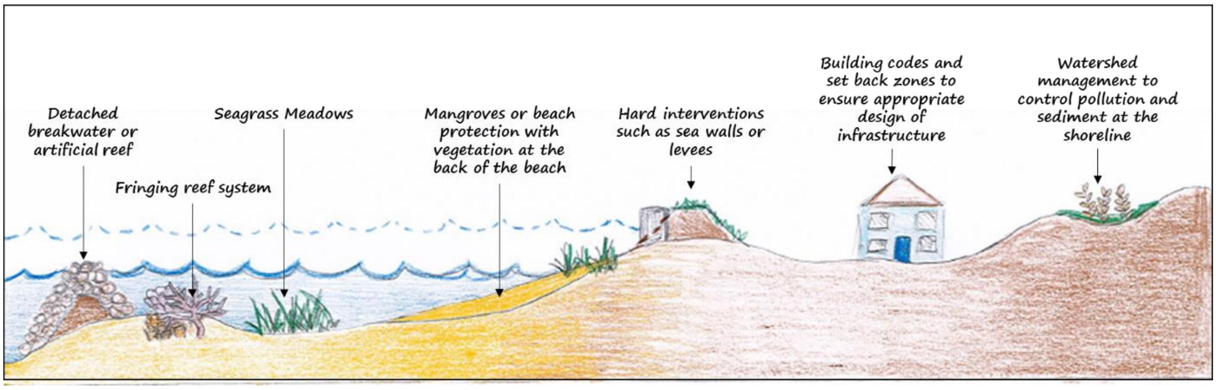
Case Studies: Reef Balls

Several companies specialize in the design manufacture and deployment of artificial reefs, typically constructed of limestone, steel, and concrete. Examples included the Reef BallTM which has significantly increase the beach width and elevation along the shoreline of a project in the Dominican Republic (Harris, 2009). However, in St Lucia, reef balls are no longer used after historic issues of them overturning during storm events.

Multiple lines of defence

Hybrid interventions should not be confined to considering only the combination of two **interventions,** but many **interventions** can be considered and undertaken over the **R2R** profile. Within Parts D2 to D4, the area within the **R2R** profile that the **interventions** can be applied has been noted. This information should be used to consider the strategic plan for the coastline. Generally speaking, the increased number of **interventions** which are used within a scheme is likely to increase the overall resiliency to future climate changes. Figure D3 presents a representation of how some of the **interventions** can be aligned and complement each other within a scheme.

Figure D3 Diagram to represent where several of the interventions can be placed within the R2R profile and how they can complement each other.



Upstream Management

Management across the **R2R** profile, from the hinterland to the nearshore, is critical. Given the close inter-connections between land, water and coastal systems in Jamaica, the integration of upstream activities with coastal area management is essential to foster effective cross-sectoral coordination in the planning and management of land, water, and coastal uses.

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Inherent in the delivery of coastal management across the **R2R** profile is the philosophy of cross-sectoral coordination in the planning and management of freshwater use, sanitation, wastewater treatment and pollution control, sustainable land use and forestry practices, balancing coastal livelihoods and **biodiversity** conservation, hazard risk reduction, and climate variability and change.

There are several hinterland activities that can affect coastal management. These cover different sectors and demonstrate the importance of cross-sectoral coordination. Some key issues for consideration are presented below:

- Pollution of river courses, drainage, and groundwater all leaks down to the shoreline and affects the water quality of the nearshore environment. This can be caused by: agricultural techniques, poor wastewater management, industry etc. The pollutants can cause degradation of shoreline and nearshore ecosystems which in turn affect wave attenuation (such as mangroves, seagrasses, and coral reefs) and sediment supply to beaches (coral reefs and seagrasses). Pollution affects the marine life, impacting fishing and tourism and the nearshore waters which can affect the recreational and tourism use of the coastline.
- Catchment management can affect the sediment supply to the coastline from the hinterland. In some areas, the beaches may rely on supply of sediment from rivers, particularly in coastal fan environments. Alternatively, in some environments such as mangrove areas, increased suspended sediment coming from the hinterland can decrease the health of the environment.
- One of the key risks for Jamaica's nearshore environment is that of overfishing. Food security is an important consideration for Jamaica's communities and increasing agricultural production inland could help alleviate the pressures and stress that are on the fishing industry.
- The hinterland can provide a source for sediments used to nourish beaches artificially. However, planning control of these sediment sources is required as the mining of these, particularly if un-licenced or unregulated, will remove vital sources for beach nourishment.

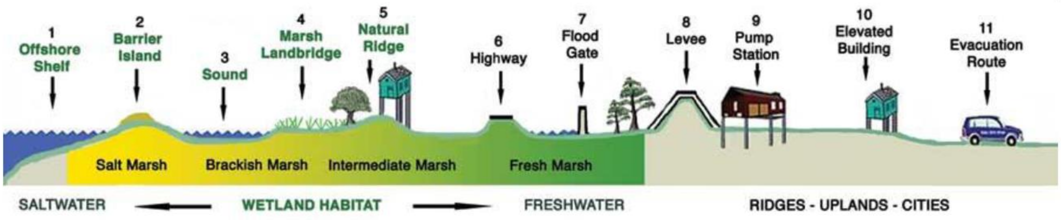
Case Study: Trenchtown, Kingston

Trenchtown in Kingston has an open storm water drainage system. However, particularly where the culverts are placed under the coastal road connecting this system, it is often blocked with rubbish and waste. When a heavy rainfall event occurs, this drainage system becomes overloaded and floods as cannot effectively drain into the sea affecting the local communities. Due to the rubbish and waste, this can cause problems of pollution and water quality, which can then impact the nearshore environment around Kingston.

Case Studies: Multiple Lines of Defence in Louisiana, USA

The strategy which has been adopted in Louisiana involves using environmental features (barrier islands, marshes) to complement hard infrastructure (levees and flood gates) as well as non-structural measures (raised homes and evacuation routes).

Figure D4 The defence strategy implemented in Louisiana which uses a wide combination of interventions to provide a more resilient and robust solution.



Source: National Science and Research Council, 2015.

D1.4.2: Choosing **Hybrid Interventions** in Jamaica

The potential for the use of **hybrid interventions** as a shoreline protection **intervention** has been highlighted throughout Parts D2 to D4. Under each **hard or nature-based intervention**, the potential for combination with other **interventions** to provide a **hybrid intervention** has been highlighted. These sections should be read alongside the coastal typologies presented in Appendix B and the Coastal Management Units presented in Part B to enable identification of where these interventions are most appropriate and what the site specific considerations need to be.

D1.5: Costs

Table D2 provides indicative cost ranges for different **interventions**. These ranges have been used on the **intervention** sheets in the following sections, Parts D2 and D3. It is to be noted that the cost of a construction scheme will vary significantly depending on the specific environment and location constraints. The cost ranges therefore provide only an indication of average regional costs for the supply of material and placement for the **interventions**. This cost does not consider the cost of preliminary studies, overhead management fees, specialised equipment/ working practices, design fees or environmental assessments or mitigation costs.

When considering an **intervention**, as outlined in Part C1, it should be noted that future maintenance and monitoring costs should also be considered. Part F considers the potential costs and requirements in further detail.

When referring the table below, please note that the "relevant **interventions**" row describes whether the **intervention** cost has been considered in unit cost per m^3, m^2, or linear m. Under the separate **intervention** sheets under D2, D3 and D4, the **intervention** has been given one, two or three money bags as per the table below. In some cases, there are different levels of one **intervention** which can be undertaken, and therefore some **interventions** have sub-options for that **intervention**, each which has been provided a cost.

Table D2 Indicative cost ranges for different interventions

	Cost / m^3	Cost / linear m	Cost / Hectare
Relevant Interventions	*D2.1 Natural Beach Protection* *D2.2 Beach Nourishment / Recharge* *D2.3 Beach Recycling* *D3.5 Land Reclamation*	*D3.1 Breakwater* *D3.2 Revetments* *D3.3 Seawalls* *D3.4 Groynes* *D3.6 Gabions* *D3.7 Flood Barriers* *D3.8 Levees* *D3.9 Sand Bag Structures*	*D2.4 Beach Vegetation Planting* *D2.5 Coral Reef Restoration* *D2.6 Mangrove Restoration* *D2.7 Seagrass Restoration* *D2.8 Wetland Management*
	≤ US$ 100	≤ US$ 1k	≤ US$ 100k
	US$ 100 - US$ 500	US$ 1k - US$ 5k	US$ 100k – US$ 1m
	≥ US$ 500	≥ US$ 5k	≥ US$ 1m

D2: Nature-based intervention

As discussed in Part D1, **nature-based interventions** are projects that are inspired and supported by nature. They provide habitat for plants and animals through careful consideration of the site and strategic placement of components along the entire **R2R** profile.

Corals reefs, seagrass meadows, mangrove forests, sand dunes, and sand bars/barriers retain water and dissipate wave energy, acting as a buffer against tidal waves, storms, and coastal flooding. Restoration activities can promote these natural functions such as mangrove regeneration and dune naturalisation. A key benefit of **nature-based interventions** over **hard interventions** is that they often show remarkable **resilience**.

The following chapter provides an overview of **nature-based interventions** including; where they can be positioned; the key design considerations required including preliminary studies required, cost, environmental impacts, hybrid opportunities, adaptability to climate change and **buildability**; case studies; and further data sources and references.

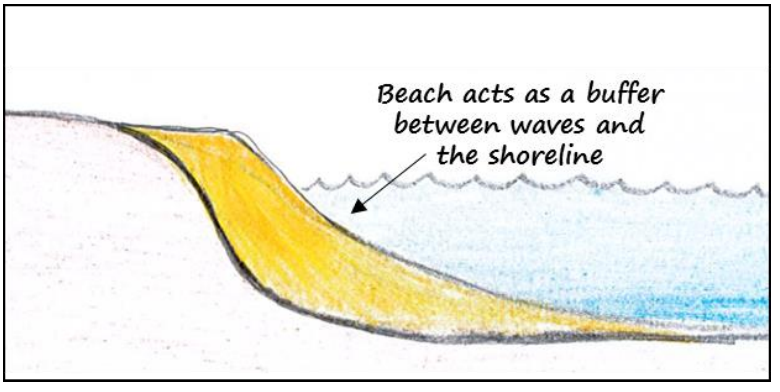
Reference should also be made to Part C (for stakeholder engagement and sea level rise guidance) and Part F (monitoring and maintenance requirements). Case studies are used throughout to exemplify **interventions**, and where possible Jamaican or regional examples are used. Occasionally international example case studies are used where they provide best practice examples. However, it is to be noted that whilst case studies can provide a context and best practice examples, often **interventions** required specific site conditions and cannot simply be completely replicated. Site conditions must be considered for the specific site when designing **interventions**.

D2.1 NATURAL BEACH PROTECTION

Build	×
Protect	✓
Accommodate	×
Retreat	✓

What is Natural Beach Protection?

Beach protection is the protection that the naturally existing beach, a coastal defence, offers to the hinterland from erosion, flooding and encroachment by the sea. Beaches act as a natural buffer as they efficiently dissipate wave energy. This reduces damages to hard landforms at the back of the beach, and assets in the hinterland due to **overtopping,** flooding, erosion or direct wave action. Natural beach protection is the protection/conservation of existing beaches, allowing the beach to develop naturally and not hindering its movement, rather than the enhancement of the beach itself. Through this process the beach retains its required coastal defence standards with no further **intervention**.



Where can Beach Protection be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	×

Key Design Considerations

Beaches are dynamic structures, and as such they respond to changes in the coastal environment over short- and long-term. These responses, such as landward migration, are natural to a beach and therefore should not be seen as a negative impact, however they do need to be considered for the management of the beach. A beach must be assessed to identify the **standard of protection** (SoP) it offers at present, and that at which it is likely to provide in the future. Backshore stabilisation measures such as picket fencing, vegetation planting or footpath management can be used to protect the existing beach alongside other measures. Where applicable, beach access needs to be provided in line with the Beach Access and Management Policy - Draft Policy 2014 (Part E).

Preliminary Studies Required

Beaches are frequently altered by coastal processes with the movement of sediment, and the resulting changes to the **beach profile** occurring continuously. The main natural processes (**longshore drift** and on-offshore movement) that alter beaches are driven by the following factors: wave and water level conditions, nearshore currents and wind conditions. Exceptional or extreme values of these processes are important for beach designers, as well as the current natural profile of the beach, however significant changes in beaches can be caused by frequent small events and seasonal variations.

CASE STUDY

Negril's Long Bay Beach is a long stretch of sandy beach which had stimulated growth of the tourist industry in the area.

However, Negril has seen a huge amount of erosion over the last few decades. Work assessing the cause of erosion has suggested the following causes:

1. Degradation of seagrass beds has led to a reduction in the volumes of sand being supplied.
2. Over the past five (5) years, the volume of sand on the beach has reduced due to a series of damaging hurricanes and severe swell events.

KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Water Levels
- Wind Conditions
- Crest Size / beach volume
- Health & Safety
- Sediment transport
- Sediment budget
- Storm responses
- Beach grading
- Records of maintenance activities
- Identification of areas of natural erosion and **accretion**

D2.1 NATURAL BEACH PROTECTION

Intervention	Natural Beach Protection
Cost	

As natural beach protection is the protection and conservation of the existing beach and does not require any structural **intervention** the cost of this **intervention** is minimal.

Environmental Impacts

A naturally occurring beach has little impact on the environment. Activities undertaken to maintain the beach such as beach recharge and recycling can be one of the most environmentally friendly and sustainable ways of reducing or reversing a beaches deterioration and thereby reducing the threats of coastal erosion and flooding.

Hybrid Opportunities

Natural beach protection is often paired with other **interventions** including **nature-based and hard interventions**. For example, groynes or an offshore breakwater may be used to reduce sediment loss within a coastal cell, beach vegetation planting could be used to stabilise the backshore, artificial coral reef creation could be used to reduce erosion or beach protection may be used in conjunction with a sea wall, to stop the toe of the sea wall being undermined through **scour**.

Adaptability to Climate Change

It is recognised that a healthy beach is probably the most effective form of sea defence (provided it is not constrained by space or material supply limitations) due to its ability to adapt its shape naturally to changing wave and tidal conditions and can dissipate wave energy. A beach can be designed for future SLR, with hybrid structures being used to account for climate change. However when incorporating hybrid structures, such as seawalls inland, the resulting effect of **coastal squeeze** should be considered, resulting in the erosion of beach material.

Buildability

Natural beach protection does not include a **buildability** aspect until other **interventions** are incorporated to protect or enhance the beach. As hybrid structures are developed the **buildability** is dependent on the additional structure.

Summary

- Beach protection is the protection that the beach, a natural coastal defence, offers to the hinterland from **erosion**, flooding and encroachment by the sea
- A healthy beach is probably the most effective form of sea defence due to its natural adaptability
- Natural beach protection entails the protection, maintenance and conservation of existing beaches, as opposed to any enhancement or maintenance of the beach itself
- An assessment is required to identify the **standard of protection** a beach offers

References and Data Sources

Relevant Policies:

NEPA (2000) 'A Beach Policy for Jamaica'

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

Discussion of Impacts and Risks:

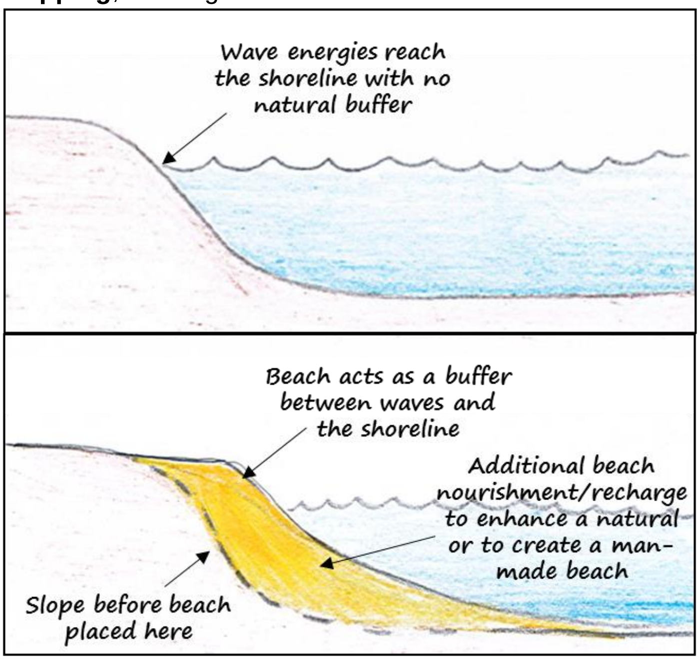
Cunniff, S. and Schwartz A., 2015. 'Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features'

D2.2 BEACH NOURISHMENT / RECHARGE

Build	✓
Protect	✓
Accommodate	×
Retreat	✓

What is Beach Nourishment / Recharge?

Beach nourishment / recharge incorporates the adding of beach material to an existing beach to maintain or increase the **standard of protection** (SoP) and the creation of artificial beaches where they did not exist previously. A beach is a coastal defence that offers protection to the hinterland from erosion, flooding, **overtopping** and encroachment by the sea. Beaches act as a natural buffer as they efficiently dissipate wave energy. This reduces damages to hard landforms at the back of the beach, and assets in the hinterland due to **overtopping**, flooding or direct wave action.



Where can Beach Protection be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	×

Key Design Considerations

Beaches are dynamic structures, as such they respond to changes in the coastal environment over short- and long-term. A beach must be assessed to identify the SoP it offers at present, and that at which it is likely to provide in the future. When required, the SoP of the beach can be increased or **coastal squeeze** can be reduced through;

- Beach nourishment / recharge
    - *the replacement of sediment lost from a beach or the addition of new sediment to increase beach volume. The frequency and volume is dependent on the design and the environment*
- Beach re-profiling
    - *involves the adjustment of the **beach profile** from its natural condition to an artificial one*
- Artificial beach creation
    - *involves the creation of a new beach by importing sediment to the location*

Where applicable, beach access needs to be provided in line with the Beach Access and Management Policy - Draft Policy 2014 (Part E).

CASE STUDY

The Palmyra hotel in Rose Hall, Montego Bay has a completely changed shoreline: from rocky, shallow, unusable pavement typical of the ‘Ironshore’ in Montego Bay to a lovely bathing beach with a sandy shoreline. The Palmyra beach works involved a Met.Ocean study, detailed numerical modelling of waves, currents, sediment transport etc. In order to create an artificial beach, nourishment was used alongside **hard interventions**.

Before

After

KEY DESIGN PARAMETERS

- Waves; Height / Length / Predominant Direction
- Water Levels
- Wind Conditions
- Average and storm conditions
- Crest Size / beach volume required for SoP
- Health & Safety
- Sediment supply and transport
- Sediment budget
- Storm responses
- Beach grading
- Records of maintenance activities
- Identification of areas of natural erosion and **accretion**

D2.2 BEACH NOURISHMENT / RECHARGE

Preliminary Studies Required

The main factors driving natural processes (e.g. **longshore drift**, cross shore storm response) that alter beaches and need to be considered are; wave conditions, water level variations, nearshore currents and wind conditions. Exceptional or extreme values of these driving factors are important for beach designers, in addition to (if applicable) the current natural profile of the beach, however significant changes in beaches can be caused by frequent small events and seasonal variations. When selecting beach nourishment material there is often a conflict between material required and material available, therefore the design of beach nourishment should consider offshore and land based sources available locally.

Intervention	Recharge	Re-profiling
Cost		

Environmental Impacts

If it is carried out in a sensitive manner, beach nourishment / recharge can be one of the most environmentally friendly and sustainable ways of reducing or reversing any beach deterioration and thereby reducing the threats of coastal **erosion** and flooding. Thought should be given to the sediment type and grain size used to ensure it does not impact the natural conditions. The environmental impacts of hybrid opportunities would need to be considered on a case-by-case basis.

Hybrid Opportunities

Beach nourishment / recharge is often paired with other **interventions** including **nature-based and hard interventions**. For example, groynes or an offshore breakwater may be used to reduce sediment loss within a coastal cell, beach vegetation planting could be used to stabilise the backshore, artificial coral reef creation could be used to reduce erosion or beach protection may be used in conjunction with a sea wall, to stop the toe of the sea wall being undermined through **scour**.

Adaptability to Climate Change

It is recognised that a healthy beach is probably the most effective form of sea defence (provided it is not constrained by space or material supply limitations) due to its ability to adapt its shape naturally to changing wave and tidal conditions and can dissipate wave energy. As a response to climate change and future SLR, the frequency and volume of beach nourishment / recharge can be increased as required. When incorporating hybrid structures, such as seawalls and other restrictions to movement inland, the resulting effect of **coastal squeeze** should be considered.

Buildability

The **buildability** of beach nourishment / recharge is relatively simple compared to other **interventions** available, however as hybrid structures are developed the **buildability** is dependent on the additional structure. Beach nourishment / recharge material is usually obtained from offshore sources with a similar grading to the natural beach and brought to site using seaborne transport, although there is the possibility of using inland resources and land transport. When beach recharge has been selected as an **intervention**, all relevant permits must be gained before works can begin.

Summary

- Beach protection is the protection that the beach, a natural coastal defence, offers to the hinterland from erosion, flooding and encroachment by the sea and is probably the most effective form of sea defence due to its natural adaptability
- Beach nourishment, recharge, control structures and stabilisation measures can all be used to maintain or increase a beaches **standard of protection**
- The frequency and volumes of beach nourishment / recharge are dependent on the design conditions and environment required to maintain the required SoP
- The **buildability** of beach nourishment / recharge is relatively simple, however as hybrid structures are developed the **buildability** is dependent on the additional structure

References and Data Sources

Relevant Policies:

NEPA (2000) 'A Beach Policy for Jamaica'

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

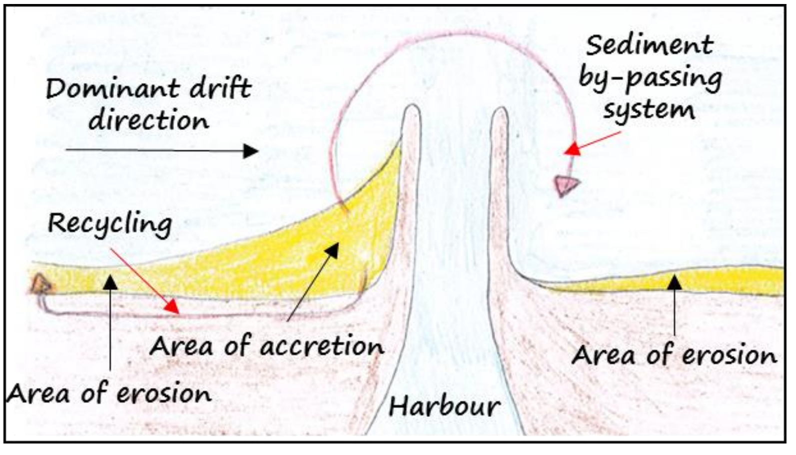
Discussion of Impacts and Risks:

Cunniff, S. and Schwartz A., 2015. 'Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features'

D2.3 BEACH RECYCLING

What is Beach Recycling?

Beach recycling is the process of collecting material from where it has naturally accumulated in a **downdrift** location and transporting it to the updrift end of a beach frontage on a regular basis. Beach recycling does not provide additional materials to the coastal cell, only redistribution. Beach bypassing is where material that is locally in excess of requirements and accreting against a structure such as a harbour arm causing a blockage is moved further along the frontage in the natural drift direction. A beach is a coastal defence that offers protection to the hinterland from erosion, flooding and encroachment by the sea. Beaches act as a natural buffer as they efficiently dissipate wave energy. This reduces damages to hard landforms at the back of the beach, and assets in the hinterland due to **overtopping**, flooding or direct wave action.



Build	×
Protect	✓
Accommodate	×
Retreat	✓

CASE STUDY

The mouth of the Negril River experiences blockage by longshore sediment transport. The beach material could be removed and placed back on eroding areas of the beach which would help reduce beach erosion as well as help maintain a clear mouth of the river. This has been done a number of times, however the frequency would need to be increased and the long term sustainability of this questioned.

Where can Beach Protection be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	×

Key Design Considerations

Beaches are dynamic structures, as such they respond to changes in the coastal environment over short- and long-term. These responses, such as **overtopping** or landward migration are natural to a beach and therefore should not be seen as a negative process, however they do need to be considered for the management of the beach. A beach must be assessed to identify the **standard of protection** (SoP) it offers at present, and that at which it is likely to provide in the future. When required, the SoP of the beach can be increased or **coastal squeeze** can be reduced through beach recycling; the movement of material from a **downdrift** location to the **updrift** end of a beach frontage on a regular basis. When considering beach recycling the sediment supply and transport within the coastal cell should be evaluated along with the effects of disturbing the existing process. Where applicable, beach access needs to be provided in line with the Beach Access and Management Policy - Draft Policy 2014 (Part E).

KEY DESIGN PARAMETERS

- Waves; Height / Length / Predominant Direction
- Water Levels
- Wind Conditions
- Average and storm conditions
- Crest Size / beach volume required for SoP
- Health & Safety
- Sediment transport
- Sediment budget
- Storm responses
- Beach grading
- Records of maintenance activities
- Identification of areas of natural erosion and **accretion**

D2.3 BEACH RECYCLING

Intervention	Recharge
Cost	

Preliminary Studies Required

The main factors driving natural processes (e.g. **longshore drift**, cross shore storm response) that alter beaches and need to be considered are; wave conditions, water level variations, nearshore currents and wind conditions. Exceptional or extreme values of these driving factors are important for beach designers, in addition to the natural profiles of the beach, however significant changes in beaches can be caused by frequent small events and seasonal variations.

Environmental Impacts

If it is carried out in a sensitive manner, beach recycling can be one of the most environmentally friendly and sustainable ways of reducing or reversing a beaches deterioration and thereby reducing the threats of coastal **erosion** and flooding. Environmental impacts to the local vegetation can be mitigated by avoiding plant tracking over vegetated areas etc. The environmental impacts of hybrid opportunities would need to be considered on a case-by-case basis.

Hybrid Opportunities

Beach recycling is often paired with other **interventions** including **nature-based and hard interventions**. For example, groynes or an offshore breakwater may be used to reduce sediment loss within a coastal cell, beach vegetation planting could be used to stabilise the backshore, artificial coral reef creation could be used to reduce erosion or beach recycling may be used in conjunction with a sea wall, to stop the toe of the sea wall being undermined through **scour**.

Adaptability to Climate Change

It is recognised that a healthy beach is probably the most effective form of sea defence (provided it is not constrained by space or material supply limitations) due to its ability to adapt its shape naturally to changing wave and tidal conditions and can dissipate wave energy. A beach can be designed for future SLR, with hybrid structures being used to account for climate change. However when incorporating hybrid structures, such as seawalls inland, the resulting effect of **coastal squeeze** should be considered, resulting in the erosion of beach material. It would be anticipated that the frequency of recycling required will increase with climate change.

Buildability

The **buildability** of beach recycling is relatively simple compared to other **interventions** available, however as hybrid structures are developed the **buildability** is dependent on the additional structure. Beach recycling can be undertaken using land or seaborne transport depending on access, tidal range, beach levels and the quantity of material to be moved. Shore parallel structures such as groynes can act as barriers making the transport of the recycled material along the beach more problematic. When beach recycling has been selected as an **intervention**, all relevant permits must be gained before works can begin.

Summary

- Beach protection is the protection that the beach, a natural coastal defence, offers to the hinterland from erosion, flooding and encroachment by the sea and is probably the most effective form of sea defence due to its natural adaptability
- Beach recycling is the process of collecting material from a **downdrift** location and transporting it to the updrift end of a beach frontage on a regular basis
- Beach recharge can be used to maintain or increase a beaches **standard of protection**
- If it is carried out in a sensitive manner, beach recycling can be one of the most environmentally friendly and sustainable ways of reducing or reversing deterioration

References and Data Sources

Relevant Policies:

NEPA (2000) 'A Beach Policy for Jamaica'

Discussion of Impacts and Risks:

Cunniff, S. and Schwartz A., 2015. 'Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features'

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'

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D2.4 BEACH VEGETATION PLANTING

What is Beach Vegetation Planting?

Beach Vegetation Planting refers to the planting of vegetation in beach systems. Plant roots hold sediment in place and therefore help stabilise the areas where they are planted. In addition, they reduce runoff erosion as well as trapping windblown sand, increasing the ability of sand dunes and associated beaches to buffer inland areas from storm waves, erosion and flooding. It is important to bear in mind that planting vegetation will help to prevent erosion, as well as accelerate natural recovery following storm damage. The vegetation creates a reservoir of sand that improves the capability of beaches to withstand the next period of erosion.

Build	×
Protect	✓
Accommodate	×
Retreat	✓

Where can beach vegetation be positioned?

Hinterland	Shoreline	Nearshore
×	✓	×

Key Design Considerations

When designing beach vegetation schemes a number of factors need to be considered to ensure their viability. These may include, but not limited to:

- **Location:**
  - *Selection of appropriate locations for planting (i.e. avoiding areas which are regularly over washed by tides and waves).*
- **Protection:**
  - *Provision of protection mechanism before the plants' root systems become stablished.*
- **Species selection**
  - *Selection of suitable species for planting (subject to site specific conditions such as wind, salt, soil, exposure, native species etc).*
- **Removal/replacing of invasive plants:**
  - *Removal and replacement of invasive species to allow appropriate growth.*
- **Time of planting**
  - *Planting of vegetation at adequate times in line with the selected species requirements and taking account of local conditions (i.e. planting after the hurricane season).*

Preliminary Studies Required

Prior to the undertaking of vegetation planting works, an assessment of the dynamics and native vegetation of the beach system under consideration should be carried out. Ecological surveys will be required as well as **hydrodynamic** understanding of the site.

CASE STUDY

Dune restoration and replanting in the Bahamas

Over 80% of Caribbean beaches are eroding, and this is a particular concern in the low-lying states, such as the Bahamas Dunes can be rebuilt with sand from the immediate locality, and this can be done in conjunction with beach nourishment if necessary. Vegetation replanting is essential to provide stability to the dunes. A successful example of dune restoration is currently being monitored on Guana Cay. A combination of beach nourishment and replanting of dune vegetation is often needed to restore functional sand dunes.

Dune replanting in the Bahamas
Photos: Neil Sealey, www.pilebuck.com

KEY DESIGN PARAMETERS

- Location
- Protection
- Species selection
- Invasive plants
- Time of planting
- **Hydrodynamics** (exposure)

D2.4 BEACH VEGETATION PLANTING

Cost		Beach vegetation planting is relatively cheap however thought must be given to the cost of protection before the plants roots have stabilised.

The following vegetation is native to Jamaica, and therefore should be the initial vegetation considered during species selection:

- Sea Grape - Coccoloba uvifera
- Pigean Plum - Coccoloba diversifolia
- Chrysobalanus icaco
- Scarlet Cordia -Cordia sebestera
- Jacquinia arborea Vahl
- Sesuvium portulacastrum
- Sporobolus
- Paspalum distichum
- Coccothrinax jamaicensis

Environmental Impacts

Beach planting is an environmentally friendly and sustainable way of reducing or reversing the deterioration of beach systems and thereby reducing the threats of coastal erosion and flooding. There is also the opportunity to create new habitats. The environmental impacts of hybrid opportunities would need to be considered on a case-by-case basis.

Hybrid Opportunities

Prior to the introduction of vegetation, additional works which may be necessary to increase the potential for success should be investigated. Additional measures may include thatching, fencing, and beach recycling as these assist in the **accretion** of sand, whilst providing protection from waves and help in reducing damage due to trampling. Sand trapping fences is the use of permeable fences along the seaward face of dunes to encourage the deposition of wind blown sand, reduce trampling and protect existing or transplanted vegetation.

Adaptability to Climate Change

Healthy beach systems constitute an effective form of sea defence due to its ability to adapt its shape naturally to changing wave and tidal conditions and can dissipate wave energy and can be designed for future SLR. Vegetation planting further contributes to the **resilience** of beach systems thus increasing their **resilience**.

Buildability

The **buildability** of beach vegetation planting is relatively simple, however it can be difficult to ensure that the vegetation takes root. However, as hybrid structures are developed the **buildability** is dependent on the **buildability** of the additional structure. Beach vegetation planting is generally undertaken using land transport and uses easily procured materials.

Summary

- Plant roots hold sediment in place, therefore helping to stabilise the areas where they are planted
- Planting vegetation helps to prevent erosion and accelerates natural recovery following storm damage
- Beach vegetation planting is an environmentally friendly and sustainable **intervention**

D2.4 BEACH VEGETATION PLANTING

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D2.5 CORAL REEF RESTORATION

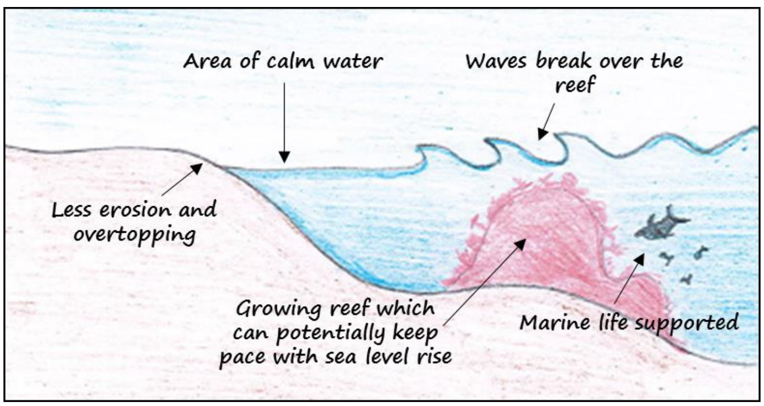
What is Coral Reef Restoration?

The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed is referred to as ecological restoration. When applied to coral reef ecosystems this process is known as coral reef restoration.

In addition to providing essential ecosystem services and habitat for valuable fish species as well as other marine organisms, coral reefs act as natural breakwaters, offering protection from wave damage to other important habitats (i.e. beaches, seagrass meadows & mangroves), coastal communities and infrastructure (roadways, ports, private property, leisure and tourism installations, etc). Thus, coral reefs play an important role in reducing the risk of coastal erosion and flooding while underpinning key ecosystem services that support and maintain **biodiversity**. Coral reefs are degraded naturally by storm events such as hurricanes as well as **coral bleaching** events. In addition, reefs are subject to degradation from human activity such as overfishing and destructive fishing, coastal development

Where can coral restoration be positioned?

Hinterland	Shoreline	Nearshore
×	×	✓



Key Design Considerations

When designing coral reef restoration measures and to ensure their viability, due regard should be given to the stressors which may be affecting reefs in the area under consideration.

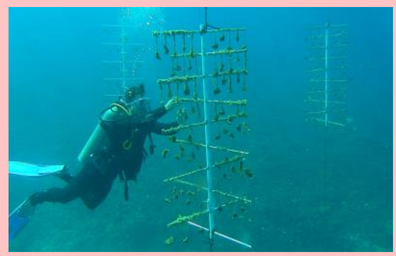
Interventions that can be applied in the context of coral reef restoration include:

- **Artificial reef creation:**
  - *increasing the area of substrate for settlement of coral larvae by installing artificial & natural substrates.*
- **Coral reef nurseries:**
  - *Coral fragments can be transplanted to nurseries and 'grown out' to a certain size before being used for restoration.*
- **Coral Relocation:**
  - *harvesting of coral from an area where damage to a reef is anticipated and cannot be avoided (i.e. as result of a coastal development project) and transplantation/reattachment in suitable alternative reef areas.*

Build	✓
Protect	✓
Accommodate	×
Retreat	×

CASE STUDY

Coral restoration is becoming increasingly widespread in the Caribbean as an approach for coastal managers to accelerate the natural recovery of coral reefs. Coral restoration is currently being undertaken in Jamaica, Belize, Grenada, Bonaire and Dominican Republic among other Caribbean countries.



KEY DESIGN PARAMETERS

- Reef structure
  - Elevation
  - Roughness
  - Geometry
  - Species composition
- Water quality
- Light requirements
- Waves and currents
- Salinity
- Depth

D2.5 CORAL REEF RESTORATION

Preliminary Studies Required

In advance of any coral reef restoration activity, diver surveys to determine coral species and densities at the recipient site and an assessment of the space available to accommodate coral transplants should be carried out.

A number of ecological factors affect the amount of wave reduction that can be expected from reef ecosystems including reef depth and reef crest height, both of which are critical to wave reduction in coral reefs. A detailed understanding of the physical and ecological structure of the reef is therefore required to maximise the potential for a successful **intervention**.

Habitat mapping as a tool for development of baseline conditions, key species, percentage coverage of hard and soft corals, etc. will also provide a robust basis for future monitoring.

Intervention	Small – scale Relocation	Large – scale Relocation	Artificial Reef Creation	Coral Reef Nurseries
Cost				

Environmental Impacts

If it is carried out in a sensitive manner, coral reef restoration is an environmentally sound and sustainable way of mitigating, reducing or reversing the deterioration of coral reefs and thereby reducing the threats of coastal erosion and flooding, whilst maintaining/enhancing the ecological and socio-economic services that coral reefs provide. Not only are there limited environmental impacts caused by coral reef rehabilitation, it can also increase the **biodiversity** of the marine ecosystem.

Hybrid Opportunities

Coral reef restoration may be paired with most **interventions**. Coral reef restoration can be used in parallel with shoreline **hard interventions** to reduce wave energy hitting the beach or structure. In addition, they can contribute to the stability of beaches by reducing erosion and stopping the toe of structures being undermined by **scour**. Artificial reefs can be used as offshore breakwaters providing additional environmental and recreational benefits. Live corals can be moved from areas where they are at risk of being damaged or nursery grown and attached to the artificial structures, increasing dissipation of waves and allowing the reef to grow with sea-level rise. The combined coastal protection of coral reefs with seagrass meadows and mangroves can also be used. The use of the three habitats together has been shown to provide more protection than a single habitat or combinations of two habitats. It is also important to consider the geomorphic setting when considering the most effective habitat. For example coral reefs are more effective in a fringing reef profile than seagrass, however in a barrier reef profile seagrass supply more protective services than coral.

