GOJ/Adaptation Fund Programme
Building the Resilience of the Agriculture Sector and Coastal Areas
BREAKING THE TIDE, RENEWING THE LAND

# CLIMATE RISK ATLAS

## of Coastal Hazards & Risk in Negril

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Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and improve Food Security Project/Programme

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Final acknowledgement goes to the project team and staff at the ODPEM who worked diligently to deliver the outputs despite the many challenges. A special thanks is being extended to the Ministry of Tourism and Entertainment for their partnership and collaboration throughout this project.

It is hoped that the atlas will serve its intended purpose and that the stakeholders involved in its preparation and moreso the intended users will apply the information for the sustainable development of Negril and the tourism sector.

# About the Atlas

The atlas is based on sound, scientific hazard and vulnerability analysis and mapping of areas adjacent to the Negril coast. It identifies the hazards, elements at risk and projected impacts of the hazards for Negril under specific climate scenarios and return periods. It addresses three major climate threats - sea level rise, coastal erosion and storm surge. **These threats were identified in keeping with the climate risk focus of the atlas.**

The assessment and analyses were prepared using modern technology that facilitated detailed data collection derived from several surveys and GPS mapping. Data was collected and analysed at a scale to make the atlas useful as a guide for development planning at the local level and the processing of development applications. The outputs show the current and projected impact of sea-level rise and storm surge on the natural and built environment of Negril.

## Objectives of the Atlas

It was important that the atlas was prepared with as much detailed information as is available to guarantee the integrity and credibility of the data in its application by intended users "*... to ensure land owners and regulators have the relevant information on projected climate hazards and their effects*." (programme proposal, 2011).

Based on the intended use of the atlas, its main goal is to provide national and local stakeholders with information about existing and potential climate related hazards, vulnerability and risks that are a threat to the Negril community. The atlas is also intended to provide government, non-government and private entities with information that will guide development of policies, plans and strategies that contribute to climate change adaptation and disaster risk reduction. The information in the atlas is useful in the design and implementation of projects as it allows an evaluation of the vulnerability and risks posed by climate change to Negril and forms the basis of evidence-based decision-making about the most effective solutions.

The Atlas is divided into five main sections:

**a** **Section 1 – Background**
This section summarizes the project under which the atlas is being implemented, indicating the objectives, partners and rationale for a climate risk atlasThis section also elaborates climate change and disaster risk reduction locally, looking at national frameworks and mechanisms and institutions through which both are implemented. It contextualizes the climate risk atlas in the disaster risk management framework and examines perspectives on DRR and Climate change from two main platforms internationally, UNISDR and UNFCC.

**b** **Section 2 – Community Profile**

**c** **The community** profile presents background information on the study area, describing its boundary, physiographic, and socio-economic profile. The disaster profile of the study area is also examined.

**d** **Section 3 – Hazard Assessment**
This section summarizes, describes and characterizes the hazards studied for this atlas: storm surge, sea level rise and coastal erosion. It describes and illustrates the hazard footprints and current and future scenarios that factor climate change projection. This section also discusses the findings from pre- and post-mitigation scenarios looking at the effect on coastal erosion from the implementation of breakwater structure as proposed under component 1 of the project. The methodology used for undertaking the hazard component is also summarized in this section

**e** **Section 4 – Vulnerability Assessment**
This section quantifies the exposure of physical assets (buildings, infrastructure), Social assets (Population and critical facilities) and economic assets (loss to GDP) that are located within the hazard footprints. The exposure is illustrated using a series of maps and quantified using tables and charts. It identifies the specific locations and properties that will be impacted by current and future scenarios of the hazards studied. Included in the social analysis is the community perception of risk illustrated through Community Hazard Maps for the five major communities located within the project boundary.

A multi-temporal analysis is contained in this section, This analysis enhances the understanding of the changes that have taken place in Negril over four time periods: 1941, 1968, 1999 and 2014 and analyzes how these changes may have impacted the natural and built environment. Additionally, it shows the progression of vulnerability over the stated time periods.

This section (not included in draft) includes an assessment of physical vulnerability of buildings incorporating the use of vulnerability (stage-damage) curves to estimate the degree of damage to buildings relative to the hazard intensity (water depth). This information is used to quantify and estimate the risk associated with the hazards of focus. The methodology used to derive the risk was done using the formula R = H(storm surge and sea-level rise) X Vulnerability (stage damage curve) X A(Amount). The latter represents the amount in monetary value (replacement cost)

**f** **Section 5 – Community Risk Perception**
**This section highlights the communities perception about the characteristics, location and severity of the risks they face.. Conclusions about the communities risk perceptions are drawn from community hazard maps, and vulnerability and capacity assessment derived through a community participatory approach.**

**g** **Section 6 – Risk Assessment**
Risk analysis based on a semi-quantitative method that estimates the level of expected losses for a certain reference period, using the following equation: **Risk = H * V * A.**

**h** **Section 7 – Conclusion ad Recommendations**
This section states some major conclusions from the study and identifies recommendations to consider based on the findings.

# List of Abbreviations

| Abbreviations | Meanings |
|---|---|
| AR | Assessment Report |
| CSGM | Climate Studies Group Mona |
| ENSO | El Nino Southern Oscillation |
| EPA | Environmental Protected Area |
| GAR | Global Assessment Report |
| GCM | Global Circulation Model |
| GDP | Gross Domestic Product |
| IPCC | Intergovernmental Panel on Climate Change |
| MDG | Millennium Development Goals |
| NOAA | National Oceanic and Atmospheric Administration |
| ODPEM | Office of Disaster Preparedness and Emergency Management |
| OFDA/CRED | Office of Foreign Disaster Assistance/Centre for Research ob the Epidemiology of Disasters |
| PIOJ | Planning Institute of Jamaica |
| PRECIS | Providing Regional Climates for Impact Studies |
| RCM | Regional Climate Models |
| RiVAMP | Risk and Vulnerability Assessment Methodology Development Project |
| SIDS | Small Island Developing States |
| SLR | Sea Level Rise |
| SRES | Special Report on Emission Scenarios |
| TWG | Thematic Working Group |
| UNEP | United Nations Environment Programme |
| UNFCC | United Nations Framework Convention on Climate Change |
| UNISDR | United Nations International Strategy for Disaster Risk Reduction |
| UNWTO | United Nations World Tourism Organization |
| USCS | Unified Soil Classification System |

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# Background

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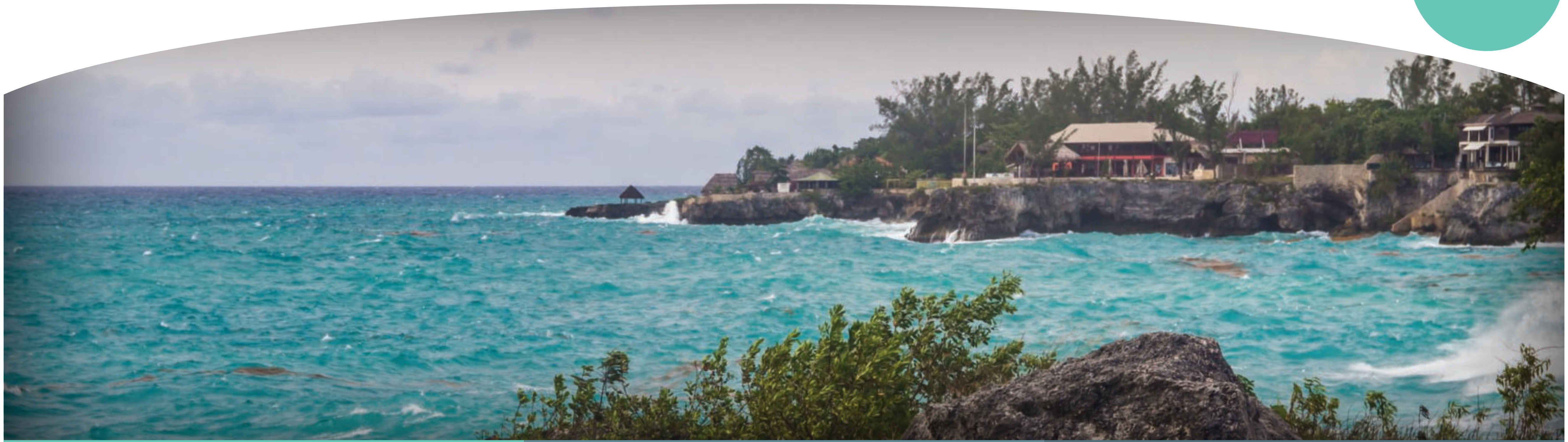


## 1.1 The GOJ/Adaptation Fund Programme

The GOJ/Adaptation Fund Programme, "**Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and improve Food Security Project/Programme** is intended to facilitate the implementation of options that are integral to the climate change adaptation initiatives for Jamaica, particularly as it relates to livelihoods protection and food security.

### Project/Programme Objectives

The primary objective of the programme is "to increase livelihoods security of the population in the targeted communities and to increase the climate resilience of sections of the Negril coastline, which will also contribute to increased security of livelihoods". The programme consists of three (3) components:

*Component 1:* *Increasing the climate resilience of the Negril Coastline*

*Component 2:* *Enhancing climate resilience of the agricultural sector by improving water and land management in select communities.*

**Component 3:** ***Improving institutional and local level capacity for sustainable management of natural resources and disaster risk reduction in the targeted vulnerable areas; raising awareness for behaviour modification***

This Climate Risk Atlas is an output under component 3 of the project and is intended to raise the awareness of the presence from and impact of climate related hazards, specifically storm surge and sea level rise on the Negril Community. The atlas is also critical to improving the capacity of key stakeholders, primarily relating to tourism, agriculture, coastal resources and other commercial activities. The atlas will be used to guide development planning both at the local level, for the processing of development applications and the development of Adaptation Plans and Beach Restoration Guidelines and Standards under the project.

The proposed activities under the programme will help to build Jamaica's adaptive capacity in accordance with the objectives of Vision 2030, Jamaica's National Development Plan and Jamaica's Second National Communication on Climate Change.

### Project Partners

The National Implementing Entity for the project is the Planning Institute of Jamaica. The Climate Risk Atlas was completed by the Office of Disaster Preparedness and Emergency Management (ODPEM), the Executing Partner, in collaboration with the Ministry of Tourism and Entertainment, the Executing Entity.

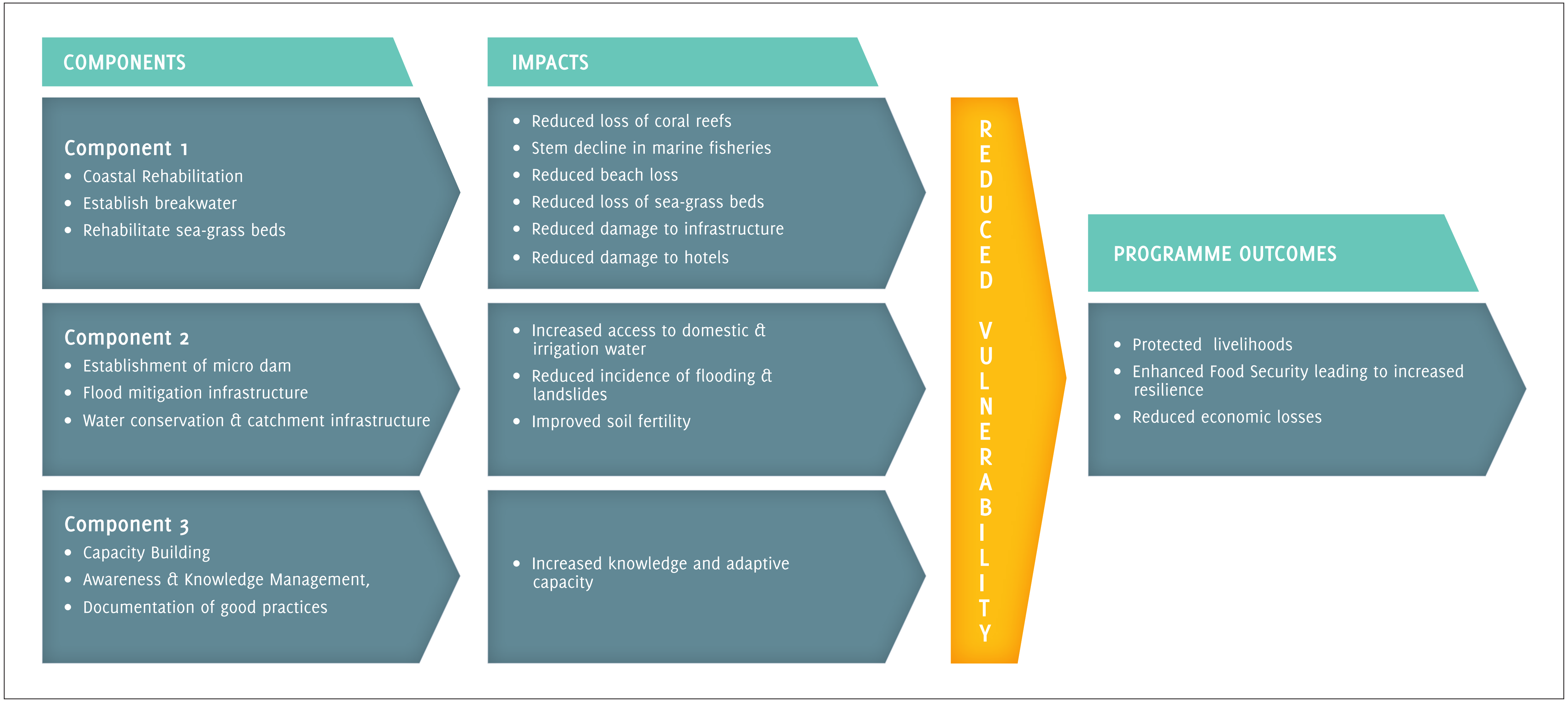



**Figure 1.1 Relationship between Programme Components in Achieving Programme Outcomes**
*(Source: PIOJ, 2011)*

## Justification for A Climate Risk Atlas

Degradation of coastal and marine ecosystems has resulted in the loss of their protective and provisioning functions. Moreover, Negril has consistently been impacted by climate related hazards. Anticipated climatic changes – storm activity, sea level rise and sea surface temperatures will exacerbate existing degradation in Negril (PIOJ, 2011).

Therefore, the necessity for a Climate Risk Atlas for Negril is predicated on the premise that sound analysis, communication and awareness of risks, are key to understanding the underlying risk factors which will in turn impact sound environmental management and risk reduction.

# 1.2 General Background

## The Global Context of Increasing Natural Disasters

The number of natural disasters affecting the world has significantly increased over the past two decades (Figure 1.4). During the decade of the 1990's, the number of catastrophes increased five-fold, with corresponding damages of nine, contrasted to the decade of the 1960's (Munich Re, 1999) (see Figure 1.5). From 2000 to 2006 there were 2860 natural disasters as recorded by the OFDA/CRED International Disaster Database. Recent data by the Global Assessment Report on Disaster Risk Reduction, 2013 reported that *"one trillion dollars have been lost in the last decade due to disasters and one million people killed"* (p.38). The report further indicated that rapid increase in exposure is a major driver of disaster risk today in that developments are situated in areas that are prone to the effects of natural hazards.

Since 1980, there has been approximately 21,700 loss events, 41% of which are classified as meteorological events (Including tropical storms) which generally give rise to storm surges (Figure 1.2). These events have resulted in over 1.7 million fatalities (Figure 1.3), a little less than a quarter of which have been attributed to meteorological events.

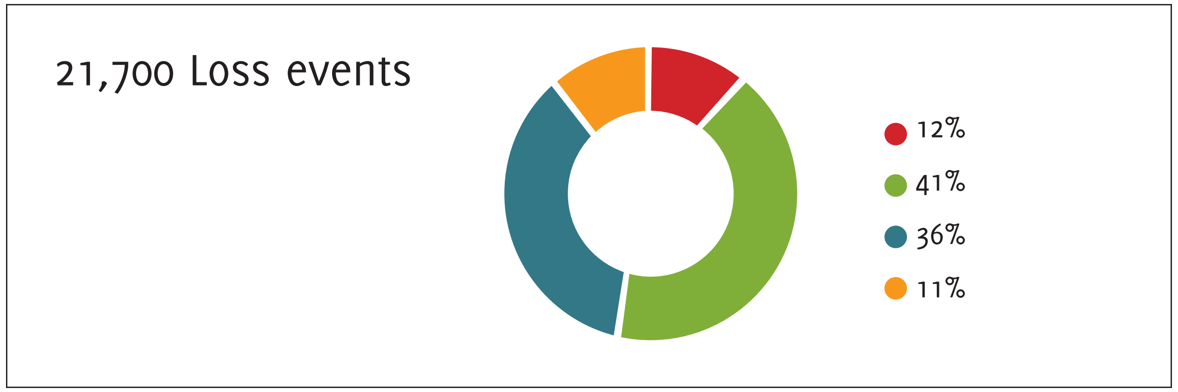



Figure 1.2 Losses associated with meteorological events since 1980

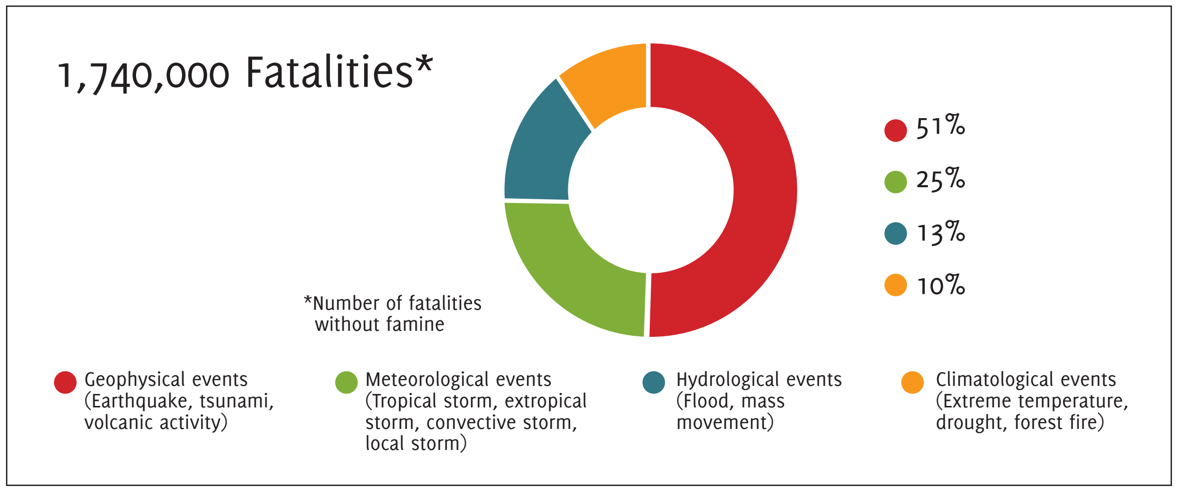



Figure 1.3 Fatalities associated with natural hazards since 1980

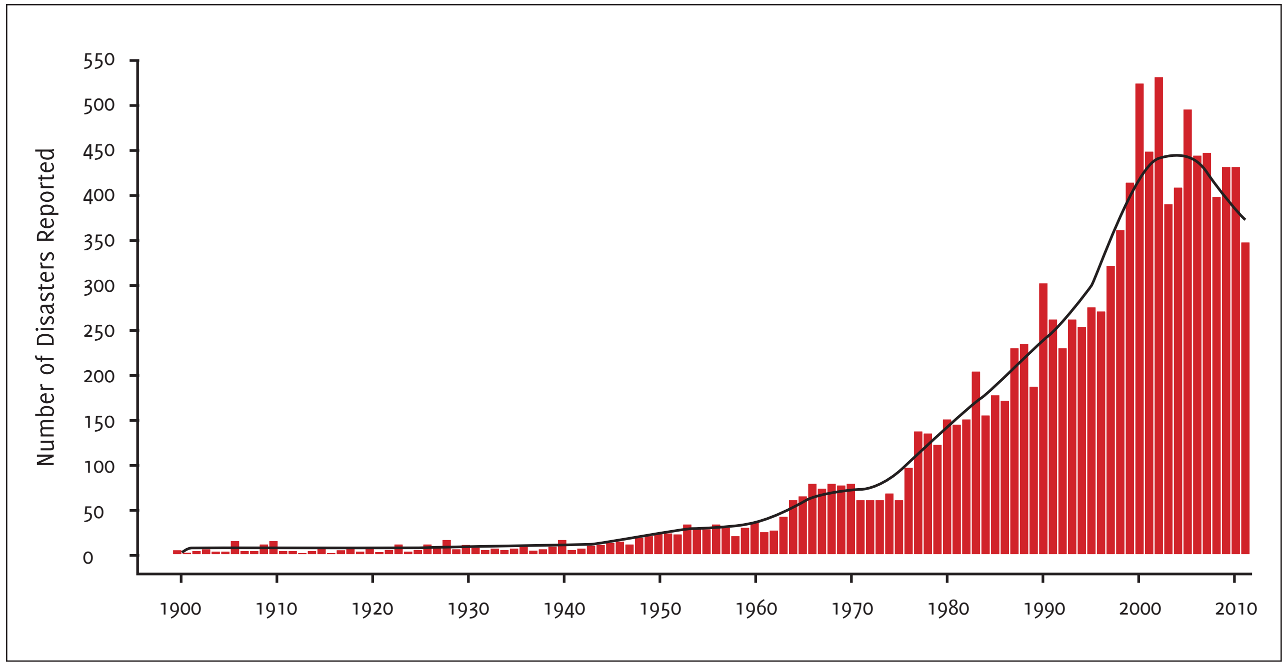



Figure 1.4 Natural disasters reported 1900 - 2010

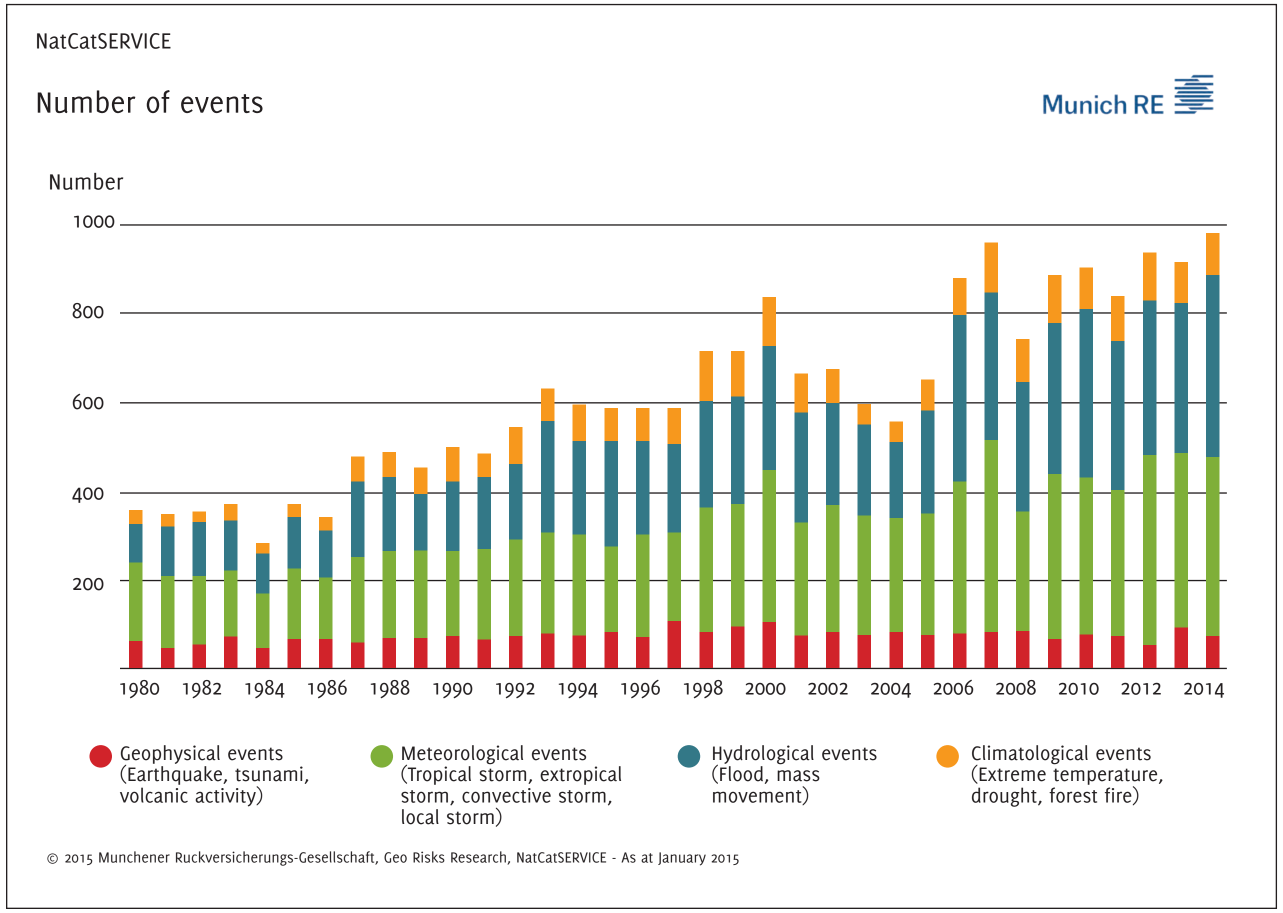
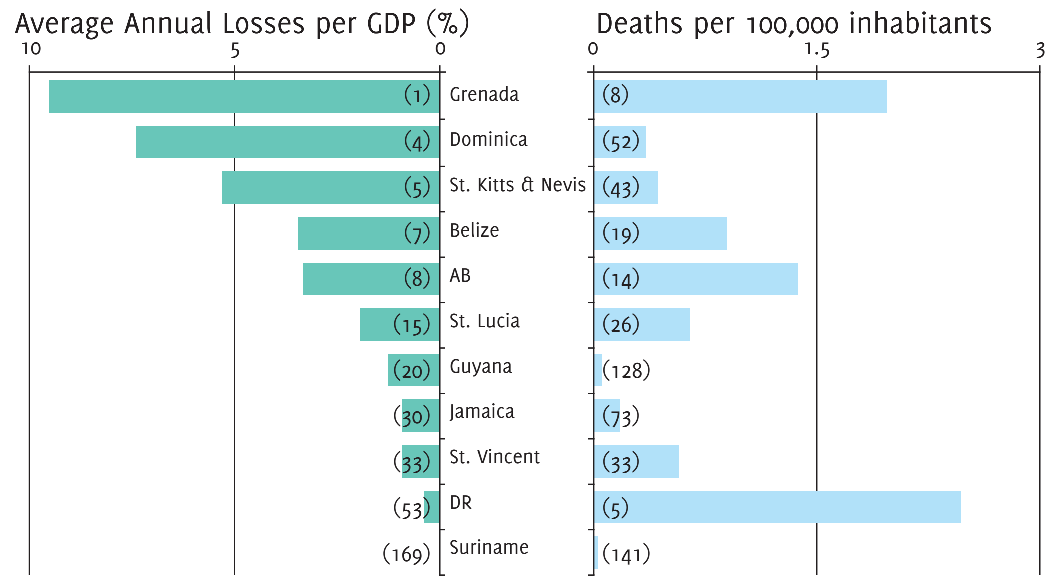



Figure 1.5 Loss events worldwide 1980 - 2014

Regionally, average annual losses due to extreme weather events between 1992 and 2011 show that in some instances, losses account for as much as 9% of GDP.




- () indicates Global Rank of 183 countries or territories evaluated.
- Sorted by Losses per GDP (%)

Source: Harmelingm S. and Eckstein D. "Global Climate Risk Index 2013" . Germanwatch, November 2012. http://germanwatch.org/fr/download/7170.pdf

**Figure 1.6 Local Context of Increasing Natural Disasters**

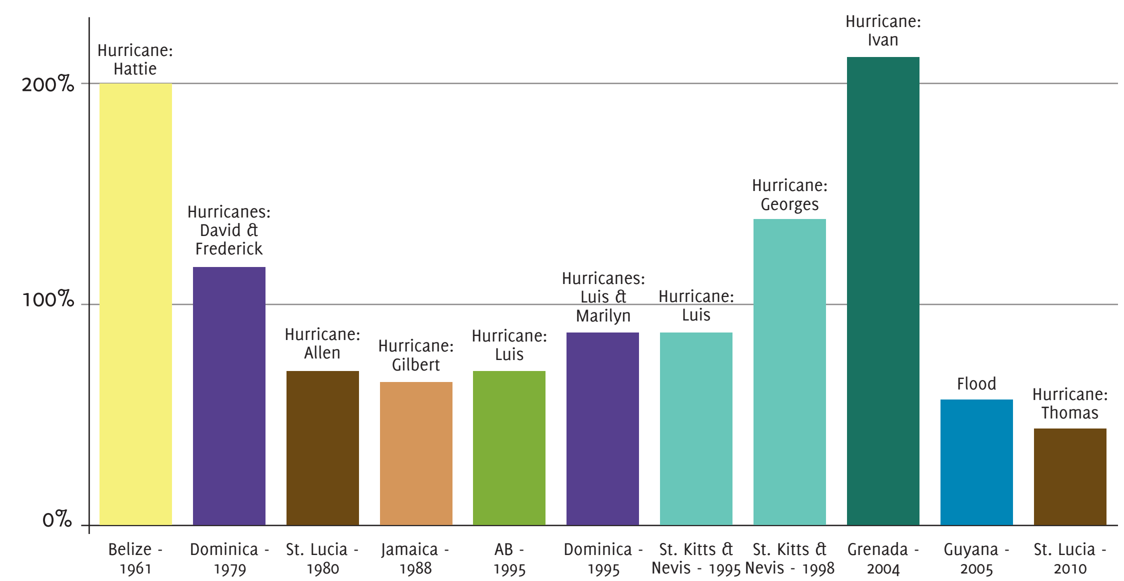



**Figure 1. 7 Select Damages from Disasters as a % of GDP**

For countries such as Grenada, the impact of a single event, Hurricane Ivan in 2004, resulted in losses amounting to as much as over 200% of GDP (Figure 1.7).

The situation for Jamaica is no different. According to the GAR Report, 2013, Small Island Developing States (SIDS) like Jamaica face high levels of disaster risk and have comparatively low economic resilience because a large proportion of SIDS total produced capital are at risk to earthquakes, cyclone wind damage and tsunamis. In addition, given the high exposure of SIDS to weather-related hazards, they are likely to disproportionately suffer from the magnifying effect of climate change. These effects include sea level rise and associated flood and storm surge hazard, increasing cyclonic wind intensity, erosion, saltwater intrusion into coastal aquifers and worsening water scarcity and drought (CCRIF, 2010; Perch-Nielsen, 2009; UNWTO and UNEP, 2008; IPCC, 2012; Simpson et al., 2008). In fact, research by Toba, 2009 revealed that in the Caribbean, changes in annual hurricane frequency and intensity could result in additional annual losses of US$446 million by 2080—incurred mainly from business interruption to the tourism sector.


*Plate 1.1 Popular Negril landmark - Negril Hills Golf Club*

Jamaica's historical spatial development and subsequent land use patterns have also increased the country's exposure and vulnerability to the adverse effects of climate change and sea level rise. From 2002-2012 the country experienced six (6) named storm events, three major hurricanes and several flood events amounting to a total of JMD$118.67 billion in losses (ODPEM, 2013). The most recent event to have caused considerable damage to the island's shores is Hurricane Sandy which struck the island on October 23, 2012 with damages amounting to JMD 9.4 billion [US$ 107.14 million (PIOJ, 2012)].

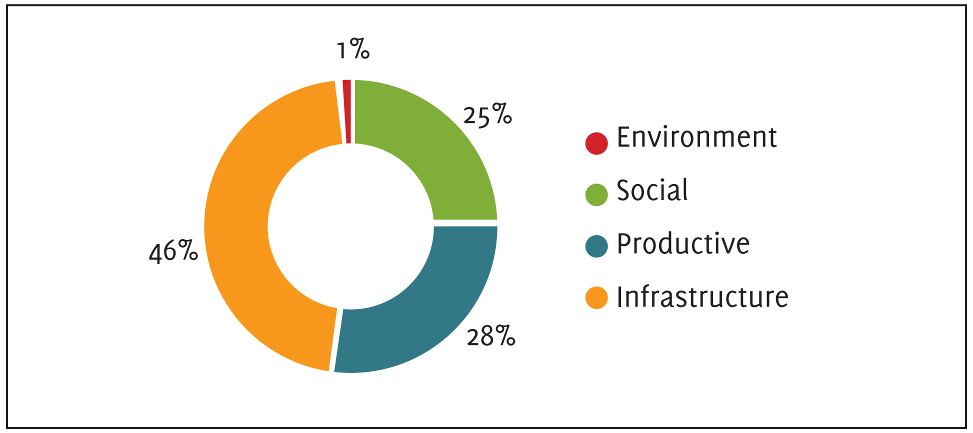



**Figure 1.8 Damage to Sectors from the Impacts of Disasters in Jamaica between 2004 and 2010**

Between 2004 and 2010, losses from seven (7) tropical storm and hurricane systems that affected the island amounted to just over $J106 billion, of which infrastructural damage accounted for just less than half of the losses (see Figure 1.8). The productive sector was responsible for 28% of the losses from these events with the agriculture and tourism sub-sectors accounting for 78% and 9% of the losses respectively (see Figure 1.9).

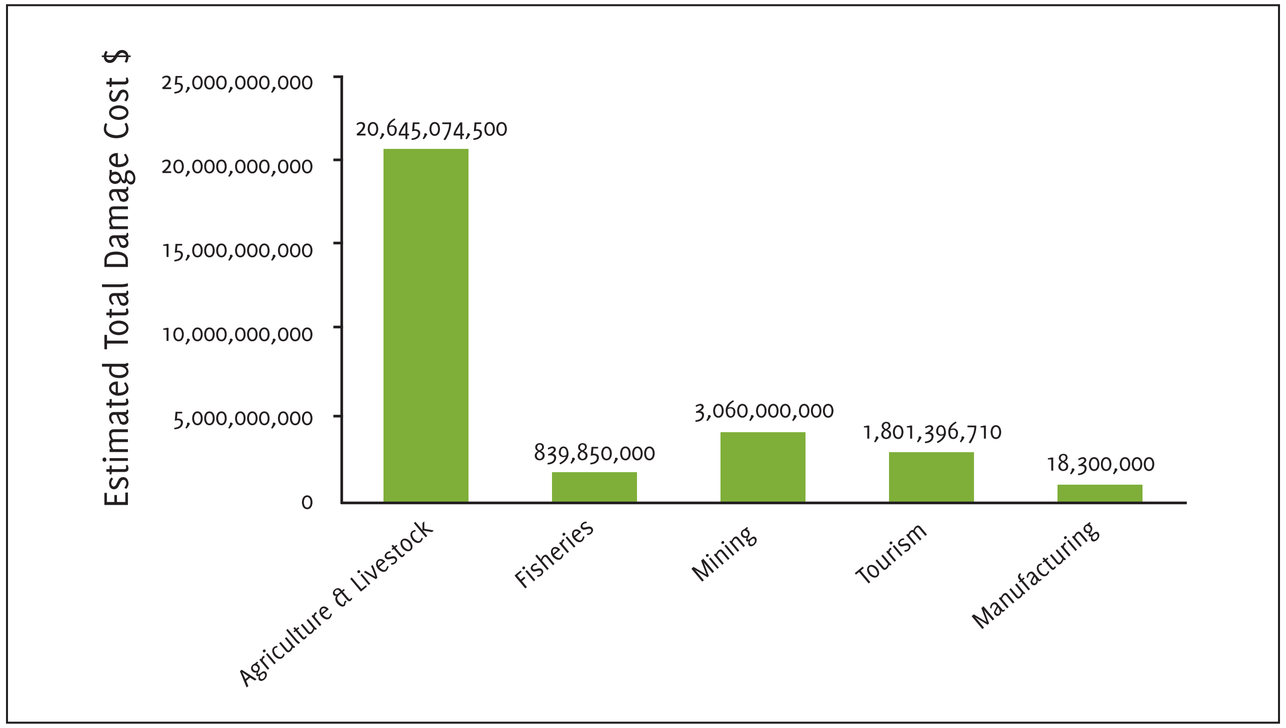
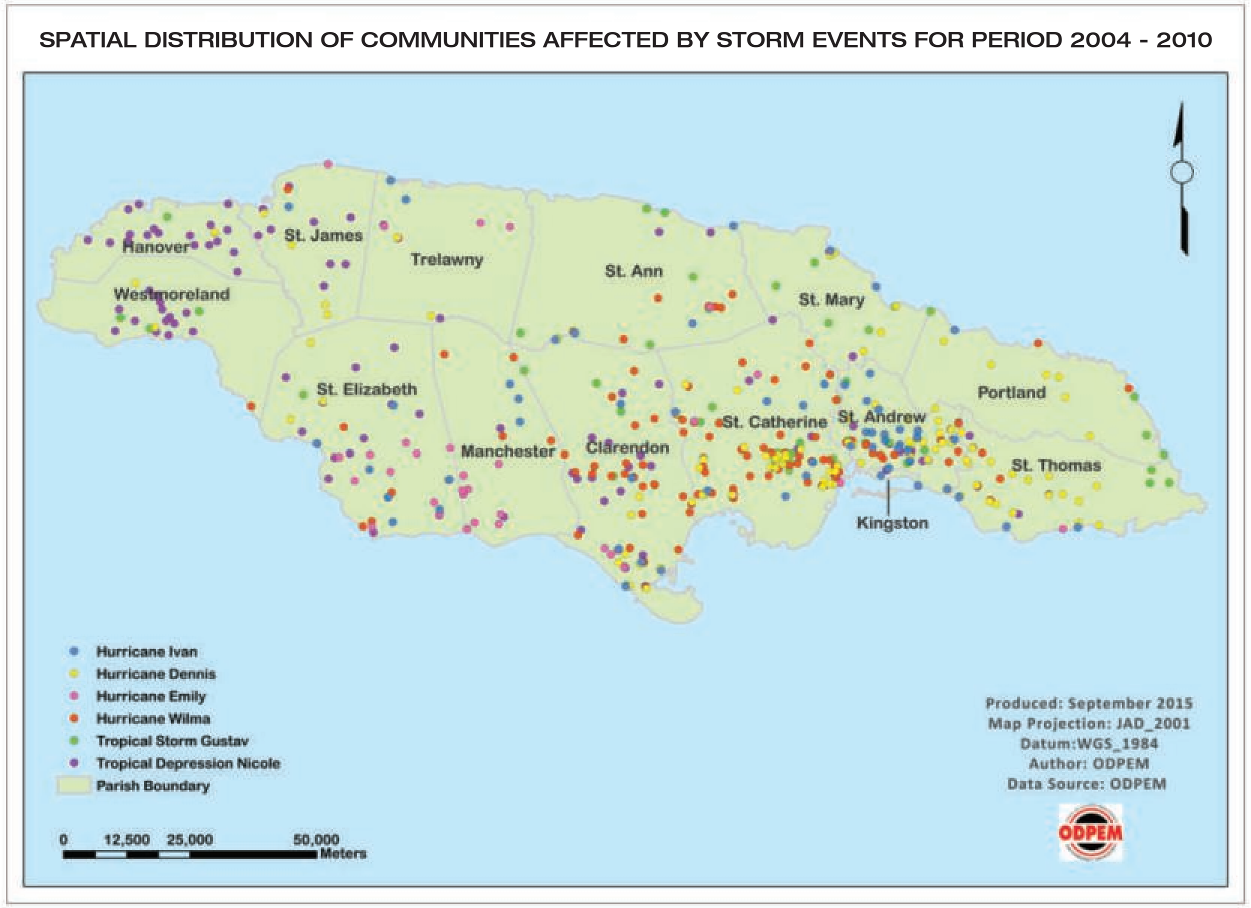



**Figure 1.9 Breakdown of the estimated total damage cost of the Productive Sectors between 2004 and 2010**

*Plate 1.2 Dwelling destroyed in Mount Lebanus during the passage of Hurricane Dennis and Emily, 2005*

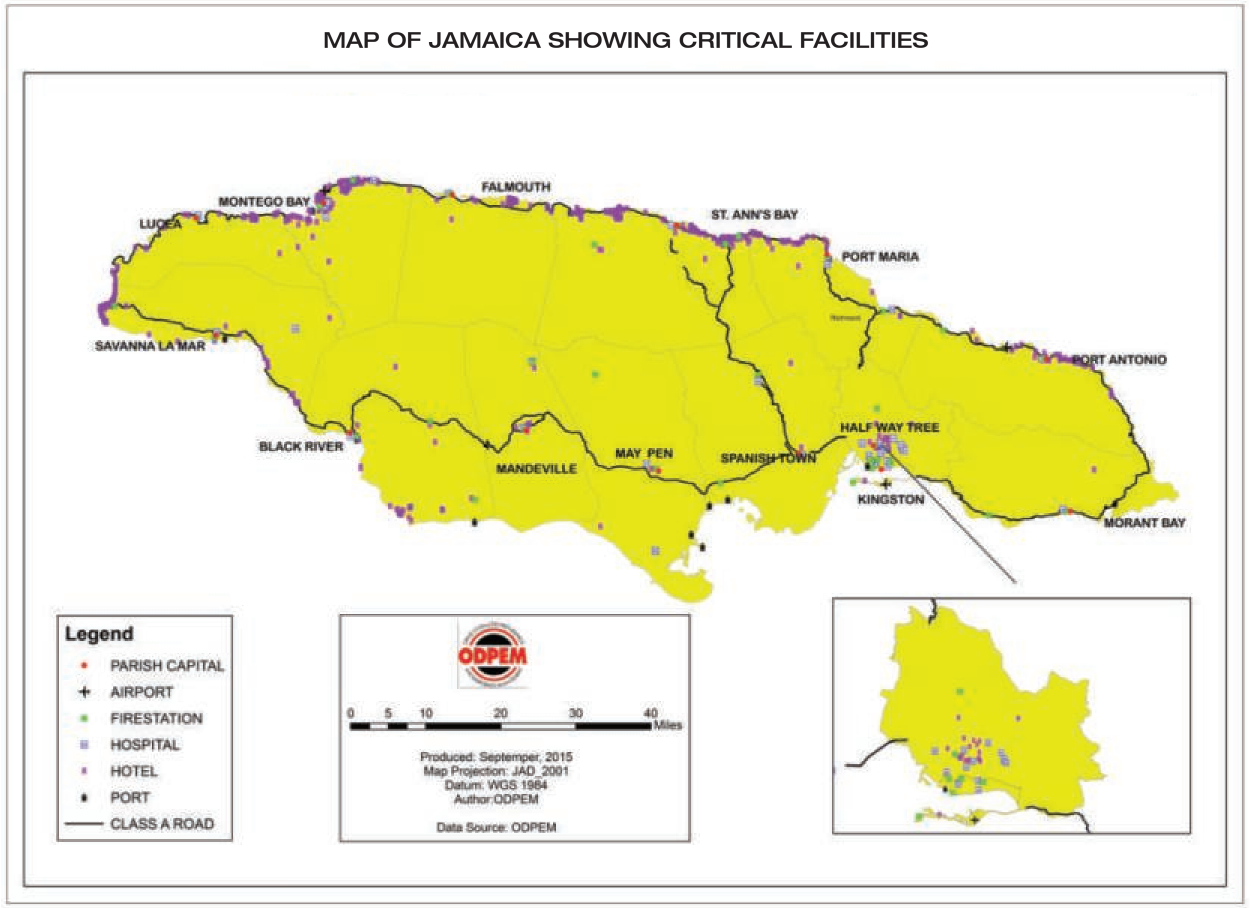
*Plate 1.3 Dwelling destroyed in New Monkland, St. Thomas during the passage hurricane Dennis and Emily 2005*

Historically, Negril has been impacted by several events but has been spared the worst for most of the events based on the general trajectory of recent storms.




Map 1.1: Spatial Distribution of Damage by Natural Hazards between 2004 and 2010

The most recent event to have impacted the area was Tropical Depression 16 which later developed into Tropical Storm Nicole.




Map 1.2 Spatial Distribution of critical facilities in Jamaica

The cost of disasters on the economy has hindered the achievement of key national strategic goals outlined in the Vision 2030 Plan and erased gains made towards achieving Millennium Development Goals (MDGs) as well.

Specific concern has now been given to the impact of climate change on coastal areas in SIDS. This is because, continued coastal development is very likely to exacerbate risk to life and property from sea-level rise and storms and will have detrimental socio-economic effects if it continues unabated. Such situations therefore puts the population, infrastructure and socio-economic livelihood of coastal areas at risk given their current and projected development trends.

One such coastal area is Negril which is located towards the western tip of Jamaica, straddling two parishes - Westmoreland to the south and Hanover to the north (Refer to Map 2.1). Protected under the Natural Resources Conservation Act of 1991, Negril has been declared an Environmental Protection Area (EPA).

Historically, Negril has been impacted by several events but has been spared the worst for most of these events based on the general trajectory of recent storms. Notwitstanding the fact that Negril does not rank among the most frequently impacted areas in the island, recent environmental changes, the fragile nature of the coastal ecosystems and its status as the second largest resort are in the island, boasting a high density of small, medium and large hotels (fig) has increased its vulnerability.

# 1.3 The Disaster Risk Management Framework

Simultaneous with the International Decade for Natural Disaster Risk Reduction, Jamaica, in the latter part of the 1990's and early 2000's, re-evaluated and realized that a comprehensive approach to Disaster risk management is required if losses were to be abated. The disaster cycle gave way to the disaster risk management framework (see Figure 1.10) and this move was necessary to build awareness of the need for disaster risk reduction and promote a culture of integrated thinking that will emphasize risk prevention and mitigation rather than response.

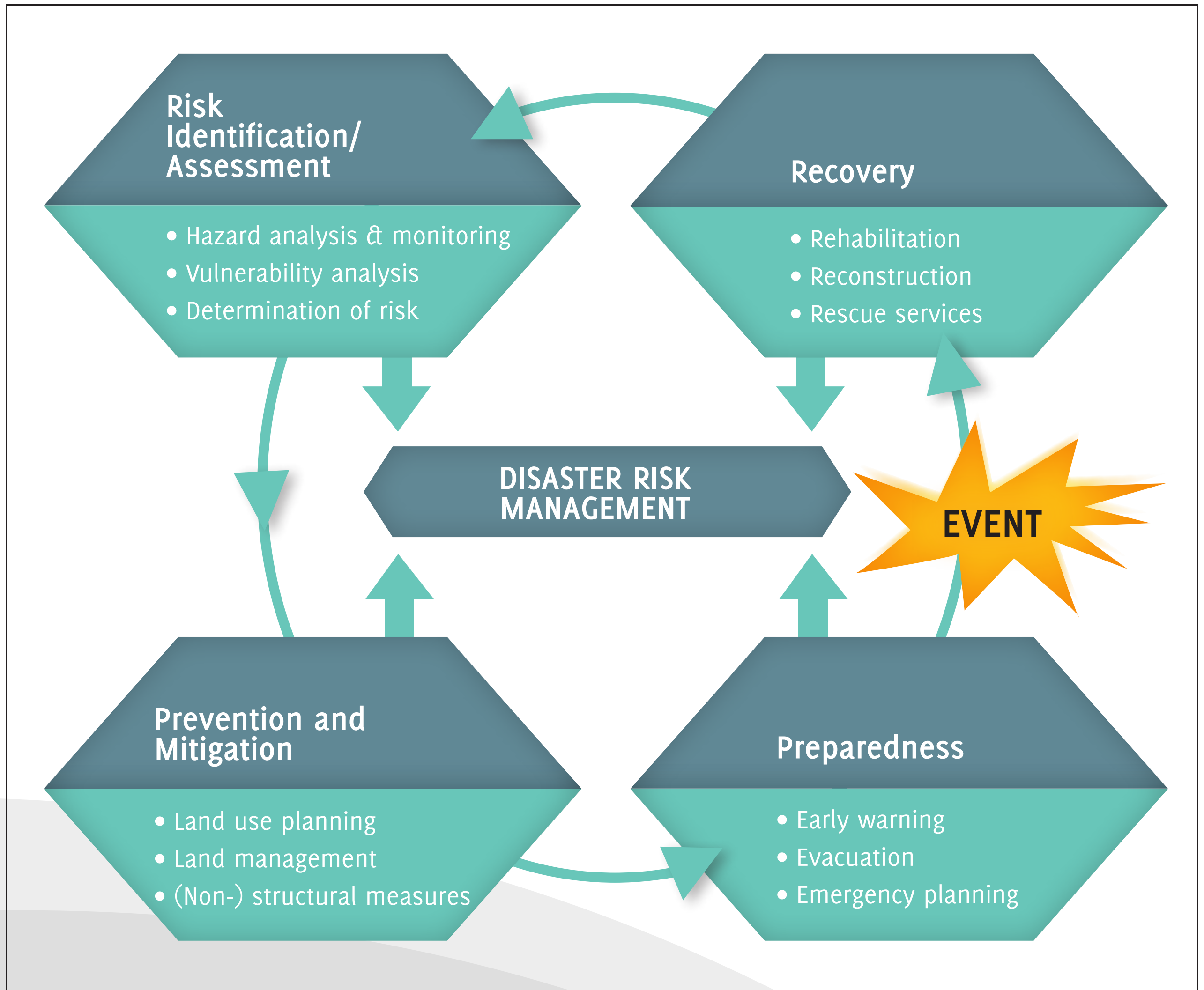



**Figure 1.10: The Disaster Risk Management Framework**

*Source: www.fig.net*

## Risk Identification/ Assessment

*"Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters."*

–Sendai Framework for Disaster Risk Reduction, 2015 - 2030

Understanding Risks is Priority 1 in the Sendai framework for Disaster Risk Reduction 2015-2030. To achieve this, the framework recognizes that the"…use of traditional, indigenous and local knowledge and practices, as appropriate, to complement scientific knowledge in disaster risk assessment…." is important. Therefore, any risk assessment must integrate the community perspective on the risk as well as scientific models to derive and estimate the risks from various hazards.

It is not by chance that this component of the Disaster Risk Management Framework is the first priority as the UNDP believes that *"Understanding the interaction of hazards, exposure and vulnerability is crucial to effective disaster prevention."*

*"The starting point for reducing disaster risk … lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities … and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge."*

–Hyogo Framework for Action, 2005-2015

# 1.4 Disaster Risk Management in Jamaica

The Office of Disaster Preparedness and Emergency Management (ODPEM), is the agency responsible for coordinating and facilitating disaster risk management interventions. The Office was established in July 1980 after the June 1979 floods (see Plate 1.4) which devastated sections of western Jamaica and brought to the fore the need for a permanently established body responsible for disaster management in the country. The responsibility of the office at the time was limited to coordinating and responding to hazards as well as educating the nation on all aspects of disaster management, hence the name at the time, Office of Disaster Preparedness and Emergency Relief Coordination (ODIPERC).

In 1993, the name ODIPERC was changed to Office of Disaster Preparedness and Emergency Management, a statutory body established under section 15 of the Disaster Preparedness and Emergency Act (1993). The functions of the Office were expanded to include preparedness, mitigation, identification and analysis of hazards among other functions.

Since 1993, the high frequency of events, coupled with the progressively increasing disaster losses necessitated a re-evaluation of the Act and how it could be strengthened to help curb the loss of life and property that were being experienced. The Disaster Preparedness Act, 2014 was enacted in May 2015 and the previous 1993 Act repealed. The 2014 Act better represents the current directions in Disaster Risk Management addressing issues such as mandatory evacuation, specially vulnerable areas, financing disaster risk reduction and national alerting which were either never before included or strengthens the authority and/or clarity of previous provisions of the 1993 Act.

## The National Disaster Management Framework

The Disaster Risk Management mechanism in Jamaica functions at three levels; national, parish and community.

At the national level, changes have been made in the new 2014 Disaster Act, for a National Disaster Risk Management Council to replace the National Disaster Committee. Such a Council is chaired by the Prime Minister of Jamaica with other Ministers, Permanent Secretaries, Heads of Agencies, key non-governmental agencies and private sector umbrella organization as members.

The main functions of the Council are to:

a. Review and advise on national strategy for disaster management
b. Review the state of disaster management in Jamaica and report its findings at least annually, (by May of each year) to Cabinet
c. Facilitate effective national coordination or, preparedness for, response to and recovery from any disaster or emergency situation and collaboration of stakeholders in relation thereto.

At the Parish level there is a parish disaster committee with responsibility for managing and giving effect to matters within its local jurisdiction relating to the prevention of, mitigation of, preparation for, response to and recovery from disasters.

Linked to each Parish Disaster Committee are Zonal Committees established to address vulnerability in the parish. These zones are often referred to as communities and their purpose includes public education, liaising with Parish Disaster Committees on matters relating to disaster preparedness and emergency response, nominating persons to be trained in shelter management and preparation of zonal/community plans to be incorporated in the Parish Disaster Risk Management Plan.

*Plate 1.4 Response and Rescue operations after Hurricane Gilbert, 1988 and the 1979 Flood*

## Disaster Risk Management, Climate Change Adaptation and Development

The work of the ODPEM is an integral component of Vision 2030 National Development Plan for the country. Hazard Risk Reduction and Climate Change are captured under Goal 4 of the Plan – Jamaica has a healthy Natural Environment. The vision for this goal is that *"By 2030 we will have increased ability to cope with natural and man-made hazards such as hurricanes, earthquakes, and to reduce the loss of lives and properties when these events occur. We will be equipped to prepare for and respond to the negative impacts of climate change. Jamaicans will be aware of the ways and means each person has to reduce and cope with hazards and risks."*

Two of the main strategies that will be implemented to ensure that this vision is achieved are:

- implement a comprehensive disaster management programme, including strengthening our capability to prepare for and respond to emergencies and
- implement measures to improve how we adapt to climate change impacts.

Thematic Working Groups (TWG) have been established as an important mechanism/tool to support the implementation, monitoring and evaluation of Vision 2030 Jamaica. One such TWG is the Hazard Risk Reduction and Climate Change.

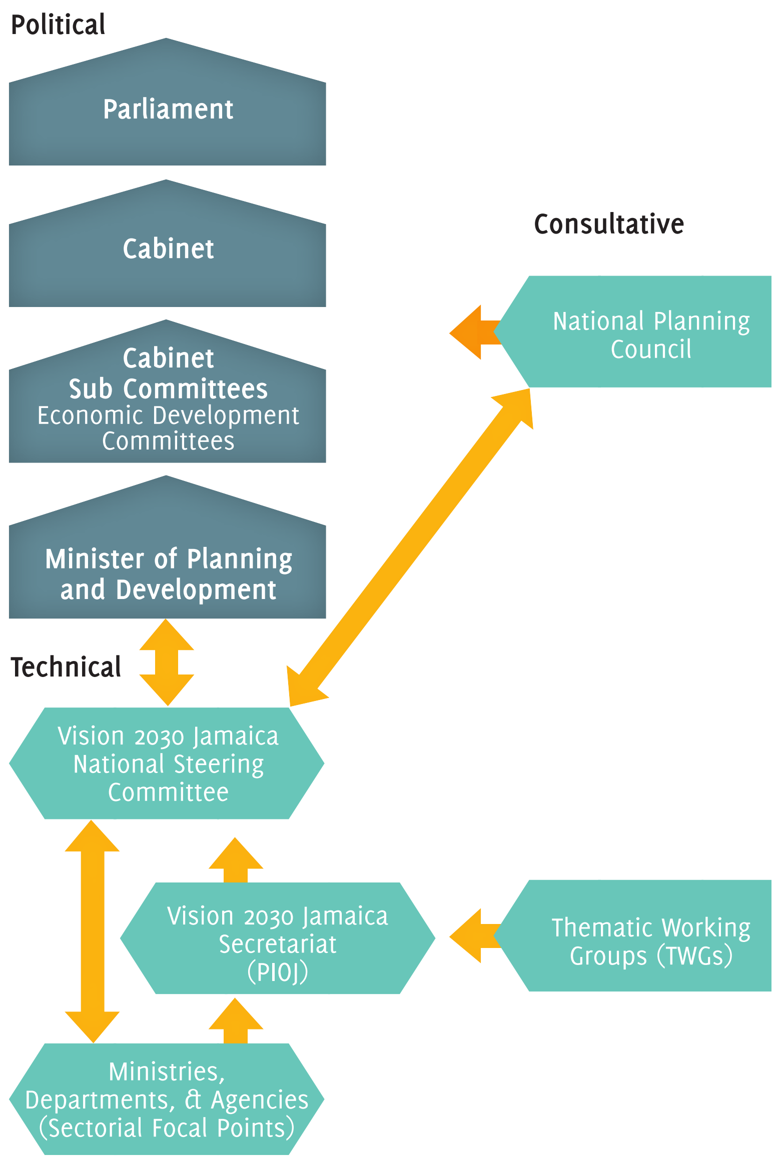



Figure 1.11: Institutional Framework for Implementation, Monitiring and Evaluation

# 1.5 Climate Change and Disaster Risk Reduction

The necessity to bring climate change and disaster risk reduction together locally, through mechanisms such as the TWG, is supported by global platforms such as UNISDR which believes that *"Climate change and disaster risk reduction are closely linked. More extreme weather events in future are likely to increase the number and scale of disasters, while at the same time, the existing methods and tools of disaster risk reduction provide powerful capacities for adaptation to climate change"* UNISDR, 2008.

The UNISDR further believes that *"The expressions "disaster risk reduction" and "climate change adaptation" represent policy goals, the former concerned with an ongoing problem (disasters) and the other with an emerging issue (climate change). While these concerns have different origins, they overlap a great deal through the common factor of weather and climate and the similar tools used to monitor, analyse and address adverse consequences.* ***It makes sense, therefore, to consider them and implement them in a systematic and integrated manner.***

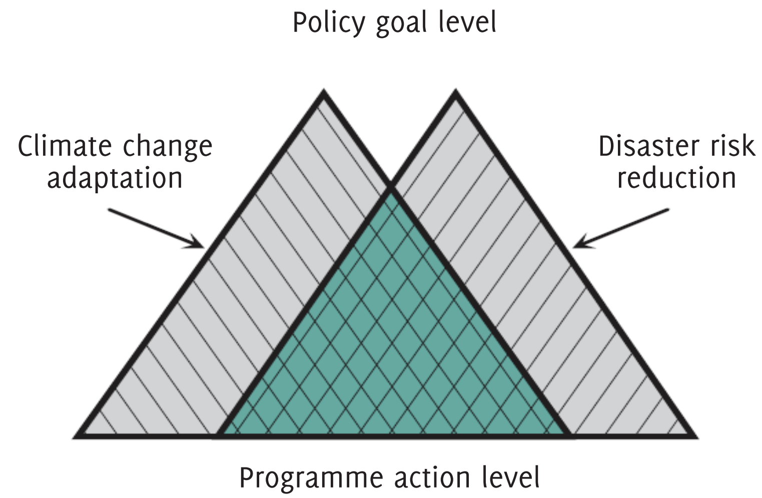



Figure 1.12: Relationship between climate change adaptation and disaster risk reduction

Climate change adaptation and disaster risk reduction share another common feature – they are not sectors in themselves but must be implemented through the policies of other sectors, in particular, those of agriculture, water resources, health, land use, environment, finance and planning (UNISDR, 2008).

The United Nations Framework Convention on Climate Change (UNFCC) defines Climate Change adaptation as *The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*. United Nations International Strategy for Disaster Risk Reduction (UNISDR) defines *Disaster Risk Reduction as "action taken to reduce the risk of disasters and the adverse impacts of natural hazards, through systematic efforts to analyse and manage the causes of disasters, including a voidance of hazards, reduced social and economic vulnerability to hazards, and improved preparedness for adverse events"*. Disaster Risk Reduction is therefore tailor-made to help counteract the added risks arising from climate change.

The risks to Jamaica arising from climate change have been most notably captured in the State of the Jamaica Climate, 2012 report and Caribsave Climate Change Risk Atlas, Jamaica, 2011 and the Near Term Scenarios Technical Report, Jamaica 2014. With permission from the author, the Planning Institute of Jamaica, this section of the atlas on climate change will refer directly to these reports as they represent the most current studies on Climate Change in Jamaica. These reports draw heavily on the (Caribbean) Regional Climate Models (RCM) and Statistical Downscaling. Other sources of information included Jamaica's First and Second National Communications on Climate Change.

The RCM is derived from the PRECIS Regional model developed at a resolution of 50km. The PRECIS data represents the only RCM data available for the countries of the Caribbean. Because of the 50km resolution, data for Jamaica exists for 12 grid boxes covering the island.

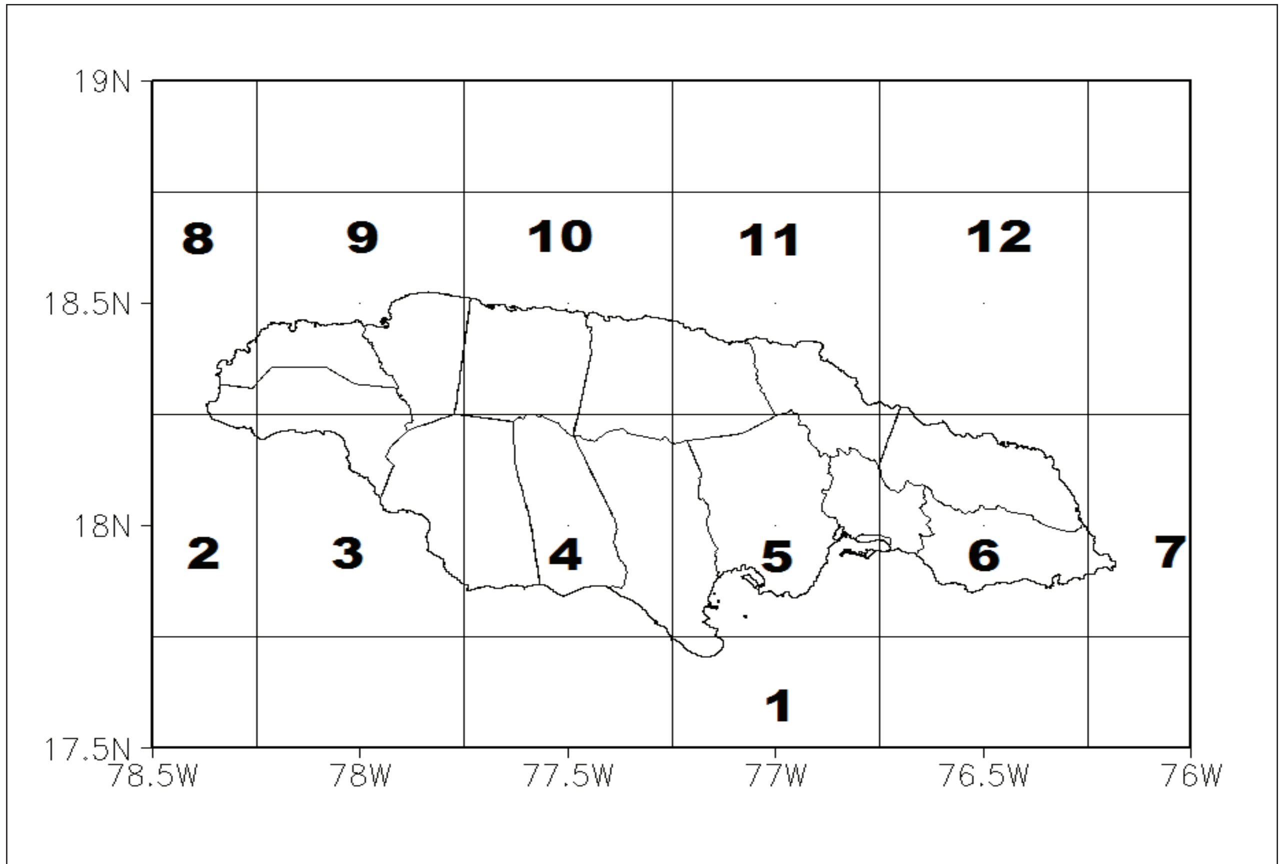



Figure 1.13: PRECIS RCM grid representation at a resolution of 50km over Jamaica

## Recent Changes
## Temperature Trend

Jamaica's climate has shown a warming trend that is consistent with a warming globe. Data from the airport stations indicate historical warming of 0.20 – 0.31 °C per decade, with greatest warming occurring between June and August. There has also been an increase in the number of warm days and nights, a decrease in cold days and nights, and a decrease in the daily temperature range (CSGM, 2012).

## Rainfall Trend

The Rainfall trend for Jamaica (as a whole) shows no stastically significant trend in annual rainfall amounts over the period 1880 to present. This is due to significant inter-annual (year-to-year) variability in the rainfall record associated with the global fluctuations such as El Niño. The year-to-year variability is superimposed upon decadal variability (See Figure 1.14) which manifests itself as groups of years for which rainfall is largely above normal (1930s, early 1950s, 2000s) and years for which rainfall is below normal (1920s, 1970s).

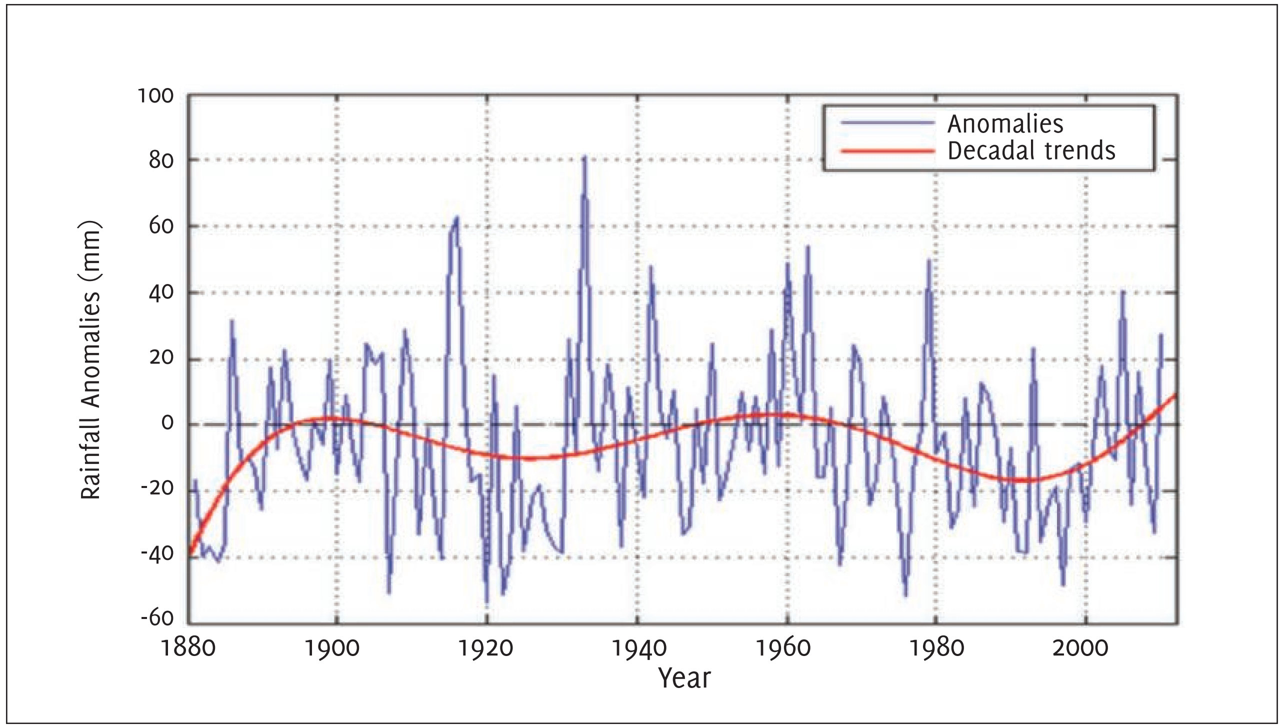



Figure 1.14: Graph of Jamaican rainfall (blue) with decadal trends (red) superimposed.

