# Cities and Climate Change Initiative

ABRIDGED REPORT

## Port Moresby
## Papua New Guinea

Climate Change
Vulnerability Assessment

UN-HABITAT
FOR A BETTER URBAN FUTURE

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### Climate Change Vulnerability Assessment

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**Port Moresby, Papua New Guinea – Climate Change Vulnerability Assessment**



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| | |
|---|---|
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# 01 Introduction

## 1.1 Cities and Climate Change

Climate change is already affecting millions of people worldwide. In urban areas, which are typically characterized by significantly higher population density, climate change will exacerbate and compound existing climate vulnerabilities, especially for the urban poor. As a result of climate change, it is expected that storm frequency and intensity will increase, flooding will become more serious and drought will affect food production in rural areas, which will have damaging effects in urban areas. Coastal areas are also threatened by inundation from storm surges and sea-level rise. Existing urban development challenges, such as poor health and inadequate housing, are substantially exacerbated by the effects of climate change. At the same time, urban areas are the main drivers of increasing greenhouse gas emissions. This means that cities must be at the centre of efforts to address the challenge of climate change, both to mitigate its causes and to adapt to its anticipated effects.

In Papua New Guinea, as in many areas in the Pacific, urban populations are often located in hazard-prone areas in the coastal zone. Storm surges and sea-level rise can affect settlements, food production and infrastructure. A lack of basic services such as clean water supply and solid waste management can exacerbate the negative effects of climate change. Amid all this, the poorest are almost always the most vulnerable, as they have less access to infrastructure, basic services and social safety nets in the event of a disaster.

## 1.2 UN-Habitat's Cities and Climate Change Initiative

It is within the power of cities and local authorities to work towards the reduction of greenhouse gas emissions which are the causes of climate change, and to understand how to protect themselves from the effects. The Cities and Climate Change Initiative (CCCI) promotes the mitigation of, and adaptation to, climate change in developing countries. More specifically, it supports the development of pro-poor innovative climate change policies and strategies. It builds on UN-Habitat's rich experience of sustainable urban development (through the Environmental Planning and Management approach of the Sustainable Cities and Agenda 21 Programmes), as well as on well-recognized capacity building tools, to support city managers and practitioners in adapting to climate change. It also promotes collaboration by local authorities and their associations in global, regional and national networks, with the triple rationale of: 1) enhancing policy dialogue so that climate change is firmly established on the agenda; 2) supporting local authorities' efforts to bring about these changes; and 3) enhancing awareness, education and capacity-building in support of climate change strategies. A major outcome of the initiative will be the development of a set of tools for mitigation and adaptation. CCCI now operates in over 30 cities in 15 countries in the Asia-Pacific region.

## 1.3 Assessment Framework

The climate change assessment framework is adapted from the Intergovernmental Panel on Climate Change (ICFF) Third and Fourth Assessment Reports. Vulnerability to climate change is described as a function of exposure, sensitivity and adaptive capacity. Exposure is the degree of climate stress upon a particular unit; it is represented as either a long-term change in climate conditions or in climate variability, including the magnitude and frequency of extreme events. Sensitivity is the degree to which a system is affected either adversely or beneficially by climate related stimuli. Adaptive capacity refers to the ability of a system to adjust to climate change, including climate variability and extremes.

Figure 1. Assessment Framework


Source: UN-Habitat

# 02

# Overview of the City

## 2.1 Geographic Location

Port Moresby is the capital city of Papua New Guinea, located on the shores of the Gulf of Papua, on the south-eastern coast of the island of New Guinea at latitude 9.25° south of the equator. Port Moresby, though surrounded by Central Province, is not technically part of it and instead makes up the National Capital District. While the definitions of the boundaries of Port Moresby vary, for this study National Capital District and Port Moresby are used interchangeably. The offshore islands of Daugo (Fishermans) Island, Daunagena Island, Gemo Island, Lolorua Islands and Manubada are also part of the National Capital District.

Besides being the capital, Port Moresby is also the main administrative and commercial hub for the country. As the largest and most developed urban centre, it attracts resources and people from almost every tribal group in Papua New Guinea, giving the city a rich cultural diversity. It also accommodates the seat of the National Government. The Central Business District is situated on a peninsula at the entrance of the Fairfax Harbour where the main commercial wharves and other commercial and business establishments are also located. The total population according to the 2011 census is 364,125.

## 2.2 Physical Features of the City

Port Moresby is situated within the catchment areas of the Vanapa and Brown Rivers, but is not actually located on any major rivers itself. There are rivers, streams and flood plains at the periphery of the city, such as the Loloki River, which continues to the sea outside the National Capital District boundary. However, the only bodies of water within the city are the Waigani

Table 1. Overview of the City

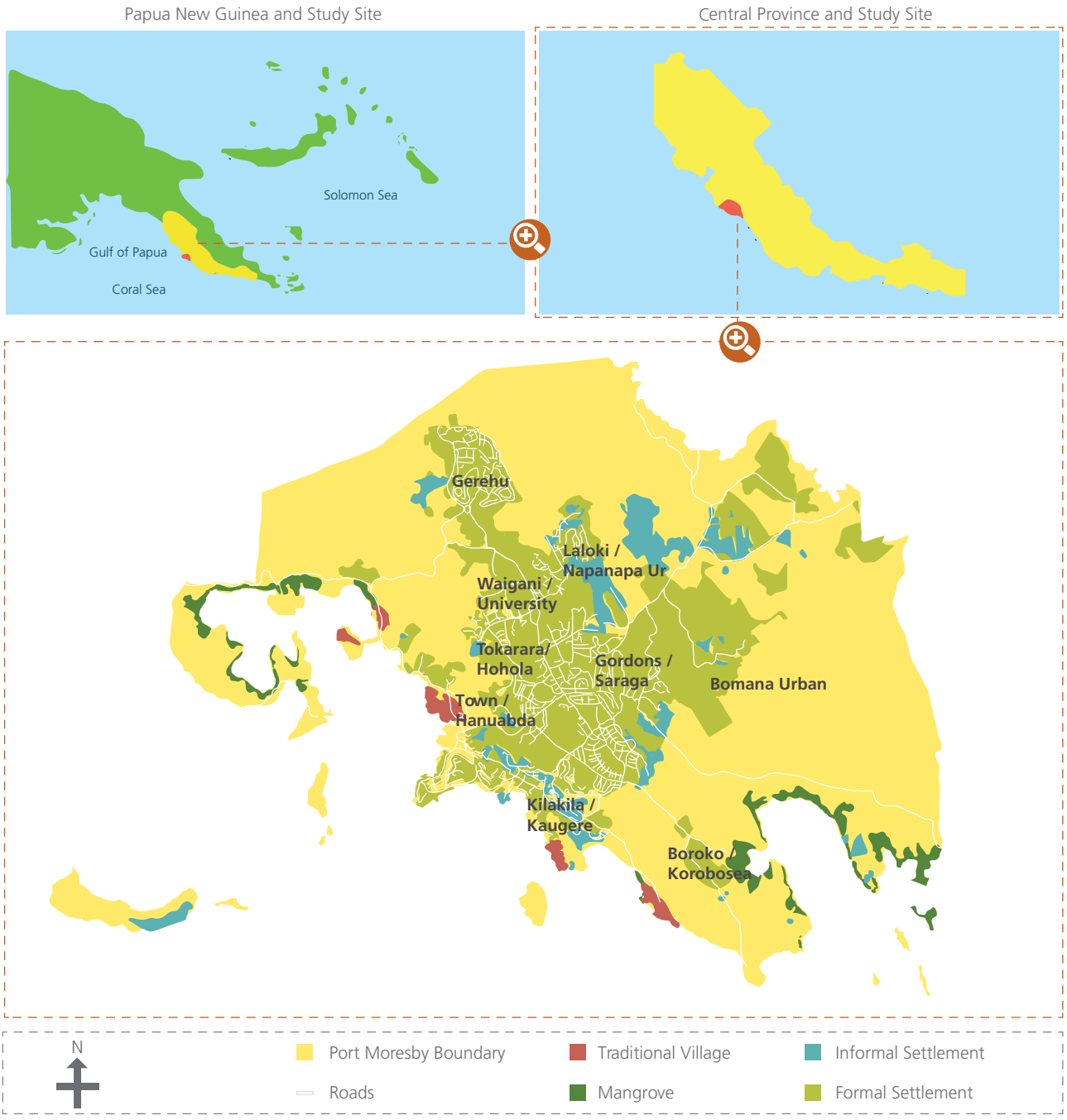
| | |
|---|---|
| Total land area | 267.6 km2 |
| Built up (formal and informal) area (2003) | 67.5 km2 |
| Rural area / unused land | 152.5 km2 |
| Total population (2011 census) | 364,125 |
| Population density (total area) | 1,188.8 persons /km$^2$ |
| Population density (on land suitable for development) | 2,086.1 persons / km$^2$ |

Source: UN-Habitat

and the Boroko Creek, which drains into it. As a result of drainage issues in this area, a shallow lake has formed.

There are several landform types, ranging from hill slopes and valley floors to beaches and mangrove swamps. The prominent feature of the topography of the Port Moresby area is a series of northeast-southwest tending ridges separated by broad flat valleys. This topography has led to the development of a widely dispersed settlement pattern. The ridges are 200 meters above sea level, while the broad valleys

Figure 2. Map of Port Moresby




Source: Base map from National Geographic Information Centre

are typically 50 meters above sea level. Many of these are quite steep, with significant elevation and other features that make them unsuitable for human settlement.

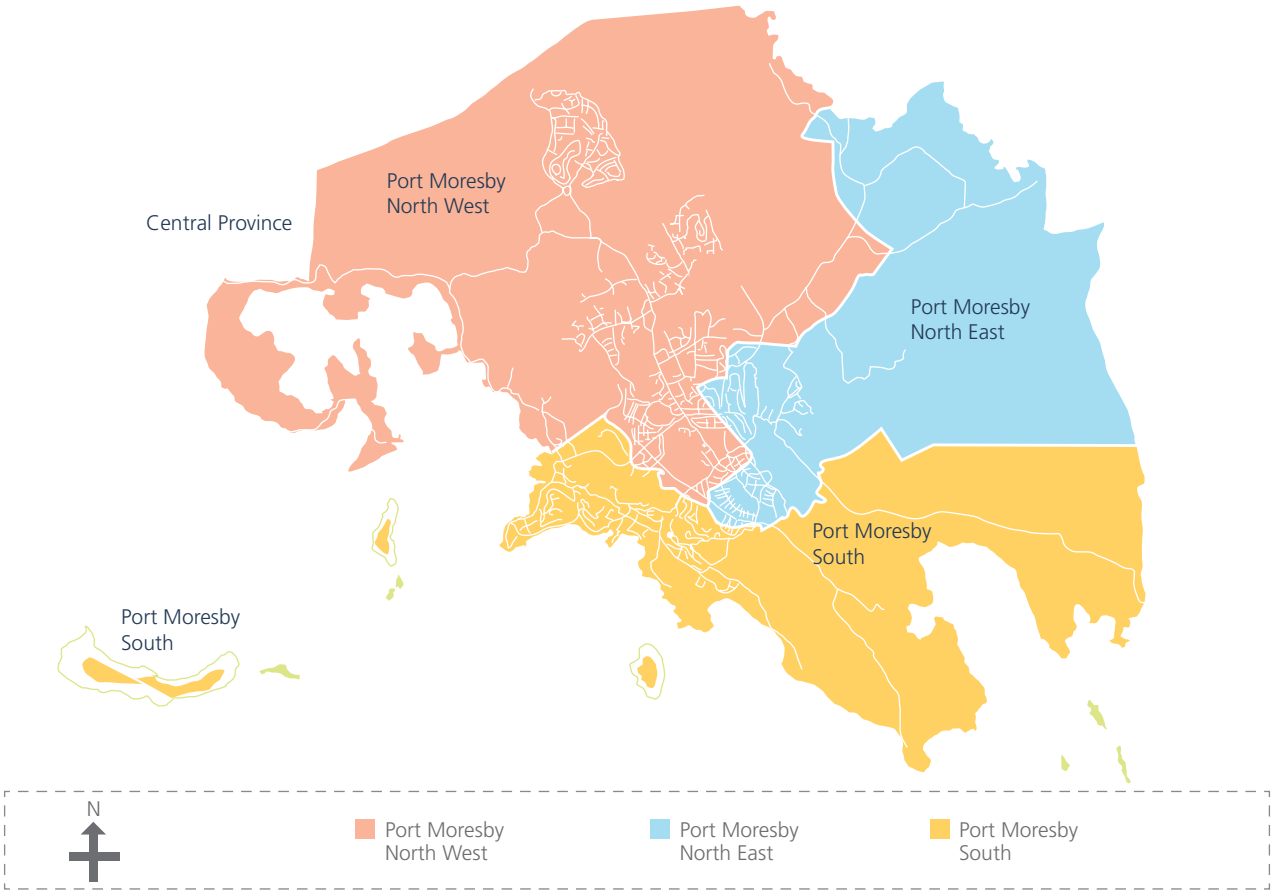
The eco-system surrounding Port Moresby is primarily made up of savannah grassland and scattered woodlands that also include mixed herbaceous swamp vegetation. This consists of scattered to moderately dense trees over a ground layer of grasses with a marked dry season, largely a fire resistant type of vegetation. The main tree species is eucalyptus on permanently dry terrain. The general geology is gravel, breccias agglomerate and a mixture of sandy loam soil.