Adaptability to Climate Change

Coral reefs adaptability to climate change is limited in comparison to that of other soft measures such as beach protection. Over the long term reefs may be able to keep pace vertically with sea level rise although this may be constrained depending on the level to which the ecosystem has been degraded and its ability to cope with multiple additional stressors.

Buildability

The **buildability** of coral reef restoration measures is relatively simple compared to other **interventions** available.

Summary

- Coral reefs provide essential ecosystem services and habitat in addition to offering protection from wave damage to the hinterland
- Coral reefs reduce the risk of coastal erosion and flooding by dissipating wave energy
- Coral reef restoration incorporates the creation of artificial reefs, the relocation of coral, and coral reef nurseries

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D2.6 MANGROVE RESTORATION

Build	✓
Protect	✓
Accommodate	×
Retreat	×

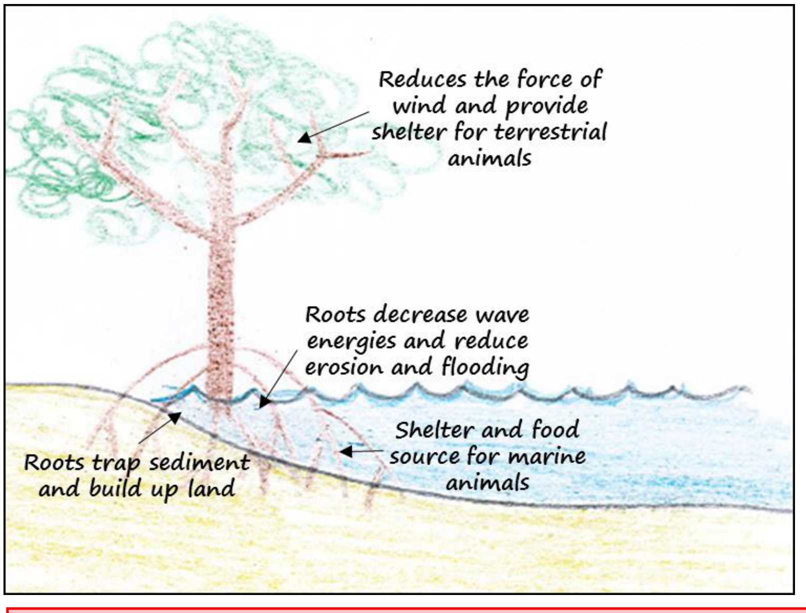
What is Mangrove Restoration?

The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed is referred to as ecological restoration. When applied to a mangrove ecosystem this process is known as mangrove restoration.

In addition to providing important habitat for many coastal species and supporting local communities (i.e. food, medicines, fuel wood and construction materials) mangrove forests play an important role in preventing coastal erosion and flooding. Their dense root systems protect the shoreline from wave action, currents and winds whilst trapping alluvial material and stabilising the soil. Mangroves play an important role as carbon sinks and in maintaining the integrity of coastal environments.

Where can mangrove restoration be positioned?

Hinterland	Shoreline	Nearshore
x	✓	×



KEY DESIGN PARAMETERS

- Wave climate
- Tidal inundation and drainage
- Topography (elevation and slope)
- **Hydrology** of the site
- Soil salinity
- Suitable species
- Barriers to the hinterland
- Sediment characteristics and supply

CASE STUDY

Hellshire mangrove restoration in August 2013 lasted for three weeks. The area was impacted by wind damage resulting from hurricanes which severely affected tree cover. Since the forest was predominantly comprised of red mangroves that do not respond well to cutting and breakage, the vast majority of the forest did not recover and as such became carpeted by dead standing and felled trees. The removal of debris was anticipated to allow for unrestricted distribution of seeds throughout the site and encourage natural regeneration over time. In addition to the removal of dead tree fragments, approximately 1500 red mangrove seedlings were planted to assist in the regeneration of the forest.

(Left) Looking south into the cleared forest from the main road shoring planted seedlings

(Right) South eastern section of forest following clearing of debris and planting of seedling

D2.6 MANGROVE RESTORATION

Intervention	Planting	Relocation	Afforestation
Cost			

Key Design Considerations

When designing measures for mangrove restoration, it is important to ensure that key ecological conditions such as **hydrology,** freshwater and sediment supply, are appropriate to allow growth. Similarly, consideration should be given to the suitability of the species selected for planting, preparation of seedlings prior to planting and the location where they are to be positioned (tidal level, exposure, land grade, etc).

Types of **interventions** that can be applied in the context of mangrove restoration include:

- **Mangrove restoration –** *Encouraging natural regeneration of a mangrove forest by addressing the stressors and planting seeds from the surrounding healthy forest*
- **Mangrove planting -** *Direct planting of mangrove seedlings in a recovery area or mangrove nurseries*
- **Afforestation -** *Planting mangroves in places where they have not occurred before. This may be an appropriate **intervention** in places where there has been major coastal engineering and where mangrove appropriate intertidal substrates have been created.*

Preliminary Studies Required

Site investigations should be carried out to assess the suitability of an area for mangrove restoration. Mangroves usually grow in intertidal areas and display a clear zonation of species depending on elevation. Therefore, frequency of tidal inundation and drainage characteristics are two of the most important factors that need to be considered when assessing a site for mangrove restoration and when selecting the most appropriate species to plant. These factors are largely determined by topography (elevation, depth of sediment above bedrock and slope) and tidal amplitude.

Prior to considering restoration the potential existence of stresses such as blocked tidal inundation that might prevent secondary succession from occurring should be investigated, and a plan to remove such stresses planned prior to any restoration.

Environmental Impacts

If it is carried out in a sensitive manner, mangrove restoration is an environmentally sound and sustainable way of reducing or reversing the deterioration of mangroves and thereby reducing the threats of coastal erosion and flooding. Not only are there limited environmental impacts caused by mangrove restoration, it can also increase the **biodiversity** of the marine ecosystem.

Hybrid Opportunities

Mangrove restoration may be paired with other **interventions**. Mangroves could be used to protect hard infrastructure as they are very effective at decreasing wave energy. They have been shown to alleviate the impact of moderate tsunami waves as well as storm surges. They also have additional benefits of stabilising the shoreline and soil , therefore can protect the toe of the structure from **scour**. Although mangroves have been found to be an effective habitat in providing coastal protection on its own, seagrass and corals enhance this by increasing stability for mangroves. For this reason the use of the three habitats together have been shown to provide more protection than a single habitat or combinations of two habitats.

Adaptability to Climate Change

Mangrove adaptability to climate change is limited in comparison to that of other soft measures such as beach protection. Over longer time scales, mangroves may be able to keep pace vertically with SLR and/or migrate inland (provided hard structures/barriers that may hinder retreat are not present). Such capabilities will be limited by the degree to which the ecosystem has been degraded and its capacity to cope with other multiple stressors.

Buildability

The **buildability** of mangrove restoration schemes is relatively simple compared to most **hard interventions** available. When using mangroves within a hybrid scheme, hybrid **buildability** issues should be considered in addition to the effect structures in the hinterland will have on the future development of the mangroves.

D2.6 MANGROVE RESTORATION

Summary

- Mangroves dense root systems protect the shoreline from wave action, currents and winds whilst trapping alluvial material and stabilising the soil
- Mangrove restoration incorporates the replanting of mangroves within nurseries, existing mangrove sites and within sites that have not previously had mangroves that now have appropriate intertidal substrate
- Mangrove restoration is an environmentally sound and sustainable way of reducing or reversing the deterioration of mangroves and therefore reducing the threats of coastal erosion and flooding.

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D2.7 SEAGRASS RESTORATION

What is Seagrass Restoration?

The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed is generally referred to as ecological restoration. When applied to seagrass meadows/ecosystems this process is known as seagrass restoration. In addition to providing important ecosystem services, such as key habitat (spawning, nursery and feeding grounds) and shelter to a variety of marine organisms, seagrasses play an important role as carbon sinks and in sand accretion. Their morphology enables them to slow down coastal currents which helps stabilise sediments and retain sand, reducing beach erosion, whilst improving the clarity of coastal waters. However it should be noted that comparatively, this is to a lesser extent than mangrove replanting and coral restoration.

Where can seagrass restoration be positioned?

Hinterland	Shoreline	Nearshore
×	✓	✓

Key Design Considerations

Seagrass are affected by natural events such as severe weather conditions, disease and overgrazing by marine animals. In addition they are threatened by various human activities; runoff of nutrients and sediments that affect water quality is one of the principal anthropogenic threats to seagrass meadows, although other stressors include aquaculture, pollution, boating, construction, coastal development, land reclamation, dredging and landfill activities, as well as destructive fishing practices.

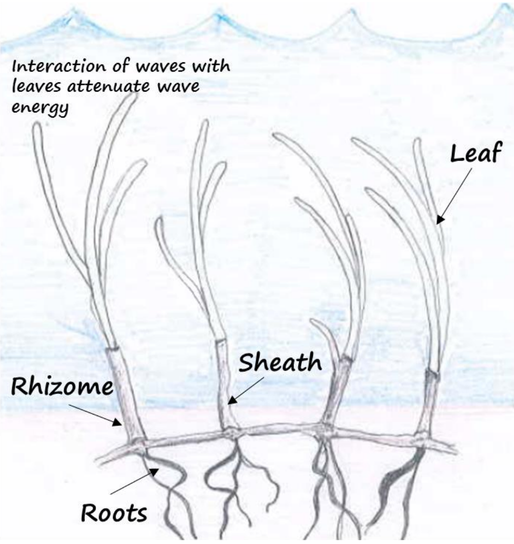
Interventions that can be applied in the context of seagrass restoration include the use of various planting techniques. These can be used where removal of some area of seagrass cannot be avoided or in beds that have deteriorated, accelerating the revegetation process. However it should be noted that Jamaican seagrass beds are not known to produce a mass number of seeds that are able to facilitate restoration.

Transplanting of adult plants

- *Generally involves the harvesting of rhizomes or shoots from healthy donor beds for subsequent transplant into degraded areas.*

Planting of seeds

- *Collection of seeds directly from a bed for subsequent plantation. Once collected, the seeds may be planted directly in the area to be restored or maintained and treated in the laboratory to promote or induce germination before being taken to sea.*



Build	✓
Protect	✓
Accommodate	×
Retreat	×

CASE STUDY

Under the GOJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction Project seagrass restoration was carried out in the Negril Marine Park in September 2012. Shortly after planting in October 2012, the island was directly impacted by Hurricane Sandy which uprooted naturally occurring seagrass beds along the entire length of the Negril coastline in addition to 84% of the planted beds. Remedial planting took place in June 2013, where approximately 1500m^2 of seagrass was replanted. The percentage cover of planting units within a 1m^2 area was on average 6-25%. At the end of the GOJ/EU/UNEP project in 2013, seagrass areal coverage had increased by 125%.

KEY DESIGN PARAMETERS

- Level of bioturbation
- Sediment thickness and stability
- Nutrient availability
- Light attenuation characteristics
- Salinity and temperature
- Waves and currents
- Species composition
- Stress from anthropogenic activities

D2.7 SEAGRASS RESTORATION

Preliminary Studies Required

Prior to designing seagrass restoration plans, detailed mapping of the seagrass beds at both impact and relocation sites should be undertaken together with an assessment of the health of the seagrasses at donor and recipient sites. The physical (depth, space, substrate type) and chemical (salinity) conditions of the sites should also be assessed to ensure the viability of their restoration. It should be noted that at times seagrass beds are not feasible for relocation, therefore assessments should be made of the sediment condition prior to relocation.

Intervention	**Planting**	**Relocation**
Cost		

Environmental Impacts

If it is carried out in a sensitive manner, seagrass restoration is an environmentally sound and sustainable way of mitigating, reducing or reversing the deterioration of seagrasses and thereby reducing the threats of coastal **erosion** and flooding. In addition, the protection and enhancement of seagrass meadows can have wider environmental benefits.

Hybrid Opportunities

Seagrass restoration may be paired with most **interventions**. Seagrass are beneficial in front of hard-infrastructure (e.g. seawalls, revetments and levees) as they reduce wave energy to the structure. In addition, areas with seagrass have been shown to have reduced erosion and therefore they have the potential to reduce **scour** at the structures toe.

The combined coastal protection of seagrass meadows with coral reefs and mangroves may be used. The use of the three habitats together have been shown to provide more protection than a single habitat or combinations of two habitats. It is also important to consider the geomorphic setting when considering the most effective habitat. For example coral reefs are more effective in a fringing reef profile than seagrass, however in a barrier reef profile seagrass supply more protective services than coral.

Adaptability to Climate Change

Historically seagrasses have successfully adapted to large scale changes in sea level and CO_2. Their potential adaptability to climate change may however be constrained depending on the level to which they have been degraded and their capability to cope with multiple additional stressors. However their impact on beach stability can help reduce potential increases to beach erosion which may occur due to sea level rise in the future.

Buildability

The **buildability** of seagrass restoration schemes compared to most **hard interventions** available is relatively simple, however in the past mangrove restoration has been more successful than seagrass restoration.

Summary

- Seagrass provides a key habitat whilst stabilising sediments, improving water clarity and reducing beach erosion. It should be noted that comparatively, the reduction in threat of erosion is to a lesser extent than mangrove replanting and coral restoration.
- Seagrass restoration incorporates both the planting of seeds and the transplanting of adult plants
- Seagrass restoration is an environmentally sound and sustainable way of reducing or reversing the deterioration of seagrasses and therefore reducing the threats of coastal erosion and flooding.

D2.7 SEAGRASS RESTORATION

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D2.8 WETLAND (MORASS) MANAGEMENT

Build	×
Protect	✓
Accommodate	×
Retreat	✓

What is Wetland Management?

Wetland management generally involves activities that can be conducted with, in, and around wetlands, both natural and man-made, to protect, restore, manipulate, or provide for their functions and values. Within the Jamaican context, wetland management addresses Morass, swamps and wetlands under this **intervention** header (see Section D2.6). Wetland management is divided into issues associated with: 1) natural wetland protection; 2) activities, involving natural wetlands, that are specifically exempted from regulatory requirements; 3) wetland creation and restoration; and 4) wetland construction for water quality improvement.

Where does Wetland Management Occur ?

Hinterland	Shoreline	Nearshore
✓	✓	×

Key Design Considerations

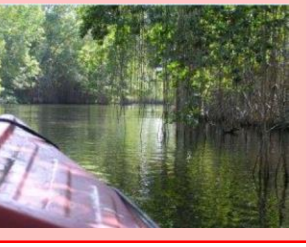
Manipulation of natural wetlands, within regulatory jurisdiction, is typically limited to restoration of degraded habitats. The use of natural wetlands for primary water quality treatment of either point or nonpoint pollution sources is inappropriate.

Natural Wetland Protection

The management goal for natural wetlands is generally constrained by regulatory and other government program requirements to the protection of existing functions or restoration of degraded functions. The management goal for undisturbed natural wetlands is typically to perpetuate existing functions. Functions are particular to a wetland's type and its position in the landscape Two major facets of managing wetlands for protection include buffering wetlands from direct human pressures, and maintaining natural processes in surrounding lands that affect wetlands and that may be disrupted by human activities.

CASE STUDY

Black River Lower Morass Ramsar site is the largest freshwater wetland ecosystem in Jamaica, and the management and protection of this has helped maintain the high **biodiversity.** This includes plants such as the Red Mangrove (*Rhizophora mangle*), the Black Mangrove (*Avicennia germinans*) and the White Mangrove (*Laguncularia racemosa*), Anchovy Pear *(Grias cauliflora)*, Swamp Cabbage (*Roystonea princeps)* and Bull Thatch (*Sabal jamaicensis)*. At least 150 vertebrate species have also been recorded, including endangered species. Just below 50% of the island's avian species have been identified in the morass including the West Indian Whistling Duck (*Dendrocygna arborea*).



Protection of Wetlands through Assignment of a Designated Use:

The level of protection provided should conform with the designated use established for a wetland; for example, aquatic life support or recreation. These coincide with two basic levels of protection recognized by environmental planners: preservation and conservation. Aquatic life support and wetland preservation connote a greater degree of protection, and involve, at most, passive use by humans. The recreation designated use, and wetland conservation status, connote a lesser degree of protection than do aquatic life support and preservation, on the level of protecting essential functions while allowing compatible human uses.

Factors to consider in setting the designated use and developing a management strategy for a wetland

- wetland type and landscape position,
- surrounding land uses,
- cumulative impacts on the wetland,
- vegetation quality,
- presence/ absence of rare/endangered species,
- surface water quality,
- wildlife habitat, and
- cultural values.

D2.8 WETLAND (MORASS) MANAGEMENT

Intervention	Land Purchase	Compensation	Habitat Restoration	Breaching of Defences	Monitoring
Cost					

Buffers and Other Protective Measures for Wetlands

A buffer typically consists of a band of vegetation along the perimeter of a wetland or water body (Morass), preferably natural habitat, but including previously altered, stable native or introduced species. Once the need for a buffer is recognized, establishment of a suitable width is the critical task. In reality, many government agencies establish buffer requirements based on political acceptability and/or assumed aquatic resource functional value. Nevertheless, a fully informed buffer design must consider the nature of the encroaching activity, the buffer itself, the resource to be protected, and the buffering function to be performed. There are usually four criteria for determining adequate buffer size to protect wetlands and other aquatic resources: as follows:

- Wetland functional value - level of disturbance, sensitivity to disturbance,
- Intensity of adjacent land use,
- Buffer characteristics - vegetation density and structural complexity, soil condition, and
- Specific buffer functions required

Hybrid Opportunities (Wetlands as treatment features)

Water quality processes in natural wetlands are much more challenging to study than those in constructed systems. One main reason is that their water sources, rainfall and runoff, are climatically driven, making them highly variable hydrologically. It is also frequently a challenge to quantify all of the input sources and output paths. Treatment efficiencies measured in natural wetlands have proven to be more widely variable than those in constructed systems, probably due only in part to differences in experimental methods, and more so to the diversity in natural system structure, function, and historical loading trends.

Adaptability to Climate Change

Riparian areas, which include floodplain uplands as well as wetlands, are considered perhaps the most important buffer areas for protecting receiving water quality. Wetland "buffers" can therefore perform important functions with regards to climate change adaptation:

- sediment removal and erosion control;
- nutrient transformation and removal;
- metals and other pollutant reduction;
- Storm-water runoff reduction through infiltration;
- reduction of water temperature;
- reduction of human impacts by limiting easy access and by minimizing edge effects from noise, light, temperature, and other changes,;
- protection for interior wetland species, and
- a barrier to invasion of nuisance and exotic species.

Summary

- Wetland management and protection will protect important ecosystems such as the Black River Morass.
- Designations and protections can help protect the ecosystems by establishing control on activities and developments in the area.
- A number of benefits are evident from wetland areas including erosion control, flood and storm protection, pollution control and biodiversity.

References and Data Sources

Specific Design Manuals: "Natural Flood Management handbook" – SEPA (2015)

D3: Hard interventions

Hard interventions are constructed on the coastline to resist the energy of waves and tides. They are typically impermeable coastal defence structures of concrete, timber, steel, masonry etc. which reflect a high proportion of incident wave energy. Hard options typically maintain or improve the **standard of protection** to the hinterland, with the possibility of associated benefits for amenity and the environment, however hard options are not always beneficial and there are numerous disadvantages associated with their use (CIRIA, 2010).

The following chapter provides an overview of hard infrastructure measures, including; where they can be positioned; the key design considerations required including preliminary studies required, cost, environmental impacts, hybrid opportunities, adaptability to climate change and **buildability**; case studies; and further data sources and references.

Reference should also be made to Part C (for stakeholder engagement and sea level rise guidance) and Part F (monitoring and maintenance requirements). Case studies are used throughout to exemplify **interventions**, and where possible Jamaican or regional examples are used. Occasionally international example case studies are used where they provide best practice examples. However, it is to be noted that whilst case studies can provide a context and best practice examples, often **interventions** required specific site conditions and cannot simply be completely replicated. Site conditions must be considered for the specific site when designing **interventions**.

D3.1 BREAKWATER

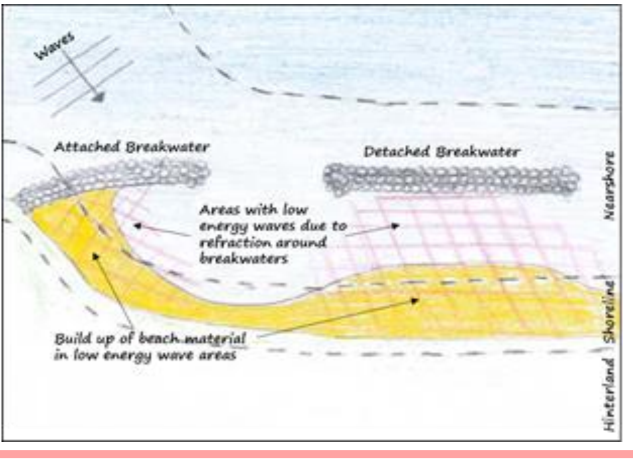
What is a Breakwater?

A breakwater is a structure built on the coast to protect the coastline and/or activities along the coast from the force of waves and **longshore sediment drift**. There are two main types of breakwater: shore-connected and detached.

A *shore-connected breakwater* is a structure that protrudes perpendicularly from the shoreline whereas detached breakwaters are usually orientated approximately parallel to shore and can be placed singly to protect a specific location against direct impact of waves or as a series of segmented breakwaters to provide protection to a longer coastal frontage. Shore-connected breakwaters provide a fully protected harbour for safe mooring of vessels from the action of waves.

Detached breakwaters are used as shore and coast protection measures to reduce the amount of wave energy reaching the protected area by dissipating, reflecting, or diffracting incoming waves in a similar manner to natural offshore bars, reefs or nearshore islands. The reduction of wave energy promotes sediment deposition leeward of the structure, forming a salient or a tombolo. A properly designed detached breakwater can allow continued longshore transport , thus reducing the adverse impact on the **downdrift** beaches.

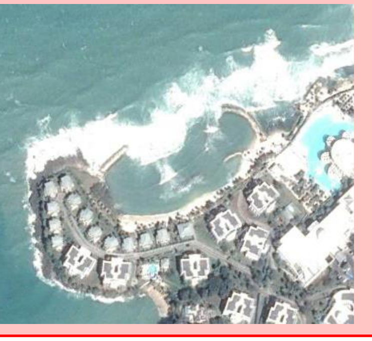
Detached breakwaters are generally placed in three categories depending on where they are located in relation to surf zone; Offshore, Coastal and Beach breakwaters. Offshore breakwaters are constructed outside of the surf zone and protect offshore ship wharfs, Coastal breakwaters are constructed between the second half of the surf zone and up to two times the surf zone and prevent coastal erosion, and Beach breakwaters are constructed within the first half of the surf zone and trap sand on the **foreshore**. The offshore and coastal breakwaters are often constructed as submerged or low crested allowing some wave transmission. A submerged structure can be dangerous to small craft navigation, **overtopping** water creates turbulence and the design is challenging. There are other types of breakwater such as floating breakwater which are limited to very sheltered sites to dissipate and reflect small waves, they move up and down on the tides and as such is used in large tidal areas. As breakwaters interrupt sediment transport, unless additional sand is brought into the system, **accretion** which occurs in the breakwater lee will generally be balanced by erosion in adjacent areas. It is therefore generally recommended that beach nourishment including control structures are included in the detached breakwater scheme.



Build	✓
Protect	✓
Accommodate	×
Retreat	×

CASE STUDY

The Grand Palladium Resort situated on the north cost of Jamaica used breakwaters and groynes to create a large, swimmable beach area for guests to the 2000 room hotel. Without the breakwaters the wave energy would be too high and not suitable for swimming. The breakwaters sufficiently retard the wave forces as shown below.



KEY DESIGN PARAMETERS

- Functionality of the structure
- Performance parameters
- Material
- Water level (including SLR projections)
- Bathymetry
- Waves
    - Height
    - Length
    - Predominant Direction

Where can a Breakwater be positioned?

Hinterland	Shoreline	Nearshore
×	✓	✓

D3.1 BREAKWATER

Key Design Considerations

When designing a breakwater the most important factor to know is the functionality of the structure and its performance parameters. Both types of structures require to be designed to be stable against forces induced by direct wave impact. In the design of rubble mound breakwaters, the key design issues include the selection of the type and material forming the main core (quarry run, sand fill geo-bags, etc.), the grading of rock under- layer and filter layers, geo-fabric to minimise migration/loss of core, and the choice of coverlayer armour (rock or concrete units depending on the wave climate). In the design of gravity structures the key issues to be addressed are the foundation and **scour** protection, the wave loading, wave reflection and assessment of the extent of wave **overtopping** to determine optimum crest level.

<u>Shore connected breakwater</u> - the principal design considerations include; the layout required for sheltering and retention of beach, water depths, wave/current climate and tide and surge water levels, obstructions on seabed and nature of sub-strata, design performance requirements, construction material resourcing, and future maintenance requirements.

<u>Detached breakwater</u> - the principal design consideration include; area or length of frontages to be protected, wave/current climate and tide and surge water levels, and obstructions on seabed and nature of sub-strata.

When designing a rock based intervention, a number of design empirical formulae have been developed, including the Hudson Formulae for typical permeability, and the Van der Meer equation for varying structure permeability and varying wave characteristics.

Preliminary Studies Required

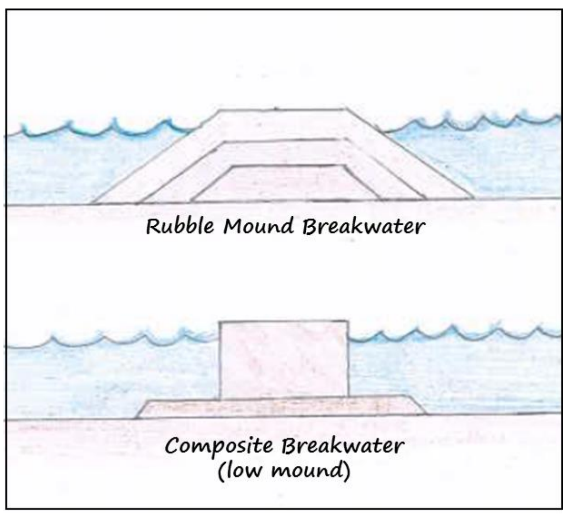
When considering land reclamation the following preliminary studies should be conducted:

- Topographic survey - *used to map the contours of the ground and existing features*
- Bathymetry survey - *used to identify the depths and contours of the seabed (near and offshore).*
- Oceanographic survey – *On site measurement of tides, wind, waves and currents to supplement existing information and assist with the Met-ocean study.*
- Met-ocean study - A *study involving the collation, review and analysis of existing and new water level, wind, wave and current data. Determines design parameters and the assessment of sediment transport to study the impact of the breakwater on the existing costal processes.*
- Ground investigation study –*This would include the construction of number boreholes, material sampling and in-situ and laboratory testing to determine the nature and thickness of substrata, strength, settlement and permeability characteristics of the material.*
- Material Resource Study –*In view of its extensive nature a detailed study of the availability of construction material where possible in close proximity to the site and the cost implications on transport and placement in paramount to the success of the project.*
- Benthic Assessment–*A benthic assessment is required to determine whether habitat relocation is necessary.*

Intervention	Shore-connected	Detached from the Shore
Cost		

Environmental Impacts

Breakwaters impact on erosion and **accretion** in the area. This could be mitigated by the physical transport of accrued material at the root of the breakwater or end of a series of detached breakwaters to the **downdrift** side which have been starved of natural material supply. Breakwater impacts also include visual, health & safety in close proximity to the structure, nearby fishery operations, and potential water quality degradation. If proper water exchange does not occur over, through and around the structures, water can be trapped in the lee and become stagnant and polluted. Over long-term some aquatic habitat could be lost, however rock structures are known to increase habitats.



D3.1 BREAKWATER

Hybrid Opportunities

There are several hybrid opportunities available for breakwaters including:

- Living breakwaters - *structures placed parallel to the shore in medium to high-energy open-water environments for the purpose of dissipating wave energy while providing habitat and* erosion *control. These breakwaters are constructed rock that is seeded with oyster spat.*
- Rubble and recycled concrete breakwaters - *used at living shorelines as material for offshore breakwaters to reduce wave energy. To provide maximum benefit to the ecosystem, these rubble and concrete breakwaters are seeded with oyster spat to improve water quality and provide habitat whilst reducing wave energy.*
- Native reef-building oysters - *oyster reefs can be enhanced or created at living shoreline sites as natural shoreline protective structures to dissipate wave energy, decrease coastal erosion, increase habitat for fish species, improve water quality and provide protection for newly planted marsh grasses and submerged aquatic vegetation.*
- Small concrete oyster balls - *can be used at living shoreline sites to decrease wave energy while enhancing fish and oyster habitat. These hollow concrete structures provide a surface on which oysters colonize and form small living reefs, thus providing habitat and food for fish and other aquatic species. These structures also dissipate waves, decreasing coastal erosion and providing an area in which newly planted vegetation can grow.*

Adaptability to Climate Change

This is best achieved when the chosen design water level incorporates recommended allowance of increase in water level to accommodate current projected rate of sea level rise for the chosen **design life** time. In addition, a recommended percentage increase to the design wave height to allow for future increased storminess should be applied. If warranted the breakwater structure footprint could be designed to accommodate any increase to crest height (freeboard) which may be required in the future to accommodate climate change effect on design water levels and wave heights.

Buildability

The breakwaters are built with land based and/or waterborne plant.

<u>Land-based construction</u> - the plant must be able to gain access to the crest of the core bund, which would determine the crest width and elevation. The construction would progress seaward from the shore by the tipping of core and moving forward on the already constructed section of the bund, followed closely behind by grading of slope and provision of protective rock layer so as to minimise damage to the core by wave action. This is quickly followed by the placement of coverlayer armour which may be either large rock or proprietory concrete blocks. To carry out the entire construction operations from the land (crest of bund), very large cranes having the appropriate reach and lift capacity to construct the breakwater toe and lower slope are required.

<u>Waterborne construction</u> - generally more expensive than land-based plant. The working of the plant is dependent on weather and down-time is significant particularly in open sea. Waterborne core construction is performed by self unloading barges with bottom dumping or side tipping. Floating craft such as a barge/or pontoon is used to house the crane or excavator for the placement of underlayer/filter rocks and coverlayer rocks or concrete armour to the toe and slope.

Summary

- A breakwater is a structure built on the coast to protect the coastline and/or activities along the coast such as ports, ship anchorage or marina from the force of waves and **longshore sediment drift**
- There are two main types of breakwater; shore-connected and detached
- Breakwaters impact on erosion and **accretion** in the area

References and Data Sources

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'

Jamaican National Building Code

SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps.

D3.2 REVETMENTS

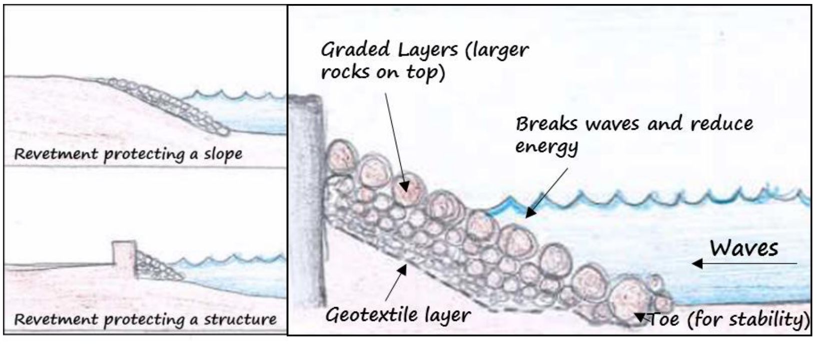
What is a Revetment?

A revetment is placed on sloping structures or against a vertical wall to protect against erosion of a natural feature on the coast by environmental loads such as waves, currents and wind and geotechnical loads and to reduce wave **overtopping** and consequential damage/flooding of land behind. They are typically permeable surfaces such as rock, Reno-mattresses, open stone/sand asphalt, to allow tidal water to flow in and out and the waves to penetrate into the structure which dissipates the energy and minimises reflection. They are flexible and allow for some degree of movement or deformation due to settlement. Revetments can also be impermeable surface protection such as concrete block and slabbing, mortared/grouted masonry, concrete mattresses and are typically rigid. Impermeable revetments are only appropriate for impermeable ground where there is no water movement and no build up of tidal water pressure and in areas of less intense wave climate. Revetments can have a significant impact on beach levels

Build	✓
Protect	✓
Accommodate	×
Retreat	×

Where can a Revetment be positioned?

Hinterland	Shoreline	Nearshore
×	✓	×



KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Geometry of Coastline
- Natural Slope
- Health & Safety
- Sediment supply and transport
- **Overtopping**
- Water level (including SLR projections)

Key Design Considerations

The key considerations for a revetment include; use and overall shape, location, wave exposure, water levels,variability of foreshore levels, length, height and slope, geotechnical stability of the soil, availability of building materials, economic feasibility limits, environmental concerns and institutional constraints. A number of failure modes are possible, including; wave impact (most severe with breaking wave plunging on a structure), geotechnical failure of slope and toe (due to excessive settlement, liquefaction of soil in seismic conditions and loss of material, etc.), **scour** (due to wave/currents), wave **overtopping**, sliding, and uplift due to water build-up during wave run-up and run-down. The revetment coverlayer may be permeable or impermeable, flexible or rigid and the selection of the type of coverlayer is dependent on the type, grading and permeability of the material forming and the hydraulic loads it experiences. In a permeable revetment each layer should be more permeable than the material beneath to ensure there is no loss of material through outer layers, to prevent settlement and failure of the slope. A number of geotextile fabrics have been developed (both woven and non-woven) which may be used on their own or in combination with stone filter layers to prevent the migration and loss of finer base material (sand, etc.) through the structure. To ensure the hydraulic stability of the coverlayer, a number of design empirical formulae have been developed, including the Hudson Formulae for typical permeability, and the Van der Meer equation for varying structure permeability and varying wave characteristics. The stability of a revetment is dependent on the design of toe protection as it provides support to the revetment face and the core materials. Toe support includes; steel sheet pile, rock apron, gabions, **scour** mattresses and a trenched rock toe. Crest of revetment and land behind are often protected from erosion and flooding from wave **overtopping** by the provision of a crest wall. The rate and quantity of **overtopping** can be assessed using the EuroTop Wave **overtopping** manual. A more accurate quantitative assessment may be made by undertaking model testing.

D3.2 REVETMENTS

Preliminary Studies Required

Preliminary studies required may include;

- a Metocean study - *to identify the combined wind, wave and tidal /wave induced current conditions (annual/seasonal/extreme for beach and structure),*
- a ground investigation study - *involving trial pits and borehole, sampling and lab testing to identify the sea bed strata for **erosion** potential and structure design,*
- an existing asset condition survey - *if the revetment is being added to an existing structure such as a seawall*

Intervention	Rock	Concrete	Reno-mattress	Masonry
Cost				

Environmental Impacts

Revetments can disrupt natural shoreline processes by cutting-off inshore supply of materials due to their positioning and can also destroy shoreline habitats and reduce the width of inter-tidal beaches. If the revetment is impermeable, and depending on the shallowness of the slope, the revetment can reflect wave energy leading to **scour** of the **foreshore** in front. A revetments effects on **coastal squeeze** should also be considered. Depending on the type of coverlayer on the surface, it may scar the very landscape and be an eyesore.

Hybrid Opportunities

Revetments are often built in conjunction with vertical seawalls to enable **scour** protection at the toe of the wall and to reduce wave **overtopping**. Vertical and re-curved concrete crest walls are often constructed on top of the revetment to limit wave **overtopping** and flooding. In more sheltered areas, natural fibre matting, a matting made of coir fibre, wood, straw, jute or a combination of organic, biodegradable materials can be laid over eroding steep slopes or coastal areas to minimize the loss of sediment from the land and trap wave-transported sediment.

Adaptability to Climate Change

Due to a revetments design and typically long structural life, they are adaptable to climate change due to the relative ease for a revetment height to be raised for sea level rise and the coverlayer strengthened for increased storminess. This is dependant however, on how well the structure has been built and maintained previously.

Buildability

Revetments are predominantly built on the upper **foreshore** and as such they can be built from the **foreshore** using standard plant and equipment and/or from land behind. In larger construction, such as **foreshore** reclamation, the peripheral revetment seawalls are built typically from shoreline working seaward from top of the constructed core bund as end-on construction or by using jack-up plant working from the sea, the latter being considerably costlier. During progress from shoreline, the bund core can be formed by end tipping quarry run material using tipper trucks and the revetment slopes armoured using suitable crane /excavator/dozer depending on method of armour placing. The toe is, in general, built either from top of the bund using large cranes or long reach excavator or from jack-up if the toe is too long and suitable plant cannot be found to operate from bund.

CASE STUDY

The White Horses community in the parish of St. Thomas features a long stretch of roadway which can be periodically inundated by wave action. The revetment constructed there serves to protect the roadway from the high wave energy to which it is exposed. However, due to improperly sized boulders used in construction this revetment is now failing as the boulders have slipped into the sea.

D3.2 REVETMENTS

Summary

- A revetment is placed on sloping structures or against vertical walls to protect against erosion of a natural feature on the coast by environmental loads such as waves, currents and wind and geotechnical loads to reduce wave **overtopping** and consequential damage/flooding of land behind
- Revetments can have a significant impact on beach levels due to their effect on cross-shore and longshore beach processes
- Revetments can disrupt natural shoreline processes by cutting-off inshore supply of materials due to their positioning and can also destroy shoreline habitats and reduce the width of inter-tidal beaches

References and Data Sources

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'
NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'
EurOtop, 2016. Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., www.**overtopping**-manual.com.
Van der Meer, J.W. 1987. 'Stability of breakwater armour layers – Design formulae'. Coastal Engineering 11: 219-239.
SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers.
CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'
Jamaican National Building Code

D3.3 SEAWALLS

What are Seawalls?