*Source: Meteorological Service of Jamaica*

The long-term rainfall data suggest a small percentage decreases in the rainfall per decade for the late wet season (August-November). The wet season is the period which accounts for the most of the island's rainfall. The largest decrease is in the June-August period, which corresponds to the mid-summer drought period.

## Tropical Cyclones

Tropical cyclone activity in the Caribbean and wider North Atlantic Basin has increased since 1995 .Both frequency and duration of hurricanes have increased as well as the number of intense hurricanes traversing the tropical Atlantic. However, the maximum intensity of hurricanes has remained fairly constant over the recent past. The increase in hurricane activity is in part attributable to the Atlantic being in the warm phase of a Multidecadal Oscillation. The number of hurricanes impacting Jamaica in each decade since the 1940s is shown in Figure 1.15. El Niño and La Niña events continue strongly to influence the location and activity of tropical storms. Generally, fewer hurricanes track through the Caribbean during an El Niño and more during a La Niña.

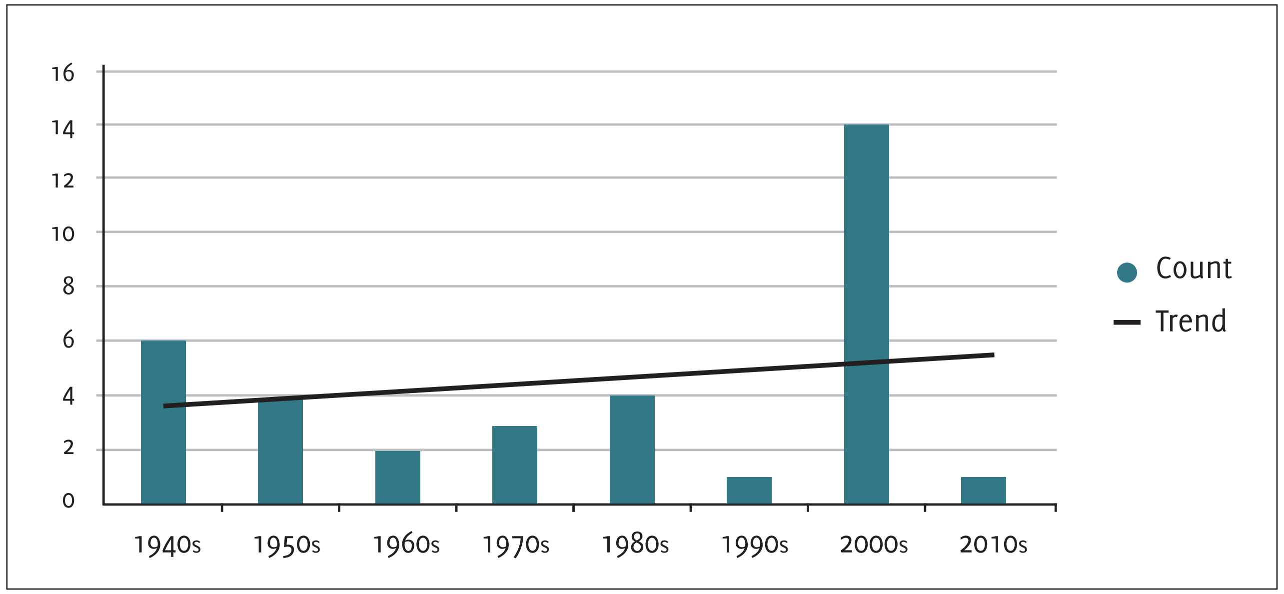



**Figure 1.15 Tropical Cyclones in the Caribbean and Wider Atlantic per decade since 1940**
*Source: Climate Studies Group, Mona (2014)*

## Sea Surface Temperature

Table 1.1 shows the annual sea surface temperatures for Negril. The sea surface temperature for Negril according to the National Environment and Planning Agency (NEPA) is amongst some of the highest around the island. Data for three (3) years of monitoring of temperatures shows fluctuation by ‹1.5 oc (See Table 1.1). In 2013 Island reef experienced the most days above 30°c most of which occurred in October. October was also the warmest month at Orange bay. In 2014 August was the warmest month at all sites and experienced the most days above 30°c (NEPA, 2015).

**Table 1.1: Annual sea surface temperature for Negril Sites, 2013 - 2015**

| | Orange Bay | | | Island Reef | | El punto | | | Bloody Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2013 | 2014 | 2013 | 2014 | 2015 | 2013 | 2014 | 2015 |
| Average T°c | 29.5 | 29 | 28.1 | 30.0 | 29.1 | 29 | 28.9 | 28.2 | 28.9 | 28.9 | 28.1 |
| Maximum T°c | 30.6 | 30.5 | 29.4 | 31.1 | 30.8 | 30.1 | 30.7 | 29.9 | 30.1 | 30.9 | 29.6 |
| Minimum T°c | 24.6 | 27.2 | 26.5 | 24.7 | 27.0 | 28.2 | 27.3 | 26.8 | 28.1 | 27.2 | 26.9 |

*Source: NEPA, 2015*

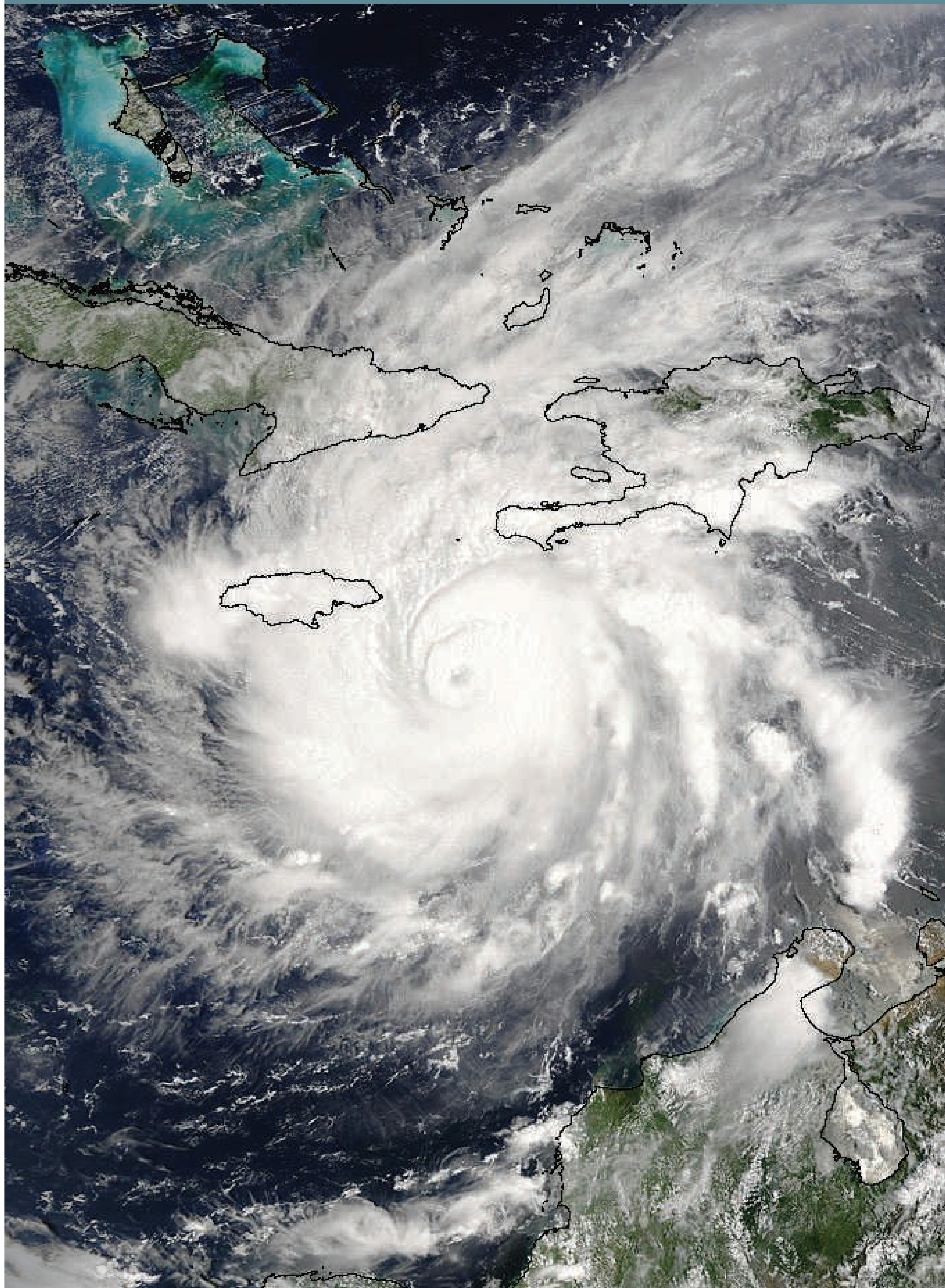


*Plate 1.5: Hurricane Ivan, 2004* | **Source: visibleearth.nasa.gov**

## Temperature Projections

The RCM projections show increases of 2.9°c and 3.4°c by 2080's with land surfaces warming more rapidly than the nearby ocean, southern Jamaica warming faster than northern Jamaica, and greatest warming occurring in June-July-August (up to 5 degrees warmer than present). These changes are relative to present day climate.

## Rainfall Projections

The RCM projections suggest a moderate decrease in rainfall in March-April-May and June-July-August rainfall, but very little change in total annual rainfall (-14%)(Caribsave, 2011).

The more severe projections suggest significantly larger decreases in annual rainfall (-41%), and June-July-August and September-October-November rainfall by the 2080s. The largest end-of-century decreases occur from May onward, and rainfall in the months of September through November is the most impacted. Rainfall in January through April is least affected.

Projected change in monthly rainfall (%), comparing baseline to the period 2071-2099. The projected changes are shown for the (A) A2 and (B) B2 SRES emissions scenarios, over the western, central and eastern sections of Jamaica, as well as an overall average

The global and regional pictures for Jamaica show that in the short-term (2020s) Jamaica will be slightly wetter than present day conditions but will transition to a much drier state by the end of the century. The 2020s will be wetter in the mean across all seasons except the early wet season (May through July), however, by the 2050s the country will be biased to being drier in the mean due to a decrease in rainfall during the traditional wet period (May through November). (The main dry season from December through March may, however, be slightly wetter). The same pattern will likely hold but intensify by the 2080s, when the models agree on a robust picture of drying (up to 60%) particularly during the two wet seasons.

## Sea Level Rise (SLR)

It is estimated that global sea levels have risen by 0.17 ± 0.05 m over the 20th century. Satellite measurements suggest the rate of rise may have accelerated in recent years to about 3 mm/year since the early 1990s. Estimates of observed sea level rise from 1950 to 2000 show that the rise in the Caribbean is near the global mean. Sea level measurements at Port Royal between 1955 and 1971 indicate a 0.9 mm/year rising trend (CSGM, 2012).

## Sea Level Rise predictions

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.

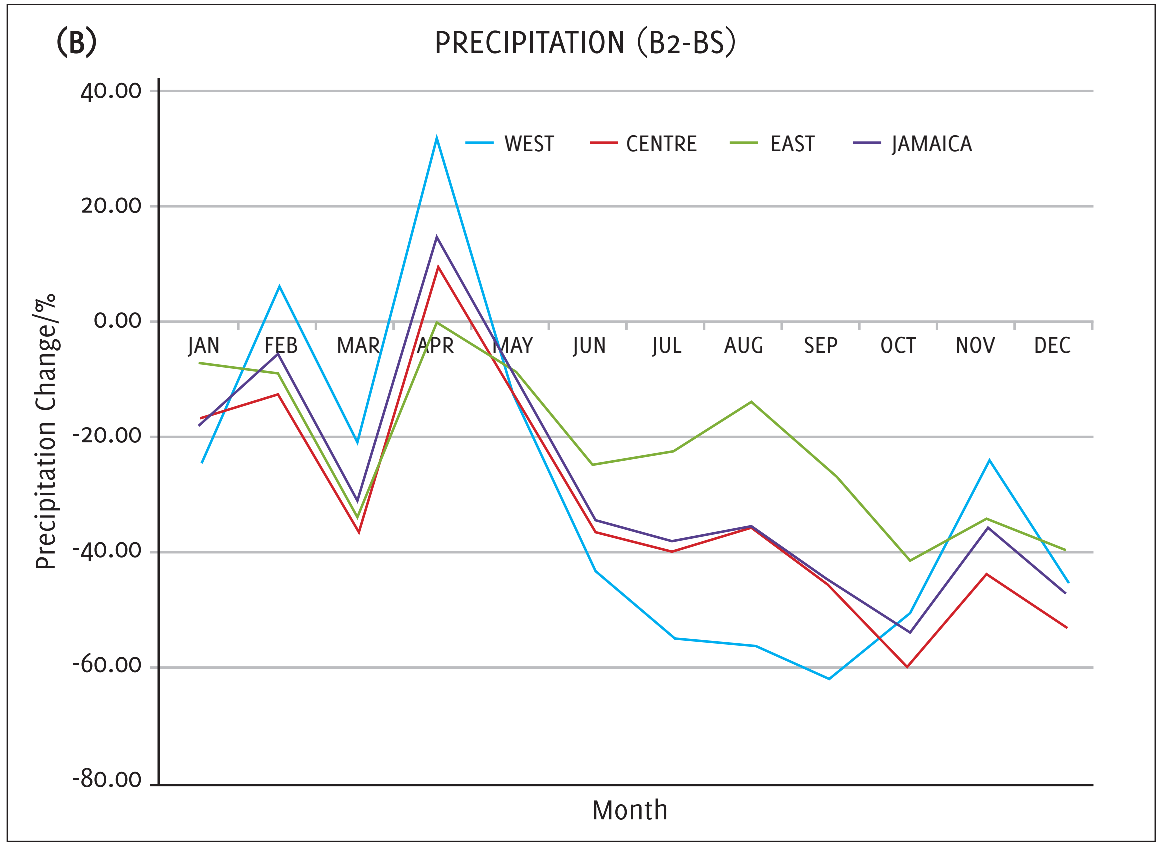



Figure 1.16 Projected percentage change in monthly rainfall for different scenarios

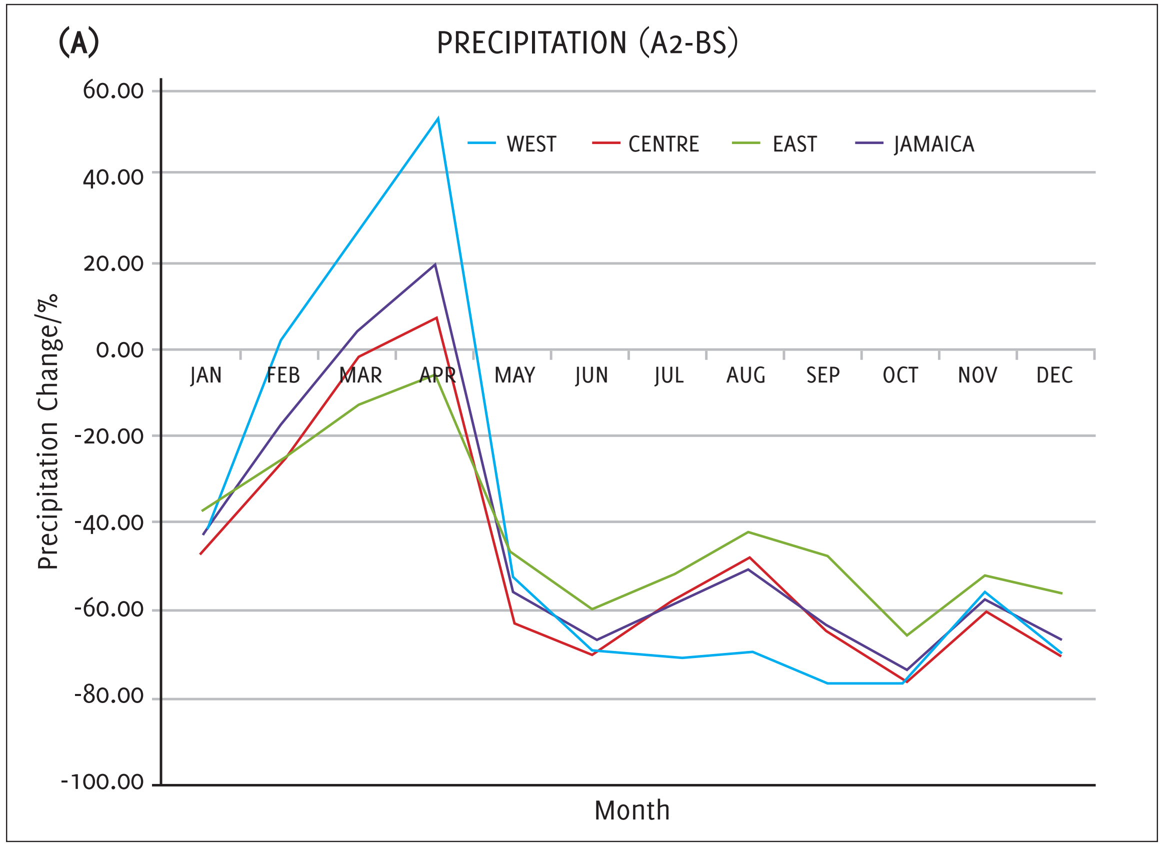



Figure 1.17 Impacts of Climate Change on different sectors


Figure 1.18 Impacts of Climate Change on different sectors in Jamaica

Source: *Climate Studies Group, Mona (2012)*

# 2

# Community Profile

2.0


## 2.1 Geographic Background

Negril is located on the west coast of Jamaica straddling two (2) parishes, Westmoreland and Hanover. This resort community covers an area of 408 $km^2$ and the physiographic environment is characterized by rugged limestone, wetlands and approximately twelve kilometres of white coral sand beach and diverse coral reefs (NEPA, 2012). The community is traversed by two (2) major rivers – the North and South Negril Rivers. In addition, a series of canals dissect the Great Morass.

Map 2.1 depicts the topographic profile of Negril, highlighting the main geographical features of the community. The project area is bordered to the west by the Norman Manley Boulevard, south by West Point and the Negril Lighthouse, east by the community of Springfield and north by Ireland Point and Orange Bay. The boundary was defined based on the project objective of Component 3 to develop a climate risk atlas mapping areas adjacent to the coast to ensure land owners and regulators have relevant information on projected climate hazards and their effects (PIOJ, 2012). Statistical Institute of Jamaica (STATIN) Enumeration Districts (ED) data was used to assist with boundary delineation.

### Topography

Negril has two distinct topographic features:

- To the east, south and west are hilly terrains reaching elevations of approximately 250m. West End in particular, the elevation rises very sharply along cliff faces located along the coast.
- The Great Morass separated from Long Bay and Bloody Bay by a narrow strip of land has elevations ranging between 0-3m above sea level.

### Geomorphology

For a detailed discussion of the geology of Negril reference should be made to Geological sheet 1 (Provisional), 1983 by Geological Survey Division. The following narrative summarizes the three (3) main geological formations which characterize the study area:

- White Limestone Group – The main outcrop of white limestone is found in Negril Hills which is located south of the Great Morass. Associated with this type of formation are karstic drainage patterns - sinkholes and depressions.
- Swamp/Marshland – The Great Morass, an extensive swamp on the Negril Coastal Plain is floored by White Limestone Group sediments. At the coastal margin to the edge of the swamp is a slightly raised area that represents old reefs.
- Coastal Limestone – can be found on West End and north of the project boundary (see Map 2.2). This geological formation comprises of hard reef limestones … often interbedded rubbly and chalky or marly limestones.


Map 2.1: Geographical Profile of Negril

## Meteorology

The Negril area, like the rest of the island, experiences a subtropical climate. Average daily temperature are lowest in March (22.9$^{oC}$) and highest in July and August (29.2$^{oC}$ and 29.1$^{oC}$, respectively). Relative humidity ranges between 65% and 85% (ESL, 2003). Rainfall is variable over the 27 km$^2$ catchment area of the Negril Morass. The highest rainfall measured at the Negril Lighthouse occurs between May and October when the average monthly rainfall exceeds 180 mm (Environmental Solutions Limited, 2003). For the rest of the year the mean monthly rainfall is less than 80 mm.

# 2.2 Coastal Environment

The coastal habitats of Negril are characterized by many ecosystems and ecotypes ranging from coral reefs to wetland areas (NEPA, 2012). One of the most notable features is a sand barrier that forms two beaches, Long Bay to the South and Bloody Bay to the North, backed by a narrow and shallow shelf exhibiting both deep and shallow coral reefs and sea grass meadows. The beaches have a total length of approximately nine kilometres (9 km) and comprise part of a sand barrier system fronting the Great Morass, a low-lying back-barrier wetland that terminates to the east at a steep escarpment formed along the limestone Fish River Hills (Rivamp, 2010).

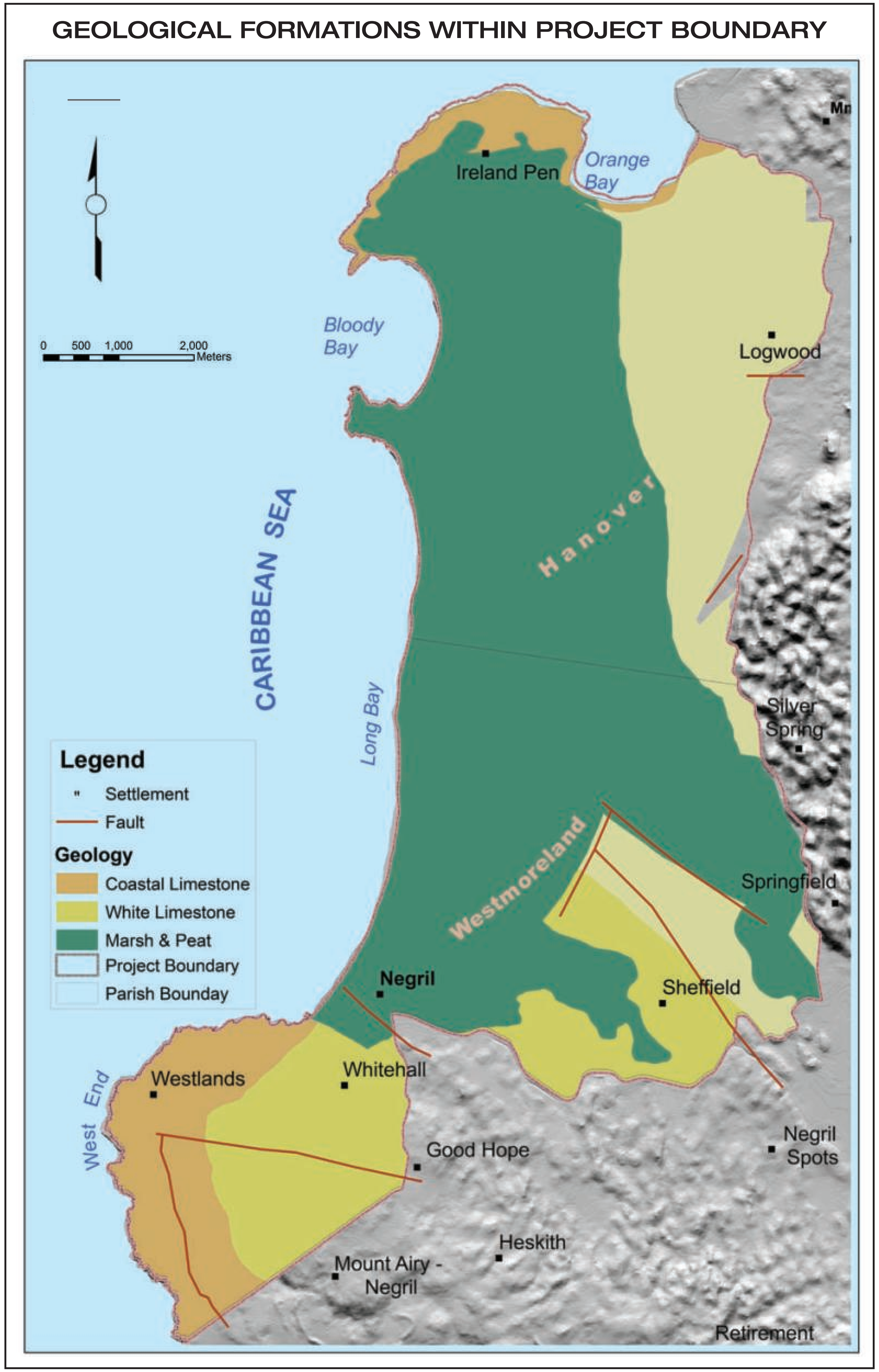
## The Negril Great Morass (NGM)

Originating landward of the beach system and terminating at the foot of the Fish River Hill, Negril's Great Morass (NGM) covers an area of approximately 2,400 hectares (NEPA, 2012). It is the country's second largest freshwater wetland and constitutes one-fifth of Jamaica's wetlands. The Morass has elevations ranging between zero (0) to three (3) metres and is underlain for the most part by peat of varying thickness. The peat exceeds 12 m in some places, especially in the southwestern part of the wetland (Bjork, 1984).

The Great Morass is a prominent feature of the area and is an extremely important habitat for local and migratory avifauna and other keystone species found in wetlands (National Environment and Planning Agency [NEPA], 2012). Ground water recharge, flood control, nutrient retention, shoreline stabilization, habitat for a variety of wildlife, habitat for specialist plant species and climate control through air quality improvement are all important functions of the NGM. Despite its ecological value, various activities are being practiced that endangers the NGM (Negril area Environmental Protection Trust [NEPT], 2012).

## Coral Reefs and Seagrass Beds

Off shore, the beaches are protected by vast expanses of seagrass beds which play a critical role in the mitigation of beach erosion (Rivamp, 2010). These seagrass beds are sometimes found interspersed with coral reef patches in the near shore areas. The seagrass beds later give way to a shallow fringing coral reef system found 2 – 3 km offshore with a depth range of 20 – 50 m (NEPA, 2012).




Map 2.2: Geoglogy of Negril

# 2.3 Socio-Economic Characteristics

## Population Overview

According to the 2011 census, the population of the project area is estimated at eleven thousand, one hundred and seventy six (11,176) persons (Statistical Institute of Jamaica [STATIN], 2011). Of this total, the percentage of males is marginally higher accounting for 52% (5,798) whilst females account for 48% (5,378) of the total population. Table 2.1 below illustrates the population distribution disaggregated by age cohort and gender which shows that the population largely constitutes the working class with 7,588 persons within the 15-64 age cohort.

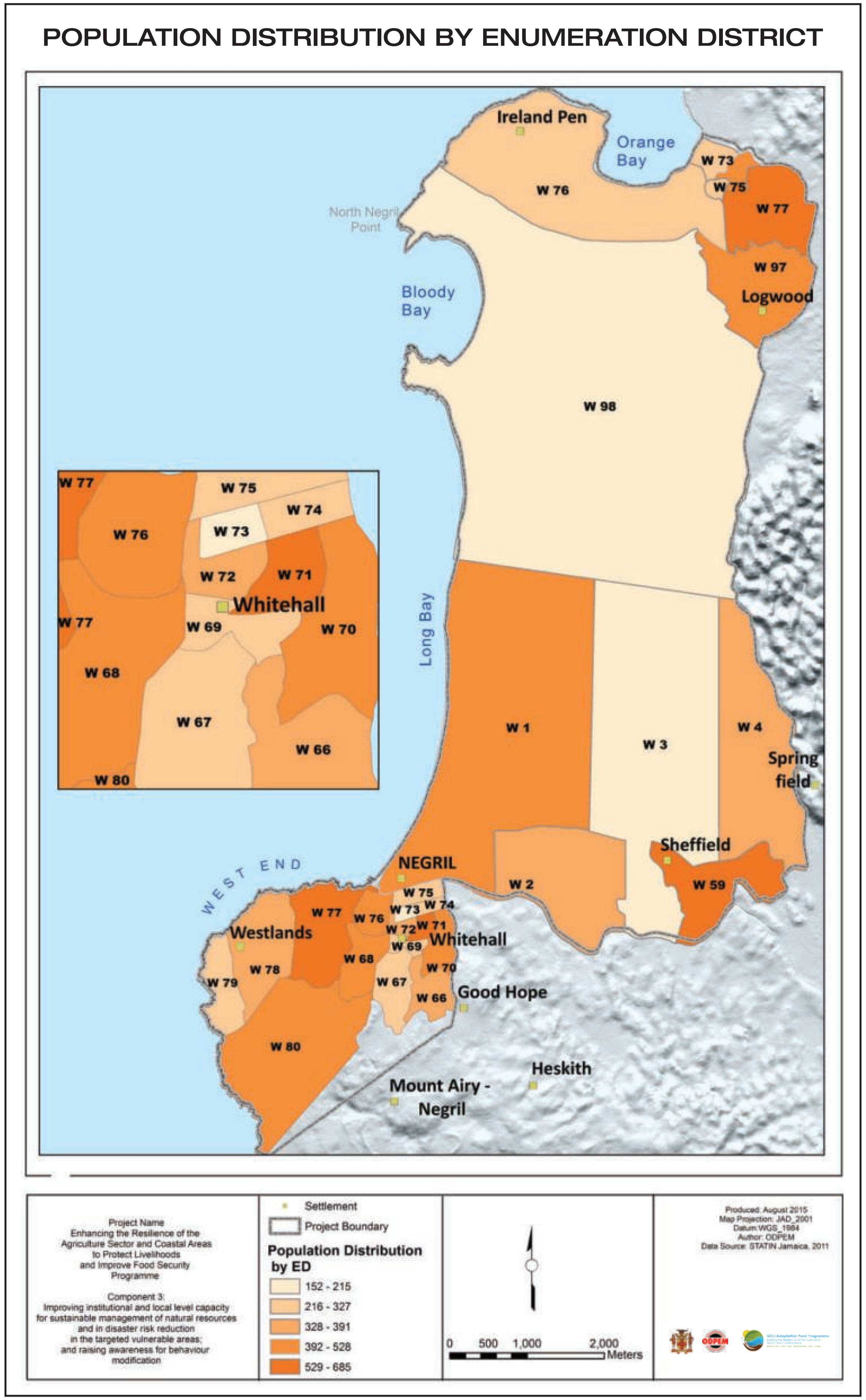
Table 2.1 Population Structure of Negril

| Gender | Age Cohort | | | Total Population 2011 Census |
|---|---|---|---|---|
| | 0-14 | 15-64 | 65 and Over | |
| Male | 1,529 | 4,018 | 251 | 5,798 |
| Female | 1,530 | 3,570 | 278 | 5,378 |
| Total | 3,059 | 7,588 | 529 | 11,176 |

*Source: STATIN, 2011*

Based on the 2001 Census, the population was 9484 and grew with an estimated population of 11,176 based on 2011 census. This represents a population increase of over 1,000 persons or 15 per cent change.

Map 2.2 shows the population distribution by enumeration district (ED). In Hanover, it can be seen that the population is concentrated primarily in ED W77 (Orange Bay Housing Scheme) and in Westmoreland, ED's W59 (Sheffield), W71 (Whitehall) and W 77 (Red Ground).




Map 2.3: Population Distribution by Enumeration District

# Economic Overview

## Tourism

The main source of livelihood in Negril is tourism, which is marked by high density tourist facilities (approximately 108 hotels) catering to both short and long stay visitors. Negril is the third largest tourist resort area in the island next to Ocho Rios, St. Ann and Montego Bay, St. James. The tourism sector in Jamaica is a major contributor to the economy contributing an estimated at 7.8% (J$1.7 billion) of total GDP in 2015 (STATIN, 2015).

Direct employment in the accommodation sector for the tourist area of Negril provided 9,712 jobs which accounted for 24.7% of total employment in the industry for the country (Jamaica Tourist Board, 2015). This is followed by Ocho Rios (21.1%) and Kingston, Port Antonio and South Coast combined (11.5%).

In 2015, the resort area of Negril recorded an average hotel room occupancy rate of 66.81% in comparison to the rate of 63.5% in 2014. This represents an increase in hotel room occupancy by 3.1% (JTB, 2015).

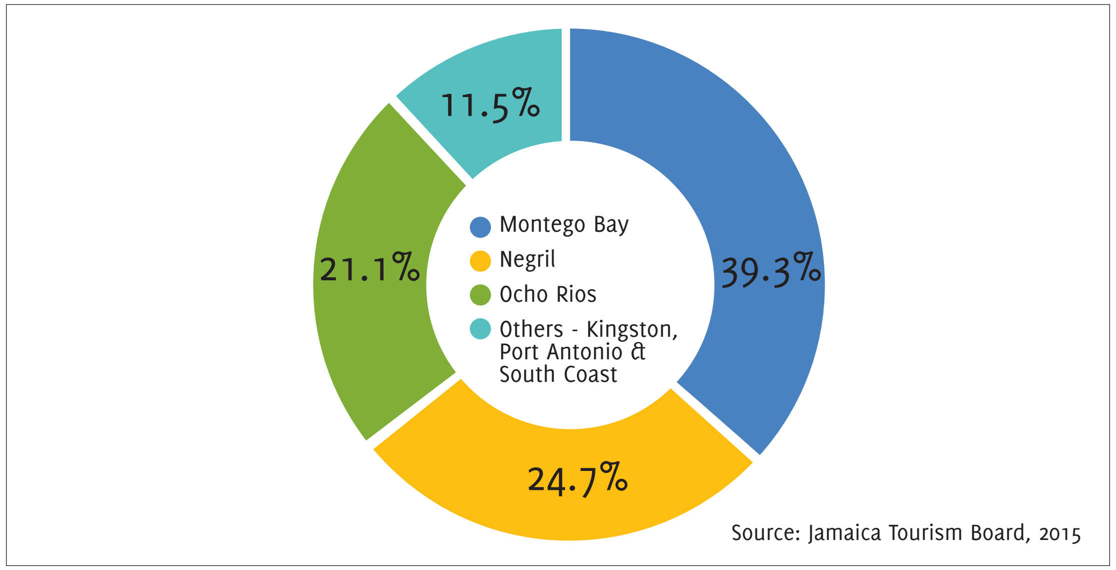



Figure 2.1 Direct Employment in the Accommodation Sector for 2015

As a result of the booming tourist industry, other small commercial businesses such as craft vendors, bars and restaurants also contribute to the economy. Data from Tourism Product Development Company (TPDCo) shows that there are 260 registered craft vendors operating in Negril. Other commercial activities that contribute to the economy include petrol stations, retail stores, car wash and garages, among others.

## Agriculture

Agriculture is another primary source of income for communities located within the project boundary. Data from the Fisheries Division shows that there are four hundred (400) registered fishermen with approximately one hundred and twenty (120) registered vessels operating within the Negril area (Ministry of Agriculture and Fisheries, 2006). Although fishing remains an important source of livelihood, this activity has experienced significant decline over the past two decades (RiVAMP, 2010).

Farming is the other major use of natural resources which is the predominant land use within the Morass [Negril area Environmental Protection Trust (NEPT), 2012]. Farming activities include crop production in the interior sections and on the fringe where cash crops such as cabbage, sweet potato, sweet pepper, broccoli, lettuce, and callaloo are grown mostly at artisanal levels. Subsistence sugar cane and banana cultivation also occurs close to the bank of the South Negril River and on the eastern fringe ([NEPT, 2012).

*Plate 2.1 An artisan at work at the Negril Craft Market*

Cattle farming also contributes to the economy in Negril albeit, on a small scale mainly in the communities of Sheffield and Negril Spots areas.

## 2.4 Natural Hazard Profile

Negril is exposed to a number of hazards due to its geographical location and topography. The community is primarily exposed to hydro-meteorological hazards, in particular flooding and hurricane induced storm surges and strong winds. Coastal erosion is also another major hazard which has and continues to severely impact Negril's coastline. The profile in Table 2.2 shows the number of events recorded per hazard type (See Table 2.4 below for detailed profile). These events have had devastating effects on physical infrastructure, economy and livelihoods.

**Table 2.2 Natural Disaster Profile summary in Negril**

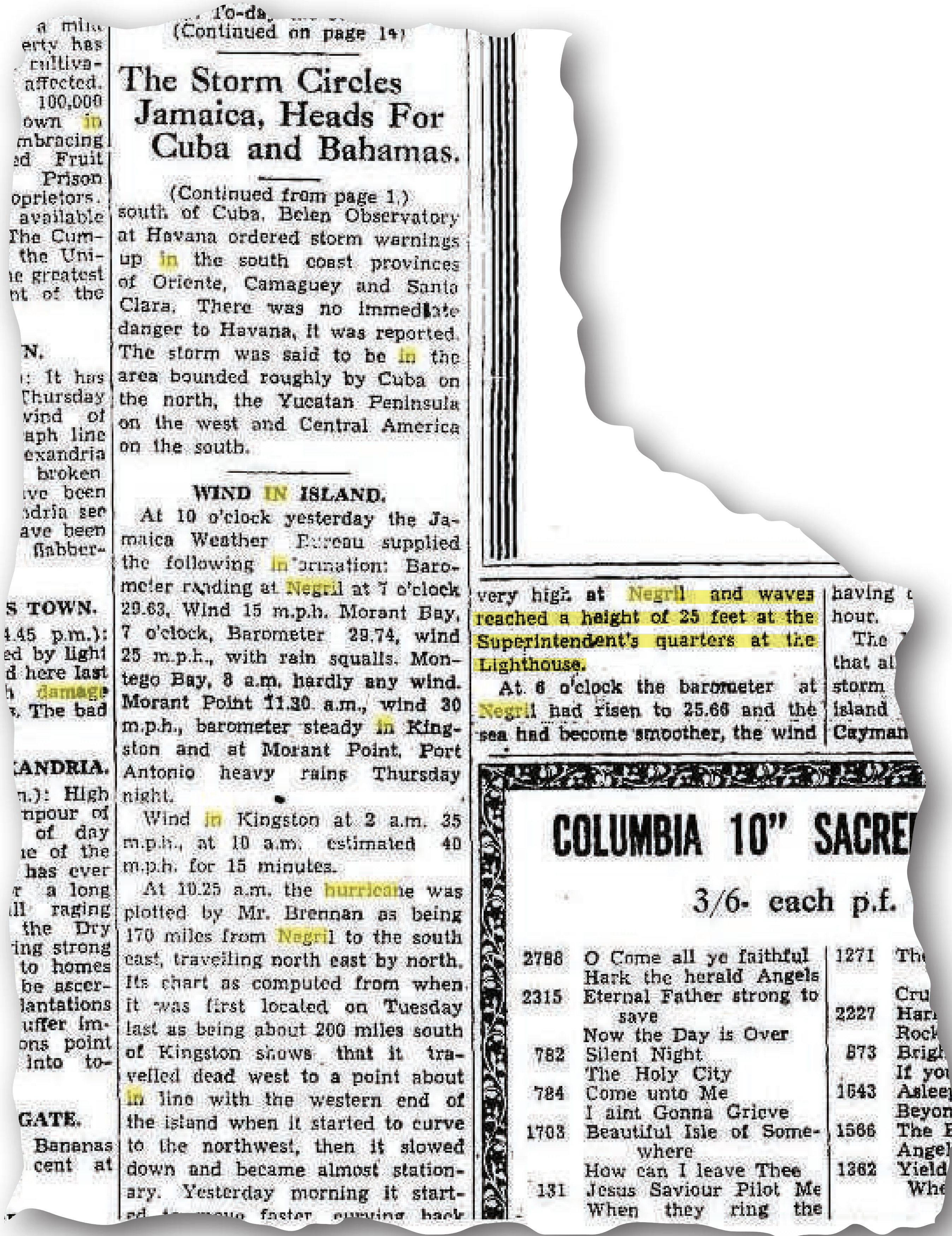
| Hazard | Years | Number of Events | Casualties |
|---|---|---|---|
| Tropical Storms/Hurricanes | 1904-2010 | 15 | 2 |
| Flood | 1990-2002 | 3 | - |
| Hailstorm | 1922 | 1 | - |

*Source: Gleaner Archives and ODPEM Disaster Catalogue*

### Tropical Storms/Hurricanes

One of the most significant hurricane events to have caused severe physical damage to buildings and infrastructure as well as environmental damage in Negril was Hurricane Mitch in 1998. The following account of the impacts of the hurricane was extracted from Office of Disaster Preparedness and Emergency Management Disaster Catalogue, 1999:

- The resort town experienced storm surges with height of 13-17m along West End and Long Bay.
- 5 hotels sustained damage - Negril Tree House, Foote Prints, Sandal Negril, Negril on the Rocks and Mariners Inn amounting to JA$6.2 m.
- Environmental damage - ~ 10m³ of sand was loss from beachfront properties as well as loss of reef structures and reef dwelling organisms.



(Continued on page 14)

**The Storm Circles Jamaica, Heads For Cuba and Bahamas.**

(Continued from page 1.)

south of Cuba. Belen Observatory at Havana ordered storm warnings up in the south coast provinces of Oriente, Camaguey and Santa Clara. There was no immediate danger to Havana, it was reported. The storm was said to be in the area bounded roughly by Cuba on the north, the Yucatan Peninsula on the west and Central America on the south.

**WIND IN ISLAND.**

At 10 o'clock yesterday the Jamaica Weather Bureau supplied the following information: Barometer reading at Negril at 7 o'clock 29.63, Wind 15 m.p.h. Morant Bay, 7 o'clock, Barometer 29.74, wind 25 m.p.h., with rain squalls. Montego Bay, 8 a.m. hardly any wind. Morant Point 11.30 a.m., wind 30 m.p.h., barometer steady in Kingston and at Morant Point. Port Antonio heavy rains Thursday night.

Wind in Kingston at 2 a.m. 35 m.p.h., at 10 a.m. estimated 40 m.p.h. for 15 minutes.

At 10.25 a.m. the hurricane was plotted by Mr. Brennan as being 170 miles from Negril to the south east, travelling north east by north. Its chart as computed from when it was first located on Tuesday last as being about 200 miles south of Kingston shows that it travelled dead west to a point about in line with the western end of the island when it started to curve to the northwest, then it slowed down and became almost stationary. Yesterday morning it start-

very high at Negril and waves reached a height of 25 feet at the Superintendent's quarters at the Lighthouse.

At 6 o'clock the barometer at Negril had risen to 25.66 and the sea had become smoother, the wind



*Source: Gleaner Archives, 1935*

## Coastal Erosion

Associated with the passage of these storms/hurricanes is storm surges and coastal erosion. Hurricane induced storm surges are the primary contributor to severe erosional activity along the Long Bay and Bloody Bay coastline. There has been an observable modification to the Negril coastal landscape with studies by UWI (2002), Smith Warner International Limited [SWIL] (2007) and RiVAMP (2010) indicating that over the last 40 years beaches in Negril have been experiencing severe erosion.

The Long Bay and the Bloody Bay strips are identified as 'critical risk areas' having experienced the greatest shoreline loss for the periods 1968 to 2006 and 2006 to 2008. For the period 1968-2006, average beach erosion rates have been estimated at 0.8 m per year for Bloody Bay and 1.1 m per year for Long Bay (SWIL, 2007).

From table 2.3, it can be seen that from recent events, the greatest loss of beach was 4m during the passage of Hurricane Ivan in 2004. The cost to restore beach in Long Bay and Bloody Bay after the passage of Hurricane Ivan was estimated to be JMD$600 million.

### Table 2.3 Coastal Erosion Trends for Negril

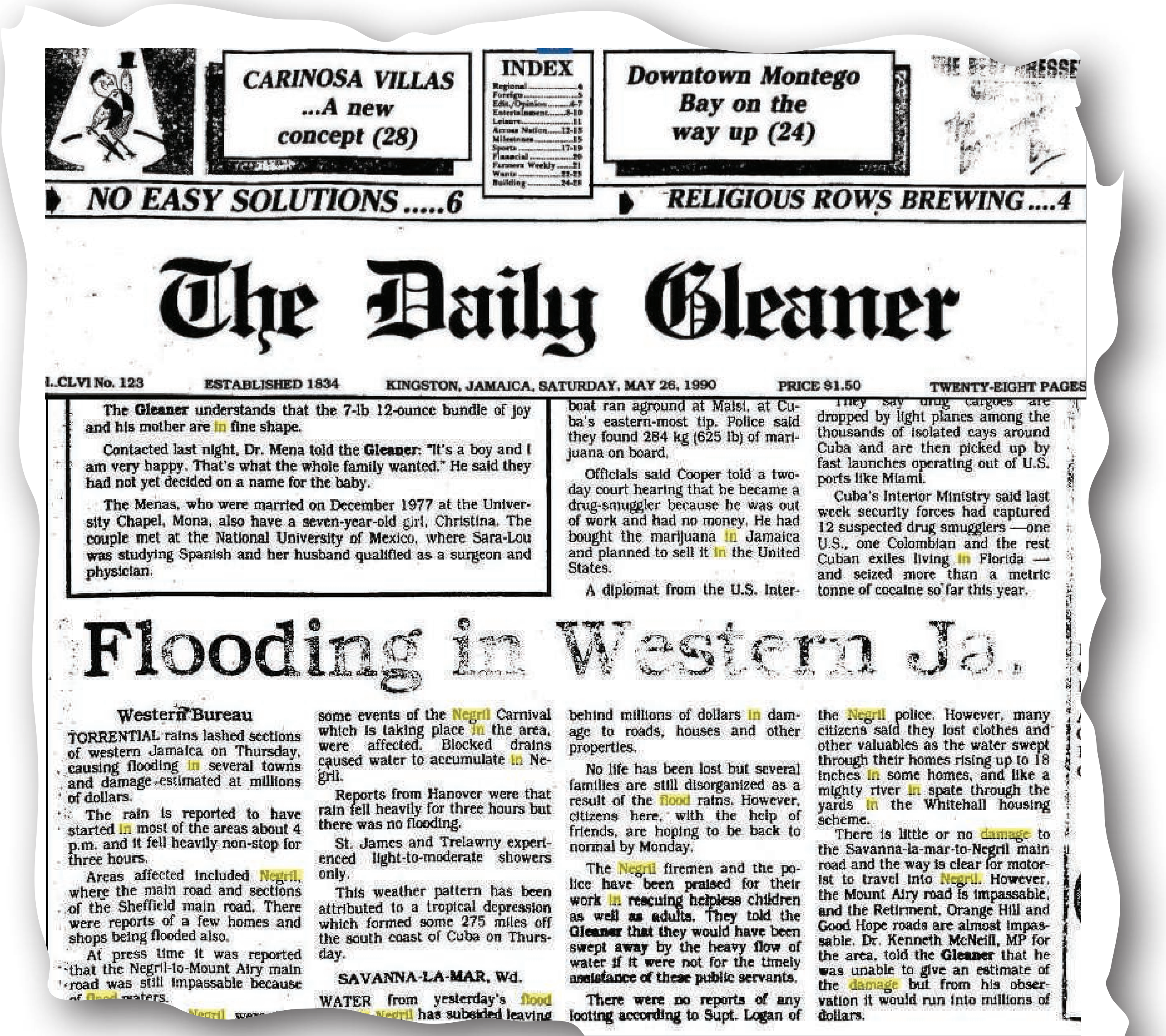
| Major Events | Impact on Beach |
|---|---|
| Hurricane Michelle, 2001 | 1. Eroded 14 m<br>2. Accreted 14 m |
| Hurricane Ivan, 2004 | 1. Average erosion of 16 m<br>2. Average accretion of 12 m<br>Net change: Loss of 4m of beach |
| Hurricane Wilma, 2005 | 1. Average erosion of 19 m<br>2. Average accretion of 18 m<br>Net change: Loss of 1 m |
| Hurricane Dean, 2007 | 1. Average erosion of 11 m<br>2. Average accretion currently not available |

*Source: National Environment & Planning Agency (NEPA) [n.d.].*

## Floods

Historical data shows that Negril has been affected by numerous flood events, primarily triggered by hurricanes/storm events. Some of the worst flood events have been recorded in the years 1990, 1997 and 2002 and documented in the Office of Disaster Preparedness and Emergency Management (ODPEM) Disaster Catalogue. The following briefly describes some of these events;

- In 1990 – Millions of dollars in damage to roads, houses and other properties were caused by flood rains. Blocked drains caused water to accumulate. Floods waters were so high resulting in a negative effect entertainment events in Negril.
- In 1997 – Flooding was caused by damaged pipelines which resulted in traffic delays in Sheffield.
- In September 2002 – Tropical Storm Isidore caused major flooding in Negril leading to flood waters creating deep trenches across both major and minor roadways.



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# The Daily Gleaner

..CLVI No. 123 | ESTABLISHED 1834 | KINGSTON, JAMAICA, SATURDAY, MAY 26, 1990 | PRICE $1.50 | TWENTY-EIGHT PAGES

The Gleaner understands that the 7-lb 12-ounce bundle of joy and his mother are in fine shape.

Contacted last night, Dr. Mena told the Gleaner: "It's a boy and I am very happy. That's what the whole family wanted." He said they had not yet decided on a name for the baby.

The Menas, who were married on December 1977 at the University Chapel, Mona, also have a seven-year-old girl, Christina. The couple met at the National University of Mexico, where Sara-Lou was studying Spanish and her husband qualified as a surgeon and physician.

boat ran aground at Maisi, at Cuba's eastern-most tip. Police said they found 284 kg (625 lb) of marijuana on board.

Officials said Cooper told a two-day court hearing that he became a drug-smuggler because he was out of work and had no money. He had bought the marijuana in Jamaica and planned to sell it in the United States.

A diplomat from the U.S. Inter-

They say drug cargoes are dropped by light planes among the thousands of isolated cays around Cuba and are then picked up by fast launches operating out of U.S. ports like Miami.

Cuba's Interior Ministry said last week security forces had captured 12 suspected drug smugglers —one U.S., one Colombian and the rest Cuban exiles living in Florida — and seized more than a metric tonne of cocaine so far this year.

## Flooding in Western Ja.

**Western Bureau**

TORRENTIAL rains lashed sections of western Jamaica on Thursday, causing flooding in several towns and damage estimated at millions of dollars.

The rain is reported to have started in most of the areas about 4 p.m. and it fell heavily non-stop for three hours.

Areas affected included Negril, where the main road and sections of the Sheffield main road. There were reports of a few homes and shops being flooded also.

At press time it was reported that the Negril-to-Mount Airy main road was still impassable because of flood waters.

... Negril were ...

some events of the Negril Carnival which is taking place in the area, were affected. Blocked drains caused water to accumulate in Negril.

Reports from Hanover were that rain fell heavily for three hours but there was no flooding.

St. James and Trelawny experienced light-to-moderate showers only.

This weather pattern has been attributed to a tropical depression which formed some 275 miles off the south coast of Cuba on Thursday.

**SAVANNA-LA-MAR, Wd.**

WATER from yesterday's flood ... Negril has subsided leaving behind millions of dollars in damage to roads, houses and other properties.

No life has been lost but several families are still disorganized as a result of the flood rains. However, citizens here, with the help of friends, are hoping to be back to normal by Monday.

The Negril firemen and the police have been praised for their work in rescuing helpless children as well as adults. They told the Gleaner that they would have been swept away by the heavy flow of water if it were not for the timely assistance of these public servants.

There were no reports of any looting according to Supt. Logan of the Negril police. However, many citizens said they lost clothes and other valuables as the water swept through their homes rising up to 18 inches in some homes, and like a mighty river in spate through the yards in the Whitehall housing scheme.

There is little or no damage to the Savanna-la-mar-to-Negril main road and the way is clear for motorist to travel into Negril. However, the Mount Airy road is impassable, and the Retirment, Orange Hill and Good Hope roads are almost impassable. Dr. Kenneth McNeill, MP for the area, told the Gleaner that he was unable to give an estimate of the damage but from his observation it would run into millions of dollars.

*Source: Gleaner Archives, 1990*

Table 2.4 Historical Disaster Events that impacted Negril

| Event | Year | Impact |
|---|---|---|
| Tropical Storm | 1904 | • Caused strong winds and heavy rainfall at Negril Point |
| Hailstorm | 1922 | • A whirlwind, accompanied by hail, was experienced at Negril Point Lighthouse |
| Hurricane | 1933 | • Erosion of sand for 2 miles along beach.<br>• Two persons died as a result of Influenza outbreak.<br>• The fishing grounds sustained damage.<br>• Winds recorded at 60 miles/hr along with heavy rains affected Negril Point. |
| Hurricane | 1935 | • Waves reached heights of 25ft were recorded at the Negril light house.<br>• Windward Road was blocked due to high volumes of water, a number of toppled banana trees were observed. |
| Hurricane Gilbert | 1988 | • West End - light poles, electrical wires, buildings and popular tourist venues such as Rick's Café sustained damage.<br>• Destruction of vegetation and limestone forest.<br>• Tensing Pen hotel lost almost all its trees.<br>• Houses of seven families were destroyed.<br>• Negril Primary School lost its entire roof. |
| Flood | 1997 | • Rains caused damage to pipelines.<br>• Heavy water flows dislodged lateral sewer line across Sheffield Road from its two (2) meter depth. |
| Hurricane Mitch | 1998 | • West End and Long Bay Beach was affected by storm surge.<br>• The height of the storm surge was between 13-17 meters.<br>• Loss of coral reef and reef-dwelling organisms, beach migration & damage to shoreline structures. |
| Hurricane Michelle | 2001 | • Erosion of beach property of Negril Tree House.<br>• Long Bay - damage to impound was estimated at $45,000. |
| Hurricane Ivan | 2004 | • West End damage to several hotels and attractions.<br>• Complete destruction of facilities in Mariner's Inn and Rick's Café by waves.<br>• 318mm of rainfall in was recorded in Negril point.<br>• Several large trees were uprooted in several sections of the town, down power lines was also observed in several sections as well. |
| Hurricane Wilma | 2005 | • Strong waves caused significant beach erosion along 7 miles stretch.<br>• Large mats of sea grass beds uprooted. |
| Hurricane Dean | 2007 | • Damage to accommodation sub-sector in Negril, estimated at JMD $2M |
| Tropical Storm Nicole | 2010 | • Negril hit by storm surge and brutal waves. Surges reaching up to 30ft high were recorded in West End accompanied by crashing waves.<br>• Many businesses and resorts suffered damages by wind and storm surge. |

*Source: Gleaner Archives and ODPEM Disaster Catalogue*

A cavity on the seaward side of West End main road associated with Hurricane Mitch

**Source: ODPEM**

Deposition of large amounts of sea weed, Long Bay beach, associated with Hurricane Mitch, 1998

**Source: ODPEM 1998**

*Plate 2.2: Wave overtopping along West End associated with Hurricane Dean, 2007.* © **Negril Escape** | **Source: RiVAMP, 2010**

3

# Hazard Assessment

3.0

Hazard assessment is an essential first step of the overall risk assessment process. It involves gathering and analyzing data on meteorological, hydrological and geological hazards in terms of their nature, frequency and magnitude. Hazard assessment is characterized by triggering factors, degree of severity, spatial occurrence, duration of the event and their relationship (UNDP Myanmar et al, 2011).

The assessment of priority hazards (storm surge, wave overtopping, sea level rise and coastal erosion) within the scope of this project was undertaken by Civil, Environmental and Coastal Engineering Solutions (CEAC). Climate Studies Group Mona provided guidance for data input of sea level rise scenarios. The analysis of the hazard assessment results was done by ODPEM and CEAC Solutions.

A description of the methodologies, data used and hazard maps are presented in subsequent sections.

## 3.1 Storm Surge Hazard Assessment

Storm surge is an abnormal rise of water generated by a storm, over and above predicted astronomical tides *(www.nhc.noaa.gov/surge/)*. Storm surge is caused primarily by the strong winds in a hurricane or tropical storm. This rise in water level can cause extreme flooding in coastal areas, especially when storm surge coincides with normal high tide, resulting in storm tides where the water may reach levels of up to 20 feet or above mean sea level (msl).

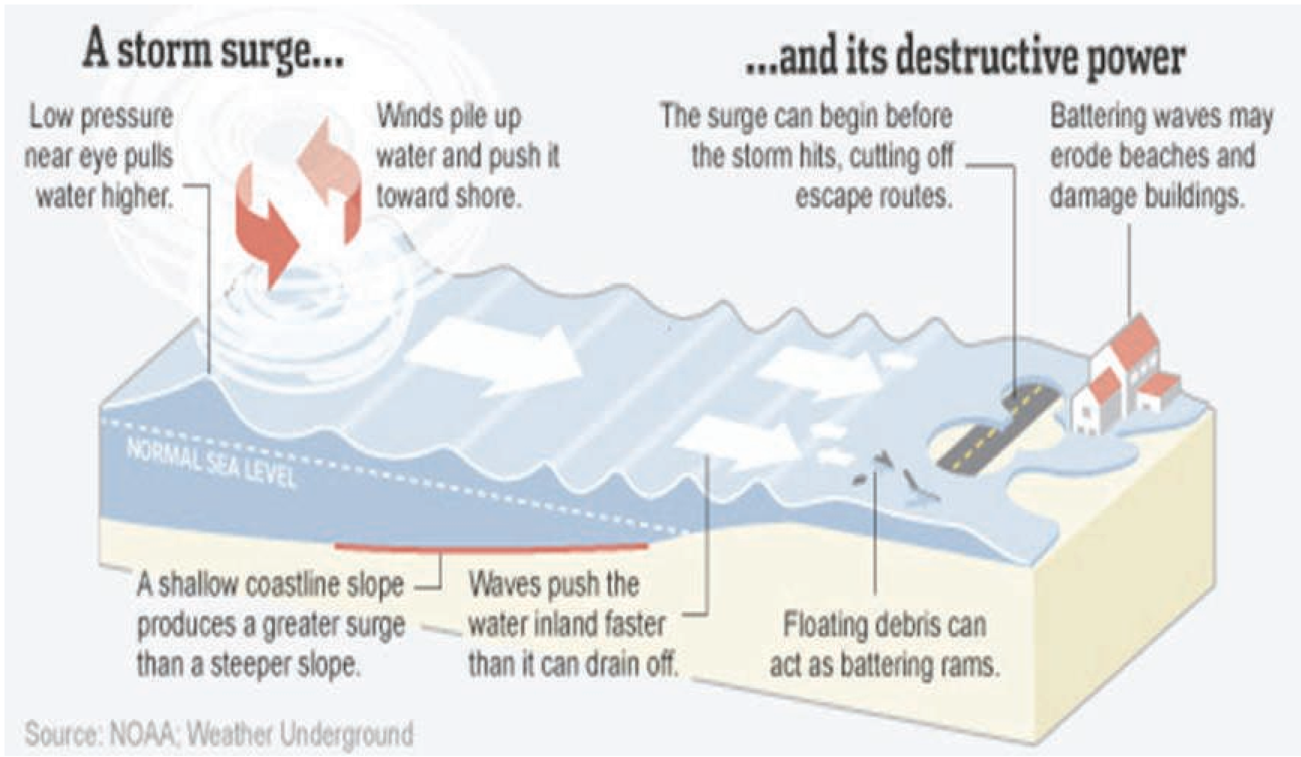



Figure 3.1: Schematic of Storm Surge Phenomenon

## Methodology*

The methodology described in this section is based on Technical Report for Storm Surge Modelling and Sea Level Rise Scenarios for Negril (See Figure 3.3). The methodology for storm surge and sea level rise mapping has been developed using both primary and secondary data.

## Data Collection

## Anecdotal Storm Surge Survey

Structured questionnaires were administered to 280 persons who live and/or work in Negril. The interviews focused primarily on major storms experienced and areas with greatest impact, height of storm surge, damage and losses, width of beach erosion experienced at discrete locations, and the time to recovery of shoreline associated with different hurricane events. The locations of the interviews and observations of storm surges were referenced geospatially.

## Bathymetric Survey

Storm Surge and wave heights on shore are affected by the configuration and bathymetry of the ocean bottom. Bathymetric data is required in order to facilitate wave transformation modeling of the impact of storm surge and sea level rise in Negril. Understanding the movement of currents along the seafloor aids in the prediction of wave intensity and direction on the shoreline. Bathymetric data was acquired from the following surveys:

- Smith Warner International (SWIL) - 2007
- CEAC Solutions - 2013 & 2014

## Topographic Survey

This survey was carried out to Mean Sea Level (MSL) datum at 30 m spacing along the road centerline. Topographic survey is required to improve the results of hazard analysis in determining the elevation at which storm surge will propagate inland from shoreline. The topographic survey involved:

1. Control survey - A control point is a point on the ground or any permanent structure whose horizontal and vertical location/position is known1.The control points were set out by a Commissioned Land Surveyor using National Land Agency's (NLA) horizontal and vertical controls.
2. Aerial Surveys - An unmanned aerial vehicle (UAV) was used to capture building footprints, road centerline, and beach dune and shoreline information. This technology was used to conduct topographic survey, provided base imagery from which detailed building footprint digitizing in ESRI ArcGIS. The survey mission was carried out to an accuracy of 5cm per pixel.
3. Finished Floor Level - Floor levels are important in order to determine susceptibility to floor inundation. The traditional survey method was used to gather the topographic data at a nominal distance of 40m along the road centerline on either side of the roadway. The elevation relative to MSL was determined and the number of storeys for the buildings recorded and incorporated into the topographic data.

*Detailed descriptions of the data used, sources and methodologies can be found in Technical Report: Storm Surge Modelling and Sea Level Rise Scenarios for Negril Climate Risk Atlas.*

## Storm Surge Modeling (Numerical Modeling)

The following procedure was carried out for storm surge assessment:

1. Hurricane wave track data in the Caribbean Sea was used to determine the hurricane wind and wave conditions at a deep water location offshore Negril.
2. Extraction of storm parameters that passed within 300 km radius of Negril's coast from National Oceanic and Atmospheric Administration (NOAA) hurricane database.
3. Application of the JONSWAP2 wind-wave model. A wave model was used to determine the wave conditions generated at the site due to the rotating hurricane wind field.
4. Application of extremal statistics - to estimate different return periods for waves and surge levels
5. A bathymetric and topographic profile from deep-water to the site was then defined, respectively. This is used to calculate the wave run-up (height) based on topography of shoreline and nearshore waves.

## Validation of Model

Model performance for storm surge was analyzed by comparing both storm surge model predictions with anecdotal observations of past storms. Hurricane Ivan, 2004 was used to validate model because all other storms the residents recalled, the data was insufficient for calibrating and verifying the storm surge model.

Figure 3.2 presents the storm surge elevation plot for Negril that was observed by residents during the passage of Hurricane Ivan, 2004 (purple) and the computed storm surge (blue). Results show that the model predictions of wave setups for Hurricane Ivan compared well with the observations of the residents. The observed setups were subjected to extremal statistical analysis to estimate the return period of the setups experienced. The statistical tool used was the Weibull function which is widely used for this type of extremal data analysis.