The National Capital District's coastline is 88.14 kilometres in length, comprising Port Moresby, Fairfax Harbour and the Bootless Bay. This also forms the Papua coastal lagoon, which is separated from the open ocean by a barrier reef. The reefs of Port Moresby are part of the Papuan Barrier Reef, the third largest in the world, stretching from the Gulf of Papua through Port Moresby before ending at Rossell Island in the neighbouring province of Milne Bay [1]. The coastal morphology is primarily made up of sand, beaches, seagrass and reef areas; mudflats along the eastern coastline; silt with mud flats surrounding Fairfax Harbour; mud and mangrove systems along the eastern and northern coastlines; and the rocky shores of southern and western coastlines.

## 2.3 Governance Structure

The National Capital District is the administrative unit that encompasses the city of Port Moresby. Port Mo-

Figure 3. Administrative boundaries in Port Moresby



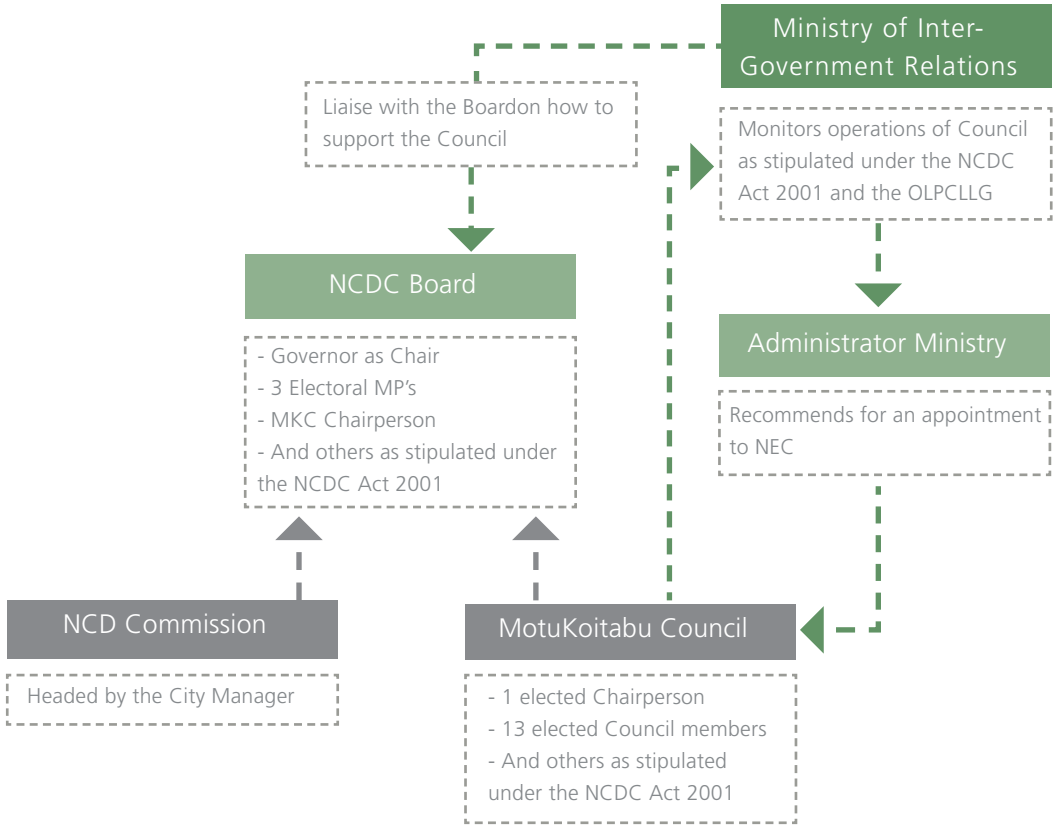

Source: Base map from National Geographic Information Centre

[1] EcoStrategic Consultants and PNG Natinal Maritime Safety Authority. (2011). Papua New Guinea National Marine Pollution Risk Assessment -Volume 1: Port Moresby.

resby is divided into three electorates - Port Moresby North East, Port Moresby North West and Port Moresby South East - and twelve wards (Figure 3). The National Capital District is classified as an Urban Local Level Government and is different to the Provincial Government systems in Papua New Guinea. However, for electoral purposes, it is classified as the equivalent of a province, with a Provincial Member who becomes the Governor of the district and who is also the chair of the National Capital District Commission. The electorates are not considered districts in the same administrative sense as the other open electorates of Papua New Guinea, due to the broader mandate of the Commission [2]. The National Capital District Commission is the administrative authority and operates under the National Capital District Commission Act. This law establishes the Commission as a governing body for the purpose of providing municipal services such as urban planning and regulation, roads, waste management and basic urban services for the entire city, employing 700 staff.

The Commission Board is made up of 11 members, with the Governor as the Chair of the Board. Under its regulatory framework, the National Capital Development Commission falls under the supervision of the Ministry of Inter-Government Relations. Its physical planning responsibility is guided by the National Capital District Urban Development Plan 2006 and is in line with the Physical Planning Act 1989. The only recognized locally elected government in Port Moresby is the Motu Koitabu Council, which represents the interests of the seven traditional villages within the National Capital District (Figure 4). The Motu Koitabu people are the traditional land owners upon whose land the city of Port Moresby is located. The seven villages, with a total population of 30,000, are represented by their councillors on the Motu Koitabu Council. This political unit operates under the National Capital District Commission Act. This is a traditional form of governance which recognizes the traditional land owners of Port Moresby in a formal system of local level government. The council's chairman and councillors are voted by

Figure 4. Port Moresby's Governance Structure Framework




Source: UN-Habitat

[2] National Research Institute. (2010). Papua New Guinea District and Provincial Profiles.

the traditional land owners, who themselves have the voting right, and the Motu Koitabu chairman automatically becomes the deputy governor of the National l Capital District.

The National Capital District Commission functions are similar to those of the provincial government who have direct representation to the National government, while the Motu Koitabu Council's functions are similar to the local level government but come directly under the National Capital District Commission.

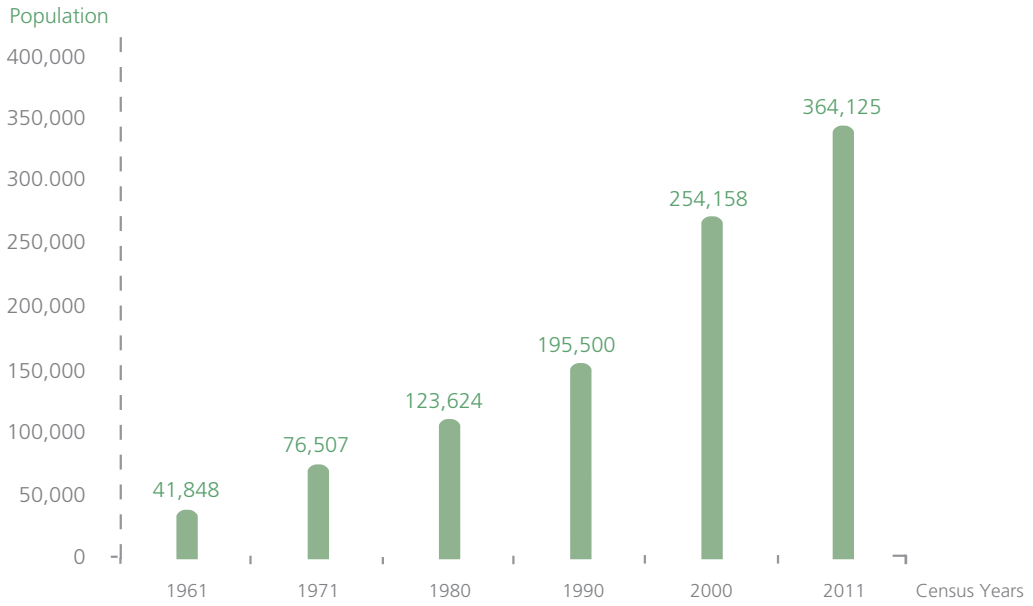
## 2.4 Demographic Trends

The population of Port Moresby has shown a steady but significant increase since Papua New Guinea's independence in 1975. The 2000 population census shows a total population of 254,158 in the National Capital District, rising to 364,125 in 2011, with a consistent growth of around three per cent per year since the 1980s (Figure 5).

The dependency rate in the 2000 census, defined as the proportion of the population persons aged under 15 or over 65 years of age, is 35 per cent - 34 percent 0-14 years and 1 percent over 65 years - indicating the likelihood that the city's population will continue to grow in future, even without migration. There are more males than females in the National Capital District, according to the 2000 census, with a ratio of 120 males to 100 females.

The unemployment rate of the labour force (population age group 15-65) in National Capital District for 2000 was 34 per cent (21.2 per cent of the total men and 12.8 per cent of the total women), while the 66 percent are either less 15 years or over 65 years). In the 2000 census, 9.3 percent of all households in National Capital District were female-headed.

Figure 5. Population Growth of the National Capital District



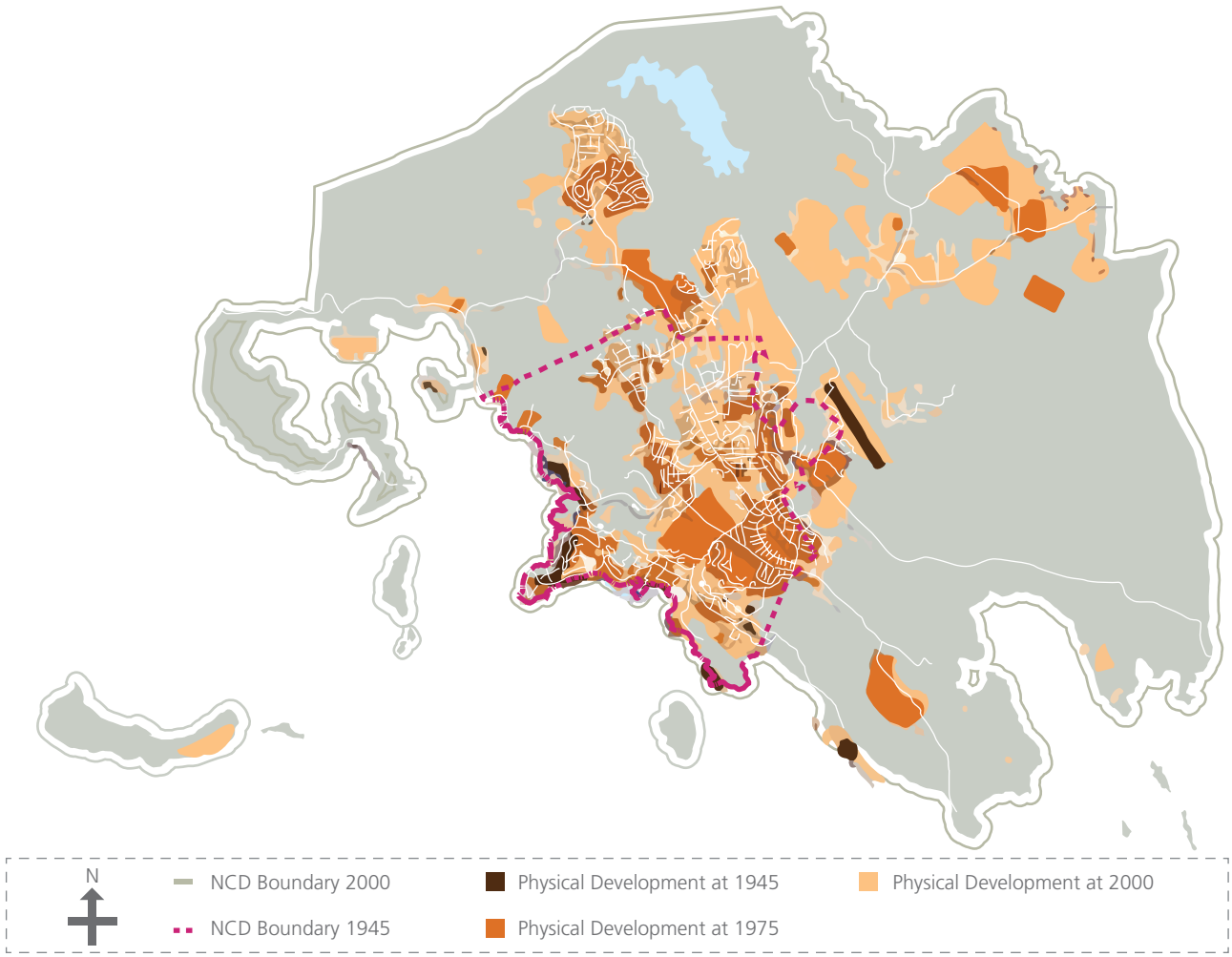

Source: National Statistical Office

## 2.5 Urbanization Trends

Port Moresby has experienced rapid urban growth since the country's independence in 1975. Prior to independence, development was concentrated only at Port Moresby (Down Town), Konedobu and Koki-Badili. The city grew and expanded eastward and northward inland as its functions diversified. The town area still acts as the central business district, with support centres dispersed throughout the city at Koki-Badili, Hohola, Boroko, Korobosea, Gordons, 6 Mile, Waigani and Gerehu. The suburbs of Kaugere and Hohola, Tokorara and others of varying sizes were developed for civil servants. At the same time, unplanned settlements grew within these suburbs. For example, while there are planned settlements such as Rainbow and Gahanadi in Geruhu, there are also unplanned settlements such as Morata and Horse Camp in the Kilakila/Kaugere and Waigani suburbs, as indicated in Figure 6. Residential development also spreads towards the top of the hills between the harbour and Koki, and more recently (from the mid 2000s) to hills around Waigani, Hohola and Garden Hills.