Seawalls are coastal defence structures constructed parallel to the shoreline to separate a land area from the sea. Their primary purpose is to protect the land and upland areas from erosion and flooding by tidal storm surge, waves and currents. They can also be built at the foot of cliffs and dunes. Seawalls are often considered to be the last line of defence, due to them being positioned as far landward as feasible to provide a clear and fixed distinction between the beach and mainland. Seawalls are static features which is in conflict with the high energy dynamic nature of the coast and thus they impede on the exchange of sediments between the land and the sea.

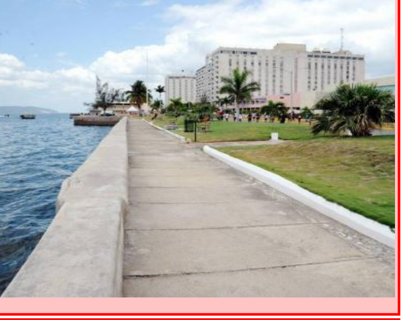
Seawalls are primarily gravity structures built in highly exposed settings. There are two main types; plain vertical seawalls – designed to reflect wave energy, and stepped/curved seawalls – designed to enable waves to break to dissipate wave energy. Other types of seawall include sloping, cantilever, tied back sheet pile, rubble mound with armoured slope and breastwork.

A vertical faced seawall, although robust in construction to withstand direct impact of waves, is less effective in reducing wave **overtopping** due to its more reflective nature when compared to curved or stepped seawalls. The fronting steps induces some wave breaking and energy dissipation in front of the vertical whilst the recurve wall profile deflects the waves back to the sea instead of **overtopping** the wall. Seawalls have a long structural life and are easily adaptable for future, however they can exacerbate **coastal squeeze**, can cause **downdrift** problems and can effect existing wave and current patterns.

Build	✓
Protect	✓
Accommodate	✗
Retreat	✓

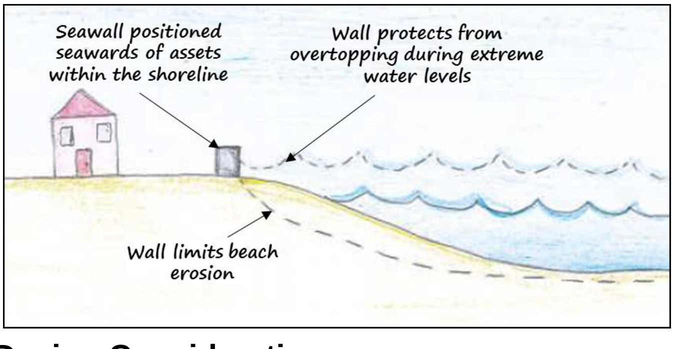
CASE STUDY

Ocean Boulevard in Downtown Kingston, borders the famous Kingston Harbour. The vertical seawall separating the Harbour from the boardwalk there was constructed in the 1970's atop sheet piles, successfully protecting the area since.



Where can Beach Protection be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	✗



KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Geometry of Coastline
- Water level (including SLR projections)
- Wall geometry
- Geotechnical parameters

Key Design Considerations

Seawalls should be positioned as far landward as possible to allow the natural coastline freedom to move. The alignment should be as smooth as possible and follow the natural contours of the coastline. Seawalls should be designed to dissipate as much wave energy as possible. The effect a seawall will have on sediment distribution should also be considered, and how much **scour** will be caused at the toe of the structure. Seawalls can also cause beach steepening and lowering of the **foreshore**. Other considerations for design include: length, crest height (based on wave **overtopping** and beach drawdown level), stability against environmental loads (still water level/wind/wave/ current and service and construction surcharge) and geotechnical loads (from back fill ground and foundation stability) seaward and landward of the wall, availability of building materials, and economic feasibility limits. Principal materials used in vertical seawalls are concrete, structural (steel piling) and reinforcing steel, and in less exposed wave environment, rock fill gabion basket and timber breastwork, etc. A seawall may, to a varying degree, accelerate erosion requiring additional fronting structures such as groynes, erosion mattress, beach recharge etc. to stabilise the **foreshore** and to secure the seawall foundation. Where applicable, beach access needs to be provided in line with the Beach Access and Management Policy - Draft Policy 2014 (Part E).

D3.3 SEAWALLS

Intervention	Vertical	Stepped	Sheetpile	Breastwork
Cost	$ $	$ $	$ $	$ $

Preliminary Studies Required

When designing a seawall the stability against direct wave attack, water level, wave reflection, and the run-up and **overtopping** amongst others will need to be considered. Therefore the necessary preliminary studies required will include; data collection of environmental parameters, such as offshore wave heights and direction, wind, currents, etc., geology of the area through surveys (topographic and bathymetric surveys), a ground investigation study and a met-ocean study including numerical and physical wave modelling (where appropriate 2Dflume models) to evaluate the loading the seawall will be subjected to and its effectiveness in reducing wave overtopping.

Environmental Impacts

Seawalls can cut-off the possible inshore supply of material to the beach (reducing sediment budget) from coastal erosion along the frontage, thus disrupting the natural shoreline processes and destroy shoreline habitats. In extreme cases this can render the beach useless for beach goers, and can encourage localised scouring to the beach in front of the wall due to wave reflection where the wall is regularly exposed to the sea. Seawalls effects on **coastal squeeze** should also be considered. Due to a seawalls size and appearance, it can have adverse landscape and visual impacts.

Hybrid Opportunities

Seawalls, when in conjunction with beach control structures and nourishment can provide a wall design which has a less expansive and obtrusive impact on the surrounding landscape. Concrete seawalls fronted by stepped apron should provide seating amenity to beach goers and allow the provision of promenades and walkways as well as safe access to the **foreshore**. A revetment in front of the wall can provide scour protection and depending on the extent reduce potential overtopping. Other hybrid opportunities include the use of seagrasses and corals in front of the wall.

Adaptability to Climate Change

Seawalls are fairly adaptable to climate change due to the ability to extend the height of the seawall. This should be considered during design stage to enable sufficient foundations for future alterations.

Buildability

Typical materials used within a seawall include concrete, masonry, rock armour, gabion baskets or pre-cast concrete units which are easy to manufacture/fabricate/or source on site or locally. The construction process can be done on land at all times, and on the **foreshore** during low tides.

Summary

- Seawalls are coastal defence structures constructed parallel to the shoreline to separate a land area from the sea. Their primary purpose is to protect the land and upland areas from erosion and flooding by tidal storm surge, waves and currents
- There are two main types: plain vertical seawalls – designed to reflect wave energy, and stepped/curved seawalls –to enable waves to break to dissipate wave energy
- Seawalls can cut-off the possible inshore supply of material to the beach (reducing sediment budget) from coastal erosion along the frontage, thus disrupting the natural shoreline processes and destroy shoreline habitats

References and Data Sources

Relevant Policies:
Jamaican National Building Code
Specific Design Manuals:
CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'
CIRIA, 2010. 'Beach management manual (second edition)'
NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'
SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers.

D3.4 GROYNES

Build	✓
Protect	✓
Accommodate	×
Retreat	×

What are Groynes?

Groynes are shore protection structures which are used to control and manage the natural movement of beach material. A well designed groyne system can arrest or slow down the **longshore drift** of material by building up the material in bays. Groynes also deflect tidal currents away from the shoreline. They are designed to principally alter the natural orientation of the beach line and trap longshore drift to prevent further erosion of the beach. The effectiveness of the groynes re-establishing the beach is dependent on the magnitude and direction of the longshore transport and available sediment budget. They are narrow structures of varying height and length (generally long) and are typically constructed perpendicular to the shoreline. They are generally constructed with a straight body in plan, although Zig Zag shapes as well as straight ones with Y (fish tail), T (hammer head) and L shaped have been constructed. They extend from a point above high water line to a point on the beach usually not below low water line. They rarely extend beyond the zone in which wave induced longshore currents occur naturally. Groynes are formed of a variety of materials, depending on whether they are permeable or impermeable, and include but not limited to; timber, rock, concrete, steel, infilled gabion baskets, and coral. The groynes found commonly around Jamaica's coastline are constructed either of rock or precast concrete. The permeability of a groyne can vary in the long term due to either their structural deterioration or blockage of drift material. Permeable groynes can be used on beaches which have sufficient supplies of littoral material for some proportion to pass through them resulting in more uniformly shaped beach plans than that created by impermeable groynes.

Where can Groynes be positioned?

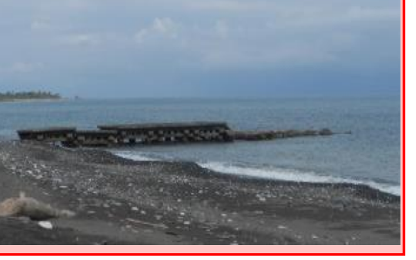
Hinterland	Shoreline	Nearshore
×	✓	✓

Key Design Considerations

In considering the application and effectiveness of groynes at a particular site, it is necessary to take into account the following: how the whole coastline has evolved/changed over time, the existing orientation of the coastline at the site, and where there are no defences presence, then that of the adjacent coastline, any changes that have occurred to the orientation the coastline due to any groyne system which exist, the location and prominence of any headland features and its likely influence on **littoral drift** and natural bay formation, and the extent of offshore banks and their orientation and effects relative to stabilised coastline. When considering the use of groynes it should be noted that groynes can only be used to interrupt longshore transport, and that they will modify the **beach profile** which will then try to re-establish its natural shape once the groyne bay is full. It should also be noted that by capturing the sediment from the longshore transport it will be prevented from reaching the **downdrift** area, upsetting the current sand balance. Once groyne bays are full longshore transport rates are restored due to sediment movement over and/or around the end of the groynes. The effectiveness of a groyne field will depend on the type of beach material grading (sand, shingle, mix, upper or lower), the wave climate, the tidal regime, the dimensions and hydraulic characteristics of the groyne, and in the long term the stability of the substrata and the durability of the groyne material. When designing a rock based intervention, a number of design empirical formulae have been developed, including the Hudson Formulae for typical permeability, and the Van der Meer equation for varying structure permeability and varying wave characteristics.

CASE STUDY

The shoreline of St. Margaret's Bay beach is dotted with remnants of Makepeace Wood groynes. These groyne structures were designed to be semi-permeable and were used extensively in Jamaica many decades ago (≈ 1940's). Storms and lack of maintenance have damaged these structures and they no longer function as intended.



KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Sediment type, supply and transport
- Water level (including SLR projections)
- Beach profile and variability

D3.4 GROYNES

Preliminary Studies Required

Preliminary studies required may include;

- a Metocean study - *to identify the combined wind, wave and tidal /wave induced current conditions (annual/seasonal/extreme for beach and structure),*
- a ground investigation study - *to identify the sea bed strata for* ***erosion*** *potential and structure design,*
- an existing asset condition survey - *if an existing groyne field is being modified as opposed to a new installation.*
- Historic beach cross section variations

There are several rules of thumb that have been derived from experience of successful schemes, from lesson learned from failures and from relatively unsophisticated assessment of **littoral drift**. These rules of thumb have traditionally been applied in the past but subsequent improved scientific understanding of the coastal environment has led to the development of better analytical and predictive techniques, particularly through the development of numerical modelling. Experience and engineering judgement still play a part in good design practice for groynes. Numerical models (**hydrodynamic** and **littoral transport** models) are often required to derive the wave induced currents and better estimate the extent of littoral movement of material (potential and actual based on sediment budget) and calculate how much material can be trapped within the groyne bays. Numerical modelling is also required to accurately identify the optimum length and spacing of a groyne field. In instances, limited physical 3D basin modelling can be carried out to visually observe the movement process of material within the groyne bay, although they have limited capability with sediment dynamic problems due to lack of proven scaling relationship.

Intervention	Timber	Rock	Concrete
Cost			

Environmental Impacts

Rip currents can be created by water pushed by waves into a groyne bay returning offshore as a rip current along the side of a groyne. This can result in an increased amount of sediment moving offshore as well as increasing the distance seaward the sediment travels. The long term-effects of installing a groyne field often leads to further coastal defences being built **downdrift**, due to the reduction of longshore transport.

Hybrid Opportunities

Groynes have traditionally been used as a barrier to prevent material movement, however they can also be used to reduce the occurrence of **scour** trenches at the toes of seawalls. Therefore, hybrid opportunities with groyne systems include beach protection, beach vegetation planting, and seawalls. It is also possible to install temporary groynes using sand bags.

Adaptability to Climate Change

An option to enable the groynes to be adaptable to climate change would be to install ‘adjustable groynes’. Adjustable timber groynes consist of removable planks between piles. The planks are designed to be added or removed to maintain the groyne at a specific height above the beach level. The height and profile of rock groynes can be adjusted by adding/removing armour layers. Concrete or SSP groynes are more difficult to adjust.

D3.4 GROYNES

Buildability

Although from a structural point of view the construction of groynes is straight forward, the activities are complicated due to the limitations placed on access and tidal window. This is worst when working on the head which is at low water level. In such instances designs such as rubble mound structures, or sheet pile designs are favoured as construction access and working platforms are possible above tides and the work can proceed from shore. For future maintenance, the working access on top of the completed works would provide access. As a groyne system is intended to interrupt and retain **littoral drift**, construction of new groyne system is best commenced with the **down-drift** terminal groyne. Ideally construction is followed in phases with initially, say 3 groynes being built, monitored and assessed to determine beach response to the groynes.

Summary

- Groynes are shore protection structures which are used to control and manage the natural movement of beach material
- They are designed to principally alter the natural orientation of the beach line and trap **longshore drift** to prevent further erosion of the beach
- The long term-effects of installing a groyne field often leads to further coastal defences being built **downdrift**, due to the reduction of longshore transport

References and Data Sources

Relevant Policies:

Jamaican National Building Code

Specific Design Manuals:

CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'

CIRIA, 2010. 'Beach management manual (second edition)'

SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

D3.5 LAND RECLAMATION

What is Land Reclamation?

Land reclamation is the process of creating new land from the sea or marshes. The reclaimed land gives added benefits to countries which do not have sufficient land for development. The benefits include land for:

- residential and business purposes through building housing and business parks, community facilities and public open spaces
- major transport infrastructure such as highways, airports, and ports
- and other uses such as agriculture land, to eliminate badly polluted coastal water, and improve hydraulic conditions

The principal structural components are the fill and the containment seawall along its periphery. In order to protect the surrounding environment from pollution, damage to ecology and effect on fishing industry, it is recommended to place the fill within a containment **bund**. The reclaimed land should fulfil the requirements of the planned use and programme for development, in particular with regard to time and settlement characteristics. Reclamation projects are usually extensive, time consuming, costly and may endure problems during and after construction carrying major financial implications. The fill for reclamation includes marine dredged sand fill, crushed rock, or fill generated by construction industry (unused and demolished building material etc.). The use of fill generated by construction is encouraged to prevent waste.

Build	✓
Protect	✗
Accommodate	✓
Retreat	✗

Where can Land Reclamation be positioned?

Hinterland	Shoreline	Nearshore
✗	✓	✓

Key Design Considerations

When designing for land reclamation the following should be considered. It is to be noted that land reclamation can cause areas of land to become increasingly exposed to coastal erosion and flooding and the design must be carefully considered to ensure that it is undertaken in a sustainable way.

- **Peripheral wall design** – comprising structures such as *rock/concrete armoured revetment* (preferred as it is less reflective and can be constructed without the use of expensive marine floating plant), *steel sheet pile vertical wall* (less preferred due to wave reflectivity and resulting bed **scour**. Requires floating marine plant), and *mortared/grouted masonry gravity wall* (applicable only in mild wave climate).
- **Fill material** – often dependent on the proposed land use. Thought should be given to settlement issues, the fill material grading, and the source of the fill material (land as opposed to offshore). Extensive chemical contamination testing is required to establish that the material is not harmful. In large scale reclamation marine dredged sand fill is preferred.
- **Fill Treatment** – The densification of the fill to improve the settlement characteristics include (i) static methods (pre-loading, etc.) (ii) dynamic methods (vibratory probe technique or dynamic loading, etc.). The choice would depend on the degree of improvement, the depth of fill and the project programming required.
- **Drainage requirements**

Cost	

CASE STUDY

The Montego Bay Shoreline was dramatically re-shaped in the 1970's through a substantial land reclamation project. Just over 26,000 sq. meters (6.5 acres) was reclaimed from the sea just west of the city centre. This reclamation, created three crescent-shaped beaches and a small marina area.

KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Existing Sediment Material
- Proposed Sediment Fill
- Water level (including SLR projections)
- Drainage

D3.5 LAND RECLAMATION

Preliminary Studies Required

When considering land reclamation the following preliminary studies should be conducted:

- Topographic survey - *used to identify and map the contours of the ground and existing features at the specific location .*
- Bathymetry survey - *used to identify the depths and contours of the seabed (near and offshore to deepwater).*
- Oceanographic survey – *On site measurement of tides, wind, waves and currents to supplement existing information and assist with the Met-ocean study.*
- Met-ocean study - A *study involving the collation, review and analysis of existing and new water level, wind, wave and current data. Determines design parameters and the assessment of sediment transport to study the impact of the reclamation on the existing costal processes.*
- Ground investigation study – *The ground investigations shall cover the reclamation area and the potential sources of fill materials. This would include the construction of number boreholes, material sampling and in-situ and laboratory testing to determine the nature and thickness of substrata, strength, settlement and permeability characteristics of the underling and fill material.*
- Environmental Impact Study **–** *a study of it's impact on (i) the coastal processes, (ii) existing drainage system, study of drainage impact necessary at early stage of project to assess potential drainage and flooding problems.*
- Material Resource Study **–***The peripheral seawall containing the fill requires to be armoured with natural quarried rock or concrete proprietory armour units depending on the wave climate the structure is exposed to. If good quality rock of required grading is locally available and the transport to the site is by road/sea depending on it's impact on the existing transport highway and local traffic, this would provide considerable cost savings compared to import of rock from overseas. Similarly, if suitable offshore licensed burrow pits are available in close proximity to the site, the fill material sourced and transported by dredger and directly pumped into position would provide considerable savings on cost.*

Environmental Impacts

Draining wetlands or creating land from the sea is a form of habitat destruction, with many parts of the world not allowing or restricting reclamation projects due to environment protection laws. Reclaiming land can also destruct longshore movement within the coastal cell. The potential impacts would include:

- Dredging – noise, sediments plumes, release of nutrients or contaminants from dredged sediments, reduced oxygen ,ecological impact and interruption to natural beach material supply
- Filling Delivery & Placement – noise, dust and smoke generation and water quality impact.
- Resulting landform – interference in tidal flow, wave and sediment transport patterns, siltation, **scour**, water quality, elevation of water table uphill and erosion
- Erosion/**accretion** – **Down-drift** erosion due to the sudden interruption to the natural sediment movement could be significant. Consideration should be given to physically transport by trucks or pump the material from one side to the other on an annual basis.

Buildability

Reclaimed land is highly susceptible to soil liquefaction during earthquakes, which can amplify the amount of damage that occurs to buildings and infrastructure. Subsidence is another issue, both from soil compaction on filled land, and also when wetlands are enclosed by levees and drained. Drained marshes will eventually sink below the surrounding water level, increasing the danger from flooding. Method of Construction – There are two types of construction, namely the Dry method which is suitable for land based materials using trucks or conveyors and best suited for **foreshore** reclamation where the underlying seabed is competent, or Hydraulic Fill (two methods) *Drained method* where the seabed marine deposits and underlying soft alluvial clay are left in place, and fill placed directly on top. This results in the pore water pressure gradually dissipating and the load transferred to soil with resulting settlement. *Dredged Method* in this method all marine and alluvial materials are removed, and dredged materials brought to site from offshore licensed burrow pits. The settlement of the free draining fill, typically sand, will take place quicker and more predictably.

D3.5 LAND RECLAMATION

Hybrid Opportunities

When reclaiming land hard structures in the forms of seawalls or revetments are often required. In certain instances the peripheral seawall could act as a terminal groyne to the adjacent shoreline. Furthermore, there can be opportunities for habitat creation and environmental enhancement, and opportunities to link with restoration of mangroves, coral reefs or seagrass meadows where applicable should be sought.

Adaptability to Climate Change

Land reclamation is adaptable to climate change through increasing the height of the reclaimed land by the provision of suitable strength foundation in the peripheral seawall to accommodate increased loading due to the wall heightening.

Summary

- Land reclamation is the process of creating new land from the sea or marshes
- Reclamation projects are usually extensive, time consuming, costly and may endure problems during and after construction carrying major financial implications
- The environmental damages caused by land reclamation are extensive

References and Data Sources

Relevant Policies:

Jamaican National Building Code

Specific Design Manuals:

CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'

CIRIA, 2010. 'Beach management manual (second edition)'

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

D3.6 GABIONS

What are Gabions?

Gabions are wire mesh baskets that are compactly filled, either in-situ or off-site, with crushed rocks, cobbles or stones. They are commonly used to prevent **erosion** and to stabilise banks, cliffs and dune slopes. Gabions are generally used as either sloping “Reno-mattresses” on revetments and the **foreshore** or as vertical cubic baskets in seawalls where the exposure to waves is mild. Gabion mattress revetments are generally preferred in coastal environments due to there increased stability and softened appearance.

Build	✓
Protect	✓
Accommodate	×
Retreat	×

Where can Gabions be positioned?

Hinterland	Shoreline	Nearshore
×	✓	×

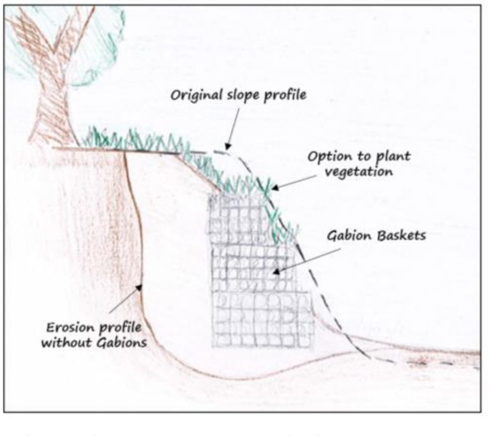
Gabions are suited to low energy beaches and are usually best placed above the tidal zone as they are not durable enough to withstand regular, direct wave action. They should not be installed on shingle beaches as wear and tear will rapidly cause damage to the baskets.

Key Design Considerations

When designing gabions the long-term evolution of the beach and the effectiveness of the structures over their full life should be considered. In addition to this, special consideration should be given to the placement and maintenance of gabions as the baskets are susceptible to rust and damage by water-bourne debris, causing a health and safety **risk** to beach users. When gabions are degrading, they present a hazard to public safety due to rocks falling out of the baskets, and they do not provide firm footing for climbing as well as degradation of the wires causing sharp hazards. The wires used to form the baskets is usually galvanised, and preferably plastic coated (PVC) to protect against corrosion. Abrasion from beach material is the greatest problem to a gabion baskets durability. Vertical gabion walls are prone to structural failure and outflanking and are also more intrusive on the landscape compared to sloping gabion reno-mattresses. It is generally recommended that stones of 75mm – 150mm (not exceeding 2/3 of depth of mattress) are placed tightly to achieve the maximum density and weight for stability. The gabion walls and mattresses designs are limited to sites with wave exposure of up to heights of Hs = 1.0m – 1.5m, subject to sub soil and stone fill are adequately compacted.

Preliminary Studies Required

When designing gabions a metocean study may be required to identify the combined wind, wave and climate conditions of the site to verify that the gabions would be able to withstand the conditions. A ground investigation study may also be required to determine the existing ground conditions and requirement for foundation.



CASE STUDY

Gabion baskets have been used to prevent river bank **erosion** at Berridale, Rio Grande, Portland, Jamaica. The gabion baskets are well-located as they afford some protection to the outer meander bend, however they are poorly constructed as the boulder material used to fill the baskets is commonly finer than the mesh size itself.

KEY DESIGN PARAMETERS

- **Waves**
  - Height
  - Length
  - Predominant Direction
- Sediment type
- Rock size
- Mesh size
- Water level (including SLR projections)
- Ground conditions

D3.6 GABIONS

Cost		Gabions are traditionally a cheap option compared to other construction materials due to their availability only being limited by the supply of stone and the use of unskilled labour who could be easily trained to erect the modular gabion systems. However as they have a typical residual life of only 10-20 years, they are expensive in the long-term.

Environmental Impacts
Gabions are often thought to have a low visual impact, and can even be aesthetically pleasing in some situations. They also have minimal ecological effects on the surrounding area, however if damaged baskets are not properly repaired they can be unsightly and dangerous as they can release their contents onto the beach, which may not be indigenous to that location. Exposed mattress can trap tidal/wave brought in debris. The presence of gabion mattress on a beach can also alter the natural interchange of materials between the beach and dunes and influence the longshore movement of beach material, modify dune habitats and disrupt natural landform.

Hybrid Opportunities
Engineering solution such as gabion walls and Reno- mattress revetments on cliff/dune slopes can be made eco friendly by providing an environment to enable the growth of vegetation. Compost socks (tubular geotextile mesh filled with composed) is placed on the outer face of the gabion which provides a suitable moisture retentive and nutrient rich substrate for vegetation. Gabions can be used with all nature-based solutions as their short **design life** (approximately 20 years) limits their effect on the environment and surrounding ecosystems.

Adaptability to Climate Change
As gabions have a short **design life** they are adaptable to climate change in terms of the structure being removed and re-installed, when initially designing a gabion structure, climate change does not need to be taken into account as it is likely the structure will fail prior to their being a significant rise in sea level.

Buildability
Gabions can be constructed, being prepared either on- or off-site, and installed rapidly providing instant protection to the coastline. However they are not durable, therefore requiring maintenance and frequent replacement, resulting in only having a 10-20 year **design life**. They are also particularly susceptible to vandalism. Gabions are a short-term solution and are particularly useful in emergency situations.

Summary
- Gabions are wire mesh baskets that are compactly filled, either in-situ or off-site, with crushed rocks, cobbles or stones
- They are commonly used to prevent erosion and to stabilise banks, cliffs and dune slopes
- Gabions have a short **design life**, resulting in large whole life costs

References and Data Sources

Relevant Policies:
Jamaican National Building Code
Specific Design Manuals:
CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'
CIRIA, 2010. 'Beach management manual (second edition)'
NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'
SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

D3.7 FLOOD BARRIERS

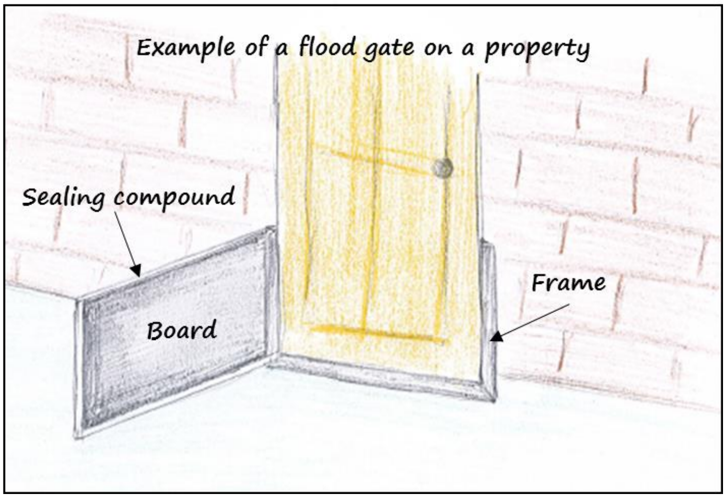
What is a Flood Barrier?

A flood barrier is designed to prevent water from flooding the protected areas behind the barrier, and can be found as part of other permanent defence structures such as seawalls. They can also be placed temporarily or permanently around individual buildings or at building entrances to keep floodwaters from entering those buildings. If flood barriers are acceptable to the local community, it is a requirement to ascertain the reliability of the flood forecasting and alert system, and their use to trigger alert. It is important that the organisation responsible for the operation of the barriers are aware of the legal issues associated with their operational powers. There are several types of flood barrier including:

- Temporary - a removable protection that is wholly installed during flood event and completely removed when water levels recede. Sand bags are the most common form. Temporary barriers are used when economic justification for demountable and permanent barriers is insufficient
- Demountables - a movable flood protection system that is fully pre-installed and requires operation during flood event, or a system that requires part-installation into pre-installed guides or sockets, with the defence components being stored elsewhere when not in use. A demountable is only functional when the barrier is in a closed position before water rises to the permanent protection level. They are needed in addition or as an alternative to permanent flood protection systems when they are unable to completely provide the protection required for the area.
- Flood / Slide gates - allow water and access through the defence when required and then adjust the gates (manually or automatically) up and down along the track to close them entirely. Some flood gates slide vertically in slots along the opening, whereas others are hinged along one side. Others have hinges on both sides of the opening and seal against each other in the middle. Flood gates may be operated manually, mechanically or automatically.
- Property Level Protection - defences fitted to building to prevent the ingress of water.

Where can a Flood Barrier be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	×



Build	×
Protect	×
Accommodate	✓
Retreat	✓

CASE STUDY

In downtown Nassau, Bahamas, flood barriers have been incorporated into the seawall. As can be seen (below), demountable protection is used. When flood warnings are in place, the demountable flood barrier is installed resulting in the entire promenade being protected. The demountable are removed allowing access as well as a route for any **overtopping** flood water to disperse.

KEY DESIGN PARAMETERS

- Dimensions
- Location
- Flood depth
- **Design life**

Key Design Considerations

When designing a flood barrier the barrier dimensions and water depth need to be considered for the manufacture of the barrier. Thought should also be given to the operation of the barrier, will it be automatic, mechanical or manual, and who will be responsible for the operation, in addition to the maintenance of the defence.

D3.7 FLOOD BARRIERS

Preliminary Studies Required

When designing a flood barrier a metocean study (a study to identify the combined wind, wave and climate conditions) should be conducted to enable the calculation of the hydraulic loads and flood water depth. An existing asset condition survey may also be required when installing a flood barrier on an existing defence.

Intervention	Self-Activating Flood Barrier	Steel Door	Flood Gate	Roller Shutter Door	Flood Defender Barrier and Wall	Stop Log System
Cost	\$\$	\$	\$	\$	\$\$	\$\$

Environmental Impacts

Since they are temporary structures installed during high flood event and removed fully the and taken off site the environmental impact is insignificant. A feeling of safety is an important factor in obtaining public acceptance.

Hybrid Opportunities

Flood barriers are often incorporated into seawall defences, allowing pedestrian access to the frontage when a flood warning is not in place. Flood barriers, in particular property level protection can be incorporated with **nature-based interventions** to provide additional protection to properties against flooding.

Adaptability to Climate Change

Flood barriers, stop logs in particular, can be adapted to allow for larger water depths by increasing the height of the structure by adding additional 'logs'.

Buildability

The **buildability** of flood barriers is mainly dependent on the resourcing of the closure phase. As flood barriers are often built to the specified dimensions and then initially installed on site by the manufacturer, sufficient lead in time is required between the flood alert and time of flooding to allow for the preceding activities to the closure of the barrier; the skill and readiness of the workers, the ease of construction, and the availability of suitable plant and machinery at short notice (if required). Preparation works before the closure will be required such as; temporary road or path closures, signage, and the removal of obstructions.

Summary

- A flood barrier is designed to prevent water from flooding the protected areas behind the barrier, and can be found as part of other permanent defence structures such as seawalls
- There are several types of flood barrier including temporary, demountable, flood/slide gates and property level protection
- Since they are temporary structures installed during high flood event and removed fully the and taken off site the environmental impact is insignificant

References and Data Sources

Relevant Policies:

Jamaican National Building Code

Specific Design Manuals:

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

CIRIA, 2013. 'The International Levee Handbook'

Environment Agency, 2011. 'Temporary and Demountable Flood Protection Guide'

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CIRIA, 2010. 'Beach management manual (second edition)'

SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

D3.8 LEVEES

What is a Levee?

Levees (also known as embankments or dikes) are raised, predominantly earthen structures which are supplemented and extended at locations along its length by concrete and steel. A levees primary objective is to provide protection against flood events especially in more sheltered environments such as estuaries. They are generally constructed by placing local fill material onto flood plains. Steel sheet pile curtains are installed at the toe or through the levee to provide a barrier to under-seepage flow beneath the levee and/or raise the crest and/or concrete floodwalls are used to raise the crest without having to subject the underlying soil to additional loads by widening the foot print of the levee. Levees are often irregular in their construction and can deteriorate rapidly if they are not well maintained.

Build	✓
Protect	✓
Accommodate	×
Retreat	✓

Where can a Levee be positioned?

Hinterland	Shoreline	Nearshore
✓	✓	×

Key Design Considerations

Levees can be surprisingly complex structures; due to their function and location they are often built on soft alluvial soils which can exhibit low strengths, high compressibility and/or high permeability. Potential levee failure mechanisms include (i) structural causes such as slope stability involving soil bearing capacity failure, lateral translational and deeper rotational failure and structural failure of the walls/sheet pile/gates due to impact of physical objects (ii) hydraulic loads such as under-seepage instability, bottom heave or blowout, erosion & piping, exit and internal seepage erosion and (iii) surface erosion of front and back slopes and crest due to wave impact and **overtopping**. Levees are also prone to variability, imperfections, and deterioration with time therefore the following must be considered during design: levee alignment, crest level, cross-section, ground conditions, materials, maintenance, points of weakness, human-induced impacts, and the construction process. Other considerations include; the study of impact of trees and significant vegetation growth immediately adjacent to the levee on the stability of the walls (trees with large root system extending below floodwalls with potential to lift the wall causing cracks, separation of joints or total failure), weakening due to burrowing animals, and encroachments such as building structures which affect the performance of the levee.

CASE STUDY

Shoreham Adur Tidal Walls (UK) is a project to reconstruct and raise the existing tidal defences over 7.2km of the River Adur. These new defences constitute sheet piling, concrete walls and earth levees. The levees allow the creation of habitat, the ability to maintain heritage assets within the area and to maintain existing infrastructure whilst providing protections to the area behind.

KEY DESIGN PARAMETERS

- Waves
  - Height
  - Length
  - Predominant Direction
- Currents
- Water Level (including SLR projections) for both sides of the levee
- Geometry of Coastline
- Crest Size Required
- Health & Safety
- Geotechnical information

Preliminary Studies Required

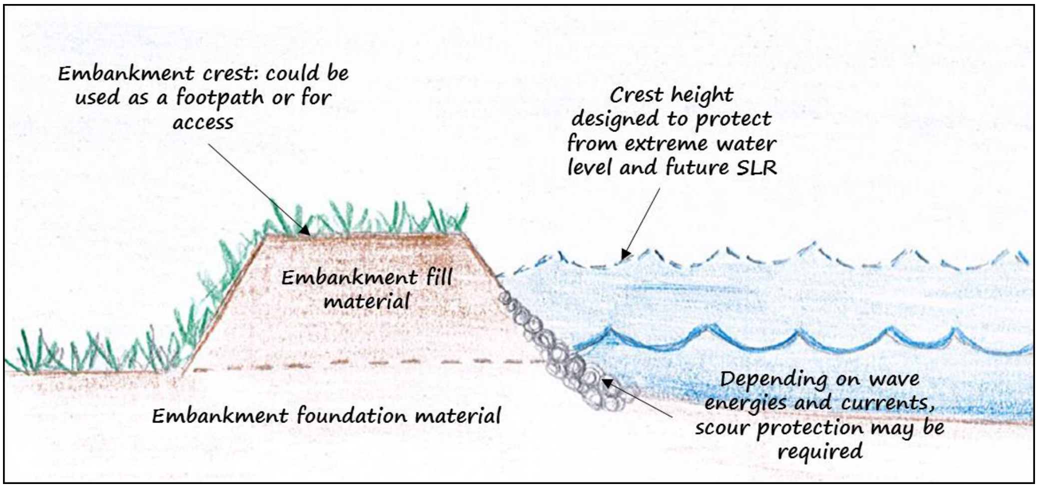
In order to begin detailed design of a levee, a series of preliminary studies will be required to collate information required in the key design parameters. These preliminary studies will include:

- Topographic survey - *used to identify and map the contours of the ground and existing features at the specific location .*
- Bathymetry survey - *used to identify the depths and contours of the seabed (near and offshore to deepwater).*
- Metocean study - A *study to identify the wind, wave and current climate conditions found in the specific location.*
- Ground investigation study - *Used to determine the existing ground conditions, often using trial pits and boreholes.*
- Existing asset condition survey (visual and intrusive) - *Used to identify the conditions and residual life of any existing man-made defence structures at the specific location.*

The preliminary studies required in particular for levee design are a ground investigation study, a met-ocean study and a topographic survey.

D3.8 LEVEES

There are many variations to the cross-section of a levee; homogeneous earthfill, zoned, and composite. Earthfill levees are made of uniform soils obtained from site excavation, and when sand is used it needs to be at least protected from both external and internal **erosion**. Zoned levees consist of a combination of permeable and relatively impermeable material (clay) making up the cross-section, and are typically constructed when a single type of material such as clay is scarce, the levee is formed with a central clay core to provide a cut of to water penetration through the levee. Composite levees include structural components such as concrete wall, steel sheet piles, and geotextiles.



Levee Material	Earthfill	Zoned	Composite
Cost	$ $	$ $	$ $ $

Environmental Impacts

Levees are often multi-functional and can provide access routes, recreation areas, farming land, utility crossings, ecological improvements and environmental provisions. When designing a levee thought should be given to minimising resources used and opportunities for environmental enhancement such as habitat and migration corridor creation.