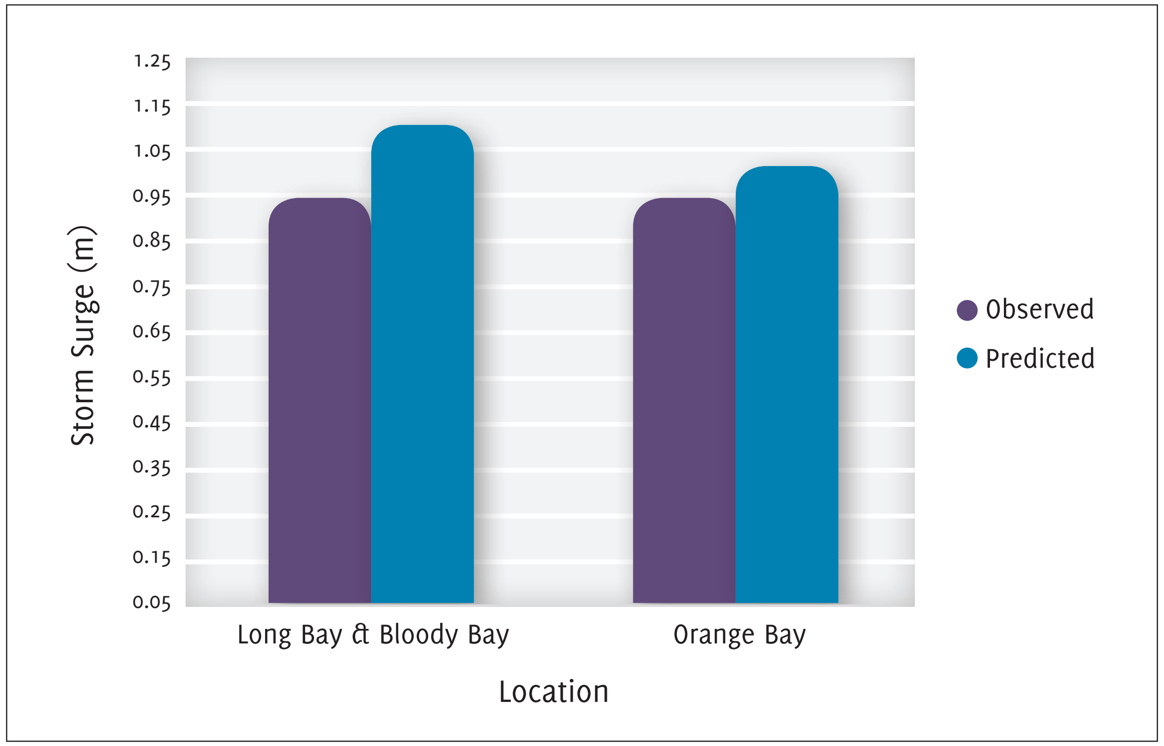



Figure 3.2: Validation of Storm Surge Model

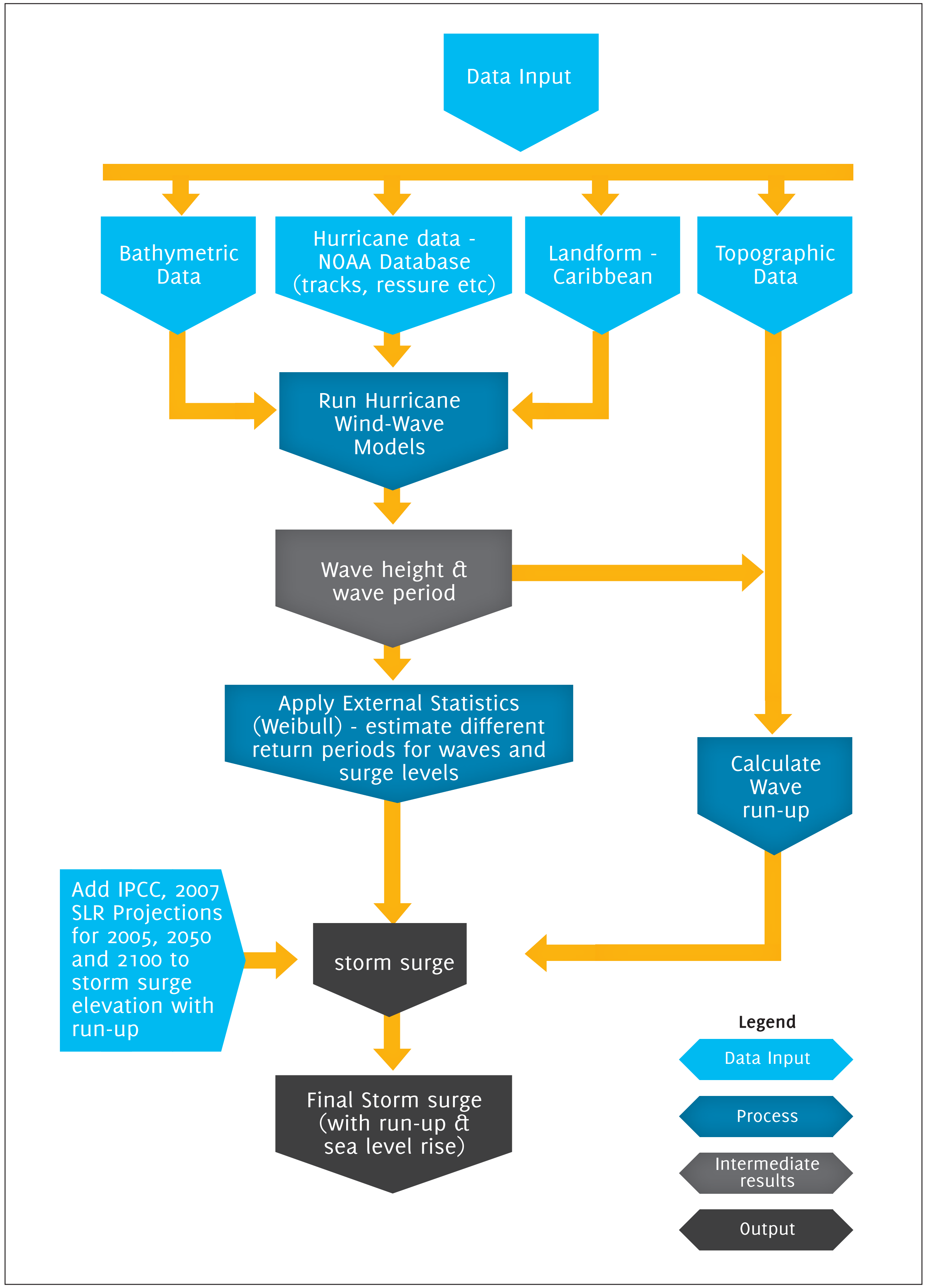



Figure 3.3: Flow Chart showing Storm Surge Methodology

# 3.1.1 Analysis of Storm Surge Hazard Assessment

The topography of Negril is such that storm surges can penetrate well inland from the coastline as shown in Maps 3.1–3.4. The predicted storm surge with run-up for the 10- 100 years return period is estimated to range from 0.880m to 1.270 m above mean sea level (Refer to Table 3.1). Wave run-up occurs when a wave breaks and the water is propelled onto the beach and land. The run up values represent the likely maximum topographic elevation storm surges will propagate inland from the coastline. Projections for climate change and sea level rise is expected to increase these values relative to current Mean Sea Level (See Table 3.4).

**Table 3.1: Predicted Storm Surge elevation without and with breakwater scenarios**

| Storm surge Return Period | Without Breakwaters Storm surge predictions with run-up (m) | With Breakwaters Storm surge predictions with run-up (m) |
|---|---|---|
| 10 - year | 0.880 | 0.83 |
| 25 - year | 1.046 | 0.98 |
| 50 - year | 1.159 | 1.08 |
| 100 - year | 1.270 | 1.20 |

Maps 3.1–3.4 shows the areal extent of flooding with water height expected to increase in the Great Morass for all storm surge scenarios. This large areal extent of flooding is likely to occur with storm surges penetrating the North and South Negril Rivers as well as the canal systems that drain to the Caribbean Sea. As such, propagation of surge through these waterway systems can reach far inland. Research has shown that storm surge penetrate approximately 10-15% more distance inland through the river systems, which is a general accepted assumption globally (Rao et al, 2007).

Recent research by Wei-Bo and Wen- Cheng (2014) also concluded that when storm surges occurred at the Tsengwen River mouth in Taiwan and meets the high water level in the river, the water cannot drain into the coastal ocean, resulting in severe flood inundation in the lowland region. They concluded that the extreme storm surge combined with high freshwater discharge increased the severity of the flooding. This conclusion can also be drawn for Negril given the results of the model.

Storm surge scenarios were further analyzed for all return periods taking into consideration the initially proposed offshore breakwaters, a structural mitigation intervention proposed under Component I of the programme. Under this component, two (2) partially submerged breakwaters are proposed to be located approximately 1.4 km offshore Long Bay. The north breakwater is proposed to be 500 m long whilst the south breakwater is to be 400m in length. The results of the analysis has shown that storm surge with run – up are expected to be reduced ranging from 0.83m to 1.20m after mitigation compared to the storm surge values without breakwater structures (Refer to Table 3.1).

# 3.2 Sea Level Rise (SLR)

Sea level rise at a particular location is a combination of the global rise in sea levels and local trends.The primary contributors to sea level change are the expansion of the ocean as it warms (thermal expansion) and the transfer of water currently stored on land to ocean, particularly from land ice [glaciers and ice sheets] (Church Et al, 2011). According to International Panel on Climate Change (IPCC), observations indicate that the largest increase in the storage of heat in the climate system over recent decades has been in the oceans and thus sea level rise from ocean warming is a central part of the Earth's response to increasing greenhouse gas (GHG) concentrations (IPCC, 2013).

The IPCC's Fourth Assessment Report (AR4), 2007 summarized a range of SLR projections under each of its standard scenarios, for which the combined range spans 0.18 - 0.56m [Avg. 0.37m] by 2100 relative to 1980-1999 levels (CARIBSAVE Climate Change Risk Atlas – Jamaica, 2011). From estimates of observed sea level rise from 1950 to 2000, the rise in the Caribbean appears to be near the global mean (Church et al 2004).

**Table 3.2: IPCC Fourth Assessment Report of SLR projections**

| Scenario* | Global Mean Sea Level Rise by 2100 relative to 1980 – 1999 | Caribbean Mean Sea Level Rise by 2100 relative to 1980 – 1999 (± 0.05m relative to global mean) |
|---|---|---|
| IPCC B1 | 0.18 – 0.38 | 0.13 – 0.43 |
| IPCC A1B | 0.21 – 0.48 | 0.16 – 0.53 |
| IPCC A2 | 0.23 – 0.51 | 0.18 – 0.56 |

*Source: IPCC AR4, Meehl et al, 2007a*

According to IPCC it is virtually certain that global mean sea level rise will continue beyond 2100, with sea level rise due to thermal expansion to continue for many centuries. The amount of longer term sea level rise depends on future emissions (IPCC, 2013).

## Methodology

For the assessment of SLR, the A2 scenario was chosen because it represents the worst case of all the emissions scenarios regarding the concentration of GHGs in the atmosphere associated with future global development patterns to the end of the century. IPCC's projection for average SLR by the year 2100 is 0.37m.

Three scenarios were selected to represent sea level rise projections for 2025, 2050 and 2100 (See Table 3.3). The values for 2025 and 2050 were calculated using IPCC's average rate of sea level rise per year of 0.0037m/yr. Having established rate of sea level rise per year, then a simple calculation was carried out to obtain values for 2025 and 2050.

**Table 3.3: Sea Level Rise Projections**

| SLR Scenarios | Sea Level Rise (m) Projections |
|---|---|
| 2025 | 0.093 |
| 2050 | 0.185 |
| 2100 | 0.370 |

**Note: At the time of preparation of this Atlas, the AR5 Report was not published and so the values for SLR could be higher*

In the calculation of future storm surges, sea level rise projections for 2025, 2050 and 2100 were added to current storm surge elevations to determine the maximum flooding and inundation levels. The following equation was used for calculation of future storm surges:

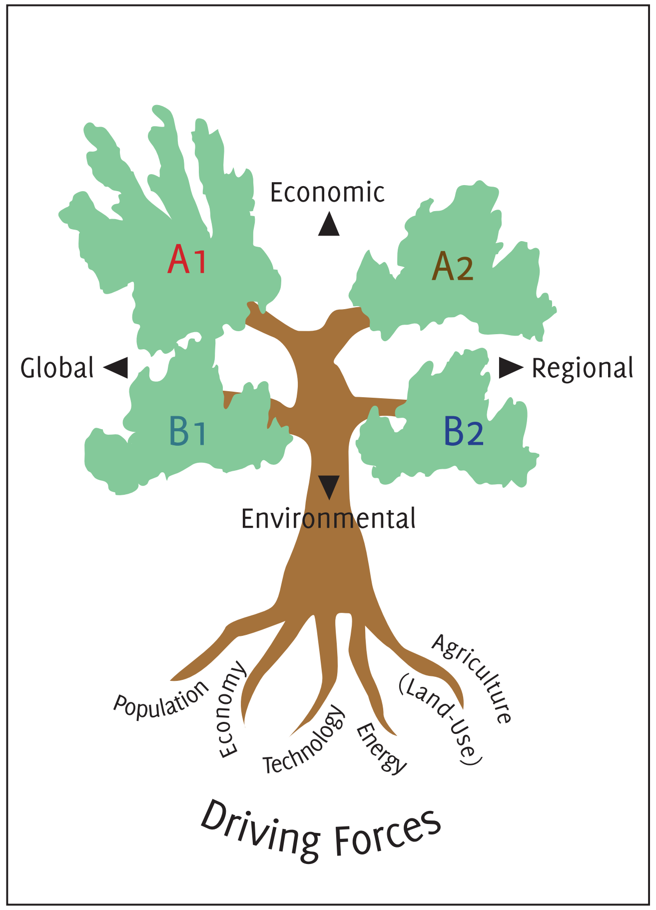
**Future storm surge = Projected SLR (e.g. [0.185m]) + current storm surge [25, 50 year RP]**

The methodology for sea level rise and determining future storm surge elevations in Negril for different storm events is shown below:

**IPCC Sea level projection for the period 2000-2100**
**0.37m/year (3.7mm)**

**Determine the interval in years SLR will be calculated: 2025, 2050, 2100**

**Add incrementally sea level rise for each scenario to storm surge depth**
**For e.g. 50x0.0037m + storm surge elevation**




To estimate future changes in climate some assumptions have to be made about what the future world might look like, especially with respect to the concentration of greenhouse gas (GHG) emissions that will be in the atmosphere. Future concentrations of GHGs will depend on multiple factors which may include changes in population, economic growth, energy use and technology. The Special Report on Emissions Scenarios (SRES) represents possible pathways for future GHG emissions premised on different storylines of change in the global development factors (Nakicenovic et al. 2000).

In all there are forty different scenarios divided into four families (A1, A2, B1, B2), each with an accompanying storyline which describes the relationships between future greenhouse gas emissions levels and driving forces.

The A-family or High-Emissions Scenarios describe a future world of very rapid economic growth, global population... The B-Family describes relatively Low Emissions Scenarios.

**Figure 3.4: Special Report on Emissions Scenarios (SRES)**

# 3.2.1 Analysis of Storm Surge and Sea Level Rise

In the analysis of future storm surges resulting from projected sea level rise, future coastal morphological changes (for example bathymetry and shore line) in Negril were not factored and so estimates may be conservative. In addition, at the time of preparation of this report, the AR Report was not published as so, the sea level rise values could be higher.

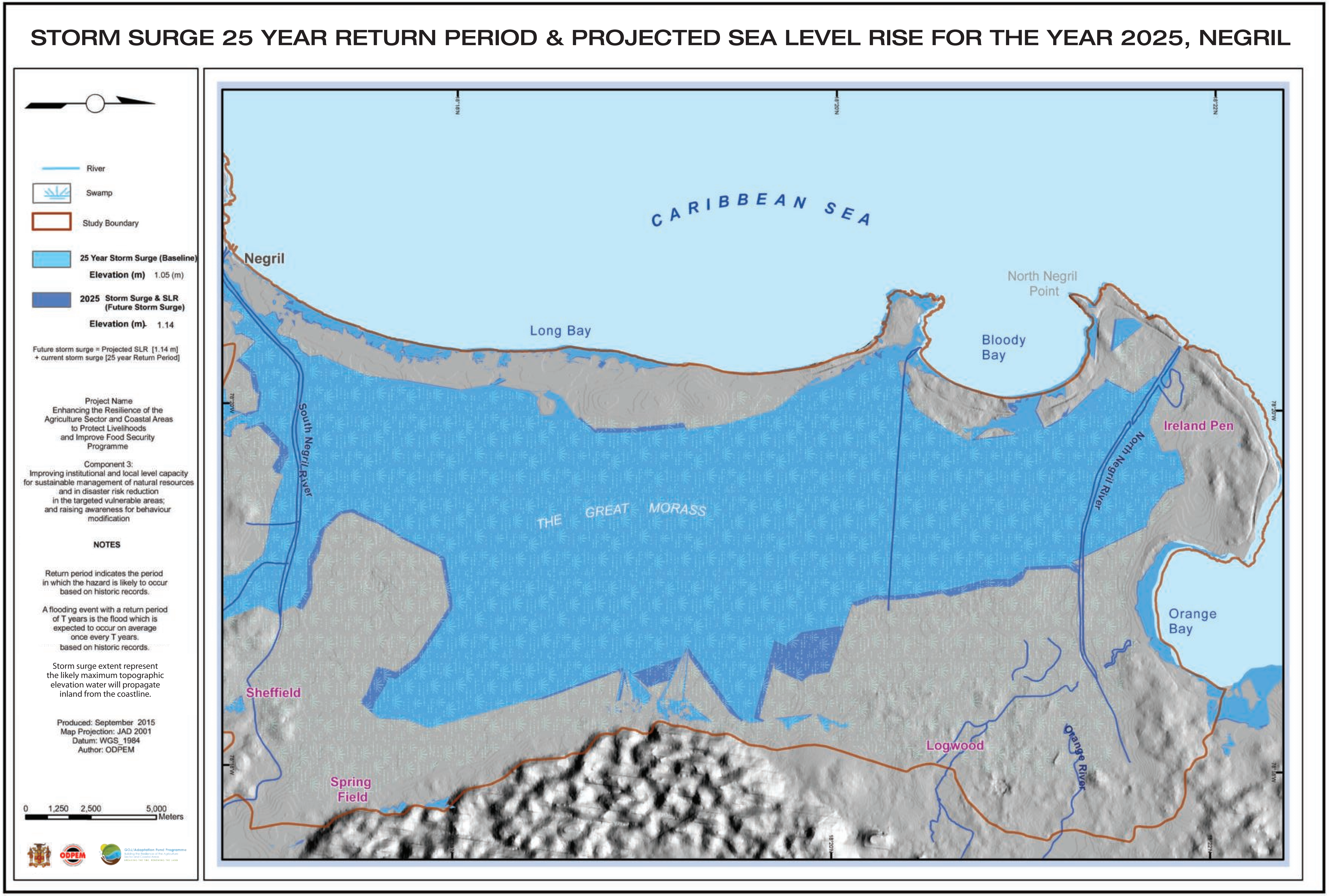
The results of the model as illustrated in Table 3.4 show that storm surge heights will be increased by the underlying rise in sea level moving from 0.880 to 1.270 m for current storm surge predictions for 10-100 return period to 1.25 to 1.64m by 2100. **It is important to highlight that the baseline 100 year storm surge elevation (1.3m) will be equivalent to the 10 year storm surge elevations under sea level rise conditions by year 2100.**

**Higher sea level provides storm surges with a higher "launch point" for the surge, which may increase both the real extent and the depth of the surge in areas already vulnerable to coastal storms** (Neumann et al, 2015). And so, as storm surges increase, they will create more damaging flood conditions in Negril as the waves propagate or move further inland as depicted. In addition, the areal extent of inundation will also increase threatening larger areas than in the past. In fact, **taking into account sea level rise, the potential inundation zone will increase by 29% by 2100 from current reference of the 1 –in-100 year storm surge** (Refer to Maps 3.1-3.4). **This means that 29% more land is likely to be affected by storm surges by the end of the century.**

**Table 3.4: Increase in Storm Surge elevation for Baseline and SLR scenarios**

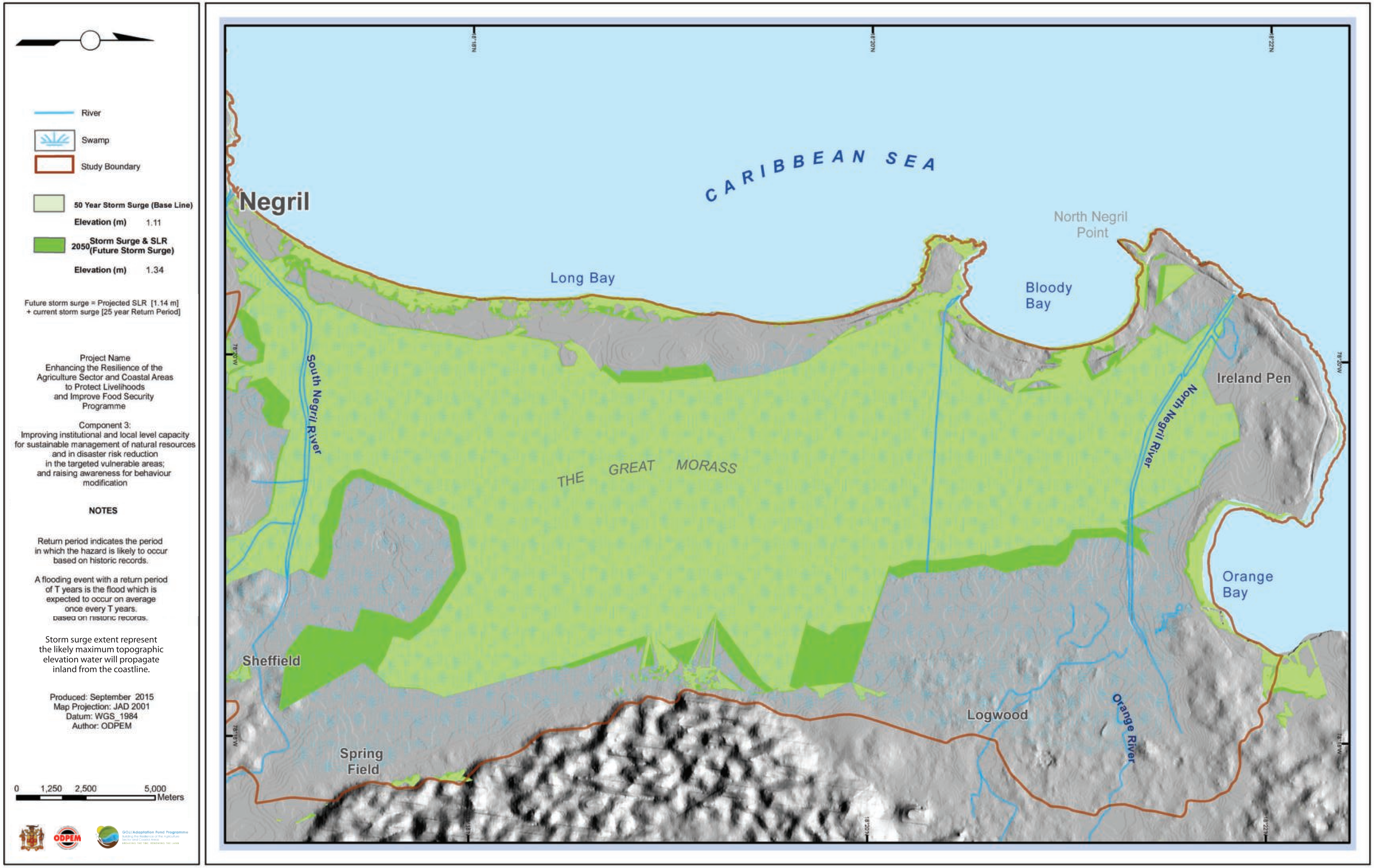
| Return Period | Storm surge Predictions (m) [Baseline] | Storm surge Predictions with SLR (m) | | |
|---|---|---|---|---|
| | | 2025 | 2050 | 2100 |
| 10 - year | 0.880 | 0.98 | 1.07 | 1.25 |
| 25 - year | 1.046 | 1.14 | 1.23 | 1.42 |
| 50 - year | 1.153 | 1.25 | 1.34 | 1.53 |
| 100 - year | 1.270 | 1.36 | 1.46 | 1.64 |

*Plate 3.1: Coastal vegetation in section of Long Bay*

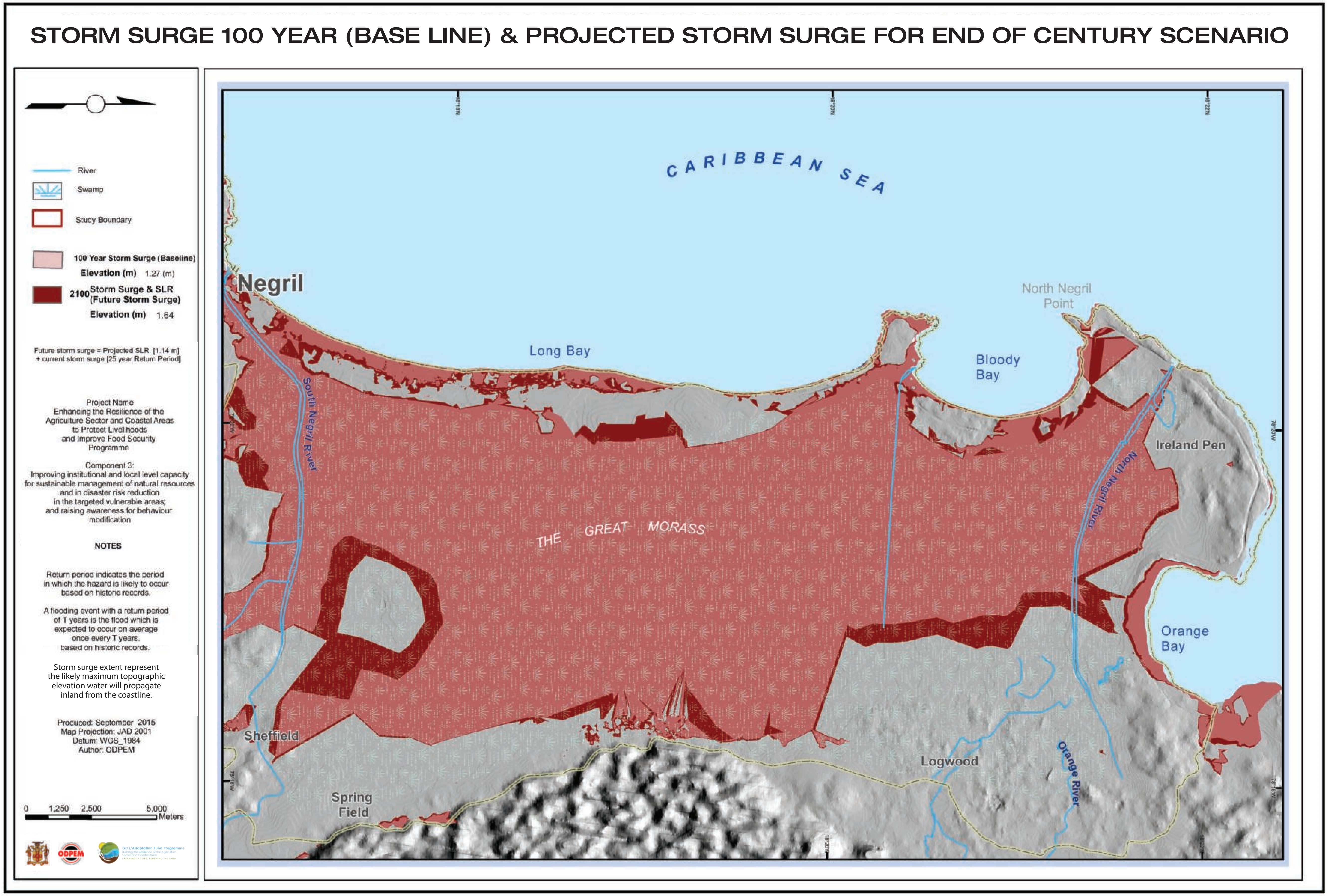



Map 3.1: Storm Surge 25 Year Return Period & Projected Sea Level Rise for the Year 2025, Negril

STORM SURGE 50 YEAR (BASE LINE) & PROJECTED STORM SURGE FOR MID CENTURY SCENARIO

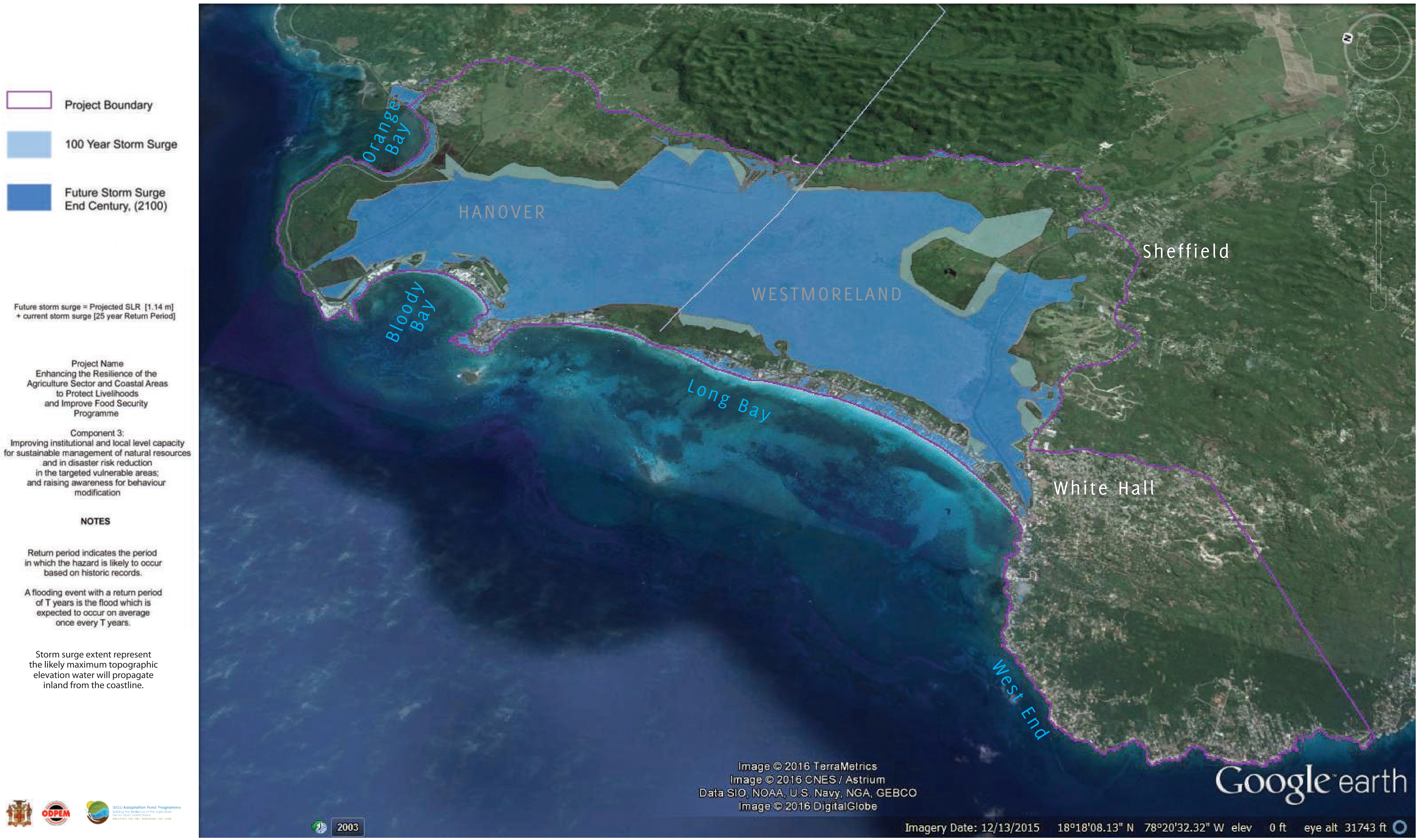



Map 3.2: Storm Surge 50 Year (Base Line) & Projected Storm Surge for mid century scenario




Map 3.3: Storm Surge 100 Year (Base Line) & Projected Storm Surge for end of century scenario

## STORM SURGE 100 YEAR (BASE LINE) & PROJECTED STORM SURGE FOR END OF CENTURY SCENARIO




Map 3.4: Storm Surge 100 Year (Base Line) & Projected Storm Surge for end of century scenario

# 3.3 Wave Overtopping Assessment

The morphological setting of West End is such that storm waves generally crash against the cliffs and are “lifted” or overtop the rocks. Wave overtopping refers to the volumetric rate at which wave run-up flows over the top or crest of a slope, be it a beach, dune or structure. Anecdotal information and technical assessments of the impact of extreme storm events on the Negril shoreline have revealed that along West End waves run up the face of the cliffs and overtop them.

## Methodology

The Technical Advisory Committee on Flood Defense in the Netherlands has published a manual that addresses Wave Run-up and Wave Overtopping of Dikes (2002).Similarly, publication by Wallingford (1999) on “*Wave Overtopping of Seawalls-Design and Assessment Manual*” presents guidance on analysis and/or prediction of wave overtopping.

Due to the steeply sloped cliffs along West End, in the order of 1:1, the approach to determining overtopping discharge for plain vertical walls was used.

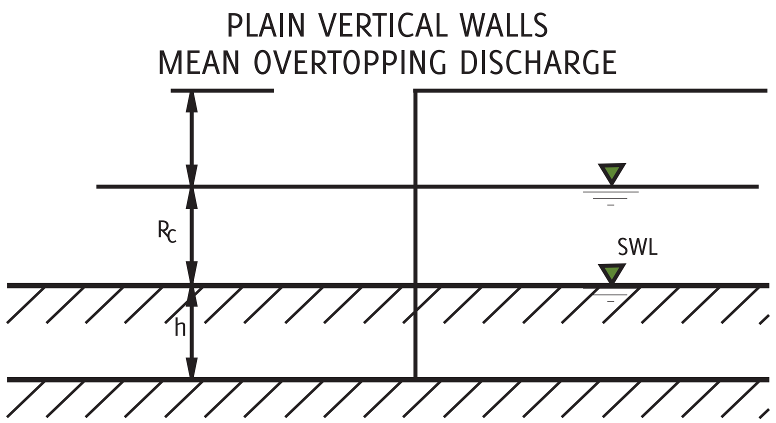



Figure 3.5: Plain vertical wall

NORMAL WAVE ATTACK
First calculate h* to determine whether the waves are predominantly impacting or reflecting.
The parameter h* is given by:-

$$h^* = (h/H_o)(2\pi h/(gT_m^2)) \qquad (22)$$

where h is the water depth at the toe of the structure (m)
$H_o$ is the significant wave height at the toe of the structure (m)
g is the acceleration due to gravity ($m/s^2$)

Reflecting waves predominate when $h^* > 0.3$, in which case the following equation applies:-

$$Q\# = 0.05 \exp(-2.78\, R_c/H_s) \qquad (23)$$

where Q# is the dimensionless discharge, given by $Q/(gH_s^3)^{0.5}$
Q is the main overtopping discharge rate per meter run of seawall ($m^3/s/m$)
$R_c$ is the freeboard (the height of the crest of the wall above still water level) (m)

Equation 23 is valid for $0.03 < R_c/H_o < 3.2$



# 3.3.1 Analysis of Wave Overtopping

Overtopping analysis was undertaken for 10-100 year storm surge return periods to determine the elevation at which waves can potentially impact assets in West End. To achieve this, the tolerable mean discharge had to be defined. Tolerable mean discharge is the overtopping discharge (peak volume of water) that can cause damage to buildings or infrastructure or danger to pedestrians and vehicles (Wallingford et al, 2007). In other words, it is the overtopping limit beyond which it becomes unsafe for the population and cause damage to buildings and infrastructure.

The overtopping limit used in the analysis for West End is 0.05m3/m/s as this is the value beyond which damage will start to occur (Wallingford’s Manual, 1999). To ascertain at which elevation the overtopping limit will be reached, the cliffs on West End were subdivided into three (3) categories as follows:

- i High cliffs - elevation greater than 10m,
- ii Moderate cliffs - elevation from 8 and 10m and
- iii Low cliffs - elevation below 8m.

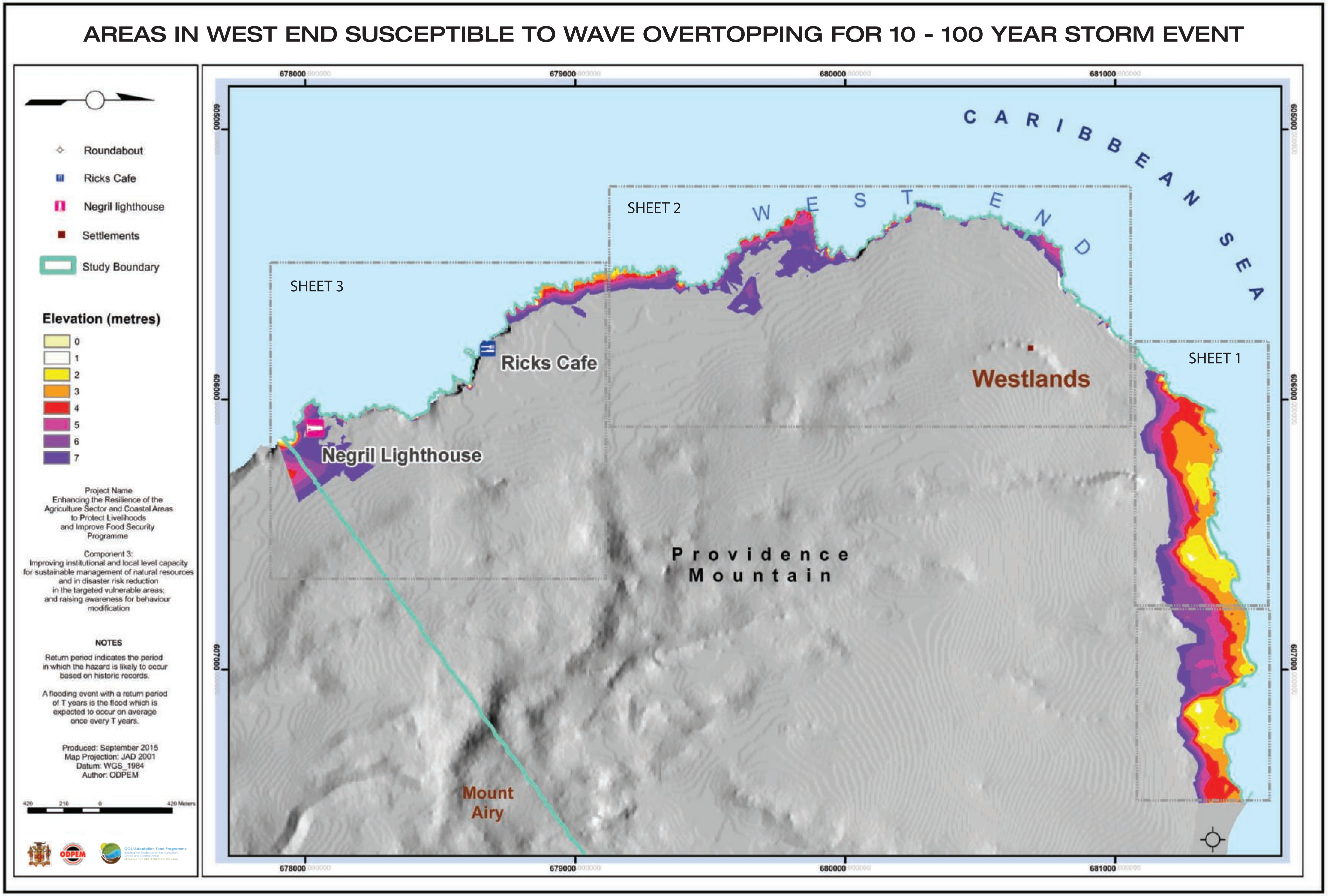
Overtopping estimates were determined for the 10, 25, 50 and 100 years storm surge scenarios. The results revealed that for areas classified as high cliffs, under all scenarios, the mean discharge is not sufficient to cause damage to buildings and properties as it is below the overtopping limit of 0.05m3/m/s. The same is true for moderate cliffs under the 10 and 25 year scenarios.

For those areas classified as low cliffs, for all storm surge scenarios, the mean discharge is more than the overtopping limit (Refer to Table 3.5) and so damage to buildings and other infrastructure can be anticipated within this zone. Similarly, the population within this zone is also at risk.

Table 3.5 below shows the mean discharge for wave overtopping along West End for all storm surge scenarios.

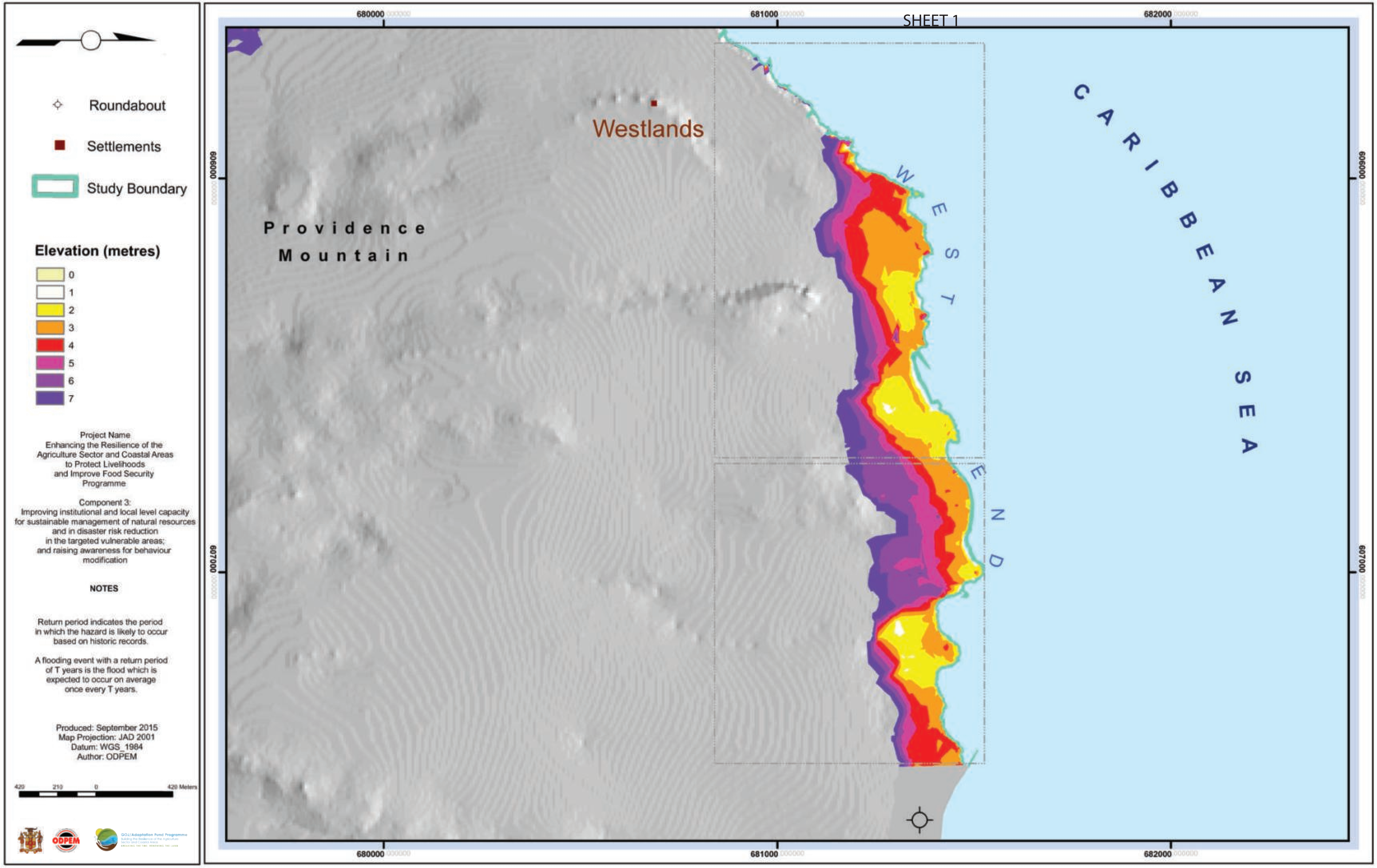
Table 3.5: Mean discharge for Wave Overtopping along West End

| Storm surge scenario | 10 Low cliffs | 25 Low cliffs | 50 Low cliffs | 100 Low cliffs |
|---|---|---|---|---|
| Hs (wave height at base of cliff) | 5.50 | 6.00 | 6.30 | 6.60 |
| Overtopping Calculations | | | | |
| h | 8 | 8 | 8 | 8 |
| h* | 0.051 | 0.102 | 0.091 | 0.084 |
| Freeboard (Distance of height of the crest of the cliff to still water level) | **7.00** | **7.00** | **7.00** | **7.00** |
| Tp (wave period) | 12.60 | 12.60 | 13.00 | 13.20 |
| Tm | 12.10 | 8.19 | 8.45 | 8.58 |
| Q | 0.059 | 0.090 | 0.113 | 0.139 |
| Criterion | 0.05 | 0.05 | 0.05 | 0.05 |

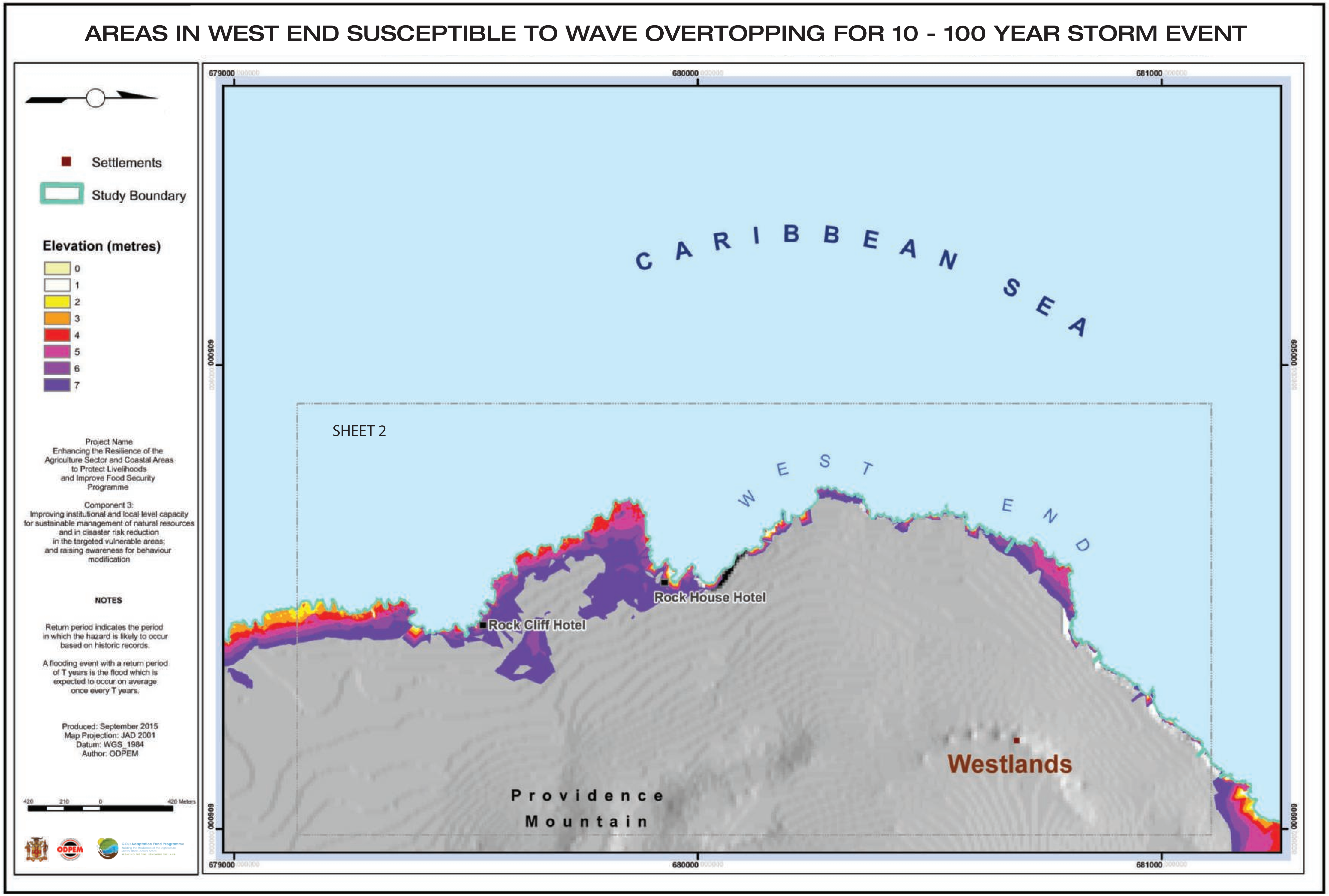



Map 3.5: Areas susceptible to wave overtopping - West End [10, 25, 50, 100 (yr)]

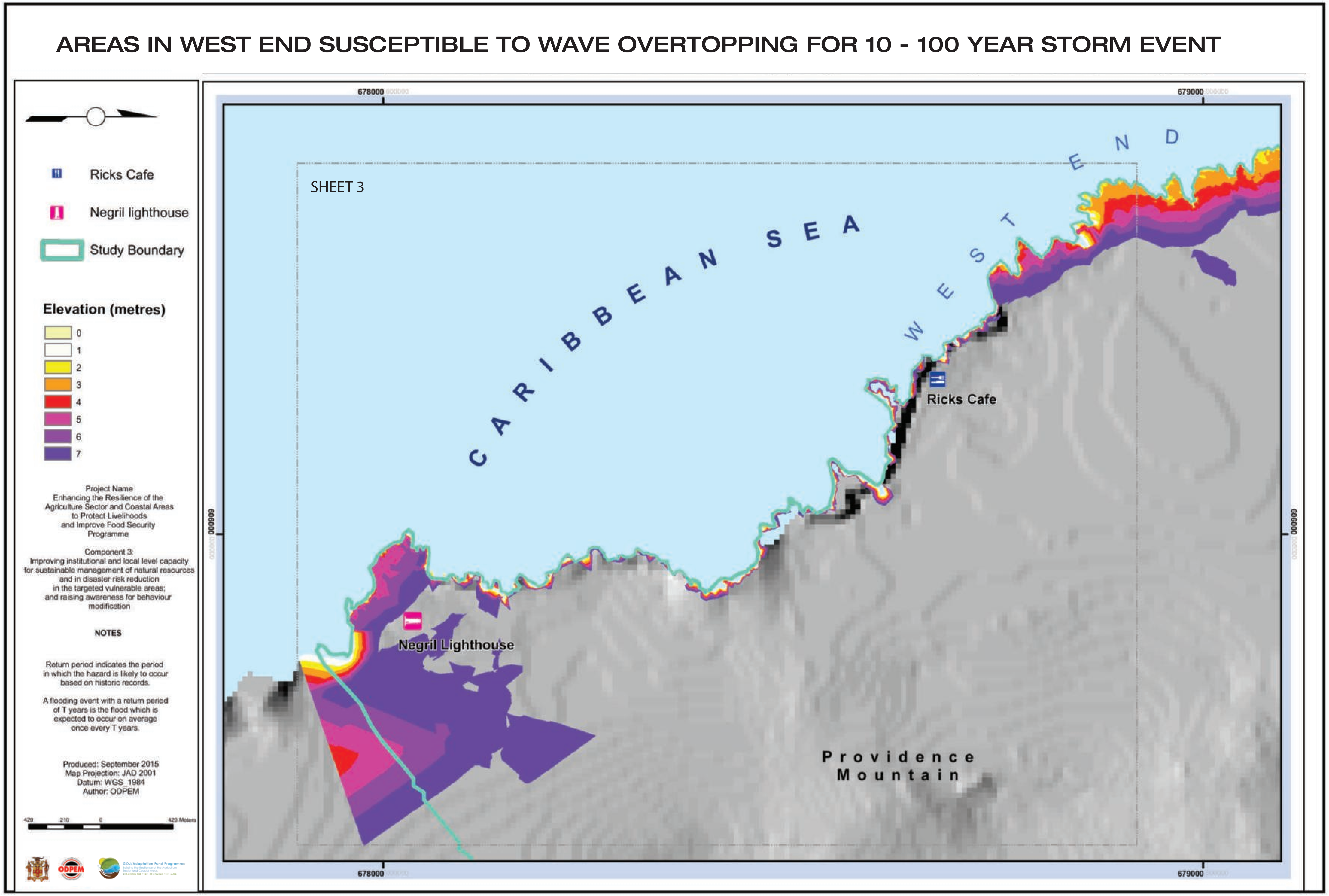
## AREAS IN WEST END SUSCEPTIBLE TO WAVE OVERTOPPING FOR 10 - 100 YEAR STORM EVENT




Map 3.6: Areas susceptible to wave overtopping - West End [10, 25, 50, 100 (yr)]




Map 3.7: Areas susceptible to wave overtopping - West End [10, 25, 50, 100 (yr)]




Map 3.8: Areas susceptible to wave overtopping - West End [10, 25, 50, 100 (yr)]

# 3.4 Coastal Erosion Hazard Assessment

Land erosion can be classified as either long term or short-term, depending on the time scale over which it occurs. Short term erosion refers to erosion that occurs over a period of days, rather than years, as a result of extreme weather events such as storms or hurricanes as well as Winter Northers in the case of Negril. Long term erosion on the other hand usually refers to a trend of erosion extending over several years and can be caused by a deficit in the annual sediment budget or in longshore transport rates along the beach.

Both short term and long term erosion hazard assessments were undertaken for Long Bay and Bloody but not for Orange Bay and West End due to morphology of the coastline with the former having wetlands/mangroves which protect the shoreline from erosion and the latter is a series of cliffs.

## 3.4.1 Short Term Erosion

### Methodology

#### Collection of Sediment and Grain Size

It was necessary to determine the representative grain size on the shoreline in order to assess and comprehend what effects hurricane waves will have on the coastline (beach). Sand samples were collected for analysis from both the beach face and back of the beach at 6 locations along the Negril shoreline. The grain size analysis was done using the Unified Soil Classification System (USCS) which is widely used for the classification of granular material for engineering and geological applications.

#### Define Nearshore Wave Climate

Deepwater wave climate offers a starting point in understanding the storm surge climate of the project area, especially as waves approach the coastline. As such, wave transformation modeling simulating the movement of waves from deepwater to the nearshore was undertaken to facilitate a better understanding of how waves will behave along the shoreline. This information allows for the identification of areas along the shoreline that is vulnerable to erosion from direct wave attack, and estimate the impact on structures in the area. At Long Bay the bathymetry changes greatly and the water depth at the shoreline approaches MSL, shoreline erosion is a common occurrence.

#### SBEACH (numerical model for simulating storm-induced beach change)

SBEACH modeling was carried out to estimate beach erosion due to storm waves and water levels in Long Bay and Bloody Bay. SBEACH is an empirically based numerical model for estimating beach and dune erosion due to storm waves and water levels. The magnitude of cross-shore sand transport is related to wave energy dissipation per unit water volume in the main portion of the surf zone. The direction of transport is dependent on deep water wave steepness and sediment fall speed. SBEACH is a short-term storm processes model and is intended for the estimation of beach profile response to storm events.

#### Wave Climate Input, Calibration and Verification

Profiles were cut from deep water to land up to a maximum elevation of approximately 2m above mean sea level, and a maximum depth of 45m spanning the entire project shoreline. This was done at three locations along Long Bay and one at Bloody Bay. The wave data corresponding to the 10, 25, 50 and 100 year storm events, Hurricane Ivan (2004) and to a swell event that took place in November 2006 were utilized in this modeling exercise. Hurricane Ivan was used to calibrate the model, and the November 2006 swell event used to verify the model results. The 10, 25, 50 and 100 year storm surge events were used to determine the beach response to the future wave climate. Table 3.5 shows the wave characteristics utilized in the model. Other input parameters included the sediment grain size on the beach face and storm duration.

Table 3.6: Input Parameters for Short-Term erosion analysis

| | Input Parameters | | |
|---|---|---|---|
| Storm surge RP | Hs (m) | Tp (s) | Wind Speed (m/s) |
| 10 year | 5.5 | 12.1 | 25.8 |
| 25 year | 6.0 | 12.6 | 31.0 |
| 50 year | 6.3 | 13.0 | 34.7 |
| 100 year | 6.6 | 13.2 | 38.4 |
| Hurricane Ivan | 6.0 | 10.7 | 41.1 |

### 3.4.1.1 Analysis of Short-term Erosion

Storm events from the west, south west and northwest were investigated in the model for the 10 to 100 year return periods. The erosion vulnerability of the shoreline for all the locations along each profile were averaged and summarized in Table 3.6 for all scenarios.

The results show that the northern section of Long Bay is most vulnerable to shoreline erosion, followed by the central section. The average distance of erosion from the shoreline inland is approximately 67m, 45m and 38m, for Long Bay's northern, central and southern sections, respectively for the 100 year storm event.

For Bloody Bay no shoreline erosion was observed for the 10 to 100 year return period scenarios. Similar results were obtained for the alongshore sediment transport analysis carried out in the following section of the report.

**The Winter Swell Event in November 2006 further highlights the vulnerability of Negril's coastline to short term erosion. According to Smith Warner, 2006 the swell waves an waves attributed to hurricane and tropical storms are responsible for the off-shore transport of sediment, resulting in loss of beach [in Negril], in southern Long Bay for example, a layer of sand almost 1m thick was eroded from the beach during the winter swell event (Smith-Warner, 2006).**

Coastal erosion scenarios were further analyzed taking into account the initially proposed breakwaters offshore Long Bay to reduce the exposure of the shoreline and slow the rate of beach erosion. The estimated average shoreline erosion along the entire bay is 41m for all storm surge periods combined. When the breakwaters were implemented the average beach erosion was reduced by 31m for the same period. The results of the model show that the breakwaters would considerably reduce the erosion in the central section of the bay, followed by the northern section (See Map 4.41).

**Table 3.7: Predicted erosion for As-Is and Breakwater scenarios**

| Location | Predicted Erosion (As-Is) | | | | Predicted Erosion (with Breakwater) | | | |
|---|---|---|---|---|---|---|---|---|
| | 10 year | 25 year | 50 year | 100 year | 10 year | 25 year | 50 year | 100 year |
| Long Bay North | 29 | 49 | 61 | 67 | 29 | 49 | 61 | 61 |
| Long Bay Central | 37 | 37 | 45 | 45 | None observed | | | |
| Long Bay South | 27 | 27 | 31 | 38 | 26 | 27 | 57 | 64 |
| Bloody Bay | None observed | | | | None observed | | | |

# 3.4.2 Long Term Erosion

## Methodology

Long term shoreline change was determined from 1968 to 2013 from the shoreline positions along the Long Bay Beach and compared in order to determine the spatial and temporal erosion trends. This was important in order to identify the high risk areas that are erosion hotspots and in order to verify the wave transformation modelling. The overall long-term erosion trend was estimated by assessing:

1. Estimated long-term shoreline positions from aerial photography and satellite imagery in a historical Shoreline Analysis;
2. The effects of global sea level rise on long term erosion trends that were due to chronic global trends using the Bruun rule.

## Historical Shoreline Analysis

The observed shoreline from Satellite and aerial imagery for the years 1968, 1991, 1999 and 2005 was used for this analysis. The most recent (September 2013) shoreline position was marked manually by walking the beach and taking GPS points. The shoreline movement was analyzed by measuring and noting the displacements of the shoreline at intervals of 500 and 100m along the shoreline for Long Bay and Bloody Bay, respectively. The rates of accretion and or erosion between the time intervals were determined using the following relationships:

$$E_y^1 = \frac{D}{N}$$ EQUATION 1

, where

E – the rate of erosion or accretion between two successive intervals (metres per year)

D – the displacement between two intervals (metres)

N – the number of years between two successive intervals (years), and

$$E_y^0 = \frac{D_T}{N_T}$$

, where

E y – the rate of erosion or accretion from the datum year to the final interval

DT – the displacement from the datum to the final interval

NT – the number of years from datum year to final interval

## Bruun Model

The Bruun model (Bruun 1983 & 1988) is perhaps the best-known and most commonly used model that relates shoreline retreat to sea level rise. It is a two-dimensional model which assumes an equilibrium profile in that the volume of sediment deposited is equal to that eroded from the dunes and that the rise in the nearshore bottom as a result of the deposited sediment is equal to the rise in sea level. The model is not without criticism for its simplicity but remains the most commonly used means of estimating the impact of rising sea levels on shoreline retreat (Dubois, 1975; Cooper & Pilkey, 2004).The original Bruun model is expressed below and this mathematical relationship was the basis for estimating shoreline retreat within the study area.

$$\Delta y = \frac{\Delta s \cdot l^*}{h^*}$$ EQUATION 2

, where

- y – Dune line erosion (meter s/ year)
- s – Rate of sea level rise (meter s/ year)

l* – Length of the offshore profile out to a supposed depth, h*, of the limit of material exchange from the beach and the offshore (meters)

h* – Depth at offshore limit, l*, to which near shore sediments exist (as opposed to finer-grained continental shelf sediments) (meters)

### 3.4.2.1 Analysis of Long Term Erosion

Historical shoreline analysis results show that there is a general trend of erosion occurring from 1968 to 2013 (See maps 3.9 - 3.13) for Long Bay and Bloody Bay. Smith-Warner, 2006 report also concluded that aerial and satellite image comparison demonstrates a trend of general retreat along the entire Negril Coast line.

For Long Bay some accretion was observed between 1999 and 2005 as well as between 2005 and 2013. An overall erosion rate between 0.2 and 1.4 m/year was observed. Over the past 45 years, approximately 62.6 meters of erosion has occurred along Long Bay based on the observation of historical aerial and satellite images of the area. These results also show that the central section of

Long Bay is the most vulnerable to long term as well as short term erosion. This is supported by the studies done by Smith Warner International Limited, 2007 and RIVAMP, 2010.

For Bloody Bay, an overall rate of erosion between 0.2 and 0.8 m/yr was observed for the same period. The greatest erosion took place between 2003 and 2009, following the passage of Hurricanes Ivan (2004), Wilma (2004) and Dean (2007) which eroded the Negril shoreline. Accretion was observed between 2009 and 2013, where there was a reduction in the number of extreme storms affecting the western side of the island, and in turn, the project boundary. The rate of accretion varied between 0.6 and 4.5 m/yr over the period.

Having analyzed the historical movements in the shoreline, the Bruun Model was used to estimate the projected shoreline retreat resulting from sea level rise for 2025 and 2050. The following input values were used in Equation 2.

- Rate of sea-level rise = 3.7 mm/yr (IPCC, 2007)
- Depth to which near shore sediment exists (h *, dc) = 2.56 m

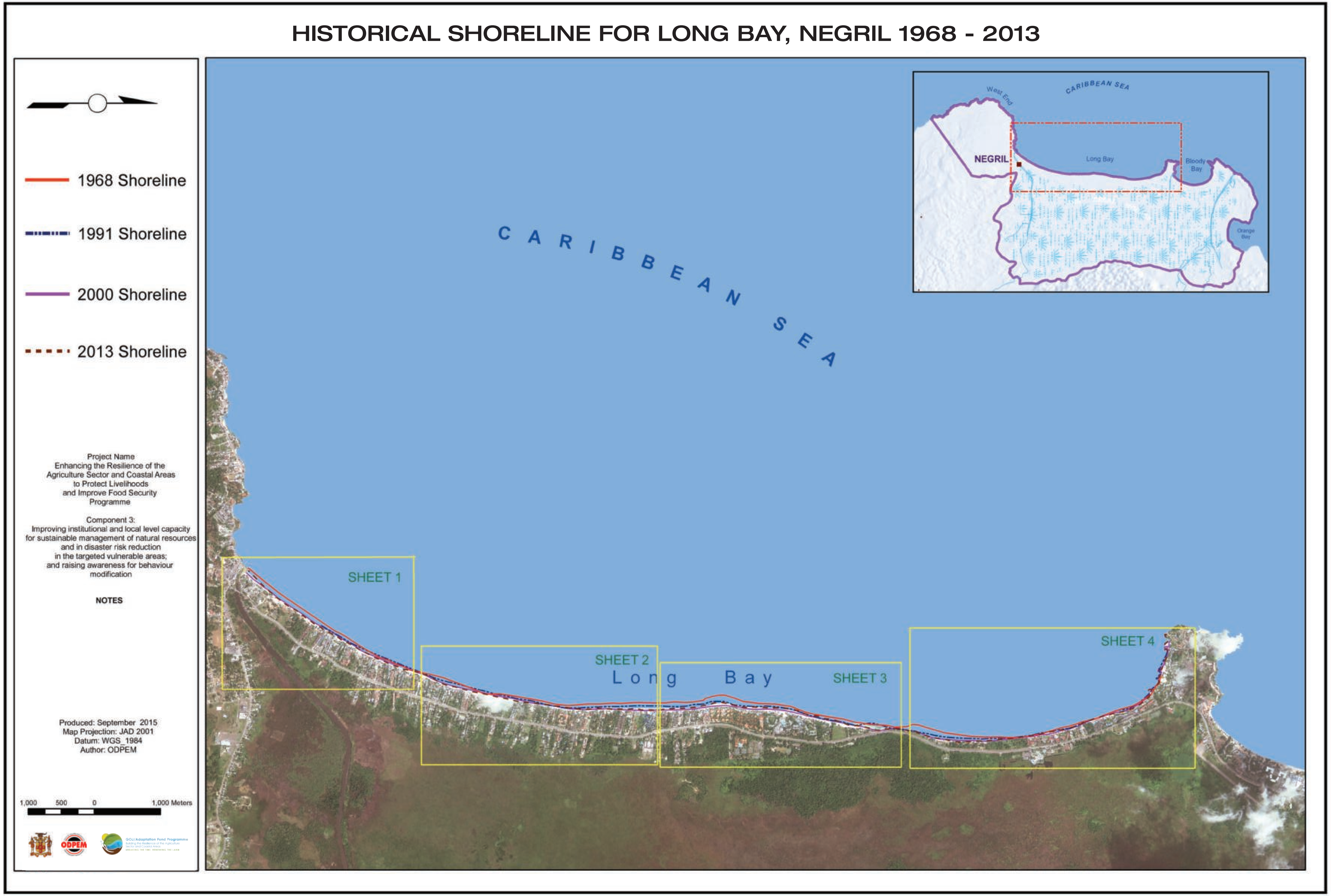
**For Long Bay, the shoreline was estimated to retreat at varying rates between 0.3 and 1.1 metres per year as a result of sea level rise. The southern section of Long Bay is expected to experience the largest rate of erosion of 1.1 m/yr, whilst the central and northern profiles have erosion rates between 0.30m/yr to 0.43 m/yr. Projected shoreline retreat for Bloody Bay is estimated to retreat at 0.3 m/yr which is less than projections for Long Bay.**

Further analysis of future shoreline projections was simulated using wave data for the period 2000 through 2006 for both Long Bay and Bloody Bay. The results of the simulation show that approximately 92% of the beach planform in Long Bay will be eroded with a total volumetric loss of approximately 114,000 $m^3$ over 7 year period. The analysis further revealed that the central and northern sections of the shoreline are most vulnerable to erosion with widths of 30m and 90m, respectively. The average erosion along the shoreline is predicted to be 27m in width. The alongshore model prediction are indicative of trends in erosion that are currently being observed and likely to continue if same waves heights are experienced in the future.

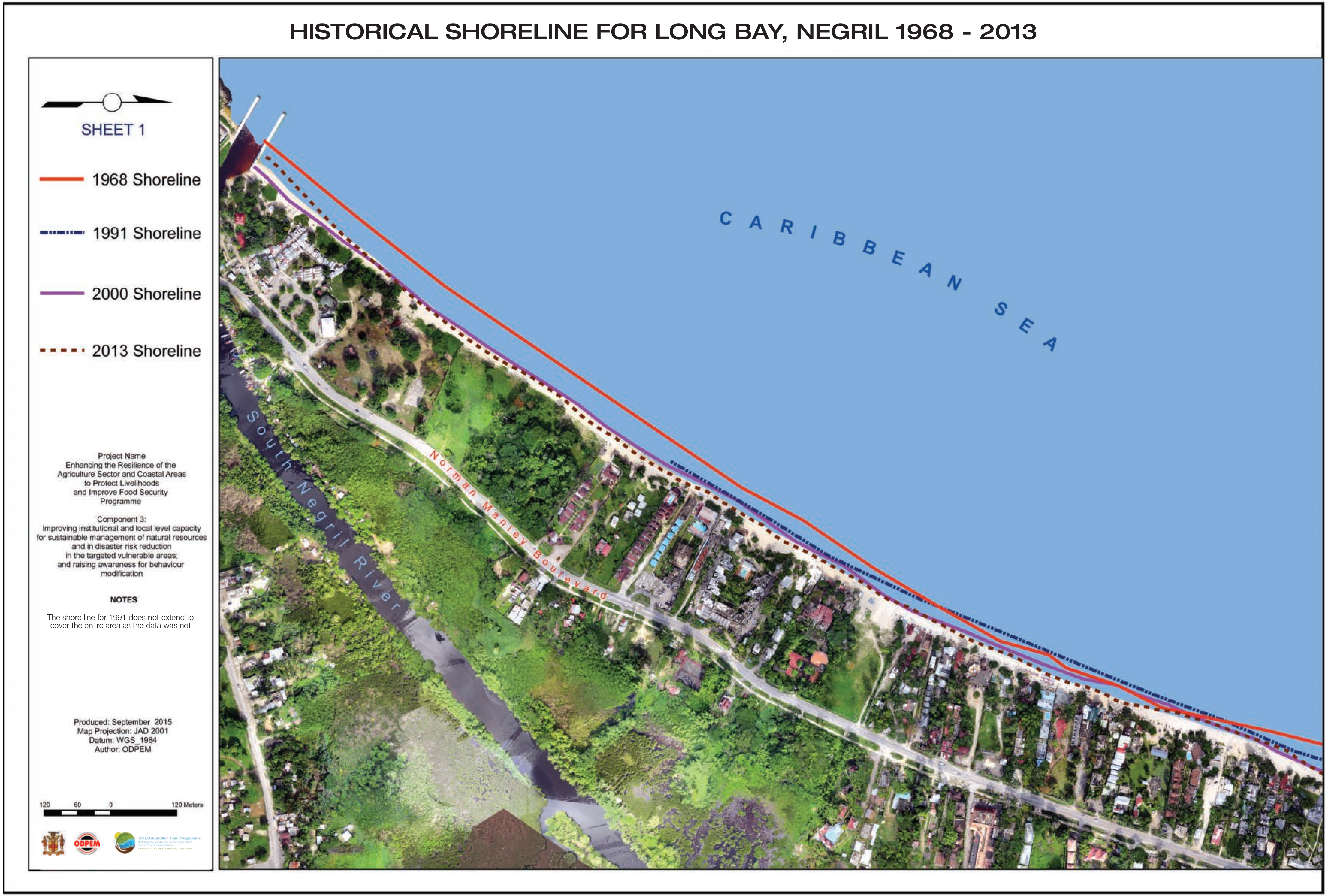
For Bloody Bay, only 10% of the beach is expected to be eroded for the over the same 7 year simulation period with a total volumetric loss of approximately 501 $m^3$. This erosion volume is quite minimal compared to Long Bay.