As shown in Figure 7, the historical growth of Port Moresby has been somewhat unplanned, both in urban and peri-urban areas, except for some govern-

Figure 6. Port Moresby's growth since 1945

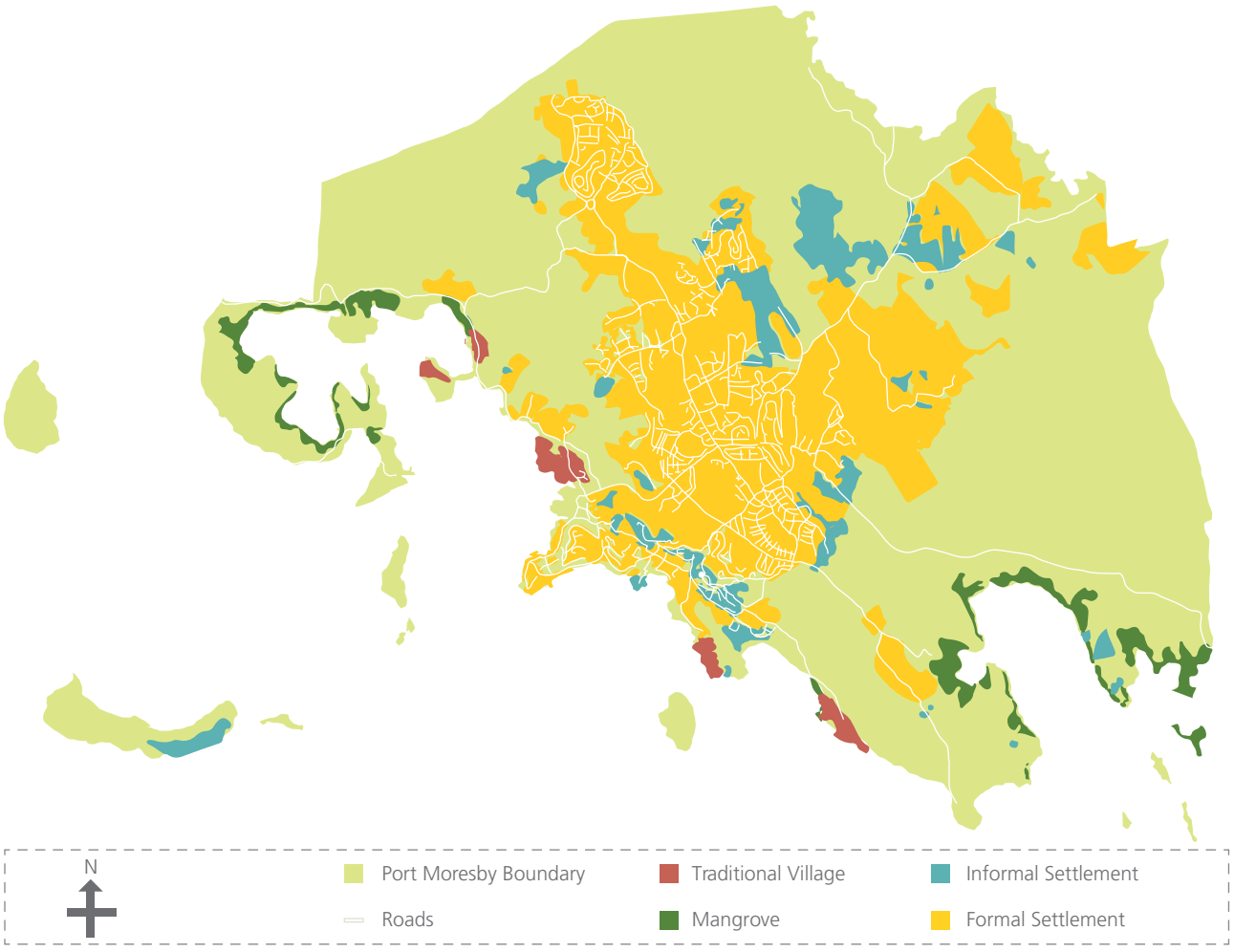



Source: National Capital District Commission

ment housing areas. The main population growth has been on the peninsula, where the port and other facilities are located, but according to the 2000 census the main population expansion has occurred in the inland suburbs of Gerehu, Morata, Gordens and Tokara. The city sprawls over a large area, and the only public transport options are buses (known as PMVs – Public Motor Vehicles) and taxis. Private car ownership has increased substantially without a corresponding increase in the scope of the road network. The city has an urban development framework, known as the Port Moresby Local Development Plan (2006-2020), which provides a vision of the city's policies and proposals for development controls such as the main commercial area of the city including the port, residential densities, settlements assessments and building heights.

About 58 per cent of Port Moresby's population were not born in National Capital District but are considered in-migrants, and this is also contributing to the rapid expansion of the city, especially in settlement areas. There are 20 planned settlements, 79 informal settlements and seven urban villages in Port Moresby. Of the 79 informal settlements, 44 are on state land and 37 are on customary land. About 40 per cent of the 2000 National Capital District population lived in in-

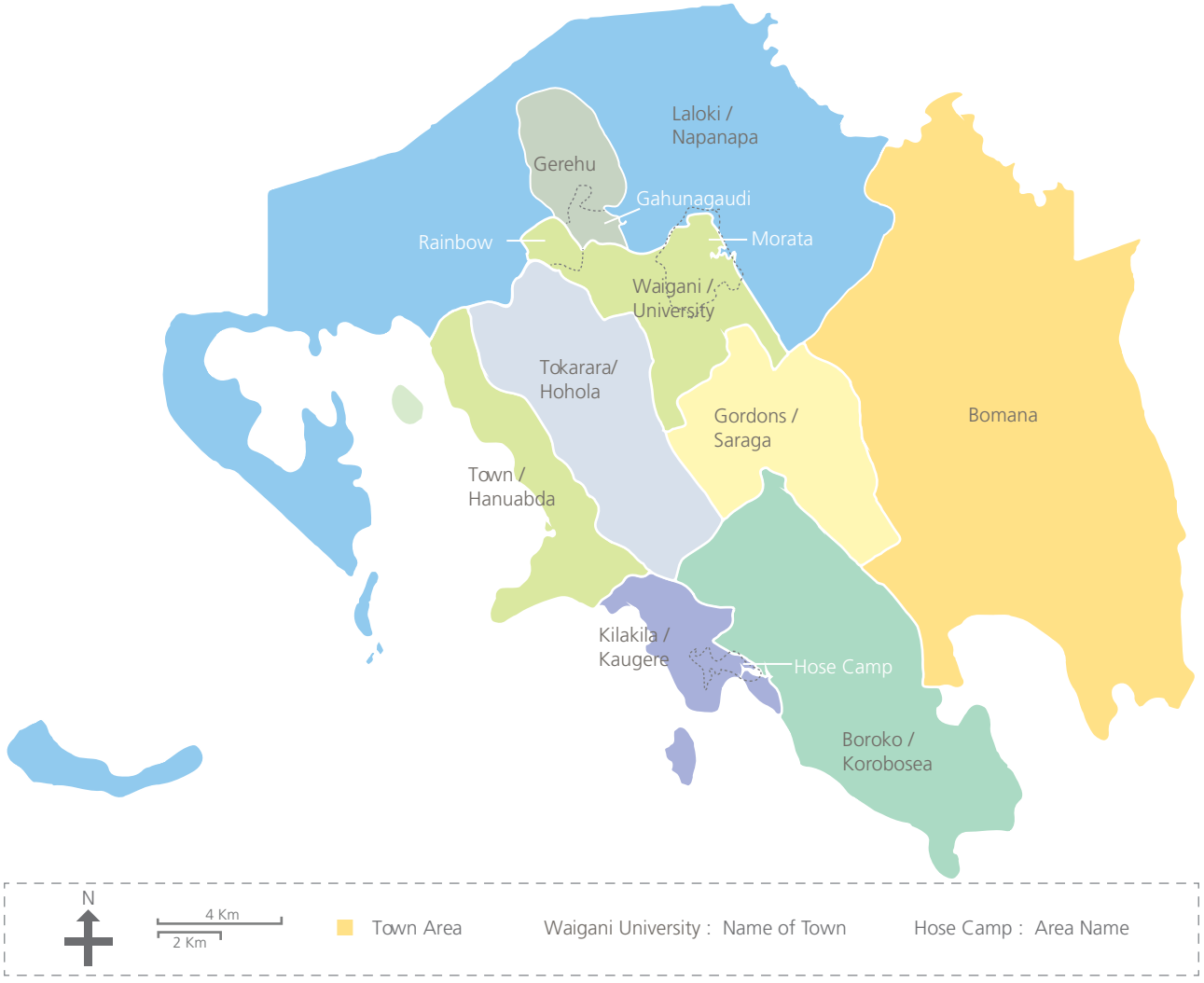
Figure 7. Formal settlements, informal settlement and traditional villages in Port Moresby




Source: R. Kiele, UPNG ESG, 2013

formal settlements. These are located within formal settlements and on the outskirts of the city, on steep mountain ridges and low lying areas that are often prone to flooding. Most of the housing in informal settlements is of a semi permanent character or built from materials such as off-cut timbers, corrugated iron and canvas. Access to basic services like water, electricity, sewer and waste disposal are mostly lacking in informal settlements.

Figure 8. Settlements and urban villages in National Capital District




Source: National Capital District Commission

## 2.6 Economy and Livelihoods

The economy of Papua New Guinea relies heavily on agriculture and extractive industries such as minerals, forestry and fisheries. 80 per cent of the country's total population of about 7 million live in rural areas where basic services are lacking. Poor or non-existent infrastructure in most areas in Papua New Guinea hinders the movement of goods and services, which in turn undermines economic and social opportunities. Rapid migration into the city is further straining basic services.

Governance challenges are also a major contributing factor, especially with regional planning. The absence of adequate land use plans or proper management frameworks results in increased vulnerability, low quality of live and natural resource exploitation. Despite an overall improvement between 1980 and 2012, Papua New Guinea was ranked 156 out of 187 countries in the UN's Human Development Index.