Hybrid Opportunities

In addition to composite levees which can include superstructures both externally and internally, levees may also be associated with other structures such as offshore breakwaters, groynes and dunes. The primary functions of these structures are to prevent erosion and maintain the levee integrity. Beach protection in addition to other **nature-based interventions** can be used in front of the levee, ensuring that the **intervention** is not prone to the effects of **coastal squeeze.**

Adaptability to Climate Change

When designing levees climate change and its effects on sea level, wave height and direction, currents and storm frequency and intensity should be considered. Climate change can effect the rate at which the levee will erode and can also induce settlement. The levee can be adapted in the future for effects of climate change such as sea level rise, and increased storminess through; reinforcement of the slope with rip-rap rock, proprietary concrete/ reno- mattresses, etc., and by installing concrete/steel sheet pile flood walls on top of a levee. An alternative to adapting the original levee would be to build an additional levee behind the first levee in case it is overtopped during a high water event.

Buildability

When designing a levee, the dimensions should accommodate access for construction vehicles and future maintenance plant and equipment. Crest widths of 3-5m are often considered to be the minimum feasible for construction using modern heavy earthmoving and compacting equipment, Earth levees in the coastal environment are often limited in height to approximately 4m, depending on the shape of the levee and the thickness of any surface crust.

D3.8 LEVEES

Summary

- A levees primary objective is to provide protection against flood events
- Levees are often multi-functional and can provide access routes, recreation areas, farming land, utility crossings, ecological improvements and environmental provisions

References and Data Sources

Relevant Policies:

Jamaican National Building Code

Specific Design Manuals:

CIRIA, 2007. 'The Rock Manual. The use of rock in hydraulic engineering (second edition)'

CIRIA, 2010. 'Beach management manual (second edition)'

NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'

CIRIA, 2013. 'The International Levee Handbook'

SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

D3.9 SAND BAG STRUCTURES

Build	✓
Protect	✓
Accommodate	×
Retreat	×

What are sand bag structures?

Sand bag structures are used as a soft stabilisation strategy that temporarily stops or slows the effects of coastal erosion. They are generally placed in front of and parallel to development to prevent the destructive forces of the sea reaching coastal structures.

Sand bags can be used to build a number of shoreline structures and are particularly useful when used as a buried revetment. For instance, if buried under a beach ridge they can form a final line of protection once the overlaying sand is eroded as a result of storm waves or other processes. When buried, sand bags are required to be covered by recycled or imported sand and stabilised by transplanted vegetation and fencing/thatching to ensure effectiveness.

Where can sand bag structures be positioned?

Hinterland	Shoreline	Nearshore
x	✓	×

Key Design Considerations

Exposed sand bag structures are only appropriate as a temporary and short-term measure until other management solutions can be implemented, whilst buried structures have a longer life expectancy, therefore sand bag positioning must be considered. Other considerations will include:

- Material – often geotextile however jute can be used.
- Fill material – sand or sediment.
- **Beach profile** – natural gradient and the varying gradient due to seasonal and/or storm change.
- Risk of exposure – particularly from a health and safety perspective

CASE STUDY

Geotextile bags and tubes have seen a rapid growth in popularity when dredging or excavating to store silt and sand from dredge spoils. The dredged materials are then dewatered to be used for replenishing beaches or creating brand new land mass, protecting levees, creating breakwaters or groins for protecting shorelines and coastal areas. These are used in the Bahamas, Trinidad and Tobago, Aruba, Turks and Caicos, Virgin Islands, Cayman Islands, Puerto Rico, Costa Rica, Belize, Nicaragua and Honduras.

Geotextile bags used for coastal protection in the Bahamas (photo: Caribbean Geotextiles)

KEY DESIGN PARAMETERS

- Depth of burial
- Material
- Size
- **Beach Profile** (including future changes)
- Risk of exposure
- Water level (including SLR projections)

Preliminary Studies Required

An assessment of the dynamics of the sand dune and beach system will need to be undertaken to ensure the viability of this **intervention.**

When applied in dune systems, preliminary works will have to be undertaken in advance to shape the dune face to form a plane slope to allow for bags to be laid evenly.

D3.9 SAND BAG STRUCTURES

Cost		When buying sand bags thought should be given as to whether pre-filled sand bags will be bought, or whether the bags and the fill will be bought separately.

Environmental Impacts

As with all fixed defences, sand bag structures may interfere with the natural dynamic interchange of material in beach systems. Given their temporary nature and the fact that they are easily removed, sand bag structures have less long term impacts on the physical or natural environment.
Where installation is carried out in a sensitive manner, sand bag structures are an environmentally friendly and sustainable way of reducing or reversing the deterioration of beach systems.

Hybrid Opportunities

Sand bag structures are often paired with other **interventions** including **nature-based interventions** (such as beach vegetation planting and beach replenishment) as well as various **hard interventions**. This may include a seawall or revetment structure at the back of the beach ridge. Another option would be to use sediment-filled geotextile material tubes., which are placed parallel to shore to dissipate waves in high-energy environments. The tubes create new avenues for dredge material disposal, and produce a hard surface on which reefs can be constructed.

Adaptability to Climate Change

Healthy beach and dune systems constitute an effective form of sea defence due to its ability to adapt its shape naturally to changing wave and tidal conditions and can be designed for future SLR. Sand bag structures further contribute to the **resilience** of beach systems.

Buildability

The **buildability** of sand bag structures is relatively simple. If using buried sand bag structures, excavation within a tidal environment may be required.

Summary

- Sand bag structures temporarily stop or slow the effects of erosion
- Sand bags are only appropriate for use in the short-term
- Due to a sand bag structures simplicity, they are easy and relatively cheap to install

References and Data Sources

Relevant Policies:

NEPA (2000) 'A Beach Policy for Jamaica'

Specific Design Manuals:

Heerten, G., Jackson, A., Restall, S. and Stelljes, K. (2000). Environmental Benefits of Sand Filled Geotextile Structures for Coastal Application. International Society of Rock Mechanics. ISRM International Symposium, 19-24 November, Melbourne, Australia.
SNH (2000). A guide to managing coastal **erosion** in beach/dune systems. Scottish Natural Heritage, October 2000. http://www.snh.org.uk/publications/on-line/heritagemanagement/**erosion**/index.shtml
CIRIA, 2010. 'Beach management manual (second edition)'
NRCA, Circa 1995. 'NRCA Guidelines for the Planning Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines'
SPM (1984). Shore Protection Manual. Coastal Engineering Research Center. U.S. Army Corps of Engineers

D4: Non-structural Solutions

Non-structural interventions relate more to the planning and policy work that can be undertaken to improve overall resiliency within the **R2R** profile. Although these **interventions** are not traditionally thought of as solutions to coastal management, they should be considered either on their own or to complement all developments within the coastal zone.

Reference should also be made to Part C (for stakeholder engagement and sea level rise guidance) and Part F (monitoring and maintenance requirements).

Case studies are used throughout to exemplify **interventions**, and where possible Jamaican or regional examples are used. Occasionally international example case studies are used where they provide best practice examples. However, it is to be noted that whilst case studies can provide a context and best practice examples, often **interventions** required specific site conditions and cannot simply be completely replicated. Site conditions must be considered for the specific site when designing **interventions.**

D4.1 MANAGED REALIGNMENT

What is Managed Realignment?

Managed Realignment (or retreat) is an alternative coastal management option that can be economically preferable, whilst conserving natural processes by minimising the effect of **coastal squeeze.** It involves retreating inland from the existing line of flood defence or coast protection, while monitoring and maintaining an awareness of the consequences of the landward realignment. It entails the loss of some land area that was previously defended, so normally, it will only be considered where the existing defence is no longer viable or where there is an environmental benefit. The landward realignment may entail removing infrastructure, roads or breaching existing seawalls. Landward realignment may require the provision and maintenance or establishing of defences at the retreated position although it may be feasible to allow the shoreline to retreat to a stable alignment in which is will form a natural defence. However, the landward realignment defences can potentially be less substantial than the former primary defence as the wider **beach profiles** gained through retreating will absorb a greater proportion of the incident way energy. Natural infrastructure can be used to protect built infrastructure in order to help the built infrastructure have a longer lifetime and to provide more storm protection and benefits.

Build	×
Protect	×
Accommodate	×
Retreat	✓

Where can Managed Realignment be positioned?

Hinterland	Shoreline	Nearshore
✓	×	×

Key Design Considerations

The design of a successful managed realignment scheme depends largely upon the creation of appropriate physical conditions and morphological responses within the scheme and adjacent natural environment. They require a careful assessment of physical processes and morphology prior to their implementation. These are relevant issues to consider in any MR scheme for two principal reasons:

1. Existing physical processes and morphology may influence the design of the scheme; and
2. Existing physical processes and morphology may be affected by the design of the scheme, both within the MR site and within the wider coastal or estuarine system.

CASE STUDY

To date, 64 different managed realignment schemes have been implemented in the UK over the last 25 years (ABPMer, 2015). These schemes are predominantly designed to be flood protection measures and are undertaken at locations where it will improve the sustainability of the existing coastal defences. However, they also have a key function as coastal habitat creation initiatives and, indeed, the majority of completed projects in the UK have been undertaken with habitat creation as the motivation (often as compensation for losses of habitat elsewhere).

Source: Environment Agency, UK

Preliminary Studies Required

Key physical process and morphological parameters in need of consideration or study are as follows:

- **Hydrodynamics**
    - Tidal levels and range
    - Tidal prism and discharges
    - Tidal current velocities
    - Tidal asymmetry
- Waves
    - Wave energy
    - Wave transformation
- Sediment dynamics and morphological response
- Topography of realignment area and any need to re-profile to achieve the environment required for any new habitat

KEY DESIGN PARAMETERS

Morphological regime:

- Topography (level, gradient);
- Presence of morphological features (e.g. creeks, deltas).

Hydrodynamic regime:

- Tidal levels and range;
- Tidal prism;
- Tidal current velocities;
- Tidal asymmetry;
- Wave action.

Sediment regime:

- Sediment composition;
- Sediment budgets;
- Sediment transport (bedload and suspended load).

D4.1 MANAGED REALIGNMENT

Intervention	Land Purchase	Compensation	Habitat Restoration	Breaching of Defences	Monitoring
Cost					

Environmental Impacts

If it is carried out in a sensitive manner, managed realignment can be one of the most environmentally friendly and sustainable ways of reducing or reversing its deterioration and thereby reducing the threats of coastal erosion and flooding. The environmental impacts of hybrid opportunities would need to be considered on a case-by-case basis. Its adoption can provide many co-benefits in addition to coastal protection including fishery habitat, water quality improvements, carbon sequestration and storage, and recreational use, and can provide these benefits to coastal communities all the time, not just during storm events.

Hybrid Opportunities

Managed Realignment is often paired with other **interventions** including soft and hard measures. For example, **watershed** management, habitat rehabilitation, or defence breaching may be adopted in conjunction with an existing sea wall or embankment re-design.

Adaptability to Climate Change

Managed realignment has many advantages in certain coastal and estuarine situations with regards to climate change adaptation. It can be used to:

- Improve the 'functioning' of a coastal or estuarine system, if implemented on a large scale within a strategic framework, leading to possible reductions in flood risk to certain areas (i.e. by reducing water levels or through the provision of flood storage areas);
- Provide accommodation space for the natural landward migration of coastal features, such as wetlands, mangroves, dunes, under long term sea-level rise;
- Provide habitat creation (or re-creation) opportunities that assist with maintaining or enhancing **biodiversity** or compensating for habitat losses elsewhere.

Buildability

Managed Realignment likely requires a substantial amount of space to implement natural approaches (such as ecosystem restoration or protection of existing ecosystems) which may not be possible . As hybrid structures are developed the **buildability** is dependent on the **buildability** of the additional structure.

Summary

- Managed realignment involves retreating inland from the existing line of flood defence or coast protection
- Managed realignment is an alternative coastal management option that can be economically preferable, whilst conserving natural processes by minimising the effect of **coastal squeeze**
- If it is carried out in a sensitive manner, managed realignment can be one of the most environmentally friendly and sustainable ways of reducing or reversing an areas deterioration and thereby reducing the threats of coastal erosion and flooding

References and Data Sources

Specific Design Manuals:

CIRIA, 2010. 'Beach management manual (second edition)'

Discussion of Impacts and Risks:

Pontee, N., et al (2016)Nature-based solutions: lessons from around the world. Proceedings of the Institution of Civil Engineers—Maritime Engineering 169:29–36.

Sutton-Grier et al., (2015) Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems.

Van Slobbe, E., et al., (2013) Building with Nature: in search of resilient storm surge protection strategies. National Hazards 66: 1461 - 1480

D4.2 WATERSHED PLANNING ("RIDGE TO REEF")

What is Watershed Planning?

Watershed planning embraces all human activities and non human events/features that are influenced by the water cycle within a defined catchment area. **Watershed** planning, or **Ridge to Reef** planning, targets ways to reduce the transfers of pollutants, nutrients, and sediments from terrestrial catchments, to minimize the damage to coastal ecosystems, including beaches, coral reefs and coastal waters.

Legislation and Regulation?

In Jamaica, the **Watersheds** Protection Act, 1963, is the principal law governing watersheds and is administered by the NRCA/NEPA. The primary focus of the Act is the conservation of water resources by protecting land in or adjoining the watersheds. The Act has not benefited from any substantial revision since its promulgation and needs updating with respect to participatory approaches, and the more recent division of the island into 26 **Watershed** Management Units. The focus of the Act is on regulating activities to protect **watersheds**. In May 2000 Cabinet authorized the establishment of Local **Watershed** Management Committees and Local Forest Management Committees as mechanisms to contribute to **watershed** management in Jamaica.

Key Design Considerations

The following design aspects need to be embraced by any **R2R** or **watershed** planning project in Jamaica: Demand-driven – based on stakeholder needs; Focused, practical, and achievable – learn from lessons of the **R2RW** case study (see opposite); Flexible - with the ability to respond to changing situations and take advantage of opportunities; Results oriented; Sustainable – strengthening local partners to govern and manage their own **watershed** programs; Relevant to the existing Jamaican context of policy on devolution of responsibility and local natural resource governance and management; Collaborative – building partnerships among a wide variety of stakeholders through an understanding of prevailing incentive structures at all levels; Buttressed, with economic incentives built into action programs within existing policy frameworks, as well as support for policy reform as needed.

KEY R2R PLANNING GOALS FOR JAMAICA

- A coherent and rationalized legislative and institutional framework for the integrated management of **watersheds** on a sustainable basis is put in place
- Provision and development of adequate human resources for effective **watershed** management
- Adequate financing secured for **watershed** management activities
- Availability of technical information for effective **watershed** management
- Increased public awareness for improved participation in **watershed** management
- Initiatives to encourage proper land use supported

Build	×
Protect	×
Accommodate	✓
Retreat	×

CASE STUDY

The Jamaica **Ridge to Reef Watershed** Project (**R2RW**) Project 2000-2005 was a five-year, $8 million initiative undertaken by NEPA and USAID. The Project attempted to address the degradation of **watersheds** in Jamaica by improving and sustaining the management of **natural resources** in targeted **watershed** areas that are both environmentally and economically significant. **R2RW** targeted the Great River and Rio Grande **watersheds**, which differ considerably in their characteristics and offer unique challenges. The Great River **watershed** includes Montego Bay and impacts mainly on the parishes of St. James and Hanover. The **watershed** faces numerous environmental threats caused by agriculture and urban development. The Rio Grande **watershed**, in the parish of Portland, is extremely mountainous and heavily dependent on agriculture and tourism. An area of significant **biodiversity**, the Rio Grande **watershed** is threatened by deforestation, soil erosion, inappropriate land use, and mining.

D4.2 WATERSHED PLANNING ("RIDGE TO REEF")

Environmental Impacts

The ecosystem approach views **watershed** management as the management of a complex ecosystem, and regards all its components – air, land, water, fish, wildlife and humans - as interrelated. Key features of the approach are:

a) Any of the components of the ecosystem can be understood only in the broader context of the other components. Research and policy management must, therefore, be integrated across administrative boundaries and specific core interests.

b) An understanding of the ecosystem is best achieved by focusing on the processes and functions within the system, including the ecological, economic and social ones

c) Human beings are part of ecosystems and human use of resources (rather than human exclusion) must be factored into management systems

d) Social equity issues must be considered and a bottom-up approach to learning adopted. There is an emphasis on participatory capacity building.

Adaptability to Climate Change

The distinct inter-connection between land, water and coastal systems in Jamaica, coupled with their high vulnerability to climatic changes and limited human resource capacity make a strong case for the **R2R** delivery approach.

Proposed Steps for Watershed Management in Jamaica

The six-step planning and implementation process is summarized in below. Each step includes several sub-steps that further clarify what should be accomplished before planning moves on to the next step

Steps	Sub-steps	
Step 1 – Build Partnerships	• Identify key stakeholders • Identify issues of concern	• Develop preliminary goals • Initiate outreach activities
Step 2 – Characterise the **Watershed**	• Gather existing data and create a **watershed** inventory • Identify data gaps and collect additional data if needed	• Analyse data • Identify causes of water quality impairment and pollutant sources including assessment of wastewater management • Estimate pollutant loads
Step 3 – Set Goals and Identify Solutions	• Set overall goals and management objectives • Develop indicators and targets • Estimate load reductions expected of management measures	• Identify critical areas • Describe management measures needed to achieve load reductions
Step 4 – Design an Implementation Programme	• Develop an implementation schedule • Develop interim milestones to track implementation of management measures • Develop criteria to measure progress toward meeting **watershed** goals • Develop monitoring component	• Develop information/education component • Develop evaluation process • Identify technical and financial assistance needed to implement plan • Assign responsibility
Step 5 – Implement the **Watershed** Plan	• Prepare work plans • Implement management strategies • Conduct monitoring	• Conduct information and education activities • Share results
Step 6 – Measure Progress and Make Adjustments	• Track progress • Make adjustments	

D4.2 WATERSHED PLANNING ("RIDGE TO REEF")

Summary

- **Watershed** planning embraces all human activities and non human events/features that are influenced by the water cycle within a defined catchment area
- In Jamaica, the **Watersheds** Protection Act, 1963, is the principal law governing **watersheds** and is administered by the NRCA/NEPA
- The proposed steps for **watershed** planning in Jamaica are: Step 1 – Build Partnerships; Step 2 – Characterise the **Watershed**; Step 3 – Set Goals and Identify Solutions; Step 4 – Design an Implementation Programme; Step 5 – Implement the **Watershed** Plan; and Step 6 – Measure Progress and Make Adjustments

References and Data Sources

Relevant Policies:

Jamaica Draft Watershed Policy (2003)

Specific Design Manuals:

Tetra Tech (2010) "Hawaii Watershed Guidance - A report prepared for the Hawai`i Office of Planning Coastal Zone Management"

D4.3 SETBACK ZONES

Build	✓
Protect	✗
Accommodate	✓
Retreat	✗

What are Setback Zones?

A coastal setback is a buffer zone defined by a specific distance from the shoreline's highest winter water mark, within which permanent constructions are not allowed. Setback zones consist as a coastal zone management tool for a number of different reasons, such as:
to ensure public access, to protect the ecological and landscape integrity of the coast, to minimize the natural risk hazards protecting population and developments. **Setback** can be defined as horizontal or vertical and hence can be applied to the hinterland, shoreline or nearshore areas.

Setback categories

1. Vertical **setback** - calculated minimum elevation above a permanently fixed sea level benchmark
2. Rolling vertical **setback** - calculated minimum elevation above a sea level benchmark whose position changes over time.
3. Horizontal **setback** - a specified distance landward of a permanently fixed benchmark
4. Rolling horizontal **setback** as a specified distance landward of a coastal reference feature whose position changes over time
5. Horizontal - calculated distance (which uses dynamic, natural phenomenon) landward of a permanently fixed benchmark
6. Rolling horizontal - calculated distance (which uses dynamic, natural phenomenon) landward of a coastal reference feature.

CASE STUDY

In Negril, a specific Development Order states that "no development will be permitted on land adjacent to the line of high water mark which would preclude public access to and from the **foreshore**... to enable the fullest enjoyment of the natural beauty of Negril, at no point will the erection of structures or fences be allowed within 45m (150 feet) of the high water mark except where, due to the presence of rocks, no beach exists or with the permission of ... the local planning authority..."

Calculating Coastal Setback

Calculations are often based on the following parameters:

1. Chronic erosion – normal coastal processes
2. Acute erosion – storm events
3. Estimated sea level rise
4. Safety factors

$$\textit{Setback distance} = (A + B + C) \times D$$

Where:
A is the **setback** distance needed to account for acute erosion from a major storm event;
B is the **setback** distance needed to account for historical or chronic erosion;
C is the distance needed to account for sea level rise; and
D is a safety factor which increases from 1 to 2 as uncertainty increases or to account for ecological, planning or social considerations.

SETBACK BENCHMARKS

Fixed point on the shore
•Seaward limit of vegetation
•High water high tide
•Dune crest

Key Planning and Legal Considerations

Rolling Easements are a legal planning tool that are often used in countries to determine **setback** distances. This is a legal instrument that allows publicly owned land, and/or land use restrictions, to migrate inland as shorelines retreat and sea levels rise. These tools are useful in that it provides clarity on responsibilities and helps supports planning in coastal areas prone to flooding or erosion. For example, property that falls within the changing easement area cannot be rebuilt if damaged during storms. Governments may then clearly declare that they are not responsible to provide financial compensation for storm and flood damage to private properties. Likewise it can be used to help dictate clearly where new development should be prohibited or where public access to the shore is protected.

D4.3 SETBACK ZONES

Current Jamaica Policy

As a result of a 1954 special commission of inquiry on beaches and **foreshore** lands, the Beach Control Act of 1956 was passed which is currently being administered by the Natural Resources Conservation Authority (NRCA). In 1997, the NRCA began work on a beach policy to address issues surrounding public access and a Green Paper was drafted which proposed open access. This was amended in 2000 and 2002.

With reference to **setback**, the Beach Policy (2000) states that the Beach Control Act will need to be amended to define 'beach' and an area 15m landward of high water mark that should be subject to regulatory control in order to provide for management of coastal zone resources. This minimum **setback** is intended to incorporate safety considerations for both cliff-type shorelines and also for erosion considerations for beach-type shorelines. However, private developments have repeatedly sprung up within the **setback** zone as shown.

Key Considerations

A key challenge for Jamaica is to provide a suitable planning structure to manage future increased pressure and uncertainty with respect to future changes in coastal processes. Coastal development "buffer zones" would be advisable to establish for Jamaica as these shall seek to provide essential space for natural processes that operate on the coastline to vary and should accommodate/allow for:

- Physical **setback** zones to cope with the processes;
- Environmental **setback** zones to provide space for habitat creation;
- Social **setback** zones to facilitate access to natural beach areas for informal recreation;
- Requirements for tourism/waterfront development;
- Reductions in environmental impact.

It will be important not to define any buffer zones that are excessively onerous on development and in addition, to encourage Jamaican stakeholder communities (rural and development focused) to operate and live close to the water (sea or river) should they choose to. Therefore the size of the buffer needs to be proportionate to the risk of the hazard (flooding or erosion), the land pressures and the environmental importance. For example, a Negril fishing access points (where no development is advocated) with a 50m buffer zone would negate the purpose of the fishing community to continue their livelihoods close to the water.

Summary

- A coastal **setback** is a buffer zone defined by a specific distance from the shoreline's highest winter water mark, within which permanent constructions are not allowed
- There are six **setback** categories; vertical, rolling vertical, horizontal, rolling horizontal, calculated horizontal and calculated rolling horizontal
- At present, the minimum **setback** limit is 15m from the high water mark in Jamaica

References and Data Sources

Relevant Policies:

Jamaica Beach Control Act (1956)

Natural Resources Conservation Authority and the Ministry of Environment and Housing: Green Paper No. 2/97 Towards a Beach Policy for Jamaica 1997

NEPA (2000) 'A Beach Policy for Jamaica'

Specific Design Manuals:

Ramsay, D.L., Gibberd, B., Dahm, J., Bell, R.G. (2012) Defining coastal hazard zones and setback lines. A guide to good practice. National Institute of Water & Atmospheric Research Ltd, Hamilton, New Zealand.

D4.4 BUILDING CODES

Build	✓
Protect	✓
Accommodate	✓
Retreat	✓

Building Codes in Jamaica

Jamaica's decades old Building Code has been replaced by a new National Building Code (2009) which is hoped to bring the country's construction practices in line with international standards . It comprises eleven application documents which will be used in conjunction with international codes developed by the International Code Council (ICC) tailored to suit Jamaican conditions. It will replace the older Building Code that was last updated in 1983 and which was previously based on the Building Code of 1908. The Jamaican application documents comprising the new National Building Code (2009) incorporates residential, plumbing, energy conservation, private sewage disposal, and property maintenance codes as well as existing building and international codes.

The Jamaica National Building Code was updated in 2009 adopting the International Building Code 2003. A new Draft Building Act (2016) in Jamaica has been set up to repeal the Kingston and St. Andrew Building Act and the Parish Councils Building Act and make new provisions for the regulation of the building industry. The Draft Building Act (2016) also facilitates the adoption and application of national building standards (the National Building Code of Jamaica) to ensure safety in the built environment, enhance amenities and promote sustainable development.

Key Building Code Considerations

The National Building Code (available through the offices of the Bureau of Standards Jamaica) has been developed under the National Building Act to give some real meaning to code. For example, all development in Jamaica must now legally refer to the Development and Investment Manual and other regulatory documents (www.moj.gov.jm). It is required that all buildings be designed to Jamaica Building Code standards. Buildings greater than 300m² must be designed and stamped by registered professionals (architects/Engineers). Buildings less than 300m² can be designed by other qualified practitioners (Licensed Draughtsman). However, buildings that are considered to be complex structures and or requiring complex services are not size dependent and should be designed by registered professionals. There is currently no Building Code consideration for coastal specific infrastructure or for any development within a defined hazard zone (or legally defined Coastal Management Area).

The current situation regarding the National Building Code is that there is limited evidence of it taking into account climate variability and change predictions for Jamaica. As a result, and in anticipation of warmer temperatures and prolonged periods of drought, buildings should incorporate features such as insulation in the roofs and walls; use of green roofs; and rainwater harvesting.

It is also important to include training programs in code requirements and construction techniques for local builders and carpenters, including the informal housing community. Strengthened building codes are of little use if they are not properly enforced; therefore, any efforts to revise codes or implement new ones should also include training programs for building inspectors.

KEY BUILDING CODE PARAMETERS (FOR IMPROVED COASTAL RESILIENCE)

Studies conducted worldwide have shown that strict adherence to building codes and standards reduce the amount of destruction caused by extreme events. In the future, Jamaica may revise building codes to include:

- Improved construction techniques such as stronger connections (at the ridge board, between the joists and the top plate, between the floor and the foundation, at the foundation footing), long screws/nails, hurricane straps and strong roofing materials within buildings;
- Modify engineering designs to include **climate change** projections, particularly for sea level rise, in addition to historical data typically used;
- Limit the siting of new structures in hazardous areas, restricting siting of any public buildings in such areas;
- Elevate structures in high hazard areas (e.g. on pilings) through the designation of minimum floor elevations, piling depths and bracing requirements; and
- Add additional specifications to ensure that new buildings are built to better withstand wind and flooding.

D4.4 BUILDING CODES

In addition to revised building codes for the quality and siting of new coastal structures, regulations should be introduced to plan a strategic retreat of existing development located in low-lying coastal floodplains and high hazard areas along the coast. These regulations should consider:

- Prohibiting the construction of protective structures in sensitive high hazard areas;
- Prohibiting the reconstruction of storm-damaged property in high hazard areas; and
- Conditioning land ownership in high hazard areas to expire when a property owner dies or when sea levels reach a particular point along a map.

The new Building Code would also prohibit persons from building in areas that are prone to disaster. The new Building Code also seeks to provide for greater level of safety in light of increased threats from man-made and natural phenomena. All material inputs will be required to comply with their appropriate standards. Materials include roofing materials, cement, blocks, concrete etc.

The National Building Code of Jamaica does not give specific distances for coastal setback of buildings in V Zones (coastal flood hazard areas) but outlines the requirements for building in in coastal flood hazard areas. These requirements are adopted from the ICC's 2009 International Residential Code requirements of Sections R301.2.4 and R322 generally but specifically R322.3 as well as the International Building Code Section 1612. These requirements may be summarized as follows:
Design of buildings in coastal flood hazard areas may be done to the American Society of Civil Engineers (ASCE) 24 or alternatively to 2009 IRC Section R322.3 require the following:

- New buildings or buildings undergoing substantial improvement shall be located landward out of the reach of mean high tide.
- All buildings lowest floor level shall be elevated above the 100-year design flood elevation or at the base flood elevation level plus 300 mm (I foot) or the design flood elevation whichever is higher.
- Basement floors below grade on all sides is prohibited.
- The use of fill or structural support is prohibited.
- Minor grading and minor placement of fill for landscaping purposes and for drainage under and around buildings as well as for the support of parking slabs, pool decks, patios and walkways are permitted.
- Buildings and structures shall be supported on pilings or columns and shall be adequately anchored to those pilings or columns.
- Walls and partitions below design flood elevation are permitted if they are not part of the structural support of the building or structure.
- Enclosed areas below the design flood level shall be solely for parking of vehicles, building access and storage.
- The construction documents submitted for building permit shall include documentation that is prepared and sealed by a registered design professional that the design and methods of construction to be used meet the applicable criteria of this Section.

Private and Public Linkages

One key area where private sector involvement is essential is in amendments to national codes and standards, such as the engineering standards, building codes, or hurricane proofing standards. Often the best method is for the Government to set a specific target and request the private sector to find the best ways of achieving that target. Standing committees may be formed to regularly review such standards and codes as additional information on climate change predictions becomes available.

At the community level, NGOs have proven to be effective intermediaries between the government and the community. Governments should encourage active civil society involvement in all areas of climate change responses. Local and international NGOs may be particularly helpful in documenting and codifying traditional and indigenous adaptation measures, which may hold the key to future adaptation measures. Environmental NGOs can contribute considerable experience in ecosystem-based approaches to climate change adaptation to facilitate less vulnerable and more **resilient** communities.

D4.4 BUILDING CODES

Summary

- The Jamaican application documents comprising the new National Building Code (2009) incorporates residential, plumbing, energy conservation, private sewage disposal, and property maintenance codes as well as existing building and international codes
- The Draft Building Act (2016) facilitates the adoption and application of national building standards to ensure safety in the built environment, enhance amenities and promote sustainable development

References and Data Sources

Relevant Policies:

Government of Jamaica, 2016. 'Building Act, 2016'

D4.5 STAKEHOLDER AWARENESS, EDUCATION, ENGAGEMENT AND PARTICIPATION

The Importance of Stakeholders

A stakeholder is a person or organisation with an interest in the preparation of, and outcomes from, beach management activities, and they play an important role in coastal management in Jamaica as clearly stated within the Jamaica Beach Policy (2000).
Stakeholders provide vital input to the consultation process when designing and implementing beach management programmes.
They can also assist in the gathering of data and distribution of information, and their involvement in monitoring could also result in a reduction in the need for enforcement. Involving stakeholders in the management of beach resources will lead to greater community stewardship due to a sense of ownership. Community-based organizations should therefore be encouraged to take on operational functions, public education, monitoring and outreach activities.
Community participation is fundamental at each stage of beach management, especially regarding preparedness for, response to, and recovery from **erosion** and flood events.
The extent and level of participation is often based on the communities historical experience and traditional backgrounds, therefore the starting point of engagement would be to identify the communities vision for the coastline as a whole.

KEY STAKEHOLDERS TO CONSIDER

When compiling a list of stakeholders the following groups should be considered:

- Agencies
- Authorities
- Organisations
- Individuals
- Private Bodies

Build	✓
Protect	✓
Accommodate	✓
Retreat	✓

If the activities based on individual initiatives are pooled together and carried out in an organized manner at community level, vulnerability and **risks** due to floods can be substantially reduced.
Community engagement should be addressed to local leaders who organize community activities and build capacity through participation of community members.

Key Principles of Effective Stakeholder Engagement

Community participation can be organized effectively through adopting three principles as follows:

1. Community participation has to match community's needs for:

- vulnerability reduction;
- sustainability in activities for infrequent events;
- establishing public-private partnerships, NGOs.

2. Community participation keeps their effectiveness and efficiency by;

- synergy effects for limited financial and human resources;
- best-mixed methods with community experience and technological knowledge;
- connection between individual requirements and government preparedness.

3. Community participation seeks practicability for implementation;

- capacity-building and coordination through dialogue and participation;
- opportunities for 'real' activities, trainings and drills.

Planning Stakeholder Engagement

The goal of stakeholder engagement and community participation is also to transform vulnerable or at-risk communities to flood or erosion **resilient** communities. Based on the community contexts and organisational mandates, the process and requisites for organising community participation are shown below referring six step of planning (adapted from APFM Technical Document No. 9, Flood Management Tools Series WMO, 2007):

1. Process design

- identify the stakeholders related community activities;
- draft shared visions reflecting community's needs and concerns;
- launch a public awareness campaign to keep the community informed and ensure community participation in decision-making, implementation and review;
- identify information required and develop data collection methodology.

D4.5 STAKEHOLDER AWARENESS, EDUCATION, ENGAGEMENT AND PARTICIPATION

2. Risk Assessment (to be presented in the form of maps, tables and graphs)

- understand flood and erosion events through historical records or hearing from people who experienced floods or erosion, as an existing local knowledge;
- create a database inventory determining current land-use practices (potential future land-use patterns or patterns of human settlement, location of resources (natural and artificial) or map the natural courses of the river (for example);
- undertake hazard assessment from a multi-hazard perspective;
- check to ensure that the risks identified are the same as those perceived by all stakeholders;
- facilitate the risk assessment at the community level.

3. Problem analysis

- conduct vulnerability and capacity assessment to determine the community at risks;
- identify the human factors that contribute to flooding;
- identify the flood plain areas in terms of their risk level with respect to different magnitudes of floods.

4. Setting goals

- determine objectives based on risk assessment results and vision;
- decide the scope of community activities. Goals are largely set by regional development objectives and driven by the need to reduce flood risks, secure livelihoods, sustain economic development and preserve environmental quality].

5. Draft an action plan

- evaluate various possible measures to address flood risks within the given scope such as land-use planning, building codes, zoning, conservation, drainage improvement, etc.
- develop an action plan listing specific activities, roles and responsibilities of key stakeholders'
- set the timeline and the expected results'
- carry out economic analysis and financing arrangements'
- set monitoring, evaluation and review procedures '
- widely disseminate the draft plan, particularly to all those who are directly affected.

6. Implementation

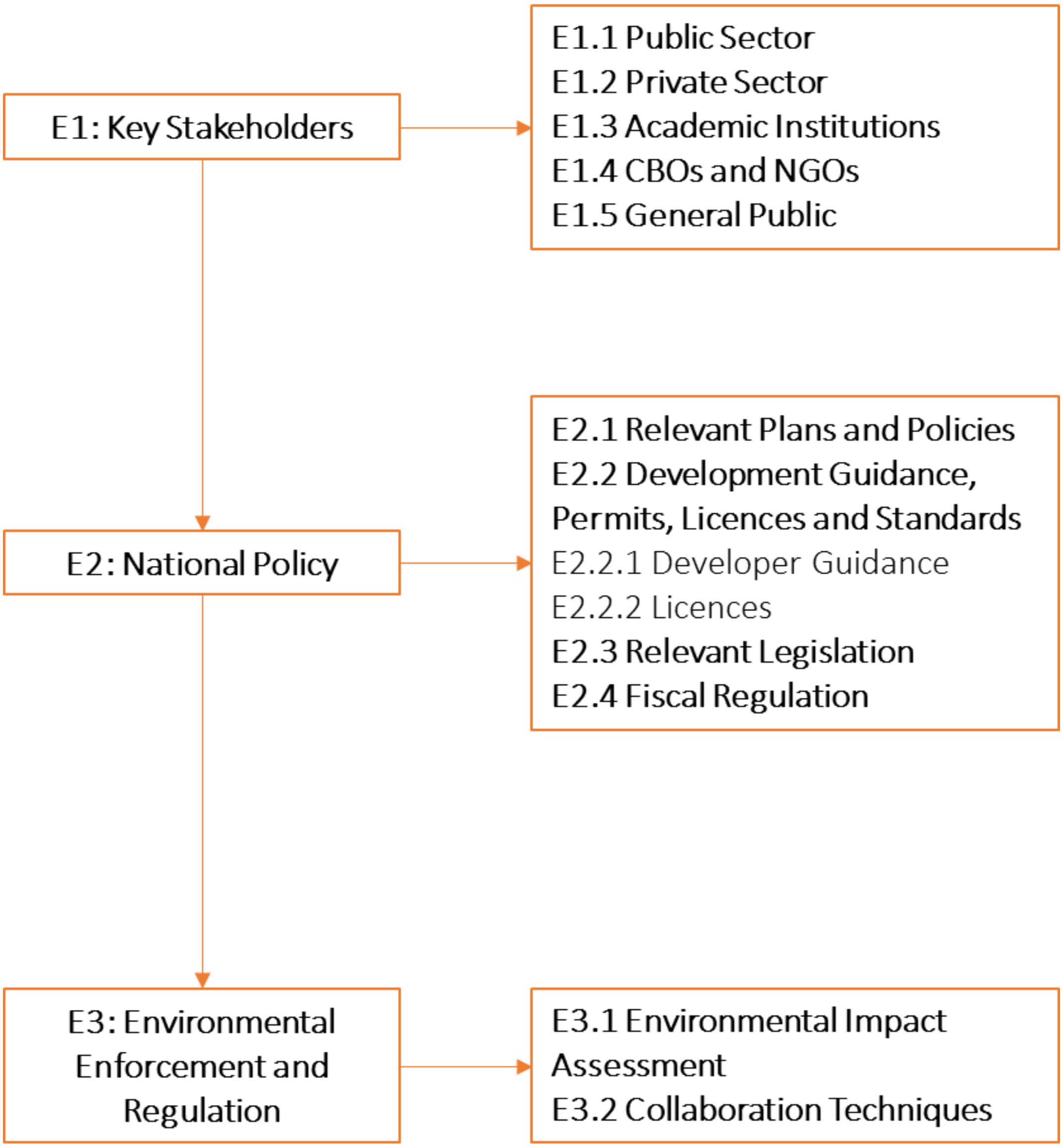
- approval of the plan in the community;
- formation of community activities - The grassroots flood management/response organizations (community based organizations, groups or volunteers) are the key to mobilize the community at large;
- implementation of short-, medium-, and long-term community activities towards floods;
- monitoring and evaluation - continuous improvement of participation, documentation and dissemination of good practices for replication

Summary

- A stakeholder is a person or organisation with an interest in the preparation of, and outcomes from, beach management activities
- Stakeholders provide vital input to the consultation process when designing and implementing beach management programmes

Part E: Governance and Stakeholders

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.