Having established future shoreline changes for Negril, further analysis was undertaken with the implementation of offshore breakwaters. When these breakwaters are implemented, for the said 7 years of simulation, accretion (or beach growth) and beach stability particularly in the sections of the beach most vulnerable to alongshore erosion will result. The analysis of the model shows that over 80% of the shoreline experienced accretion with the breakwaters in place (See Map 4.40). Most of the growth occurred at the northern section of Long Bay with a maximum predicted growth of 41.7m in beach width and 109,400 $m^3$ volumetric gain.

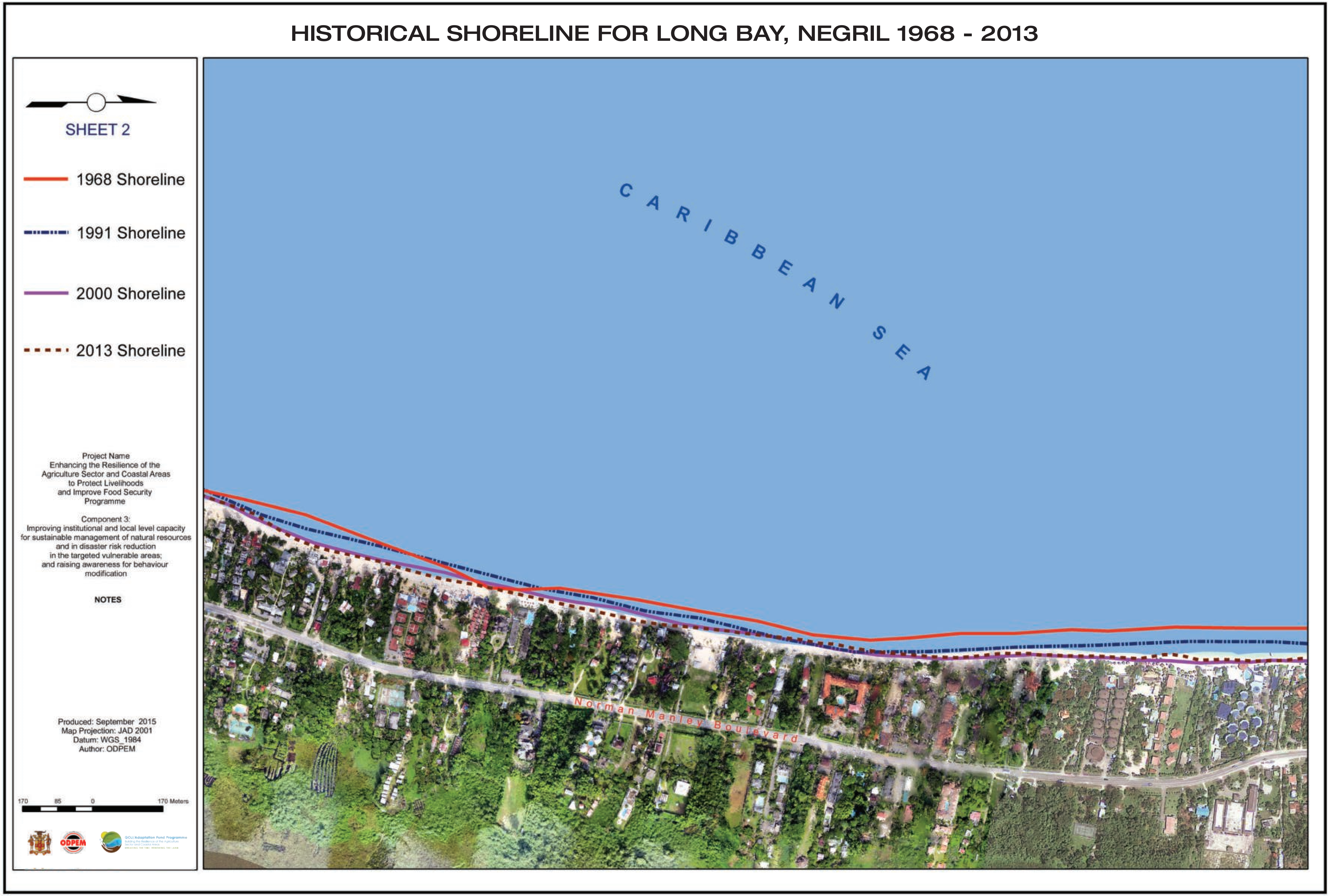
*Plate 3.2: Erosion in Long Bay and deposition of Sargassum Sp. along the shoreline.*



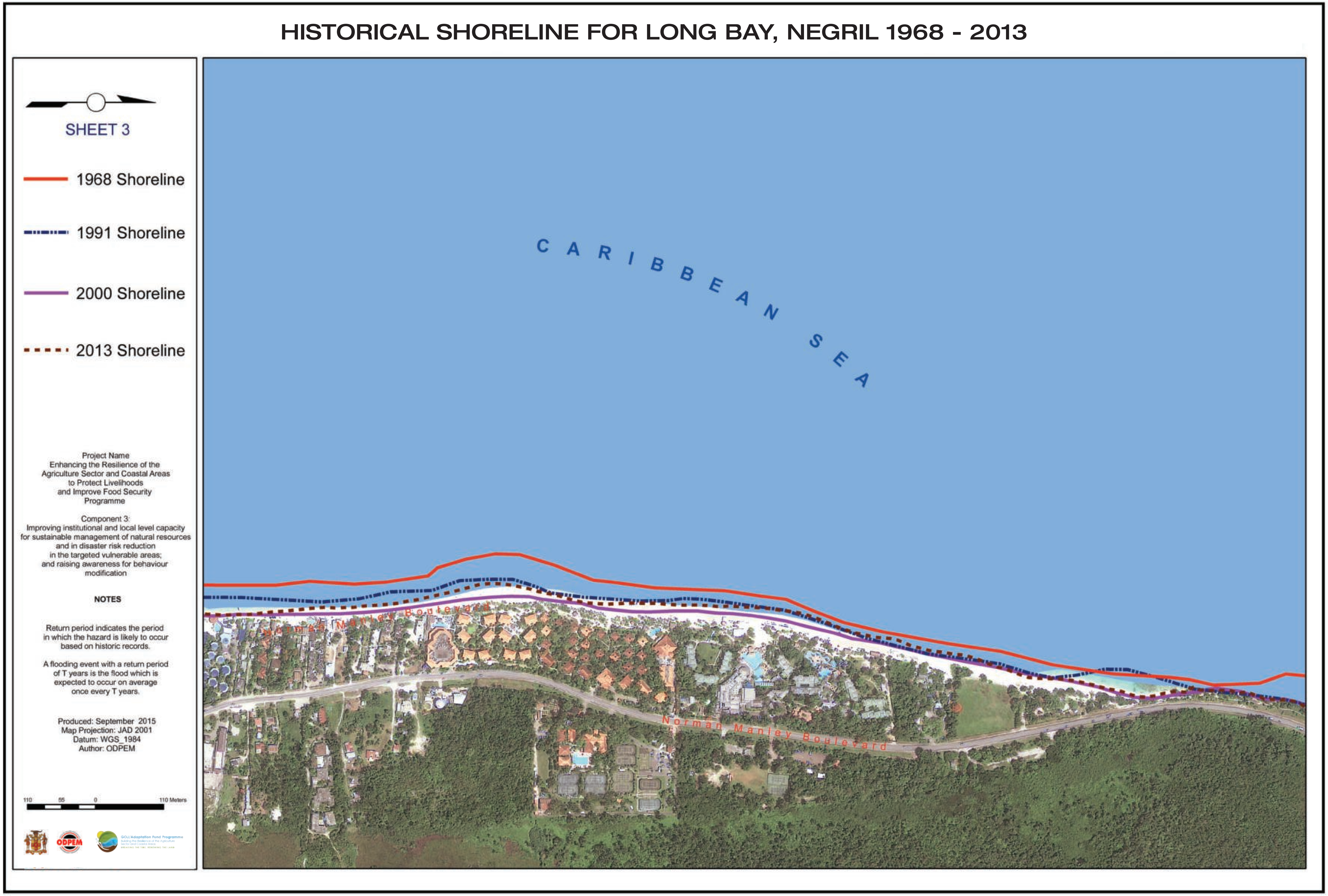

Map 3.9: HIstorical shoreline for Long Bay, Negril 1968 - 2013



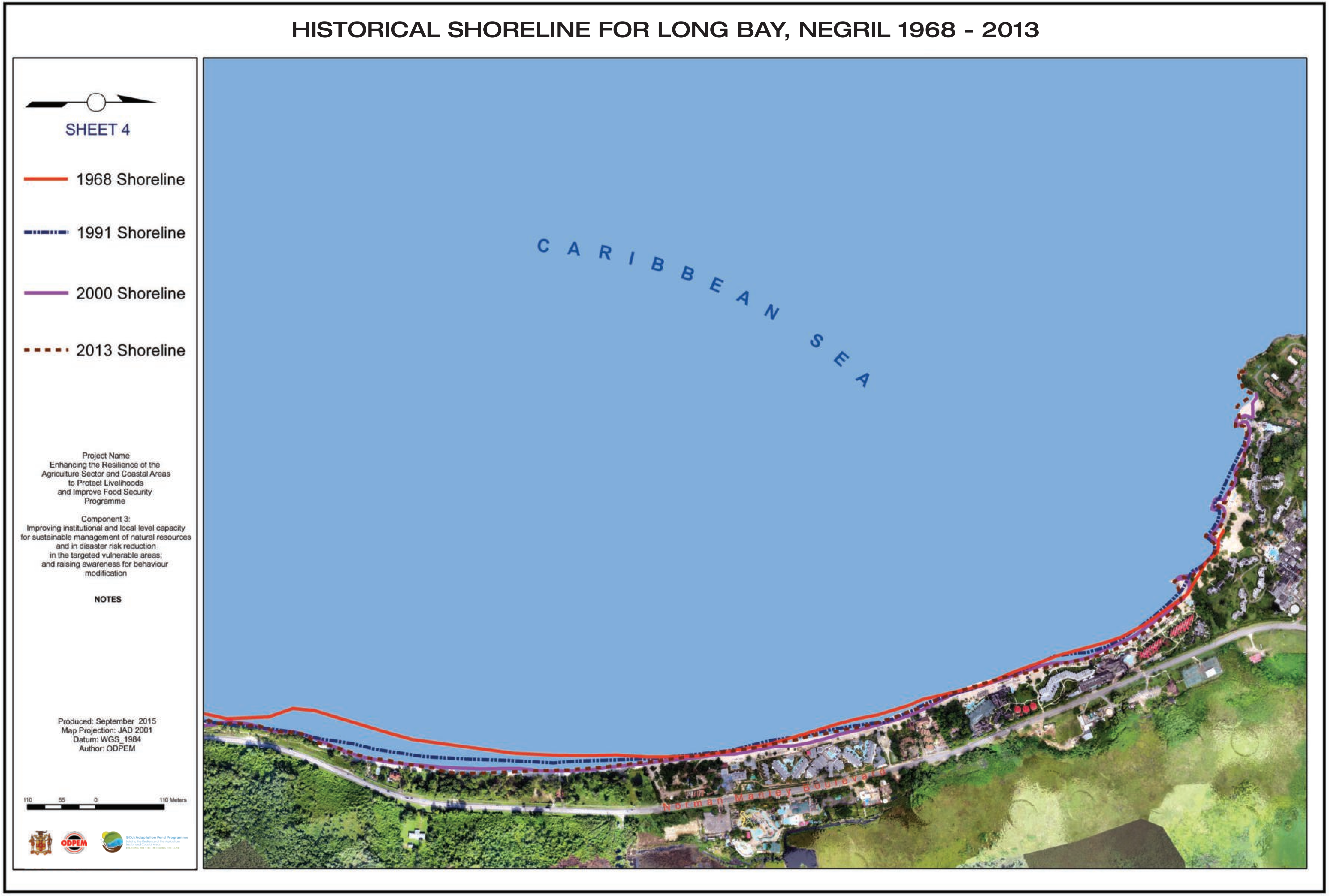

Map 3.10: HIstorical shoreline for Long Bay, Negril 1968 - 2013




Map 3.11: HIstorical shoreline for Long Bay, Negril 1968 - 2013




Map 3.12: HIstorical shoreline for Long Bay, Negril 1968 - 2013




Map 3.13: HIstorical shoreline for Long Bay, Negril 1968 - 2013


Plate 3.3: West End, Negril

4

# Vulnerability Assessment

4.0

## 4.1 Multi-temporal Analysis

To fully understand the changes that have taken place in Negril and how these changes may have impacted the natural and built environment a multi-temporal analysis was undertaken using historical data. A multi-temporal analysis is a method used to detect changes by comparing and analysing historic data and current data across multiple time periods. The data used for this analysis were for four time periods:

- 1941
- 1968
- 1999
- 2014

Each set of imagery was observed and changes in the built environment (houses, roadways, agriculture infrastructure, etc), and natural environment (swamp, beach, vegetation cover) noted for each time period. To facilitate analysis, building footprints for each time period were digitized in GIS and comparisons made.

In an attempt to identify the causes of the changes observed, the findings of the multi-temporal analysis were analysed with that of the literature review. Development changes were associated with observed changes to reasonably determine the development policies and strategic direction that drove the changes.

The multi-temporal analysis is useful in helping to understand:

- Changes in the natural environment that may have contributed to the current vulnerability issues in Negril
- Development patterns and landuse planning issues
- Possible solutions that maybe required given development trends
- Possible future outcomes and vulnerability issues if current development pattern persists

### Summary of key findings

- As the built environment expanded (hotels, residences, road and agriculture infrastructure), the environment declined, evidenced by reduced forest cover, beach loss and encroachment into the Negril morass
- The changes began in 1968 and coincide with the post-independence period when the government embarked on a strategy of tourism development, Negril being a key target area.
- There is an inverse relationship between the built environment and the natural environment. As the built environment expanded, the natural environment declined
- As the environment declines and the assets or built environment expands, the vulnerability increases

**1941**

Negril can be considered virgin territory with little evidence of development. Houses are extremely sparse and road network are mainly footpaths and parochial roads. Natural environment is pristine

**1968**

Clear evidence of development with new and enhanced road infrastructure, realignment of river, expansion of agriculture and agriculture infrastructure. Land clearance and encroachment into morass noticeable. Emergence of buildings though density is low.

**1999**

Drastic changes in the built environment. Major increase in the building concentration including hotels and residential developments in all communities in the study area. Similarly noticeable increase in infrastructure (sewage plants, road networks) which became denser and more organized. Very noticeable changes in natural environment to include encroachment in to the Negril morass, loss of forest cover, beach erosion and agriculture in the morass.

**2014**

Hotels and resorts dominate the 7 mile beach strip. Significant loss of vegetation is noticeable in Westland Mountain and other areas to make way for buildings and infrastructure. Loss of white sand beach and vegetation are observed along the strip and widening of major arterial roadway.

**Figure 4.1: Multi-temporal change for Negril for period 1941 - 2014**

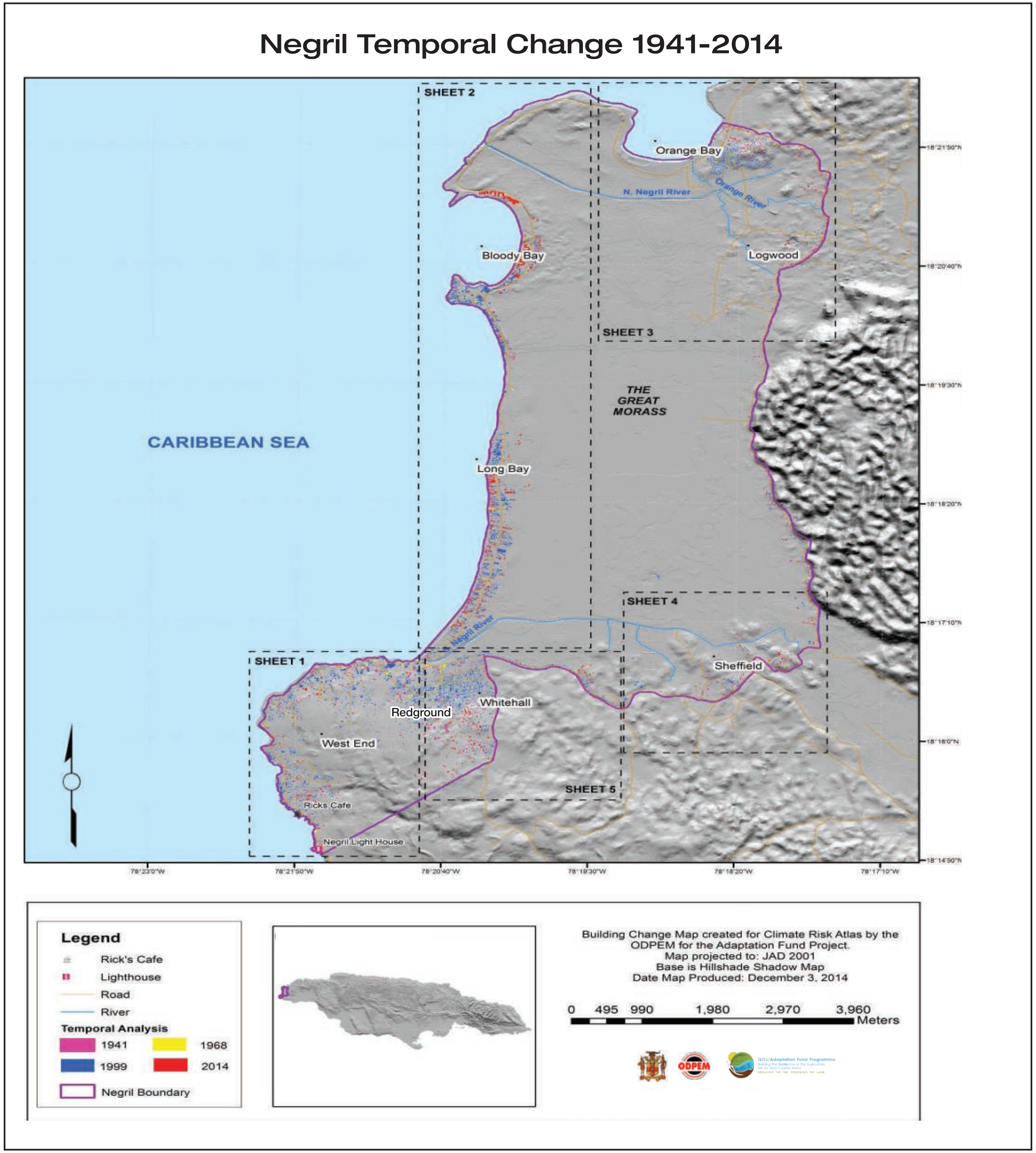
**Table 4.1: Change in building footprint for period 1941 - 2014**

| Period (Yrs) | ~ No. of Building Footprints | % change in Building Footprint |
|---|---|---|
| 1941 | 161 | - |
| 1968 | 420 | 160.87 |
| 1999 | 5213 | 1141.19 |
| 2014 | 8806 | 68.92 |

## Findings from RiVAMP, 2013 study:

- 1968 – 2009 - Significant vegetation clearance, approximately 6.23% change in area covered by broad leafed forest
- 1999 – 2009 - 66.94% beach loss over this 10 year period
- 1999 – 2009 - Overall decline of fields; herbaceous crops, fallow and cultivated vegetables. (RiVamp, 2013) reports a -45.21 % of area loss
- 1968-2009 - Buildings and other infrastructure increased by 30.30 %

*Plate 4.1: Negril Craft Market*




Map 4.1: Negril Temporal Change 1941-2014

Results from the multi-temporal analysis, showing changes in the study area over four time periods, have shown that for most of the 1900s Negril remained a sparsely inhabited coastal village which was situated on the islands' remote west coast and separated by an extensive wetland called the Great Morass (Rhiney, 2012). By the 1960's efforts to develop Negril as a tourist destination materialized starting with some much needed infrastructure investment with the construction of an all-weather surfaced highway (Lalor, 1980). This growth in the built environment may be attributed to the impetus of Jamaican government in the period leading up to independence in 1962, to diversify the economy with tourism as a major post war development strategy (cf. Jamaica Tourism Development Board, 1945). Resultantly, **the period that recorded the greatest growth was the period 1968-1999 evidenced by a tremendous increase in building** density particularly along the coast in West End and Long Bay and Bloody Bay.

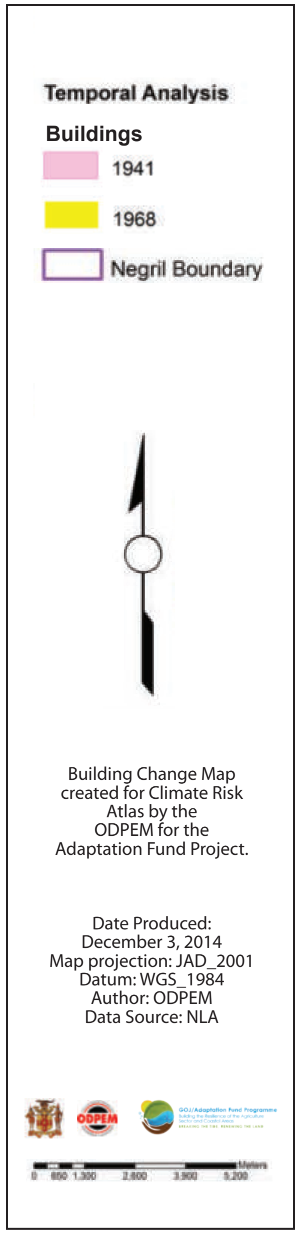
West End experienced a steady increase in infrastructure between the years 1941 – 1968, then showed significant developmental changes for the period 1999 to 2014. A similar trend was noted for the Long and Bloody Bay area which showed a steady increase in building density over the past 6 decades with buildings now concentrated on the previous pristine and unoccupied sand dunes. Changes in Orange Bay mainly occurred to the North East with conversion of agricultural lands for residential use.

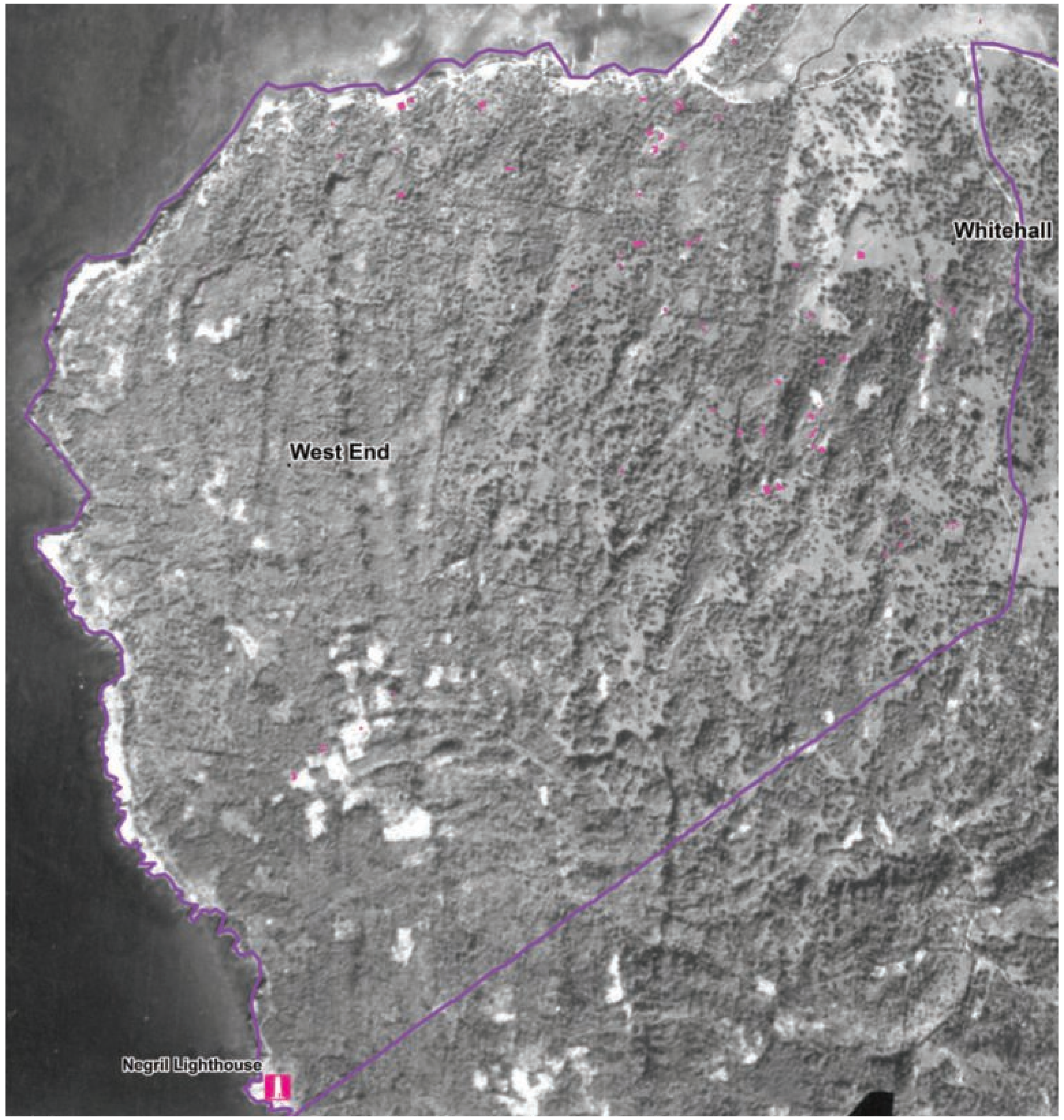
The greatest change for the Whitehall/ Red Ground area is the period 1968-1999. The area with least infrastructural and building development growth occurred in Sheffield.

Trends in land cover change also significantly affected the natural environment with significant losses of mangrove forest and wetland of 8.90% and 2.79%, respectively (RiVAMP II). By 2014, Negril was transformed from the once sparsely inhabited coastal village in 1941 to a densely populated tourism resort area. In 2012 Negril hosted an estimated 375, 396 stopover visitors, representing approximately 20.8 percent of Jamaica's total number of stop-over arrivals (Jamaica Tourist Board, 2012). The town has continued to experience remarkable growth in its visitor accommodation sub-sector which is reflected annually. Between 2011 and 2012 Negril's hotel room capacity increased by approximately 4.7% and is only exceeded by Montego Bay, the country's largest resort town (Jamaica Tourist Board, 2012). The resort area of Negril recorded an average hotel room occupancy rate of 61.3% in comparison to the rate of 58.5% in 2011. This was also reflected in the number of hotel room nights sold in this resort area as it increased by 3.3%, recording 1,147,701 room nights sold compared 1,111,386 sold in 2011. This growth and success of the area as a preferred destination has had socio-economic effects. Pertaining to direct employment in the accommodation sector, Negril was ranked second to Montego Bay, providing 26.6% of labour in the sector across the island with 9,365 direct jobs in 2012 (See Table 3 and Figure 2). As a result of its booming tourist industry many other small businesses have emerged such as other tourism support related activities such as restaurants, watersports operators, tour guides, transportation and other commercial activities.

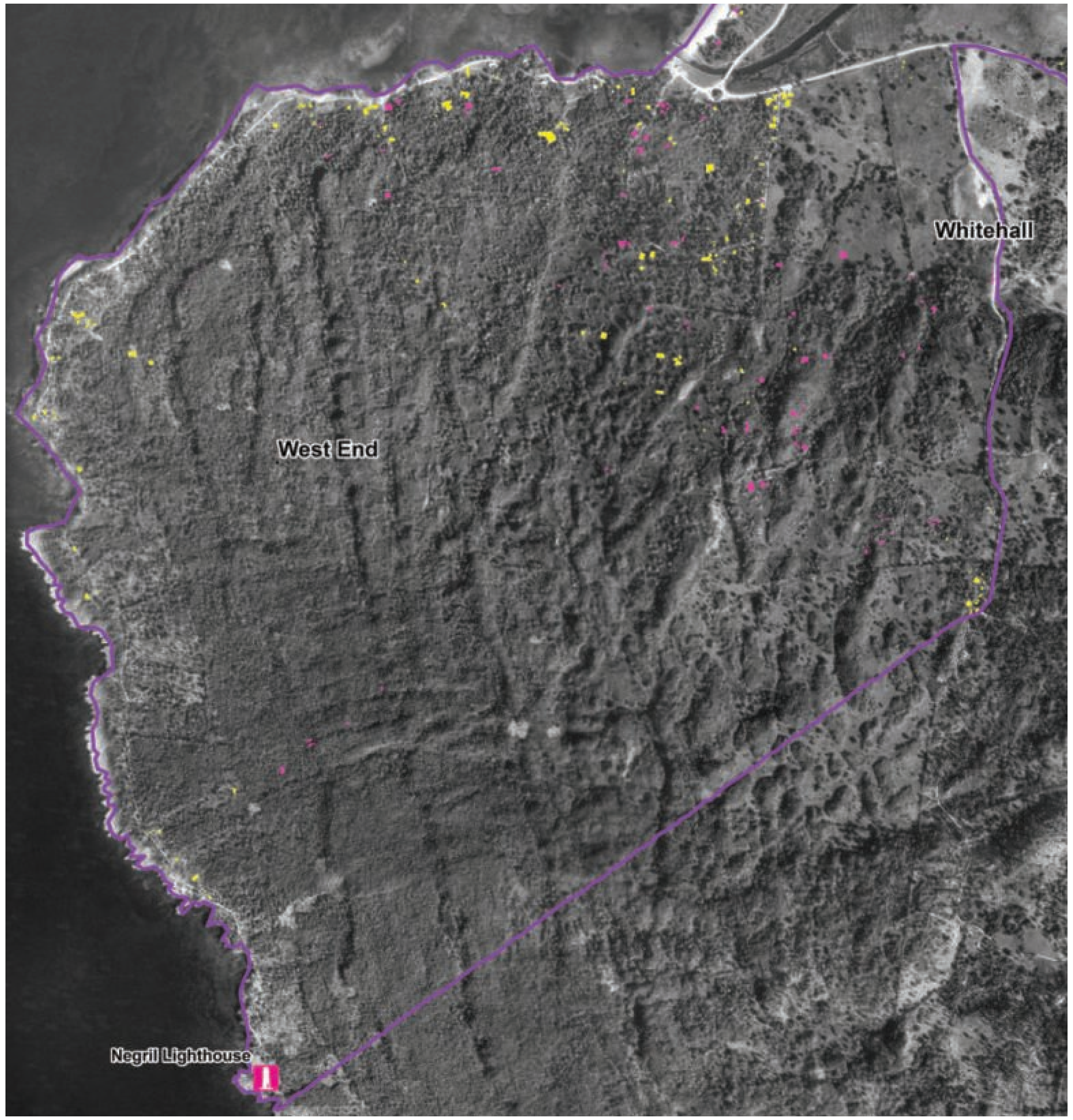
Maps 4.2 – 4.17 provide a comparative analysis of the main differences in the morphology of Negril at the community level (West End, Long & Bloody Bay, Orange Bay, Sheffield and Whitehall)

# DEVELOPMENT OF WEST END IN 1941-1968




Map 4.2: Aerial imagery depicting West End in 1941




Map 4.3: Aerial imagery depicting West End in 1968

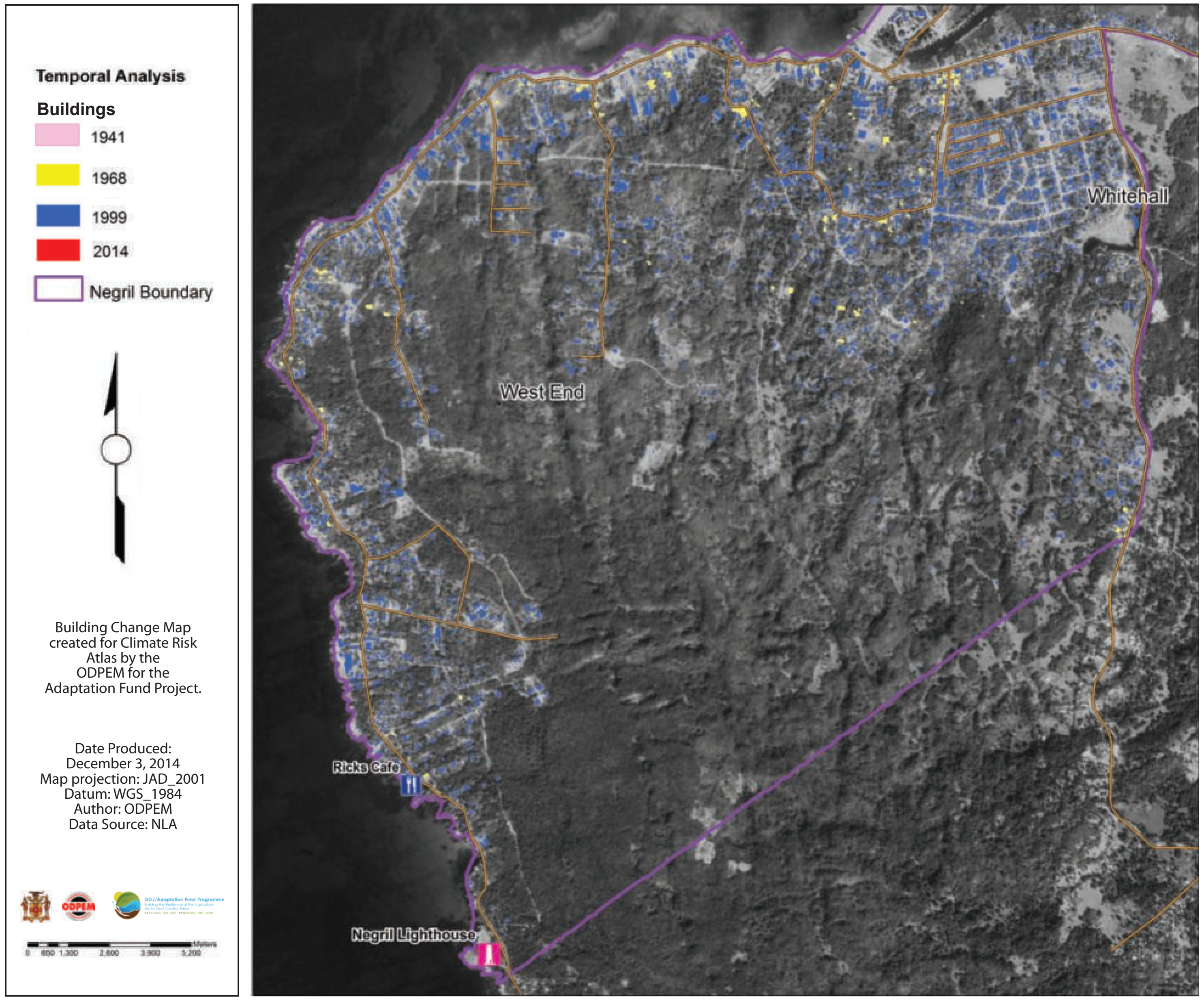
## 1941

- Little development and/ or organized infrastructure along the coast of West End. The Negril Light house is evident.
- Evidence of an indistinct road along the coast. The presence of thick shrub and woodland was notable on the eastern side of the road more landwards.
- Dense vegetation is observed throughout West End with few buildings located South West and North East of the area.
- Evidence of predominantly undisturbed coastal vegetation along the coast of West End is evident.
- Predominantly cliffs present along the coast of West End.

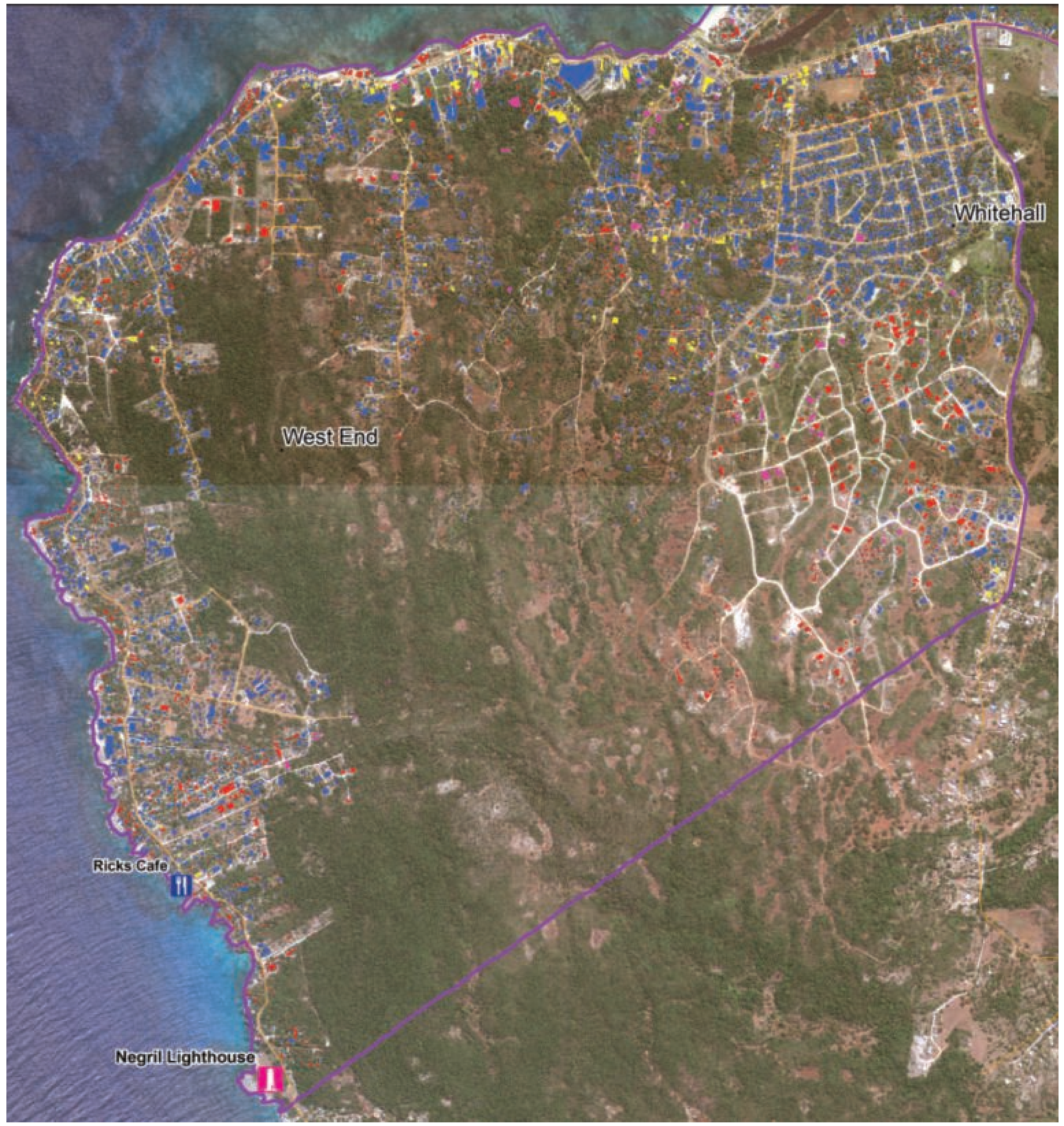
## 1968

- Evidence of land clearance observed throughout West End and East of the Light house property.
- Emergence of sparse linear residential development along the road network. Observed clearance of vegetation just South West of the round-about.
- No major distinct change of infrastructural development except for a noticeable increase in building development, in the White Hall area (See Map 4.3).

## DEVELOPMENT OF WEST END BETWEEN 1968-2014




Map 4.4: Aerial imagery depicting West End in 1999




Map 4.5: Aerial imagery depicting West End in 2014

### 1999

- Drastic anthropogenic changes observed. Major decline in vegetation cover mainly over the Northern and coastal sections.
- Increased building concentration along the coast, along the cliff face and Whitehall.
- Growth of the built environment; housing schemes, hotel industry, commercial zones, other land uses and increased road network

### 2014

- Major Increase in building concentration along the road network mainly within the urban space.
- Significant growth of the built environment along the coast specifically on the cliff environs.
- Significant loss of vegetation surrounding the environs of Negril town area.

# LONG BAY AND BLOODY BAY TEMPORAL CHANGE 1941 - 1968

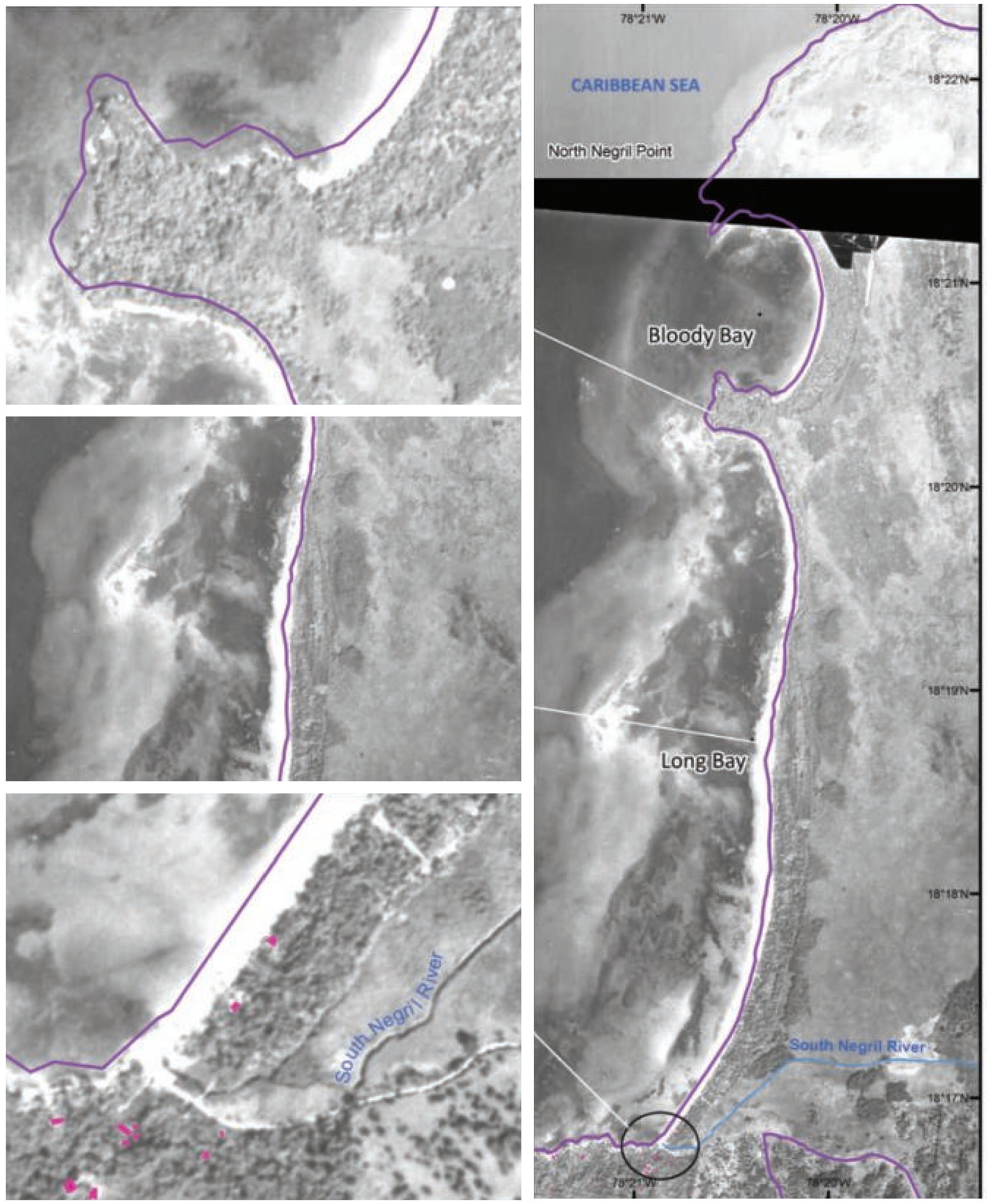
**Temporal Analysis**

**Buildings**

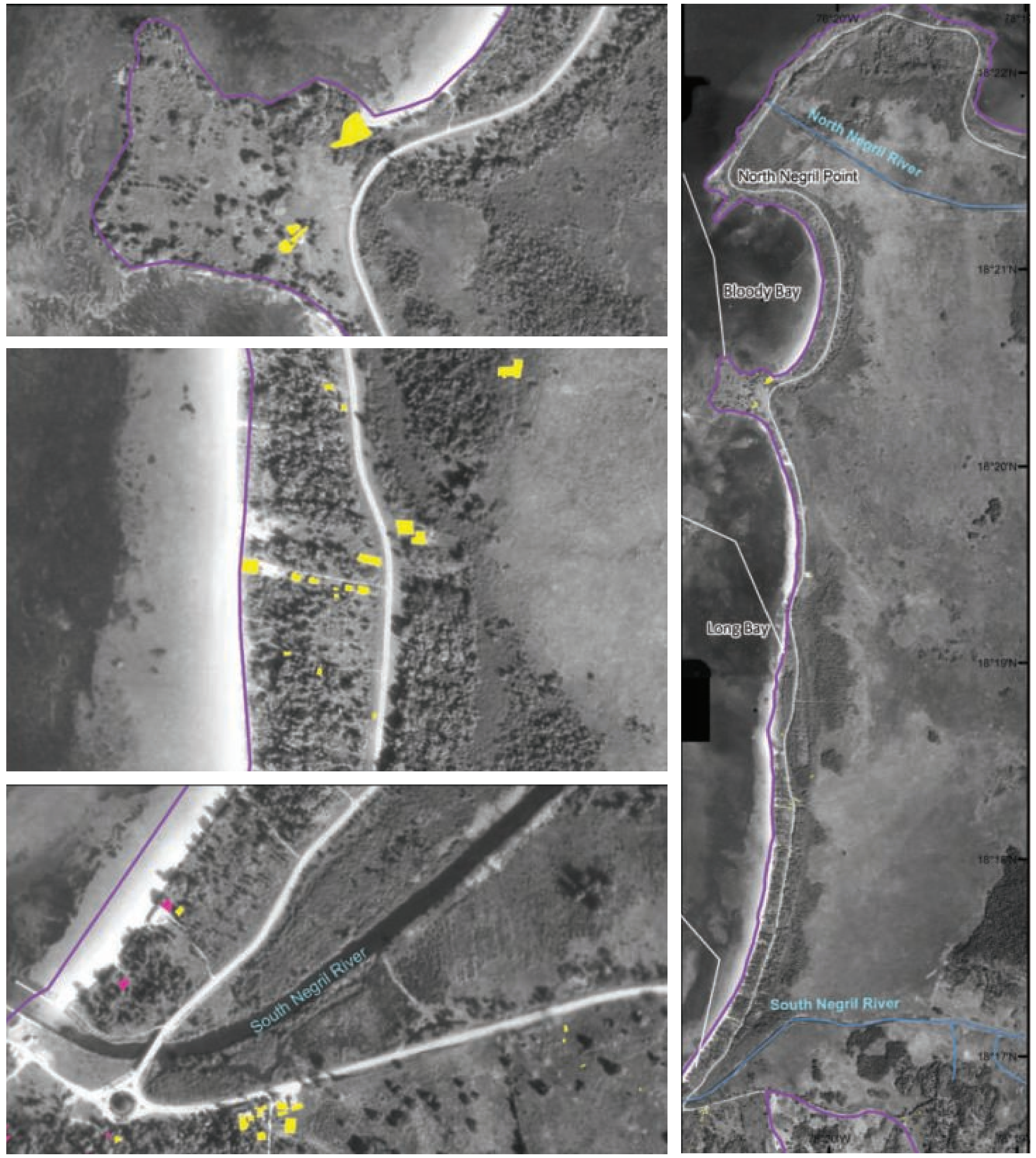
- 1941
- 1968
- Negril Boundary

Building Change Map created for Climate Risk Atlas by the ODPEM for the Adaptation Fund Project.

Date Produced: December 3, 2014
Map projection: JAD_2001
Datum: WGS_1984
Author: ODPEM
Data Source: NLA




Map 4.6: Aerial iof Long Bay and Bloody Bay Temporal Change 1941



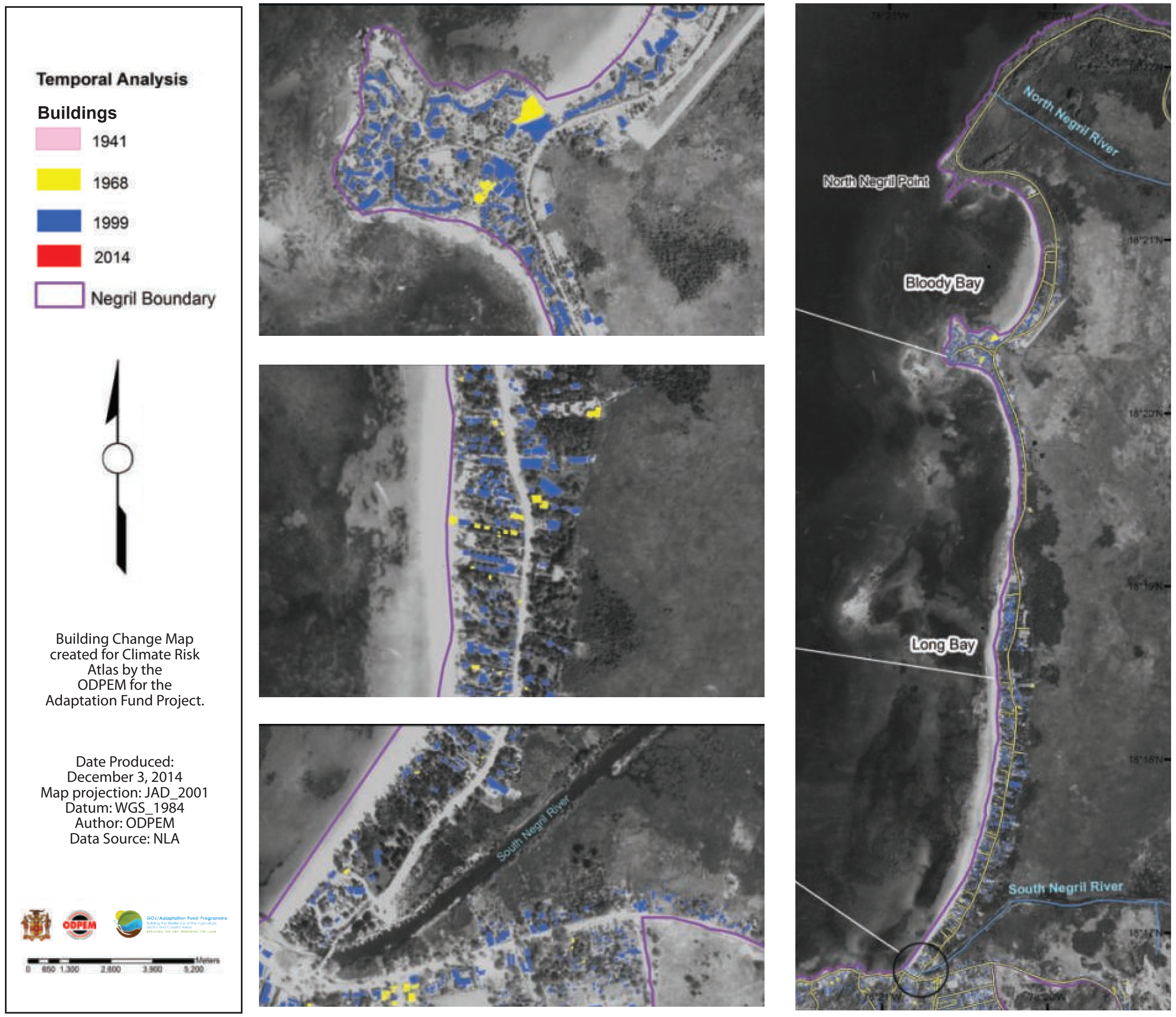

Map 4.7: Aerial iof Long Bay and Bloody Bay Temporal Change 1968

## 1941

- Dominant presence of thick shrub and woodland and dense mangrove observed along the coast.
- Extensive sand dunes and beach which was approx. 119.30 m.
- Little or no development observed.
- Little or no human activity visible in Morass.

## 1968

- Increased vegetation clearance, decrease in mangrove cover along the coast line. The previously vegetated headland which separates Long Bay from Bloody Bay is cleared by approximately 90%. Only few buildings were observed at this location.
- Loss of sand dunes and white sand observed along the coast.
- Expansion of road network observed along the coastal area and through the mangroves sparse. Building footprint is sparse. Road network is more distinct on the Norman Boulevard and road infrastructural development is distinct - Emergence of a round-about and a bridge over Negril South River.
- Construction of a network of Canals (North Negril River). This appears to be associated with agriculture network just North East of Bloody Bay. The South Negril River was channelized to accommodate construction of Norman Manley Blvd.




Map 4.8: Aerial iof Long Bay and Bloody Bay Temporal Change 1999


Map 4.9: Aerial iof Long Bay and Bloody Bay Temporal Change 2014

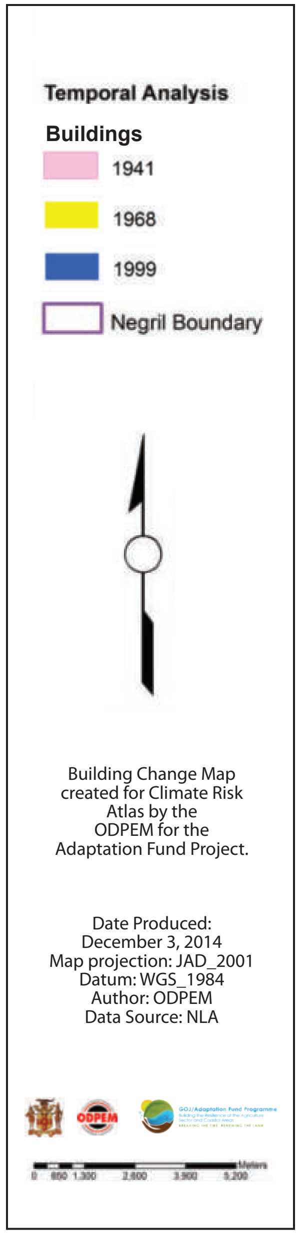
## 1999

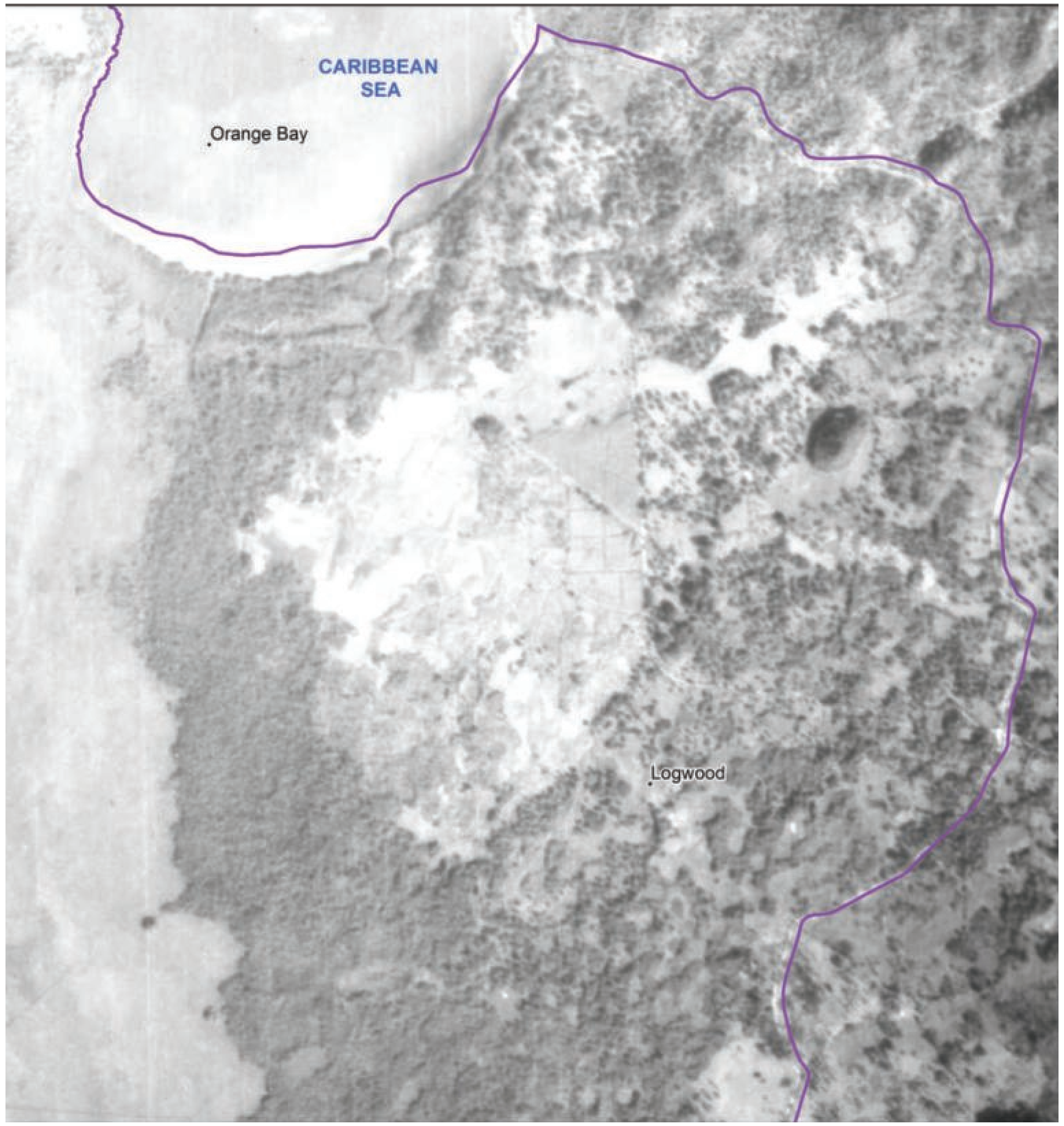
- Significant loss of white sand dunes and receding shoreline observed. Increased deforestation, mangrove clearance and encroachment on the Great Morass.
- Increased concentration of buildings along the strip, specifically a dominance of resorts and recreation land use zone. Intensification of building developments South West of the Great Morass. (see figure 3)
- Greater building spread and density, buildings are concentrated along the coast and Morass of the Southern section of Norman Manley Blvd.
- Construction of infrastructure notably the presence of the Negril air strip South West of Bloody Bay located in the Great Morass.

## 2014

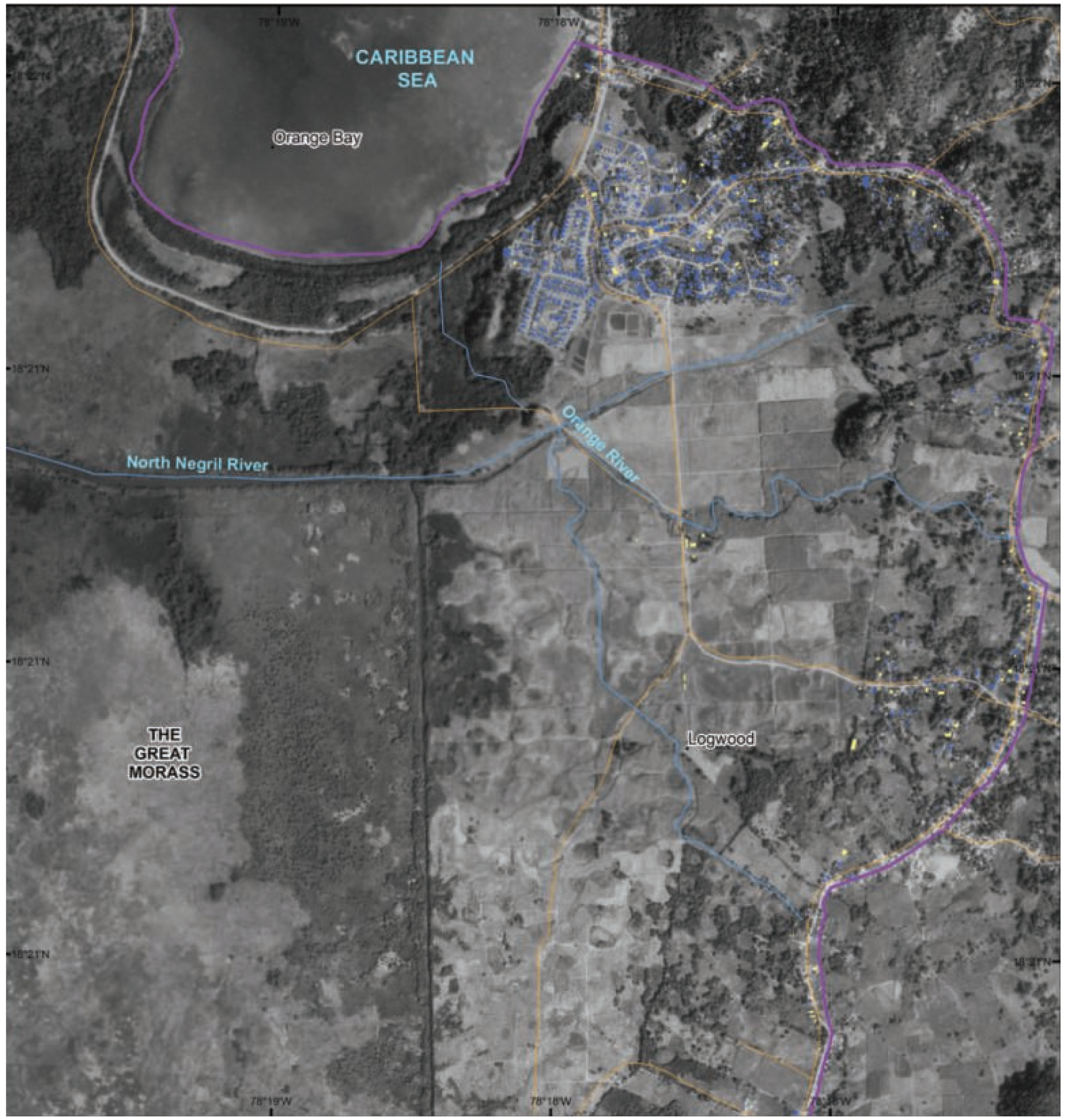
- Hotel and resort dominate the 7 mile strip.
- High building concentration along the coast. Increased pockets of residential land use  observed just north of the Great Morass  along the Norman Manley Blvd.
- Development expanded along Norman Manley Blvd. Since 1999 growth in infrastructure along thisroadway has significantly increased and become more dense.

# ORANGE BAY TEMPORAL CHANGE 1941 - 1968




Map 4.10: Aerial of Orange Bay Temporal Change 1941




Map 4.11: Aerial of Orange Bay Temporal Change 1968

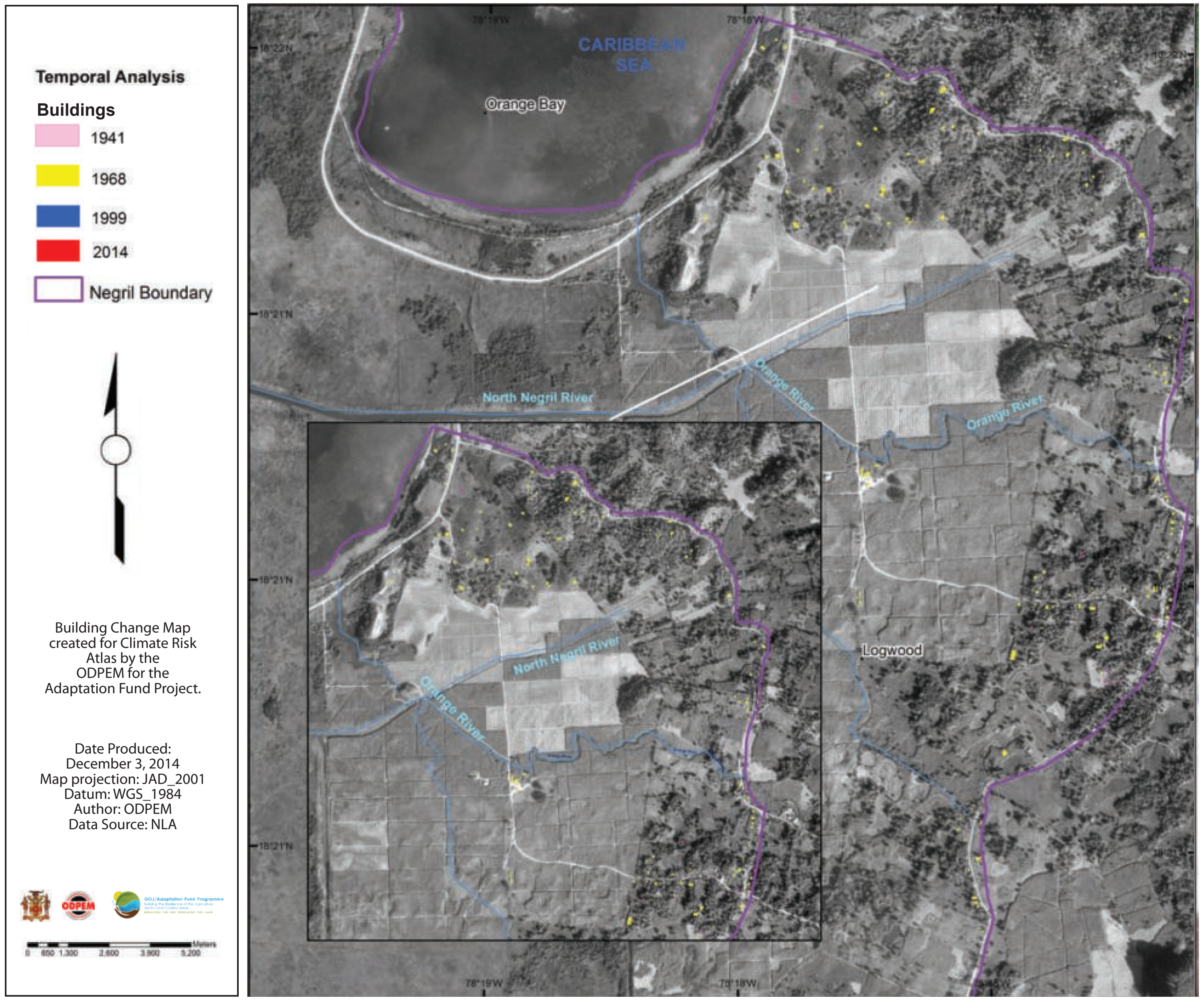
## 1941

- Dense mangrove cover along the coast, undisturbed vegetation.
- Beach appears untouched, no extensive amount of sand visible, mainly bare rock present.
- No human activity present along the Orange Bay, agriculture occupies a small area located at the South Eastern section of Orange Bay.
- The Great Morass appears untouched for the most part.
- No buildings identified or any organized infrastructure evident here.