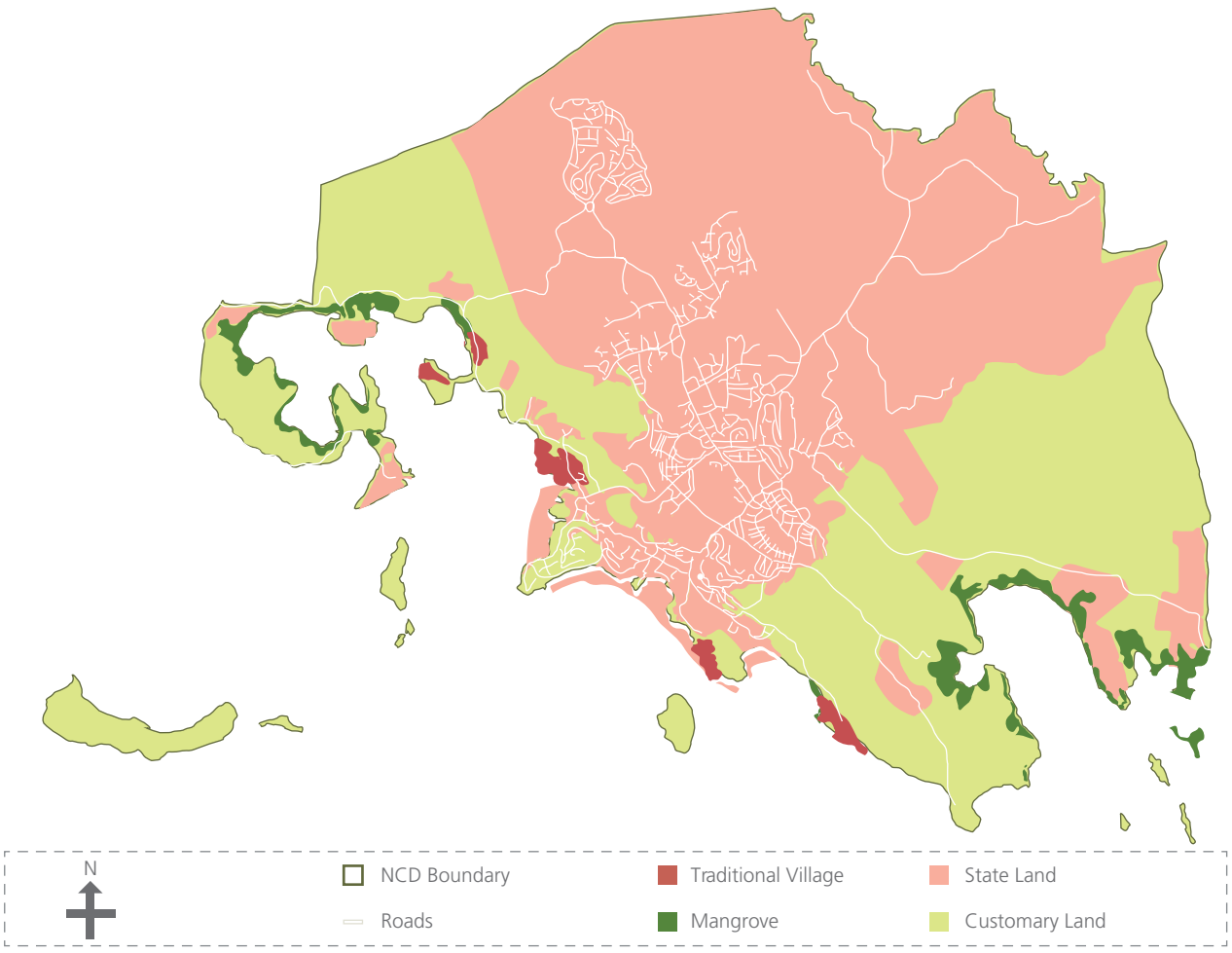
It is likely that climate related impacts such as flooding, drought and sea-level rise will be detrimental to key livelihoods such as agriculture, trade and tourism. In addition, since climate issue is a relatively new concept in the country, it has not been incorporated into most of its institutional policies and work plans. However, the establishment of the Office of Climate Change and Development and other related institutions are helping align climate change issue into their work programmes.

## 2.7 Existing Tenure and Land Use

### 2.7.1 Land Ownership

Ninety-seven per cent of all land in Papua New Guinea is customary, owned by the people of Papua New Guinea through birth. The National Capital District

Figure 9. Customary and State Land in the National Capital District




Source: National Capital District Commission

covers a total land area of approximately 267.6 km², 60 per cent of which is state owned and 40 per cent customary (Figure 9). As the National Capital District is the administrative hub of Papua New Guinea, the state has acquired over 50 percent of customary land for its developmental purposes. The state land is formally administrated by the Land Act 1996 and related laws. The National Capital District Commission has administrative planning responsibilities, but no powers to administer or allocate land to specific uses. These are held by the National Government through the Department of Lands and Physical Planning (DLPP). This arrangement makes decisions concerning land access and use problematic, potentially resulting in conflict.

### 2.7.2 Land use

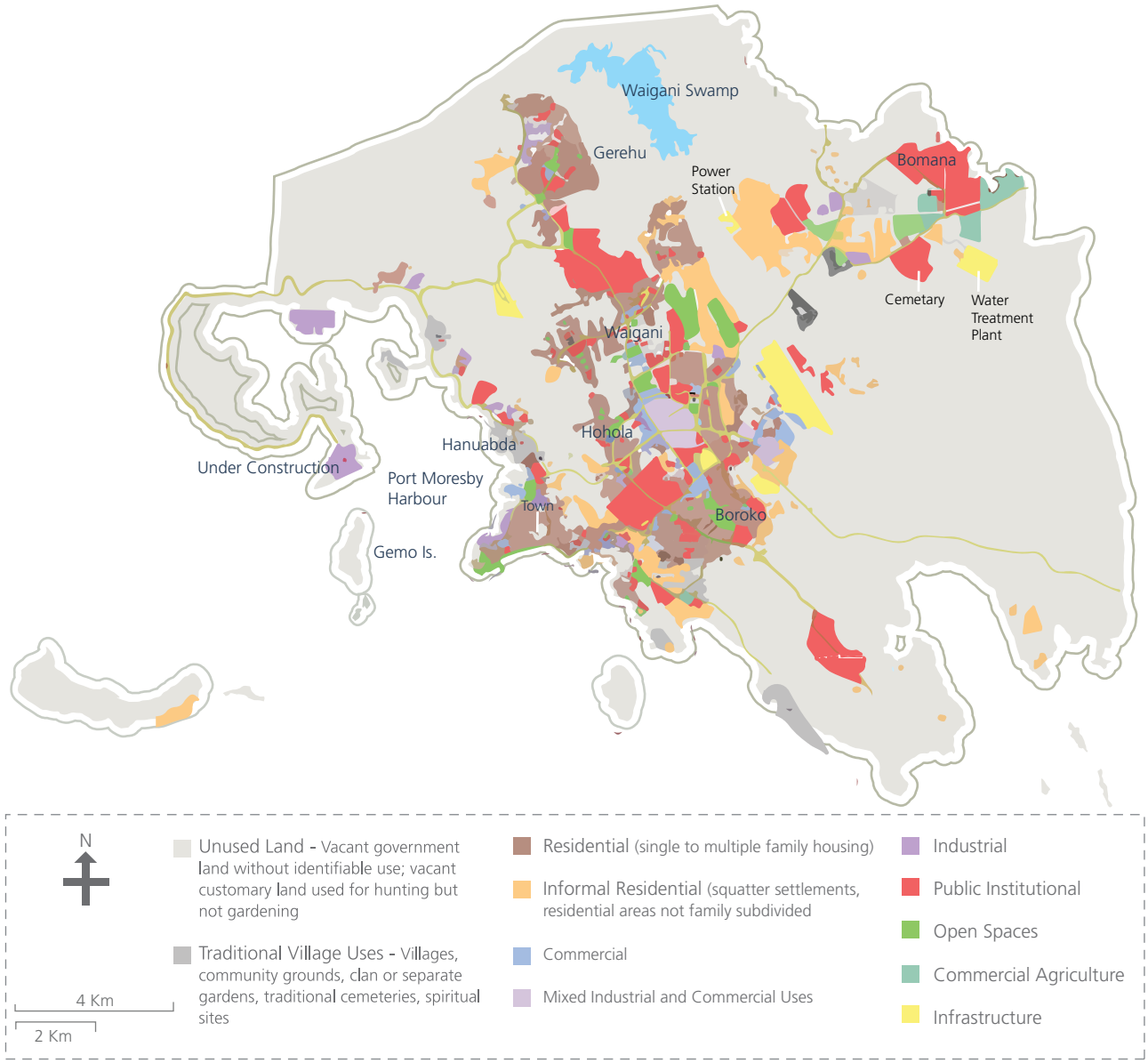
The Physical Planning Act (1989) and the Physical Planning Regulation (2007) govern the control of zoning, subdivision, consolidation, development and use of land in designated Physical Planning Areas in Papua New Guinea. Table 2 shows the existing land uses and activities in Port Moresby.

Table 2. Land Use and Activities in Port Moresby

| Land use | Type of activities |
|---|---|
| Commercial | Auto based retail, banks, doctor's surgeries, food stores, hotels, insurance, markets, offices, petrol stations, private gym, shopping centres, retail |
| Commercial agriculture | Farms, forestry, livestock, nurseries, plantations, smallholdings |
| Industry | General industry and warehousing |
| Informal residential | Residential areas, informally subdivided squatter settlements. |
| Mixed commercial and industrial uses | As indicated above |
| Open space | Botanical gardens, club pools, formal and open space, golf course, private open space, sports fields, stadia, wildlife sanctuary |
| Public institutions | Churches, government offices, health centres, hospitals, institutions, police stations, schools |
| Public utilities | Airports, broadcasting sites, dams, drainage reserves, major roads, power reserves, power stations, reservoirs, rubbish dumps, sewerage ponds and treatment plants, telecommunication reserves |
| Residential | Residential (single to multiple family housing), including planned settlements |
| Traditional village uses | Clan or separate gardens, singsing and community grounds, traditional cemeteries and spiritual sites, villages |
| Unused land | Vacant customary land used for hunting and not for gardening, vacant government land without identifiable uses. |

Source: National Capital District Urban Development Plan, 2006-2015:

Figure 10. General Land Use in National Capital District




Source: National Capital District Commission

# 03

# City-wide Vulnerability – Scoping Exposure, Sensitivity and Adaptive Capacity

## 3.1 Exposure

### 3.1.1 Sea Level Rise

While there is no specific data for Port Moresby, the general sea level rise in Papua New Guinea was measured by satellite altimeters at 7 millimetres between 1993 and 2010, more than double the global average during the same period. The mean sea level rise is projected to continue to rise (very high confidence) based on 18 global climate models from the Coupled Model Intercomparison Project phase 3 database, for up to three emissions scenarios: B1 (low emissions), A1B (medium) and A2 (high). The Coupled Model Intercomparison Project phase 3 (CMIP3) multimodel ensembles have been widely utilized for climate research and prediction using past data to stimulate future climatic projections. The Coupled Model Intercomparison Project 3 models simulate an increase of approximately 5-15 cm by 2030, with increases of 20-60cm indicated by 2090 under the higher emissions scenarios [3]. This is already having a noticeable effect on coastal communities, the marine environment and the built environment of the city. Sea levels for Papua New Guinea are predicted to rise by between four and 15 centimetres by 2030. Increased storm surges and sea levels have caused inundation along the coastline, threatening human settlements and roads that are prone to erosion in particular.

Table 3. Sea-Level Rise Projections for Papua New Guinea

| Land use | 2030 (cm) | 2055(cm) | 2099 (cm) |
|---|---|---|---|
| Low emissions scenario | 4 - 14 | 10 - 26 | 17 - 46 |
| Medium emissions scenario | 5 - 14 | 9 - 30 | 20 -58 |
| High emissions scenario | 4 -15 | 10 -29 | 22 - 60 |

Source: UN-Habitat

*Note: Sea-level rise projections for Papua New Guinea for three emissions scenarios and three time periods. Values represent 90% of the range of the models, with changes relative to averages during 1980-1999.*

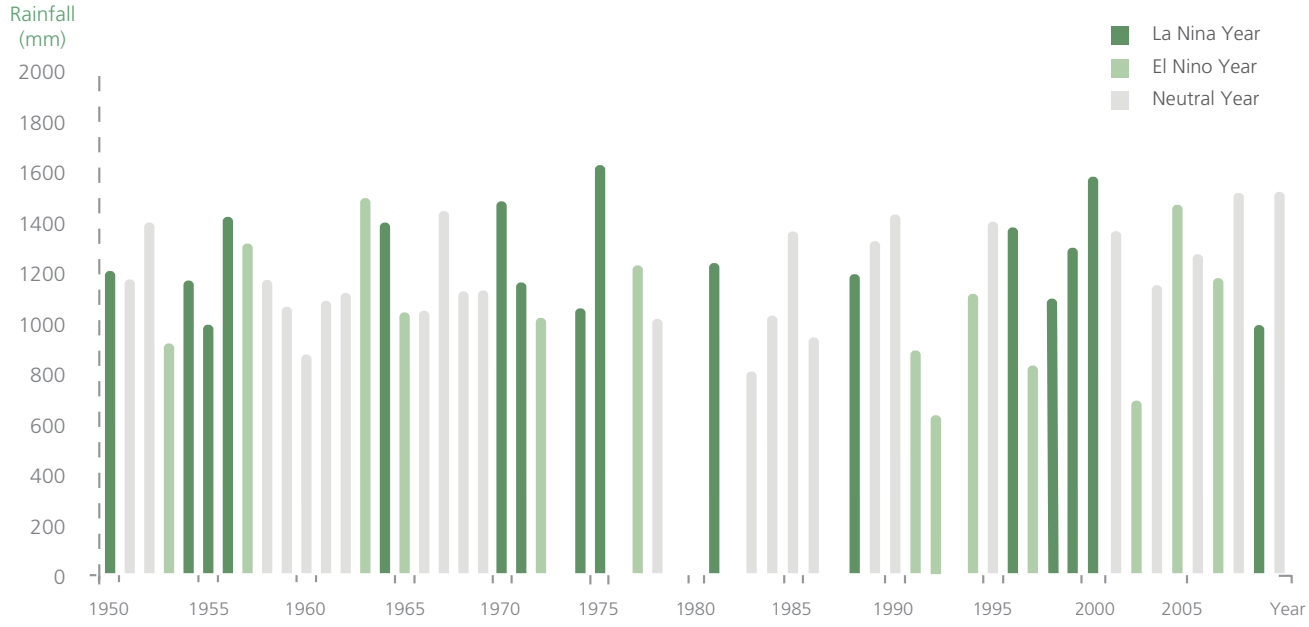
[3]All climate data in this section is derived from the Australian Bureau of Meteorology and CSIRO (2011). Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2, Country Reports.