Contents

E

It is to be noted that the information provided within this chapter was completed as of March 2017. However, as legislation, policies and organisations are currently changing, caution should be used when using information in this chapter to ensure the most up to date information in used within a project.

E1: Key Stakeholders

Within any country attempting to implement coastal management for the long term, the adequacy of the governance structure and institutional base is a key aspect to consider. The existence of national institutions with clear mandates, roles, responsibilities, and capacities is essential if the successful management of a country's coastal resources is to be achieved (CWIP, MFAFT & NRCA, 2000). Fragmented authority, often between governmental departments though also vertically between national government and local community organisations or Parish Councils, is frequently cited as the main obstacle towards delivering effective management. A lack of clarity regarding ministerial or department roles and responsibilities and overlapping mandates are generic problems that are prevalent to many coastal state nations. Nevertheless, these challenges can be dealt in an iterative manner (learning by doing), with the experienced gained over time helping to create the basis for the development of new policies and legislation (CWIP, MFAFT & NRCA, 2000). It is also vital to involve all sectors and associated stakeholders (users) within the coastal environment as they all have a stake in how coastal lands and resources are to (or should) be managed.

Many industries in Jamaica rely on resources (living or non-living) that occur within the coastal environment (refer to Part B2). There is a strong need to encourage these stakeholders (ranging from community organisations, industries, private and public sectors etc.) to improve their awareness of malpractice within the coastal zone, plus also providing opportunities and livelihood alternatives that encourage improved coastal and marine stewardship. Non-Governmental Organisations (NGOs), along with Community Based Organisations (CBOs), can both play a critical role in galvanising local interest in coastal matters, through involving and educating local groups on the importance of coastal management, which is vital for choosing sustainable and **resilient interventions**. The involvement of tertiary education establishments (academic institutes) can also play a significant role in proving the knowledge base required to develop new innovative techniques and applications for coastal adaptation. University research findings can both direct policy and help educate stakeholders into new ways of thinking, interpreting, constructing and adapting to the pressures of climate change that coastal communities are now facing.

The key stakeholder "groups" of relevance to these Guidelines are defined as follows:

- Public Sector;
- Private Sector;
- Academic institutions;
- CBOs and NGOs; and
- General public.

E1.1: Public Sector

The main roles and responsibilities of public sector agencies, that are linked (formally or informally) towards delivering coastal management mainly involve activities such as coordinating, managing, regulating, training, enforcing and developing plans and policies. The importance of a tiered public sector hierarchy (national to local government) is also of critical importance in order to convey national level policy and regulation into a local context. Therefore, it is vital to strengthen the capabilities of Local Government to ensure that national policy is communicated and delivered in a meaningful manner for coastal stakeholders to effectively embrace and adopt. Whilst funding shortages (from national government) to deliver coastal management **interventions** and approaches at the local level will always remain a constant issue, local Parish Administrations in Jamaica can play a significant role in, for example, overseeing, managing and facilitating involvement and engagement of CBOs in local recreational area activities.

Table E1 below outlines Government organisations that can be involved in coastal management related activities.

Table E1 Government organisations in Jamaica related to coastal management. Adapted from CWIP, MFAFT & NRCA (2000).

Agency	Coastal-Related Mandate, Function, and/or Activity
Airports Authority of Jamaica (AAJ)	Management of Norman Manley and Donald Sangster International Airports. Involved in initiatives that protect mangrove areas around the airport and help support the protection of Montego Bay Marine Park by participating in beach clean-ups.
Chief Parliamentary Counsel (CPC)	Review of documentation and preparation of draft legislation.
Council on Ocean and Coastal Zone Management (COCZM)	Define national policy, promote co-ordination of administrative and operational functions, ensure compliance with enacted treaties and protocols.
Environmental Health Unit (EHU)	Water quality monitoring and testing on public beaches.
Forestry Department (FD)	Implementation and regulation of the Watershed Policy for Jamaica and associated management activities.
Jamaica Constabulary Force (JCF)	Enforcement of law and order on beaches.
Jamaica Fire Brigade (JFB)	Control of fires (including forest fires).
Jamaica National Heritage Trust (JNHT)	Preservation of buildings, landmarks, and artefacts of historical or archaeological importance.
Jamaica Social Investment Fund (JSIF)	Mobilises resources and channels these to community-based socio-economic infrastructure.
Jamaica Tourist Board (JTB)	Recreational areas/cruise ship terminals.
Maritime Authority of Jamaica (MAJ)	Marine transportation regulatory agency.
Mines and Geology Division (MGD)	Regulation of mining and quarrying.
Ministry of Industry, Commerce, Agriculture, and Fisheries	Sustainable management of fisheries.
Ministry of Local Government and Community Development (MLGCD)	Acts as the agent of local development. In relation to coastal management the MLGCD is involved in development planning, minor water supplies, municipal parks, and disaster preparedness (Jamaica Information Service).
Ministry of Economic Growth and Job Creation	Policy related to environmental matters with water, the environment, land use and climate change.
Ministry of National Security and Justice (MNSJ)	Policy on matters of national justice.
Ministry of Tourism	Tourism policy and planning.
Municipal Corporations / Local Authorities	Responsibility for enhancing civic order; ensuring good governance and efficient public management; and spearheading, promoting and facilitating orderly, balanced and sustainable development within that jurisdiction.
National Environment and Planning Agency (NEPA)	Promotes sustainable development by carrying out the technical and administrative mandate of three statutory bodies the Natural

	Resources Conservation Authority (NRCA), the Town & Country Planning Authority (TCPA), and the Land Development & Utilisation Commission (LDUC).
National Water Commission (NWC)	Treatment of water for domestic supply, treatment of waste water and sewage.
National Works Agency (NWA)	Plans, builds and maintains a reliable, safe, and efficient main road network and flood control system (National Works Agency, 2015).
Office of Disaster Preparedness and Emergency Management (ODPEM)	Natural hazards contingency planning, disaster response and recovery.
Petroleum Corporation of Jamaica (PCJ)	Petroleum shipments.
Planning Institute of Jamaica (PIOJ)	Initiation and co-ordination of planning for economic, financial, social, cultural, and physical development.
Port Authority of Jamaica (PAJ)	Management of ports and port operations.
Scientific Research Council (SRC)	Responsible for the fostering and coordination of scientific research and the promotion and application of its results (Scientific Research Council, 2012).
Shipping Association of Jamaica (SAJ)	Provision of skilled labour to shipping industry operations and management of relevant parts of the industry.
Social Development Commission (SDC)	Promotes and controls schemes that serve the advancement of sport, social, cultural & economic development (Social Development Commission, 2017).
Tourism Product Development Company Ltd. (TPDCo.)	Product development company contributing to a diverse, enhanced tourism product and visitor experience, resulting in an improved quality of life for all Jamaicans (Tourism Product Development Company Ltd., 2015).
Urban Development Corporation (UDC)	Leading urban and rural development and planning agency in the Caribbean (Urban Development Corporation, 2017).
Water Resources Authority (WRA)	Ground water quality and extraction.

E1.2: Private Sector

There are several private sector stakeholders whom, either directly or through trade organisations, represent important interested bodies that must be considered in delivering sustainable coastal management. Many of Jamaica's industries rely heavily upon living (e.g. fisheries) or non-living (minerals) coastal resources. Ports and harbours represent key infrastructural assets on the coast. The construction industry in Jamaica, for example, relies heavily on the availability of sand for concrete production whereas the tourism industry and related businesses (including hotels, tour operators, airlines, support service industries such as restaurants and public transportation), all require a healthy coastal environment to sustain economic stability (CWIP, MFAFT & NRCA, 2000).

The above groups themselves collectively possess the responsibility to actively contribute both financially and in terms of human capacity, to help support the delivery of sustainable coastal management through assisting the GoJ with the effective management of coastal resources within the public domain. Therefore, improving and nurturing partnership arrangements between relevant government agencies and private sector groups, such as the Jamaica Shipping Association (JSA), the Jamaica Hotel and Tourist Association (JHTA), and the Private Sector Organisation of Jamaica (PSOJ) are deemed essential for effective implementation of sustainable coastal management.

E1.3: Academic Institutions

In addition, academic institutes can play a large role in the effective implementation of coastal management. In Jamaica the University of the West Indies carries out key ocean and coastal zone management research programmes. Covering topics from aquaculture, coral reef management, pollution studies to marine ecology, these programmes are key to developing an overall understanding of the condition of the coastal and marine environment. The findings of these programmes help to educate and train local communities on sustainable best practise and influence government coastal plans and policies. The main academic institutes are listed in Table E2.

Table E2 Academic Institutions in Jamaica related to coastal management. Adapted from CWIP., MFAFT., & NRCA (2000).

Academic Institution	Mandate
Climate Studies Group (CSGM), University of the West Indies, Mona	Research and predicts climate in Jamaica and the wider Caribbean. Also promotes awareness of global warming and renewable energy resources (The University of the West Indies (UWI), 2017a).
College of Agricultural Science and Education (CASE)	Training in agricultural sciences, agri-business and related subjects.
Department of Life Science, University of the West Indies, Mona	Teaching, research and outreach of high quality education and training for students of biology (UWI, 2017b).
Disaster Risk Reduction Centre, University of the West Indies, Mona	Development of all initiatives in disaster **risk** reduction and disaster management (UWI, 2017c).
Discovery Bay Marine Lab and Port Royal Marine Lab and Alligator Head Marine Lab (DBML/PRML)	Education and training; coastal and marine resource research; laboratory testing; ecosystem monitoring.
Hofstra University Marine Laboratory (HUML)	Off-shore laboratory facilities providing education on tropical marine systems for students from Hofstra University on the USA mainland.
International Institute for Sustainable Development (UWI)	Promotes human development and environmental **sustainability** through innovative research, communication, and partnerships (International Institute for Sustainable Development, 2017).
Jamaican Maritime Institute (JMI)	Maritime training and education.
University of Technology (UTech)	Education and training in technology and communication and postgraduate research.
Centre for Marine Sciences, University of the West Indies, Mona(UWI/CMS)	Education and training in coastal and marine resources, post-graduate research.

E1.4: Community Based Organisations and Non-Government Organisations

National governments do not always have the resources to implement and manage all programmes and plans related to coastal management. For this reason, the involvement of civil societies and NGOs can be vital for effective implementation. Such organisations can provide local communities with the opportunities to engage directly on coastal management issues including local plan production, pilot **interventions**, and community monitoring activities. Co-management between the GoJ and these organisations (in partnership) can help to create improved two-way dialogue to help with regulatory enforcement issues and to help advocate and communicate new ways of implementing **resilience** on the coast. These organisations provide a vital function of educating local communities, carrying out critical scientific research and monitoring, as well as funding projects. Table E3 below shows some of the key civil societies and NGOs in Jamaica involved in coastal management.

Table E3 Civil societies and NGOs in Jamaica related to coastal management. Adapted from CWIP., MFAFT., & NRCA (2000).

Organisation	Mandate
Bluefields Bay Fisheries	Educates in sustainable fishing practices and develops employment alternatives that will enhance the quality of life and preserve the natural environment of Bluefields (Bluefields Bay Fishers, 2017).
Caribbean Coastal Area Management (C-CAM)	Promotes coastal conservation in Jamaica and involves communities in conservation projects. Key organisation to manage Portland Bight Protected Area (PBPA).
Environmental Foundation of Jamaica (EFJ)	Funds projects that deal with the environmental **sustainability** issues of Jamaica.
Friends of the Sea (FOTS)	Non-Jamaican organisation that led an international certification project for products originating from both sustainable fisheries and aquaculture. FOTS also promotes education, awareness, and conservation of ocean resources.
Jamaica Conservation and Development Trust (JCDT)	Promotes environmental conservation and sustainable development, with particular focus on the Blue and John Crow Mountains National Park.
Jamaica Environment Trust (JET)	Implements projects related to environmental education, law and advocacy, and conservation. Its main project is the School's Environment Programme, an environmental education programme for students and teachers.
Jamaica Institute of Environmental Professionals (JIEP)	Accreditation of environmental professionals and monitoring of performance standards.
Jamaica Protected Areas Trust (JPAT)	Supports management of Jamaica's protected areas via stakeholder engagement, monitoring conservation funds, implementing Jamaica's National Biodiversity Strategy and Action Plan, providing technical and managerial assistance to fulfil international obligations and provides education material on Jamaica's Protected Areas.
Montego Bay Marine Park Trust (MBMPT)	Manages Montego Bay Marine Park and provides public education, financial support, monitoring and interpretive enforcement.
National Environmental Societies Trust (NEST)	Acts as an umbrella organisation for environmental NGO's in Jamaica. Assists NGO's to find solutions to environmental problems at a national and at a community level.
Negril Area Environmental Protection Trust (NEPT)	An umbrella organisation that represents the environmental and sustainable development concerns for the Negril area.
Oracabessa Foundation	Promotes sustainable development focused on increasing employment, protection of Jamaica's Bays and engaging Jamaica's youth (Oracabessa Foundation, 2017).
Portland Environment Protection Agency (PEPA)	Raising awareness of environmental issues within the parish of Portland.
St. Ann Environmental Protection Agency (STAEPA)	Education and raising awareness of environmental issues, especially within the parish of St. Ann.
St. Thomas Environmental Protection Association (STEPA)	Protection of the St. Thomas environment.

Case Studies: Caribbean Fish Sanctuary Partnership – working with the Community

A community-centred approach was used by the Caribbean Fish Sanctuary Partnership Initiative (C-FISH) a four-year project implemented by CCCCC and CARIBSAVE that was aimed at improving the management of fifteen MPAs in five Caribbean countries, including 7 fish sanctuaries in Jamaica. C-FISH was successful in improving the management of several Fish Sanctuaries in Jamaica (with an increase in fish biomass of over 1,400% in one fish sanctuary in Boscobel) because it has focused on building the capacity and engagement of the local communities.

C-FISH has been working at Bluefields Bay (right) – source: www.c-fish.org

E1.5: General Public

The general public are the end users of any coastal management plan produced. Often, public consultation remains a pivotal aspect of acceptance of coastal schemes, as the beneficiary of any scheme will directly, or indirectly, impact on those living nearly to the **intervention**. Local communities are therefore integral to the successful outcome of a coastal scheme. Effective stakeholder engagement is important to ensure that plans and **intervention** options are developed to provide wider benefits and outcomes. Furthermore, the local community can often provide anecdotal knowledge which can benefit the optioneering process and ensure that a suitable **intervention(s)** is chosen for that location.

The local community can further play an important part in coastal **resilience** through consideration of "climate proofing" both livelihoods and households. In addition, the local community can be an important driver in the longer term monitoring and management, particularly for **nature-based interventions**. Involving the community in the protection and monitoring of seagrass meadows, mangroves and coral reefs is much more likely to ensure the successful delivery of a project.

The social interactions between stakeholders and their environment must be understood to develop successful **nature-based interventions**. A key consideration should be to examine the willingness of the local community to support and participate in any restoration activity. Whilst it is hoped that any **intervention** shall provide long-term benefits, there may be some short-term sacrifices that the community will be required to make. For instance, local community members may unwittingly damage corals through their fishing activities, or be currently harvesting mangrove wood in an unsustainable fashion. Educating and involving the local community in the planning and implementation phase of restoration **interventions**, are critical components to success. While there may be some resistance initially, there are many examples of restoration activities providing benefits to communities, and ultimately the community takes ownership of the long-term management of the programme (e.g. Oracabessa and Boscobel Coral Restoration Programmes).

E

E2: National Policy

National governments play a key role in adaptation, planning and implementation through coordinating actions and providing framework support. As stated in Part A, these Guidelines have been developed to align to the GoJ Vision 2030: National Development Plan (Government of Jamaica, 2009): *"to protect biodiversity and enhance adaptive capacity towards sustainable use of* ***natural resources****"*.

At present, a combination of national plans, policies and legislation is used to implement coastal management in Jamaica. The Vision 2030 Jamaica is the latest strategic plan to guide the country towards a set of development goals. One of these goals is for Jamaica to achieve a healthy and natural environment. As part of this goal the issues related to the coastal management are addressed through the Plan's aim of developing a sustainable management framework of the country's **natural resources** and by developing a comprehensive approach for hazard risk management and climate change. Other Plans and Policies pre-date Vision 2030 Jamaica, however, are still relevant and must be considered when developing coastal management **interventions** and planning.

Copies of specific policies that follow may be accessed from the following link: http://nepa.gov.jm/new/legal_matters/laws/index.php.

E2.1: Relevant Plans and Policies

National Strategy and Action Plan on Biological Diversity in Jamaica (2016-2021) (GoJ, 2016)

The National Strategy and Action Plan for Biological Diversity in Jamaica 2016-2021 is an updated strategy and action plan, which was prepared in 2003. The document outlines Jamaica's conservation efforts and includes biodiversity conservation to align with the Convention on Biological Diversity Targets. Several activities to achieve the Achi targets have been outlined within the Plan. In relation to the coastal environment the Plan states three strategies: enhance protection against marine invasive species; minimize the impact of dredging activities; and enhance preparedness for marine oil spills (Environmental Solutions Limited., 2016).

Climate Change Policy Framework for Jamaica (2015) (GoJ. 2015)

The Climate Change Policy Framework for Jamaica supports the goals of Vision 2030 Jamaica by reducing the risk of climate change to all of Jamaica's sectors. The Framework's objectives are as follows:

1. To implement climate change adaptation and mitigation into all national policies;
2. Support institutions responsible for researching the effects of climate change on Jamaica for informed decision-making;
3. Facilitate national coordination in response to climate change impacts and promote low carbon development;
4. Improve communication at all levels on climate change impacts, so that decision makers and the public are better informed; and
5. Mobilize climate financing for adaptation and mitigation initiatives.

In relation to Jamaica's coastal and marine resources the Framework outlines the following strategies:

- Expand and strengthen coastal monitoring and data collection, to aid decision making;
- Promote and facilitate national assessment of coastal areas and of coastal and fisheries resources at risk;
- Identify measures to restore coastal wetlands as a defence to storm surges;

- Identify and delineate vulnerable areas (including marine areas) in the formulation of a National Spatial Strategy which will utilize hazard mapping; and
- Create and conserve marine protected areas to prohibit destructive fishing practices and increase the resiliency of marine ecosystems to withstand acidification (GoJ, 2015a).

Beach Access and Management Policy (Draft Policy 2014) (GoJ, 2014)

Sets out a new and updated policy for public access to beaches. Builds on the Beach and Coastline Preservation Policies in the present Development Manual which state: *"Development and subdivisions along the coast and river banks should be so designed as to allow the public to enjoy the seaside, the river banks and the beaches. For that reason, special areas should be left for fishing beaches and for good bathing beaches with access provided from a public thoroughfare. In some areas, adequate parking may be required.*

An area of seaside park should also be provided in every housing development or subdivision along the coast, between the high water mark and the nearest row of lots. This will add value to the lots within the subdivision and at the same time allow unrestricted passage along the ***foreshore****."*

Protected Areas Systems Master Plan (PASMP): Jamaica (2013-2017)

The aim of the PASMP is to develop a comprehensive and representative system of protected areas including landscape, seascape and natural and cultural heritage. The Plan will be the primary national policy document for strengthening management and extending protected area coverage. The PASMP sets out strategies and activities that will lead to the establishment of a network of protected areas, which are representative, effectively managed, and sustainably financed. In relation to the coastal environment the plan states that by 2020 20% of the coastal and nearshore habitats to the 200m bathymetric contour will be effectively managed.

National Cays Management Policy, (Draft Policy) (GoJ, 2012)

Cays are of significant ecological, economic, and geo-political importance, however, they face several activities that threaten their sustainability. This Policy provides an institutional framework to help support the management of cays in Jamaica (Environment and Risk Management Division).

Vision 2030 Jamaica, (Planning Institute of Jamaica, 2009)

Vision 2030 Jamaica is a strategic road map to guide the country to achieve its goals of sustainable development and prosperity by 2030. The key underlying objective of Vision 2030 Jamaica is to secure sustained and broad based improvement in the quality of life of our people that will transform Jamaica into: *"the place of choice to live, work, raise families and do business"*. In order to achieve this objective, the National Development Plan articulates a comprehensive and integrated strategy around four fundamental goals:

- Goal 1: Jamaicans are empowered to achieve their fullest potential
- Goal 2: The Jamaican society is secure, cohesive and just
- Goal 3: Jamaica's economy is prosperous
- Goal 4: Jamaica has a healthy natural environment.

Vision 2030 Jamaica recognizes the role that hazard risk reduction can play in achieving sustainable prosperity for Jamaica and proposes to 'disaster-proof' development by: "transforming 'vicious spirals' of risk accumulation and disaster losses into 'virtuous spirals' of development, risk reduction and effective disaster response". Vision 2030 Jamaica further provides the framework to ensure that climate change issues are mainstreamed into national policies and development activities. The objective is to avoid or minimize the impact of disasters related to climate change by increasing coping capacity at various levels (including economic sectors and communities) within the country. One of the key areas for action is to embed climate change mitigation and adaptation in the physical planning system. Vision 2030 Jamaica will ensure that adaptive measures become the mechanism to manage risks, and adjust economic activity to reduce vulnerability and reduce vulnerability.

Draft Fisheries Policy (Ministry of Agriculture and Lands Fisheries Division, 2008)

The fisheries resources in Jamaica have importance for the economy, employment, food security, social environment, and fiscal elements. Fisheries resources in Jamaica are dominantly consisted of Marine capture fisheries and Aquaculture. However, in more recent years, increasing population and overfishing, in addition to loss of habitats and biodiversity and increased costs of production have severely impacted the fishing industry in Jamaica.

The main goals of the National Fisheries Policy are:

1. Contribute to economic growth and reduction of poverty;
2. Contribute to sustainable livelihood of Jamaicans through employment in fisheries and related activities; and
3. Contribute to the provision of Food security.

Its immediate objectives are:

1. Ensure sustainable development of the fisheries industry;
2. Promote efficiency of the fishing industry;
3. Promote economic and social development of fisheries industry;
4. Improve systems and procedures for the management of the fishing industry;
5. Promote partnerships with stakeholders in the management of fisheries and ensure transparency and accountability in the governance of fisheries resources; and
6. Comply with international standards and best practices for fisheries development and management in keeping with Jamaica's commitments under various agreements and conventions.

National Environmental Action Plan (2006-2009) (NEPA., 2006)

This Paper documents the major environmental problems facing Jamaica and formulates the appropriate policy framework, institutional arrangements, legal instruments, strategies, programmes, and projects to address and mitigate these problems (NEPA, 2017). In relation to the coastal and marine environment the Plan outlines the following priority actions:

1. Development of the regulations and guidelines enunciated in the Fisheries Management Plan.
2. Completion and implementation of the Beach Policy;
3. Preparation of an Ocean and Coastal Zone Policy;
4. Rehabilitating areas of severe degradation such as Kingston Harbour;
5. The monitoring of coastal water quality;
6. The development of an Integrated Coastal Zone Management Plan; and
7. Completion of the various draft policies, regulations etc. that have been worked on over the past four years (Ministry of Environment & Housing & Natural Resources Conservation Authority).

Watershed Policy of Jamaica (2003) (GoJ, 2003)

Primarily the objective of this Policy is to promote integrated protection, conservation and development of both water and land resources within each of the country's 26 **watersheds** to help promote the sustainable use of water resources for the benefit of upstream and downstream communities, as well as the whole nation (NEPA, 2017). To achieve this, the policy's goals are as follows:

1. A coherent and rationalized legislative and institutional framework for the integrated management of **watersheds** on a sustainable basis is put in place;
2. Provision and development of adequate human resources for effective **watershed** management;
3. Adequate financing for **watershed** management is secured;
4. Availability of improved technical capacity for effective **watershed** management;
5. Increased public awareness for improved participation in **watershed** management; and
6. Initiatives to encourage proper Land Use supported (GoJ, 2017).

Beach Policy for Jamaica (GoJ, 2000).

This policy aims to address the following goals:

1. The provision of physical and equitable access to the **foreshore** and the sea on a managed basis to all persons;
2. Expansion of beach-related recreational opportunities for both local residents and tourists;
3. Implementation of measures for pollution control and safety for the users of coastal resources;
4. Protection of the traditional rights of fishermen to access to the **foreshore** and the sea, and beaching rights on their return from sea;
5. Management of wildlife associated with beaches and the near shore; and
6. Management of coastal resources in the light of their vulnerability to the effects of climate change and natural disasters (GoJ, 2000).

It should be noted that at the time of writing the Beach Management Policy for Jamaica is currently being reviewed and therefore any updates post March 2017 should be sought from the PIOJ.

National Policy on Ocean and Coastal Zone Management, 2000

The Council on Ocean and Coastal Zone Management was established in 1998, with a mandate that included definition of national policy. The need for a rational, harmonized national policy on ocean and coastal resource management was identified and presented within "Toward Developing a National Policy on Ocean and Coastal Zone Management" (GoJ, 2000). Five goals were identified within this Policy:

1. Promotion of Sustainable Development;
2. Conservation of Ocean and Coastal Resources and Ecosystems;
3. Baseline Data Collection and Research;
4. Utilizing the Role of Science and Traditional Ecological Knowledge for Integrated Coastal Area Management; and
5. Providing the Conditions of Governance Required for Effective Integrated Coastal Area Management.

Jamaica Coral Reef Action Plan (1999)

This Action Plan builds on the International Coral Reef Initiative (NEPA., 2017). The plan focuses on the following five topics, and outlines the objectives and activities to achieve each topic's goal:

1. Integrated coastal zone management and related institutional policy and legal issues;
2. Environmental education and awareness;
3. Co-management of coastal resources;
4. Prevention and reduction of sources of marine pollution; and
5. Research and monitoring for the management of coral reef and coastal resources.

It should be noted that the Action Plan for Coral and Reef Jamaica is being revised at the time of writing in 2017.

Draft Mariculture Policy and Regulation (1998), (NRCA, 1998)

The aim of this Policy is to support the managed use of Jamaica's marine resources to increase output of marine food products for domestic consumption and export, as well as generate local employment. To achieve this, the GoJ will pursue the following goals:

1. Establish the principles for carrying out sustainable mariculture;
2. Either eliminate of effectively control practices that could potentially damage mariculture;
3. Promote mariculture as a sustainable option for the use of coastal resources.

To achieve these goals, the Policy seeks to:

- Establish designated areas for mariculture activities;
- Exercise greater control over mariculture operations;
- Develop the economic potential of mariculture, and in particular the oyster culture;
- Protect mariculture operations from pollution;
- Protect the environment from the harmful effects of mariculture by carrying out an Environmental Impact Assessment (EIA) for mariculture operations;
- Increase public awareness of the benefits of mariculture as an alternative or supplement to capture fishery, and as a useful tool for species management; and
- Draft provisions for inclusion in a lease agreement, as well as some possibilities for expanding mariculture operations are annexed (NRCA, 1998).

National Environmental Education Action Plan for Sustainable Development in Jamaica (1997), (National Environmental Education Committee (NEEC), 1998)

This policy aims to pursue education of Jamaicans to enable the transition to a sustainable society; by creating awareness, enhancing knowledge, understanding skills, encouraging more responsible behaviour, and promoting learning that leads to action (NEEC,1997). The policy's objectives are as follows:

1. Conduct an inventory and design database of existing curriculum material and related resources on environmental education;
2. Mobilize resources and encourage public and private investments in supporting the programs for environmental education; and
3. Develop a monitoring and evaluation scheme for the implementation of National Environment and Planning Agency (NEEC, 1997).

Policy for the National System of Protected Areas (1997)

The policy sets out the following:

1. Goals for Jamaica's system of Protected Areas, such as economic development, environmental conservation, sustainable resource use, recreational and public information, public participation and local responsibility and financial sustainability;
2. Types of Protected Areas;
3. Roles and responsibilities of the various agencies and groups;
4. Planning Protected Areas;
5. Establishing Protected Areas;
6. Financial management of Protected Areas;
7. Legal framework
8. Management and operations policies;
9. A two year implementation programme; and
10. Other protected area candidates (NEPA, 2017).

Draft Coral Reef Protection and Preservation Policy and Regulation (1997) (National Resources Conservation Authority (NRCA))

This Policy is intended to be adopted for the improvement of coral reef protection and sustaining the reefs ecological and socio-economic function. To achieve this aim the Policy sets the following goals (NRCA,1997):

1. Reducing the quantity of pollutants being released to the coastal environment with special emphasis on nitrogen, phosphorus and sediment;
2. Reversing the trend of overfishing by more stringent regulation of the fishing industry, particularly with respect to trap and net type and mesh specifications;
3. Reducing the physical damage of reefs as a result of recreational boating, souvenir hunting, spear fishing, dynamiting and other human activities;
4. Improving the response capability for dealing with oil and other chemical spills; and
5. Ensuring that Jamaica's public and private sectors avoid coastal zone development which contributes to coral reef destruction and/or degradation.

Specifically, this policy seeks to:

- Improve the management of coral reefs;
- Improve the capability of organizations, individuals and communities having an interest in coral reef management;
- Promote research and monitoring; and
- Promote periodic review to determine the effectiveness of management strategies (NEPA, 2017).

Draft Policy & Regulation for Mangrove & Coastal Wetlands Protection (1997)

This Policy aims to promote the management of coastal wetlands to ensure that the many benefits they provide are sustained. To achieve this, the Policy's goals are as follows:

1. Establish the guidelines by which wetlands can be developed in order to ensure their continued existence;
2. Bring to an end all activities carried on in wetlands which cause damage to these resources;
3. Maintain the natural diversity of the animals and plants found in wetlands;

4. Maintain the functions and values of Jamaica's wetland resources;
5. Integration of wetland functions in planning and development of other resource sectors such as agriculture, forestry, fisheries, ecotourism, and waste management; and
6. Ensuring that Jamaicans are aware and committed people to their environment (NEPA, 2017)

Specifically, the Policy seeks to:

- Provide protection against dredging, filling, and other development;
- Designate wetlands as protected areas;
- Protect wetlands from pollution particularly industrial effluent sewage, and sediment;
- Ensure that all developments planned for wetlands are subject to an Environmental Impact Assessment (EIA); and
- Ensure that traditional uses of wetlands are maintained.

Draft National Policy for the Conservation of Sea Grasses (1996) (NRCA, 1996)

The Policy aims to provide guidelines on issuing licences or permits for activities that directly or indirectly affect these plant communities. Activities include dredging, port development, the disposal of dredge spoil, beach development and effluent disposal. To achieve this the government will pursue the following goals:

1. Establish the principles by which seagrasses can be managed and their productivity maintained in the future;
2. Control practices, which result in the destruction of seagrasses;
3. Maintain and enhance seagrass beds; and
4. To promote the consideration of seagrass function and uses in decision making with regard to the development of the coastal areas (NRCA, 1996).

E2.2 Development Guidance, Permits, Licenses and Standards

E2.2.1 Developer guidance

The Urban Development Corporation (UDC) assists in setting out strategic development areas and the type of development that may be suitable, including development and policy zoning. Each of the 14 Parishes have, or are in the process of having, Development Plans provided.

Generally, developers in Jamaica are aware of the planning and development processes, and can refer to the 'Development Manual', maintained by NEPA, and available for access on their website. This includes those requirements for which a Beach Licence is appropriate. Some key themes and guidance has been developed within these Guidelines and should also be considered by the developer. This is particularly revenant to the selection process for **interventions** (Part C), inclusion of sea level rise (Part C) and development of **interventions** (Part D). Furthermore, specific reference has been made to Stakeholder engagement in Part C and this links to the Government of Jamaica Communication Policy (GoJ, 2015) which needs to be followed if the developer is a Government Institution.

There is also the facility to incorporate the benefits of the existing 'Developer Assistance Centre', which assists in providing a meeting forum to allow the Developer to discuss Plans early with NEPA and NWA for example as a technical stakeholder. This can ensure the developer understands early specific issues for which they may have to demonstrate compliance with, or potential conditions that they may need to meet.

The Development Assistance Centre (DAC) and the development manual can be accessed at:

http://nepa.gov.jm.209-99-16-20.ddmd-plesk-web1.webhostbox.net/Development-Invest-Man/

The DAC provides assistance to clients from concept stage to approval of their development projects. In addition, the DAC tracks the progress of projects submitted for approval. This enables the monitoring of the approval process so as to highlight issues requiring action by the appropriate agency to keep the process flowing smoothly.

Typically, guidance regarding beach development is sought from NEPA. This regulatory need is founded on the fact that the **foreshore** in Jamaica is Crown Land and permission is therefore required for any development that affects it by the Commissioner of Lands. For the purposes of these guidelines that definition covers the coastal zone through the **R2R** profile (see Part A).

Any built or environmental activity on the coastline that could include provision of new **interventions** (hard or nature-based) shall require a Beach Licence to be granted by NEPA, prior to the activity commencing. The Beach Licence once obtained is valid for 1 year, and is required to be renewed annually for any ongoing activities associated with provision of the original licence. There is also an Environmental Permit that is required should any development or activity, require the modification of wetlands. Such Permits are valid for 5 years. In addition, and if required, drainage plans (for hinterland design and works) may be required for subsequent approval by NWA.

E2.2.2 Licenses

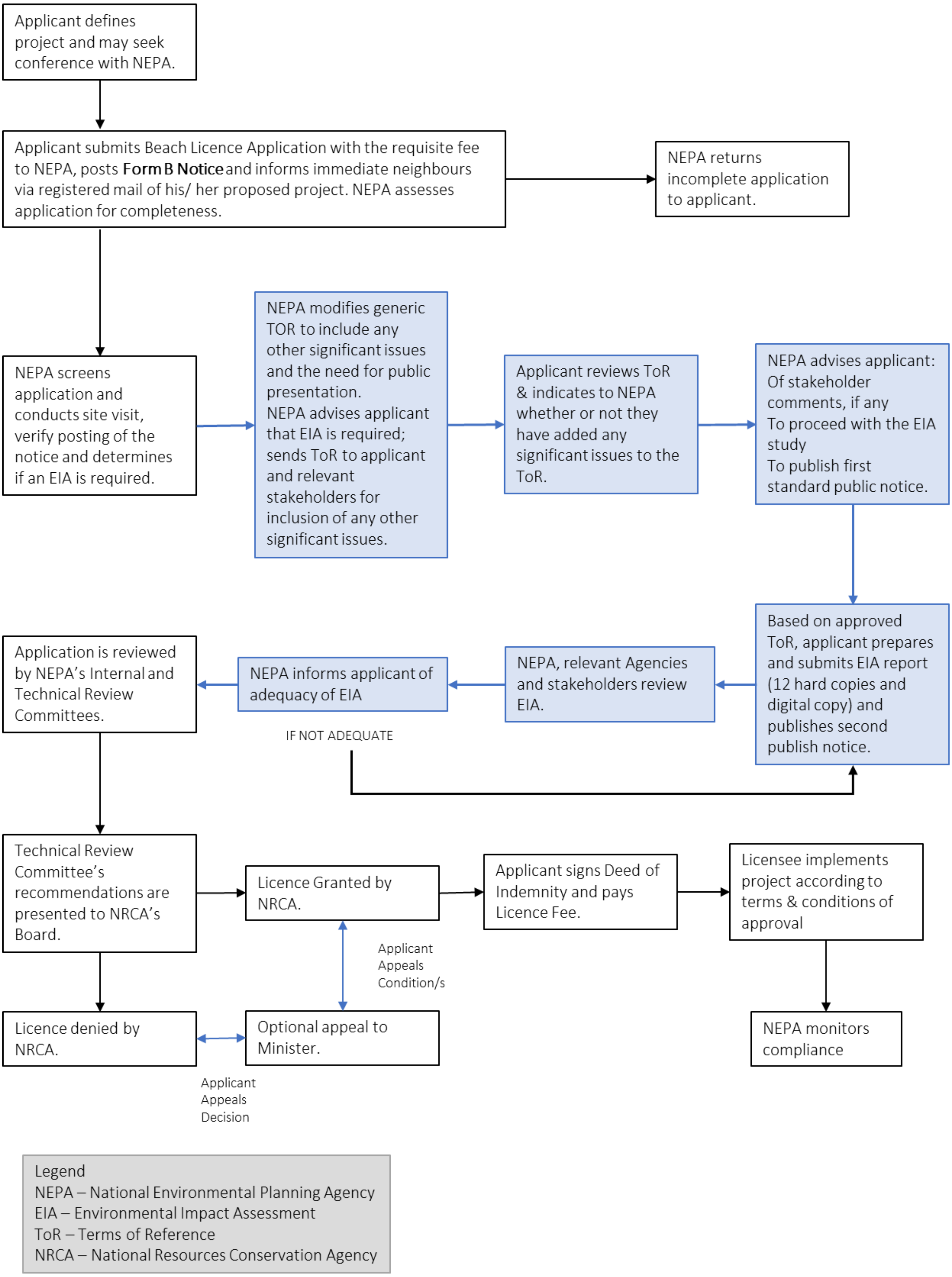
A Beach Licence must be applied for pursuant to the Beach Control Authority (Licensing) Regulations 1999 for any of the following works:

- Hotel / Recreational / Commercial / Industrial Use of the **Foreshore** and Floor of the Sea and the water column;
- Any encroachment on the **Foreshore** and Floor of the Sea and in the water column; or
- Any Dredging and or Reclamation on the **Foreshore** and Floor of the Sea and in the water column

It should therefore be noted that all works within the nearshore zone, including breakwaters, groynes, beach nourishment and any benthos removal / relocation required to accommodate the structures on the seafloor, require licences though the construction of a seawall on private property (once it is located outside of the **setback** limit) does not require a beach licence.