## 1968

- Vegetation loss along the coast, and notable on the Western section of Orange Bay, substantial decrease in mangrove coverage observed.
- Receded shoreline evident between 1941 and 1968.
- Emergence of road infrastructure, presence of a road network along the coast where the mangroves once dominated.
- Increase in human activity, more organized and expanded agricultural lots.
- Evidence of interference with the natural Morass (West of Orange Bay) transitioned to the development of a canal not present in 1941.

# ORANGE BAY TEMPORAL CHANGE 1968 - 2014




Map 4.12: Aerial of Orange Bay Temporal Change 1999


Map 4.13: Aerial of Orange Bay Temporal Change 2014

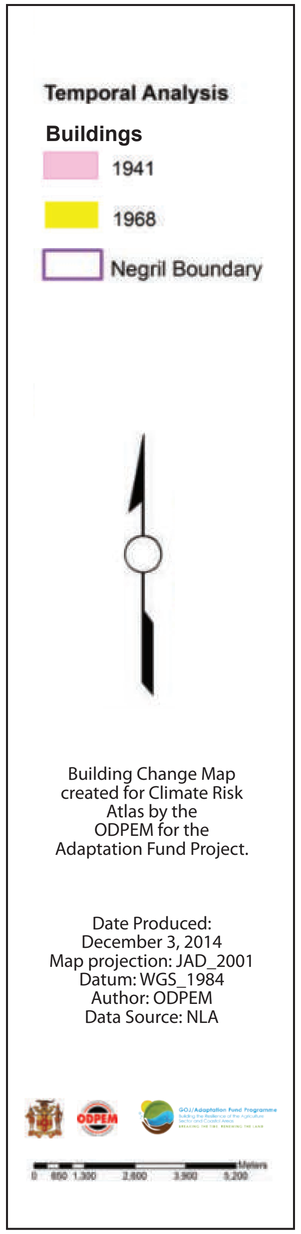
## 1999

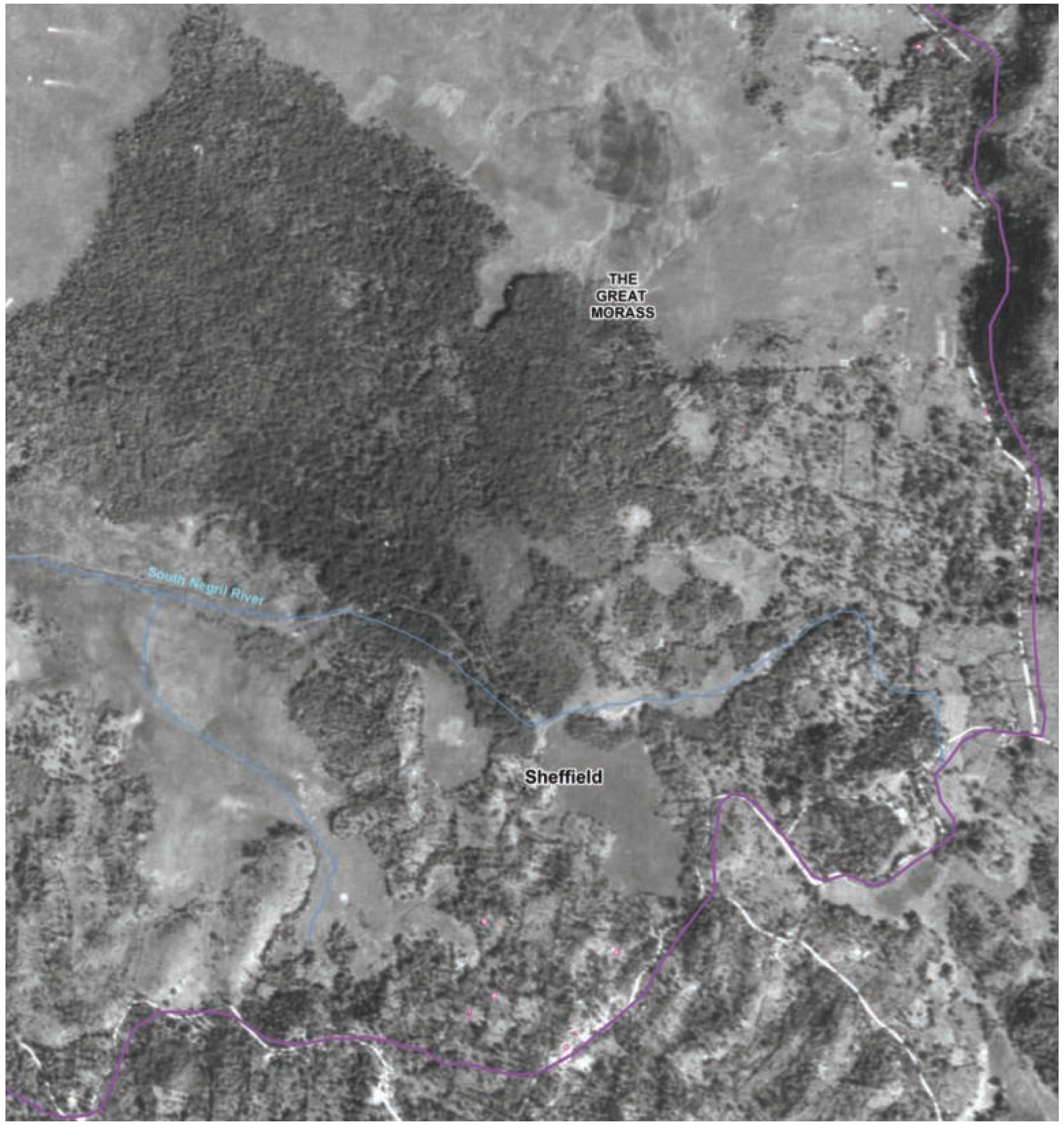
- Emergence of housing scheme and other buildings located on land East of Orange Bay which was once used for agriculture.
- Evidence of beach recession, narrow strip of beach is visible compared to the wider area of sand present on the 1941 imagery.
- Expansion of the built environment on the Eastern end and other infrastructure such as higher road concentration and the construction of sewerage ponds south of the housing schemes.
- More organized and extended agricultural zone just South-South East of Orange Bay.
- Substantial decline in the vegetation density and coverage on the Western section of Orange Bay.

## 2014

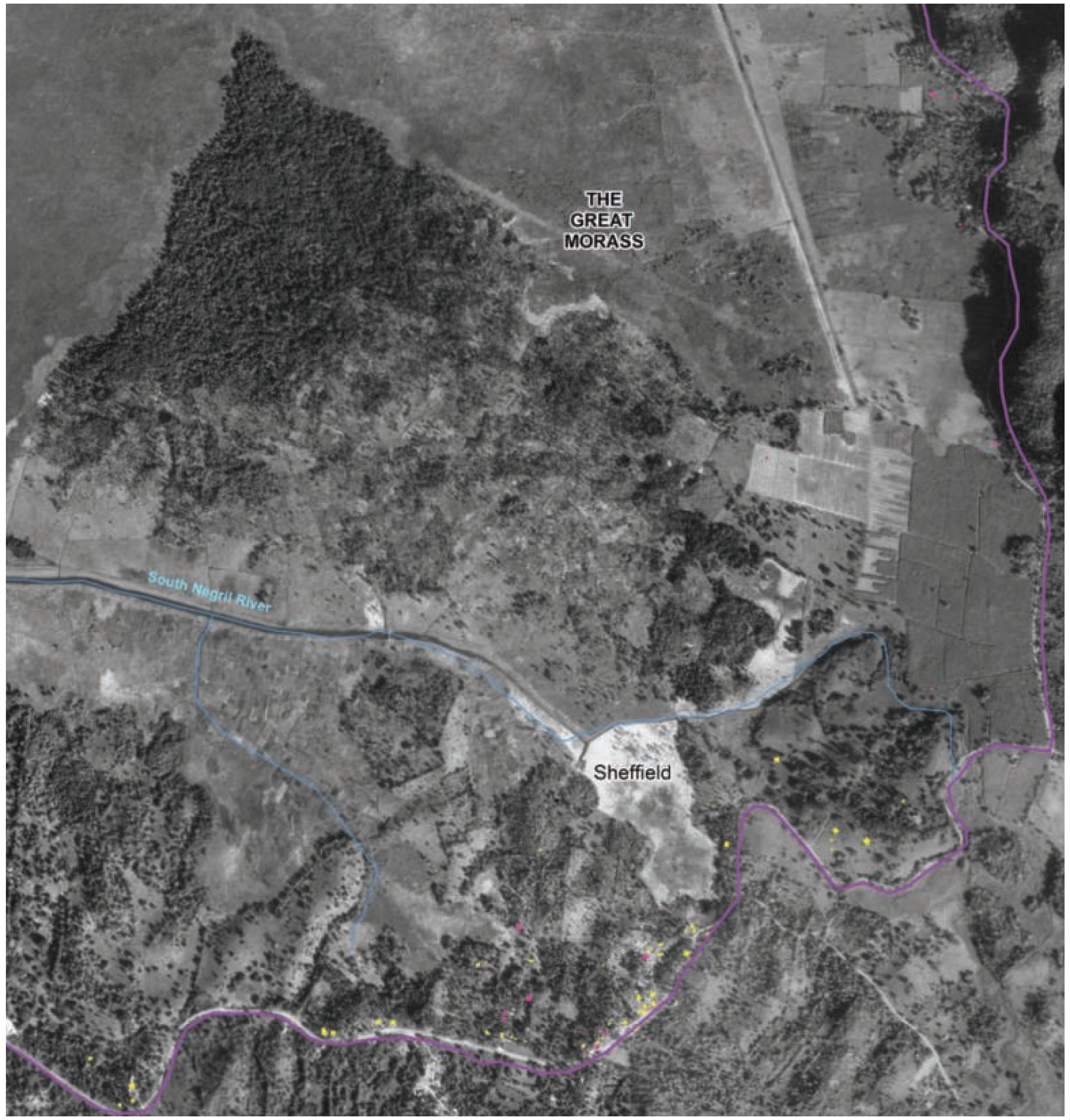
- Increased housing units were identified for this period.
- Housing schemes seems to spread further in the Morass.
- Well organized housing schemes.
- Expansion of road network observed.
- Expansion of the logwood community and increased building concentration along the road network leading to Sheffield.

# SHEFFIELD TEMPORAL CHANGE 1941 - 1968




Map 4.14: Aerial imagery depicting Sheffield Temporal Change 1941




Map 4.15: Aerial imagery depicting Sheffield Temporal Change - 1968

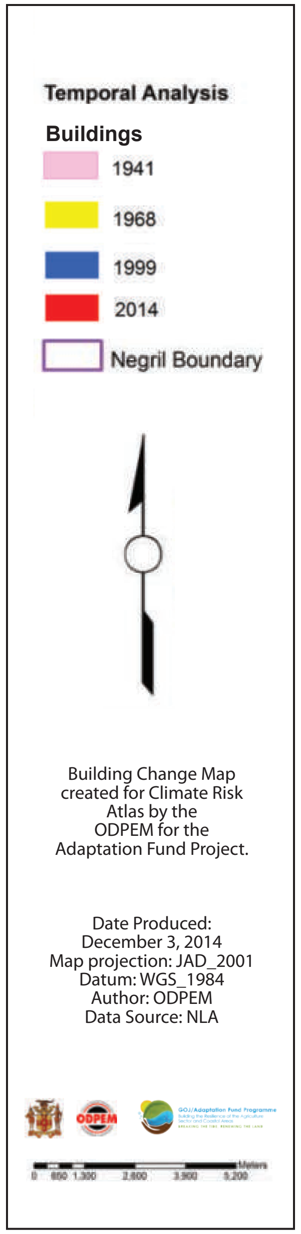
## 1941

- No concentration of buildings observed. Few buildings identified along the road network. No major infrastructural development except the road network which appears unpaved.
- No sign of building concentration in any one area, only a few buildings identified along the road network. No major infrastructural development except the road network which appears unpaved.
- Moderate to sparse vegetation for the most part. The mangrove forest within the herbaceous swamp appears untouched, dense and lush.

## 1968

- Evidence of agricultural development within the South West and North East sections of the Great Morass in Sheffield. This was not present on the 1941 imagery. A more organized agricultural zone observed East of Sheffield.
- Loss of vegetation and mangrove forest mostly within the central section of Sheffield. Increased agricultural zone
- Development of water ways forming riparian vegetation within the herbaceous swamp forest. Development of the canal South of Sheffield. Increased waterways mainly South and North East of Sheffield.

# SHEFFIELD TEMPORAI CHANGE 1968 - 2014





Map 4.16: Aerial imagery depicting Sheffield Temporal Change 1999


Map 4.17: Aerial imagery depicting Sheffield Temporal Change 2014

## 1999

- Increased housing development and increased building density emerged in a linear pattern along road network just South East and North East of Sheffield. Construction of a pond into the Royal Palm reserve channeling specifically North of Sheffield within the Great Morass.
- Increased human activity, mostly South East of the Morass in Sheffield, mainly land clearance, topographic alterations and implementation of ponds observed along with a few agricultural lots.
- North North West of Sheffield the sewerage plant infrastructural development is the most notable change, as this was once an agricultural zone within the Morass.

## 2014

- Significant loss of vegetation tp accommodate housing units.
- Increase in the concentration of planned settlement. Nucleated building pattern extended towards the hilly interior lands.
- Greater building spread is mostly noticed on the south eastern section.

# 4.2 Exposure Analysis

## Introduction

One of the most important components of the risk assessment process is exposure analysis. The interaction between the elements at risk and hazard footprint defines the exposure. Elements at risk as defined in this assessment are housing, critical facilities (schools, hospital, health centre, fire station and police station), population and economic activities which are exposed to hazards in Negril. Exposure analysis was undertaken for the following hazard types: storm surges, future storm surge (Current storm surge + sea level rise), overtopping and coastal erosion. The analysis will help identify what and how much of the various elements in Negril are at risk of the hazards listed above.

## Methodology

The analysis of exposure aims at identifying the physical as well as societal elements that are at risk. By quantifying the proportion of assets that are located in the hazardous areas, it provides an understanding of the assets that is prone to damage and losses caused by various hazard intensities.

*Plate: 4.2: Negril Lighthouse*

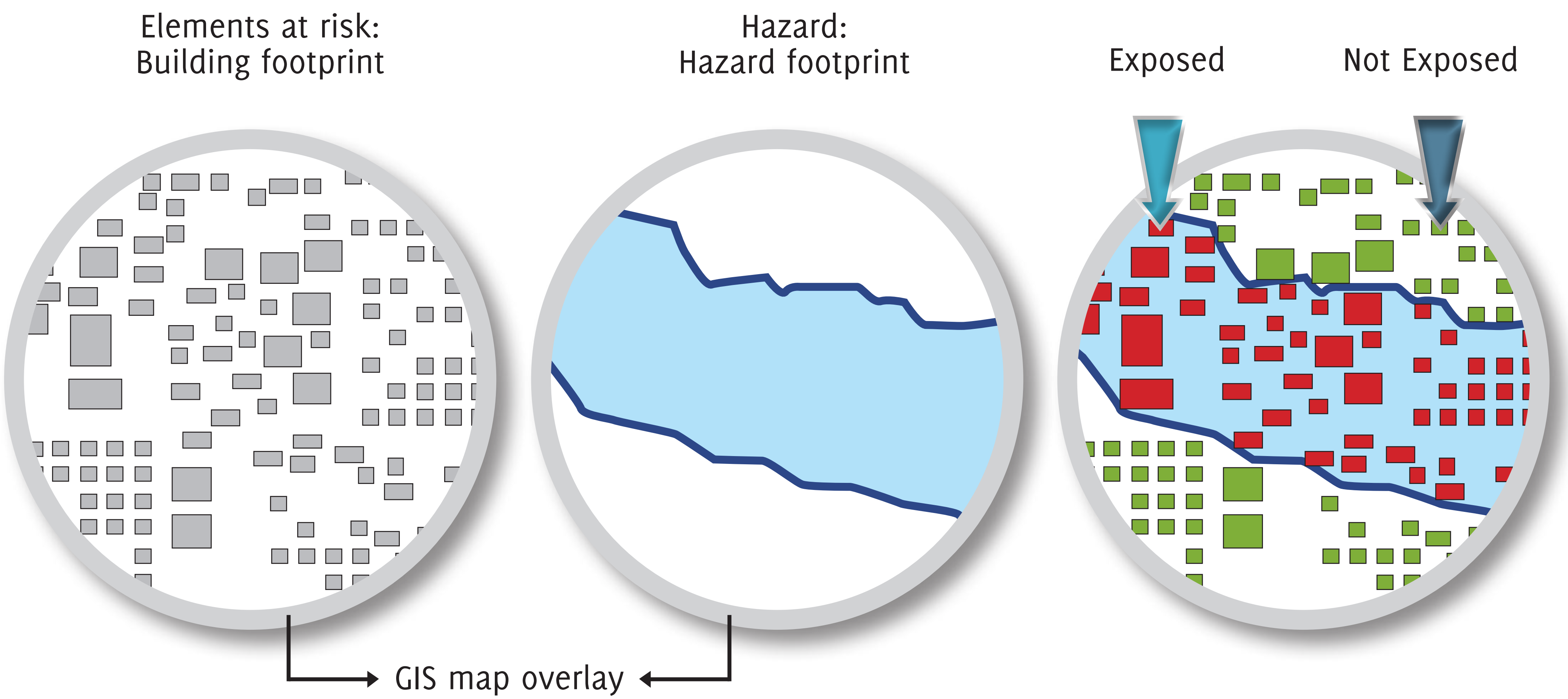



Figure 4.2

Source: Westen etal 2001

## Data Collection

- Detailed building inventory mapping of buildings was conducted within the project boundary with a total of 4160 positional reference points captured. For each building the following attributes were collected:
  1. Land use and building type – The land use categories used in this analysis are the same as those defined by NEPA
  2. Material of construction – The categories of construction material used in this analysis are as defined by STATIN
  3. Number of floors – Determined by direct observation
- Finished Floor Levels was collected sampling 300 buildings within the project boundary. This is information is useful to determine vulnerability and above what water depth damage is likely to occur.

## Elements at Risk Database

The purpose of the data collection is to build an elements at risk database containing information and location on buildings, population, road network and other physical infrastructure using a Geographic Information System (GIS). The aim of the database is to facilitate the evaluation of the vulnerability of the elements at risk for the hazards being focused in this atlas.

Over 8, 500 building footprints were digitized from 2014 imagery captured for the project boundary using an Unmanned Aerial (UAV) Survey carried out to an accuracy of 5cm per pixel. The footprints were digitized using ESRI's ArcMap.The attribute information from the point data shapefile was joined to the building footprint which did not contain any attribute information.

The data from the elements at risk database, when overlain on the hazard maps illustrates the exposure of people, buildings and infrastructure relative to the four (4) named hazards above. By understanding the type and number of assets that exist and where they are located in relation to known hazards areas, the relative risk and vulnerability for such assets can be assessed. In other words spatial overlay of hazard footprints and elements at risk provides information on exposure (See Figure 4.2).

## Exposure Analysis

Exposure analysis for the elements at risk is defined as follows:

- Buildings: Number of buildings that are within hazard footprint
- Population: Number of people and by age cohort that are within hazard footprint
- Roads: Length of road networks in meters that are within hazard footprint

# 4.2.1 Exposure of Buildings

Table 4.2 displays the total number of buildings that are exposed to the four (4) hazard types in Negril. From the table it is clear that majority of the buildings are exposed to coastal flooding resulting from storm surge hazards.

Table 4.2: Exposure of Buildings

| Element at risk: Buildings | Hazards | | | | |
|---|---|---|---|---|---|
| | Storm Surge [SS] 100 year RP | Future storm surge, 2100 [SS+ SLR] | Wave overtopping | Coastal Erosion | |
| | | | | 100 Year Storm Event | SLR |
| Number of buildings Exposed | 1191 | 15.1 | 926 | 372 | 477 |
| % of Total Buildings Exposed | 14% | 18% | 11% | 4% | 5.6% |

Table 4.3: Number of buildings exposed to Storm Surge Hazard

Hazard: Storm Surge Number of Structures

| Land Use | Total Buildings | 10 YR RP | % in Hazard Area | 25 YR RP | % in Hazard Area | 50 YR RP | % in Hazard area | 100 YR RP | % in Hazard Area |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 5113 | 129 | 3% | 160 | 3% | 182 | 4% | 209 | 4% |
| Commercial | 1718 | 168 | 10% | 210 | 12% | 240 | 14% | 286 | 17% |
| Industrial Light | 48 | 4 | 8% | 5 | 10% | 5 | 10% | 5 | 10% |
| Educational | 14 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Office | 48 | 1 | 2% | 2 | 4% | 4 | 8% | 4 | 8% |
| Public Assembly | 31 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Public Buildings | 21 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Institutional | 5 | 0 | 0% | 0 | 0% | 0 | 0% | 1 | 20% |
| Resorts | 1254 | 443 | 35% | 527 | 42% | 585 | 47% | 632 | 50% |
| Resort (Guest House) | 170 | 44 | 26% | 55 | 32% | 64 | 38% | 73 | 43% |
| Resort (Villas/Cottages) | 144 | 95 | 66% | 97 | 67% | 97 | 67% | 97 | 67% |
| Resort (Hotel) | 940 | 304 | 32% | 375 | 40% | 424 | 45% | 462 | 49% |
| Utilities | 29 | 0 | 0% | 1 | 3% | 2 | 7% | 3 | 10% |
| Recreational | 44 | 11 | 25% | 15 | 34% | 18 | 41% | 20 | 45% |
| Sewerage/ Lift Station | 14 | 0 | 0 | 1 | 7% | 2 | 14% | 3 | 21% |
| Vacant Buildings | 114 | 18 | 16% | 21 | 18% | 22 | 19% | 24 | 21% |
| Derelict Building | 54 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Under Construction | 71 | 2 | 3% | 2 | 3% | 4 | 6% | 4 | 6% |
| Ware House | 9 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Total | 8573 | 776 | 9% | 944 | 11% | 1064 | 12% | 1191 | 14% |

Of the total number of buildings within the project boundary, which is estimated to be 8,573, approximately 25% of these are exposed to Future storm surges associated with sea level rise, 20% to the 100 year storm surge event, 11% to wave overtopping and 5.6% to coastal erosion resulting from sea level rise.

## 4.2.1.1 Buildings Exposed to Baseline and Future Storm Surges

Exposure of buildings was further disaggregated to show exposure by land use and hazard type. The land use classification resorts accounts for the highest percentage of 50% of buildings exposed to the baseline 100 year storm surge scenario. By 2100 under sea level rise scenario exposure of resorts in Negril could potentially increase by 3% (Refer to Table 4.3). This level of exposure of the tourism plant is not surprising because Jamaica's tourism product is based primarily on "sand, sun and sea" and so the majority of the facilities are sited along the coast close to the water's edge. The buildings that are situated on the seafront will be directly exposed to the sheer hydraulic force of storm surge waves and to flood depths of up to 2m for the baseline 100 year storm scenario. Maps 4.22 – 4.29 shows the spatial distribution of hotels that are exposed to current and future storm surge for the 100 year return period scenario.

Of the commercial activities which play a role in tourism in Negril such as craft vendors, small business operators (bars, restaurants), 17% of these buildings are exposed to storm surge hazard. For residential housing, only 4% and 6% respectively are exposed to baseline and future storm surges resulting from sea level rise. This indicates that the majority of residential developments are not located in the flood zone and is primarily situated inland from the coastline. Of the residential buildings exposed, single family dwellings account for the highest percentage under both baseline and end of century storm surge scenarios accounting for 80% and 76%. This is followed by multifamily dwellings with a very small percentage (1%) of squatter/informal housing (determined during asset mapping) being exposed to storm surge hazard.

As it relates to critical facilities, there are thirteen (13) such facilities (schools, Negril Police Station and Negril Health Centre) within the project boundary of which none are located within the baseline and future storm surge hazard footprint. Critical facilities can be defined as the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community both in routine circumstances and in extreme circumstances of an emergency (UNISDR, 2009).

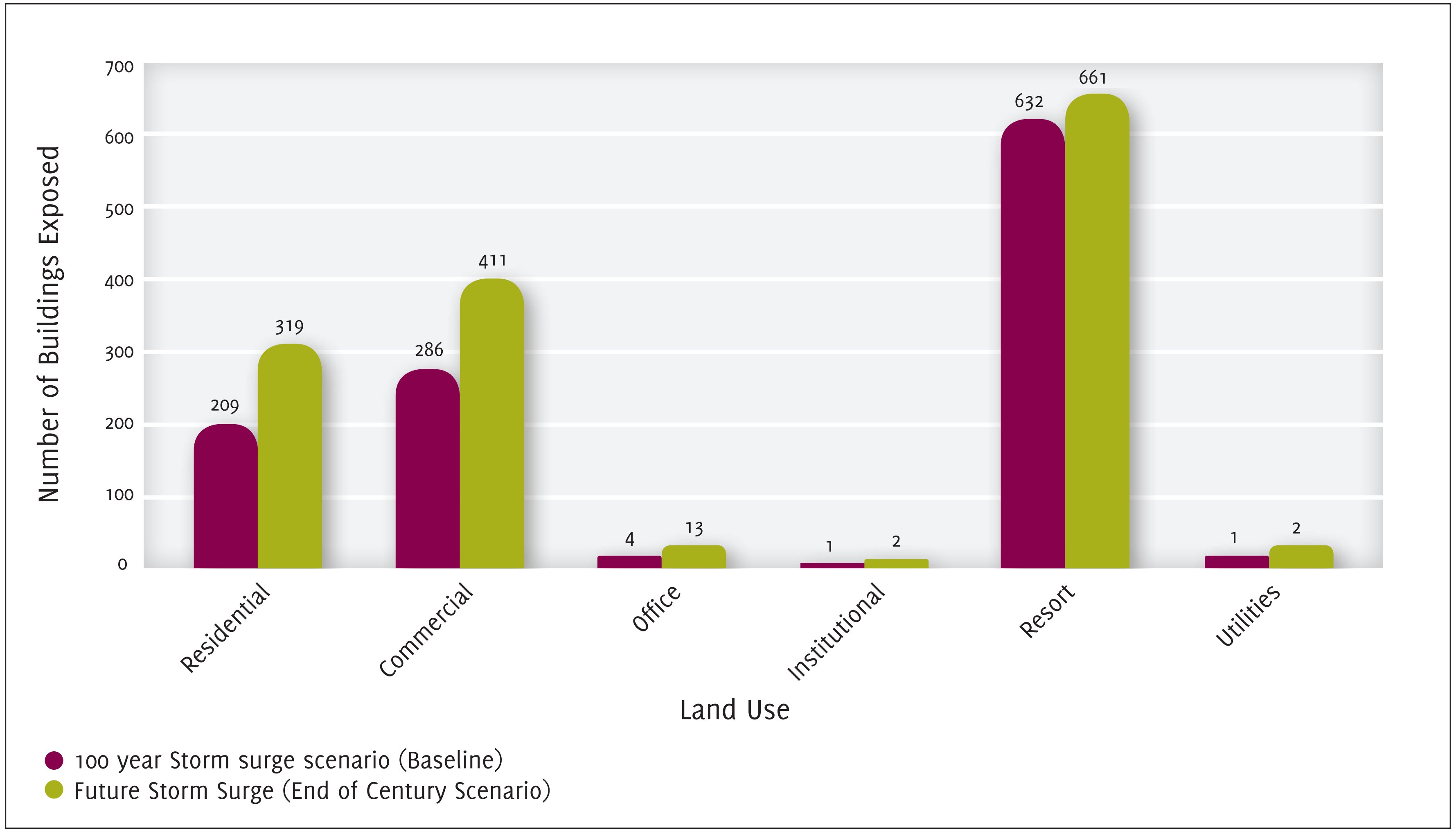
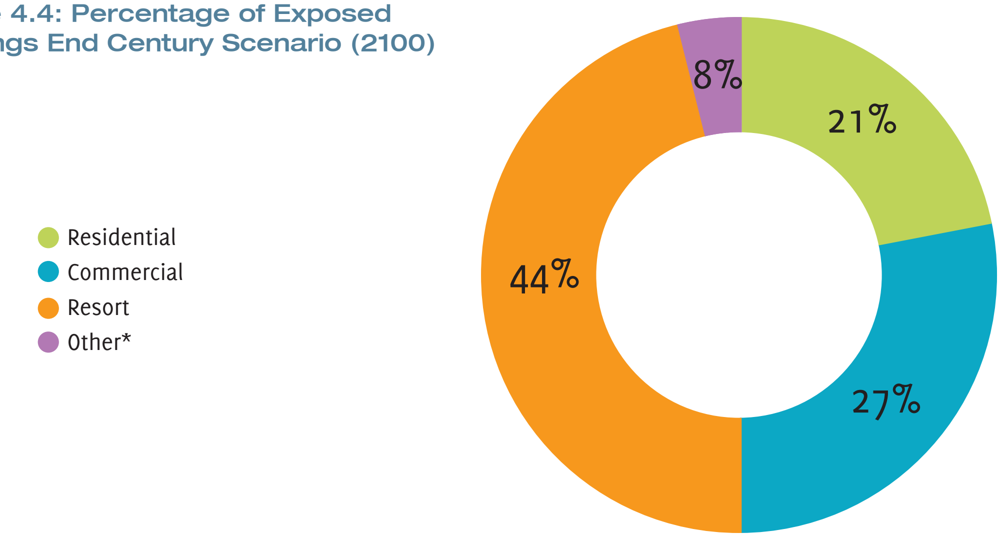



Figure 4.3: Exposed Buildings by Land Use 100 year Storm surge scenario (baseline) and Projections for 2100

Figure 4.4: Percentage of Exposed Buildings End Century Scenario (2100)




*Other: Office, Recreation, Industrial Light, Institutional, Utilities, Sewerage/ Lift Station

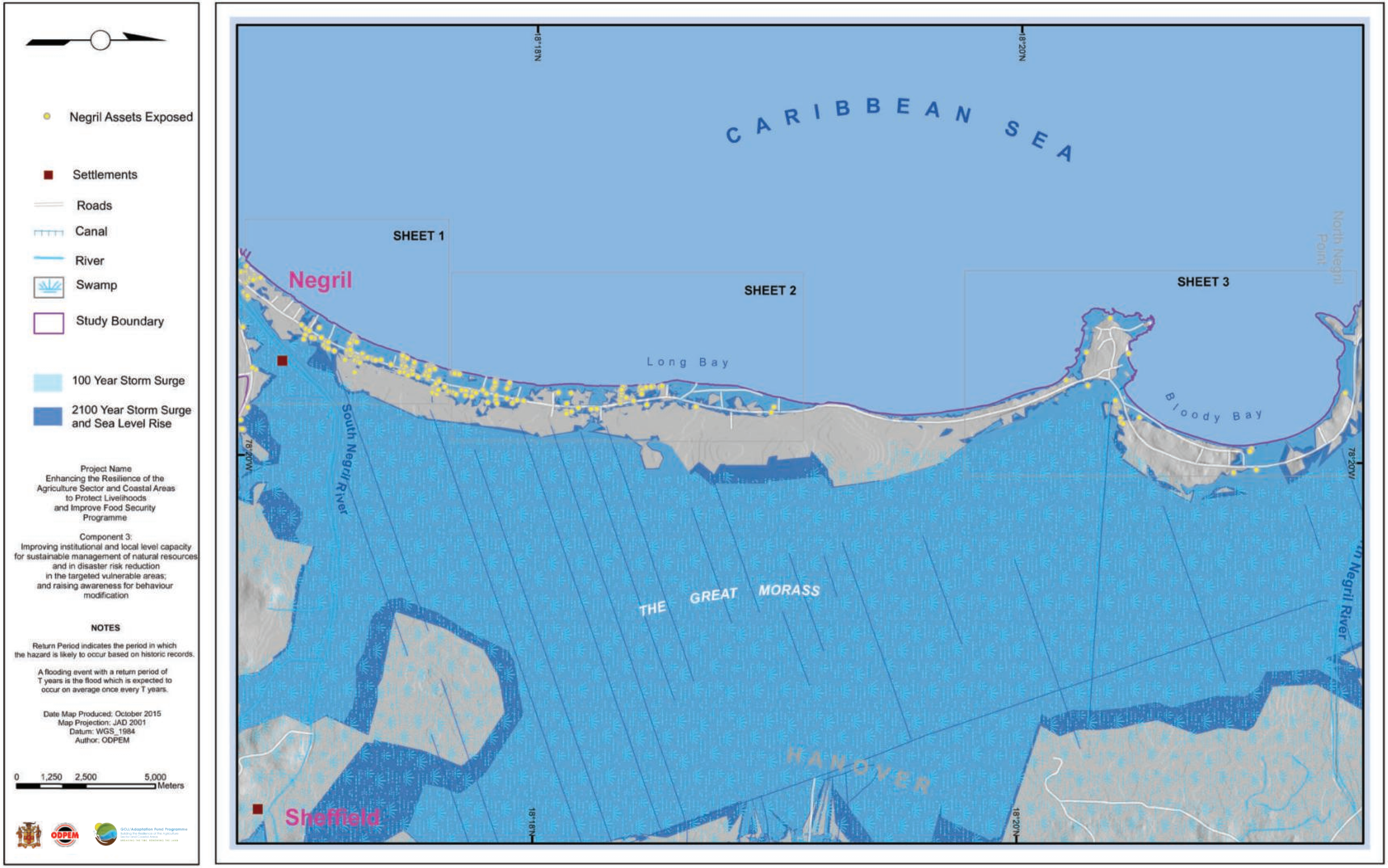
Results show that of the total buildings that are exposed (1501), the three (3) main land uses that are expected to be the most affected by future storm surges for the end of century scenario are resort, commercial and residential. Resort, resedential and commercial combined account for over 92% of buildings exposed. The other land uses combined account for 8%.

Table 4.4: Number of buildings exposed to Future Storm Surge Hazard

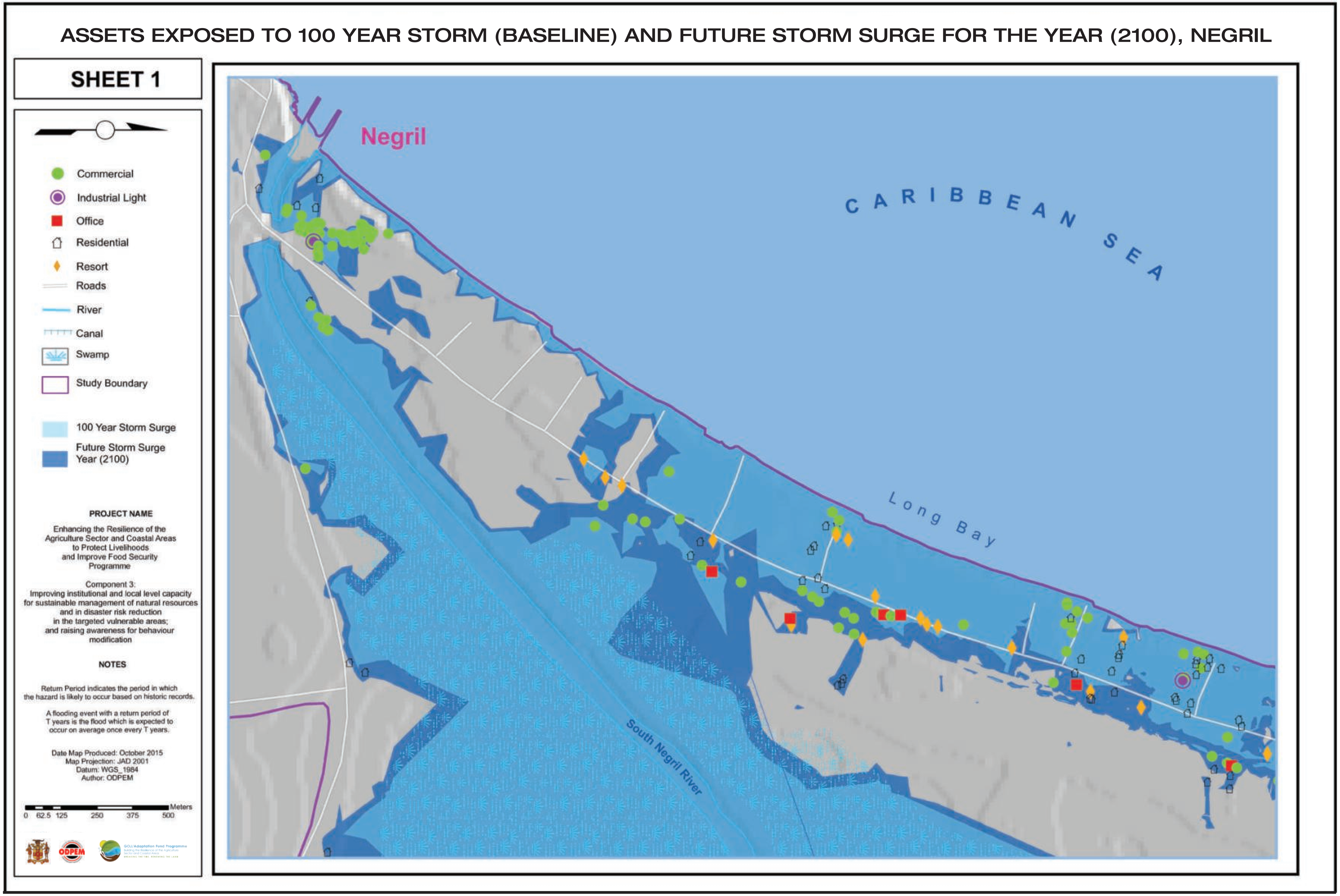
**Hazard: Future Storm Surge (SLR)**

| Land Use | Total Buildings | Number of Structures | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2025 YR RP | % in Hazard Area | 2050 YR RP | % in Hazard area | 2100 YR RP | % in Hazard Area |
| Residential | 5113 | 225 | 4% | 256 | 5% | 319 | 6% |
| Commercial | 1718 | 314 | 18% | 351 | 20% | 411 | 24% |
| Industrial Light | 48 | 5 | 10% | 6 | 13% | 7 | 15% |
| Educational | 14 | 0 | 0% | 0 | 0% | 0 | 0% |
| Office | 48 | 4 | 8% | 7 | 15% | 13 | 27% |
| Public Assembly | 31 | 0 | 0% | 0 | 0% | 0 | 0% |
| Public Buildings | 21 | 0 | 0% | 0 | 0% | 0 | 0% |
| Institutional | 5 | 1 | 20% | 2 | 40% | 2 | 40% |
| Resort | 1254 | 571 | 46% | 604 | 48% | 661 | 53% |
| - Guest House | 170 | 80 | 47% | 85 | 50% | 92 | 54% |
| - Villas/Cottages | 144 | 18 | 13% | 20 | 14% | 21 | 15% |
| - Hotel | 940 | 473 | 50% | 499 | 53% | 548 | 58% |
| Utilities | 29 | 4 | 14% | 8 | 28% | 13 | 45% |
| Recreational | 44 | 22 | 50% | 24 | 55% | 31 | 70% |
| Sewerage/ Lift Station | 14 | 3 | 21% | 3 | 21% | 8 | 57% |
| Vacant Buildings | 114 | 24 | 21% | 25 | 22% | 27 | 24% |
| Under Construction | 71 | 4 | 6% | 4 | 6% | 8 | 11% |
| Total | 8573 | 1177 | 14% | 1290 | 15% | 1501 | 18% |

ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE FOR THE YEAR (2100), NEGRIL

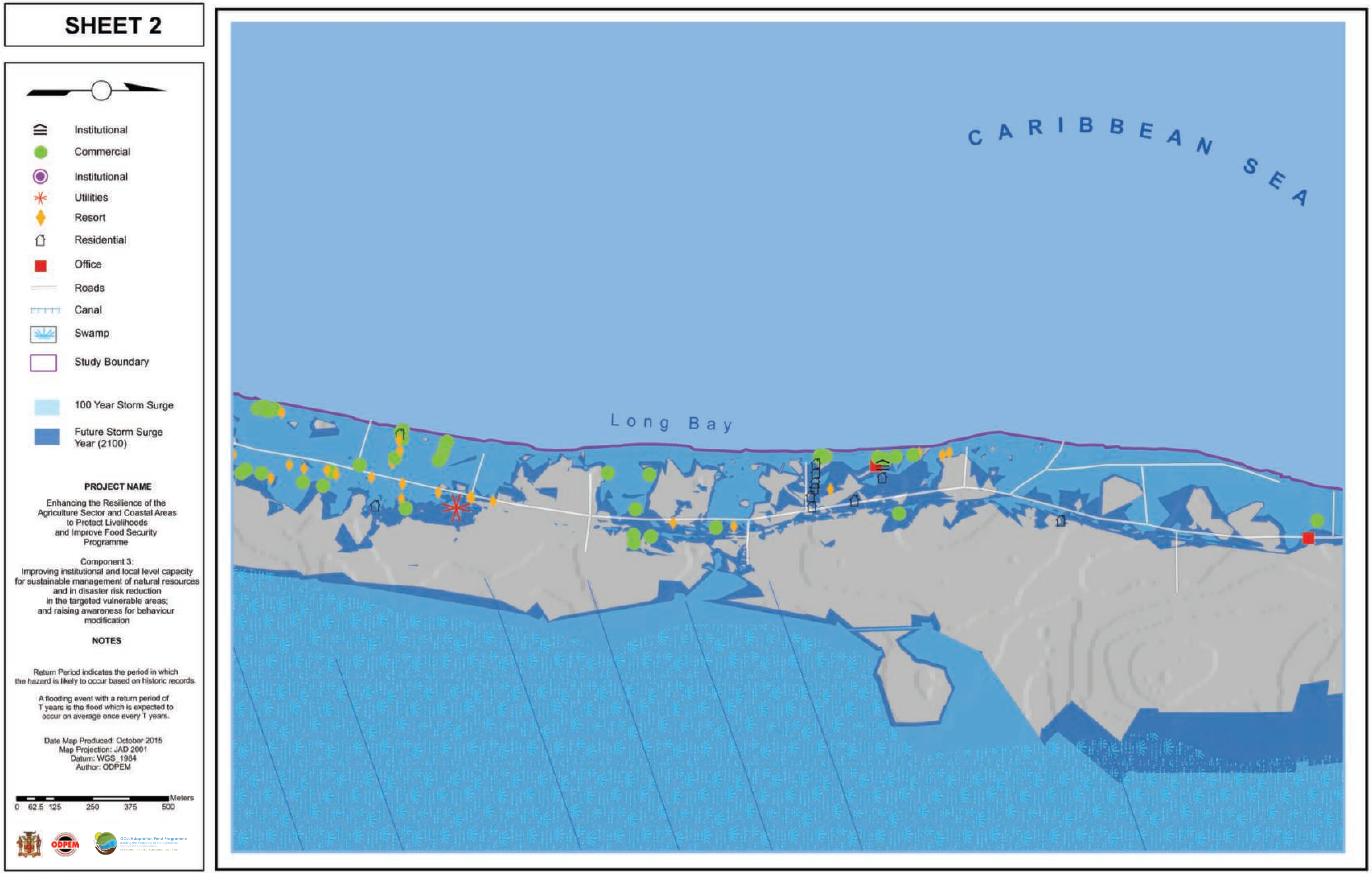



Map 4.18: ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE

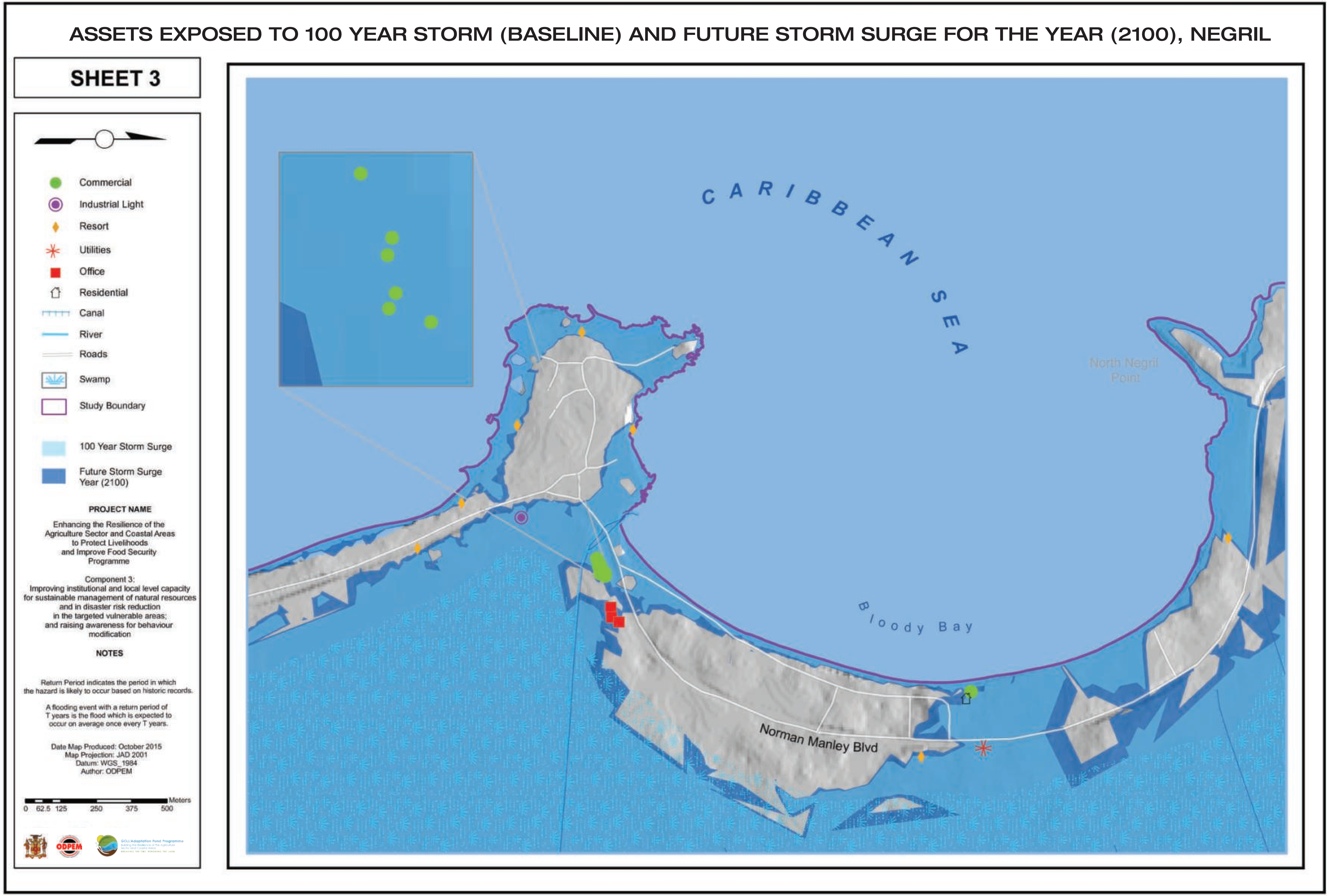



Map 4.19: ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE

## ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE FOR THE YEAR (2100), NEGRIL

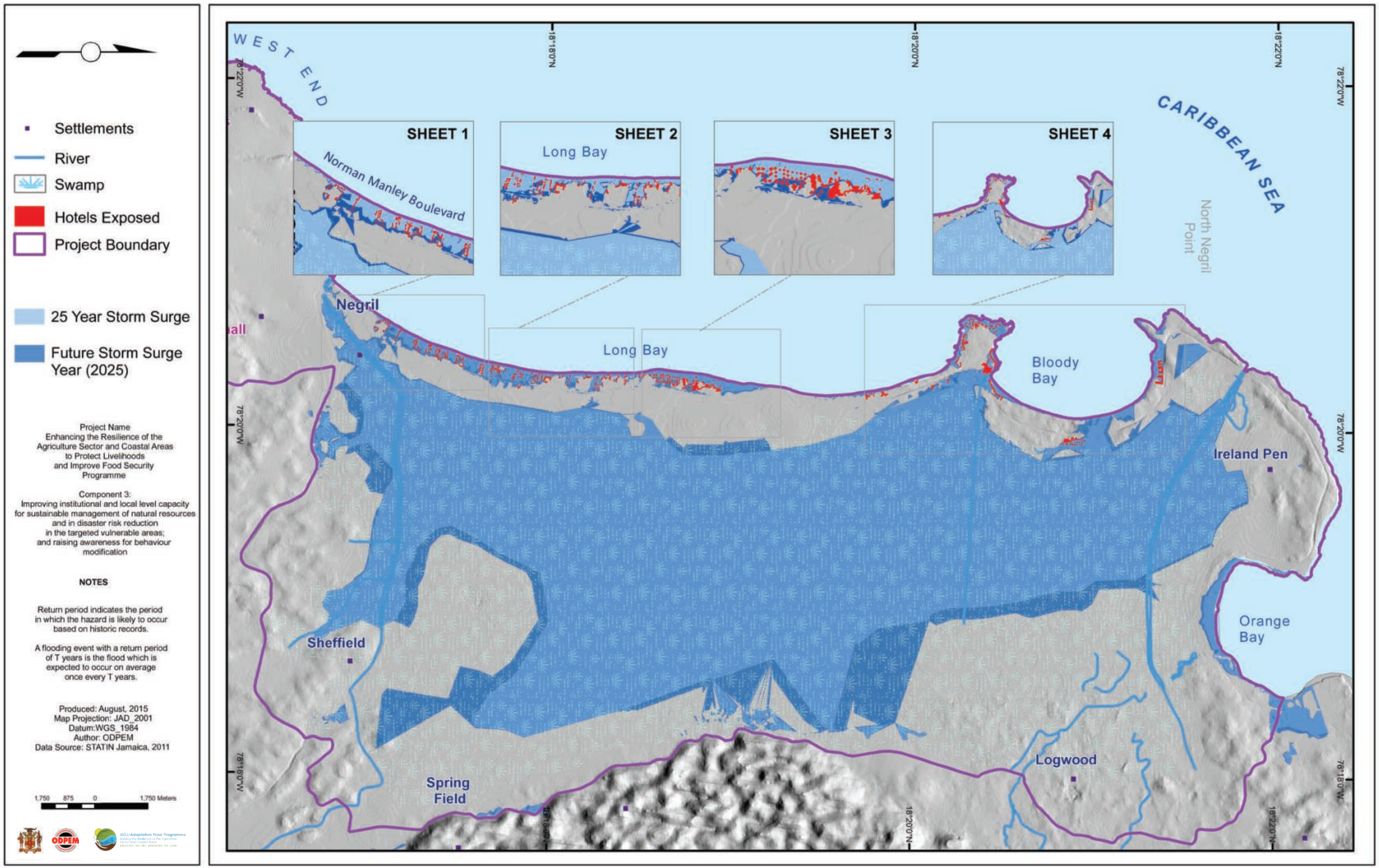



Map 4.20: ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE

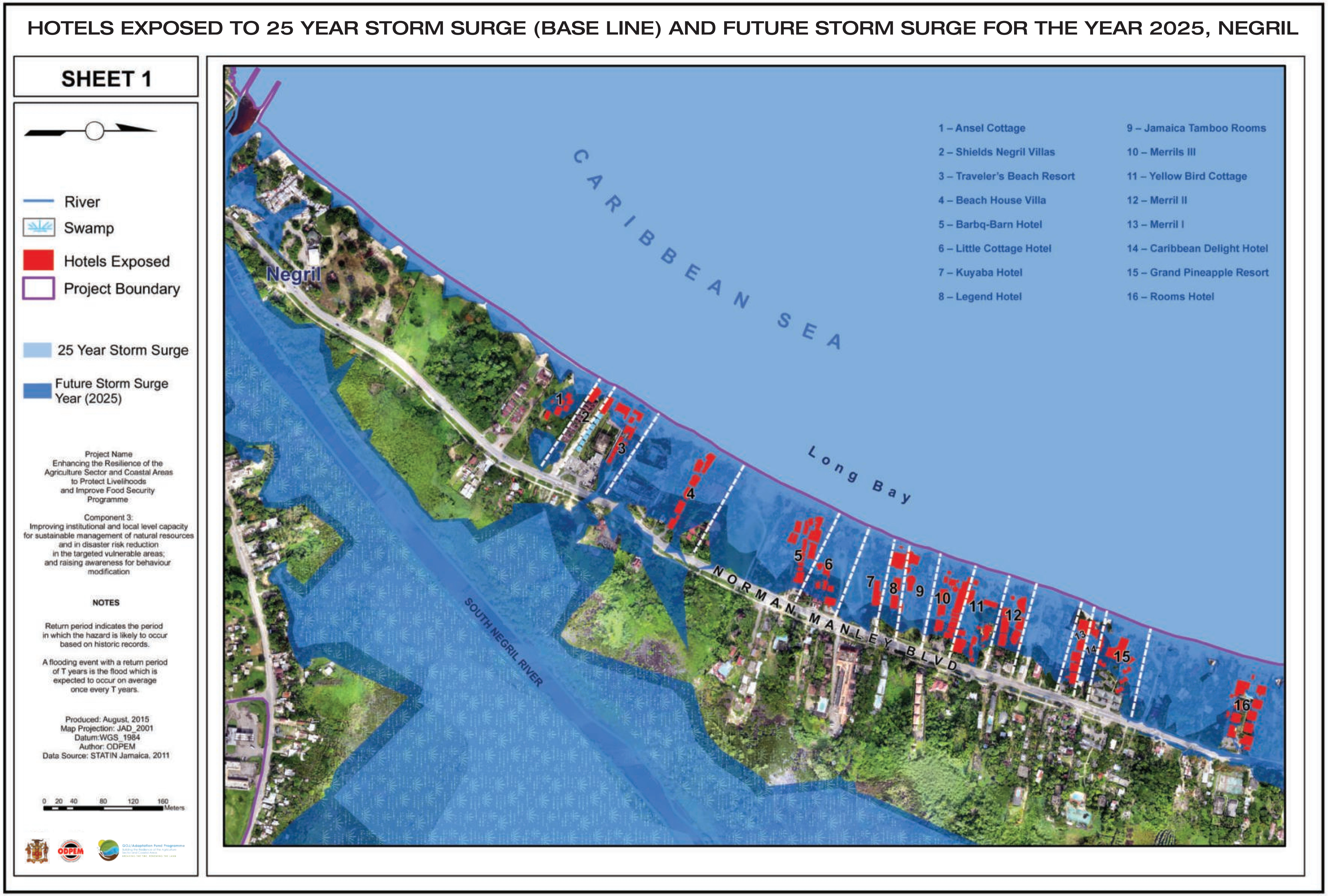



Map 4.21: ASSETS EXPOSED TO 100 YEAR STORM (BASELINE) AND FUTURE STORM SURGE

## ASSETS EXPOSED TO 25 YEAR STORM (BASELINE) AND FUTURE STORM SURGE FOR THE YEAR (2025), NEGRIL

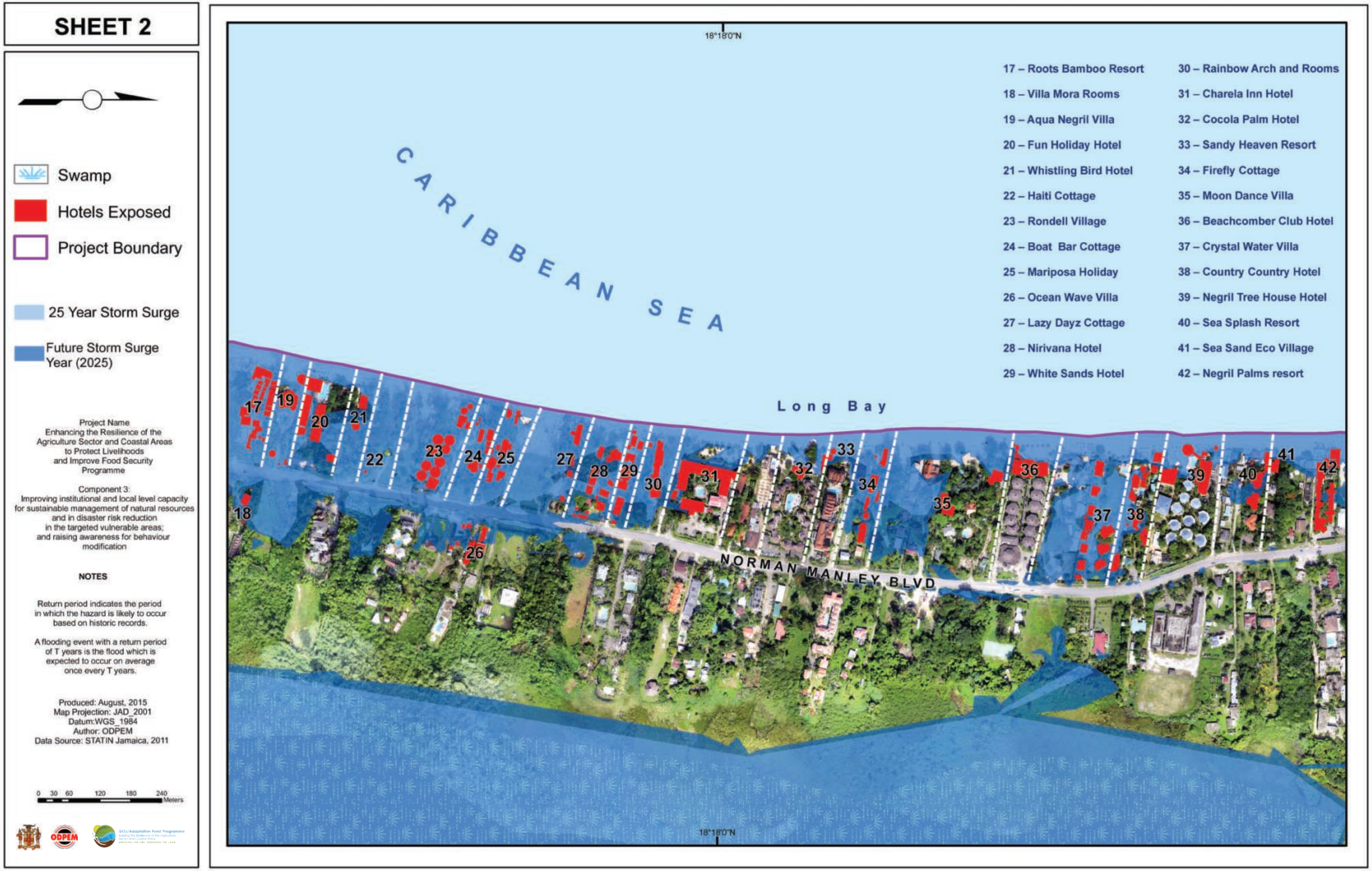



Map 4.22: ASSETS EXPOSED TO 25 YEAR STORM (BASELINE) AND FUTURE STORM SURGE

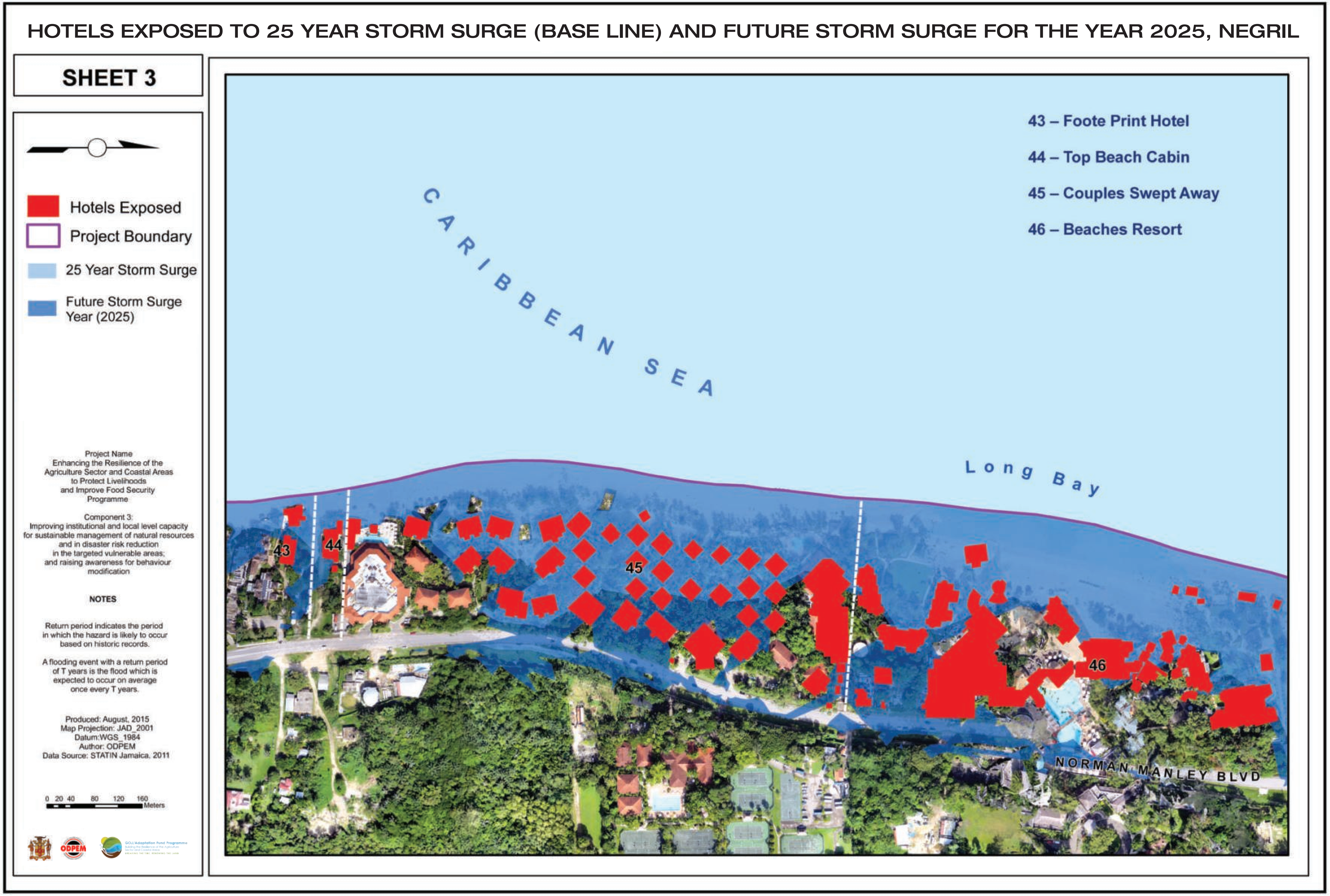



Map 4.23: Hotels exposed to 25 year storm surge (base line) and future storm surge for mid century scenario

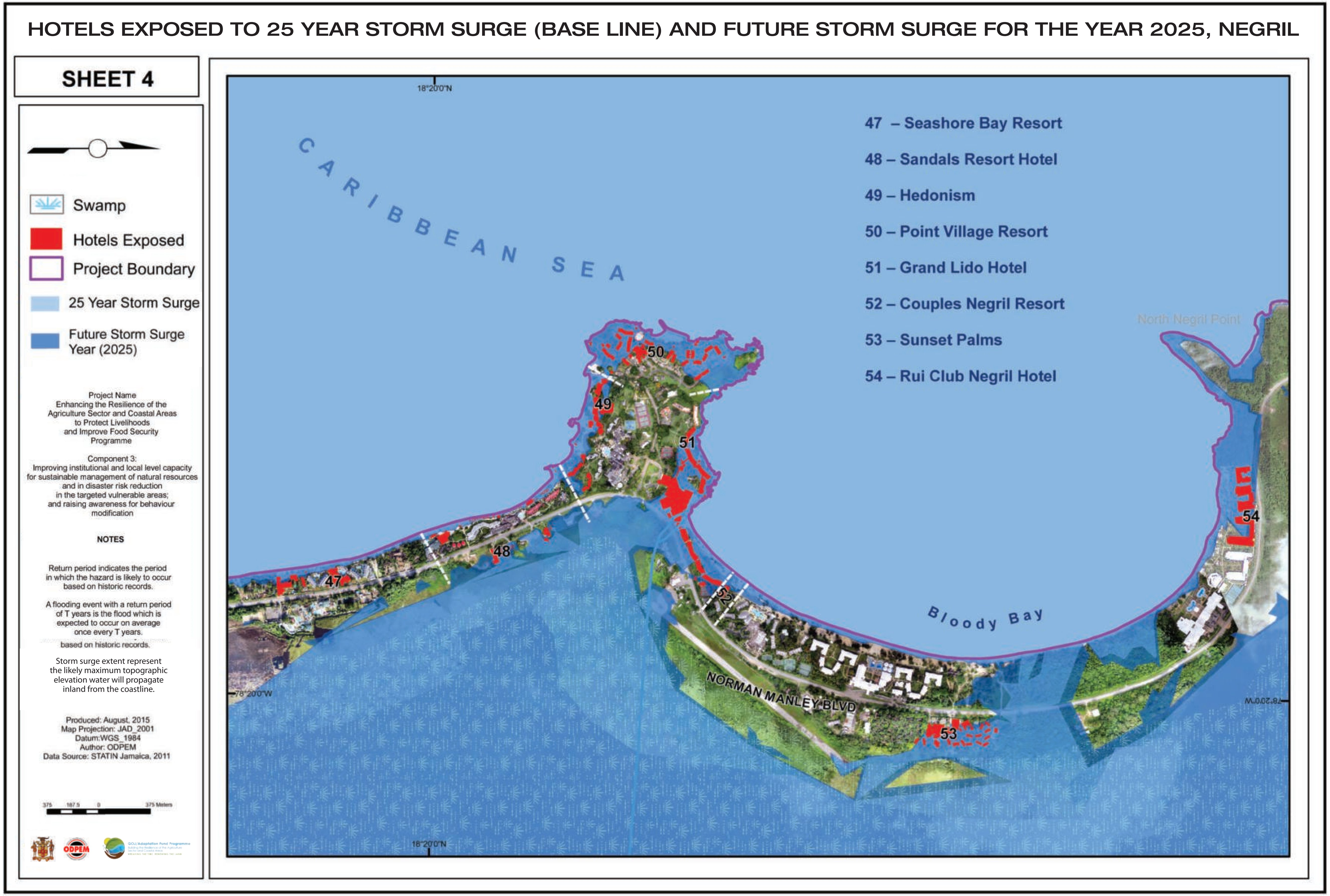
## HOTELS EXPOSED TO 25 YEAR STORM SURGE (BASE LINE) AND FUTURE STORM SURGE FOR THE YEAR 2025, NEGRIL