### 3.1.2 Extreme Rainfall and Increased Precipitation

Rainfall data for Port Moresby is available from 1890 and is largely complete from 1905. Port Moresby has a wet season from November to April and a dry season from May to October. The local geography creates a micro climate: the city is in the rain shadow area created by the Owen Stanley Range, which means that the average yearly rainfall is 1,270 millimetres. This is considerably less than the average rainfall on the island of New Guinea, which can be up to 5,000 millimetres per year in mountainous areas. About 78 per cent of the annual average rainfall comes in the wet season and is influenced by the West Pacific Monsoon with high year to-year variability in rainfall, largely due to the impact of the El Nino Southern Oscillation. During the dry season Port Moresby is exposed to dry south-easterly winds. The observed annual and seasonal rainfall for Port Moresby for the period 1950–2009 shows no clear trends. The future projections for both the wet (November-April) and dry seasons (May-October), including annual average rainfall, are all projected to increase with high confidence. The intensity and frequency of days of extreme rainfall are also predicted to rise. Figure 11 shows that historical rainfall suggests a very slight increase over the 1950-2009 dataset, with annual rates of rainfall showing considerable variation around the mean. In particular, El Niño years tend to be characterized by lower rainfall, while El Niña years often experience higher levels of precipitation.

Future projections clearly indicate that Port Moresby is exposed to extreme rainfall events, including an increase in the intensity and frequency of rainfall. This will have damaging impacts on the city's population, infrastructure and socio economic development. Port Moresby is already facing significant problems with the flooding of low lying areas, both along the coastline and inland where most residential, commercial and industrial zones, as well as schools, offices and other social and economic facilities, are located. Extreme rainfall is also causing hill slope erosion with sediment and other solid waste clogging the storm drains, resulting in storm water spillover causing damage to homes and infrastructure. Figure 12 suggests that is it likely that rainfall in Port Moresby will increase between 5 and 15 per cent by 2035, with a potential increase of 20 per cent by 2100. Not only will average annual rainfall increase significantly over the coming decades, but changes in the frequency and amplitude of severe weather events will also impact Port Moresby. There is predicted to be a high likelihood of an increase in both wet and dry periods affecting the city as a result of climate change.

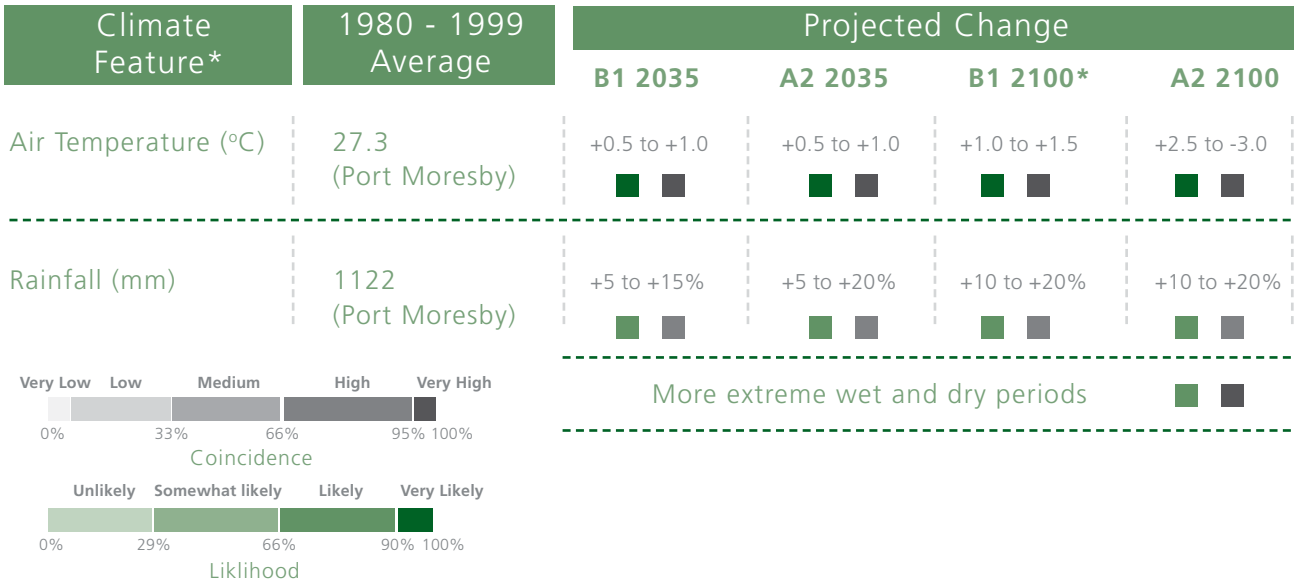
Figure 11. Annual Rainfall in Port Moresby, 1950-2009




Source: Australian Bureau of Meteorology and CSIRO 2011

*Note: Annual rainfall at Port Moresby. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral year respectively.*

Figure 12. Projected Temperature and Rainfall in Port Moresby




* Approximates A2 in 2050; a = for more detailed projections of rainfall and aair temperature in the vicinity of Papua New Guinea, see www.cawcr.gov.au/projects/PCCSP

Source: Centre for Australian Weather and Climate Research

### 3.1.3 Extreme Temperatures

Average daily high temperatures range from 28°C to 32°C depending on the time of year, while average low temperatures show very little seasonal variation at around 24°C. It tends to be slightly cooler in the city during the dry season. The hottest temperature ever recorded in Port Moresby was 37°C, while the lowest temperature recorded was 10.4°C. The mean maximum and minimum temperatures are 31°C and 22.6°C respectively. Warming trends are evident in both annual and seasonal mean air temperatures (Table 4). Surface air and sea surface temperatures are projected to continue to increase, according to CSIRO, as well as the intensity and frequency of days of extreme heat.

Figure 12 and Table 5 similarly show that the temperature increases predicted to affect Papua New Guinea depend on the level of emissions that continue into the future. Even in a low emissions scenario, average temperatures in Papua New Guinea are expected to

Table 4. Port Moresby Temperatures and Rainfall, Annual and Seasonal Trends 1950-2010

| | Port Moresby Tmax (°C per 10 yrs) | Port Moresby Tmin (°C per 10 yrs) | Port Moresby Tmean (°C per 10 yrs) | Port Moresby Rain (mm per 10 yrs) |
|---|---|---|---|---|
| Annual | +0.11 | +0.31 | +0.21 | +7 |
| Wet Season | +0.14 | +0.32 | +0.23 | -4 |
| Dry Season | +0.08 | +0.31 | +0.20 | +4 |

Source: Centre for Australian Weather and Climate Research and other sources.

rise between 0.3°C and 1.1°C by 2030. This trend is likely to be exacerbated in the event of persistently high emissions, which will raise the projected temperatures experienced in the country. The magnitude of these increases in temperature could have severe effects on the climatic impacts felt by people in Papua New Guinea over the coming years.

The data shows that Port Moresby is exposed to extreme temperature events. This will impact significantly on people's health, especially among vulnerable groups such as the young, elderly, disabled, women and the poor. High increases in sea surface temperature and ocean acidification will have devastating impacts on the state of the ocean, with serious repercussions for the city and the coastal communities whose economy and livelihood depends on marine resources. In the long term, estimates also suggest that Port Moresby will experience increasing air temperatures and rainfall. By 2035 it is very likely that temperatures will increase by between 0.05 and 1.0°C. Similarly, rainfall in Port Moresby is predicted to increase by between 5 and 15 per cent during the same period. These factors indicate that the city will face more variable and intense weather patterns, increasing the possibility of climatic damage and violent storms.

Table 5. Annual Average Air Temperature Projections for Papua New Guinea

| | 2030 (°C) | 2055 (°C) | 2090 (°C) |
|---|---|---|---|
| Low emissions scenario | 0.3 - 1.1 | 0.6 - 1.6 | 1.0 - 2.2 |
| Medium emissions scenario | 0.4 - 1.2 | 1.0 - 2.0 | 1.6 - 3.2 |
| High emissions scenario | 0.4 - 1.0 | 1.1 - 1.9 | 2.2 - 3.4 |

Source: Australian Government, Pacific Climate Change Science Program

*Note: Annual average air temperature projections for Papua New Guinea for three emissions scenarios and three time periods. Values represent 90% of the range of the models, with changes relative to averages during 1980-1999.*

### 3.1.4 Drought

The dry climate created by the rain shadow leads to occasional droughts, which are more likely to occur during El Niño years. In Port Moresby the wettest years receive up to three times the rainfall of the driest years. The El Niño-Southern Oscillation drives much of this variability. Generally, El-Nino years are drier and La Niña years wetter than average. The dry season also tends to be cooler in El Niño years and warmer in La Niña years. It is very likely that Port Moresby will be affected by more extreme wet and dry periods in the future. One of the main impacts of El Niño is that it delays the start of the monsoon, causing water shortage problems which affect settlements, agriculture, commerce, businesses and industries. Future predictions indicate that drought will decrease in line with the increase in rainfall, but mild drought conditions are projected to still occur based on the CMIP3 climate models.

Port Moresby is the only part of the country with distinct wet and dry seasons, exposing it to drought-like conditions from April to November. This situation, coupled with non-climatic factors such as population increase, rapid urbanization, pollution, outdated water utilities and inadequate service delivery, will have negative effects on the city's water quality and provision.

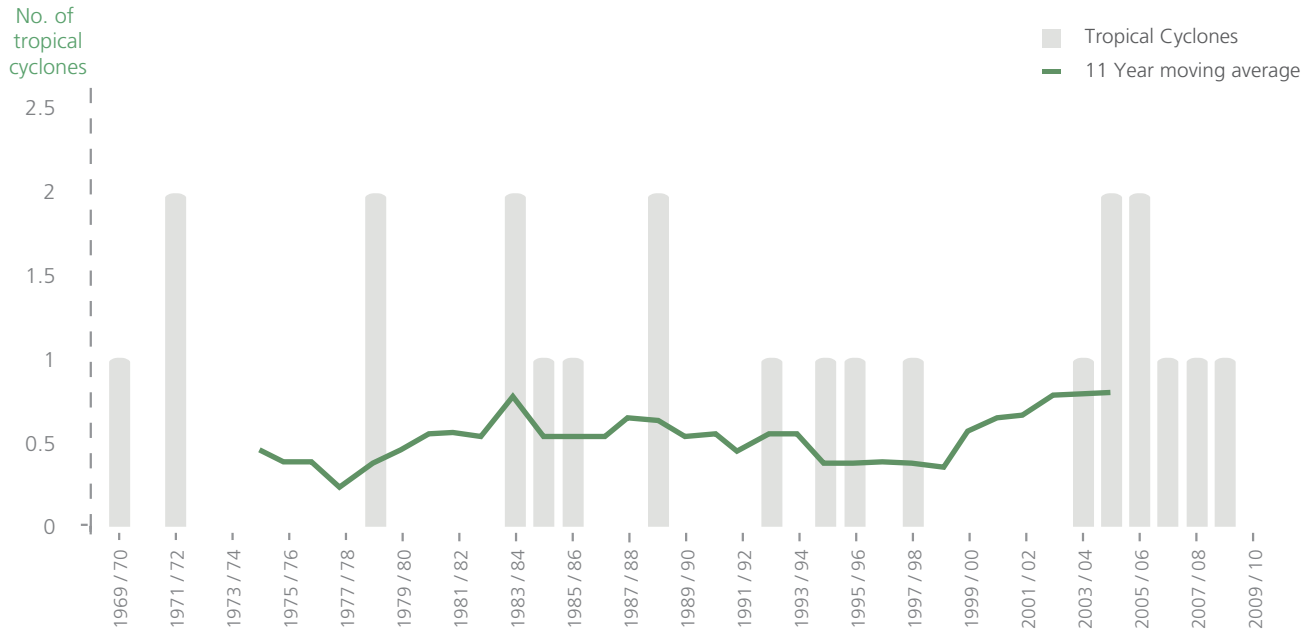
### 3.1.5 Strong Winds and Tropical Cyclones

Port Moresby is located in the Gulf of Papua in an area of low to moderate cyclone risk. It is not directly impacted by severe tropical cyclones, but is often affect-

ed by strong winds and heavy rain from cyclones that form further to the south in the Coral Sea. Cyclones occur mainly between February to April. However, Tropical Cyclone Guba occurred in mid-November 2007, causing flooding and evacuations in the neighbouring provinces of Oro and Milne Bay. The cyclone originated in the Coral Sea and spread towards the south coast of mainland Papua New Guinea, including the Gulf of Papua and Port Moresby. During this time peak winds reached 140 km/h [4]. On average, Port Moresby experiences six tropical cyclones per decade, with most occurring between November and April. Tropical cyclones were more frequent in El Niño Southern Oscillation neutral years. Overall, projections show that the frequency of tropical cyclones will decrease, but that their intensity will increase.