The general process for acquiring a beach license is shown below in Figure E1; the process can be quite lengthy (3-6 months) but is thought generally to be comprehensive. The license granted will have general and specific conditions, which must be observed or NEPA can (after undergoing some monitoring of the site) shut down the works for non-compliance.

Figure E1 A schematic of the Beach License Application Process in Jamaica



E2.3: Relevant Legislation

Primary legislation relating to coastal management in Jamaica is limited. The legislation that exists mainly focuses on the commercial marine sector, such as shipping, harbours, fisheries, aquaculture, and marine by-products, rather than measures for maintaining and sustaining the coastal environment.

One of the core pieces of relevant legislation is the Beach Control Act (1956) which was formed to protect both the sea floor and the **foreshore**. The act focuses on regulating offensive activities, such as carrying out activities without a license or exploiting beach users (NEPA, 2003). The main focus of the Act is: *"An act relating to the floor of the sea and the overlying water and to the* ***foreshore*** *and beaches of this island, and to the establishment of a Beach Control Authority for the purpose of controlling and regulating the use of the floor of the sea and the overlying water and of the* ***foreshore*** *and beaches of this island in the interests of the public and of persons who have acquired rights therein and for purposes incidental to or connected with the matters aforesaid"* (GoJ, 2017).

As coastal management has critical links to marine resources and **natural resources**, the following legislation may also be of relevance (complete copies maybe found at the following link: http://www.nepa.gov.jm/new/legal_matters/laws/index.php.)

- **Aquaculture, Inland and Marine Products and By-Products (Amendment 2002)**
- **Endangered Species (Protection, Conservation and Regulation of Trade) Act (2000):** An act to provide for the prosecution, conservation, and management of endangered species of wild fauna and flora and for the regulation of trade in such species and for connected matters. This act outlines the coastal and marine species that are classified as endangered.
- **Fishing Industry Act (1976):** An act to provide for the regulation of the fishing industry
- **Maritime Areas Act (1996):** An act to declare Jamaica to be an archipelagic State and to make provision with respect to certain Maritime Areas of Jamaica and to provide for matters incidental thereto or connected therewith
- **Natural Resources Conservation Authority Act (1991):** An act to provide for the management, conservation, and protection of the **natural resources** of Jamaica, to establish a Natural Resources Conservation Authority, to make consequential amendments to certain enactments and to provide for matters incidental thereto or connected therewith. In relation to the coastal and marine environment the act outlines the conservation of marine parks in the country.

E2.4: Fiscal Regulation

Each year the GoJ issues annual Fiscal Policy Papers, which outline the government's intended contribution to each sector. Currently, the GoJ are attempting to reduce the country's debt and therefore funds to certain sectors have been significantly reduced. However, for coastal management projects and activities there is a general increasing trend of government funding within this sector.

The focus presented within the GoJ Financial Year (FY) 2015/2016 was to continue with strategies that maintained the surplus at 7.5% of GDP, equivalent to $126,727.5 million.

Within the Fiscal Policy Paper Financial Year 2015/16 for Jamaica, projections for the contribution to the coastal and marine habitat for FY 2016/17 were made. These are presented in table below. Similar figures will be published annually by the Government of Jamaica and can be accessed from the Ministry of Finance webpage: http://www.mof.gov.jm/budgets/fiscal-policy-papers.html.

Table E4 Financial contribution projection for 2015/16 and 2016/17 (GoJ,2015b).

Projects	Projection 2015/2016 Total	Projection 2016/2017 Total
Office of the Cabinet		
Enhancing the Resilience of the Agri Sector and Coastal Areas	15,000	6,950
Ministry of Tourism and Entertainment		
Enhancing the Resilience of the Agri Sector and Coastal Areas	18,000	11,873
Ministry of Youth and Culture		
Enhancing the Resilience of the Agricultural Sector and Coastal Areas	126,844	99,001
Ministry of Transport, Works & Housing		
Enhancing the Resilience of the Agriculture Sector & Coastal Areas	80,000	150,000
Ministry of Science, Technology, Energy, and Commerce		
Palisadoes Shoreline Protection & Rehabilitation Works Project	25,000	8,000
National Water Commission		
Dunn's River Beach Replenishment	46,000	200,000
River Bay Road Beach Development (Fisherman's Co-Op)	41,500	200,000
Close Harbour Recreational Amenity (Dump up Beach)	0	100,000
Ocho Rios Fisherman's Beach	210,000	0
TOTAL	**562,344**	**775.824**

Further to Table E4, the Fiscal Policy Paper FY2015/16 stated that $100mn would be set aside for weather-related risk mitigation and a further $3.3mn to mitigate the risk of adverse movements in petroleum prices (GoJ, 2015b).

E

E3: Environmental Enforcement and Regulation

E3.1: Environmental Impact Assessment (EIA)

The National Environmental Protection Agency (NEPA) undertakes the role of the enforcement body for activities on the coastline of Jamaica, through the NEPA Enforcement Department. Legislation and regulations stipulate that persons undertaking new developments, which fall within a prescribed category (which includes coastal **interventions**) will require a permit. Licenses will be required for the discharge of trade or sewage effluent and for the construction or modification of facilities. As part of the permit application an EIA may be required. Sections 9 & 10 of the NRCA Act gives the Authority the power to request that an EIA be conducted as part of a permit application. The Authority also has the power to request that the applicant furnish documents or information as the Authority thinks fit. Criteria for requesting this information may include the urgency, the level of technology employed in the operation of the project, and the likely adverse impacts to be expected from the project.

NEPA has undertaken a review of the existing EIA Guidelines to update the document, to incorporate emerging global issues, and natural hazard impacts as well as to create a more user friendly and practical set of guidelines for developers and consultants.

The guidance on the approach for developers to follow prior to any construction can be found at the following link:

http://www.nepa.gov.jm/new/services_products/guidelines/docs/EIA-Guidelines-and-Public-presentation-2007.pdf

This EIA Guidelines document (updated in 2007) attempts to present procedures for conducting an EIA in accordance with the legal and regulatory framework of Jamaica, ecological realities and development imperatives of the island nation, and international agreements and standards for sustainable development.

E3.2 Collaboration Techniques

Whilst having an enforcement role, NEPA considers that achieving compliance through mutual collaboration with Beach Licence holders is a more reasonable approach than direct enforcement. That said there are a few cases where Beach Licence Holders have been taken to court for non-compliance with their obligations under the granting of a Beach Licence. The obligations for a developer are provided with any Planning Conditions following any Planning Application.

To demonstrate that a Developer is meeting their requirements under Planning Conditions and the Beach Licence terms, they are required to provide 'Self-Monitoring Reports' to NEPA, to demonstrate that the coastal **intervention** is performing in accordance with expected outcomes, that damage is limited or has been repaired, and the extent of habitat planting and health has met with defined criteria etc. The Self-Monitoring Reports can be quite technical, and are provided directly by the Developer to NEPA, often being authored by a suitable coastal environmental or coastal engineering company.

NEPA has, within its remit, the opportunity and capability with in house field officers, or consultant staff to check the submitted 'Self-Monitoring Reports' directly on the ground, to ensure what is being described in the reports is reflective of actual conditions. NEPA can, depending on observations, issue an 'On-Site Warning Notice' that provides the Developer with a time to comply with the Beach Licence requirements. The time allocated is normally 30 days.

Subsequently, if the Warning Notice is not actioned appropriately, then there are two subsequent stages that can be invoked by NEPA. The first is to suspend the Beach Licence which prevents the

Developer from utilising the development asset in the coastal zone until the cause of suspension has been rectified, and ultimately on a final breach of the Beach Licence obligations the Licence can be completely revoked.

NEPA is moving towards the requirement for there to be Performance Bonds included in Planning Approvals, whereby the Developer provides a Bond against the performance of the engineering or environmental coastal assets. Should the performance not be met, or ownership / responsibility for the development change hands, then NEPA would have recourse to drawdown on the Bond to cover costs in mitigating or improving the coastal asset under question. There is some good experience of the provision of Environmental Performance Bonds in the wider Caribbean Region, and one of the most rigorous examples being implemented recently has been in Turks and Caicos.

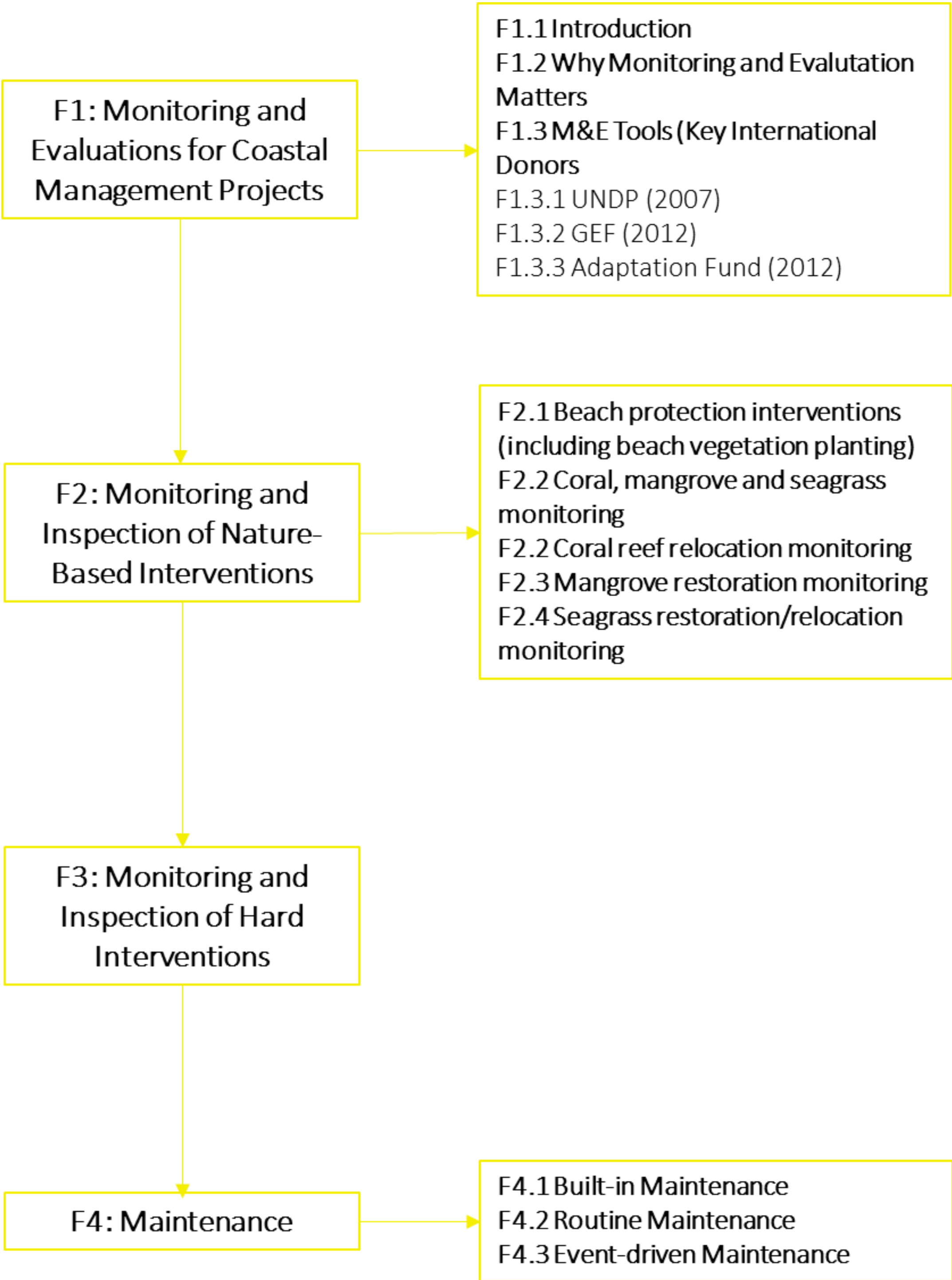
Summary

- There are a wide number of stakeholders who should be involved in a coastal management project.
- Community engagement is particularly important for ensuring the long term sustainability of the **interventions**.
- A number of plans, policies and legislation should be considered in the development of a coastal management project, in particular consideration of a Beach Licence and undertaking of an Environmental Impact Assessment.

E

Part F: Monitoring and Maintenance

This flowchart demonstrates where to find information within this chapter. Use it in conjunction with the contents pages to navigate around the Guidelines and the glossary within which words in **bold** can be found.



Contents

It is important that once coastal **interventions** have been constructed that they are monitored to determine that they remain viable and are performing to their designed function and performance outcomes (see Part C). Monitoring of the performance of an **intervention** is also important from both a client, consultant and contractor perspective. Usually, a client pays for an **intervention** to be undertaken based on a defined set of outcomes and levels of quality assurance. The contract documentation will commonly provide performance clauses relating to the design and construction phases of a project including a 6 to 12 month monitoring/defects period for which the responsibility of the project performance is held by the design engineer and the contractor. During this period, any inadequacies in the project are rectified by the engineer and/or contractor.

Performance monitoring is a tool used in quality assurance and can be a useful mechanism for improving design and construction methods. Performance monitoring may include:

- biological monitoring for a project's impact on water quality;
- beach and dune surveys for effectiveness of erosion control;
- breakwater surveys for subsidence or rock displacement;
- ecological monitoring for species presence or **biodiversity**; and
- general workmanship.

The monitoring requirements for **nature-based interventions** (F2) and **hard interventions** (F3) are slightly different and therefore have been considered in turn below. It is further important under all **interventions**, including **non-structural interventions** to be able to monitor and evaluate the successes and outcomes of the project. This is discussed in F1.

F1: Monitoring and Evaluations for Coastal Management Projects

F1.1 Introduction

This section represents a synthesis and summary of a few M&E frameworks that are currently being used to assist with monitoring and evaluation (M&E) of coastal adaptation and resilience donor funded **interventions**. Therefore a specific focus is placed on international development projects and programmes (not private sector funded programmes which are addressed by F2-F4).

F1.2 Why monitoring and evaluation matters on donor funded coastal projects

Climate change represents a 'problem' as it is deeply complex, intractable, and resistant to solution. Climate change threatens to reverse gains made toward sustainable human development and compromises the lives, health, and livelihoods of people across the globe. Coastal adaptation and resilience represents a new focus of development programming, although not an entirely novel one. Rather, this programming builds upon existent practice. However, it is not simply development 'business as usual.' There is a consensus that for resilient coastal interventions to be effective, they must be tailored specifically to the challenges and dilemmas posed by climate change.

Given these challenges, a growing number of organisations responsible for funding and/or delivering **resilient** and **sustainable interventions** are now examining how to best approach M&E of it. In addition, programming itself has evolved, becoming both more ambitious and more widespread. When done well, the M&E can serve both to demonstrate the effectiveness of policies and programmes, and to generate new learning.

The following key M&E guidelines, toolkits, and frameworks are put forward as being of possible relevance to the Jamaican situation (variety of donor organisation M&E operational guidelines).

F1.3 M&E Tools (Key International Donors)

F1.3.1 UNDP (2007) Monitoring and evaluation framework for adaptation to climate change

This document is intended to guide UNDP staff in the design of M&E frameworks for coastal management related initiatives and to ensure that log-frames can be aggregated to track progress of an overall portfolio that is in alignment with Millennium Development Goals (MDGs). This report provides a framework for climate change adaptation across seven Thematic Areas (TAs) that includes coastal adaptation.

The framework for both the portfolio and project levels was developed with a focus on National Adaptation Programmes of Action (NAPAs) under the Special Climate Change Fund (SCCF) and resilience under the Least Developed Countries Fund (LDCF). It provides useful insights into the need for multi-level M&E frameworks and was a valuable starting point for many later M&E resources. While this document does not address conceptual or theoretical matters in great detail, it provides useful insight into some of the most fundamental issues which need to be tackled in establishing an M&E framework for coastal adaptation interventions. It provides clear and concrete instruction on designing log-frames and indicators that would be used to measure an aggregated portfolio of endeavours in terms of coverage, impact, sustainability, and replicability.

This document represents one of the first attempts to develop an M&E framework specifically in relation to adaptation **interventions** (including coastal), in this case those funded through the SCCF and the LDCF. It provides a useful insight into the challenges of linking portfolio-level goals and objectives to project level goals, objectives, outcomes and outputs (i.e. a traditional logframe) in the context of climate adaption. This portfolio multi-level approach is interesting, and relevant specifically to UNDP structures and goals.

The example project level indicators provide a useful illustration of the types of indicators which can be developed for each of the Thematic Areas, and there is also a description of indicator types. The framework encourages the use of consistent units of measurement at the project level in order to be able to aggregate project results within UNDP's Thematic Areas.

F1.3.2 GEF (2012) Climate change adaptation monitoring and assessment tool (AMAT)

Climate change adaptation monitoring and assessment (AMAT) tool is designed to enable the Global Environment Facility (GEF) to measure outputs and outcomes from the Least Developed Countries Fund / Special Climate Change Fund (LDCF/SCCF) portfolios and aggregate them in order to report progress at an international level. It is intended that this will ultimately enable GEF to track and examine common indicators over time to assess progress and identify measurable achievements.

AMAT is a "tracking tool" that serves to document progress across the overall agency's results framework for coastal adaptation related projects. Each funded project is required to report against at least one specified objective, outcome, and output indicator defined in its menu of options. Reporting is required at three points in time:

a) at Chief Executive Officer endorsement/approval request;
b) at project/ programme mid-term evaluation; and

c) at project completion.

This tool is designed to only monitor information that is explicitly aligned with the agency's logframe, so that data can be aggregated and reported at a global level. The document issues brief, explicit directions for how to fill out the specified forms correctly, together with some examples.

F1.3.3 Adaptation Fund (2012) Results framework and baseline guidance: Project-level

This manual assists actual any potential Adaptation Fund (AF) implementing partners to design M&E coastal project frameworks that are in alignment with AF requirements by "clarifying core Adaptation Fund (AF) indicators, and suggesting ways to measure them" (AF 2012: 3). In addition to instructions on developing a logframe for project-level work, the manual provides basic guidance on data collection, analysis, and reporting.

The emphasis of the manual is on introducing the reader to AF's own overarching results-based management (RBM) framework, and providing instruction to ensure that funded agencies' own logframes are in alignment with it. To this end, the manual introduces the AF's guiding principles and results framework. Any AF-funded project or programme must demonstrate how it directly contributes to the Fund's own specified objectives, outcomes, and indicators. The annexes include more detailed instructions, definitions, and measurement guidelines. Detailed step-by-step instructions are given on how to design a logframe and M&E framework for the AF. The directions are easy to follow, and can be easily understood by a reader who has little familiarity with the basic components of a results-based management framework. Much of the content is quite basic; however, there is some material that touches upon some more in-depth elements of climate change adaptation programming. For example, there is discussion on the many uncertainties inherent to climate change adaptation programming, and the authors recommend choosing 'no regrets' courses of action, i.e. those that "would generate net social and/or economic benefits irrespective of whether or not anthropogenic climate change occurs".

F2: Monitoring and Inspection of Nature-based Interventions

Monitoring of **nature-based interventions** is important to ensure the outcomes prescribed at the project outset are being met. This is particularly true where recreational or **biodiversity** outcomes are required as part of the scheme approval or licences gained. Specific monitoring requirements for the following type of **interventions** are provided below: beach protection **interventions**, coral restoration, mangrove restoration, and seagrass restoration. These monitoring requirements may require adaptation to other types of **nature-based interventions**.

<u>Monitoring for performance factors</u>

Following implementation of a **nature-based intervention**, it is important to be able to monitor its success. This will allow determination of whether additional **interventions** or different maintenance is required to improve performance to meet expected outcomes (Part F3). Key performance factors and evaluation metrics are provided in Table F1, these should be defined and agreed at design stage and should be monitored following construction for a recommended minimum of five years.

Table F1 Key performance factors and evaluation metrics (adapted from EDF, 2015).

Intervention	Performance factors and evaluations metrics
Beach Protection (D2.1, D2.2, D2.3)	(comparison of metrics against design requirements and **Beach Management Plan** (F1.1)): - Beach slope - Beach width - Storm berm - Sediment grain size - Presence of cliffing - Evidence of soft areas
Beach Vegetation Planting (D2.4)	- Vegetation cover - Vegetation height - Beach width and slope
Coral Reefs (D2.5)	- Reef width, elevation, and roughness - Length of reef in the direction of wave propagation, submerged depth of flow (water depth above the reef system) - Geometry of the reef (porosity, surface roughness, and the overall void matrix) - Proximity to land - Extent of reef flat (width and shallowness)
Mangroves (D2.6)	- Vegetation width, height, density, structure, age, stiffness, orientation to storm direction, continuity, health of root system, length. - Forest width and density of exposed root systems – this is most important for effectiveness in terms of wave attenuation - Water depth - Sediment composition – need continued source of sediment - Predation of seedlings/transplants of young trees
Seagrass (D2.7)	- Elevation and continuity - Species composition and density - Width of area, stem stiffness, density (for wave attenuation effectiveness) - Predation of seedlings

F2.1: Beach protection interventions (including beach vegetation planting)

When undertaking some form of beach protection, a **beach management plan** should be undertaken to dictate the monitoring requirements and trigger levels under which maintenance works need to then undertaken.

It is recommended that the **beach management plan** covers the following sections:

- Introduction to background of the scheme.
- Information on the environment including: water levels, wave climate, beach morphology, sediment properties (grain size etc.), sediment transport and environmental sensitivities.
- Description of surveys to be undertaken.

Beach Management Plans

The CIRIA Beach Management Manual (second edition) (CIRIA, 2010) provides further detailed breakdown of what an exemplar **beach management plan** should look like.

- Presentation of the monitoring plan including trigger levels defined which will then trigger maintenance works required.
- Summary of permissions and consents required to undertake monitoring and maintenance works.

The recommended surveys to be undertaken include:

- Visual inspection: walkover noting evidence of erosion, identification of soft or high sil content areas, comparison against any other structures such as a seawall or groynes, exposure of the foundations of any structures. Key aim is to observe the natural fluctuation of the beach morphology and to understand long-term and seasonal evolution. Should also note safety issues, particularly relating to swimmer safety, such as notice boards, provision of life saving equipment etc.
- Beach profile surveys: comprising of sections lines surveyed perpendicular to the shoreline. They are used to quantitatively establish beach response to storm events, beach recovery rates, long-term volume changes and areas of potential erosion. Can be undertaken using a range of technology including real time kinematic global positioning systems (GPS), traditional levelling, or a total station. Must be georeferenced using appropriate GPS.
- Fixed aspect photos: Fixed aspect photos are a useful monitoring technique that is based on the establishment of a series of locations from which to take repeatable photographs approximately at the same time of the year and similar tidal conditions, preferably close to low tide.
- Aerial photographs: If possible aerial photographs can be compared to identify changes in the shape of the beach, usually in terms of crest lines, as an indicator of sediment transport patterns and directions as well as beach alignment.

The recommended monitoring programme for a scheme is presented in Table F2.

Table F2 Table summarising the proposed monitoring programme for beach protection schemes.

Monitoring	Visual Inspection	Beach Profiles	Fix Aspect Photos	Aerial Photos
During the first two years following construction	Twice per year	Twice per year	Twice per year	Annual
Year 3 onwards	Annual	Twice per year or to be redefined	Annual	Annual
Following storm events	As soon as possible following a storm event			If possible can provide data for a rapid assessment

F2.2: Coral, mangrove and seagrass monitoring

There are some common themes in the requirements of monitoring process for monitoring of seagrass, mangrove and coral reef restoration. These include:

- Visual inspection of ecosystem – height, species composition, geometry etc.;
- Water quality;
- Assessment of cover, extent, and density; and
- Impact from high energy events.

These themes have been discussed below as general methodologies which can be applied to different marine ecosystem monitoring. Sections F2.3 to F2.5 describe specific monitoring requirements for the different ecosystems in more detail.

Many of the methods that are currently used for ecological monitoring are quite complex and require expensive equipment and specialist scientific skills. The use of photomosaics, for instance, is proving to be a very powerful tool for monitoring changes in coral reef structure but requires purpose-built camera systems and specialist software that may be beyond the price range and technical skills of most community groups.

In these Guidelines, we recommend methods that are suitable for "community-based" monitoring of the ecological, social and policy indicators. The methods build on those recommended by the Nature Conservancy in the establishment of the pilot projects, but add additional methods to ensure robustness and consistency.

The methods outlined in the following chapters require simple techniques and accessible/affordable equipment in order to ensure that the processes of data collection and analysis can be implemented sustainability and consistently by community groups. Underwater cameras are becoming cheaper and can provide a permanent and data-rich record of the underwater environment. These digital photos can be stored and shared easily, and most importantly revisited later to extract additional information. Photos also provide a wide range of data and are accessible to non-technical staff. A time-series of photos can provide compelling evidence as the effectiveness of ecological restoration and help convince policy-makers, donors, and communities of the importance of supporting this work.

Visual Inspection of Ecosystem

Growth

Growth is an important parameter to measure as it is a reflection of the health of the plant/reef and the value of the ecosystem-services it is providing. Generally speaking, the larger the coral, mangrove or seagrass, the more habitat it provides to fish and more wave energy it dissipates. Measuring growth rates also allows comparisons to be made between different species and between sites, so that the restoration programme can be improved over time.

It is not practical or possible to measure growth in all the corals/seagrasses/mangroves in the sites as the numbers will rapidly increase. Measurements of growth should be made on a sample of plants from each species if applicable. The colonies within the sites should be tracked by labelling and through position mapping (see below). This will allow for the tracking of individual colonies for growth and survival.

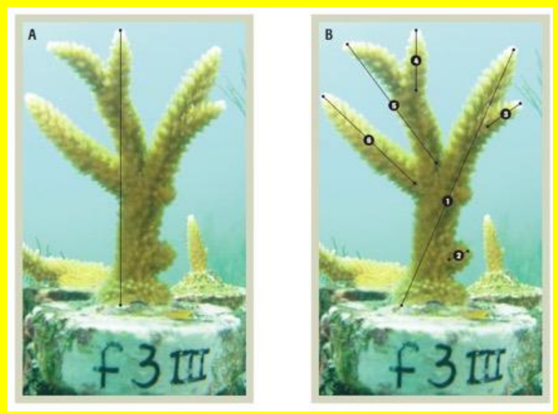
In addition, photographs should also be taken of all the labelled colonies from the same orientation and from the top with the identification number of the colony clearly visible. A wrist-mounted compass will allow all photos to be taken from the same direction (e.g., from the south looking north) at about 1 meter distance. The time series of photos will then allow easy recognition of the individual elements and of the evolution of the size and condition.

Methodology for Measuring Coral Growth in the Nurseries

Growth measurements of nursery fragments are made using the **Total Linear Extension** (TLE) method. Image A below shows how the measurement is taken for linear growth (maximum height). Image B shows tissue extension measurement, when all measurements (1– 6) are added together to get total live tissue or Total Linear Extension (TLE) for the fragment.

It is not practical or possible to measure all the corals in the nursery as the numbers will rapidly increase. Measurements of growth should be made monthly on a sample of corals (max. 30 corals) from each coral genotype (e.g. parent stock). The coral colonies within the nurseries should be tracked through position mapping of the trees and tables. This will allow for the tracking of individual colonies for growth.

Several growth measurements will be taken for the corals in the nursery. Initial measurements for total live coral will be taken for corals initially placed in the nursery to set a baseline. Each time a colony in the nursery is fragmented, the live tissue of the donor colonies and the fragment removed will be measured. This will give a measure of the total production of the colony over time. The other growth measurements that will be taken include: number of branch tips – branch tips above 1 cm should be measured and maximum branch width – width of branch at base of colony or fragment.



Source: Liz Larson - Taken from - Johnson, M. E., C. Lustic, E. Bartels, I. B. Baums, D. S. Gilliam, L. Larson, D. Lirman, M. W. Miller, K. Nedimyer, S. Schopmeyer. 2011. Caribbean Acropora Restoration Guide: Best Practices for Propagation and Population Enhancement. The Nature Conservancy.

F

Survival and Health

Monitoring survival and health are essential to assess the success of the ecosystem restoration efforts. Survival and health assessments require simple visual assessments to determine tissue loss or mortality, the presence or absence of predators, diseases, or other general indicators of overall health.

Data should be collected for the following parameters:

- Mortality: Indicate if the plant/seedling is alive or dead, and the approximate percentage of dead tissue (e.g. 40% mortality). If known, the likely cause of the mortality should be noted as a comment;
- Bleaching in coral reefs: This is an important parameter to provide information around which species are more tolerant to higher temperatures (or resistant to bleaching and/or disease events). Use broad categories of bleaching such as: Paling, Severe Paling, Bleached.
- Disease: If disease is present indicate which one.
- Predation: The number of predator species within an area is an important indicator of heath. Too many of these species will rapidly kill small, new seedlings, and they should be removed from recently restored or planted sites until the seedlings are large enough to withstand some predation and a moderate amount of tissue loss. In a healthy environment, these corallivorous species are kept in check by larger predators (e.g. lobsters and fish).

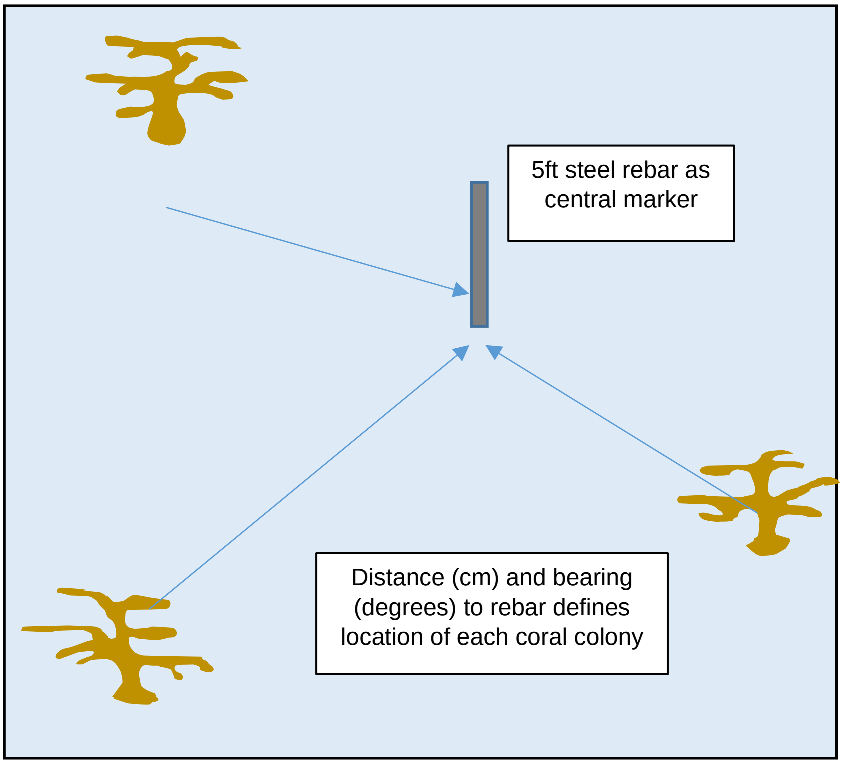
Position Mapping

Tracking individual plants, seedlings or reef elements can be achieved by using labels with a unique identifier of the genotype. This is important, as it allows managers to track the genotypes which thrive best under the conditions at the site. Various methods exist for making labels, from laminated cards to a more permanent embossed PVC card. These can be made using a PVC Card Embossing Machine.

Mapping corals

It is recommended that maps be produced of the out-planting plots to help identify and track each out-planted coral – this is called position mapping. To make this mapping exercise easier, it is recommended that a 5ft length of rebar (16mm diameter) be securely inserted into the centre of the outplant site. This can easily be done with a large hammer. The location of each labelled outplant can then be described simply by the distance and compass bearing to the central rebar. See examples below. An out-planting site map should then be drawn that clearly shows the locations of each individual outplant so that they can be tracked over time.

Figure F1 Creation of a coral outplant tracking map. The use of a marked central point (steel rebar) allows the positions of all outplants to be mapped using the distance and compass bearing to the central marker.



Water Quality

Temperature

Temperature is a very important parameter to measure as changes in temperature can cause stress to ecosystems. In particular with coral reefs it can lead to coral **foreshore** events, when the corals lose their colour. This is caused by the disappearance of the microscopic plant cells in the coral tissue, called zooxanthellae, which provide the corals with 90% of their nutrition from photosynthesis (sunlight). Bleached or partially bleached corals can recover but are very susceptible to diseases. Handling of these corals should be avoided.

Two methods should be used to measure temperature:

(1) Thermometer

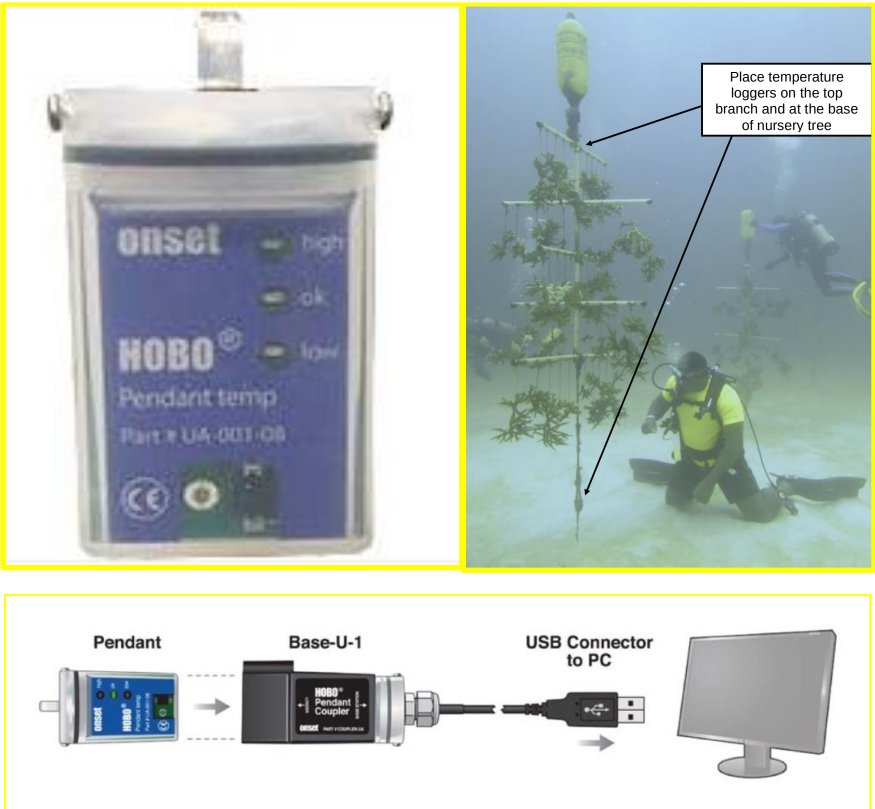
A thermometer (or a dive computer that has been checked against a reliable thermometer) should be used to measure the sea water temperature each time the sites are visited. These should be recorded at the top and bottom of the nursery trees or seagrass seedlings, or at the same depth as the coral nursery tables and coral outplants. The values should be recorded in degrees Celsius (C°) and noted on the data sheets.

(2) Temperature data logger

Temperature data loggers should also be used to provide continuous monitoring of water temperature at the various sites. These pendant temperature loggers are small, water-resistant and can be used in a wide range of applications. They can be used for short-term applications or for long logging deployments. The loggers can be programmed and the data downloaded very easily using free software provided (e.g. HOBOware) and with a USB Optic Base Station. As temperature varies significantly with depth, two loggers should be used where different depths at different heights is required. OA data logger should also be fixed to the main central rEbAr marker at each out-planting site.

The data loggers should be programmed to record temperature every 3 hours using the software and reader provided. They should be retrieved every three months and the data downloaded.

Figure F2 Example of temperature data logger. This model produced by HOBO is water-resistant down to 30m depth. They should not be used in water deeper than 15m.

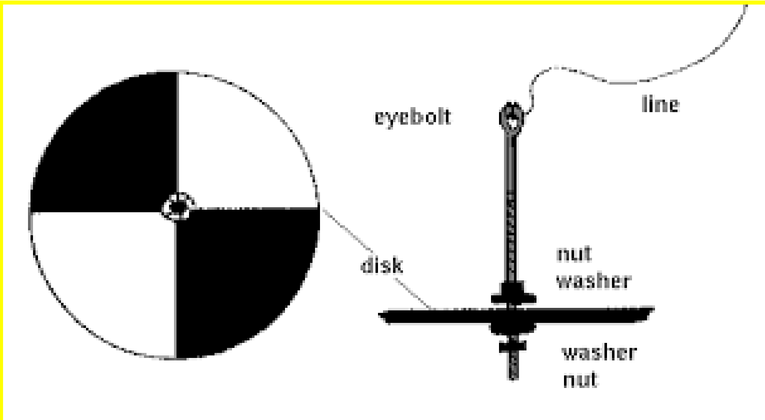


Turbidity

Water turbidity is also an important parameter of water quality as it affects the penetration of light and therefore the ability of seagrass and corals to use sunlight to make energy. The microscopic algae in plant tissue, which are called zooxanthellae, use sunlight to photosynthesize and produce sugars as a source of energy for the coral host. Without adequate sunlight, seagrass and corals are unable to grow, become vulnerable to disease and eventually die. In the Caribbean, high turbidity is usually due to sediment runoff from the land or blooms of microalgae associated with high levels of nutrients in surface waters.