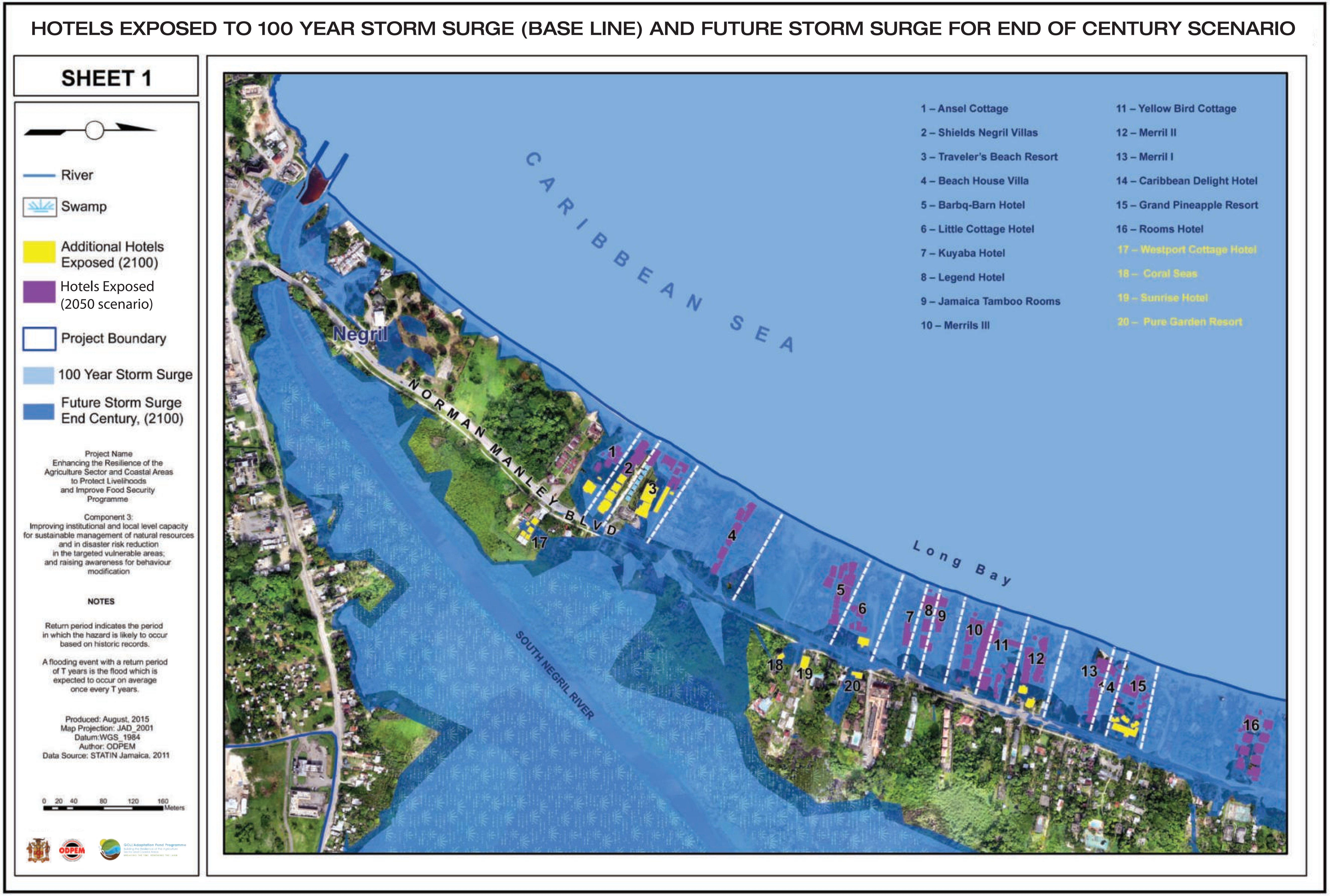

Map 4.24: Hotels exposed to 25 year storm surge (base line) and future storm surge for mid century scenario



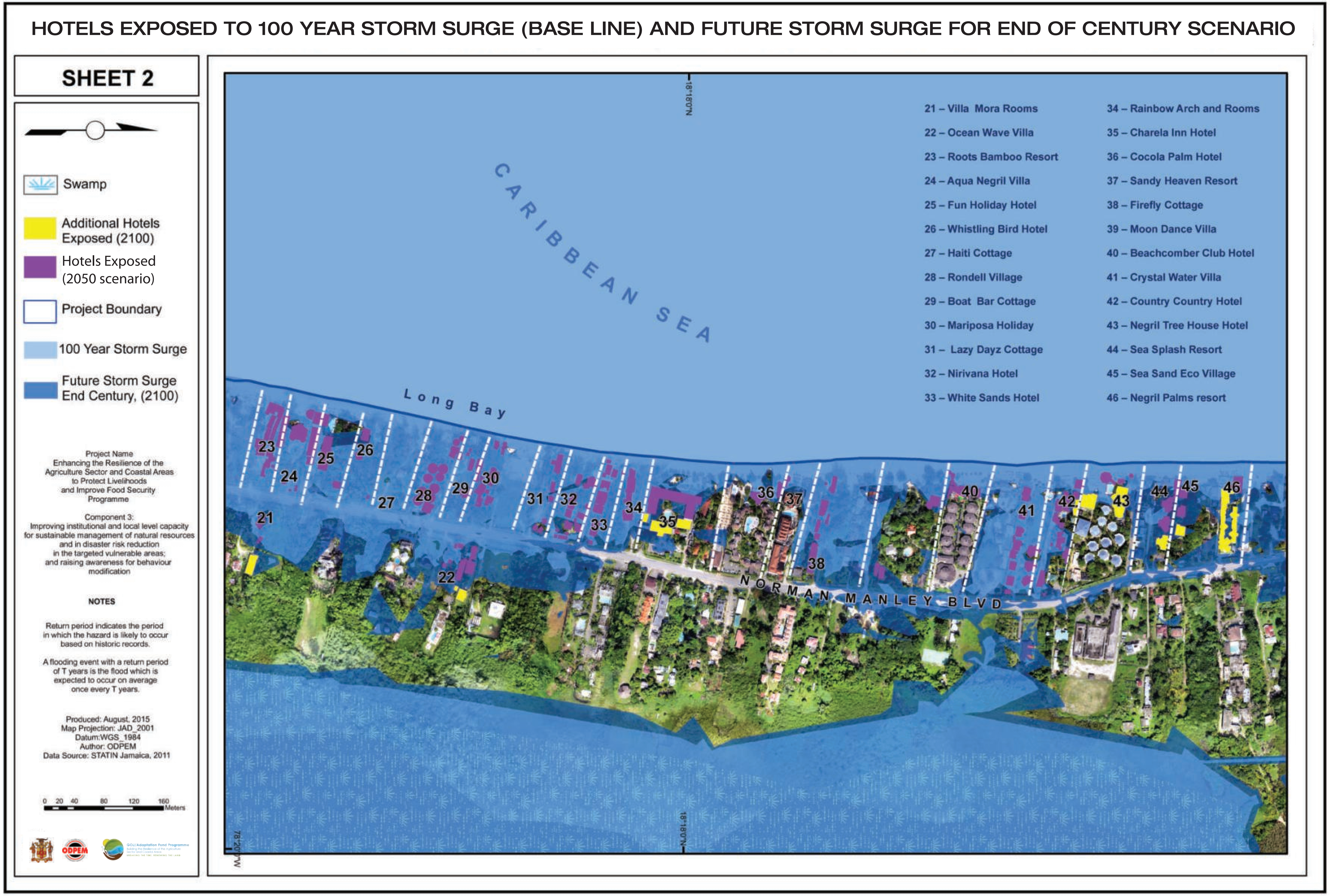

Map 4.25: Hotels exposed to 25 year storm surge (base line) and future storm surge for mid century scenario



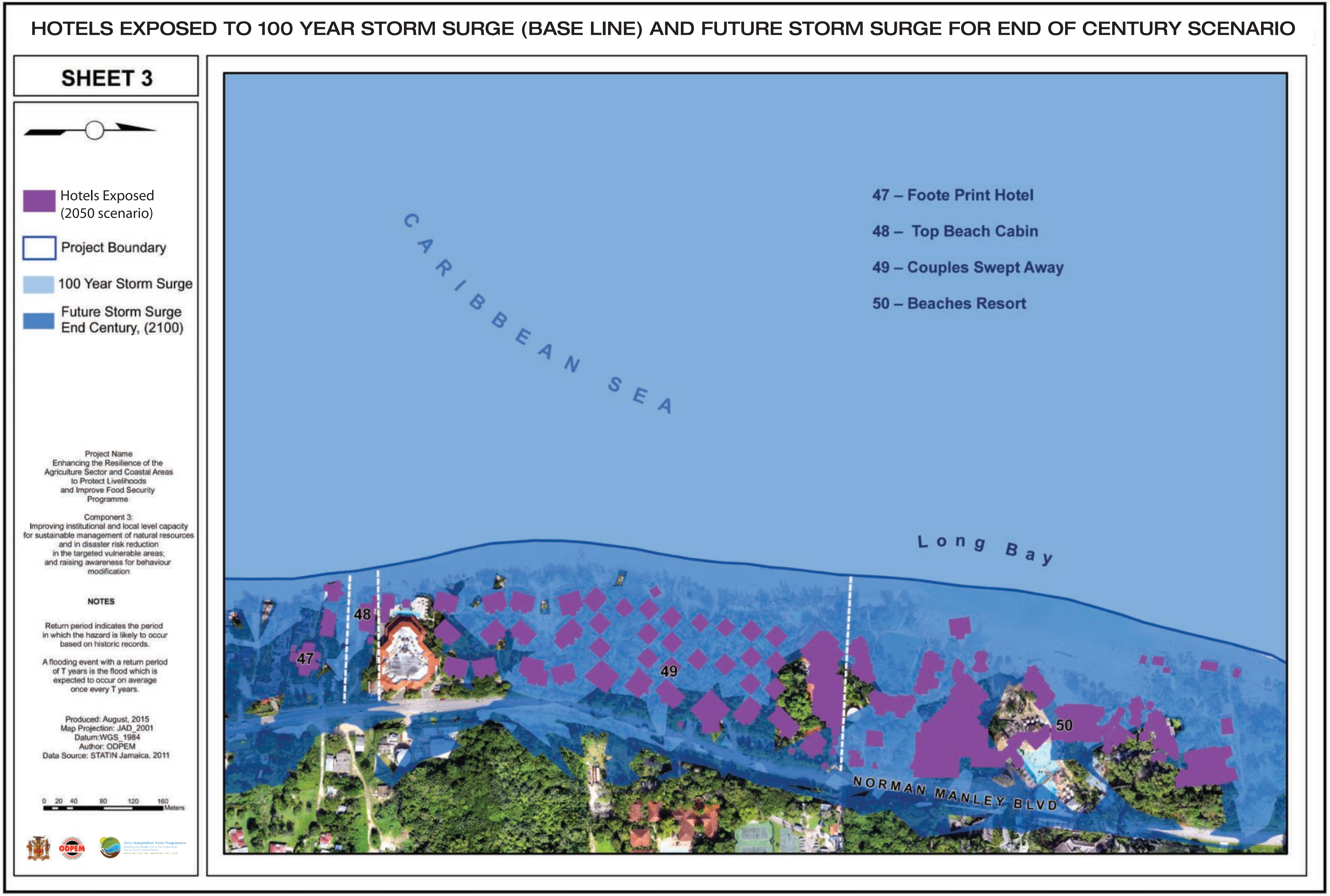

Map 4.26: Hotels exposed to 25 year storm surge (base line) and future storm surge for mid century scenario



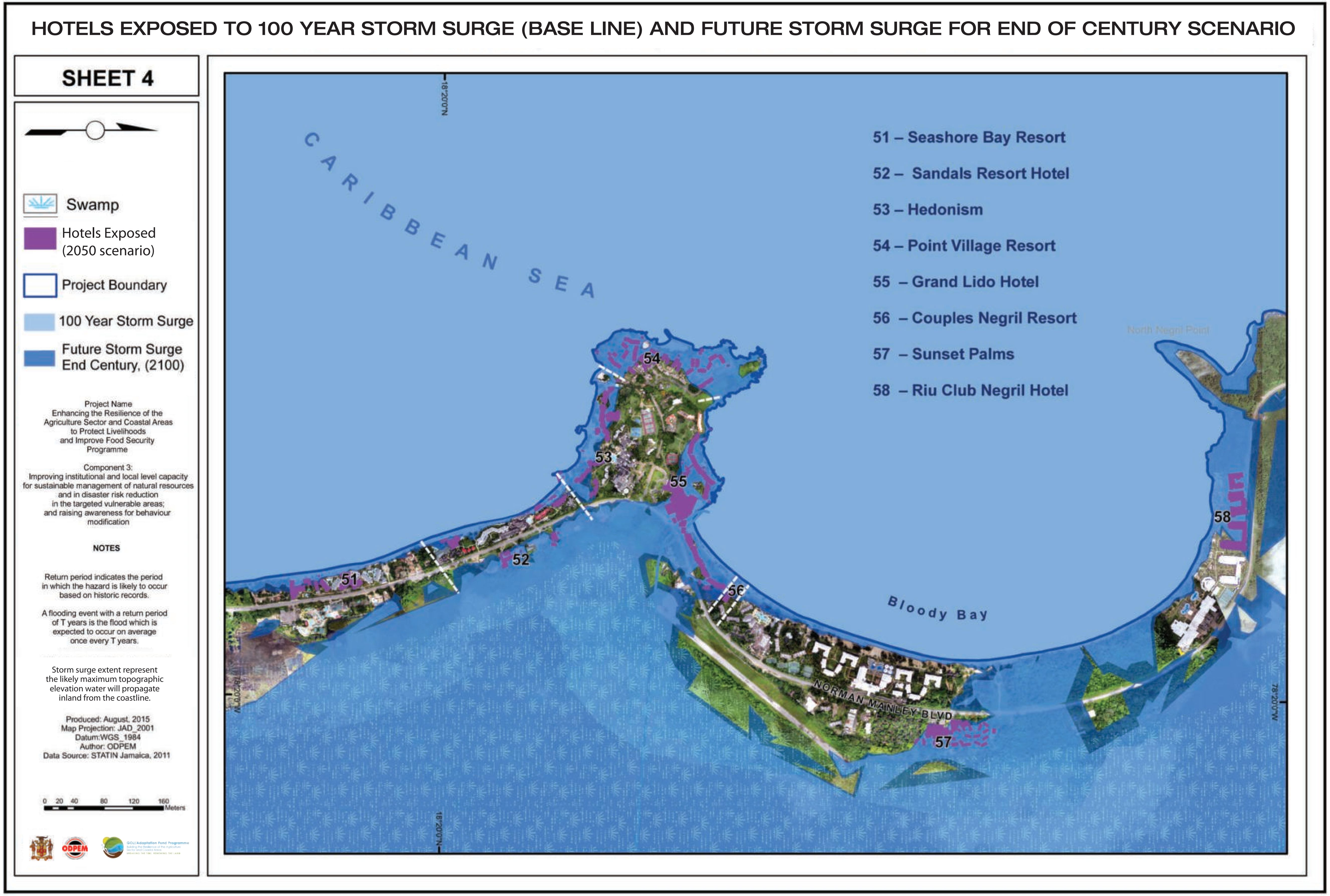

Map 4.27: Hotels exposed to 100 year storm surge (base line) and future storm surge for end of century scenario




Map 4.28: Hotels exposed to 100 year storm surge (base line) and future storm surge for end of century scenario




Map 4.29: Hotels exposed to 100 year storm surge (base line) and future storm surge for end of century scenario




Map 4.30: Hotels exposed to 100 year storm surge (base line) and future storm surge for end of century scenario

## 4.2.1.2 Buildings Exposed to Wave Overtopping

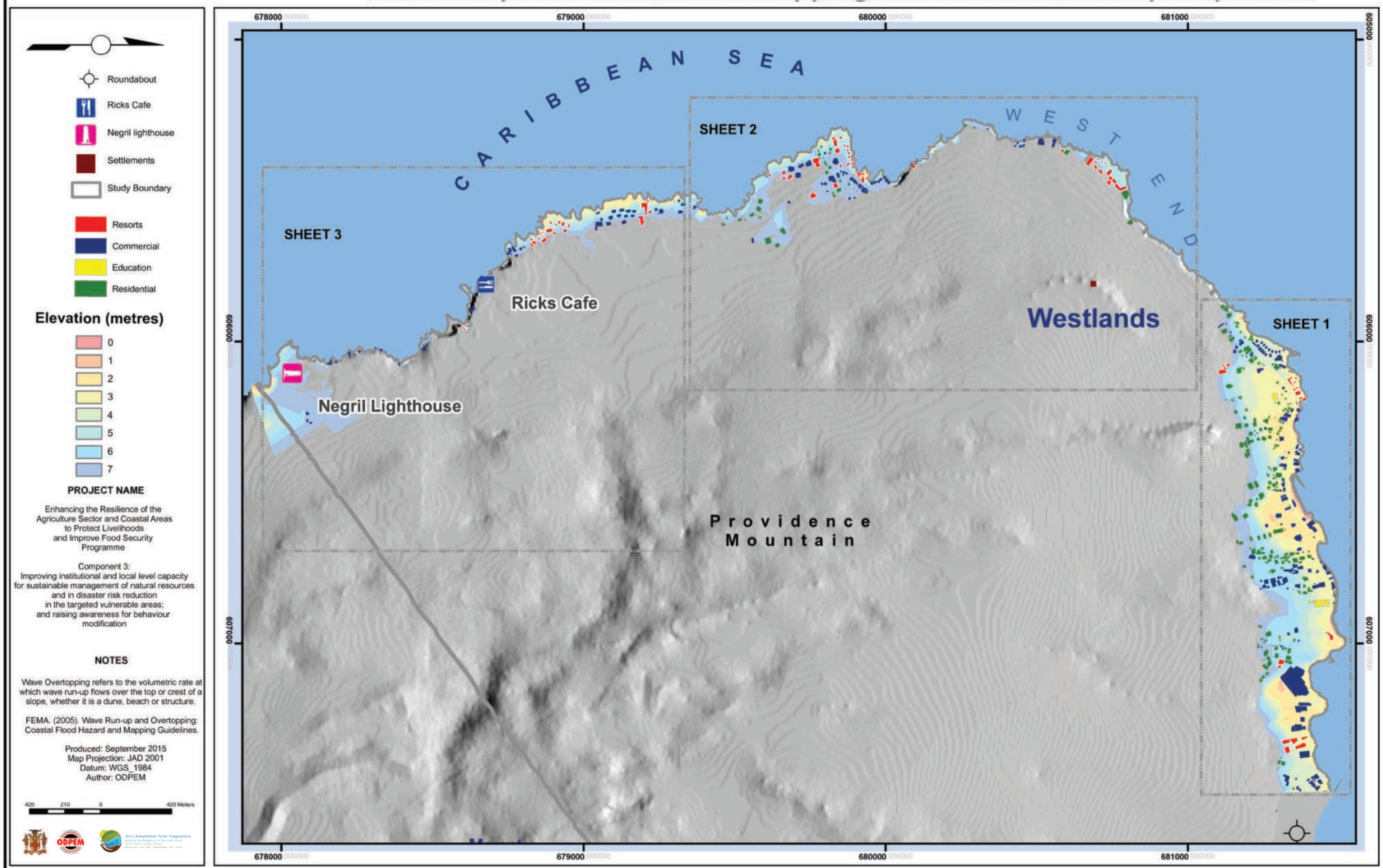
This analysis was undertaken for buildings that are located along West End in Negril. Section 3 of this atlas had established that areas of elevations up to 7.3 m along the cliff face in West End is susceptible to overtopping and so buildings that are within this elevation will be exposed to wave overtopping (See Table 4.5). From the table, 23% of commercial buildings are exposed to wave overtopping for 10 - 100 year storm event. This is 5% more than the exposure for commercial buildings (17%) to 100 year current storm surge in Long Bay and Orange Bay combined. Comparatively, fewer resorts are exposed to wave overtopping (10%) than to storm surge hazard, due to the fact that hotels in Negril are primarily concentrated along the 9 mile beach of Long Bay and Bloody Bay.

Of all the critical facilities in Negril, 5 buildings representing 36% are exposed to wave overtopping for 10-100 years storm event. These buildings are the Negril All Age and West End Basic Schools. Similarly, over 50% of public buildings to include Negril Library, Post Office and Lighthouse are also exposed to wave overtopping. Important to note is that these buildings are not exposed to as previously discussed to baseline and future storm surges resulting from sea level rise.

Table 4.5: Buildings Exposed to Wave Overtopping

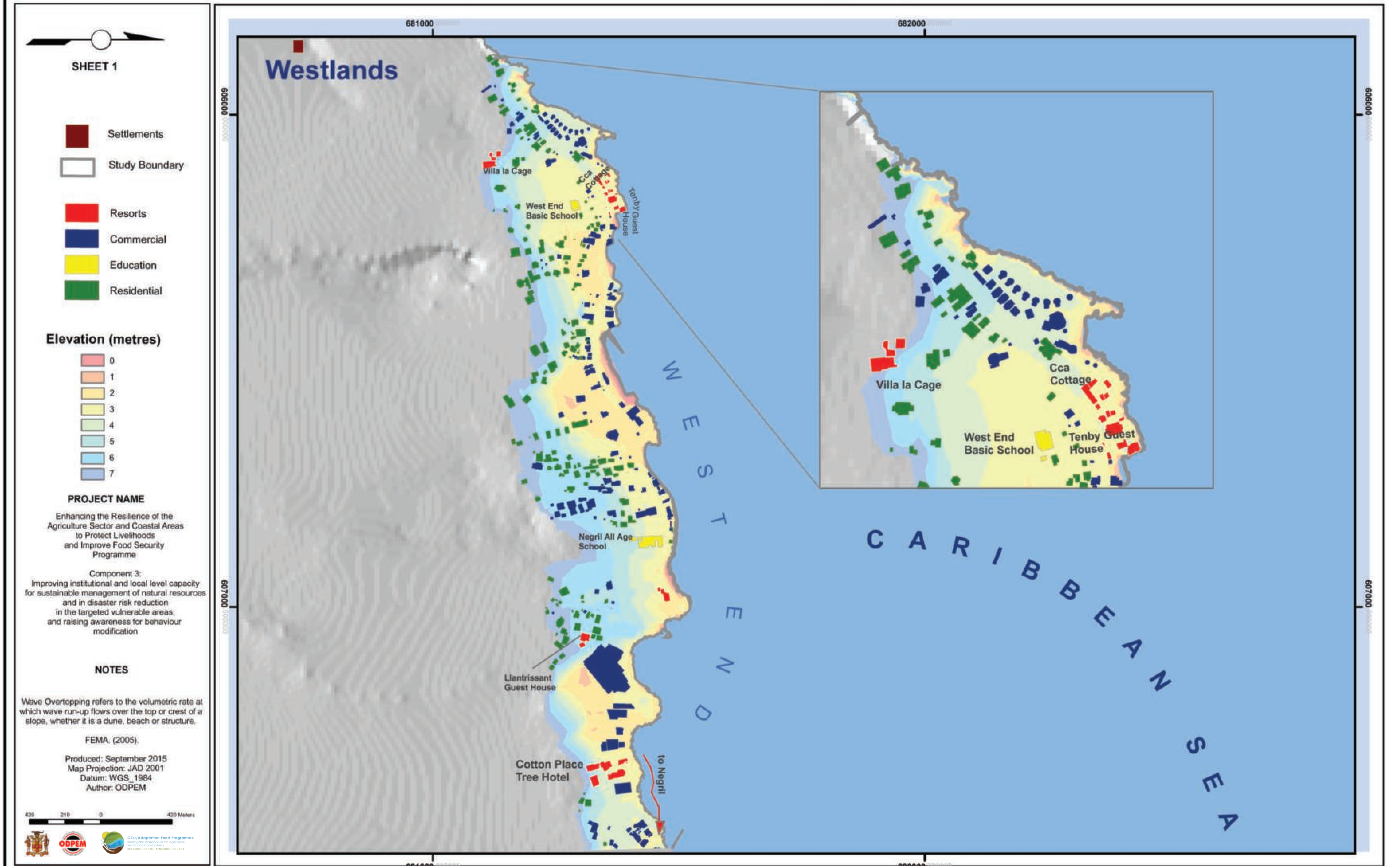
| Land use Classifications | Total Buildings | Elevation (meters) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.01 - 1 | 1.01 - 2 | 2.01 - 3 | 3.01 - 4 | 4.01 - 5 | 5.01 - 6 | 6.01 - 7.3 | Total # of Buildings Exposed | % of Buildings Exposed |
| Residential | 5113 | 0 | 0 | 14 | 25 | 29 | 31 | 47 | 74 | 220 | 4% |
| Commercial | 1718 | 0 | 9 | 50 | 77 | 71 | 45 | 48 | 93 | 393 | 23% |
| Industrial Light | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Educational | 14 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 5 | 36% |
| Office | 48 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 3 | 6% |
| Public Assembly | 31 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 9 | 29% |
| Public Buildings | 21 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 8 | 11 | 52% |
| Institutional | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10% |
| Resort (Hotel,Villas/Cottages Guest House) | 1254 | 0 | 3 | 6 | 17 | 12 | 19 | 23 | 45 | 125 | 10% |
| - Guest House | 170 | 0 | 1 | 3 | 16 | 5 | 1 | 2 | 4 | 32 | 10% |
| - Villas/Cottages | 144 | 0 | 0 | 0 | 2 | 9 | 12 | 12 | 15 | 50 | 10% |
| - Hotel | 940 | 0 | 0 | 2 | 4 | 7 | 12 | 24 | 25 | 74 | 10% |
| Utilities | 29 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3% |
| Recreational | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Sewerage/ Pump/ Lift Station | 14 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 7% |
| Vacant Buildings | 114 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1.8% |
| Derelict Building | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Under Construction | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ware House | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Total | 8573 | 0 | 13 | 79 | 149 | 137 | 125 | 159 | 258 | 926 | 11% |

## ASSETS EXPOSED TO WAVE OVERTOPPING - WEST END 10-100 (YEAR) EVENT

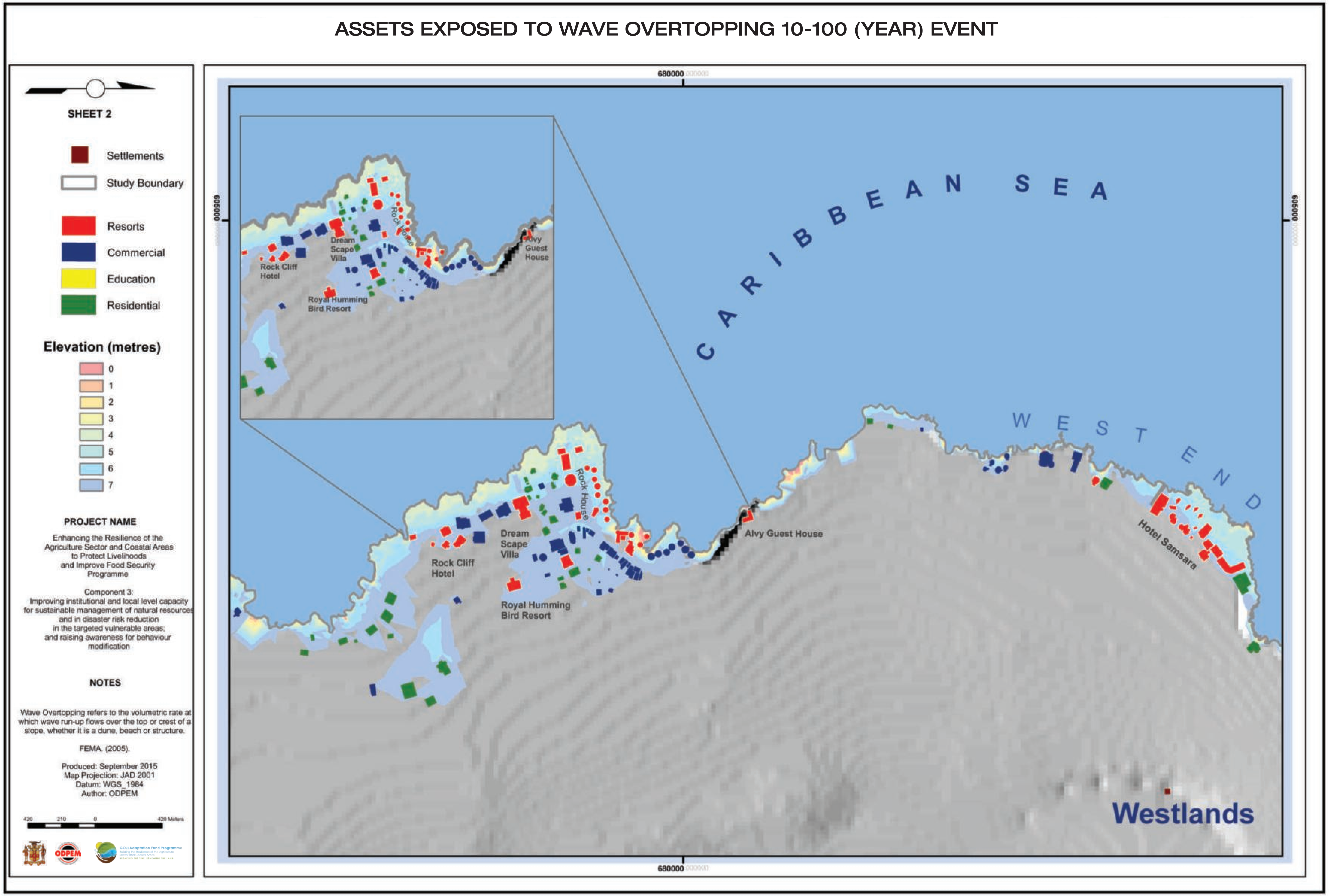



Map 4.31: Assets exposed to wave overtopping - west end 10-100 (year) event

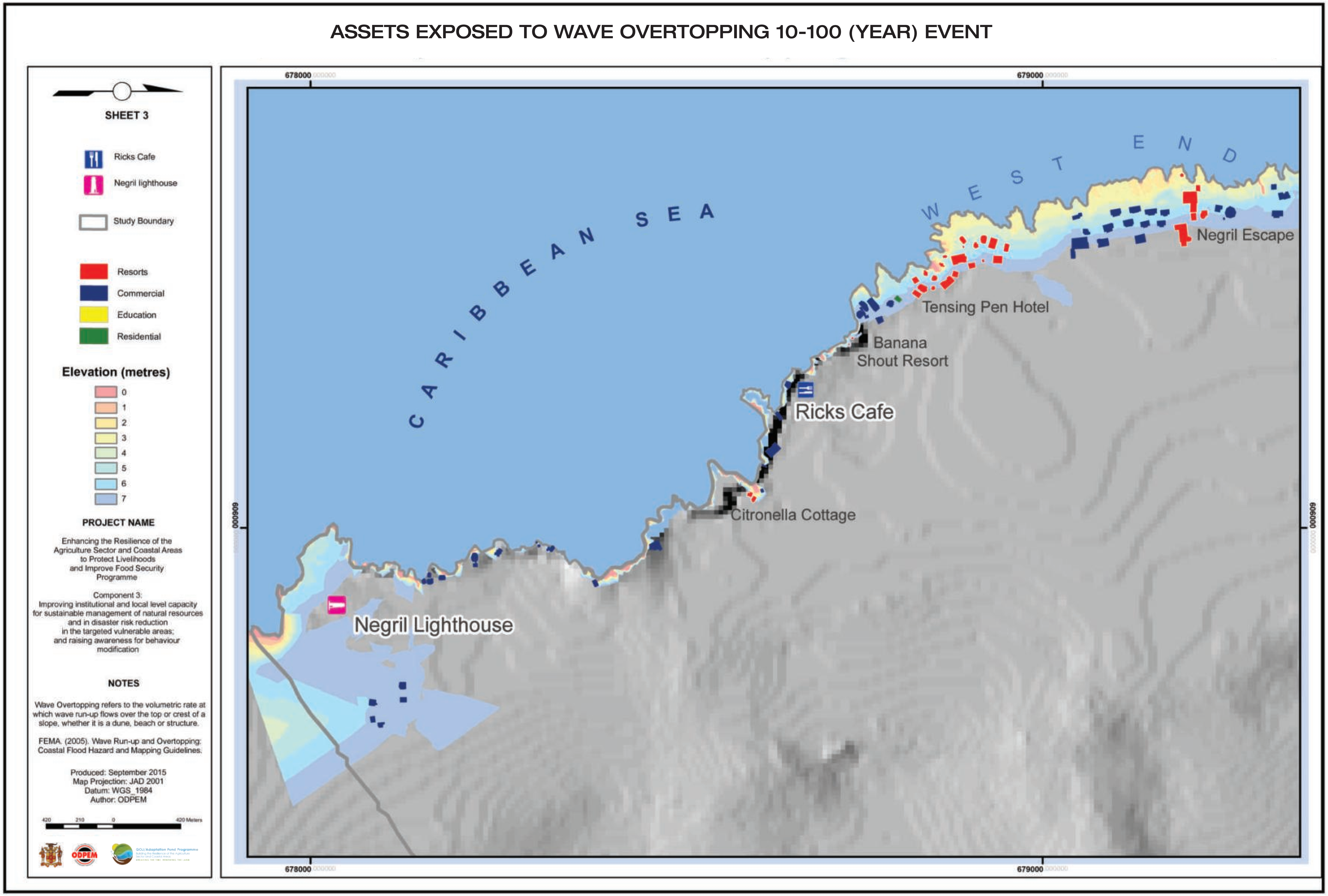
ASSETS EXPOSED TO WAVE OVERTOPPING 10-100 (YEAR) EVENT




Map 4.32: Assets exposed to wave overtopping 10-100 (year) event




Map 4.33: Assets exposed to wave overtopping 10-100 (year) event




Map 4.34: Assets exposed to wave overtopping 10-100 (year) event

## 4.2.1.3 Buildings Exposed to Coastal Erosion

Coastal erosion will affect buildings along the 9 mile stretch in Long Bay and Bloody Bay in Negril, primarily hotels. Of all the land uses, resort account for the highest percentage of buildings exposed to this hazard with 17.4% associated with 100 year storm event. A 2.3% future intensification of exposure is expected for resort land use taking into account sea level rise (2100 scenario) without mitigation (Refer to Table 4.6). According to CaribSave, 2009, a major impact of shoreline erosion as a result of projected sea level rise is *"the virtual elimination of the beach area that is a primary attraction for tourists to the region"*.

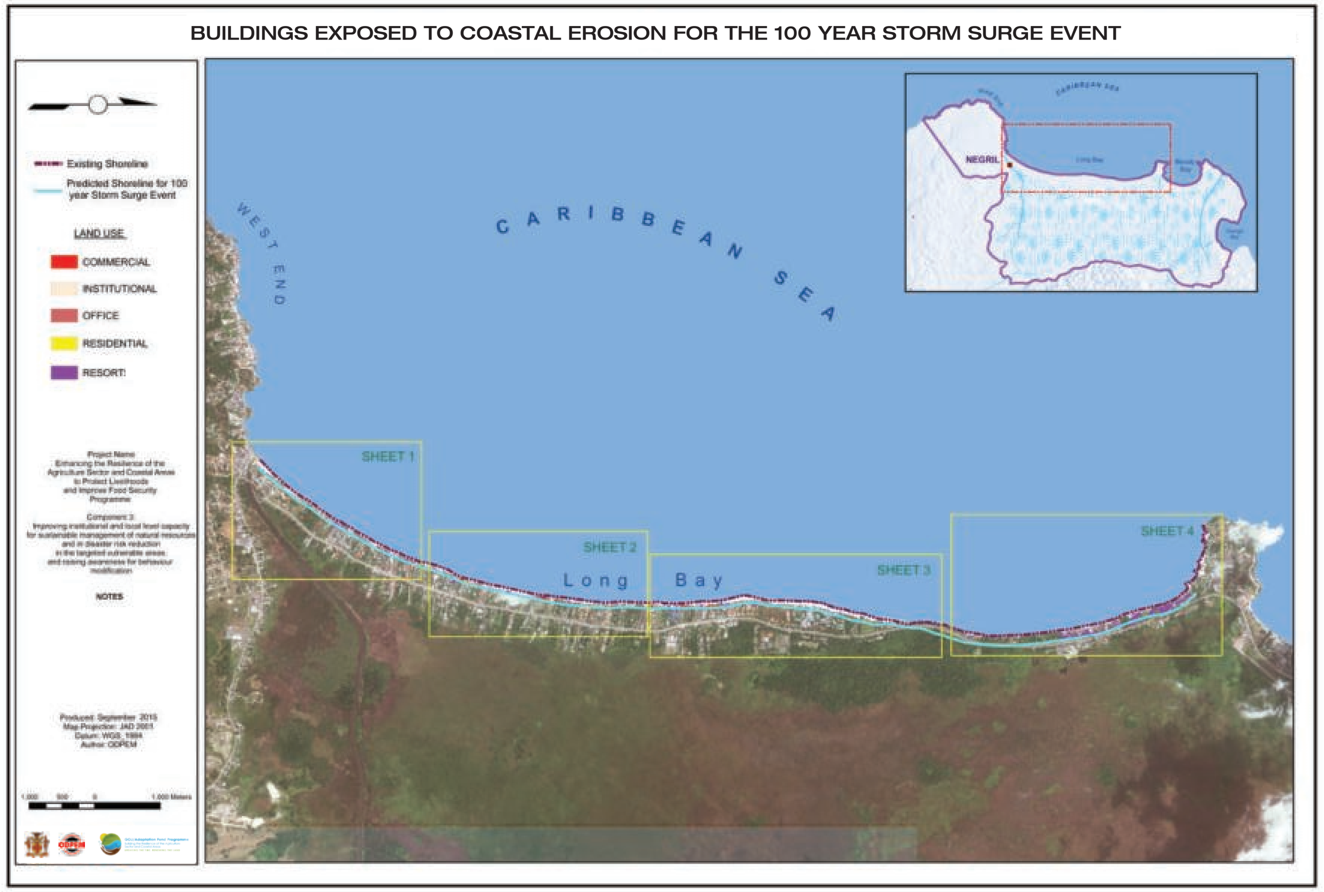
Coastal erosion scenarios were further analyzed under sea level rise conditions taking into consideration initially proposed two (2) offshore breakwaters in Long Bay, a structural mitigation intervention under Component I of the programme. The results show that accretion (beach growth) and beach stability are expected particularly in the central and northern sections of the beach in Long Bay (Refer to Figure Map 4.40). The analysis of the model further revealed that over 80% of the shoreline experienced accretion if the breakwaters in place. The beach growth is estimated to be 109,400m$^3$ with most of the growth expected to occur at the northern section of Long Bay.

Table 4.6 also shows that the number of buildings exposed to coastal erosion is expected to be reduced by 1.3% if the breakwaters are implemented. These buildings are located behind the breakwaters in Long Bay.

For commercial land use, an estimated 6.3% and 9.8% of buildings are exposed to coastal erosion resulting from the 100 year storm event and sea level rise, respectively. These commercial activities as previously mentioned play a role in tourism in Negril such as craft vendors, small business operators (bars, restaurants).

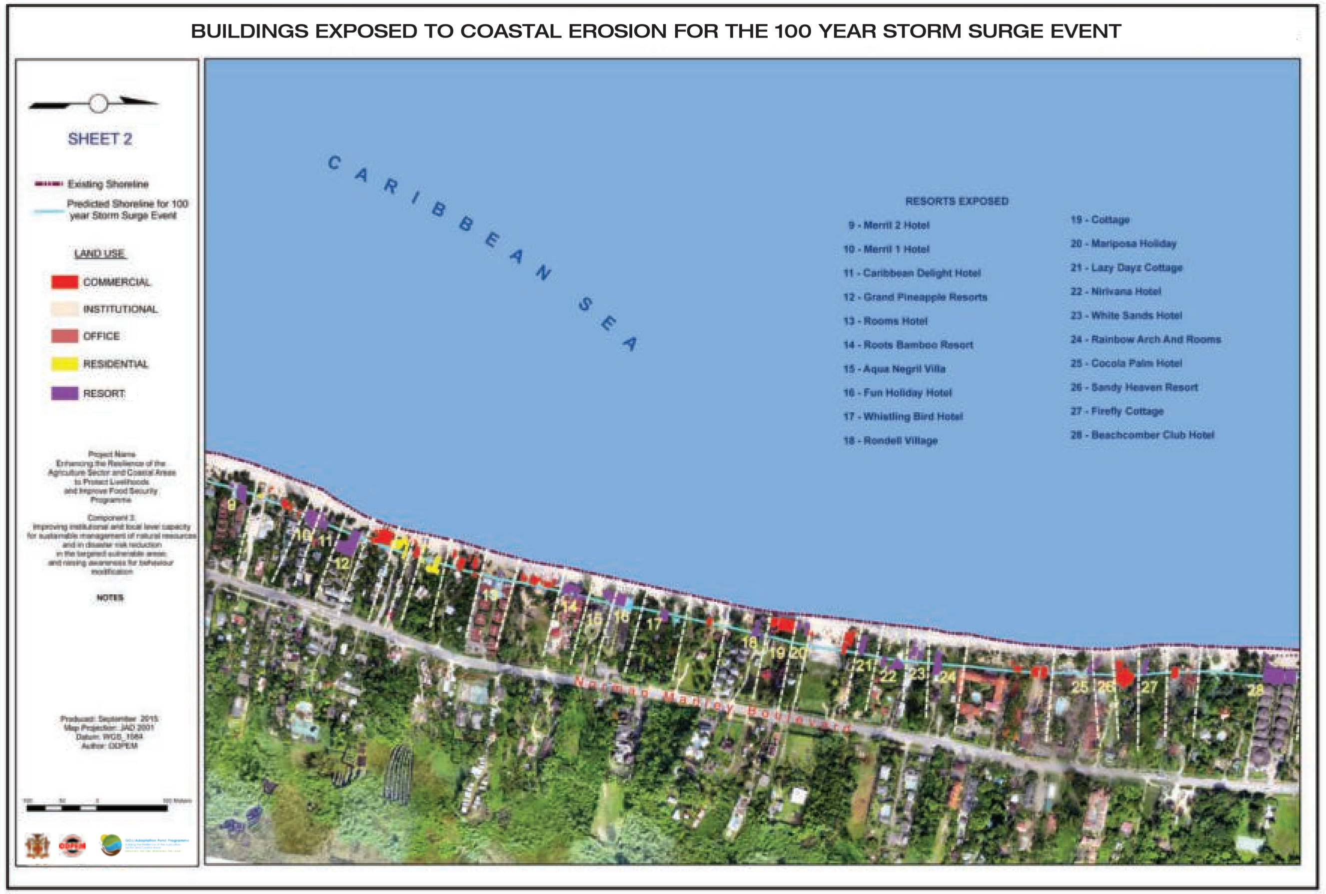
Table 4.6: Buildings exposed to Coastel Erosion

| Land Use | Total Buildings | Hazard: Coastal Erosion Number of Structures | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 Storm Event | % in Hazard Area | SLR, 2100- (Without Mitigation) | % in Hazard Area | SLR ,2100 (With mitigation) | % in Hazard Area |
| Residential | 5113 | 14 | 0.3% | 23 | 0.4% | 17 | 0.3% |
| Commercial | 1718 | 108 | 6.3% | 168 | 9.8% | 81 | 4.7% |
| Industrial Light | 48 | 0 | 0.0% | 1 | 2.1% | 1 | 2.1% |
| Educational | 14 | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Office | 48 | 1 | 0.0% | 1 | 2.1% | 0 | 0.0% |
| Public Assembly | 31 | 0 | 0.0% | 1 | 3.2% | 0 | 0.0% |
| Public Buildings | 21 | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Institutional | 5 | 2 | 40.0% | 2 | 40.0% | 0 | 0.0% |
| Resorts | 1254 | 218 | 17.4% | 247 | 19.7% | 239 | 19.1% |
| Resort (Guest House) | 170 | 20 | 11.8% | 33 | 19.4% | 34 | 20.0% |
| Resort (Villas/Cottages) | 144 | 8 | 5.6% | 8 | 5.6% | 6 | 4.2% |
| Resort (Hotel) | 940 | 190 | 20.2% | 206 | 21.9% | 199 | 21.2% |
| Utilities | 29 | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Recreational | 44 | 15 | 34.1% | 19 | 43.2% | 18 | 40.9% |
| Sewerage/ Lift Station | 14 | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Vacant Buildings | 114 | 12 | 10.5% | 13 | 11.4% | 12 | 10.5% |
| Derelict Building | 54 | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Under Construction | 71 | 2 | 2.8% | 2 | 2.8% | 1 | 1.4% |
| Ware House | 9 | 0 | 0% | 0 | 0% | 0 | 0.0% |
| Total | 8573 | 372 | 4.3% | 477 | 5.6% | 369 | 4.3% |

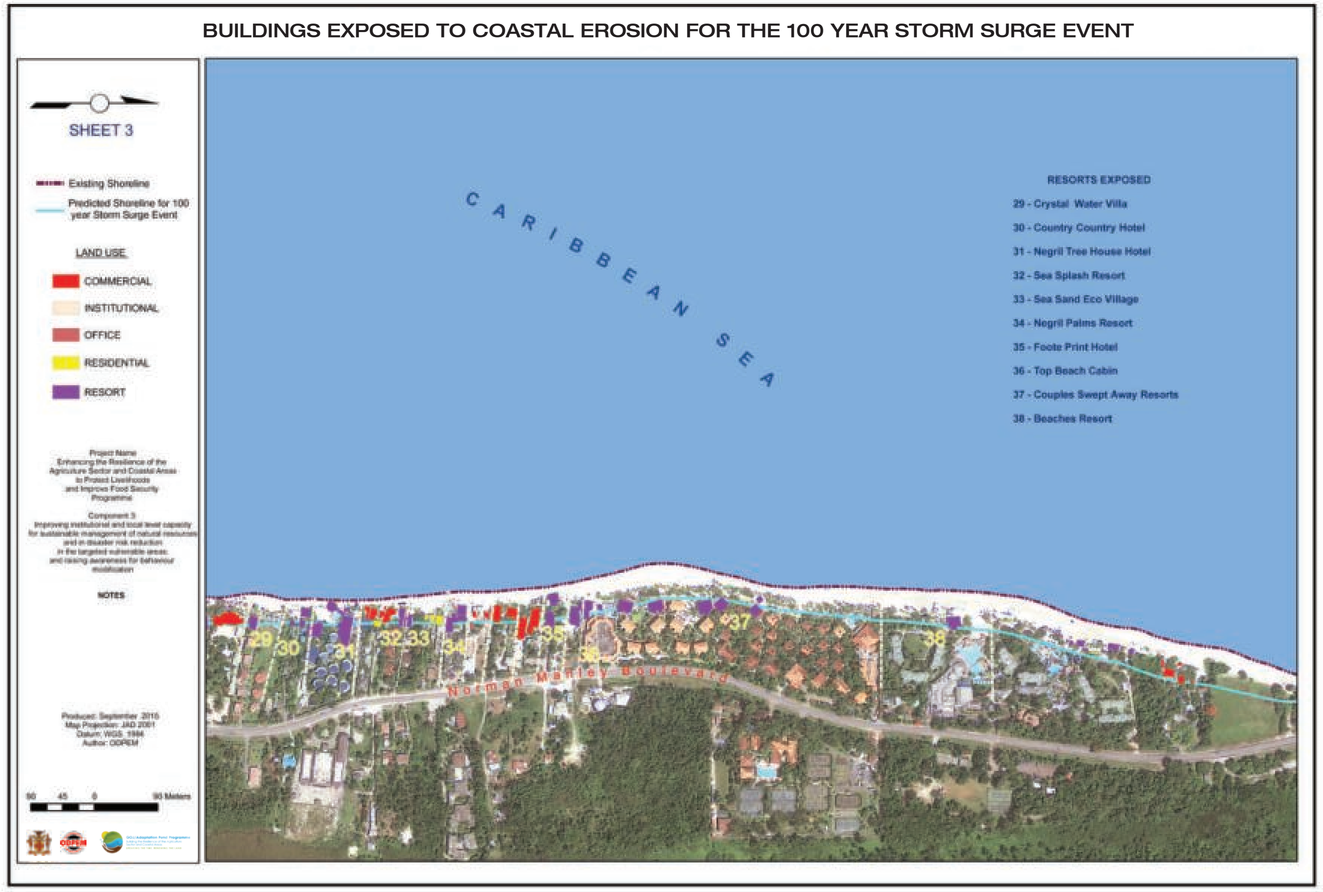



Map 4.35: Buildings exposed to coastal erosion for the 100 year storm surge event


Map 4.36: Buildings exposed to coastal erosion for the 100 year storm surge event

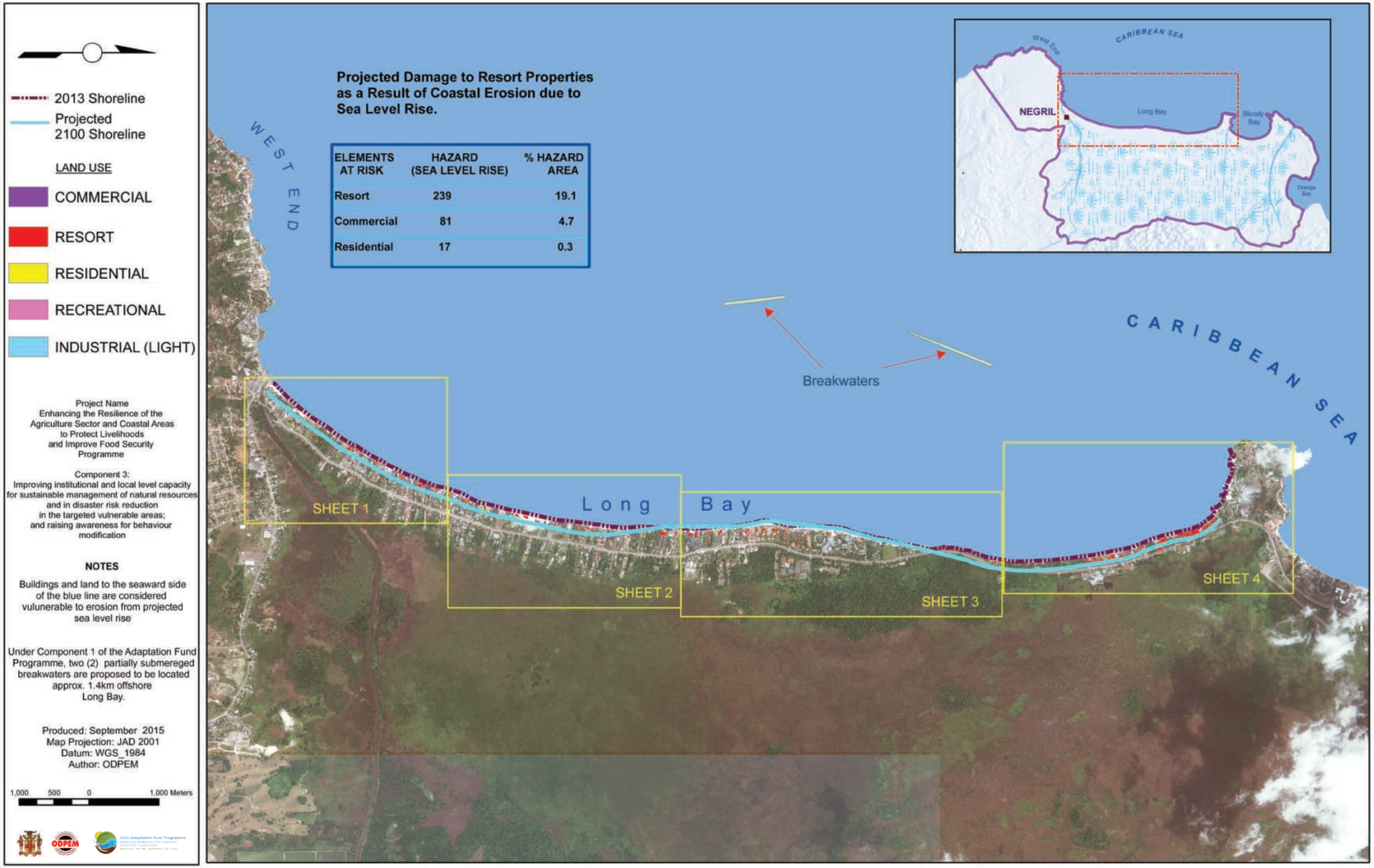



Map 4.37: Buildings exposed to coastal erosion for the 100 year storm surge event




Map 4.38: Buildings exposed to coastal erosion for the 100 year storm surge event

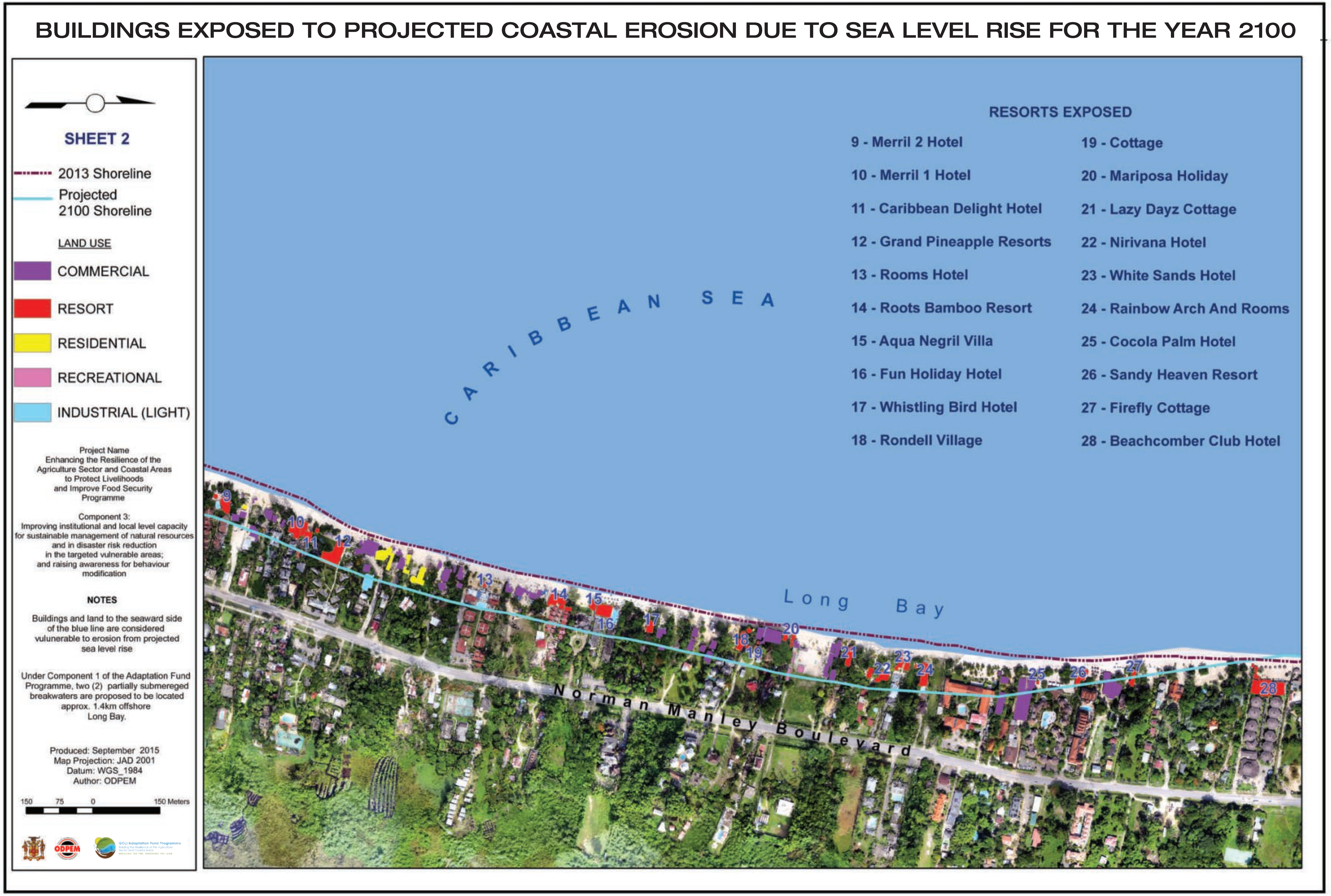
## BUILDINGS EXPOSED TO PROJECTED COASTAL EROSION DUE TO SEA LEVEL RISE FOR THE YEAR 2100



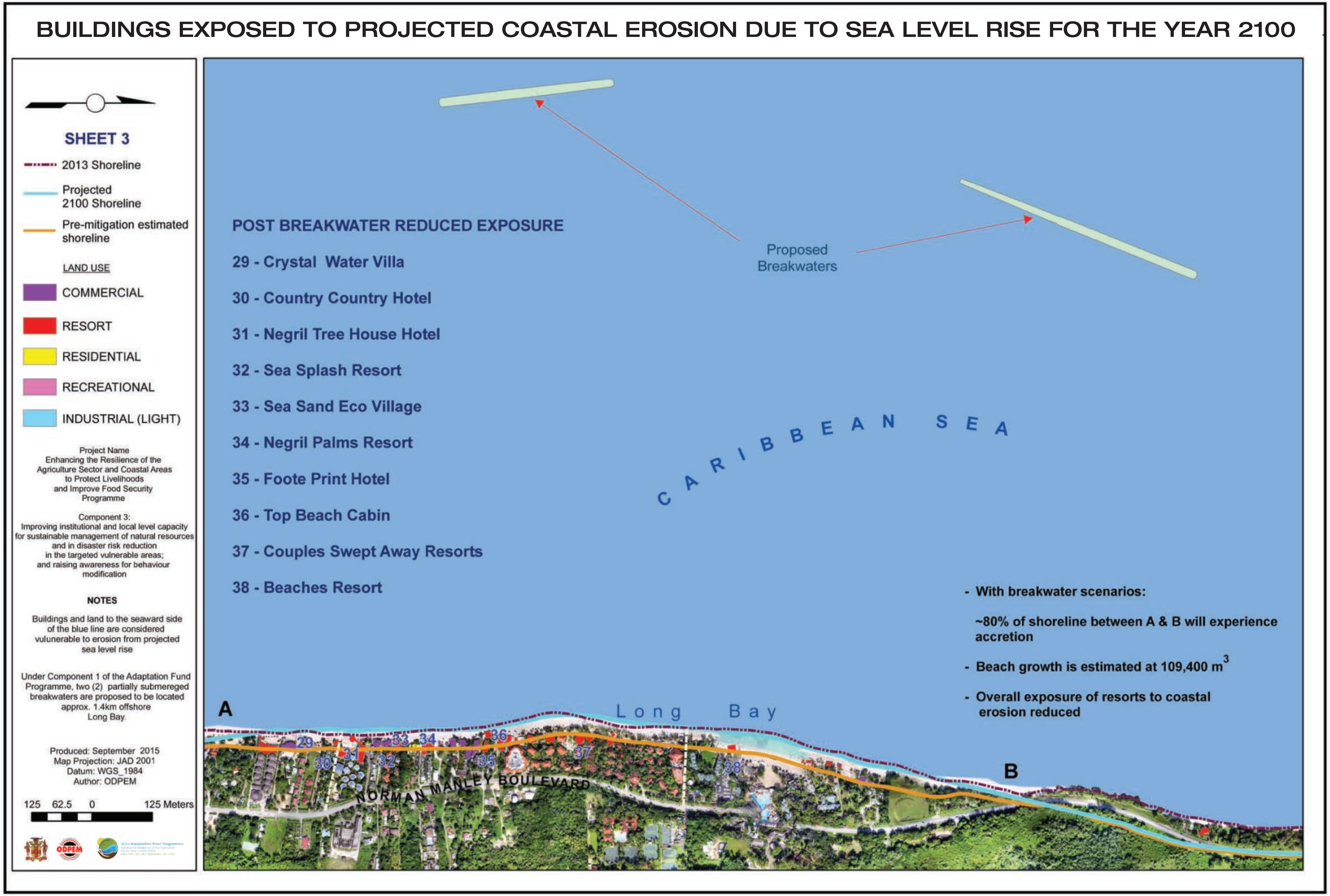

| ELEMENTS AT RISK | HAZARD (SEA LEVEL RISE) | % HAZARD AREA |
|---|---|---|
| Resort | 239 | 19.1 |
| Commercial | 81 | 4.7 |
| Residential | 17 | 0.3 |

Map 4.39: Buildings exposed to projected coastal erosion due to sea level rise for the year 2100

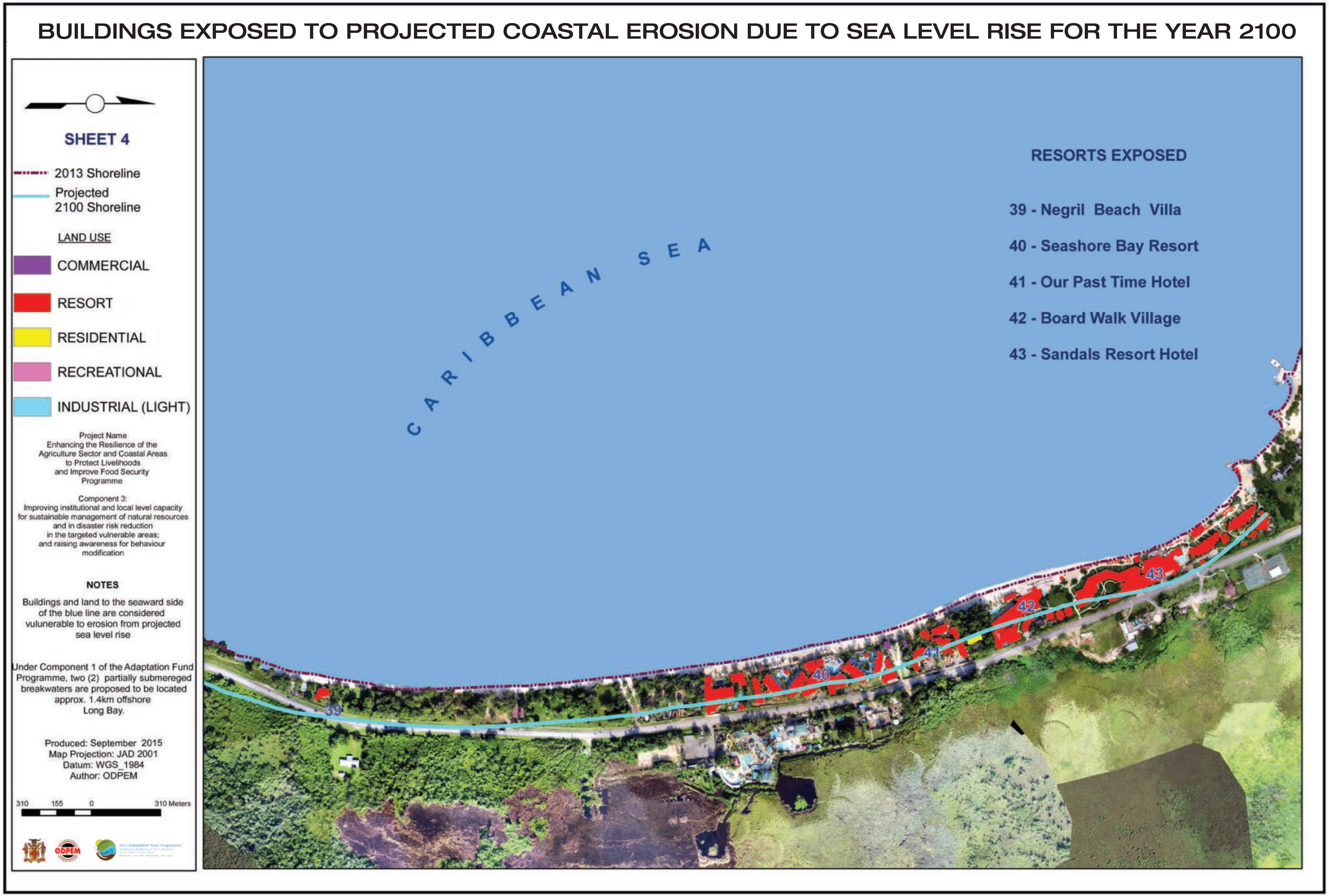

Map 4.40: Buildings exposed to projected coastal erosion due to sea level rise for the year 2100




Map 4.41: Buildings exposed to projected coastal erosion due to sea level rise for the year 2100




Map 4.42: Buildings exposed to projected coastal erosion due to sea level rise for the year 2100




Map 4.43: Buildings exposed to projected coastal erosion due to sea level rise for the year 2100

# 4.3 Exposure of Population

## 4.3.1 Population Exposed Storm Surge

An exposure analysis was carried out to assess the population living in the storm surge inundation zone. The pattern of population exposure resembles that of the location of residential buildings inland from the coastline. Using the baseline population for the year 2011, an estimated 558 persons representing five (5) per cent of total population is exposed to 100 year storm surge scenario. The majority of the exposed population resides in the Enumeration Districts (ED) of W1 in Long Bay, W2 along Non-Pariel Main Road and W73 along the coast in Orange Bay.