Despite being located outside the major cyclone path, Port Moresby is still exposed to cyclone risk impacting on nearby areas. Most cyclones that occur further to the south create strong winds and storm surges in the Gulf of Papua, also affecting the coastal waters of Port Moresby. It is notable, as shown in Figure 13, that there has been a rapid increase since the early 1980s in their frequency. Between 2003 and 2010, there has been a cyclone within 400 km of Port Moresby every year. Locally, this scenario has negative implications for coastal communities and the city's infrastructures, affecting livelihoods and disrupting vital services.

Figure 13. Tropical Cyclones Passing Within 400 km of Port Moresby, 1969/70- 2009/10




Source: Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organization (2011), Climate Change in the Pacific: Scientific Assessment and New Research: Voume 2 Country Reports.

## 3.2 Sensitivity

### 3.2.1 Ecological Systems

Papua New Guinea is rich in biodiversity, containing about 5-7 per cent of the world's flora and fauna species. The total land area is 465,000 km$^2$ and the exclusive economic zone is 2.4 million km$^2$. Altitudes range from sea level to 4,350 metres (Mt. Wilhelm), with very rugged terrains in the mountain ranges. The environment ranges from mountain glaciers to humid tropical rainforests, swampy wetlands and mangroves to tropical beaches and pristine coral reefs. Much of the terrain is characterized by steep gradients, fast flowing rivers and swamps, with some parts of the

[4] Coffey Natural Systems. Environmental Impact Assessment: PNG LNG Project.

country subject to active volcanic activities, landslides and flooding.

The varied land types found in Port Moresby mean that the city also has diverse ecosystems, both along the coastline and inland savannah. The National Capital District has an extensive coastline of about 209 kilometres, containing ecologically significant areas of mangrove, sea grass, coral reefs and areas of sandy beach. Port Moresby harbour, for example, contains 15 species of mangrove, seven species of sea-grass and 46 species of reef building corals . There is approximately 14.5 km2 of coral reef in Papua New Guinea, which is around 6 per cent of the world's total reef. More than 50 per cent of these are currently threatened, and this is projected to increase to 78 per cent due to the impacts of climate change; however, only 4 per cent of Papua New Guinea's reefs are within officially designated marine protected areas, thereby making them sensitive to manmade threats, as well as increased climate exposure [6].

Due to the high rate of natural resource extraction, including logging and mining, much of the country's forests are being depleted at a faster rate. By 2002, primary forest was degraded by 2.6 per cent per year and by 2021 it is estimated that 83 per cent of Papua New Guinea's forests will be cleared or degraded if current trends continue.

Given projected sea level rise, mangrove areas in the Gulf of Papua New Guinea are likely to undergo erosion and loss from their seaward edges, thereby adversely affecting the ecosystems, biodiversity and vegetation in Port Moresby. These natural resources provide ecosystem services to local people. Besides the coastal area being home to abundant fishery resources, which are an important source of income and nutrition, mangrove areas provide a natural coastal defence that protects coastal settlements from being impacted by flooding from storm surges, as well as act as a natural barrier to the long term effects of sea-level rise.

Mangrove forest area is also being rapidly degraded due to both natural processes and manmade uses, such as construction and fuel. The images below show the different uses of mangroves in and around the National Capital District. For example, many mangroves have been replaced by cassava and banana gardens, making the regeneration of their original habitats unlikely. The consequences are severe and unprecedented. The over-cut areas around Baruni village and the bay within the Fairfax Harbour area are now mud patches. The marine life that once abounded is now completely depleted. Crustaceans as well as the spawning areas of fish have also disappeared, and the shoreline is now more vulnerable to coastal erosion [8].

*(Left)* Mangroves cleared for fuel, house posts *(Middle)* and gardens *(Right)* in National Capital District
Photo © Kiele, R., 2008

[6] Drew, J., C. Buxman, D. Holmes, J. Mandecki, A. Mungkaje, A. Richardson and M. Westneat. (2012). "Biodiversity inventories and conversation of the marine fishes of Bootless Bay, Papua New Guinea", BMC Ecology, vol. 12, no. 15, pp. 2-21.

[7] Shearman, L. (2010). "Recent change in the extent of mangroves in the Northern Gulf of Papua, Papua New Guinea", AMBIO, vol. 39, no. 2, pp.181-189.

[8] Gaudi, H. (1999). "Effect of recent development projects on the environment of Motu Koitabu", UNESCO: Environment and Development in Coastal Regions and in Small Islands, accessed from www.unesco.org/csi/pub on 18 September, 2013.

These systems are exposed to both climate and non-climate hazards and threats; coral and sea-grass can be damaged by increasing water temperatures and heightened exposure to sunlight, while population and developmental pressures are affecting mangrove areas, and are likely to continue to do so in the future. Beaches and other coastal areas have shown signs of erosion, which could be caused by climate factors (such as rising sea-levels), non-climate factors (such as improper disposal of waste water) or a combination of both. Meanwhile, land on the coastline is showing signs of being affected by salt water incursion. In addition to these adverse impacts, it has also been noted that rising ocean temperatures, directly attributed to climate change, are resulting in increasingly frequent and severe incidents of coral bleaching, thereby causing coral reef degradation, a decline in reef organisms and depleted fish stocks. This will adversely affect the well-being and livelihoods of the local population [9].


Coastal Erosion in Port Moresby
Photo © Kaluwin, C., 2008

### 3.2.2 Physical Systems

Port Moresby has a variety of physical infrastructure that provides basic services such as water supply, electricity, sewage and drainage. Infrastructure systems are analyzed individually in the section below.

### 3.2.3 Electricity Supply

Papua New Guinea Power Limited is responsible for electricity supply throughout the country, including in Port Moresby. Rising demand has created electricity supply shortages, which results in frequent power disruptions and load shedding. Electricity is generated through three sources: Rouna Hydroelectric power station, Moitaka thermal power station and Kanudi thermal power station. A feasibility study is currently being undertaken by Papua New Guinea Power to examine the possibility of increasing supply and improving the electricity distribution network in the city. Papua New Guinea Power Limited also plans to increase hydro generation in its systems through Naoro Brown Hydro Development (60 Mega Watts - 80Mega Watts). Given the rapid expansion of the city, coupled with increased customer demand, Papua New Guinea Power Limited has projected that there will have to be an average annual five per cent increase over the next 15 years for electricity supply in the National Capital District and the neighbouring Central Province to meet rising demand. The National Capital District is also experiencing prolonged dry seasons and low rainfall, leading to low water level at the Sirinumu dam. As a result, thermal power generation - by comparison, a very expensive and carbon intensive energy source - is supplementing hydroelectricity.

### 3.2.4 Housing

Housing in Papua New Guinea is classified into four major categories - self-help low cost, self-help high cost, makeshift and traditional - all of which are evident in the National Capital District. The increasing

[9] Saenz-Agudelo, P., P.G. Jones, R.S. Thorrold and S. Plane. (2011). "Detrimental effects of host anemone bleaching on anemone fish population", Coral Reefs, vol. 30, no.2, pp.497-506.

number of informal settlements is due not only to high levels of migration and the resulting increase in population, but also the government's failure to provide affordable housing and developable land supply to match the increasing demand. Widespread unemployment is also contributing to the expansion of the informal housing sector. People living in these areas suffer from overcrowded living conditions, inadequate infrastructure and a lack of safe drinking water, sanitation or electricity, leading to diseases such as malaria and diarrhoea. Those located in very low lying areas are often subjected to flooding, while those along the coast are at risk of sea level rise and coastal flooding. Settlements on the steep ridges also contribute to increasing soil erosion.

Typical housing and sanitary facilities in informal settlements in Port Moresby
Makeshift House *(Left)* Pit Latrine *(Middle)* Shower Room *(Right)*
Photo © Susuki, W., Newalli, J., Poua, R. and Malu, J. (2012)

### 3.2.5 Water Supply and Sewerage

Water supply and sewerage services are provided by Eda Ranu, a government Public Utility Company under the Independent Public Business Corporation. It is also responsible for the planning, development and management of the whole system. Water is supplied to the city from the Sirinimu Dam, an artificial lake in the neighbouring Central province. In recent years, because water supply has not been able to meet the increasing demand for city residents, Eda Ranu had been rationing to help rectify shortages. Water ac-

*(Left)* Illegal water usage
*(Right)* Vandalized water pipe
Photo © Susuki, W. and Newalli, J.

cess is especially problematic in unplanned settlements. In some, water is available from randomly placed communal standpipes, with very few having individual connections to their own homes. However, most of these standpipes have been vandalized or are poorly maintained, meaning water supply to these settlements has been disconnected. This has led to the development of many illegal water connections.


*(Left)* Children washing in open drains in the Boroko creek
*(Right)* Illegal Water Connection in National Capital District's 8 Mile Settlement
Photo © Poua, R. and Malu, J. (2012)

As a result of rapid urban growth in the National Capital District and delayed monsoon seasons, water shortage problems are evident despite a water supply capacity of up to 184 million litres daily . Rainwater storage and ground water extraction are not practiced in the National Capital District, as both would require water permits from the Water PNG (formally the PNG Water Board). Women and children are especially vulnerable since they are generally responsible for obtaining the water sources and performing other domestic duties.

The sewerage system in Port Moresby City includes:

- 400 kilometres of sewer line (395 kilometres < 600 mm and the remaining five kilometres 600 – 1500 mm in diameter).
- 10 sewage pumping stations (Konedobu, Yacht Club, Stanley, Paga, Davara, Lawes Rd, Koki, Badili, Kaugere and Morata)
- 6 sea outfalls (coastal)
- 3 sewage treatment plants (inland) (Gerehu, Morata, Waigani Waste Stabilization Ponds)

Sewers in the National Capital District are disposed into several outlets or trunk sewers to meet the requirement of different suburbs, as stipulated in the Environment Act (2000). For example, the Gerehu, Waigani, and Moitaka utlize the Waigani Swamp, while the other areas go to Joyce Bay or Paga Point outlets. All formal settlements are connected to the sewerage network, while the informal settlements are not connected and so resort to alternative outlets such as pit latrines or direct disposal into the sea, bushes, drains or waterways. This in turn contributes to numerous environmental impacts, such as water-borne disease. In addition, septic tanks and pit latrine spillages are common, while heavy rainfall causes flash flooding which creates added environmental risk. In addition, the direct disposal of waste into the sea from both the coastal villages and Eda Ranu's outlets poses a danger to residents who use the sea and beaches for recreational activities.

[10] National Capital District Settlement Strategic Plan 2007.

### 3.2.6 Roads and Stormwater Drainage

The National Capital District Commission administers and maintains all roads in Port Moresby, including national roads which pass through or terminate within the city boundary. The city's road system comprises approximately 400 kilometres of paved roads, and the maintenance of this system accounts for the largest proportion of the National Capital District Commission's annual budget. Many roads have fallen into disrepair, partly as a result of the effects of the types of road construction materials used and design issues leading to wear and tear during the dry season, as well as through flooding and soil erosion during extreme wet seasons. An additional reason for the deterioration of roads in the National Capital District is the practice of gardening on hill slopes, contributing to high soil erosion during rainy seasons.

The impact of flooding on roads in the Gordens Area
Photo © Goiye, B., Kioma, T., Bobora, N., Bomai, A. and Kamaso, D. (2012)

In the last three years traffic congestion has become a concern in the National Capital District due to the high number of people owning vehicles. This has contributed to the deterioration of the road networks while also increasing greenhouse gas emissions.

Traffic congestion on the road from Gerehu to Waigani, Boroko and Gordons
Photo © Powe, E., 2013

The storm drainage systems in the National Capital District are undersized, built from low quality material, and the culverts are often blocked at the intersections which causes flooding. The storm drainage systems are also poorly maintained due to erosion, solid waste and sediment build up. Some of the areas most affected are Hohola Wards Road and Manu Autoport Roundabout.

Drains blocked with soil and other waste materials in the Gordens Area
Photo © Goiye, B., Kioma, T., Bobora, N., Bomai, A. and Kamaso, D. (2012)

### 3.2.7 Protective Infrastructure and Sea-walls

Port Moresby has a number of protective infrastructure systems designed to minimize the impact of climate related hazards on the coastal area. This includes a seawall running along Healy Parade Road from Koki to Ela Beach that is designed to reduce erosion in the coastal area, while protecting coastal ecosystems and manmade structures such as roads and homes. It was built to cater for the increasing number of vehicles travelling to the Central Business District. However, part of the seawall is currently in a state of disrepair due to the effect of salt water breakers and design limitations.

Large boulders were also deposited just in front of the sea line, helping to minimize and slow down the process of coastal soil erosion. There is also some artificial infrastructure made from concrete and steel, but the cost of this is too high. For instance, from Koki to Ela Beach, adaptation measures to climate change are at estimated K3.6 million Kina (approximately US$1,410,000). Consequently, outside this stretch, in other parts of Port Moresby the road is totally exposed.