Turbidity can be measured very easily with a Secchi disk. The Secchi disk, as created in 1865 by Angelo Secchi, is a simple white and black circular disk of 20cm in diameter that is used to measure water transparency. The disc is mounted on a pole or line, and lowered slowly down in the water. The depth at which the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity.

Figure F3 Construction and use of a Secchi disk



A Secchi can be made very easily with a 20cm diameter disk of PVC or wood painted in white and black. The disk is weighted with a stainless steel eyebolt stack of washers and large nut. Extra weight can be added to the base of the disk. The disk is lowered over the side of a boat on a measuring tape until it is no longer be visible. The depth is then recorded.

Secchi disk measurements should always be taken off the shady side of a boat, ideally between 10 am and 2 pm (not earlier than 9am or later than 3pm).

Secchi disk readings do not provide an exact measure of transparency, as there can be errors because of the sun's glare on the water, or one person may see the disk at one depth, but another person with better eyesight may see it at a greater depth. However, it is an inexpensive and straightforward method of measuring water clarity. Because of the potential for variation between users, methods should be standardized as much as possible.

Chemical Pollutants

The concentrations of chemical pollutants are important water quality parameters that affect the health of coastal ecosystems. There is a very wide range of chemicals that may occur in coastal waters, ranging from those found in sewage and domestic grey water, fertilizers, pesticides, herbicides, anti-fouling compounds, industrial by-products, etc. Monitoring these chemical contaminants is expensive and technically complex as it requires regular sampling schedules and specialist analytical laboratories.

The most pervasive and common chemicals found in coastal waters are those described as nutrients, in particular nitrate, nitrite, ammonia and phosphates. These are often elevated in coastal areas because of land-based sources of pollution from inadequately treated sewage, domestic waste water enriched with phosphate-based detergents, fertiliser run-off and industrial effluents from factories or distilleries. The levels of Total Inorganic Nitrogen (TIN) and Total Phosphates (TP) are often used to capture the levels of these common nutrients.

The collection of water samples and analysis of chemical pollutants should be coordinated by a certified laboratory under the guidance of expert environmental chemists. The analysis should be done using equipment that can detect concentrations of TIN in the range of 10-6 molar (10-6 moles/litre), as coral reef ecosystems are sensitive to TIN at these very low levels.

Assessment of Habitat Cover, Extent, and Density

Although habitat cover, extent and density can be collected during the visual assessments, photography, satellite imagery and aerial imagery can be used to calculate cover, extent, and density values efficiently and effectively. These values are some of the most important values to assess when considering the effectiveness of the habitat in attenuating wave energy.

Taking underwater photographs of coral and seagrass colonies with a visible scale can be a valuable tool in tracking and monitoring fragments in the outplants sites, providing a photographic record of size and overall health of the colonies over time. Photos also facilitate identification of colonies if the labels have become lost or overgrown tags or identification.

Aerial and satellite imagery can also be used effectively. Particularly for mangrove restoration areas, where much of the vegetation isn't submerged, image interpretation software in GIS can be used to assess vegetation cover for large areas in short space of time. The accuracy will depend on the source of data being used, with aerial images generally provided much better accuracy. There is also the potential to use this method for seagrass restoration assessments and potentially coral reefs, however the method and data used for the analysis need to be carefully considered.

Normalised difference vegetation index

The normalised difference vegetation index (NDVI) can be used to assess aerial or satellite imagery with a NIR band. It will highlight live vegetation, as it uses the interaction between the NIR part of the spectrum with chlorophyll within the plants. Chlorophyll is required for photosynthesis which is the process plants use for sourcing energy. The following equation allows calculation of the NDVI:

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

Where: NIR – Near Infrared part of the spectrum and VIS – visible red part of the spectrum

Impact from High Energy Events

Following high energy events, such as hurricanes and flood events, the above parameters should be monitored even if this is outside of the monitoring plan. This is to capture the potential impact and mortality experienced as a result of the event.

F2.3: Coral reef relocation monitoring

In all cases, coral restoration requires careful planning and evaluation with restoration experts, followed by training and monitoring. The NEPA Guidelines for the Relocation and Restoration of Jamaica's Coastal Resources: Corals Seagrass & Mangroves (NEPA, 2010) provides an outline to the required monitoring for coral reef restoration projects. However, these requirements have been expanded upon in these Guidelines. The recommended various steps involved in this process are outlined in Figure F4. These are based on a new coral restoration programme underway in Jamaica implemented by the Sandals Foundation in partnership with the Coral Restoration Foundation and the Bluefield's Bay Fishermen Friendly Society.

The project should involve local stakeholders, in particular scuba divers and spear-fishermen, who could be trained to become coral gardeners. The project should aim to provide these coral gardeners with the skills and equipment needed to assist with the initial coral restoration activities and to maintain the nursery and out-planting sites once the set-up is complete.

The project should also explore private sector partnerships and sustainable financing mechanisms to pay for coral gardeners to continuously maintain the newly established coral restoration sites. Support and recruitment may be sought from local dive shops that could benefit from the restoration of corals as an attraction for customers. These restoration sites can also serve to create new diving and snorkelling sites away from the traditional dive sites.

The coral restoration project should develop collaborations with coral geneticists in order to build on recent scientific research focusing on the genetics of coral **resilience**. The input of geneticists would allow the project team to select, characterize and monitor coral genotypes that demonstrate greater tolerance to local and projected stressors (e.g. thermal stress) across several generations.

Monitoring reports are required to be submitted to NEPA, 3 times a year for the year following construction and then 2 times a year for years 2 to 5 following construction. These reports should contain monitoring data on:

- Survival;
- **Bleaching** and disease;
- Percentage hard coral and algae cover; and
- Impact of any external stressors such as storm events.

Figure F4 Recommended steps in establishing a coral restoration programme. Source: Coral Restoration Foundation.

Site survey and evaluation, permitting and initial meetings

Step 1: Site visit and assessment

- Reef Evaluation
- Nursery site selection
- Restoration site selection
- Brood stock sourcing
- Land Based Work
- Stakeholder meetings
- Permitting meetings

Step 2: Permitting

- Create and submit Applications
- Respond to questions and comments about the applications
- Assemble and prep nursery materials
- Ship nursery materials and startup kits prior to nursery trip.

Coral nursery established, training of local partners, follow-up visit

Step 3: Nursery setup

- Lay out the nursery and install trees
- Collect and hang corals
- Set up growth comparison studies
- Train host employees and key community partners

Step 4: Six month follow-up visit

- Prune and hang second generation corals
- Re-visit collecting sites
- Train local stakeholders
- Promote the program locally

Coral out-planting sites established, training of local partners, monitoring

Step 5: One year follow-up visit

- Prune and hang additional second generation corals
- Install additional trees for corals
- Transplant 25% of six month old coral to the reef
- Train local stakeholders
- Launch Coral Restoration dive certification programs

Step 6: 18 mth follow-up visit

- Transplant additional corals to the reef
- Prune additional second generation staghorn corals and hang on new trees
- Prune third generation staghorn corals
- Prune additional second generation elkhorn corals
- Train local stakeholders
- Monitor previously transplanted corals

Step 7: 24 mth follow-up visit; annual visits

- Check to make sure everything is running smoothly
- Give status reports to the permitting agencies
- Assist with coral transplants
- Assist with monitoring
- Evaluate nursery and restoration processes
- Look for additional transplant opportunities
- Consider adding corals
- Evaluate research opportunities
- Train new local stakeholders

F2.4: Mangrove restoration monitoring

Mangrove restoration has been used successfully in many countries worldwide and several publications provide useful reviews (McLoad and Salm, 2006; Kaly and Jones, 1998). The NEPA Guidelines for the Relocation and Restoration of Jamaica's Coastal Resources: Corals Seagrass & Mangroves (NEPA, 2010) provides an outline to the required monitoring for mangrove restoration projects.

Mangrove restoration areas can be located across the nearshore/shoreline/hinterland zones and therefore monitoring of mangroves must be considered on an integrated coastal zone management scale and within spatial coastal zone planning. Mangrove afforestation areas are often located in Protected Areas in Jamaica and therefore it is also critical that the monitoring plan is integrated into the management plan for the area.

Monitoring reports are required to be submitted to NEPA, 3 times a year for the year following construction and then 2 times a year for years 2 to 5 following construction. These reports should contain monitoring data on:

- Survival;
- Aerial coverage;
- Percentage cover of all species;
- Plant density;
- Height of the plants;
- Faunal characteristics;
- Water quality;
- Photographs from ground level stations; and
- Impact of any external stressors such as storm events.

The above parameters are described in F2.1. Specific considerations and reference to useful literature and guidelines are provided below.

Survival

Survival of seedlings is one of the most important considerations, and monitoring of the survival is required to not only track potential success of the scheme but to also identify maintenance requirements where necessary. If through monitoring survival is identified as being low, the main cause should be identified and mitigated through maintenance. The following key causes and maintenance requirements are typical for mangrove restoration and afforestation:

- Grazing cattle such as goats – protection required using fencing.
- Debris brought in by the tide – should be removed using hands or salt water.
- Barnacles (Crustacea: Cirripedia) – can be reduced at design stage by planting in shallow inundation sites. Barnacles can be removed by hand if identified during monitoring and maintenance inspections.
- Sesarmid crabs (Crustacea: Grapsidae) eat propagules and young leaves (Schmitt and Duke, 2015) – bamboo tubes can be used to protect seedlings.
- Beetles and scale insects – can be washed off with salt water or removed by hand. In particular, the common boring weevil (*Coccotrypes fallax*) attacks *Rhizophora* and *Bruguiera* propagules. To mitigate this impact, propagules should not be placed in shaded areas as sunlight will kill the weevil.

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Aerial coverage

To undertake mangrove monitoring, visual inspections should be undertaken. If necessary, this should partly be from a boat to ensure the entire area can be covered and assessed. Useful data that can be used to compliment the visual inspection includes LiDAR data, which could be used to assess vegetation height and density. Furthermore, aerial images could be used to assess vegetation density and extent, particularly if Near Infrared (NIR) photography in included.

Species cover

Within the species cover assessments it is important to ensure that the zonation of species is clearly identified. Within mangrove systems, due to the often-varying topography, different species will be expected to establish in different areas. When assessing the growth of species across the site, this should be linked through to the elevations and hydrology of the area (Schmitt and Duke, 2015).

Further information and tools for mangrove monitoring

English S. *et al.,* (1997) Survey manual of tropical marine resources. ASEAN Project: Living Coastal Resources by the Australian Institute of Marine Science, Townsville

Lewis RR. and Brown B (2014) Ecological mangrove rehabilitation – a field manual for practitioners. Mangrove Action Project, Canadian International Development Agency and OXFAM.

Schmitt, K. and Duke, NC. (2015) Mangrove Management, Assessment and Monitoring. Tropical Forestry Handbook, Springer-Verlag Berlin Heidelberg.

Case Studies: Monitoring of mangrove restoration and planting at Portland Bight (part of GOJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction Project)

Restoration activities commenced in April 2012 and were completed by August 2012 to restore and improve the **hydrological** connections in the Portland Bight Protected Area by recreating historical tidal channels and creating new ones to facilitate tidal flushing and natural regeneration overtime. This was enhanced by planting 4,920 red and black mangrove seedlings that were common to the area prior to the forest being disturbed.

Monitoring was undertaken at: time zero, five months, eight months and 11 months following construction. This monitoring has enabled the Project Team to identify factors which are effecting the success of the project (such as seedlings being eaten by goats and larvae) and identify that the density of growth is still such that it meets the design parameters (results of the time zero plus 8 and 11 months monitoring shows an increase in seedling height, number of leaves and an overall survival rate of 1 seedling/1.3 m^2).

Picture left: seedlings had been eaten by goats and right: black areas show seedlings which have been eaten by larvae

Source: NEPA, 2013

F2.5: Seagrass restoration/relocation monitoring

Seagrass restoration or relocation is required to have a 'no net loss' in species coverage and therefore monitoring is crucial for providing the evidence that the scheme has met this requirement by NEPA. Seagrass monitoring will depend on the species of seagrass and the predicted growth rates of the species. The NEPA Guidelines for the Relocation and Restoration of Jamaica's Coastal Resources: Corals Seagrass & Mangroves (NEPA, 2010) provides an outline to the required monitoring for seagrass restoration projects.

F

If slower growing species such as *Thalaisia testudinum* (Figure F5a) are used, then detailed monitoring is required for at least five years. If faster growing species such as *Syringodium filiforme* (Figure F5b) or *Halodule wrightii* (Figure F5c) are used then detailed monitoring is required for at least three years.

Figure F5 Pictures of seagrass species: a) *Thalaisia testudinum*; b) *Syringodium filiforme*; and c) *Halodule wrightii*

Source: Smithsonian Tropical Research Institute

Monitoring reports are required to be submitted to NEPA, 3 times a year for the year following construction and then 2 times a year for years 2 to 5 following construction. The following elements should be included in a monitoring report:

- Seagrass mapping preferably within GIS
- Geographical location
- Water depth
- Percentage cover of all species;
- Plant density;
- Height of the plants;
- Faunal characteristics;
- Sediment composition;
- Algae percent cover;
- Water quality;
- Photographs from ground level stations; and
- Impact of any external stressors such as storm events or predators.

The above parameters are described in F2.1. Specific considerations and reference to useful literature and guidelines are provided below.

Mapping of sea grasses

The mapping of sea grasses can use satellite or aerial imagery and this is likely to be the most effective way of achieving an overall view of the percentage cover of seagrass in an area. However, as the seagrasses will normally be submerged, the accuracy and effectiveness of the mapping will depend on the spectral optical depth of the water column, the brightness and density of the seagrass and the spectral contrast between the sea grass and the substrate (McKenzie, 2003). Aerial photographs can be easier to interpret than satellite imagery as can often be analysed visually by an ecologist rather than needing more detailed software to interpret the spectral data.

McKenzie *et al.,* (2001) provides a decision tree to facilitate the formulation of a mapping strategy (Figure F6).

Figure F6 Decision tree looking at different data capture methods to map distribution of seagrass meadows according to information required and spatial extent (adapted from McKenzie *et al.,* (2001)).

What is the size of the region or locality to be mapped?

	Intertidal	Shallow subtidal (<10m)	Deepwater (>10m)
Less than 1 hectare: Fine/Micro-scale 1:100	Aerial photos, *in situ* observer	*In situ* diver, benthic grab	SCUBA, real time towed video camera
1 hectare to 1km^2: Meso-scale 1:10,000	Aerial photos, *in situ* observer, digital multispectral video	*In situ* diver, benthic grab	SCUBA, real time towed video camera
1km^2 to 100km^2: Macro-scale 1:250,000	Aerial photos, satellite	Satellite, real time towed video camera	Real time towed video camera
Greater than100km^2: Broad-scale 1:1,000,000	Aerial photos, satellite	Satellite, aerial photos, real time towed video camera	real time towed video camera

If mapping the seagrass extent using transects, the number generally recommended depends on the extent of the coastline (McKenzie, 2003):

- 10-100km length: transects should be no more than 500-1000m apart;
- 1 to 10km length: transects should be no more than 100-500m apart; and
- Less than 1km length: transects should be no more than 50-100m apart.

Sediment composition

The sediment composition should be recorded in line with guidance in McKenzie (2003) which is described briefly below.

1. Dig fingers into the top cm of substrate to feel texture;
2. Describe the sediment as mud/fine sand/sand/coarse sand/gravel; and
3. Make a note of whether there are any small shells mixed in with the substrate.

Sediment descriptions (from McKenzie, 2003)

Mud – has a smooth stick texture. Grain size is less than 63µm.

Fine sand – fairly smooth texture with some roughness just detectable. Not sticky in nature. Grain size greater than 63µm and less than 0.25mm.

Sand – rough grainy texture, particles clearly distinguishable. Grain size greater than 0.25mm and less than 0.5mm.

Coarse sand – coarse texture, particles loose. Grain size greater than 0.5mm and less than 1mm.

Gravel – very coarse texture, with some small stones. Grain size is greater than 1mm.

Percentage algae cover

Algae often is present in seagrass meadows and can cover or overlie the seagrass blades. If using grids or quadrants to measure the seagrass percentage cover, the algae cover should also be noted.

Predators and other features

In order to fully analyse why percentage cover may not be as high as expected or targeted, potential external stressors need to be considered. When undertaking an *in situ* survey, any evidence, and if applicable number of shellfish, sea cucumbers, sea urchins and evidence of turtle feeding should be recorded.

Further information and tools for seagrass monitoring

McKenzie, LJ. (2003) Guidelines for the rapid assessment and mapping of tropical seagrass habitats. Seagrass Watch.

McKenzie, LJ. *et al.,* (2001) Methods for mapping seagrass distribution *in* Short, FT. and Coles, RG. eds. (2001) Global Seagrass Research Measures. Elsevier Science B.V., Amsterdam.

F

F3: Monitoring and Inspection of Hard interventions

Hard interventions have **design lives** which means that they essentially have an expiry date; at some point in time the damage to the structures will be such that they cannot adequately fulfill their function. However, although a **design life** can be predicted, in reality the structure can be damaged earlier or later. In particular extreme events such as hurricanes can cause damage as well as ongoing developments and activities in the area. It is therefore important that any **intervention** has a regular monitoring regime. This will enable any damage to be recorded and maintenance can be carried out to ensure that the functionality of the structure does not deteriorate.

Upon inspection of **hard interventions**, the following features should be considered (structure dependent):

- Rock armour and masonry units – a visual inspection should be carried out on a yearly basis and after any extreme events or large storms.
- Mass concrete, reinforced concrete and precast concrete structures including capping and cope beams, promenades and concrete armour units - a visual inspection should be carried out on at least an annual basis and after any extreme events or large storms. If the structure shows signs of subsidence or structural instability (through issues such as cracking), an intrusive investigation may be required.
- Grating, handrails, access ladders and stairs – a visual inspection should be carried out on at least an annual basis and after any extreme events or large storms.
- Outfalls and manholes - a visual inspection should be carried out on at least a 6 month basis. Outfalls should have CCTV surveys or internal inspections (requiring entry into confined spaces) on at least an annual basis or following a storm where sediment appears to have been deposited in the area of the outfall to ensure there is no blockage of the outfall.
- Structural steel and steel framed components including steel sheet pile wall - a visual inspection should be carried out on at least an annual basis and after any extreme events or large storms. Some sediment removal may be required depending on location to allow clear assessment of the wall. A thickness test should be carried out every five years on the sheet piles to assess corrosion.
- Timber components - a visual inspection should be carried out on at least a six month basis.
- Toe structure – the toe structure can be difficult to assess as it is often buried under sediment. However **scour** to the toe can cause instability within the structure and therefore should be inspected visually on an annual basis. Unless there are any other visible signs, if the toe is buried it is most likely to be in a good condition as it is not exposed to the hazards. If there is a lot of vegetation around, the impact of the roots on the structure should be considered.

Table F3 provides common causes of structural deterioration in these features.

Table F3 Common causes of structural deterioration to features of coastal structures

Feature	Common Cause of Structural Deterioration	Visual Symptoms of Structural Deterioration
Rock armour and masonry units (refer also to toe structures)	Movement	abrasion/erosion, cracking, spalling, disintegration, scouring, missing/loose blocks
	Damage from impact	cracking, spalling, holes, loosening/ movement of component connections, souring, missing/loose blocks
	Loss of rock mass	rock pitting and holes evidence of chemical or biological attack
Mass concrete, reinforced concrete and precast concrete structures including capping and cope beams, promenades and concrete armour units	Movement	cracking, spalling, disintegration
	Chemical attack, ASR, ACR, and similar	efflorescence deposits, leaching, sulphate attack, cracking, spalling, surface pitting
	Corrosion	discolouration on material surfaces/rebar corrosion, flaking surface, disintegration. Note that spalling of concrete over corroding rebar or strands is the most common problem with reinforced concrete, particularly in a marine environment
	Damage from impact	cracking, spalling, holes, loosening/ movement of component connections, dents. For cope beams in particular; significant cracking greater than 100mm in length and wider than 10mm, spalling, holes, loosening/ movement of component connections, dents
	Damp and water penetration	discolouration or growth on material surfaces
	Design/ Construction defects	cracking, popouts, voids, loosening/ movement of component connections, bulging walls, hogging or sagging of beams/floor slabs, removal (or lack) of stability members
	Excessive loading	cracking, bulging of walls, hogging or sagging of beams/floor slabs, pop-

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		outs, loosening/movement of component members
	Fire damage	soot, charring, discolouration, structural damage
	Gaps at joints	loss of joint material including compression material or sealant
	Ill-considered or incompatible alterations	removal of stability members e.g. cross bracing, infilling wall panels, exposed reinforcement etc.
	Microbiological growth	discolouration or growth on material surfaces
	Outdated services	abandoned pipework, disused cables, open ducts through walls
	Protective coating breakdown	flaking paint, discolouration on material surfaces
	Spalling of concrete over corroding reinforcement;	flaked, pitted, or broken up concrete
	Thermal expansion	cracking, loss of movement, loss of joint material
	Water ponding problems	puddles, leaks
Grating, handrails, access ladders and stairs N.B. inspection of structures in vicinity of waterline shall be performed at low tide to ensure maximum coverage	Corrosion	discolouration, flaking, laminations
	Damage from impact	loosening/ movement of component connections, dents
	Excessive loading	cracking, bulging of walls, buckling, loosening/movement of component members
	Fire damage	soot, charring, discolouration, structural damage
	Microbiological growth	discolouration or growth on material surfaces
	Protective coating breakdown	flaking/cracked paint / discolouration of finish
Outfalls and manholes	Damage from impact	movement of component connections, dents, buckling
	Microbiological growth	discolouration or growth on material surfaces

	Protective coating breakdown	flaking/cracked paint
	Poor operation	seized flap valves, siltation at outfall, poor condition of seals
Structural steel and steel framed components including steel sheet piles	Accelerated Low Water Corrosion (ALWC)	localised and aggressive corrosion between low water and mean sea level
	Chemical/ Biological attack	surface pitting, surface discolouration, certain marine growth
	Corrosion	disintegration, rust, flaking, loss of thickness
	Damage from impact	movement of component connections, dents, buckling
	Design/ Construction defects	hogging or sagging of beams, buckling, loosening/movement of component members, welding and bolt failures and omissions
	Excessive loading	hogging or sagging of beams, buckling, loosening/movement of component members, welding and bolt failures and omissions
	Falling object danger (concrete chunks) and loss of structural strength	loose concrete
	Fire damage	soot, charring, discolouration, structural damage
	Ill-considered or incompatible alterations	removal of stability members e.g. cross bracing, infilling wall panels, cutting holes in members for pipes or other objects to pass through, etc
	Microbiological growth	discolouration/ growth on material surfaces
	Outdated services	abandoned pipework, disused cables
	Protective coating breakdown	flaking/cracked paint
	Thermal expansion	buckling
Timber components	Damage from impact	splitting, holes, broken members, loosening/ movement of component connections, dents

	Damp and water penetration	timber rot, swelling, organic growth
	Design/ Construction defects	cracking, loosening/ movement of component connections, leaning or out of position elements
	Excessive loading	cracking, warping, loosening/movement of component members, leaning or out of position elements
	Fire damage	soot, charring, discolouration, structural damage, disintegration, accompanying loss of member thickness
	Ill-considered or incompatible alterations	removal of stability members e.g. cross bracing, infilling wall panels, etc., leaning or out of position elements
	Chemical or biological attaqch	timber rot, insect infestation, small holes, wood swelling, discolouration, mouldy/musty smells
	Microbiological growth	discolouration/ growth on material surfaces
	Potential damage as a result of damage/deterioration of adjacent buildings	cracking, loosening/ movement of component connections, e.g. lack of lateral restraint
	Soil related damage	cracking, heave, movement of elements
	Thermal expansion	warping, twisting
Toe structure	Abrasion/Erosion	cracking, spalling, disintegration, **scouring**, movement of upper unit elements
	Design/ Construction defects	cracking, popouts
	Soil related damage	cracking, heave, subsidence

F4: Maintenance

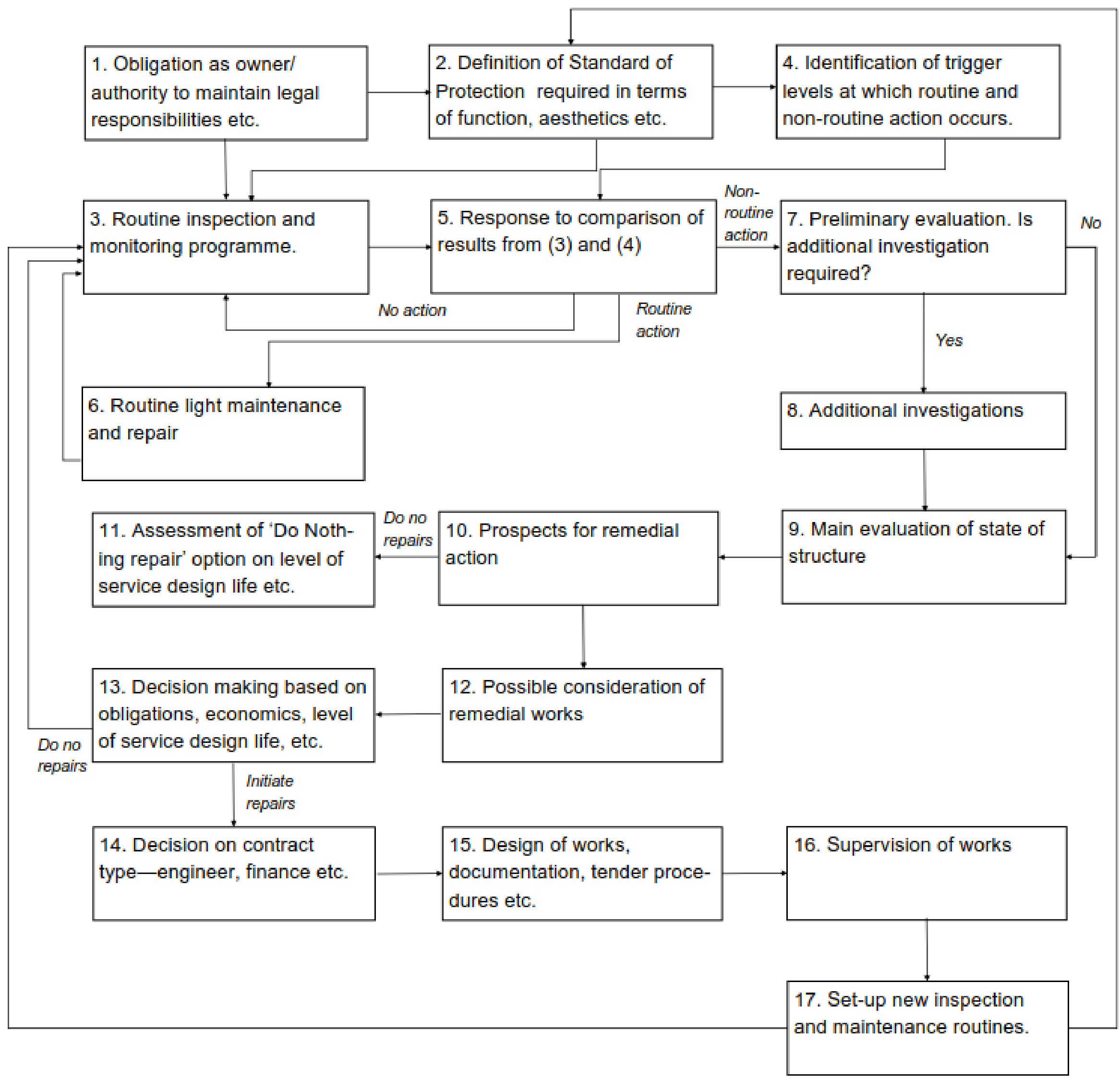
Maintenance of coastal **interventions** in Jamaica is currently strongly driven by economics (e.g. cost to replace/repair versus cost to maintain), **design life** of the project, consequences of failure and aesthetics (type of coastal typology and where the defence is location). Coastal conditions are often abrasive, corrosive, subject to extremes of natural conditions and forces, as well as attack by marine and terrestrial organisms. These conditions are predicted to become more noticeable and severe in the coming decades. Neglecting maintenance of coastal protection schemes, especially with the onset of climate change, will lead to deterioration of the facility and ultimately its failure to perform its designated tasks.

Around Jamaica, the maintenance of coastal protection projects and facilities can generally be classified into three categories:

- built-in maintenance
- routine maintenance
- event-driven maintenance.

Maintenance is only effective if planned in an appropriate and timely manner. Figure F7 provides a decision tree to help the planning and scheduling of maintenance for coastal protection structures.

Figure F7 Decision tree to help plan and schedule maintenance



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F4.1: Built-in Maintenance

This is a preventative maintenance method adopted during the construction phase of a project. Material selection and protective techniques are important criteria reflecting on both the initial capital outlay and maintenance of a coastal protection project. Built-in maintenance methods are generally employed on projects where the **design life** of the project is of significant duration and the costs can be justified.

These systems usually require some form of ongoing monitoring and routine maintenance. However, the routine maintenance is considerably less than that of a similar project without built-in maintenance. This type of maintenance can be effective for Jamaica to help address **climate resiliency** of **interventions** and to extend the life of a facility, where the **design life** is controlled by material or structure durability. Therefore, allowing for future modifications in the event of climate changes also comes under this heading, e.g. ensuring foundations and design of a seawall can accommodate height increase. Several other examples of built-in maintenance on coastal projects include the following:

- cathodic protection of steel piles;
- impressed current protection of concrete reinforcement; and
- selection of larger than required grain size for beach replenishment.

Cathodic Protection

Cathodic protection aims to reduce or prevent the corrosion of the metal. It works by setting up a potential difference between a cathode (something introduced by the designer which is often a sacrificial element) and the anode (which becomes the metal structure such as the sheet piles). The cathode corrodes and the potential difference prevents the anode from corrosion.

F4.2: Routine Maintenance

This involves regular monitoring of the completed project and being pro-active in the prevention of deterioration by providing maintenance on a routine basis. Routine maintenance also includes projects such as maintenance dredging, mechanical beach cleaning and storm water trash rack cleaning. Routine monitoring or inspection has been discussed in Part F1 and F2 and the results from this monitoring should feed into the routine maintenance plan. Having a sufficient database is critical to this and also this can be effectively be used to monitor climate change impacts on coastal protection measures and the surrounding environment.

Routine maintenance should be planned into the owner's budgets and should be considered when choosing an appropriate **intervention** (see Part C1) as certain **interventions** have much costlier maintenance requirements and therefore can alter the economic assessment of the option.

Table F4 presents the likely routine maintenance required for the **interventions** assessed in Parts D2 and D3. High level suggestions of costs are presented to enable a high level assessment at the option development stage of a project and to provide comparison between options.

Table F4 Description of routine maintenance requirements for each intervention presented in Part D2 and D3. Note that event driven maintenance (see F3.3) will likely be needed on top of the below.

Intervention	Maintenance requirements	Cost and frequency indication	Year in which it would need replacing if maintenance is carried out (Design Life)
D2.1 Natural Beach Protection	Natural beach protection should require minimal maintenance except that associated with any **hybrid** approach provided existing sediment supply is maintained / conditions do not change. If additional sediment was required, this would refer to D2.2 and if sediment needed to be re-distributed this would refer to D2.3.		N/A
D2.2 Beach Nourishment / Recharge	Recharge with additional material to replace material lost through erosion and sediment transport. Recharge of material needs to be in line with the material that was originally used as part of the design and to the design slope and crest heights that were defined in the design.	20% of capital cost every 10 years in addition to mobilisation and demobilisation costs.	N/A
D2.3 Beach Recycling	Sediment recycling involves re-distributing sediment where it has built up in one area to where it has been eroded in another. The frequency of this should be defined in the **Beach Management Plan** through the assessment of **beach profiles** and monitoring of the beach and sediment.	Mobilisation and demobilisation of plant used to recycle material.	N/A
D2.4 Beach Vegetation Planting	Weeding and removal of any invasive species. Depending on species planted, some may need cutting back or trimming more regularly. Beach vegetation can often also trap rubbish, either left by beach users or brought in by the tide. Regular maintenance to tidy the beach is therefore likely.	Cost depends on who owns the structure and will undertake the weeding.	N/A
D2.5 Coral Reef Restoration	Reattachment of detached coral. Removal of loose fouling materials (e.g. fishing nets, garbage, loose seaweed fronds). Removal of coral predators and fouling organisms which might overgrow the plants e.g. sponges.	Regular maintenance can be undertaken at the same time as monitoring. It is recommended this is completed 3 times a year for the year following	N/A

		construction and then 2 times a year for years 2 to 5 following construction	
D2.6 Mangrove Restoration	Removal of loose fouling materials (e.g. fishing nets, garbage, loose seaweed fronds).	Regular maintenance can be undertaken at the same time as monitoring. It is recommended this is completed 3 times a year for the year following construction and then 2 times a year for years 2 to 5 following construction	N/A
D2.7 Seagrass Restoration	Reattachment of detached seagrass. Removal of loose fouling materials (e.g. fishing nets, garbage, loose seaweed fronds). Removal of predators and fouling organisms which might overgrow the plants e.g. sponges.	Regular maintenance can be undertaken at the same time as monitoring. It is recommended this is completed 3 times a year for the year following construction and then 2 times a year for years 2 to 5 following construction	N/A
D3.1 Breakwater	Replace missing rock armour and reposition rock that has been moved out of place to maintain 3 contact points.	10% of capital cost every 10-20 years.	50-100 years.
D3.2 Revetments: rock	Replace missing rock armour and reposition rock that has been moved out of place to maintain 3 contact points.	10% of capital cost every 10-20 years.	50-100 years.
D3.2 Revetments: concrete	Patch and repair of concrete which is damaged, cracked or chipped.	1% of capital costs every 2 years.	100-120 years.
D3.3 Seawalls	Patch and repair of concrete which is damaged, cracked or chipped.	1% of capital costs every 2 years.	100-120 years.
D3.4 Groynes - rock	Replace missing rock armour and reposition rock that has been moved out of place to maintain 3 contact points.	10% of capital cost every 10-20 years.	50-100 years.

D3.4 Groynes - timber	Replace missing timber planks and any posts/piles that have come loose/worn.	10% of capital cost every 5 years.	10-25 years.
D3.5 Land Reclamation	Needs to be considered on specific project by project basis. In general land reclamations will have edge protection provided as part of a **hybrid intervention**. Depending on nature of reclamation, settlement may need to be considered.	Needs to be considered on specific project by project basis	N/A
D3.6 Gabions	Replacement of stones which have been lost or fixing broken wires.	10% of capital costs every 3 years.	20 years.
D3.7 Flood Barriers	Running costs of closing barriers or putting into place if they are demountable. Costs of replacing the sealant.	Running costs – vary depending on owner of structure. 5% of capital costs every 5 years for sealant.	25-50 years.
D3.8 Levees	Re-surfacing and patching holes where damage has occurred (through storms or also often through animals burying or human use of the embankment).	5% of capital cost every 5 years.	100-150 years.
D3.9 Sand Bag Structures	Replace any which have come loose or where the geotextile bag has split.	25% of capital cost every 5 years.	10-20 years.

F4.3: Event-driven Maintenance

> The Mines and Geology Division (Ministry of Transport and Mining) often undertake post-storm data collection surveys which could aid maintenance decisions post-event.

This involves maintenance or repair following storm events. For example, replacement of dislodged rocks from a breakwater following a storm or, in some instances, repeat replenishment of an islands beach after a major monsoonal storm has passed. This action is undertaken in addition to routine maintenance to ensure that repair of any damage or necessary maintenance is carried out immediately, rather than to address the maintenance or repair at the next programmed routine inspection. Unforeseen maintenance may occur where inappropriate planning, design or construction methods have been employed or when unforeseen events occur. For example a concrete mix may be incorrectly specified during the design process or the curing process may be inadequately controlled resulting in cracking and exposure of reinforcement to chloride attack. Unforeseen maintenance can be avoided when due care is exercised. The future adoption of the materials standard should reduce these risks if it is adhered to effectively in Jamaica.