Table 4.7: Hazard : Current and Future Storm Surge

| Total Population | Population Exposed to Hazard | | | | | | |
|---|---|---|---|---|---|---|---|
| | Storm Surge | 25 Year RP | % in Hazard Area | 50 Year RP | % in Hazard Area | 100 Year RP | % in Hazard Area |
| 11,178 | | 426 | 3.8% | 489 | 4.4% | 558 | 5% |

Disaggregating the exposed population by age cohort reveals (Refer to Table 4.8) that the majority is from the productive age group or working age population (15-64) accounting for 72% of the total exposed population to inundation associated with 100 year storm surge scenario. The dependent population (children 15 and under, elderly 65 years and over) represents 28% of the exposed population and these persons are generally considered the most vulnerable in the community who may require special attention during emergencies.

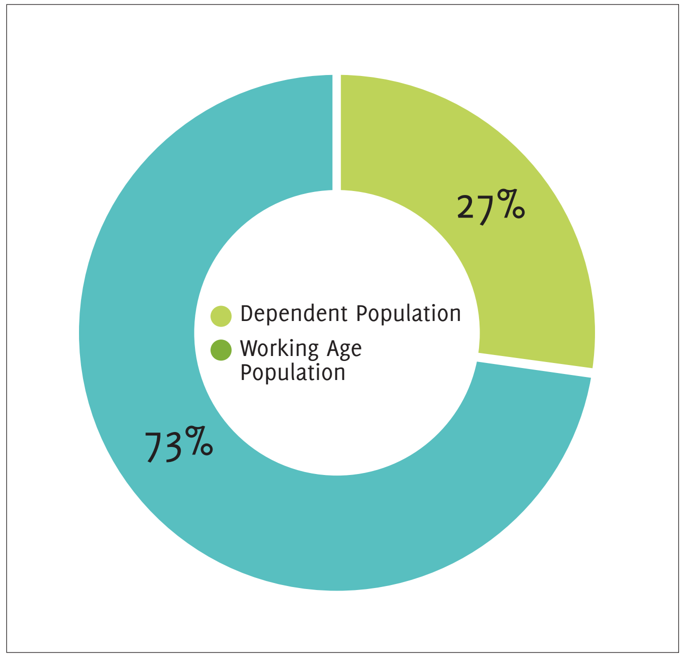



Figure 4.5: Population Exposed to Storm Surge Hazard

Tabe 4.8: Population Exposed to Storm Surge by Age Cohort

| Total Population | Age Cohorts | 25 Year RP | 50 Year RP | 100 Year RP |
|---|---|---|---|---|
| 11,178 | 0 - 14 | 87 | 100 | 114 |
| | 15 - 64 | 310 | 355 | 404 |
| | 65+ | 29 | 34 | 40 |
| | | 426 | 489 | 558 |

### Population Exposed to Future Storm Surge

Estimation of population exposure to future storm surges was carried out using Statistical Institute of Jamaica (STATIN) Population Projections (percentage distribution) for Jamaica, 2000-2050. Starting from baseline population estimates for the year 2011, the future population change was assessed using the projected percentage distribution by age cohort to estimate the population for the 2025 and 2050. The same values for 2050 were used for the 2100 scenario.

Under sea level rise conditions, exposure of the total population increased by 6.7% for future storm surge by the end of the century. This increase of 1.7% represents an additional 751 persons that could be affected by future storm surges associated with 2100 scenario. Table 4.9 shows the projected population exposure to future storm surges taking into consideration sea level rise. The productive age cohort comprises the highest number of persons exposed for all three (3) scenarios accounting for 78% of the total population exposed. This represents a 6% increase in population exposure for future storm surges.

Table 4.9: Population Exposed to Storm Surge and Sea Level Rise by Age Cohort

| Total Population | Age Cohorts | 2025 | 2050 | 100 Year RP |
|---|---|---|---|---|
| | 0 - 14 | 155 | 169 | 208 |
| | 15 - 64 | 730 | 828 | 1022 |
| | 65+ | 48 | 61 | 79 |
| 11,178 | | 933 | 1058 | 1309 |

Similar to 100 year storm surge analysis (baseline), the same Enumeration Districts (ED) of W1, W2 and W73 have the highest population exposed to future storm surges for the mid-century and end of century scenarios (Refer to Maps 4.43 and 4.44).

Figure 4.6 shows the distribution of the population disaggregated by gender exposed to 100 year storm surge scenario and future storm surges associated with 2100 scenario. The analysis reveals that under both scenarios more males are exposed to storm surge hazard than females.

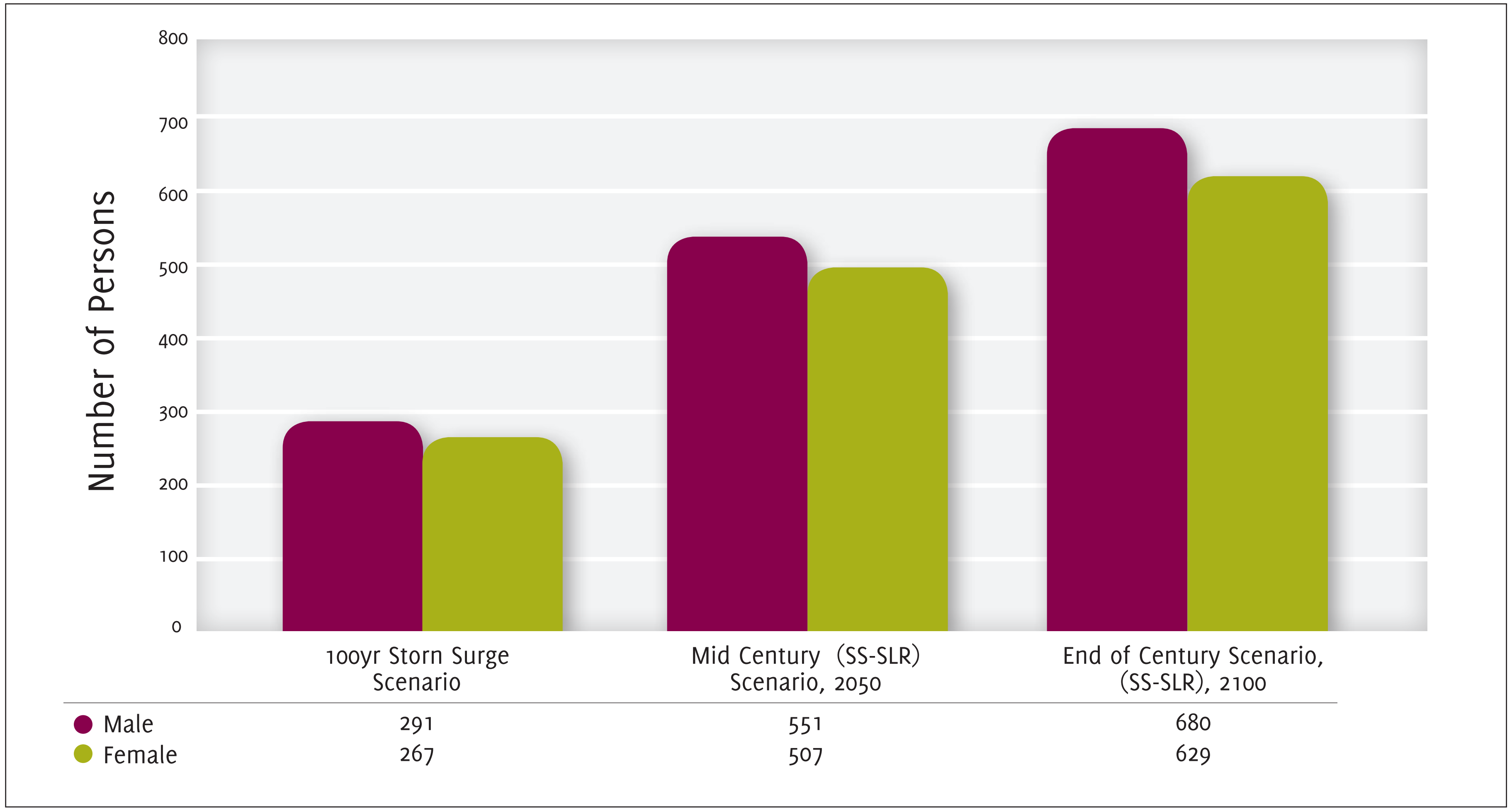



**Figure 4.6: Distribution of population by gender exposed to Storm Surges**

*Source*

## 4.3.2 Population Exposed to Wave Overtopping

Of the total population, just 3% are exposed to wave overtopping, a phenomenon that occurs along West End in Negril. Similar for storm surges and sea level rise, the population within the productive age cohort (15-6) represents the highest percentage of exposure.

**Table 4.10: Population exposed to Wave Overtopping**

| Total Population | Population Exposed to Wave Overtopping by Age Cohort | | | Total Population Exposed | % in Hazard Area |
|---|---|---|---|---|---|
| | 0 - 14 | 15 - 64 | 65+ | | |
| 11,178 | 93 | 260 | 22 | 375 | 3% |

In summary, of the three (3) hazard types and of the total exposed population, the majority (58%) is exposed to the end of century sea level rise scenario for future storm surges. This is not surprising because higher sea level will provide storm surges with a higher "launch point" for the surge (Neumann et al, 2015), and has shown by the models will propagate further inland affecting a larger area.

Baseline storm surge accounts for 25% of the exposed population whilst wave overtopping, a phenomenon which occurs along the cliffs of West End represents 17% of the total exposed population.

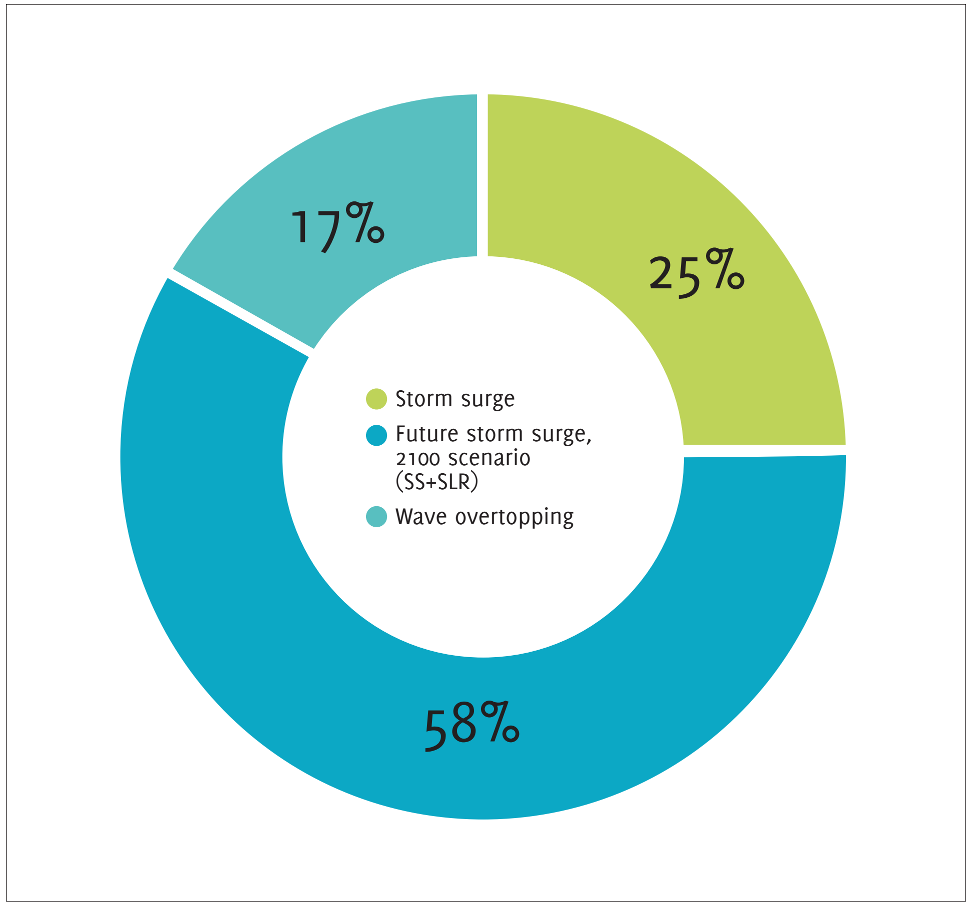



**Figure 4.7: Percentage of exposed population by Hazard Type**

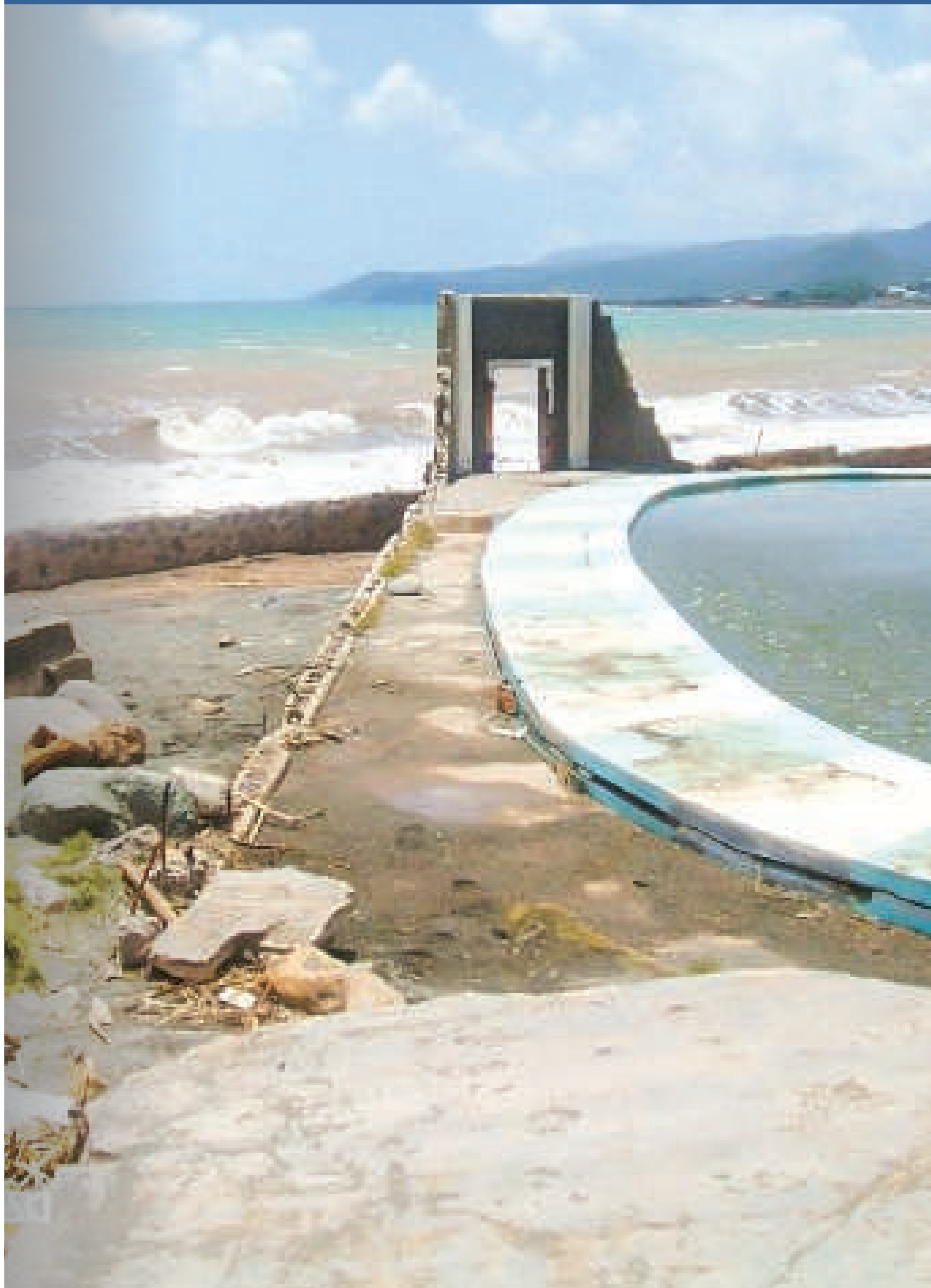
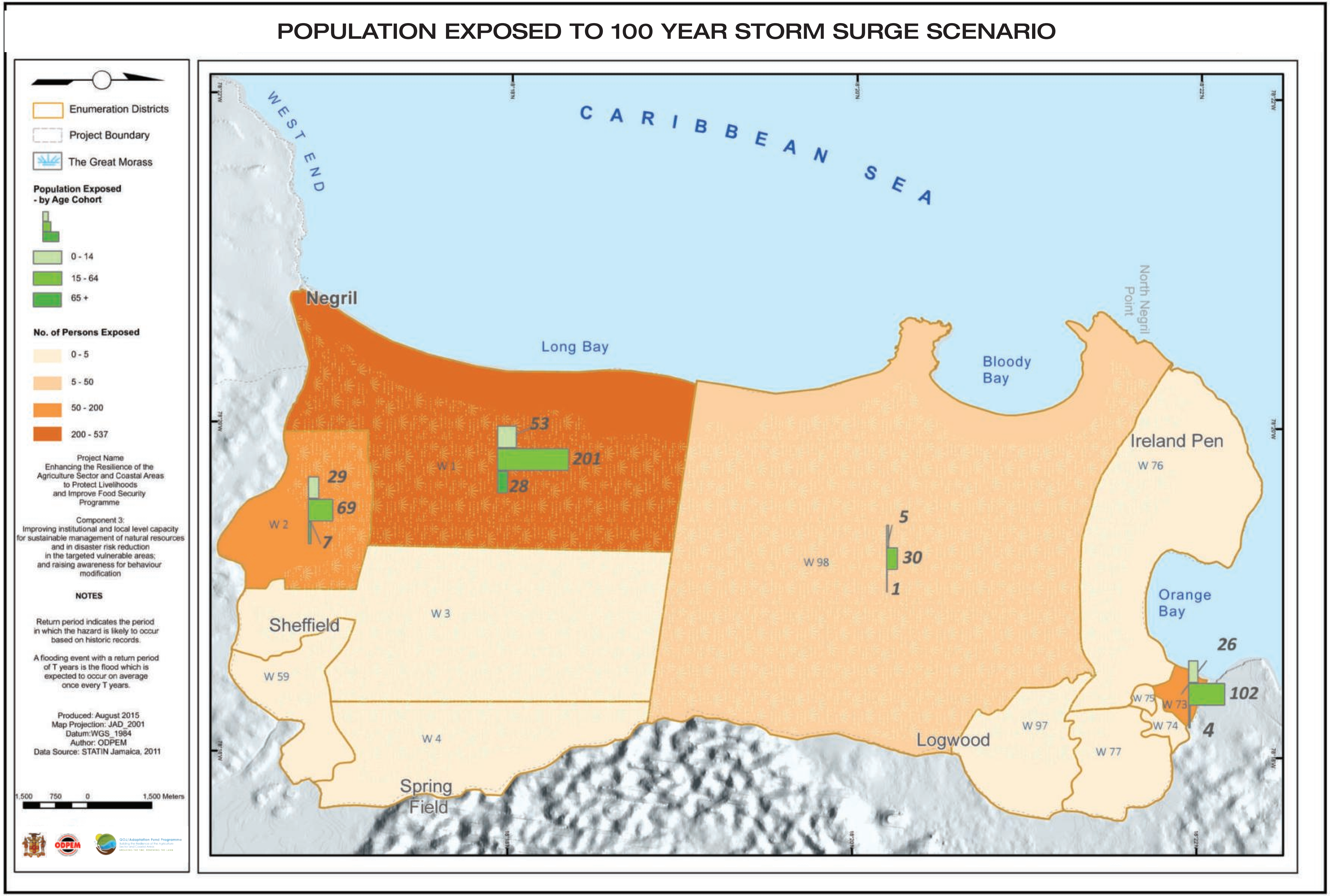


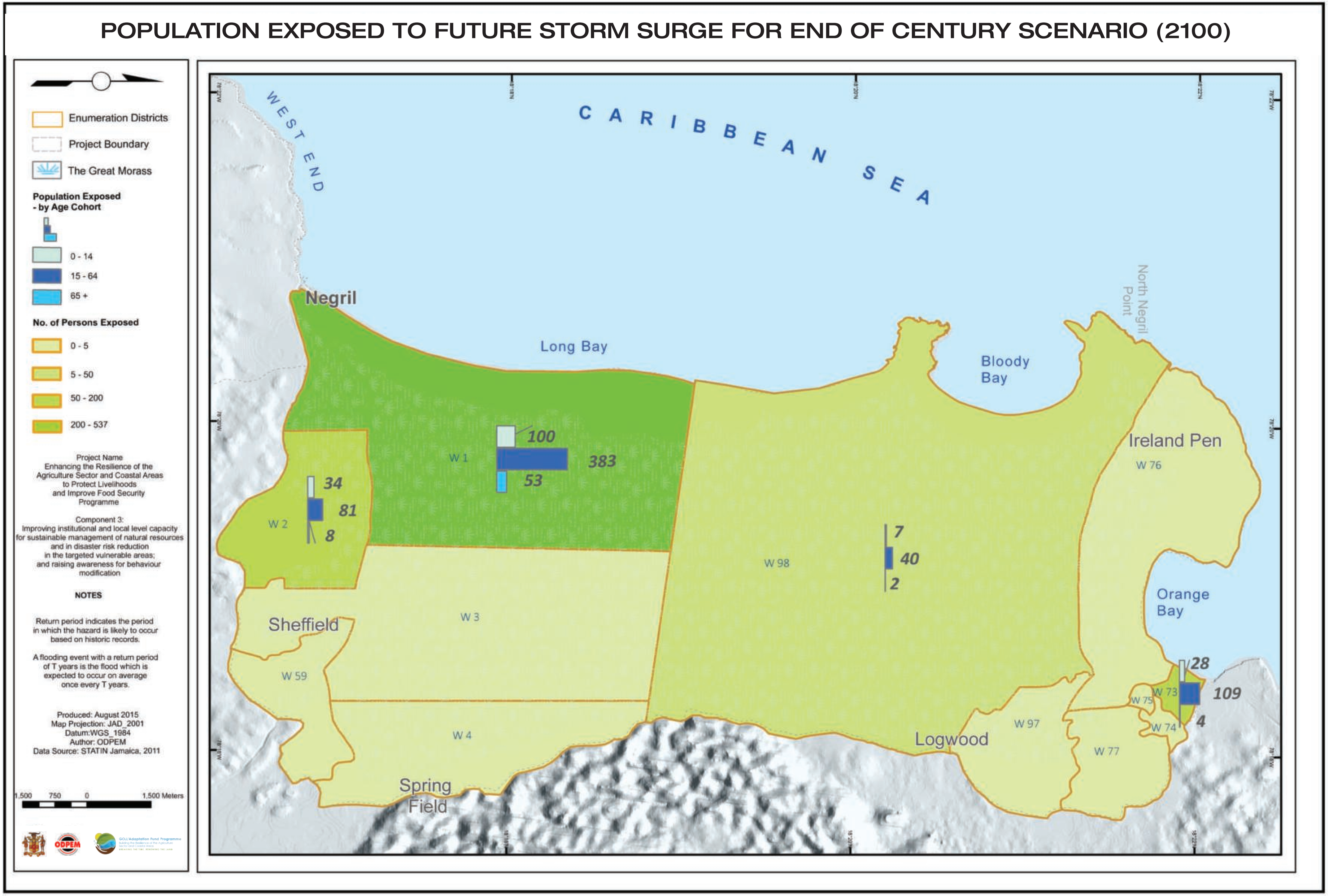
*Plate 4.3: Damage to dwellings in Caribbean Terrace, Kingston from storm surge associated with hurricane Dean, 2007*

## POPULATION EXPOSED TO 100 YEAR STORM SURGE (BASE LINE) AND FUTURE STORM SURGE FOR END CENTURY SCENARIO


Map 4.44: Population exposed to 100 year storm surge (base line) and future storm surge for end century scenario




Map 4.45: Population exposed to 100 year storm surge scenario




Map 4.46: Population exposed to future storm surge for end of century scenario (2100)

# 4.4 Exposure of Infrastructure

The greatest exposure of the road network can be found in Long Bay with least exposure in Orange Bay. Map 4.48 shows that the road network along Orange Bay is protected by fringing mangrove. Research has shown that mangroves play a vital role in attenuating storm surge waves thereby reducing the impact on areas or infrastructure behind mangroves as they act as a natural defense system.

Table 4.11 below displays the length of roads exposed to baseline storm surge scenarios and future storm surge (projections for 2025–2100). For the 100 year storm surge return period, exposure of the road network is estimated to be 4.9% primarily to minor/access roads to the hotels and commercials buildings that are located along the coast. Comparatively, a higher percentage (10.5%) of the road network is exposed to future storm surges taking into consideration sea level rise. For the end of century scenario, sections of Norman Manley Boulevard, the main thoroughfare which connects the parishes of Westmoreland and Hanover is exposed (See Maps 4.47–4.50).

Table 4.11: Infastrastructure exposed to Storm Surges

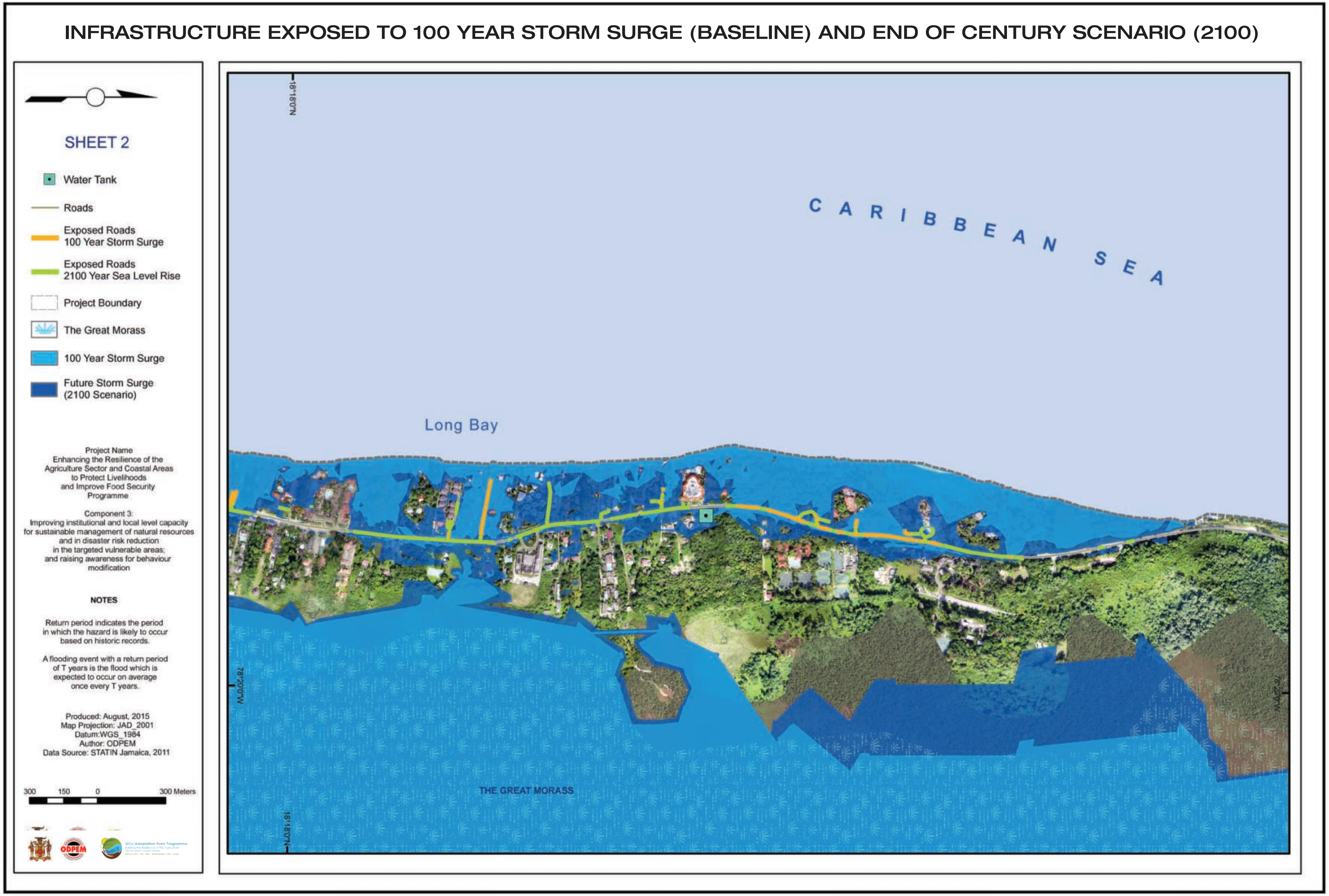
| Estimated Length of Roadway | Storm Surge (SS) | | | Future Storm surge (SS + SLR) | | |
|---|---|---|---|---|---|---|
| | Return Period | Roads Exposed (m) | % in Hazard Area | Year | Roads Exposed (m) | % in Hazard Area |
| 153,890.96 | 25 Year R.P | 4,421.01 | 2.9% | 2025 | 8,668.42 | 5.6% |
| | 50 Year R.P | 5,375.26 | 3.5% | 2050 | 10,960.70 | 7% |
| | 100 Year R.P | 7,509.02 | 4.9% | 2100 | 16,086.37 | 10.5% |

Other coastal infrastructure namely National Water Commission sewage relift stations, and a section of Negril Aerodrome is exposed to storm surge hazard (Refer to Map 4.47). For the 100 year storm scenario, 27% of the sewage relift stations in Negril are exposed. By 2100, exposure of this critical infrastructure could increase to 55%. Disruption or loss of this essential service will have serious implications for the resort town of Negril including health related risks (Refer to Tables 4.3 and 4.4).

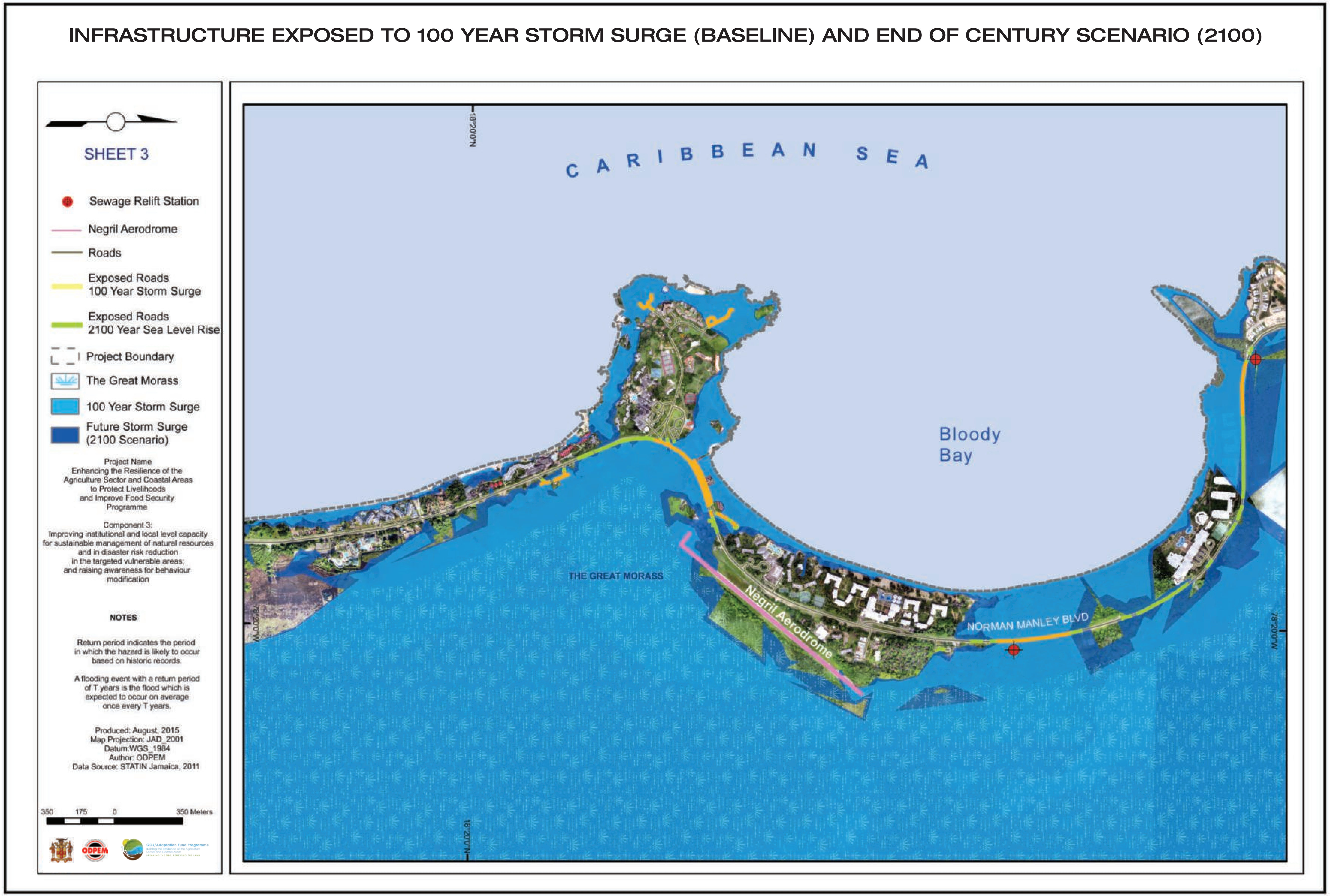
*Plate 4.4:* | Source: ODPEM

## INFRASTRUCTURE EXPOSED TO 100 YEAR STORM SURGE (BASELINE) AND END OF CENTURY SCENARIO (2100)


Map 4.47: Infrastructure exposed to 100 year storm surge (baseline) and end of century scenario (2100)




Map 4.48: Infrastructure exposed to 100 year storm surge (baseline) and end of century scenario (2100)




Map 4.49: Infrastructure exposed to 100 year storm surge (baseline) and end of century scenario (2100)

## ROAD NETWORK EXPOSED TO 100 YEAR STORM SURGE (BASE LINE) AND END CENTURY SCENARIO (2100)


Map 4.50: Road network exposed to 100 year storm surge (base Line) and end century scenario (2100)

# 4.5 Exposure of Coastal Ecosystems

The gradual rise in sea level and the transport of large pulses of sea water from storm surges can result in vegetation shifts on coasts (Teh et al, 2015). Research by UWI has argued that that the Negril Great Morass will increasingly be influenced by sea-level rise (SLR) in that inundated sections of the wetland will likely become more saline, and drained areas will likely continue to experience peat subsidence to meet the rising water table. While the long term morass vegetation productivity has the capacity to create a balance between wetland floor elevations and SLR (Hendry & Digerfeldt, 1989), recent accelerated SLR (Richardson et al. 2009) may exceed the capacity of the morass floor to maintain that balance.

Flooding can impact occurrence, growth, survival and reproduction. Different communities of invertebrates occur in wetlands with different hydrological regimes (in terms of timing, depth, and duration of flooding). Extended, uniform depth flooding tends to decrease invertebrate abundance and diversity (NEPT, 2012). For baseline and future storm scenarios water depth is expected to increase within the morass however, flood duration was not modeled which would have allowed for greater analysis on potential impact on flora and fauna.

The shoreline is also highly exposed to erosion particularly during the passage of hurricane and storm events which have historical severely impacted the shoreline in Negril. Research has shown that the Long Bay and the Bloody Bay strip are identified as 'critical risk areas' having experienced the greatest shoreline loss for the periods 1968 to 2006 and 2006 to 2008 (SWIL, 2008).

The additional stress due to anthropogenic factors has and continues to exacerbate exposure of coastal ecosystems in Negril. Several studies about human impacts on coral reefs and coastal vegetation have been undertaken in Negril. Some of the key findings are described below:

- Sea grass removal is a common practice especially in the Long Bay area where many of the hotels are located. Sea grass is removed to provide tourists with clean white sand, but it is also harvested to prepare traditional drinks or used as compost for farming. Sand dunes and trees also have been uprooted to create open beach spaces for tourists and other infrastructural development, partly contributing to progressive beach erosion in Negril since the 1980s. Land-based sources of pollution also have a major impact. Pollution sources include garbage reaching the sea or being dumped in mangrove areas, agricultural and industrial runoff, sewage runoff, and increased freshwater drainage from built infrastructure such as roads and hotels.
- Another concern is that the morass is also drying, destabilising and facing deforestation due to bush fire for illegal farming.
- The WRI study by Kusher et al, 2011 estimated that if further reef degradation occurs, erosion rates could increase significantly above the current rates (0.3m/yr) by more than 50 percent for Montego Bay, 70 percent for Ocho Rios, and more than 100 percent for Negril over a 10-year period.

Assessment of coastal ecosystems in Negril and anthropogenic impacts can be found from the following reports:

i Towards Restoration of the Negril Great Morass Ecosystem: A Rapid Assessment of Hydrologic and Biodiversity Issues Critical to Ecosystem Restoration and Management

ii Risk and Vulnerability Assessment Methodology Development Project (RiVAMP). Linking Ecosystems to Risk and Vulnerability Reduction: The Case of Jamaica.

iii CaribSave: Final Report Negril, Jamaica

iv "Coastal Capital: Jamaica – Coral Reefs, Beach Erosion and Impacts to Tourism in Jamaica." Washington, DC: World Resources Institute

*Plate 4.5: Section of Penfield, Gordon Town, St Andrew after Tropical Storm Gustav 2008* | Source: ODPEM

# 5

# Community Risk Perception

5.0

## 5.1 Community Profile

### 5.1.1 Westmoreland Communities

#### Whitehall

Of the communities within the study boundary, Whitehall is located closest to the Negril Town centre and has the transportation centre as part of its boundary. As depicted by the multi-temporal analysis, up to 1968, this area consisted of sparse residential development and landcover was mainly natural vegetation. Post- 1968, there were drastic changes and significant increases in the density of infrastructure and housing. That trend continued into the 1990's and even currently, the community continues to expand.

#### Population And Settlement

RiVAMP (2012) indicates that the population of this community was approximately 500 in the 1970's and grew to approximately 5,000 by 2009. The Census of 2011, indicates an estimated population of 2255, 70% of whom are in the 16-64 age cohort and 28% in the 0-14 age group.

Table 5.1: Population Distribution for White Hall

| Whitehall | Female | Male | Total | Percentage |
|---|---|---|---|---|
| 0-14 | 323 | 316 | 639 | 28 |
| 15-64 | 714 | 855 | 1569 | 70 |
| ›65 | 24 | 23 | 47 | 2 |
| TOTAL | 1061 | 1194 | 2255 | 100 |
| Percentage | 47 | 53 | | |

*Source: STATIN, 2011*

This development was intended to be a formal one, with some locations subdivided as recently as early and late 2000's. The community now has widespread squatter settlements which have contributed to the on-going deterioration of environmental conditions (RiVAMP 2012). "The dramatic increase in unplanned housing has resulted in the deforestation of the hillsides, poor drainage and inadequate garbage disposal systems as well as sanitation facilities. While the majority of residents now have access to flush toilets, a number of houses still remain unconnected to the main sewage lines and rely on pit latrines. Almost all residents have access to piped potable water sourced from Hanover" (RiVAMP, 2012).

The community Hazard Mapping confirms that the community is not exposed to storm surge, however, flooding is their primary hazard.

## Physiography

The topography of Whitehall rises from an elevation of 10m to 250m above sea level. The community is located on white limestone, more specifically, Gibraltar Bonnygate formation. This limestone formation consists of extensive and thick outcrops of light-colored limestones. Principal rock types are soft chalks and shelly limestones. There may be underground drainage systems; however these are usually fault controlled. Possible construction problems include flood risk in depressions or gully courses.

## Livelihood

Whitehall was developed in response to the expansion of Negril as a resort area and the resultant housing demand that ensued led to the development of areas such as Whitehall. Most persons are involved in the housing sector.

# Red Ground

## Population and Settlement

Red Ground adjoins the Whitehall community and is located in close proximity to the town centre of Negril. The community is an informal one and like Whitehall evidence from the multi-temporal analysis suggests that the community started around 1968 as a very sparse development and by 1999, the density significantly increased.

The population is about half of that of the more formal Whitehall community and based on the 2011 census was 1127 persons, 53% of whom were males and 67% of whom were in the 15-64 age cohort.

## Physiography

There are two predominant geological formations that comprise Redground. Similar to Whitehall, the dominant formation is Gibraltar Bonnygate formation. The less dominant formation is coastal limestone found mainly along the coast. This formation consists of hard reef limestones with subordinate often interbedded rubbly and chalky or marly limestones dominating this formation. Soil development is shallow and generally insignificant. Possible construction problems associated with this geological formation may include high erodability.

# Sheffield

## Population and Settlement

The Sheffield community lies approximately 4.7 km east of the town of Negril. The community is informal but unlike Whitehall and Westland Mountain has mainly rural characteristics. The population is just a few persons less than the population of Whitehall, however, the population is less dense with settlements concentrated mainly along the main and Parochial roads. The 2011 census indicates that population is 2154 persons 48% of whom are females. Consistent with trends for other communities, 66% of the population are in the age cohort 15 – 64 years while 27% are below this age.

Table 5.2: Population Distribution for Sheffield

| Sheffield | Female | Male | Total | Percentage |
|---|---|---|---|---|
| 0 - 14 | 257 | 324 | 581 | 27 |
| 15- 64 | 705 | 717 | 1422 | 66 |
| › 64 | 82 | 69 | 151 | 7 |
| **TOTAL** | **1044** | **1110** | **2154** | **100** |
| Percentage | 48 | 52 | | |

*Source: STATIN, 2011*

Based on the multi-temporal analysis up to 1968 Sheffield was very sparse with very few houses located along the main road. Post-1968, evidence of extensive farming was observed and an expansion of housing development beyond the main road.

## Physiography

The topography of the community is generally flat and the topography gently rises toward the south from a low elevation of 3m in the morass to the north to 60m in the south. The northern section of the community is bordered by the Great Morass with the majority of the community located south of the main road. The geology on which the community is located is the same as those for communities surrounding Negril, that is, Gibraltar Bonny-gate formation.

## Livelihood

According to the Agriculture Business Information System of the Rural Agriculture Development Authority (RADA), Sheffield is a part of the Little London Extension Area and consists of 182 farms and 472 farmers. The table below shows that the largest size farms are under callaloo, sweet pepper, tomato, coconut, pumpkin and cabbage cultivation. Similarly, most farmers cultivate cabbage, callaloo, corn and sweet pepper. Of the 52 crops cultivated in Sheffield, 85% are the main crops listed in table 5.3 and similarly account for 80% of the 472 farmers.

Table 5.3: Crop types cultivated and number of farmers in Sheffield

| Crop Type | Crop Area >1 (Ha) | Number of Farmers |
|---|---|---|
| Cabbage | 8.54 | 64 |
| Callaloo | 4.33 | 44 |
| Coconut | 3.79 | 17 |
| Corn | 3.59 | 38 |
| Cucumber | 1.58 | 11 |
| Dasheen | 1.82 | 10 |
| Hot Pepper | 2.11 | 10 |
| Pak Choi | 1.19 | 21 |
| Pineapple | 1.01 | 2 |
| Plantain | 3.09 | 19 |
| Potato (Sweet) | 1.17 | 13 |
| Pumpkin | 4.69 | 33 |
| Sugar Cane | 2.6 | 7 |
| Sweet Pepper | 4.14 | 35 |
| Tomato | 4.54 | 28 |
| Watermelon | 1.32 | 10 |
| Yam | 1.69 | 17 |
| **Total for Sheffield Community** | **51.2** | **379** |
| **Total for Sheffield Extension Area** | **59.92** | **472** |

*Source: Abisjamaica.com*

The Sheffield community is also engaged in Livestock rearing with the main ones being broilers, goat and pig rearing.

Table 5.4: Types of Lifestock reared by farmers in Sheffield

| Livestock | Property Size (ha) | Farmers |
|---|---|---|
| Beef | 20.2 | 13 |
| Broilers | 133.02 | 19 |
| Dairy | 13.5 | 6 |
| Goats | 46.18 | 29 |
| Layers | 1.61 | 2 |
| Pig | 26.64 | 22 |
| **TOTAL** | **241.15** | **91** |

*Source: Abisjamaica.com*

# Westland Mountain

## Population and Settlement

Westland Mountain has the smallest population of the five communities, in the study boundary. The total population is 1076 persons, 53% of whom are males and 47% females. The 0-14 age cohort accounts for 25% of the total population while the majority are between 15-64 age cohort.

Table 5.5: Population Distribution for Westland Mountain

| Westland Mountain | Female | Male | Total | Percentage |
|---|---|---|---|---|
| 0-14 | 125 | 145 | 270 | 25 |
| 15-64 | 341 | 397 | 738 | 69 |
| >65 | 38 | 30 | 68 | 6 |
| TOTAL | 504 | 572 | 1076 | |
| Percentage | 47 | 53 | | 100 |

*Source: STATIN, 2011*

Like Red Ground, Westland Mountain has two predominant geological formations that comprise the community. Similar to Whitehall, the dominant formation is Gibraltar Bonnygate formation consisting of extensive and thick outcrops of light-colored limestones.

## 5.1.2 Hanover Communities

# Logwood/Orange Bay

### Population and Settlement

The population of Logwood and Orange Bay combined is 3183 and this is the largest population of all communities in the Negril study boundary, exceeding the second largest community, Whitehall, by 40%.

Table 5.6: Population Distribution in Logwood/ Orange Bay

| Logwood/Orange River | Female | Male | TOTAL | Percentage |
|---|---|---|---|---|
| 0-14 | 462 | 471 | 933 | 29 |
| 15-64 | 944 | 1068 | 2012 | 63 |
| >65 | 127 | 111 | 238 | 7 |
| TOTAL | 1533 | 1650 | 3183 | |
| Percentage | 48 | 52 | | |

*Source: STATIN, 2011*

### Physiography

Logwood consists of a mixture of geological formations comprising coastal limestone and Swanswick formation. Hard reef limestones with subordinate often interbedded rubbly and chalky or marly limestones dominate the coastal formation and possible construction problems associated with this geological formation may include high erodability. Swanswick formation is a member of the white limestone group. It consists of extensive and thick outcrops of light colored shallow to deep-water limestones. Rocks are variable but generally hard and competent. The formation usually consists of localized crops of softer, well or thinly bedded sandy limestones. Karstic drainage patterns are usually well developed with sinkholes and depressions feeding underground systems. Soil development is usually minor or thin on steep hillsides, or hilltops. Slope stability is generally good and possible construction problems include flood risks in gully courses and landslip risk along fault scarps.

The community is dissected by the Orange River which flows from the hilly areas to the east of the community and empties in the Orange Bay area to the west of the community. The North Negril River also flows in the lower elevation of the community and empties at Rutland Point. The community is bordered by The Great Morass to the west and several ponds exist in the community.

### Livelihood

Unlike Sheffield, Logwood/Orange Bay is not a predominantly farming community and has 120 farmers when compared with 519 farmers. Data from ABISJamaica.com also shows that far less crops are cultivated in this area. Crops exceeding 1 hectare are listed in the table below.

Table 5.7: Crop types cultivated in Logwood

| | Crop Area (> 1Ha) | | Sub-total | Farmers | | Sub-total |
|---|---|---|---|---|---|---|
| Crops | Orange Bay | Logwood | (Ha) | Orange Bay | Logwood | (Ha) |
| Banana | 1.8 | 1.46 | 3.26 | 20 | 12 | 32 |
| Corn | 0.55 | - | 0.55 | 7 | - | 7 |
| Yam | 1.95 | - | 1.95 | 24 | - | 24 |
| Plantain | 1.44 | - | 1.44 | 13 | - | 13 |
| Coconut | - | 1.07 | 1.07 | - | 5 | 5 |
| Dasheen | - | 3.77 | 3.77 | - | 20 | 20 |
| Sugar Cane | - | 4.14 | 4.14 | - | 10 | 10 |
| TOTAL | 5.74 | 10.44 | 16.18 | 64 | 47 | 111 |

*Source: Abisjamaica.com*

Chicken, goat and pig rearing and the main livestock in the area with a total of 111 farmers engaged in these areas. The same number of farmers are engage in the main crop types (classified as >1 hectare) for the community.

Table 5.8: Livestock reared in Logwood and Orange Bay

| | Crop Area (Ha) | | Sub-total | Farmers | | Sub-total |
|---|---|---|---|---|---|---|
| Livestock | Orange Bay | Logwood | (Ha) | Orange Bay | Logwood | (Ha) |
| Broilers | 4.03 | 11.78 | 15.81 | 9 | 25 | 34 |
| Goats | 5.6 | 74.39 | 79.99 | 9 | 41 | 50 |
| Pig | 1 | 24.46 | 25.46 | 5 | 22 | 27 |
| TOTAL | 10.63 | 110.63 | 121.26 | 23 | 88 | 111 |

*Source: Abisjamaica.com*

The dominant crop types are listed in the table above. Most farmers are engaged in banana and yam cultivation.

# 5.2 Vulnerability and Capacity Assessment

Vulnerability and Capacity Assessment (VCA) is a participatory investigative process designed to assess the risks that people face in their locality, their vulnerability to those risks, and the capacities they possess to cope with a hazard and recover from it if it strikes. **VCA helps people to prepare for hazards, to prevent them from turning into disasters and to mitigate their effects (IFRC, 2007).** This activity was led by the Jamaica Red Cross as part of training sub -component of the overall Component 3 of the Adaptation Fund Program. VCA was undertaken in two (2) communities- Logwood and Orange Bay and summary of the findings are presented below.

To facilitate the VAC process, the following participatory approaches were used to collect data from the communities:

- a Historical profile
- b Historical visualization
- c Seasonal calendar
- d Institutional and Social Network Analysis
- e Livelihoods and coping strategies analysis
- f Mapping
- g Transect walk

## Logwood

The historical visualization shows that the community transitioned from a highly vegetated area to a more developed and populated area with more infrastructure.


## Identifying hazards and their potential impact on the community

Table 5.9: Hazards identified by residents of Logwood

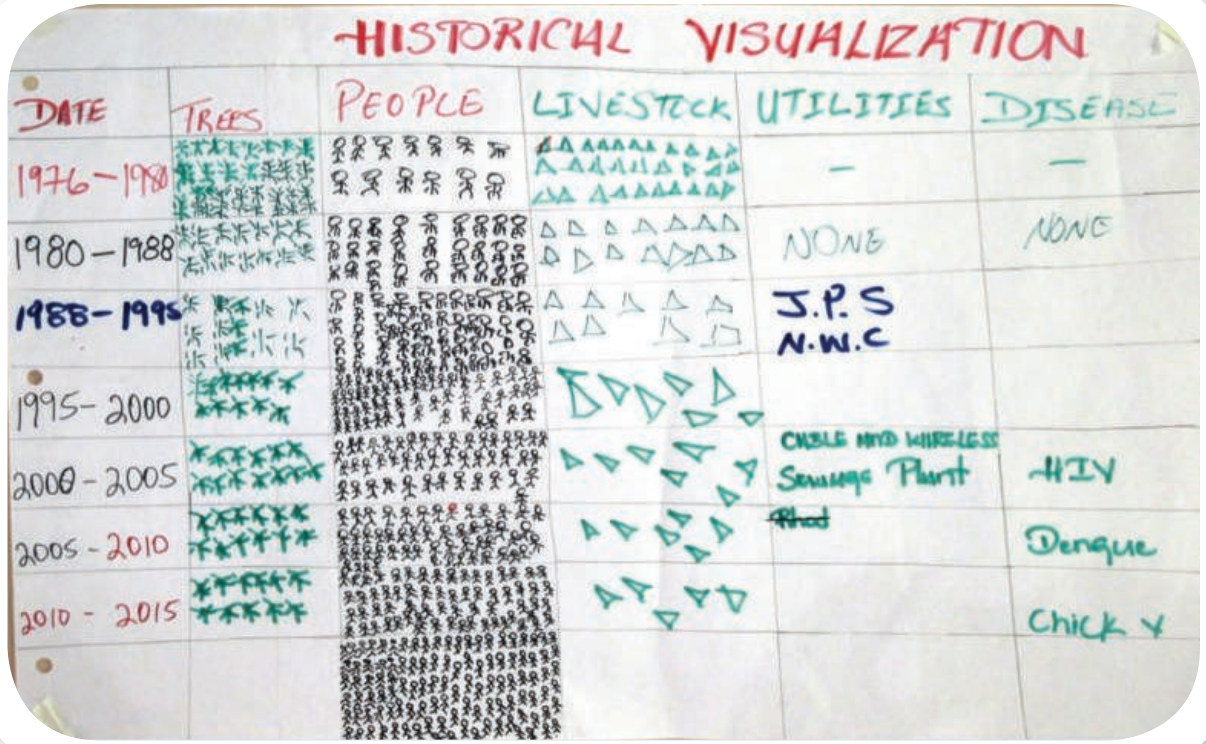
| Hazard | Potential Risk | Vulnerability | Capacity |
|---|---|---|---|
| Improper housing construction | • Property damage<br>• Death<br>• Accidents | 1. Livelihood<br>a. Property<br>b. Crops<br>c. Animals<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to NWA and the parish Council for the fixing of the roadway.<br>• Educate residents<br>• Host public forum |
| Defective fire hydrants | • Loss of life and property | • Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>• Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>• Social protection<br>a. Closure of schools<br>b. Inability to go to work/ school. | • Organize group to advocate to (NWC) National Water Commission for the fixing and implementation of Hydrants. |
| Inadequate Street light | • Injuries<br>• Death<br>• Robbery<br>• Physical abuse | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to JPS for the fixing and implementation of proper lighting |
| Blocked Drains | • Flooding<br>• Damage to property<br>• Death<br>• Damage to crops<br>• Accidents<br>• Loss of livestock | 1. Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools<br>b. Inability to go to work/ school. | • Organize group and have the drains cleaned.<br>• Organize group and advocate to relevant authorities to have the drains cleaned.<br>• Educate the residents |
| Uncleaned river channels | • Flooding<br>• Damage to property<br>• Death<br>• Damage to crops<br>• Accidents<br>• Loss of livestock | 1. Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools<br>b. Inability to go to work/ school. | • Organize group and have the drains cleaned.<br>• Organize group and advocate to relevant authorities to have the drains cleaned.<br>• Educate the residents |

Table 5.10: Local capacity in Logwood to respond to Hazards

| Hazard | Vulnerabilities Identified | Actions to transform Vulnerabilities into Capacities |
|---|---|---|
| Improper housing construction | 1. Livelihood<br>a. Property<br>b. Crops<br>c. Animals<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to NWA and the parish Council for the fixing of the roadway.<br>• Educate residents<br>• Host public forum |
| Defective fire hydrants | 1. Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools<br>b. Inability to go to work/school. | • Organize group to advocate to (NWC) National Water Commission for the fixing and implementation of Hydrants. |
| Blocked Drains | 1. Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools<br>b. Inability to go to work/school. | • Organize group and have the drains cleaned.<br>• Organize group and advocate to relevant authorities to have the drains cleaned.<br>• Educate the residents |
| Uncleaned river channels | 1. Livelihood<br>a. Property<br>b. Crops<br>c. animal<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools<br>b. Inability to go to work/school. | • Organize group and have the drains cleaned.<br>• Organize group and advocate to relevant authorities to have the drains cleaned.<br>• Educate the residents |

## Orange Bay

The historical visualization shows that the community transitioned from a highly vegetated area to a more developed and populated area with more infrastructure.



The Seasonal calendar shows that the community of Orange Bay relies heavily on Tourism and farming as the main source of livelihood.


## Identifying hazards and their potential impact on the community

Table 5.11: Hazards and their potential impacts on the community of Orange Bay

| Hazard | Potential Risk | Vulnerability | Capacity |
|---|---|---|---|
| Over hanging tree in road | • Fire<br>• Electrocution<br>• Property damage<br>• Death<br>• Accidents | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to JPS/NWA for the pruning of trees.<br>• Owners groom property<br>• Educate residents |
| Sewage Ponds are not in an enclosed area | • Children falling in<br>• Death<br>• Loss of animals<br>• Injuries | 1. Livelihood<br>a. Property<br>b. Crops<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>c. All members of the community.<br>3. Social protection<br>a. Closure of schools | • Educate the residents<br>• Erect signs / Fencing<br>• Sensitize public of the dangers |
| Pot holes | • Accidents<br>• Death<br>• Damage to property<br>• Limited access | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to NWA & the Parish Council for the fixing of the bad road surface |
| Inadequate street lighting | • Injuries<br>• Death | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to JPS for the implementation of proper lighting |
| Along road way needs bushing | • Injuries<br>• Death<br>• Damage to property<br>• Accidents | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Contact owners of the various properties to have their section groomed.<br>• As a community organize and have the road ways properly kept. |
| Old building beside the road way. | • Injuries<br>• Death<br>• Damage to property<br>• Accidents | 1. Livelihood<br>a. Property<br>2. Well-being/status<br>a. Children<br>b. Women<br>c. Elderly<br>d. Physically challenged.<br>e. All members of the community | • Contact owners to have them removed.<br>• As a community organize and have them removed. |

## Local capacity to respond to hazards

Table 5.12: Local capacity in Orange Bay to respond to Hazards

| Hazard | Vulnerability | Capacity |
|---|---|---|
| Over hanging tree in road | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to JPS/NWA for the pruning of trees.<br>• Owners groom property<br>• Educate residents |
| Sewage Ponds are not in an enclosed area | 1. Livelihood<br>a. Property<br>b. Crops<br>2. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community.<br>3. Social protection<br>a. Closure of schools | • Educate the residents<br>• Erect signs / Fencing<br>• Sensitize public of the dangers |
| Pot holes | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to NWA & the Parish Council for the fixing of the bad road surface |
| Inadequate street lighting | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Organize group to advocate to JPS for the implementation of proper lighting |
| Along road way needs bushing | 1. Well-being/status<br>a. Children<br>b. Elderly<br>c. Physically challenged.<br>d. All members of the community. | • Contact owners of the various properties to have their section groomed.<br>• As a community organize and have the road ways properly kept. |
| Old building beside the road way. | 1. Livelihood<br>a. Property<br>2. Well-being/status<br>a. Children<br>b. Women<br>c. Elderly<br>d. Physically challenged.<br>e. All members of the community | • Contact owners to have them removed.<br>• As a community organize and have them removed. |

## Type of measures to mitigate disasters

Table 5.13: Measures to mitigate disasters

| Actions to transform Vulnerabilities into Capacity | Prevention | Preparation | Mitigation |
|---|---|---|---|
| Organize group to advocate to JPS/NWA for the pruning of trees. | x | x | x |
| Owners groom property | x | x | x |
| Educate residents | x | x | x |
| Educate the residents | x | x | x |
| Erect signs / Fencing | x | x | x |
| Sensitize public of the dangers | x | x | x |
| Organize group to advocate to NWA & the Parish Council for the fixing of the bad road surface | x | x | x |
| Organize group to advocate to JPS for the implementation of proper lighting | x | x | x |
| Contact owners of the various properties to have their section groomed. | x | x | x |
| As a community organize and have the road ways properly kept. | x | x | x |
| Contact owners to have them removed. | x | x | x |
| As a community organize and have them removed. | x | x | x |

# 5.4 Community Hazard Mapping

To get a comprehensive perspective of risk in the Negril Community, it was necessary to include the community's perspective on their own vulnerability. This was done through a process of Community Hazard Mapping.

Community hazard mapping is the process of identifying spatially the high risk areas in the community as well as critical facilities and infrastructure that might be affected in the event of a disaster.

Community hazard mapping is therefore one of the most effective tools for raising community risk awareness and improving overall disaster preparedness. Hazard mapping through the lens of the community represents or facilitates visual understanding of exposure to hazard impacts, vulnerable conditions and allows strategies for risk reduction to be developed and implemented at the community level. Hence, community input and participation is important.

The five communities that fell within the project boundary were taken through a five step process of preparing community hazard maps (See Figure 5.2)

To gain a reasonably good perspective on the community's risk, the participant profile of the community hazard mapping workshops was diverse to include older persons who have knowledge of the history of the community, younger persons who would be familiar with development changes in the community and working class who would also recall the impacts. Figure 5.1 shows distribution of participants disaggregated by gender.

**Figure 5.1: Gender Distibution of Participants**

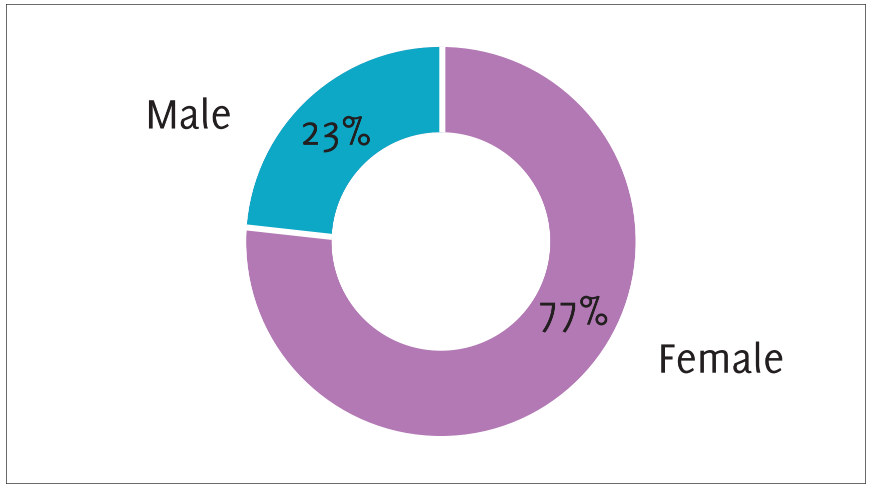




*Plate 5.1: Hazard mapping validation in Sheffield* | Source: ODPEM

**STEP 1:**
Discuss the basics of hazard mapping

**STEP 2:**
Define your community boundary and visualize all natural and physical resources in community.

**STEP 3:**
Transfer natural and physical resources onto base map (roads, rivers, houses, clinic, community centre, farm lands etc).

FEATURES such as rivers, roads, schools, clinic etc should be LABELED.

**STEP 4:**
Consider the risks

Overlay on the base map the hazard history of the community to show flood prone areas, landslide zones and potential hazardous areas in the community.Emergency shelters should be clearly shown on map.

**STEP 5:**
Community ground-truthing

Validate or "ground-truth" the information gathered in previous steps to ensure map accurately represent the community.