The seawall along Holy Parade Road, Koki
Photo © Miria, G., 2012

Koki to Ela Beach Seawall
Photo © Auka, J., 2013

Eroded section of Koki seawall
Photo © Auka, J., 2013

### 3.2.8 Economic Systems and Livelihoods

There are a broad range of formal and informal economic activities and livelihoods in Port Moresby, characteristic of its role as the main commercial centre of the country. In informal settlements the unemployment rate is more than 50 per cent, with the majority of residents participating in informal economic activities ranging from the sale and distribution of goods such as second-hand clothing, betel nuts and cigarettes to handcrafts and shoe shining [11]. However, the current ban on betel nut vending will affect those whose livelihood depends on this trade. Urban agriculture is also practiced in the city, especially by migrants from rural areas, who utilize vacant land in hilly areas. People who work in the informal sector are very unlikely to be covered by social protection systems, which means that in the event of a disaster they are more likely to lose their livelihood sources and less likely to receive protection from government or private social security initiatives.

In addition, the impacts of coral reef deterioration in the Bootless Bay, approximately 10 km from Port Moresby, creates problems for community members who rely on fisheries and marine resources for their livelihoods. Damage to coral reef areas also has knock-on effects, causing declines in fish populations [12].

[11] UN-Habitat. (2010). Papua New Guinea: Port Moresby Urban Profile.

[12] Drew, J., C. Buxman, D. Holmes, J. Mandecki, A. Mungkaje, A. Richardson and M. Westneat. (2012). "Biodiversity inventories and conversation of the marine fishes of Bootless Bay, Papua New Guinea", BMC Ecology, vol. 12, no. 15, pp. 2-21.

### 3.2.9 Social Systems and Health

Refuse collection within Port Moresby is the responsibility of the National Capital District Commission. However, the actual collection is unreliable and inconsistent. Although the National Capital District Commission undertakes to service all parts of the city, a lack of common collection points and safety problems in informal settlements has disadvantaged these areas. Consequently, it is limited to formal areas, urban villages and safer settlements. In areas where there are no refuse collection services, residents dispose their refuse haphazardly, causing more environmental degradation.

With higher rainfall and floods projected in future, climate change related hazards will cause more sanitation problems and disease. This will be exacerbated by rising sea levels, which will especially impact on residents of Koki, Hanuabada, Taikone and other coastal settlements due to their sewage or human waste disposal. In these areas, rising sea levels may transport waste back into houses, increasing the risk of an outbreak of disease such as cholera.

In addition to the above, malaria is one of the leading causes of mortality, especially for children under five years [13]. Malaria transmission is also endemic in lowland areas of Papua New Guinea [14] . As Papua New Guinea lacks sufficient medical services and supply of essential drugs, the flooding from the high rainfall may cause more serious malaria outbreaks, particularly for informal settlement dwellers in low lying areas.

## 3.4 Adaptive Capacity

In order to assess the adaptive capacity of Port Moresby, the standard 'determinants' were analyzed – wealth, technology, information, institutions, infrastructure, and social capital - at individual, collective and institutional levels. Where adaptive capacity is greater, vulnerability to climate impacts is reduced, if exposure and sensitivity remain constant.

In Port Moresby, limited learning facilities have caused overcrowding in classrooms. Despite the partially subsidized education scheme from the government, the majority of school age children in informal settlements do not attend school as the fees are still unaffordable[15]. According to the Human Development Index, it has been illustrated that the primary school dropout and adult literacy are 51.6 per cent and 60.6 per cent respectively - a significant problem for future social development [16]. In short, climate change related hazards will create serious obstacles for the government of Papua New Guinea to promote education for children in informal settlements.

### 3.4.1 Wealth and Social Capital

Papua New Guinea is a least developed country, and therefore wealth indicators are correspondingly low. In Port Moresby, more than 50 per cent of the population are dependent on informal economy activities for their livelihood. There is an assumption here that those in the informal sector have lower adaptive capacity because they have even less access to social safety nets than formalized workers. They also may have lower capacity to switch livelihood sources due to their skill constraints.

Despite all the issues informal economy workers and settlers face, Papua New Guinea has a social support mechanism known as the "Wantok System" [17] where relatives are obliged to support each other in times of need. For example, an aunt is responsible for paying her nephew's or niece's school fees if the parents cannot afford them. This can play an important role in providing financial and social assistance to those impacted by climate change related hazards. It partly explains why overcrowding exists in many areas of the National Capital District, as residents give shelter to their extended families as part of their duties within the system. Community networks also play an important role. For example, if a family losses its home

[13] Hombhanje, A., D. Linge, A. Saweri, C. Kuanch, R. Jones, Stephen Toraso, J. Geita, A. Masta, I. Kevau, G. Hiawalyer and M. Sapuri. (2009). "Artemisinin-naphthoquine combination (ARCO) therapy for uncomplicated falciparum malaria in adults of Papua New Guinea: a preliminary report on safety and efficacy", Malaria Journal, vol.8, no.196, pp.1-9.

[14] Stephen, P. (2006). "Papua New Guinea struggles to reverse health decline". The Lancet, vol. 368, no. 9530, pp.107-108

[15] UN-Habitat. (2010). Papua New Guinea: Port Moresby Urban Profile.

[16] United Nations Development Program. (2012). Papua New Guinea Country Profile: Human Development Indicators.

[17] Retrieved on July 15th, 2013 from http://www.indopacificimages.com/index.php/papua-new-guinea-2/diving-papua-new-guinea-the-wantok-system/

to fire, neighbours or social networks such as church groups may raise funds to assist them.

Port Moresby's literacy rate is around 91 per cent (2000 Census), greater than the country's average rate of over 60 per cent. However, the high rate of school children in informal settlements not attending school could in future lead to individuals having limited knowledge and skills in the type of employment they undertake. Low literacy levels would also affect their access to written information in newspapers, leaflets and public information signs.

### 3.4.2 Technology and Information

At present, Port Moresby does not have an early warning system for disasters, and only basic weather monitoring and forecasting equipment. This means that, in the event of extreme hazards, both the National Capital District Commission and the central government are unable to provide accurate and timely warning information to communities. This in turn adversely affects capacity at the individual and household level, as residents are unable to get timely information on severe climate hazards.

At a national level, Digicel PNG (a private mobile phone company), in collaboration with the National Disaster Service, has an early warning system for Tsunamis which alerts all the cell phone holders in the network. The National Weather Service also issues warnings in light of dramatic climatic events, but often these are relayed too late after the disaster has already occurred.

It is also important for Port Moresby's residents to build their own resilient household systems at the household level, such as raising plinth levels, using flood resistant building materials and choosing furniture that is less likely to be washed away.

### 3.4.3 Infrastructure and Institutions

Infrastructure gaps remain acute, particularly in poorer areas of Port Moresby. 45 per cent of informal settlement dwellers in the city lack basic facilities such as electricity, potable water and sanitation (NCD Settlement Strategic Plan 2007-2011). This impacts directly on their ability to adapt to natural disasters and other climate hazards. The vulnerability of the city is further sharpened by the deterioration of valuable natural assets. For example, it is thought that only around 4 per cent of coral reef areas in or near Port Moresby are protected.

The National Capital District Commission had recently aligned climate change with their activity plans (Appendix 1) in three different departments. The Engineering Department, through their building projects and road design units, are responsible for choosing the right materials for road construction and lighting options for street illumination. The Community and Social Services are responsible for maintaining communication networks with the seven wards in National Capital District to address environmental and social issues at the ward level. Meanwhile the Regulatory Services formulates development plans to guide land use and infrastructure development in the city, including the building code.

Other institutions, such as the Office of Climate Change and Development and Department of Environment and Conservation, as well as private institutions such as Digicel PNG and Bank of South Pacific, have their programmes addressing climate change issues. For example, solid waste collection and mangrove planting along the coastlines are supported by the Bank of South Pacific, in partnership with the Office of Climate Change and Development.

### 3.4.4 Ongoing Adaptation Measures

Economic climate change adaptation options have been developed for Gordens, Gerehu and Koki markets. UN-Women, in collaboration with the National Capital District Commission, initiated a 'safe market' project to transform Gordens and Gerehu markets into more environmentally friendly markets, while the National Government through its local member of Parliament has sponsored the rehabilitation of the Koki market.

The United Nations Climate Change Adaptation Pro-

gram technical team, in collaboration with the Office of Climate Change and Development, has undertaken mangrove rehabilitation and a risk assessment and mapping of the vulnerable features in the village. Mangrove planting along the Port Moresby coastline, including Kanudi and Pari village, has also occurred with the involvement of local communities to prevent coastal erosion. Seawalls along the coastlines from Koki to Vavukori are also being built, mostly by residents, to provide protection. For example, the Vanagi Settlement in Badili is vulnerable because of rising sea levels and coastal erosion: as a result the local community, through their own initiative and with the support of their National Member of Parliament, are building a seawall with unused tyres and mangrove planting.

To maintain air temperature and prevent soil erosion, the National Capital District Commission has identified trees to be protected under the Tree Preservation Order so that trees along roadsides from ate not chopped down illegally.

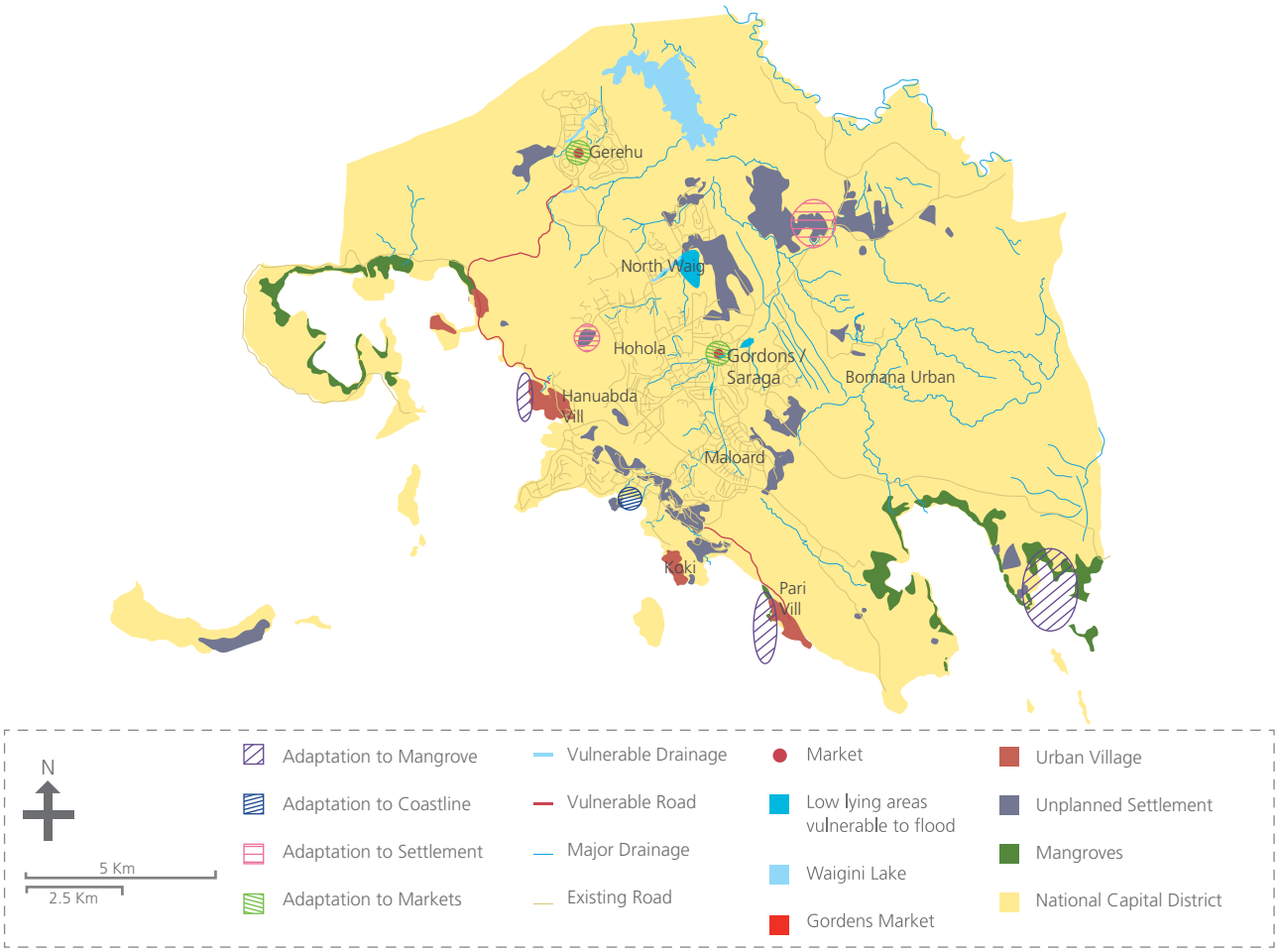
*(Left)* Avenue protected by the Tree Preservation Order along Godwit Road, Gordons
*(Right)* Mangrove planting along the Kanudi coastline
Photo © Goiye, B., Kioma, T., Bobora, N., Bomai, A. and Kamaso, D., 2012

# 04

# Vulnerable People, Places and Sectors

Port Moresby is exposed to a number of combined risks from sea level rise including storm surge, inland and coastal flooding, erosion and heat stress. As climate change take place it is likely that more powerful and frequent winds may be experienced in Port Moresby that could produce stronger and larger waves. This would pose a greater threat to the many low lying coastal areas. As sea level rises, much of the de-

Figure 14. Vulnerability and adaptation hotspots in National Capital District




Source: UN-Habitat

*Note: Only settlements, mangroves and markets currently undergoing adaptive measures are highlighted accordingly in the map. Other settlements, mangroves and markets are not included in the adaptive programs even though they are highlighted as vulnerable.*

velopment along the coastal areas would be exposed to these changes, potentially producing significant changes to the coastal sediment, erosion and deposition.