Appendices

Contents

Appendix A: References

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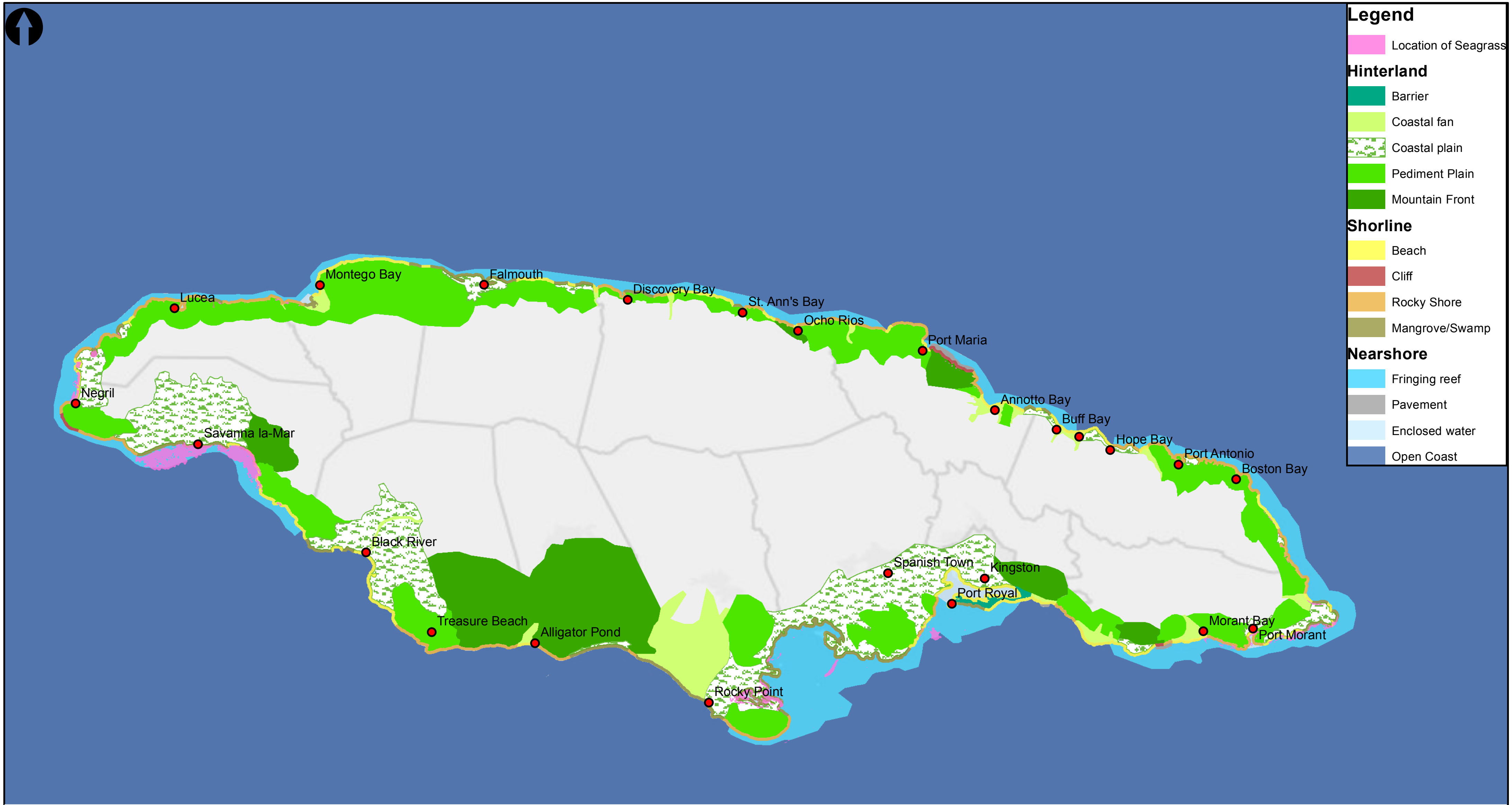
Appendix B: Jamaica Typologies



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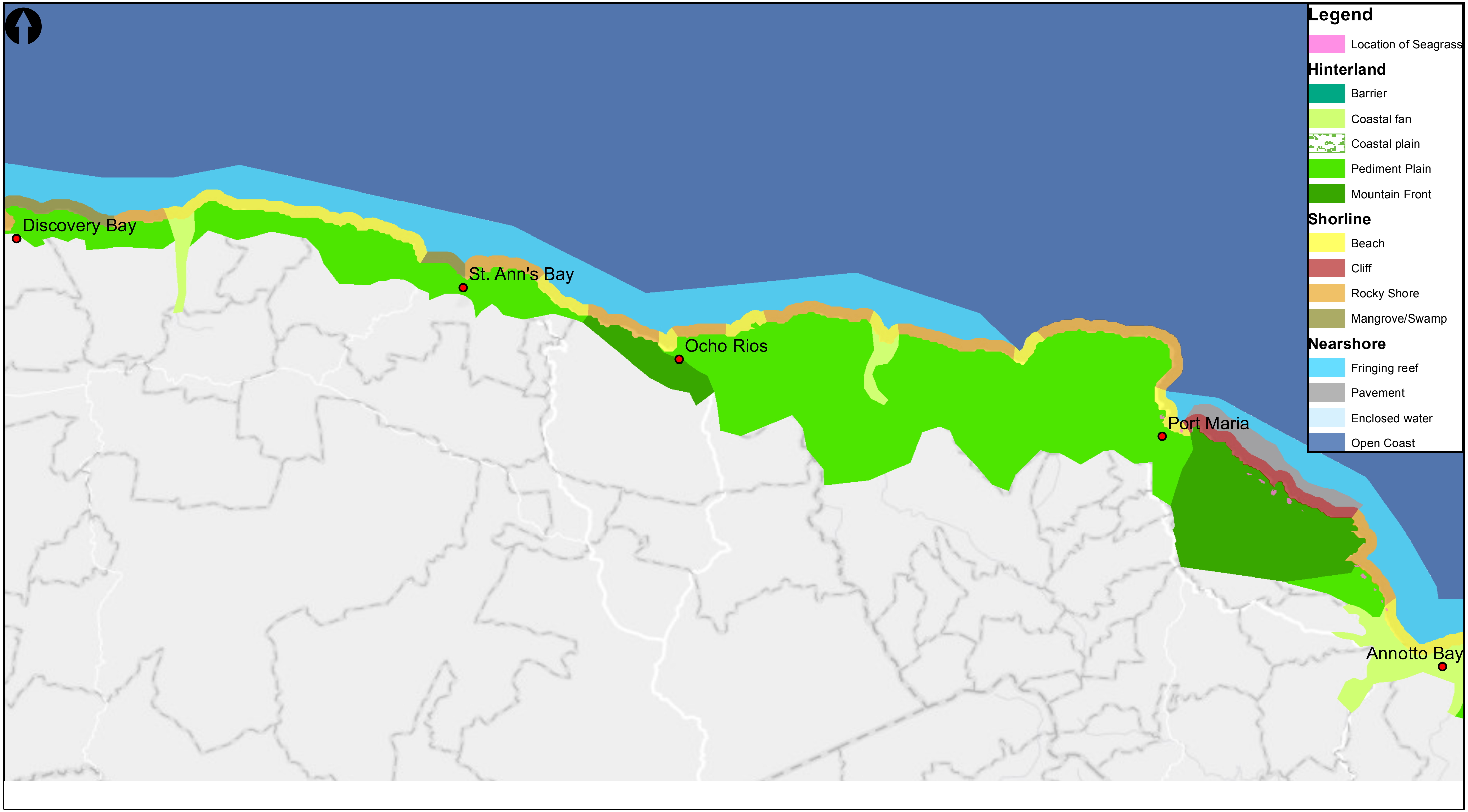
Title

Map of Jamaica
Jamaica Coastal Zones

Drawn	SC
Checked	BR
Approved	PP
Scale at A4	1:1,000,000

Drawing No.
MMD-373744-PCO-GIS-01-0001-A

Status	Rev
INF	02



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Title
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Approved	PP
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Drawing No. MMD-373744-PCO-GIS-01-0002-A
Status INF
Rev 02

MMD-373744-PCO-GIS-01-0002-9-A Jamaica Coastal Zone_A4_Rev2 Apr 04, 2017 - 11:12AM pic54635

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Title

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Drawing No.
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Status	Rev
INF	02

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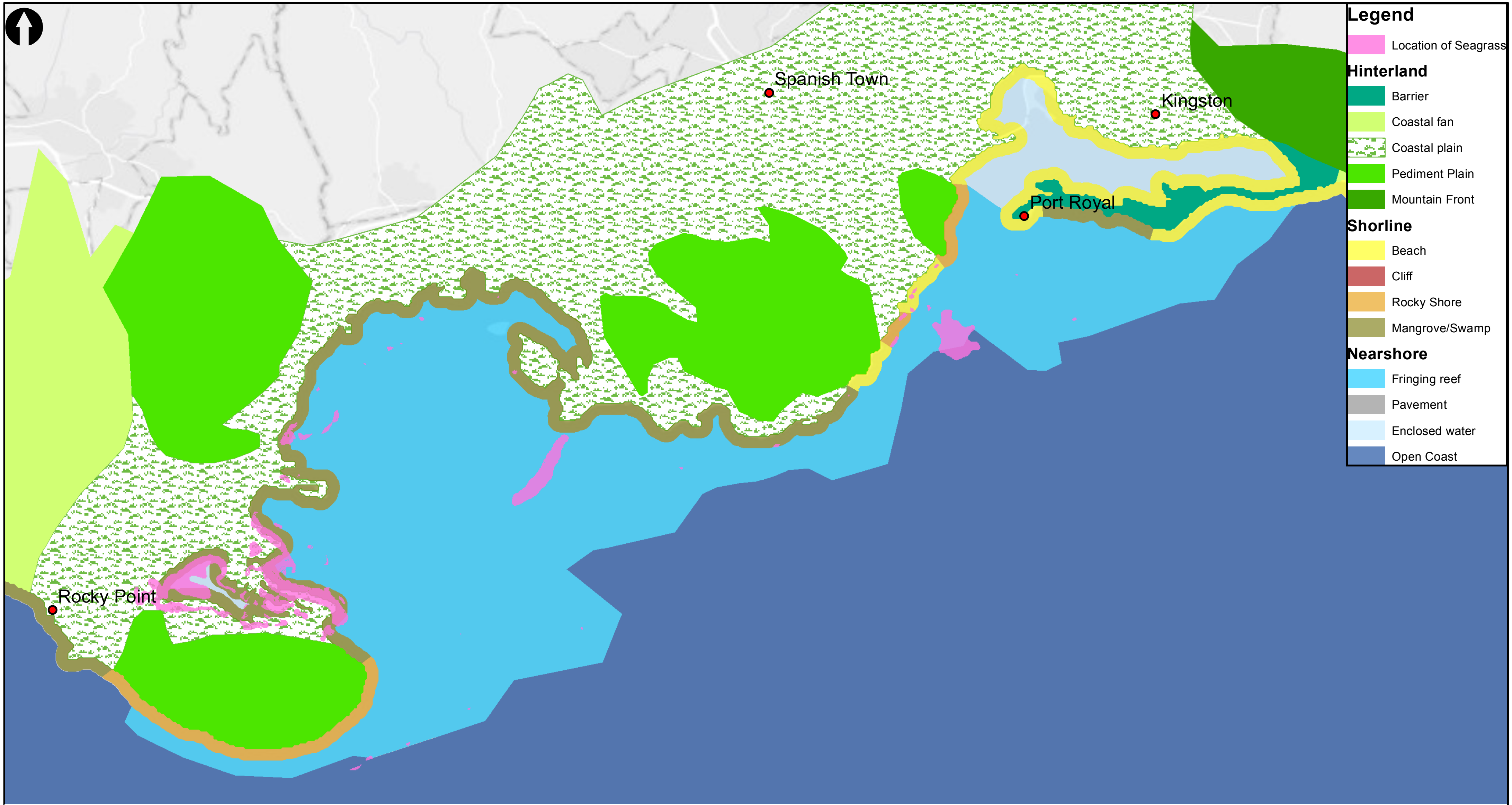

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Jamaica Coastal Zones: South

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Status	Rev
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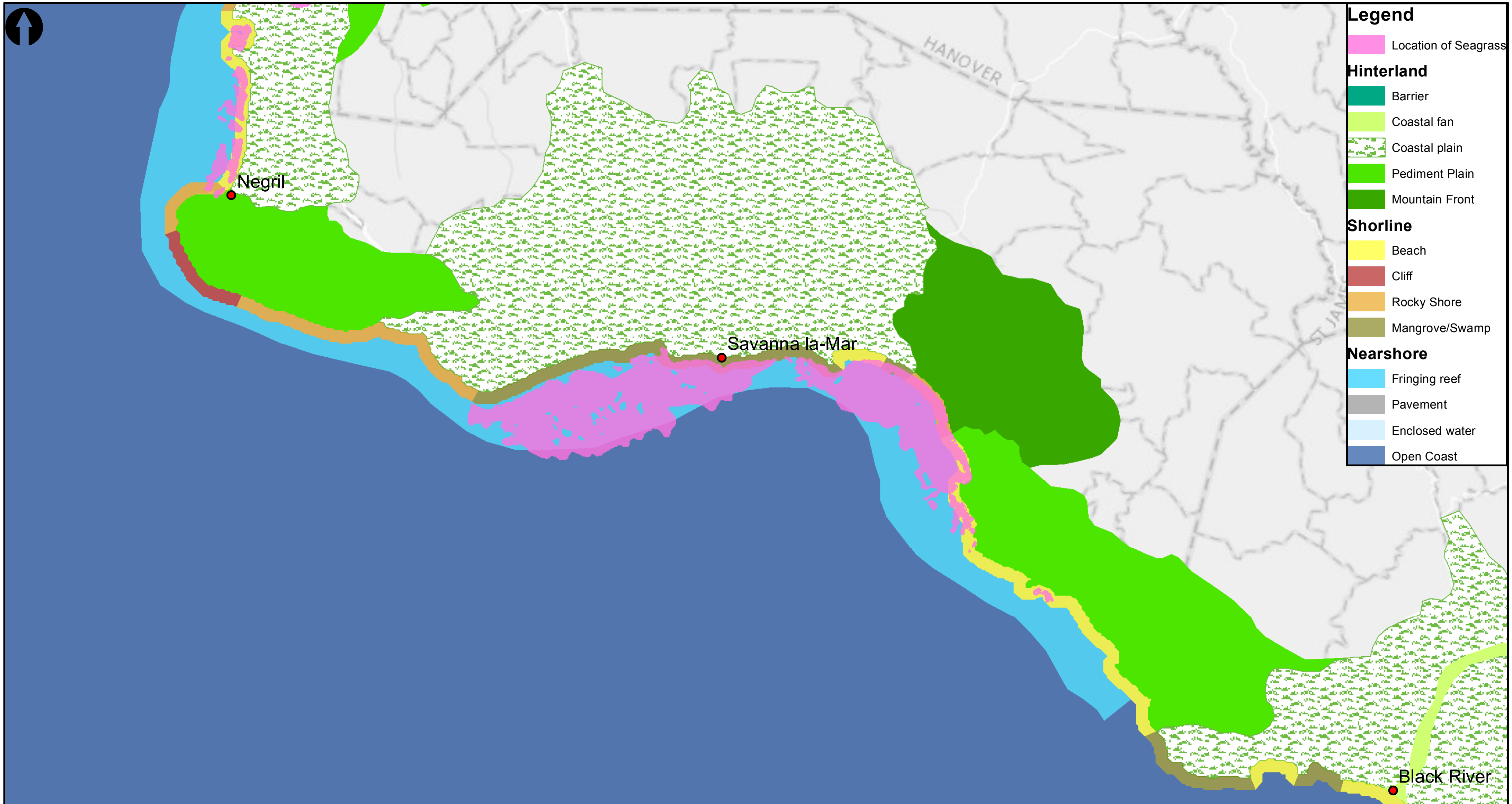

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Status	Rev
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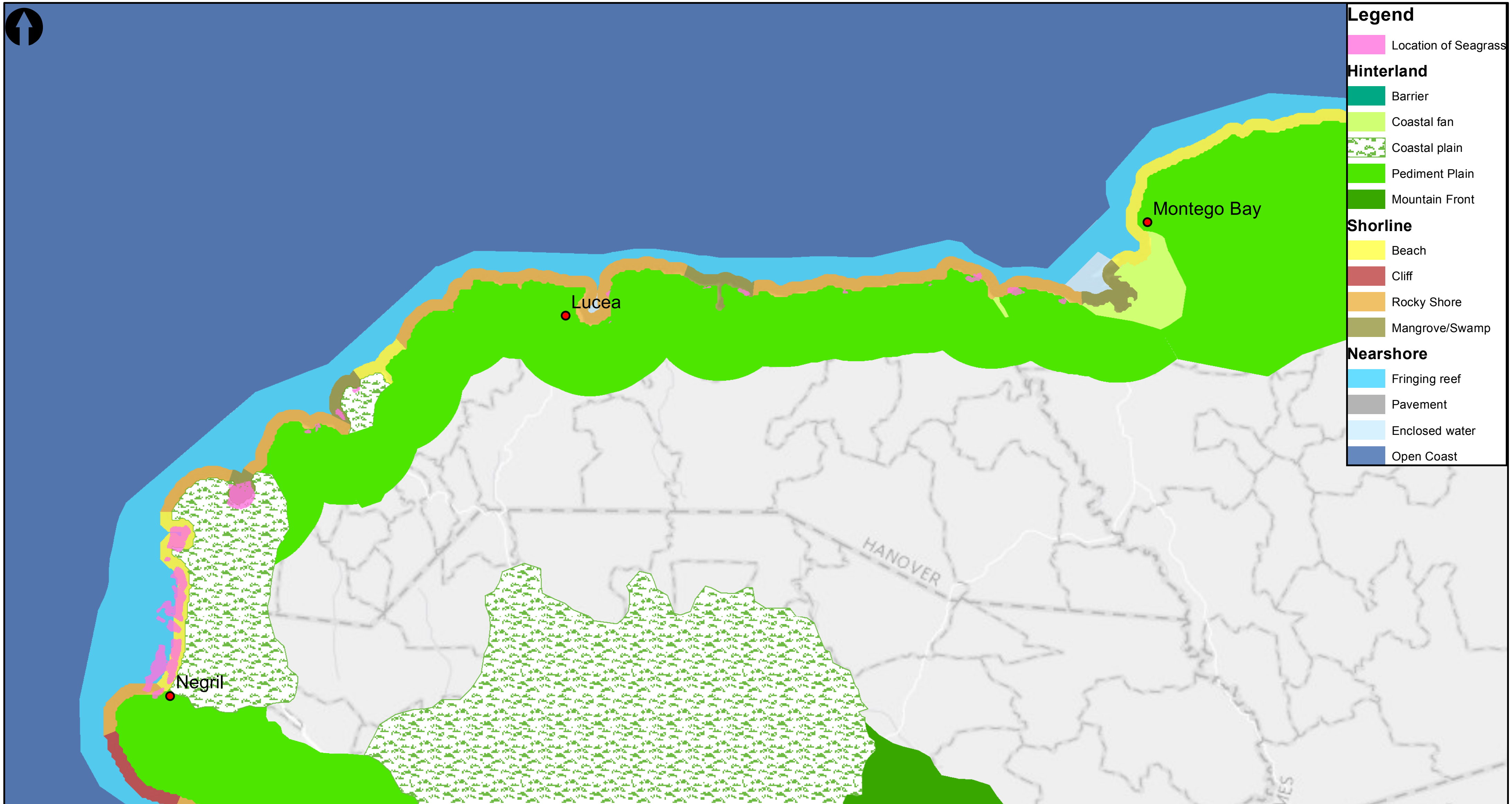

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Map of Jamaica
Jamaica Coastal Zones: West

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Status: INF

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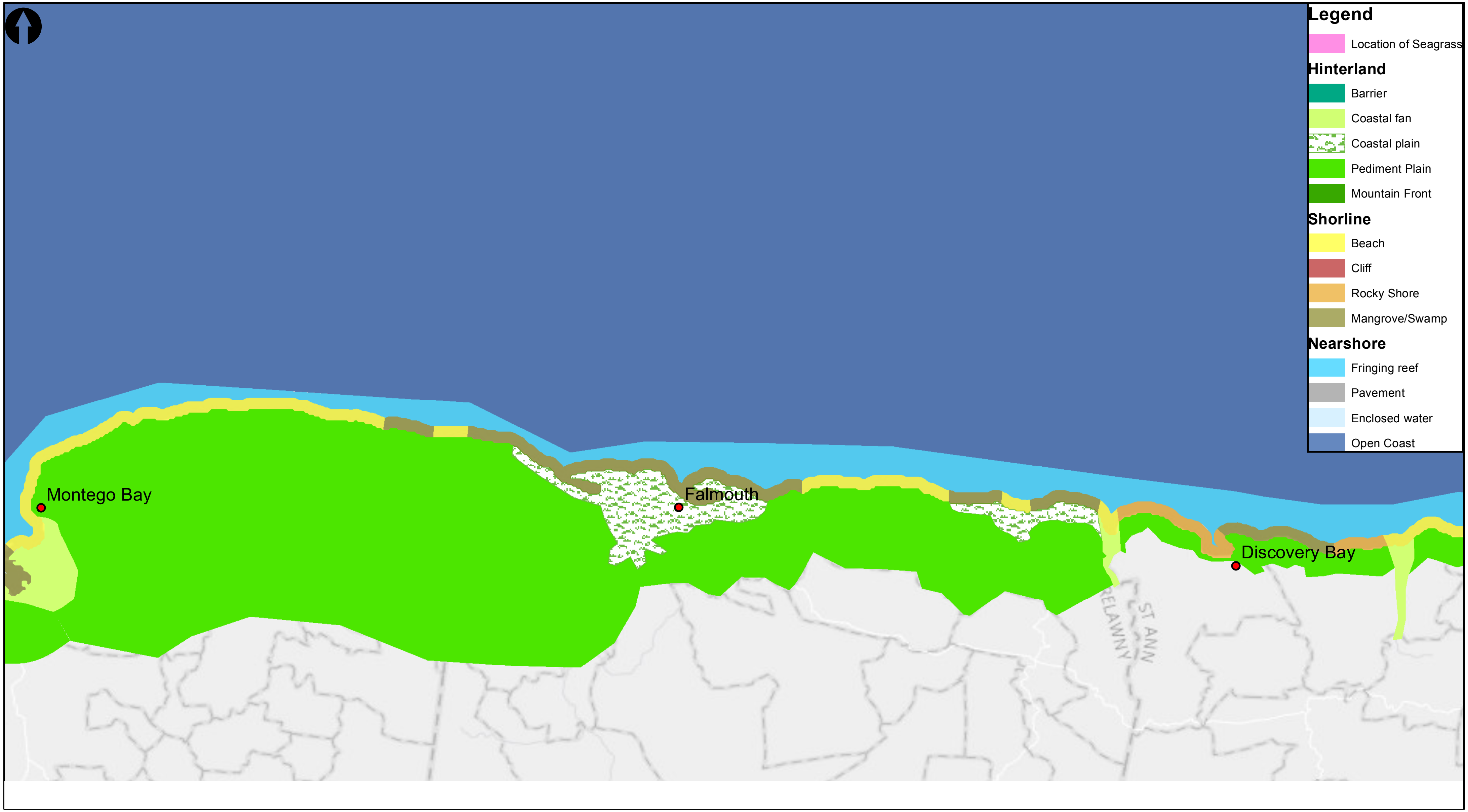

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Title

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Appendix C: Multi-Criteria Analysis

The Multi-Criteria Analysis (MCA) method of evaluating options has the potential to capture a wide range of impacts that may not be readily valued in monetary terms, especially those relating to social and environmental issues within the context of risk-resilient coastal management. MCA aims to establish preferences between options by reference to a clear set of specified objectives and associated criteria for assessing the extent to which these objectives have been (or could be) achieved by various options. Two of the key advantages of MCA are that it can allow stakeholder involvement and provide transparency to the decisions being made at all levels of appraisal.

The justification for policies, guidance and regulations to control coastal development in any defined boundary or "zone" should consider categories that envelope the R2R area. The set of impact categories and definitions included in the MCA-based method should be defined on a project specific basis and will like to the key aims and project outcomes see Part C). An example of categories which should general be considered are presented below in Table 1. These categories are given a semi-quantitative 'score' assessment by Key Experts, the Project Team and/or other Stakeholders. The different categories are assessed and impacts described in a qualitative manner, which is then attributed a number for a scale between low and high for comparative purposes. This scoring is considered appropriate for the MCA as it provides a relative scoring of the options against each other i.e. whether one option is more favourable over another.

This process is undertaken for the different potential interventions being considered. The total score is a combination of the scores for each criteria; however weighting can be applied to some criteria to reflect their relative importance. For example, the highest weighting could be applied to the 'overall effectiveness' criterion, as this is the key aim of the investment and where the majority of the benefits and justification for the investment will be derived from. If there are multiple options which provide effective coastal protection then the options which have lower scores for opportunities and lower scores for environmental, social and technical risks will be favoured.

Table 1 Example of Criteria which can be used to undertake a Multi-Criteria Analysis

Category	Description of impact	Scoring
Technical Risk		**Total score between 0 (no risk) and 12 (high risk)**
Coastal Processes	Existing coastal processes such as waves and currents, hydrological flow, sediment transport and accretion/erosion rates.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Cost	Economic resources.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Buildability	Obstacles that could cause error, delays and cost overruns during Project development and construction.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Sustainability	Overarching impact on interconnecting ecology, economics, politics and culture.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Environmental Risk		**Total score between 0 (no risk) and 12 (high risk)**
Habitats/Wildlife	Important habitats and wildlife within the area of the development as well as along adjacent shorelines	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Fisheries	Fishing grounds and natural mooring areas used by fishermen (coastal or wetland)	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Water Quality	Water quality from surface water run-off, sewage outfalls and industrial discharges	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Visual Appearance	Views of existing natural environment, interruption of views along the shoreline and loss of 'window to the water' views	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Social Risk		**Total score between 0 (no risk) and 9 (high risk)**
Public Safety	Public access and egress along the coastline	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Recreation	Recreation and amenity values.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Cultural Heritage	Sites of cultural heritage interest, historic landscapes and riverine or coastal community livelihoods.	No Risk = 0, Low Risk = 1, Medium Risk = 2, High Risk = 3
Opportunities		**Total score between 0 (highest opportunities) and 12 (no opportunities)**
Economic Opportunities	Opportunities to bring economic growth – through tourism or enhancing industry	Highest opportunities = 0, No opportunities = 4
Environmental Opportunities	Opportunities to increase biodiversity through increasing ecology/habitat diversity	Highest opportunities = 0, No opportunities = 4
Social Opportunities	Opportunities to increase access/ social mobilisation etc.	Highest opportunities = 0, No opportunities = 4
Overall effectiveness as a coastal protection intervention		**Completely effective = 0, Not effective = 5**

Appendix D: Ecosystem Services Assessment Proforma

Table 2 Example proforma which can be used to assess at a strategic level potential impacts on ecosystem services

Type of Ecosystem Service (ES)	**Is this ES present in the project area?**	**Is the project activity likely to have an impact on the ES?**	**Are the benefits of this ES likely to extend on a local, regional, national, or global scale?**	**Is the project likely to have a significant impact on any beneficiaries of the ES?**	**Does the client have direct management control or significant influence on the ES?**	**Does the project depend on this ES?**	**Based on the answers to the previous questions is this a priority ES?**	**Can the impacts be avoided?**	**Can the impacts be reduced through mitigation ?**	**Can alternative compensation be undertaken to mitigate the impacts?**	**Will there be a residual impact?**
Provisioning Services											
Crops	Yes	Potentially	Local	Potentially	No	No	Yes	Yes			
Fodder	Yes	Potentially	Local	Potentially	No	No	Yes	No	No	Yes	
Capture fisheries	Yes	Yes	Regional	Potentially	No	Yes	Yes	No	No	No	Yes
Aquaculture	Potentially	Potentially	Local	Potentially	No	No	Yes	Yes			
Wild foods	No						No				
Timber	Potentially	Potentially	Local	Potentially	Potentially	No	Yes	No	Yes		
Energy (woodfuel / biomass)	No						No				
Biochemicals/ medicine	No						No				
Freshwater (supply)	No						No				
Fibre	No						No				
Genetic resources	No						No				
Regulating Services											
Local climate regulation	No						No				
Global climate regulation	No						No				
Flood protection	Yes	Yes	Regional	Yes	Yes	Yes	Yes	No	Yes		
Air quality regulation	No						No				
Erosion regulation	Yes	Yes	Local	Yes	Yes	Yes	Yes	Yes			
Soil quality regulation	Yes	Potentially	Local	Potentially	Yes	No	Yes	Yes			
Water quality regulation	Yes	Yes	Regional	Potentially	Yes	No	Yes	Yes			

Type of Ecosystem Service (ES)	Is this ES present in the project area?	Is the project activity likely to have an impact on the ES?	Are the benefits of this ES likely to extend on a local, regional, national, or global scale?	Is the project likely to have a significant impact on any beneficiaries of the ES?	Does the client have direct management control or significant influence on the ES?	Does the project depend on this ES?	Based on the answers to the previous questions is this a priority ES?	Can the impacts be avoided?	Can the impacts be reduced through mitigation?	Can alternative compensation be undertaken to mitigate the impacts?	Will there be a residual impact?
Pollination	No						No				
Disease and pest control	No						No				
Noise regulation	No						No				
Cultural Services											
Tourism & recreation values	Yes	Potentially	Local	Yes	Potentially	Yes	Yes	No	Yes		
Wild species diversity	Potentially	Potentially	Local	Yes	Yes	No	Yes	No	Yes		
Cultural & spiritual values	Potentially	No	Local	Potentially	Potentially	No	No				
Scientific & knowledge values	No						No				

Appendix E: Mangrove Restoration: Methods

Mangrove restoration has been used successfully in many countries worldwide and several publications provide useful reviews (McLoad and Salm, 2006; Kaly and Jones, 1998). In projects specifically designed for restoration, techniques include reintroductions of seeds (propagules) or small trees. Seeds or propagules may either be directly placed in the area to be restored, or cultured to a larger size before out planting. It has often been reported that growing mangroves to a young tree stage leads to greater success by allowing plants to become less vulnerable. In Guyana, extensive areas of the East coast have been restored using red mangrove saplings gown in pots and bags by coastal communities.

Figure 1 Red mangroves, *Rhizophora mangle*

Red mangroves are easily distinguishable from other mangrove species because of their unique prop roots (see Figure 1) which offer support, protection and ability to survive in oxygen poor environments. The prop roots develop into a thick "mangle" which is very effective at absorbing and dissipating wave energy, protecting the shoreline from erosion and stabilizing sediments.

The roots also provide important habitat for an extensive community of animals, such as juvenile fish, oysters, crabs and sponges. Certain species of fish known as mangrove obligates - such as the Rainbow parrotfish (*Scarus guacamaia*) the largest parrotfish and largest marine herbivorous fish in the Atlantic - require red mangrove habitat during the early stages of their life cycle.

The **Riley Encased Methodology (REM)** was developed for the purpose of establishing mangroves along high-energy shorelines where natural recruitment no longer occurs and where conventional planting methods are ineffective. The REM method is based on protecting individual seedlings and allowing them to gradually adapt to their high-energy environment.

The REM recommends using PVC pipes (bamboo tubes have also been tested and have been found not to be as effective) (Salgado, 1999). The thin walled PVC pipes must be cut lengthwise so as to make a longitudinal split. This split allows an exchange of water with the surrounding environment, and permits the water level inside the PVC to rise and fall in accordance to tidal fluctuations. Over time, as the tree thickens, the split widens and eventually the tube break offs as the tree gains independence from the encasement.

The PVC pipes are pushed into the sediment and filled with decaying seagrass and sediment (mangrove peat) to just below average water level. Germinated, floating red mangrove propagules are collected and then placed in the pipes with some extra moss or decaying seagrass. Decaying seagrass provides nutrients as well as a substrate.

Figure 2 The Riley Encased Methodology (REM) for mangrove planting showing (a) red mangrove seedling planted in PVC tube and (b) red mangrove sapling growing roots out of the encasement (REM) Source: Owen Day.

By planting individual propagules within tubular encasements at the selected site (see Figure 2), an artificial environment is created favourable to early plant development. Plants are protected from seaweed, flotsam, wind, wave activity, and unintentional damage from human interaction. The early stage of development rapidly produces an extensive root system anchoring the seedling inside the encasement. This anchoring is so strong that after the first three months, the seedling will actually break if an attempt is made to pull it from the encasement.

As the plant grows and expands to fill the inside of the encasement, typically a single root will begin to venture through the longitudinal split. The proliferating root system ensures stability of the tree and provides essential nutrients for accelerated growth inside this isolated environment. Roots first emerge from the encasement, as shown in Figure 2 above. Over time, the split will continue to enlarge and the root system will extend beyond the confines of the protective PVC tube. It is this progressive widening of the longitudinal split that facilitates the gradual adaptation of the mangrove sapling to the high-energy environment.

Survival rates of red mangrove seedlings using the REM method have been reported from Belize and Florida to be in excess of 80% (personal communication). After planting, management is minimal and consists mostly of checking the seedlings and replacing any damaged or dead ones. Some reports from Florida suggest that November planting was preferable to August planting (Salgado Kent, 1999).

Further information on the use of mangroves for shoreline protection and fisheries enhancement can be obtained from two recent report from Spalding *et al.*, (2014) and Hutchinson *et al.* (2014) respectively. There are alternative approaches when restoring mangroves in high-energy coastal areas, such as using small semi-spherical concrete modules like Reefballs (Figure 3). Alternatively a natural breakwater can be used to protect the out planted seedlings made of wooden poles from Palmetto wood (*Sabal palmetto*), as used in Placencia in Belize (Figure 3).

Figure 3 Alternative approaches to restoring mangroves in high-energy coastal areas include (a) combining with Reef Balls and (b) using a breakwater made from small wooden poles of palmetto wood (Sabal palmetto) as seen here in Placencia Source: Owen Day

Appendix F: Stakeholder Engagement Plan Template

1.0 Introduction

1.1 Background to the Project

Background to the site area – preferably including map to show extent and to identify key features. Description of the aim of project and why it is being undertaken. What are the required outcomes of the project?

1.2 Purpose of this Plan

This engagement plan outlines how we will work with others to develop the *[insert project here]*. It aims to ensure that people inside and outside our organisation understand how we will:

"*Include key stakeholder aim"*

This plan sets out how the project team will spend our time and resources wisely, talking to the right people about the right things, at the right time.

1.3 Structure of this Plan

An outline of the structure is provided below:

- Section 2: Why work with others
- Section 3: Who should we work with?
- Section 4: How do we work with others?
- Section 5: Stakeholder Engagement Tracker

2.0 Why Work With Others?

Working with others will help us to develop a [insert outcome] that reflects the aspirations and needs of the local community as well as meeting the technical objectives of the project. Therefore we engage to:

Include a list of why you are looking to engage the community. This may include some of the following but is not necessarily limited to this: gather local knowledge that will lead to better decisions; increase mutual trust; enable as many people as possible to influence and own the outcomes; encourage problems to be jointly owned and solved; ensure everybody understands each other's views, concerns and values; make sure everyone has, as far as possible, an input into decisions; reduce miscommunication, misunderstandings and conflict; comply with our legal obligations and; support stakeholder understanding of risks.

2.1 Level of Influence

What others can influence:

Include a list of specific elements of the project that stakeholders will be able to have a say and influence. The aim of this is to be realistic and manage expectations – there will be some elements that they won't be able to have any influence over. Some examples of elements that may be able to be influenced by stakeholders includes: The specific alignment of defences and to some degree the form of the structure; the future land management strategy for the communities; the source and level of funding contributions e.g. contributions from other organisations with products such as physical models; Assess the affordability of flood risk management solutions for the community.

What others can't influence:

It is also important to be clear and manage expectations about what can't be influenced. Some examples of these include: Whether a scheme can be justified for a funding pot; our legal obligation to compensate for lost habitat within the strategic area; climate change projections and design implications; technical design standards used.

2.2 Pillars of the Government of Jamaica's Communication Responsibility

This section should be developed if the project is being carried out by a Government of Jamaica Institution to link with the Government of Jamaica Communications Policy (GoJ, 2015).

The GoJ's chief communication responsibility to the people of Jamaica is to:

i) provide timely, accurate, clear and complete information about its programmes, services and initiatives;

ii) deliver prompt, courteous, professional and responsive communication services;

iii) ensure GoJ Institutions are visible, appropriately branded, accessible and accountable to the people they serve;

iv) utilize the variety of media, channels and platforms to effectively provide information and reach Jamaicans both at home and in the diaspora;

v) encourage continuous improvement in relations with the media;

vi) safeguard the trust of the Jamaican people in the integrity and impartiality of government;

vii) establish consultation mechanisms with the people on an on-going basis;

viii) use research to identify, evaluate and address the public's information and communication needs and concerns as well as to inform government policy, programmes and services; and

ix) ensure increased collaboration and cooperation among the agencies of government in coherent and effective communication with the public.

3.0 Who Should We Work With?

A stakeholder is any individual, group or organisation that believes they could be affected by, interested in, or could affect or influence the project.

It is important to develop the relationship with the stakeholders and steering group/technical review committee that have already been initially engaged as their knowledge and experience will be vital to ensuring the successful development of the project.

This includes: Insert in here any identified stakeholders who have already been involved in the project.

In addition to the identified stakeholders, the wider community and public will need to be engaged at key points throughout the Project. Therefore, we have classified stakeholders into groups:

It is useful to classify the stakeholders into groups of similar stakeholders – ie those with similar levels of involvement in the project. You should be clear for each group who the stakeholders are, what the aim of engaging them is, whether there are any particular needs of any of the groups, what level of influence each group could have.

By classifying the stakeholders into groups, it will allow the project to focus engagement methods for each group.

4.0 How Do We Work With Others?

The type of engagement required throughout the Project can be classified in three categories:

- Provide – provide information, updates etc. to the persons to keep them updated on progress and thoughts.
- Receive – request information or meetings to receive comments, information, or data from that organisation.
- Collaborate – Develop the activities under this Project alongside and with full collaboration from the stakeholders, getting feedback at regular intervals rather than presenting work when it is completed.

The above may change or be added to depending on the type of Project.

4.1 Type of engagement for each group

Group	Type of Engagement	Key Aims / Objectives

4.2 Engagement methods

Discuss the different methods that will be used to communicate with stakeholders. This may include consideration of use of: Consultation documents; Display panels; Emails; Face to face meetings; Informal engagement with stakeholders; Interpretation boards; Letters; Newsletters; Presentations; Technical reports; Teleconferences; and Workshops and clinics.

4.3 Communication Record

The project team will be keeping a record of all the communication with stakeholders including emails, calls, letters, briefing notes, posters etc. which is regularly updated. This record will be added as an appendix to the final SEP to provide an auditable record of all the communication that the project team have undertaken. An example of a stakeholder engagement tracker is provided below:

Group	Stakeholder	Engaged?	When?	Form of Engagement	Summary of Outcomes	Link to Notes / Information
1	Example	Yes	01/01/17	Inception Meeting	Programme agreed. Will supply x,y,z data.	

4.4 Engagement Phases

The project should be split down into key distinct phases so that the requirement for engagement of stakeholders is specific for each stage of the project. A table should be produced which describes the method of engagement for each group of stakeholders at the different stages of the project, and when the engagement will be undertaken.