**Figure 5.2: Steps in Community Hazard Mapping**


Map 5.1a: Whitehall, Westmoreland

# Whitehall, Westmoreland


Map 5.1b: Whitehall, Westmoreland

| Hazard | | Profile | | |
|---|---|---|---|---|
| Major Hazard | Minor Hazard | Number of Flood Hazard Zones | | |
| | | Major | Moderate | Minor |
| Flooding | Fire, chikungunya | 3 | 4 | 0 |

| Hazard | Impact | |
|---|---|---|
| Critical Facilities Affected | Other assets affected | Other comments |
| 2 churches, 1 school, roadway | Mainly houses, a shop and 2 bars | 2 of 7 flood zone has no development<br>A drain is the source of flooding in 1 moderate flood zone. Debris flows are channelled via the drain to flood zone which is also a swamp |

**Project Name:**
**Enhancing the Resilience of theAgriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Programme**

**Component 3:**
**Improving institutional and local level capacity for sustainable management of natural resources and in disaster risk reduction in the targeted vulnerable areas; and raising awareness for behaviour modification**

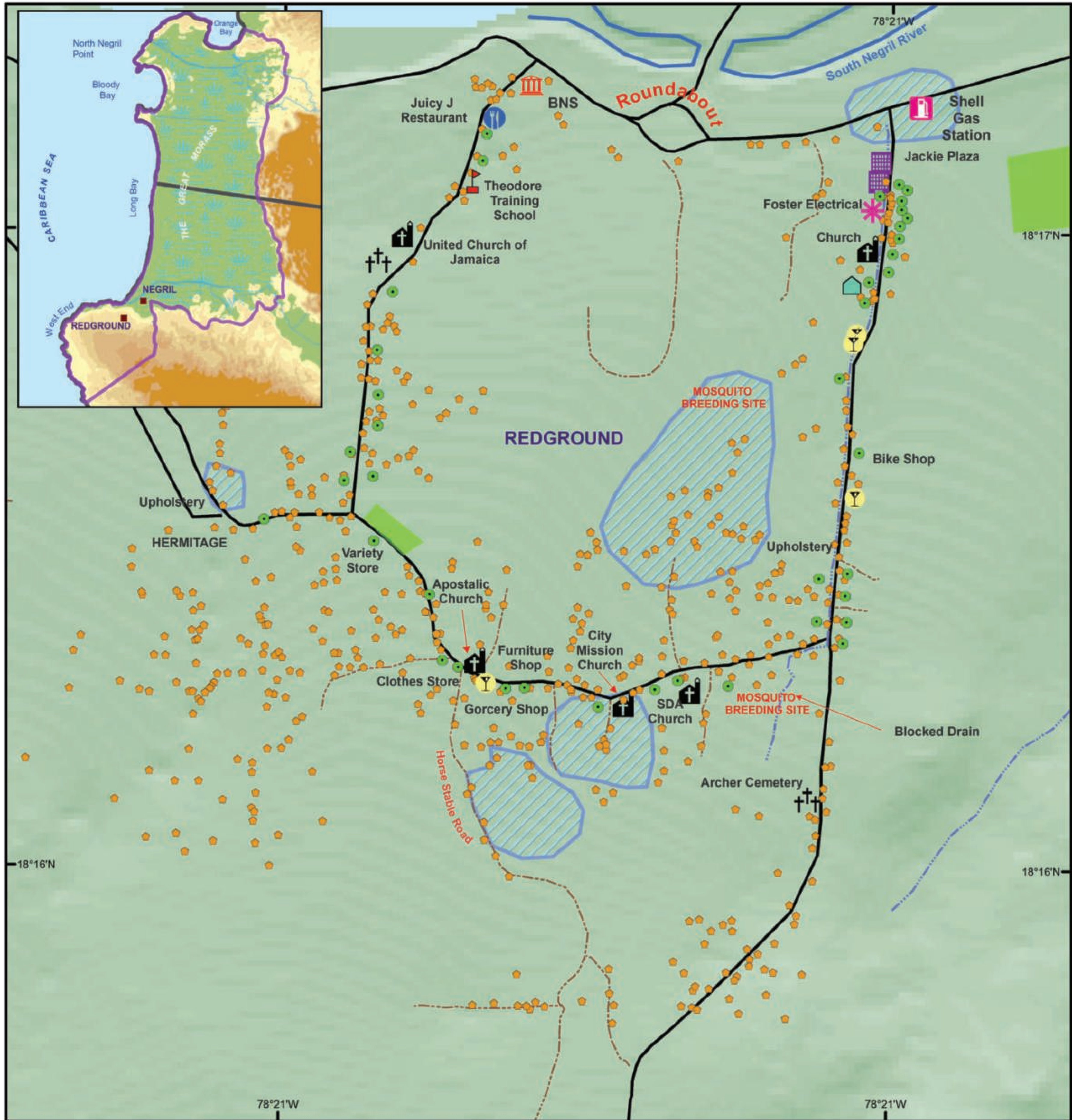
Chick-V Cases
Fire
Bus Park
Restaurant
Bar
Shop
School
House
Jamaica Fire Brigade
Digicel Tower
Logwood Health Centre
Swamp
Church
Police Station
Main Roads
Secondary Roads
Track
River
Drain
Flood Prone Area
Playfield

N
W E
S
0 30 60 120 Meters

The areal extent of areas affected by hazards were derived solely from anecdotal evidence from the community.
Author:
ODPEM and The Community of Whitehall, Westmoreland
Date: June 8, 2015


Map 5.2a: Redground Community Hazard Map, Westmoreland

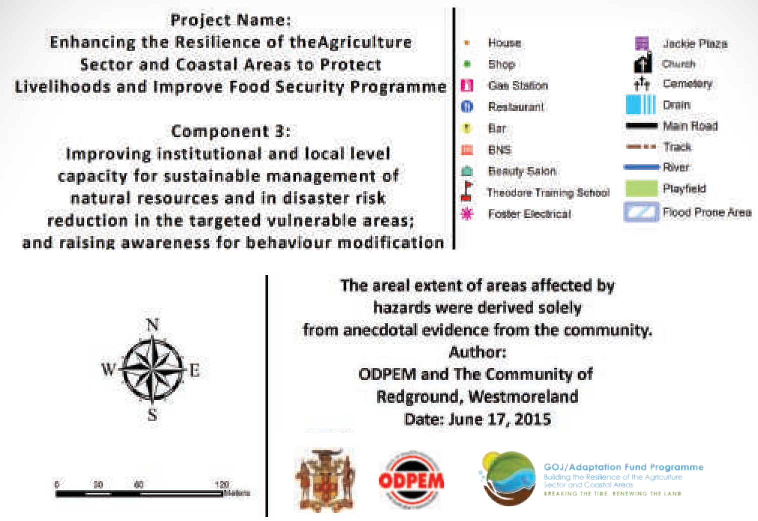
# Redground Community Hazard Map, Westmoreland




Map 5.2b: Redground Community Hazard Map, Westmoreland

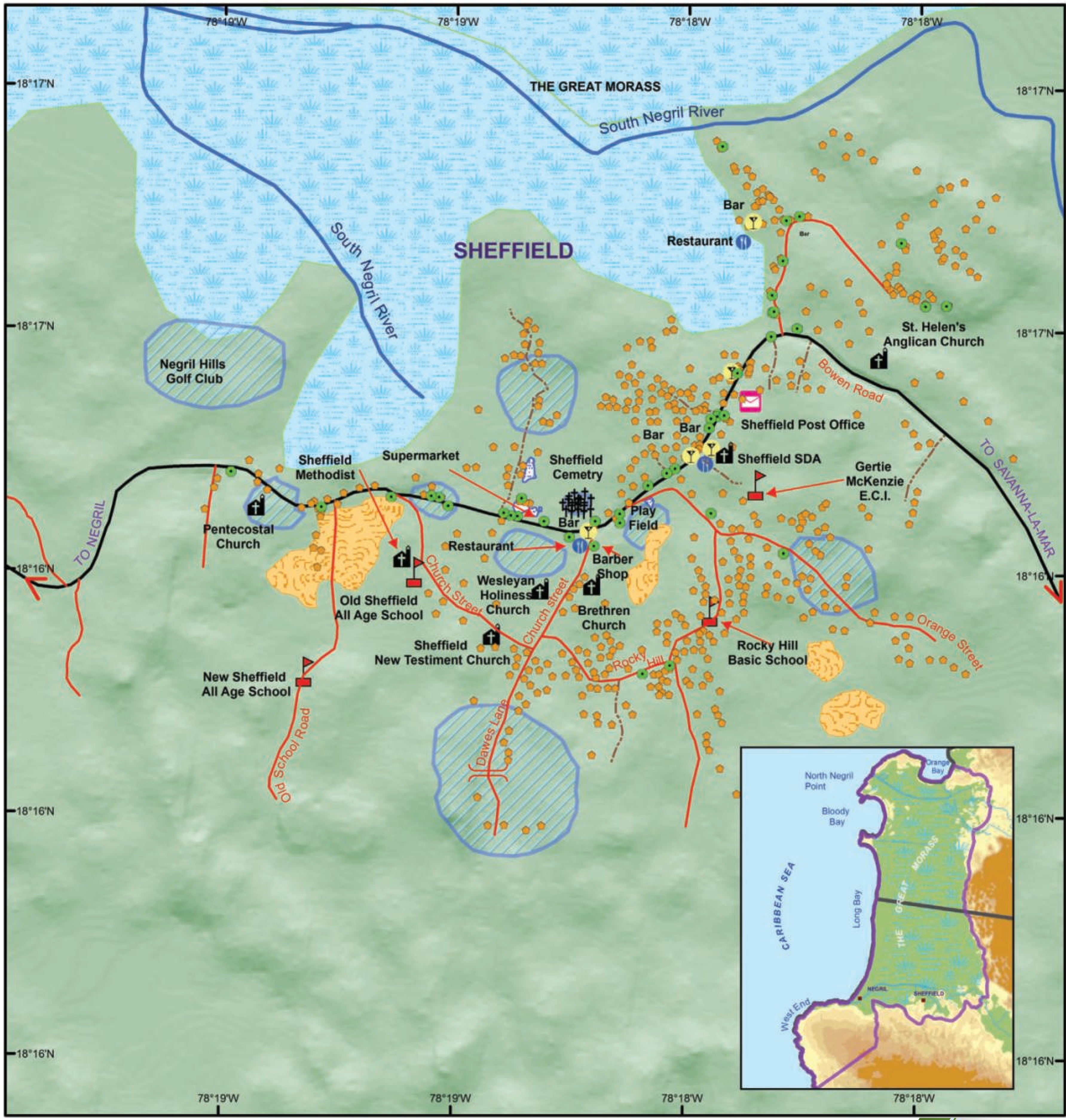
| Hazard | | Profile | | |
|---|---|---|---|---|
| Major Hazard | Minor Hazard | Number of Flood Hazard Zones | | |
| | | Major | Moderate | Minor |
| Flooding | nil | 1 | 3 | 1 |

| Hazard | Impact | |
|---|---|---|
| Critical Facilities Affected | Other assets affected | Other comments |
| 1 church, 1 gas station | Houses | Flood zones are also mosquito breeding sites |




Map 5.3a: Sheffield Community Hazard Map, Westmoreland

# Sheffield Community Hazard Map, Westmoreland




Map 5.3b: Sheffield Community Hazard Map, Westmoreland

| Hazard | | Profile | | |
|---|---|---|---|---|
| Major Hazard | Minor Hazard | Number of Flood Hazard Zones | | |
| | | Major | Moderate | Minor |
| Flooding | 4 depressions | 2 | 4 | 3 |

| Hazard | Impact | |
|---|---|---|
| Critical Facilities Affected | Other assets affected | Other comments |
| Sheffield cemetery, 1 bridge, roadway | Mainly houses, Negril Hills Golf Club and few shops | Only 1 depression has sparse houses, other have no development in them |

**Project Name:**
**Enhancing the Resilience of theAgriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Programme**

**Component 3:**
**Improving institutional and local level capacity for sustainable management of natural resources and in disaster risk reduction in the targeted vulnerable areas; and raising awareness for behaviour modification**

Restaurant
Shop
Bar
House
Post Office
Cemetery
Church
School
Bridge
Primary Road
Secondary Road
Track
River
Flood Prone Area
The Great Morass
Swamp
Depression

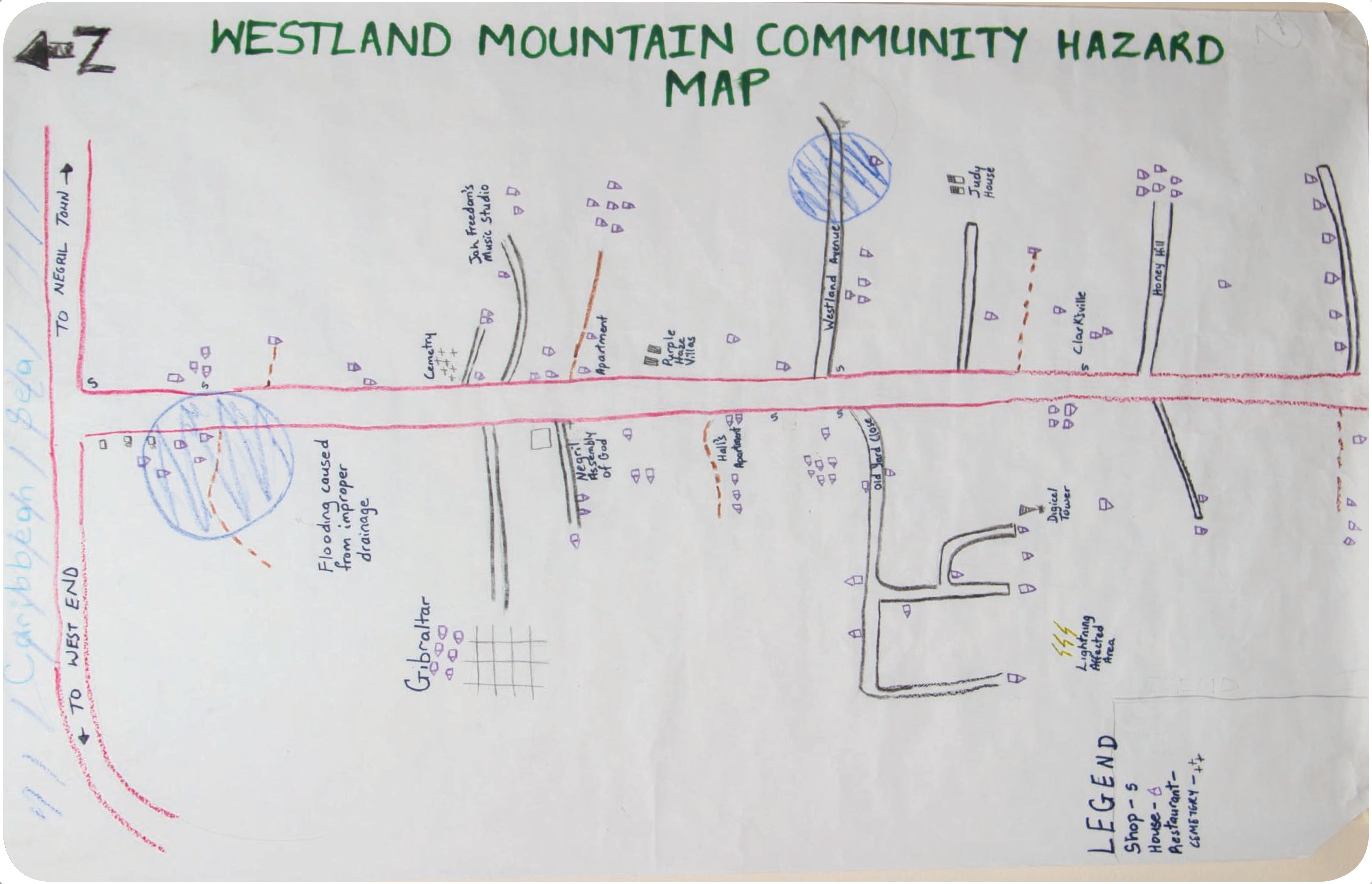
N
W E
S

0 80 160 320 Meters

**The areal extent of areas affected by hazards were derived solely from anecdotal evidence from the community.**
**Author:**
**ODPEM and The Community of Sheffield, Westmoreland**
**Date: June 5, 2015**

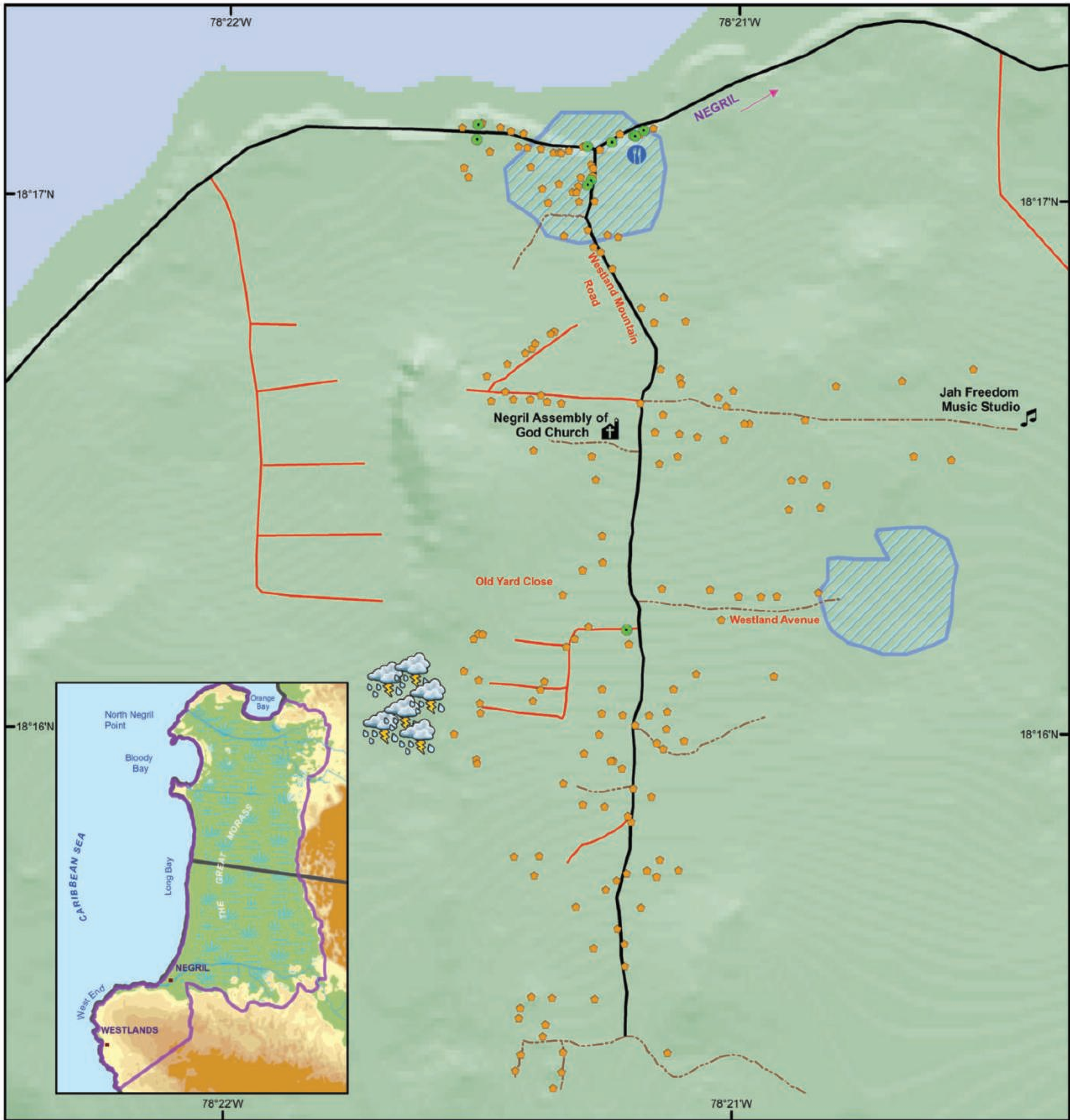
ODPEM

GOJ/Adaptation Fund Programme
Building the Resilience of the Agriculture Sector and Coastal Areas
BREAKING THE TIDE. RENEWING THE LAND




Map 5.4a: Westmoreland Mountain Community Hazard Map, Westmoreland

# Westland Mountain Community Hazard Map, Westmoreland




Map 5.4b: Westmoreland Mountain Community Hazard Map, Westmoreland

| Hazard | | Profile | | |
|---|---|---|---|---|
| Major Hazard | Minor Hazard | Number of Flood Hazard Zones | | |
| | | Major | Moderate | Minor |
| Flooding | Lightening | 2 | 0 | 0 |

| Hazard | Impact | |
|---|---|---|
| Critical Facilities Affected | Other assets affected | Other comments |
| Roadway | Houses and shops | Only 1 flood zone has houses located in that zone |

**Project Name:**
Enhancing the Resilience of theAgriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Programme

**Component 3:**
Improving institutional and local level capacity for sustainable management of natural resources and in disaster risk reduction in the targeted vulnerable areas; and raising awareness for behaviour modification

- House
- Church
- Shop
- Restaurant
- Music Studio
- Lightning
- Primary Road
- Secondary Road
- Track
- Flood Prone Area

The areal extent of areas affected by hazards were derived solely from anecdotal evidence from the community.
Author:
ODPEM and The Community of Westland Mountain, Westmoreland
Date: June 8, 2015


Map 5.5a: Logwood Community Hazard Map, Hanover

## Type of measures to mitigate disasters

The third step consisted in differentiating the types of measures, along three categories:

- Prevention actions: action which tries to reduce the probability of a disaster in the community;
- Mitigation actions: action that attempts to protect, strengthen, rehabilitate or reconstruct;
- Preparation actions: action that aims to strengthen the capacity of the community of Bamboo to respond in an effective and efficient manner

| Actions to transform vulnerabilities to Capacities | Prevention | Preparation | Mitigation |
|---|---|---|---|
| Organize group to advocate to JPS for the pruning of trees. | X | X | |
| Contact owners of the various properties to have their section groomed. | X | X | |
| Educate residents | X | X | X |
| Organize group to advocate to NWA and the parish Council for the fixing of the roadway. | X | X | X |
| Organize as a group and repair roadways. | X | X | X |
| Host public forum | X | X | X |
| Organize group to advocate to (NWC) National Water Commission for the fixing and implementation of Hydrants. | X | X | X |
| Organize group to advocate to JPS for the fixing and implementation of proper lighting | X | X | X |
| Contact owners of the various properties to have their section groomed. | X | X | |
| As a community organize and have the road ways properly kept. | X | X | X |
| Organize group to advocate to the relevant authority to have the road way groomed | X | X | X |
| Contact owners to have them removed. | X | X | |
| As a community organize and have them removed. | X | X | |
| Organize group and have the drains cleaned. | X | X | X |
| Organize group and advocate to relevant authorities to have the drains cleaned. | X | X | |

# Logwood Community Hazard Map, Hanover

| Hazard | | Profile | | |
|---|---|---|---|---|
| Major Hazard | Minor Hazard | Number of Flood Hazard Zones | | |
| | | Major | Moderate | Minor |
| Flooding | nil | 2 | 3 | 2 |

| Hazard | Impact | |
|---|---|---|
| Critical Facilities Affected | Other assets affected | Other comments |
| Health Centre, 4 bridges, community roadway | HShops, houses, 2 carwashes | - |


Map 5.5b: Logwood Community Hazard Map, Hanover

Project Name:
Enhancing the Resilience of theAgriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Programme

Component 3:
Improving institutional and local level capacity for sustainable management of natural resources and in disaster risk reduction in the targeted vulnerable areas; and raising awareness for behaviour modification

House
Hardware
Bar
Car Wash
Negril Health Centre
Cell Tower
Reservoir
School
Post Office
Shop
Church
Logwood Community Centre
Cemetry
Swamp
Bridge
Main Road
Track
Rivers
Flood Prone Area
The Great Morass
Playfield

N
W
E
S

0 62.5 125 250 Meters

The areal extent of areas affected by hazards were derived solely from anecdotal evidence from the community.
Author:
ODPEM and The Community of Logwood, Hanover
Date: June 8, 2015

GOJ/Adaptation Fund Programme
Building the Resilience of the Agriculture Sector and Coastal Areas
BREAKING THE TIDE. RENEWING THE LAND

# 6

# Risk Assessment

6.0

## 6.1 Introduction

Risk is defined as the combination of the probability of an event and its negative consequences (UNISDR, 2009). Risk can also be defined as the probability of harmful consequences or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between (natural or human-induced) hazards and vulnerable conditions in a given area (ITC, 2010).

**Did you know?**

"Risk" is a forward looking concept that implies an eventuality of something that can occur. Therefore, assessing risk means looking at what are the possible events that can occur, quantifying how likely they are to happen and appraising the potential consequences should they occur (GAR, 2015).

## 6.2 Methodology

The methodology used to assess the potential economic impacts resulting from baseline and future storm surges in Negril **is based on a quantitative approach (See Figure 6.1) which aims at quantifying risk according to the following equation:**

$$Risk = H * V * A$$

H – Hazard, represented as the annual probability of occurrence for 25, 50, 100 years return period

V – Physical vulnerability of the particular element-at-risk, expressing the degree of damage or probability of complete loss of the elements at risk given the occurrence of hazard event.

A – Amount of exposed elements risk, calculated by overlaying hazard scenarios with the elements at risk. This can be expressed in monetary values or as the number of buildings at risk of damage.

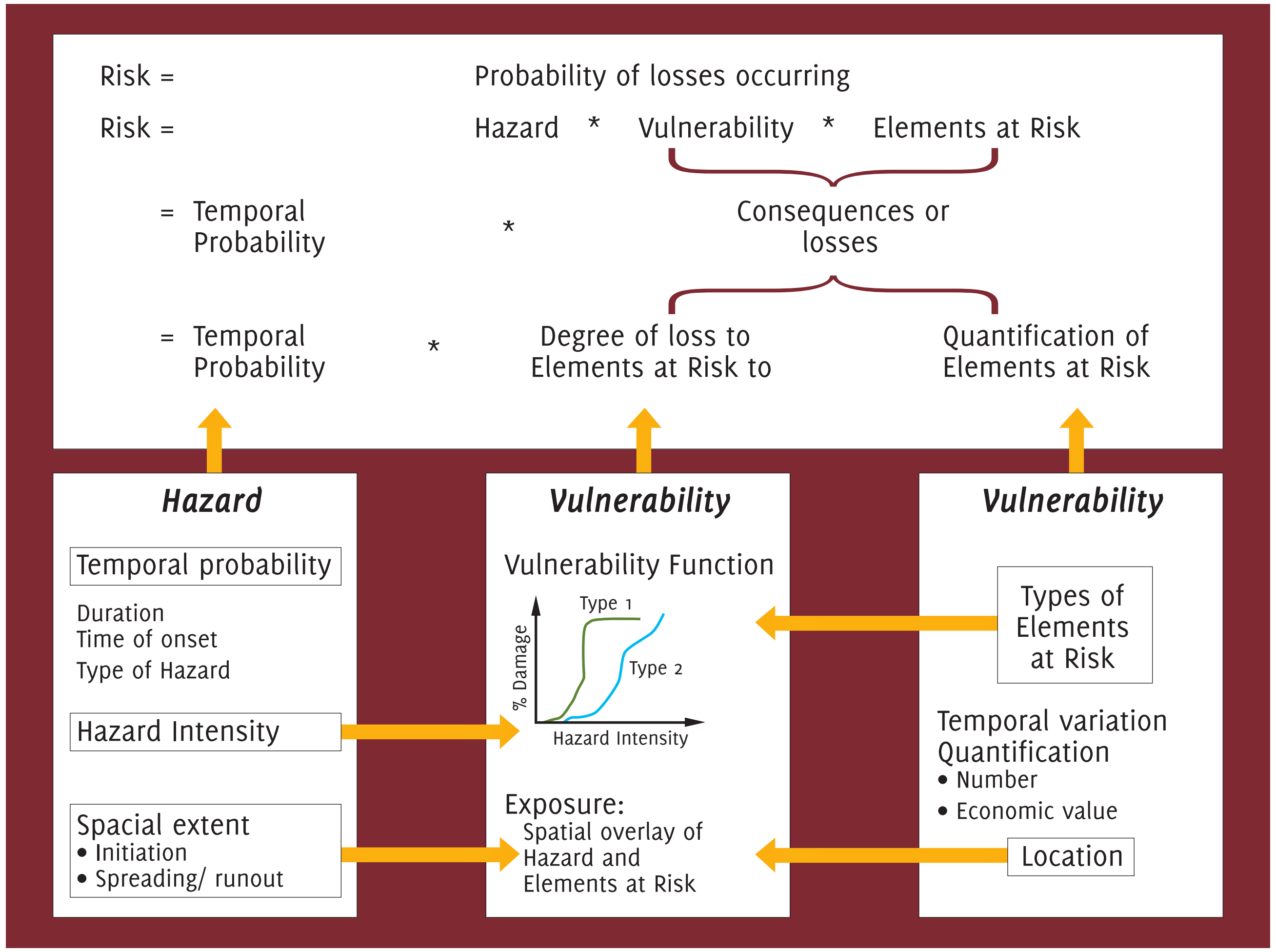



**Figure 6.1: Probabilistic Risk Assessment Methodology** *Source: ITC 2010*

## 6.2.1 Generation of Vulnerability/Stage Damage Curve

Once the exposed elements at risk (Refer to Section 4) are identified it is possible to assess how they would be impacted, that is to assess the physical vulnerability. Physical vulnerability is defined as the degree of loss, to a given element-at-risk or set of elements-at-risk (e.g. buildings) resulting from the occurrence of a natural phenomenon of a given magnitude. Once the physical characteristics for each building class are defined, it is possible to establish and assign the likely damage, and subsequently losses to that specific building class subjected to various levels of specific hazard intensity. This is done by defining relationships between a measured parameter of the hazard intensity (e.g. water depth in case of flooding) to the likely damage level of the particular building class (UNISDR, 2015).Vulnerability is expressed on a scale from 0 (no damage) to 1 (total damage).

For this project, vulnerability curves were derived through expert judgement. This method involved the consultation of five (5) experts (Coastal and Hydrologic Engineers) to estimate the percentage damage expected for three (3) structural types found in Negril (Reinforced Concrete, Wood and Zinc) having different hazard intensities (flood depth). The estimates provided by the experts for each structure type were resampled using the Bootstrapping Statistical Method. This was done to account for uncertainties by assigning measures of accuracy to sample estimates.

A comparative assessment was undertaken to validate the results of the vulnerability curves developed for Negril using historical impact of storm surges of similar building typology in three (3) coastal communities in Jamaica namely, Caribbean Terrace, Old Harbour Bay and Portland Cottage. The impact from the of passage Hurricanes Ivan and Dean in 2004 and 2007 in these coastal areas were used, respectively. Results of the validation process shows confidence limit of over 85% for all three (3) coastal communities. The vulnerability curves for Negril also compare well to expected percentage damage to buildings within V Zone used in Federal Emergency Management Agency (FEMA) HAZUS-MH. The V flood zone is "the first two or three blocks…closest to the flooding source" (FEMA, 2001).

The analysis of risk in Negril focuses on the physical vulnerability of buildings with the hazard intensity being water depth. Damage due to storm surges depend on several factors such as direct exposure to hydraulic wave action, water depth, strong winds, erosion or scour and so on. Taking these factors into consideration, three (3) vulnerability curves were created to determine percent damage for each return period and climate scenario.

For each flood depth, the percent damage to each individual structure identified in Section 4 as exposed was estimated by applying the vulnerability or depth-damage curve in Figure 6.2 below.

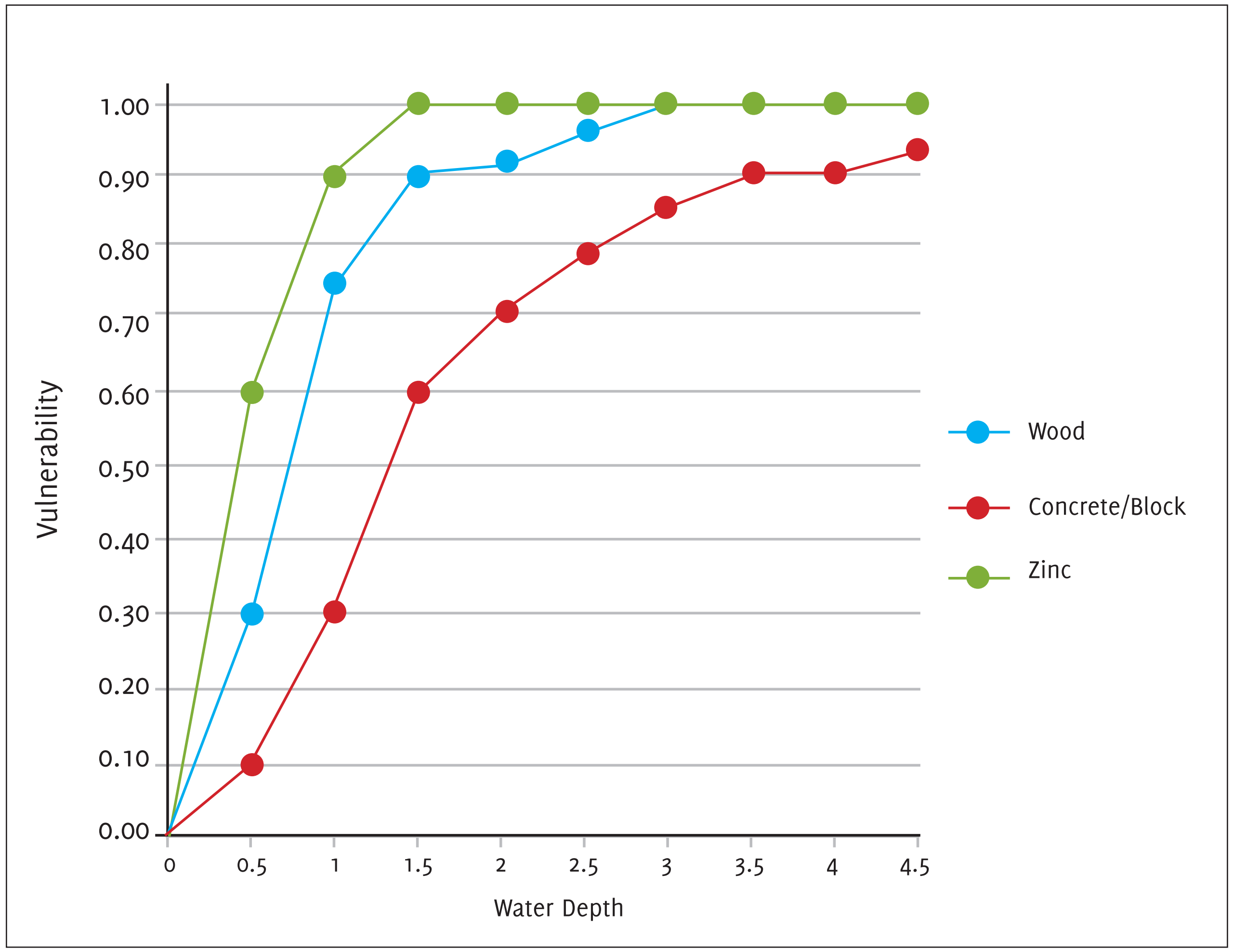



**Figure 6.2: Vulnerability Curve**

## 6.2.2 Cost Estimation for Elements at Risk

Potential damage or losses were estimated for hotels, commercial/industrial, and residential buildings. The assessment of costs focused on tangible/direct losses which account for damage to property and contents for hotels and in the case of the residential and commercial/ industrial damage to property only. The analysis did not take into account indirect losses such as functional downtime (interruption of business due to damage to buildings) or job loss due to time and resource constraints.

The replacement value for hotel buildings and contents were estimated using two construction costs to account for differences in hotel size, amenities and services provided. Replacement cost reflects the cost of labour and materials to construct a building of a particular size, type and quality (FEMA, 2001). For the hotels exposed to baseline storm surge hazard, the replacement cost was derived by multiplying estimated construction cost/room by the number of rooms for each of those hotels.

The Hotel Development Cost Survey 2014/2015 was used to determine the future replacement cost of hotel for storm surges with sea level rise to the end of the century. In the HVS Hotel Development Cost Survey, the elements of a hotel development budget are broken down into five general categories: Land; Construction Costs and Site Improvements; Soft Costs; Furniture, Fixtures, and Equipment (FF&E); and Pre opening and Working Capital. These categories provide general ranges for analyzing hotel development budgets on a per room basis and represent the true costs of building hotels across the United States at the particular time (Sahlins, 2015). The replacement cost used in the calculation for future storm surges in shown below in Table 6.1.

**Table 6.1: Estimated Hotel Replacement Costs**

| Hazard/Scenario | Hotel size | Construction cost/room ($US) | Data Source |
|---|---|---|---|
| Baseline storm surge | small – medium (<150 rooms) | 100,000 | JHTA, 2006 |
| | Large (>150 rooms) | 159,000 | Jamaica Observer,2013 (based on Riu Palace development costs). |
| Future storm surge | Small – medium | 110,900 | Hotel Development Cost Survey 2014/2015 |
| | Large | 220,000 | |

For commercial and residential buildings, the replacement cost was determined using construction cost per square foot. Using the elements at risk database discussed in Chapter 4, the building footprint (sq. ft) of each exposed commercial and residential structure was multiplied by construction cost (USD$)/sq ft to derive replacement cost (See Table 6.2). The lower end of the range was used to calculate the replacement cost under baseline scenario while the upper end of the range for future scenarios for both commercial and residential buildings.

**Table 6.2: Estimated Commercial and Residential Replacement Cost**

| Hazard/Scenario | Land Use | JMD$ Cost/Sq | USD ($) Conversion | Data Source |
|---|---|---|---|---|
| Baseline storm surge | Residential | 6,000* | 64.50 | Jamaica Gleaner, 2012 |
| | Commercial | 8,500 | 83.30 | Jamaica Gleaner, 2013 |
| Future Scenarios | Residential | 7,200 | 77.40 | |
| | Commercial | 11,000 | 107.80 | |

* USD conversion based on Bank of Jamaica Exchange rate for same period

### Risk Calculation

To calculate losses, the percent damage as determined by vulnerability curve was transformed to economic loss by multiplying it by the replacement value at risk. This procedure was followed for all exposed assets in Negril. Losses were then aggregated for each asset yielding a net loss for each return period or scenario. The total for all return periods was then converted to average annualized loss which is the expected loss per year when averaged over a long period of time (e.g. 100 years). The estimated annualized loss addresses the key issue of risk which is represented as the amount of money that has to be paid in the long term to offset the losses associated with storm surge.

# Results

## Buildings at Risk of Damage

The vulnerability curve was used to quantify and assign damage state to each asset based on hazard intensity in this case water depth. The damage state of buildings in Negril is represented according to the following four (4) classifications:

- Slight damage: 0 - 0.25
- Moderate damage: 0.26 - 0.5
- Severe damage: 0.6 -0.75
- Complete loss/Destroyed: 0.76 -1

For each storm surge scenario the buildings were reclassified according to this classification and performing GIS spatial overlay analysis, the number of buildings and damage state per Enumeration District were calculated. The number of buildings that are at risk to be potentially damaged by the different return period is given in Table 6.3 below.

Results show that the number of buildings at risk of being damaged increases with each return period with the 100 year storm surge event expected to have worse impact with 43 buildings at risk of being destroyed. Of this total, 46% comprise commercial structures such as craft shops, small businesses (bars and restaurants) are at risk of being destroyed. Hotel buildings represent 19% whilst 30% account for the residential structures that are found along the coast in the community. Most of these residential buildings are found in Orange Bay, a fishing village that is situated to the north of the highway.

**Table 6.3: Buildings at risk of damage from Storm Surge Hazard**

| | | Damage State | | | |
|---|---|---|---|---|---|
| Annual Probability | Storm Surge Return Period | Slight | Moderate | Severe | Destroyed |
| 0.1 | 10 | 392 | 188 | 105 | 0 |
| 0.04 | 25 | 473 | 144 | 147 | 12 |
| 0.02 | 50 | 538 | 217 | 187 | 19 |
| 0.01 | 100 | 573 | 196 | 220 | 43 |

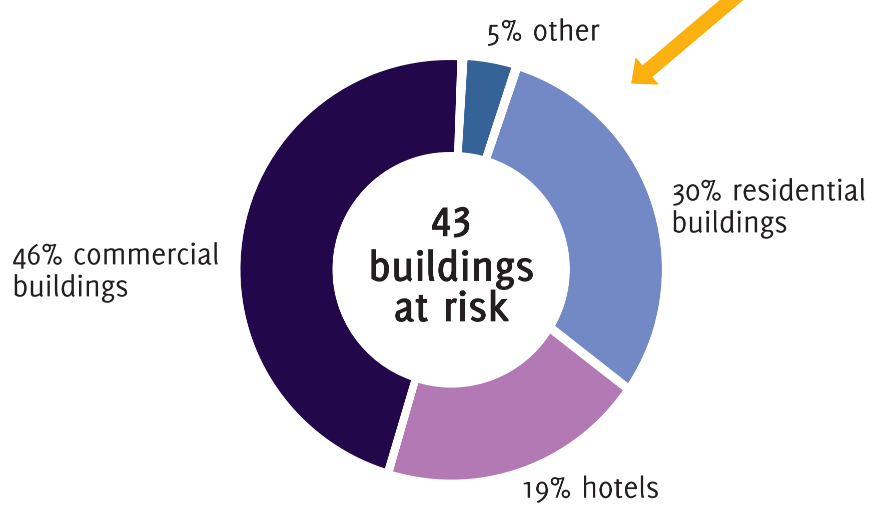
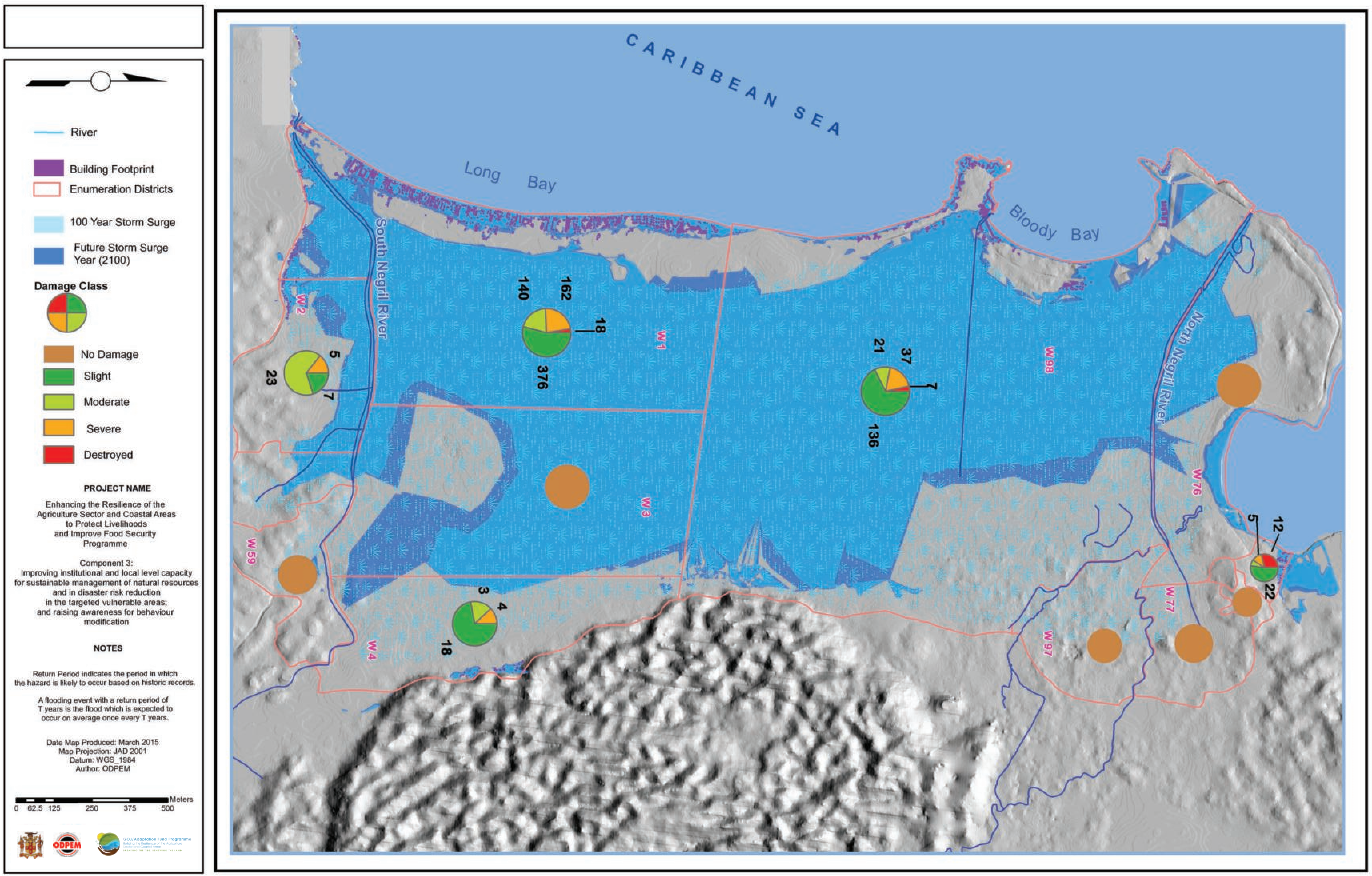



*Plate 6.1: A section of Harbour View, Kingston showing bridge washed away by the Hope River after Tropical Storm Gustav, 2008* | *Photo Credit: Jamaica Defence Force*

BUILDINGS AT RISK OF DAMAGE TO 100 YEAR STORM SURGE (BASE LINE) AND FUTURE STORM SURGE FOR THE YEAR (2100), NEGRIL




Map 6.1: Buildings at risk of damage to 100 year storm surge (base line) and future storm surge for the year (2100), Negril

## Expected Economic Losses – Baseline Storm Surge Scenario

Figure 6.3 shows the expected losses by land use for different baseline storm surge scenarios. The results show that for a given return period resort land use account for a substantial amount (95%) of total expected losses in Negril. Commercial and residential land use account for significantly less with 2%, and 3% of total expected losses, respectively. The result is not surprising given the concentration of hotels and other infrastructure along the coast in Negril.

The losses for each return period were converted to average annual loss (AAL). AAL is the expected average loss per year considering all the events that could occur over a long time frame. It represents the amount of savings that need to be set aside each year to cover the cost of long term losses from storm surge hazard in Negril (Global Assessment Report on Disaster Risk Reduction, 2015).

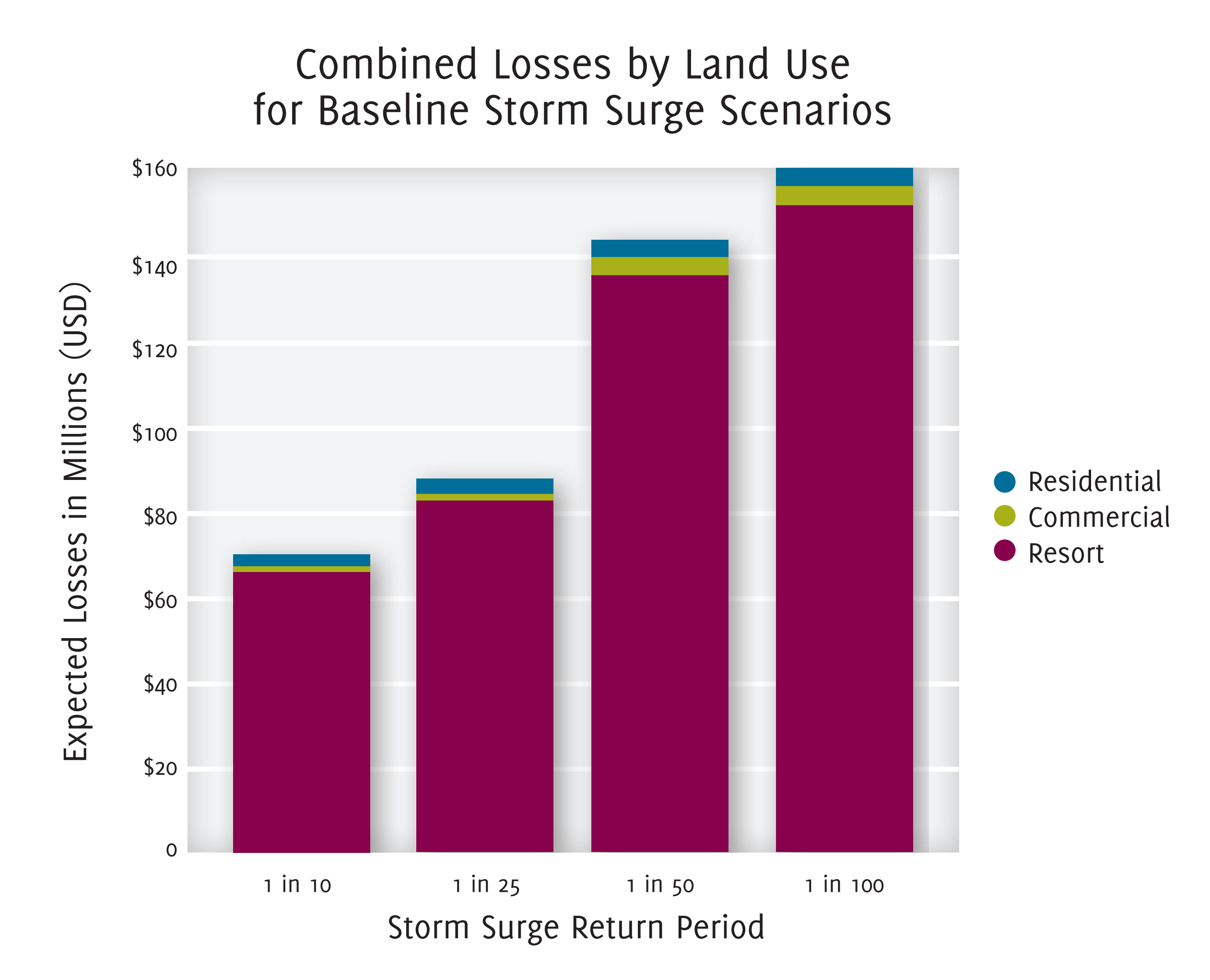



Figure 6.3: Combined Losses by Land Use for Baseline Storm Surge Scenarios

The expected annualized loss for baseline storm surge scenario is summarized in Figure 6.4. The figure displays the estimated relationship between total losses and annual probability with the area under the curve representing expected **AAL of US $4,946,521 million.** Of this total, the **tourism sector alone accounts for 94% (US$ 4,777,495) of the total annual risk in Negril.**

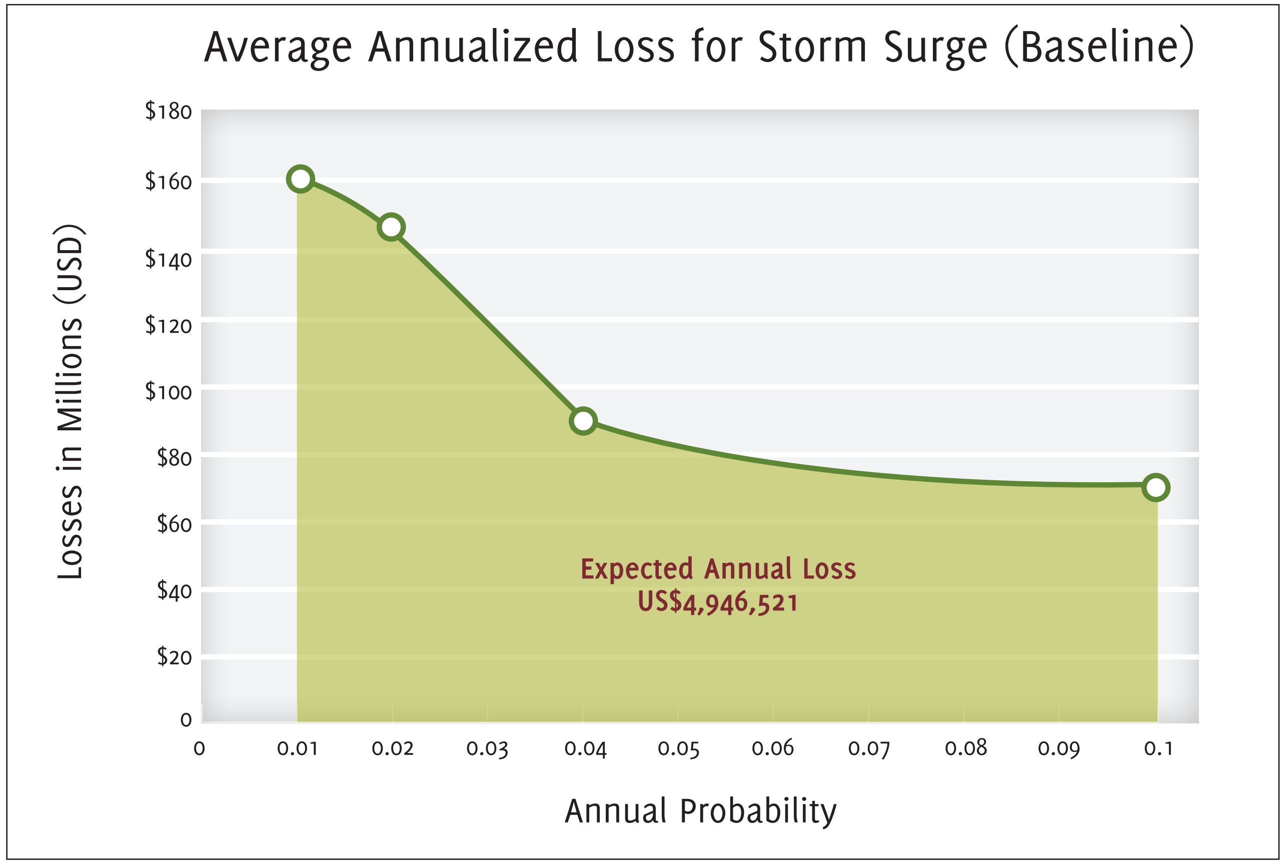



Figure 6.4: AAL for Baseline Storn Surge Scenario

## Future Storm Surge (with Sea Level Rise)

The AAL increases under sea level rise conditions by contributing an additional US$1.8 million to the expected average annual losses by the end of the century (See Figure 6.5). The yellow shaded area between the baseline and future curves represents the increased AAL associated with climate change-related sea-level rise.

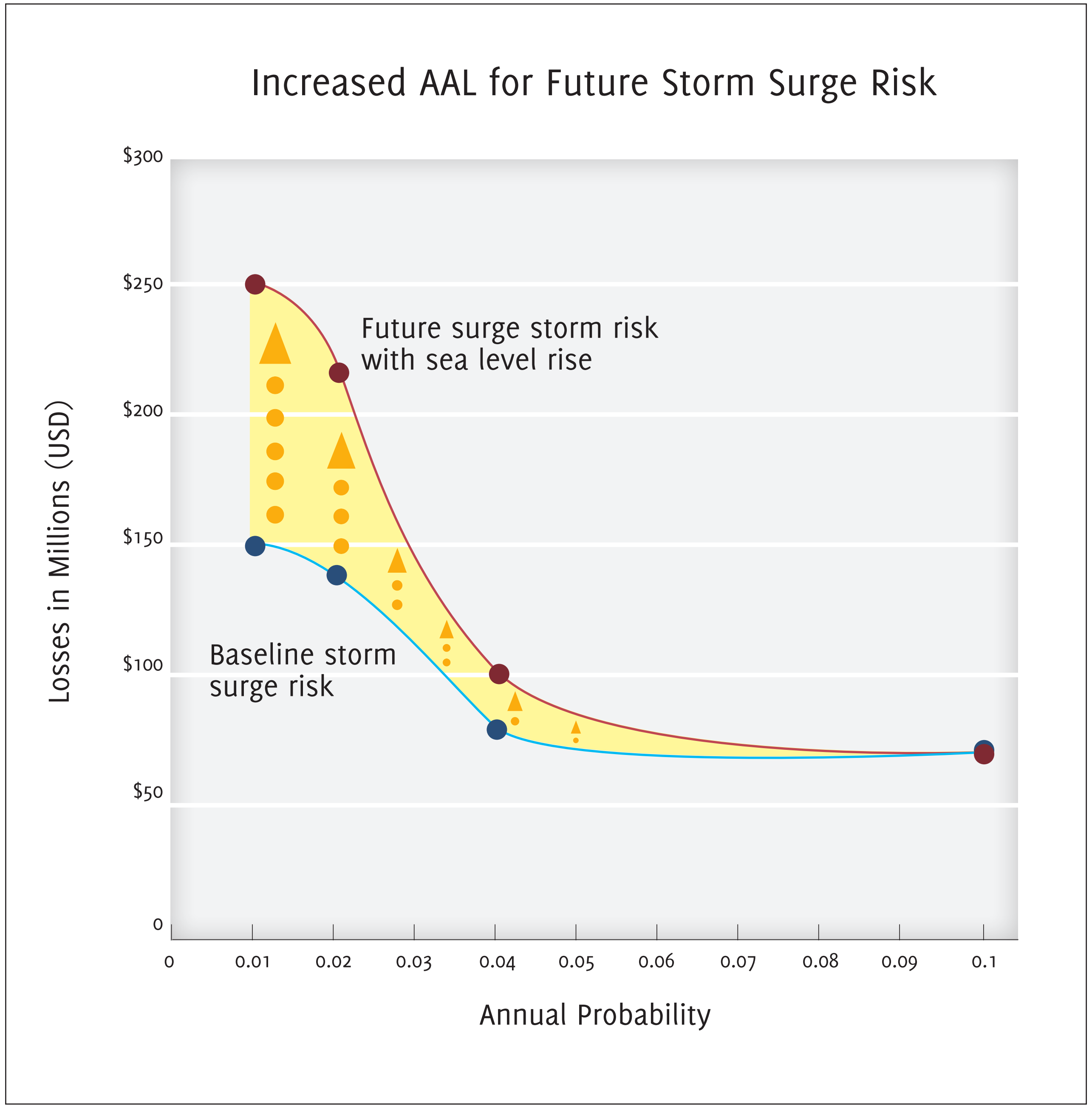



Figure 6.5: AAL for Future Storm Surge Risk due to sea level rise

By the year 2100, if climate change induced sea level rise occur as forecasted, the exposed value of assets is estimated to increase from US $ 460.1 to 621.2 million. Similarly, the AAL is expected to increase by 37% from US $4.94 million from baseline scenario to US $6.76 million by the end of the century.

Table 6.4: Comparison of Exposed Value and AAL for Baseline and Future Storm Surges

| Results | | Baseline Storm surge | Future storm surge with SLR | Change from Baseline Condition |
|---|---|---|---|---|
| Exposed Value | Million US $ | 460.1 | 621.2 | 1.82 |
| Average Annual Loss | Million US $ | 4.94 | 6.76 | |
| % | | | | 37 |

**The AAL for Negril is considered to be conservative because it does not include all hazards -coastal erosion and wave overtopping. The AAL in this atlas represents direct physical risk to hotels (incl. guesthouse and villas), residential and commercial buildings. It does not include risk to infrastructure such as roads and other facilities in Negril. Finally, the AAL does not consider indirect losses and impacts.**

## Implications for GDP

The economic risk for baseline and future storm surge scenarios does not affect the tourist resort of Negril alone; it will also impact the national economy. Tourism is one of the main sectors in Jamaica which contributed 7% to the national Gross Domestic Product [GDP] (US$13.4 billion) in 2014 for all the resort areas combined (STATIN & JTB, 2014). Of this total, the Negril resort area alone is estimated to contribute a significant percentage of 3.25% which is equivalent to US $437.3 million.

At a macroeconomic level, AAL is equivalent to 0.04% and 0.05% of National GDP for baseline and future storm surges, respectively. Taking Negril's direct contribution to national GDP, the AAL for baseline storm surge risk is equivalent to 1.1% of Negril's GDP which is expected to increase under sea level rise conditions to 1.5%. The relationship between AAL and GDP needs to be considered because of potential cascading impacts spilling over into other sectors thereby the increasing complexity of risks not only at micro but also at a macro level for the country.

# 6.3 Natural Resource Valuation Consideration

Similar to estimating potential monetary losses to the built environment from hazard events of varying intensities, it is equally important to determine economic value of ecosystems and the value they provide in DRR.

Economic valuation is a tool used to quantify ecosystem services such as those provided by coral reefs in monetary terms (WRI 2011). The World Resources Institute conducted a study in 2011 which assessed the economic contribution of coral reefs to beach erosion control and the benefits derived from the beach tourism economy in Negril, Montego Bay and Ocho Rios. The findings specifically for Negril is presented in subsequent sections.

## 6.3.1 Methodology

A model developed by Sheppard et al. (2007) was applied to each of the three sites (Negril, Montego Bay and Ocho Rios), to estimate how the further loss of live reef structure and the subsequent erosion of the reef substrate over 10 years would lead to increased wave heights and thus increased beach erosion. Using the increased erosion rates as inputs, the loss in consumer welfare associated with a decline in beach quality due to erosion at each site was calculated. The study by Edwards (2009), which looked at visitors' willingness to pay for environmental quality, was used as the basis to determine the welfare loss per meter loss of beach width.

## 6.3.2 Results

To assess the role of coral reefs in preventing beach erosion, the authors estimated how the further degradation of coral reefs would lead to increased wave heights and thus increased beach erosion. It was estimated that if further reef degradation occurs, erosion rates could increase significantly above the current rates at all three sites, by more than 50 percent for Montego Bay, 70 percent for Ocho Rios, and more than 100 percent for Negril over a 10-year period.

At the end of 10 years, current erosion rates at the beaches in Negril, will cause an annual loss in value of US$5.5 million. If reefs degrade further, it was estimated that the additional beach erosion will increase this annual loss to US$10.9 million that year. This represents an additional US$5.3 million per year — a 96 percent increase in the annual loss of value from the base scenario if the reef degrades further. As seen in Table 6.5, the greatest impact is expected to be in Negril.

**Table 6.5 Annual loss in consumer satisfaction (US$) at beaches due to coral reef degradation *(after 10 years of erosion)***

| Location | Loss in value due to current rates of beach erosion | Loss in value if the beach erodes faster due to reef degradation | Difference due to further reef degradation |
|---|---|---|---|
| | US$ | US$ | US$ |
| Negril | 5.5 million | 10.9 million | 5.3 million |
| Montego Bay | 7.1 million | 10.7 million | 3.6 million |
| Ocho Rios | 6.5 million | 11.1 million | 4.6 million |
| Total | 19.2 million | 32.7 million | 13.5 million |

*Source: Kushner et al, 2011*

**Note: The loss in consumer satisfaction was calculated using a per meter value of $5.11 per visitor (based on Edwards 2009), coupled with the average number of overnight visitors a year for each site**

The authors concluded that the economic risks to the Jamaican tourism industry are large. Beach erosion due to reef degradation will reduce visitor demand, leading tourists to consider substitute destinations. Jamaica's coral reefs have suffered significant mortality in recent decades as a result of many factors, including overfishing, pollution and coastal development. However, with adequate coastal and fisheries management it is highly likely that Jamaica's reefs could recover. In order to promote reef protection, it is crucial that key stakeholders take full account of the economic value of reef-based ecosystem services. This requires that the economic benefits of coral reefs be publicized and leveraged to build national political will for greater reef conservation. Environmental policy should also be strengthened to address the drivers of coral reef degradation (Kushner el al, 2011).

# Conclusion and Recommendations

7.0

## 7.1 Conclusion

The data clearly shows that the current risk levels posed by storm surge will increase significantly when sea level rise and coastal erosion are factored. When factored to the already significant levels of coastal erosion being experienced, a number of hotels and resorts will be significantly affected from the two main hazards of focus: storm surge and sea level.

The location of the resort area primarily along the narrow strip of sand barrier is a key contributor to this high level of exposure. This is further compounded by the quality of the level of degradation of natural protective mechanisms such as sea grass beds and coral reefs that offer a first line of protection for the coastline. Both factors threaten the viability of the Negril Resort area and by extension the tourism sector nationally.

The problem of coastal erosion has progressively worsened since the late 1960's when the government pursued a development path that relied heavily on tourism, Negril featuring heavily in this development discussion. Not only has the number of resorts increased but the types of hotels and resorts around which Negril was developed has also changed demonstrating a strong correlation between levels of coastal erosion and intensification and scope of hotel developments.

The projections show that the situation will continue to worsen if no mitigation measures are implemented, however, should the two breakwaters proposed under this project be implemented, the models show that there will be improvements in the rates of erosion and even more improvements when all 5 proposed are implemented. If unmitigated, the situation is not likely to improve and in such situations, not only will the hotels and resorts be impacted but other infrastructure such as roadways will also be impacted.

Notwithstanding the level of erosion and sea-level rise that exists, the information presented in this atlas, when used to guide development decisions, should also result in a reduction in the level of vulnerability, especially through instruments such as development plans, adaptation and disaster risk reduction plans and shoreline protection and beach restoration plans.

## 7.2 Recommendations

- Training and further assessment is needed to quantify environmental risk and an Ecosystem based approach to this assessment is recommended. Such an assessment should include the Great Negril Morass.
- An assessment of the impact on livelihood groups is required. This is best facilitated by an assessment of the current and future climate impacts on ocean temperatures in Negril and a further analysis of this impact on marine organisms and vegetation. This can then be used to gauge impact on fishing. Such assessments can be undertaken collaboratively with universities.
- The findings from this atlas should be used as a guide to developing other outputs under this programme, more specifically, the Beach Restoration Guideline, installation of the breakwaters and Adaption Plan for Negril.
- The findings from the atlas should be incorporated and form the basis for any development plan and order created for Negril.
- A number of stakeholders need to be sensitized on the findings from this atlas and this include media practitioners, Negril hoteliers, local authorities, NGO's and businesses.
- Stakeholders, when sensitized to the findings, should implement risk reduction and climate change adaption measures to reduce the risk. Such strategies and actions can include Business Continuity planning, alternate livelihood, structural mitigation, training and soft engineering.
- The three local authorities with jurisdiction over Negril should improve data collection to include impact reports on all events affecting Negril and surrounding communities. Special attention should be paid to impact on ecosystems.
- Monitoring of the coastline changes should be done by NEPA and incorporate hoteliers located along the sand barrier in the process.
- Select vulnerability and risk maps from the atlas should be placed on signboards in strategic sections of the town of Negril as part of public awareness of the risk.
- The risk atlas should be placed on the website of the ODPEM, MOTE and PIOJ and National Spatial Data Management Division (NSDMD).
- Training in Risk assessment methodology and Ecosystems based analysis needs to be provided to climate change and disaster risk reduction professionals.
- Dissemination of the atlas should be pursued as this was not an inclusion in the project. Dissemination should include various formats suited to different users of the data.


*Plate 7.1 Negril Trig Station*

# 7.3 Limitations

Users of the atlas should be aware of the following limitations:

a. Cost Estimation for Elements at risk – The availability of data for content value and replacement costs would have enhanced the accuracy of the estimation of risk. To compensate for the unavailability of this data, estimates of global average of hotel development costs were used. These costs includes cost of land, construction costs and site improvements, soft costs, furniture, fixtures and equipment and pre-opening and working capital.

b. Economic losses - There was no GDP data available specifically for Negril Resort Area. An estimate was derived from data on tourist spending,

c. Comprehensiveness of the estimated Average Annual Loss – Due to data unavailability, the estimation of the AAL did not include all hazards such as coastal erosion and wave overtopping. It also does not included risk to infrastructure such as roads and other facilities in Negril.

d. Estimation of Ecosystem loss – The estimation of AAL does not include ecosystem loss. The natural environmental is important to Negril's tourism industry and whilst environmental elements were discussed, an ecosystems based assessment was not conducted due to time and budget challenges.

e. The aerial imagery used to conduct the historical shoreline assessment represents snapshots at a moment in time and cannot be manipulated to show specific times (such as just before or after a hurricane). As such the overall imagery maybe displaying short-term shoreline configurations while others long term. The accuracy is therefore subject to the limited time periods of availability of aerial imagery.

f. Incomplete historical databases – Although an attempt was made at collecting as much historical data as possible, the historical database is incomplete. Data for localized events and local impacts is not readily available.

g. It is accepted that there are inherent uncertainties with modelling such as with the probabilistic risk assessment methodology used in the development of the Climate Risk Atlas. To address this limitation, the most appropriate and current datasets available at the time conducting the assessment were used. Assumptions and simplifications, where necessary, were applied to model coastal hazards and the validation showed a high confidence level in the results of the models and the overall atlas.

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# 8.1 Glossary of Terms

**Annual Average Loss (AAL):** The long-term expected loss per year, averaged over many years. While there may actually be little or no losses, over a short period of time, the AAL accounts much larger losses that may occur more infrequently. In other words, it is the weighted average of expected loss from every event conditioned on the annual probability of each loss's occurrence.

**Atlantic Multi-decadal Oscillation (AMO):** A multi-decadal (65- to 75-year) fluctuation in the North Atlantic, in which sea surface temperatures showed warm phases during roughly 1860 to 1880 and 1930 to 1960 and cool phases during 1905 to 1925 and 1970 to 1990 with a range of the order of 0.4°C.

**Climate Change:** The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

**Critical Facilities:** The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.

**Disaster:** A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

**Disaster Risk:** The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

**Disaster Risk Management:** The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

**Disaster Risk Reduction:** The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

**El Nino:** The conditions refer to periods when the Pacific Ocean off the coast of Peru and Ecuador is abnormally warm.

**Exposure:** people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

**Hazard:** A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

**Hydro Meteorological Hazard:** Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

**Intensive Risk:** The risk associated with the exposure of large concentrations of people and economic activities to intense hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss.

**La Nina:** A condition when the eastern Pacific Ocean is abnormally cold.

**Mitigation:** The lessening or limitation of the adverse impacts of hazards and related disasters.

**Preparedness:** the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

**Prevention:** The outright avoidance of adverse impacts of hazards and related disasters.

**Probabilistic Risk Assessment:** Uses a combination of probabilistic hazard scenarios, exposure and vulnerability, which is produced through modeling. Unlike historical estimates, probabilistic risk assessment takes into account all the disasters that could occur in the future, including very 5 intensive losses over long return periods, and thus overcomes the limitations associated with estimates derived from historical disaster loss data.

**Probability:** likelihood of an event occurring compared to all the possible events that might occur. The exceedance probability is the likelihood of one event of a given magnitude occurring or being exceeded within a defined time span.

**Resilience:** the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

**Return period:** average frequency with which a particular event is expected to occur. It is usually expressed in years, such as 1 in X number of years. This does not mean that an event will occur once every X numbers of years, but is another way of expressing the exceedance probability: a 1 in 200 years event has 0.5% of chances to occur or be exceeded every year.

**Risk:** The combination of the probability of an event and its negative consequences.

**Risk Assessment:** A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

**Sea Level Rise:** The association with atmospheric warming appears largely through the combined effects of two main mechanisms: (a) thermal expansion (the physical response of the water mass of the oceans to atmospheric warming) and (b) Ice-sheet, ice-cap and glacier melt.

**Vulnerability:** The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.