The impacts of rising sea levels on existing natural and human systems would include the inundation of land areas, service infrastructure, settlements and commercial areas if proper mitigation and adaptation strategies are not put in place. The effects will be particularly acute in extreme conditions, with Koki market and Wanigela settlement submerged under water in the event of continuous high tides and strong waves. Land reclamation at the Lancron Naval Base and Harbour City for economic development would also be affected due to inappropriate planning of the area. Inland flooding in low lying areas has rapidly increased, affecting most of the built-up areas in both the formal and informal settlements. Mangroves, coastal villages and drainage systems are also vulnerable to the effects of climate change. The magnitude and intensity of these weather patterns could expose local livelihoods and property to a very high level of risk.

The markets of the National Capital District have been identified as especially vulnerable to the effects of climate change due to increases in both inland and coastal flooding, poor drainage, deteriorating road conditions and inadequate waste management. In addition, non-climate proof building materials used are vulnerable to the rising temperatures. Security is also an issue at these markets, which are often subjected to petty crimes such as pickpocketing and bag snatching.

Women selling their wares at Gordens market
Photo © Miria, G., 2012

The Moto Kiotabu villages alone the National Capital District coastlines are vulnerable to sea level rise and tidal waves due to climate change effects such as coastal flooding. The images below show the effects of sea level rise along the coastline of Pari village.

Accelerated coastal erosion - the two pictures were taken less than six weeks apart
Photo © Miria, G., 2012

The roads along Konedobu, Hohola, Wards Road, Tokarara, Gerehu, Manu Autoport, Waigani/Morata and others are often subjected to flooding due especially to poor drainage systems in heavy rainfall. Others along the coastlines are also at risk of coastal flooding and erosion, especially the Kanudi-Tatana and Wanigela-Vavukori-Pari coastal roads.

The vulnerable drains in the National Capital District identified as hotspots include the drainage systems

along the back of Gerehu stage 2 to stage 4, at Rainbow, North Waigani to Morata, Boroko Creek, Manu Autoport and Hohola Wards Road. Another category of hotspot areas are the low-lying areas vulnerable to flooding during heavy downfalls, located at Konedobu Sports Stadium and North Waigani.

The unplanned settlements in the National Capital District are included in the hotspots map because they are at risk of flooding, increasing temperature due to poor building materials and lack of basic services and infrastructure. The 8/9 Mile area, where unplanned settlements are occurring, needs proper management to bring in essential infrastructure and basic services.

Figure 15. National Capital District Local Planning Areas, with 8/9 Mile Highlighted


Source: National Capital District Commission Development Plan, 2010

# 05

# Identifying Key Adaptation Options

The National Capital District is the fastest growing city in Papua New Guinea, where much of the country's resources are concentrated. The challenge for National Capital District Commission is to keep pace with its ever increasing population, providing adequate levels of basic infrastructure and services while also addressing the new risks associated with climate change. Efforts to boost resilience therefore require a multi-sectoral approach from the local level government, involving both the public and private sectors.

The following is a list of possible actions that could be undertaken to reduce vulnerability. Time constraints and limited human and financial resource mean that it is not possible to implement all of these actions. This means there will need to be a prioritization exercise to identify which actions are strategic, practically implementable with the resources available, and most likely to bring benefits and offer 'no regrets' solutions. Together, these measures will help achieve Port Moresby's vision "to make the National Capital District a vibrant, attractive, sustainable and liveable city for all".

## 5.1 City Level Adaptation Options

1. Enhance implementation of the National Capital District Commission's Engineering Department work plan. This would include, for example, raising the awareness of local people to prevent dumping of solid waste into drains. This action could also consider creating fences around open drains to prevent dumping.
2. Develop a broader programme of awareness raising, covering a range of adaptation and mitigation measures, with the engagement of the community. This could include education on safe livelihoods in cities and information on the role of wetlands, mangroves and other ecosystems as preventative barriers.
3. Conduct further studies to establish what exact actions should be undertaken in hotspot areas in the city.
4. Regulate land tenure and construction as a policy measure to reduce the vulnerability of the urban poor. Ensure houses are constructed according to National Capital District Commission's approved building design and other existing local development policies, including the master plan and the Urban Development Plan. Because many houses in informal settlements would not meet the minimum standards, local people need to be supported to improve their resilience to the impacts of climate change. The government should play a major role in making finance available for settlement upgrading.
5. Improve and increase capacity building in the National Capital District Commission to plan for the effects of climate change.
6. Engage in further research to explore specific adaptation actions, such as:

- Long term, low cost seawall and drainage construction mechanisms.

- Livelihoods and provision of basic services in informal settlements.
- Identification of the most appropriate mangrove, tree and grass species for an ecosystem based approach to adaptation in Port Moresby.
- Green building and the selection of appropriate climate proof materials.

## 5.2 Practical Adaptation Options at the Local Level

7. Replant mangroves on degraded sites and bare construction sites, along with special plant species along coastal roadsides for hedges as beautification and soil stabilization. At the same time, restore other ecological values and functions.

8. Enhance the implementation of the Tree Preservation Order in Port Moresby through species identification and planting to build climate change adaptation and mitigation capacities while also promoting improved urban management and environmentally sustainable development.

9. Strengthen partnerships and collaboration with national government departments, local academic institutions (University of Papua New Guinea), businesses and NGOs.

10. Terrace hill-slopes using vertiver or lemon grass to strengthen soil stability, reduce erosion and alleviate flooding impacts on roads, drainage systems, water courses and buildings. This is one of the best options to deliver cost-effective and long term adaptation.

11. Construct seawalls with patches of stones in the forefront to prevent wave energy reaching the main structure.

12. Promote measures such as the 8/9 Mile Local Development Plan to promote proper public utility connections to approved standards. The National Capital Development Commission land use plans and policies can also help guide infrastructural and physical development in Port Moresby.

13. All public reserves should be kept free of development and the National Capital District Commission should not approve any rezoning applications on drainage reserves, as allowing development in such high-risk areas will be counterproductive and may pose detrimental effects during increased rainfall.

The following images show some of the ways that mangrove planting can be used as non-structural eco logical engineering to mitigate climate change:



*(Left)* Mangrove planting between rocks at reclaimed land in Harbour City, Port Moresby
*(Middle)* An effective use of mangroves in windy or wavy sites and where plastics are a major problem
*(Right)* Restoration of degraded sites, Tahira, Port Moresby
Photo © Miria, G., 2012

## 5.3 Multi-level Adaptation Options

1. Develop a Mangrove Conservation Policy that will be integrated into all facets of development planning and implementation.

2. Review appropriate laws and policies to ensure the compulsory establishment of mitigation and adaption measures as contingencies for possible catastrophic events, in light of developments in low-lying coastal zones, environmentally sensitive areas and fault lines.

3. Encourage cooperation and continuous dialogue between the National Government and all stakeholders in developing and implementing a National Climate Change Policy. This will improve awareness while ensuring a greater 'buy-in' and commitment to climate change actions.

4. Incorporate climate change issues into educational programmes and curricula at primary, secondary and tertiary schools with the aim of increasing human capacity and awareness.

5. Strengthen private/public partnerships to combat climate changes issues.

6. Establish a National Climate Change Committee with secretaries from the Office of Climate Change Development, Office of Urbanization, Department of Environment and Conservation, Department of Agriculture and Livestock, Department of Land and Physical Planning, National Fisheries Authority, National Forest Authority and other government statutory agencies, chaired by the chief secretary and reporting to the NEC National Executive Council for political support.

# 06

# Recommendations and Conclusions

Based on the findings it is clear that urban adaptation and mitigation are necessary for immediate action. We have to note couple of challenges: firstly, there is limited knowledge and debate about climate change in Port Moresby, its impacts and green house gas emissions. Although there is institutional readiness, there is a low capacity to respond to the effects of climate change.

With regard to information networks, tools and advocacy, there are insufficient systems in Port Moresby to provide the necessary information, and to stimulate action at neighborhood as well as city level. Information sharing in a big challenge, and yet a key for adaptation and mitigation measures.

Further potential impact of climate change on the sectors of ecosystems, urban infrastructure, energy, housing, livelihoods, and social capital is important in Port Moresby, thus, there is a need for action on adaptation and adaptive capacity enhancement.

In addition to climate proofing buildings and infrastructure, there is need to implement existing tools to help adaption to climate change at national and city level. There is also a clear need for mitigating climate change in the city towards a low carbon future. This can be achieved by, for example, developing energy efficient and affordable residential neighborhoods, and better management of energy consumption in the construction sector.

Following the climate change vulnerability assessment in Port Moresby, the following recommendations are made:

1. Improve urban governance and preparedness to respond to climate change;
2. Consider social and cultural dimensions, especially in awareness creation;
3. Adapt urban land use planning and housing for energy efficiency;
4. Conserve and manage urban natural resources for biodiversity and undertake urban greening and preservation of the existing capital;
5. Integrate the informal sector into the urban economy as a way of coupling poverty and climate change effects through innovative solutions to local problems such as waste recycling;
6. Develop tools for awareness raising and capacity building in the city and at national level;
7. Invest in community projects that help build community resilience to climate change risks and impacts such as tree planting and alternative energy sources;
8. Support climate change responsive planning and development approval as well as planning policy;
9. Plan for an equitable change to a low-carbon economy including spatial planning that takes into account ‘green’ technology and buildings;
10. Re-use resources where possible; and
11. Improve the existing housing stock towards low-carbon designs and urban development.

# 07

# Annex 1. Key Adaptation Options

This table indicates what different sections of National Capital District Commission are doing to address impacts of climate change. The performed tasks are part of their annual work programmes and most of the projects in the engineering department need funding to fully accomplish these resource intensive activities.

| Department | Sections and responsibilities | Climate change effects | Projects / programmes / activities | Significance |
|---|---|---|---|---|
| Engineering | **Building projects**<br><br>Design and build classrooms in NCD schools | Extreme temperatures | White roofs (special white paint from Dulux) with lower heat absorbance | White roof and LED lights will be trialled in new classrooms and encouraged in NCD schools |
| | | | LED lights: reduce energy use and consumption | |
| | | | Solar lights installed in traffic roundabout (for example, as at Boroko Market roundabout) | Reduced tariff costs for NCDC and lower GHG emissions |
| | | | Building materials such as weather boards will be changed to Ardiplank | |
| | | Extreme rainfall and increased precipitation | Construction of seawall at Healey Parade Road in 2005 (a reclaimed land mass at approximately 40m, backfilled with boulders and concrete blocks) | Protection for roads and other infrastructure |
| | **Road design and drainage**<br><br>- Implement new engineer-designed road projects | Sea level rise / coastal inundation | Construction of Tatana causeway: backfilled with boulders | Needs upgrading to uplift or raise the causeway given the current extreme high tides from SLR |
| | | Landslides / soil Erosion | Grouting along Poreporena Freeway | Protection of land surface from landsli- |

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| - Upgrade and rehabilitate existing roads | | Construction of concrete road at Stanley Esplanade at Down-Town Port Moresby | Access to heavy duty vehicles/machinery due to regular road failure and protect high water table |
| | Poor waste management | Construction of ramp (driveway into drains) at Boroko creek along Gabaka street, Gordons, with another at Wards Road (dependent on funding) | Efficient rubbish removal around drainage systems, catering for disabled people and integrated into road design |
| | | Fencing of drains (depends on funding) | To control access and littering |
| | | Grate iron storm water drains at dump sites | Built at 75-100m to accommodate access water and prevent big rubbish entering the drainage system |
| | Extreme rainfall and increased precipitation | Construction of gabion busket upstream and downstream of the Poreporena Freeway | To hold soil and enable proper flow of water into the drainage system and allow regrowth of natural vegetation (this came about as a result of recent rains experienced in early 2012) |
| | | Construction of stone pitches at Baruni back road | Protection of roads |
| | Loss of biodiversity | Crease tramp in household kitchens and restaurant (Building Act) | To help reduce bacteria entering water system |
| | Priority 2013 road projects | Road rehabilitation (road sealing) in suburbs | To prevent surface water from entering road and divert to proper drainage system |
| | | Construction of new roads | • Dogura-Taurama<br>• Sea Park (Paga Point) - Harbour<br>• Gerehu - 9 Mile<br>• Baruni back road<br>• 9 Mile cemetery - Bautama |

| Department | Sections and responsibilities | Climate change effects | Projects / programmes / activities | Significance |
|---|---|---|---|---|
| Community and social services | **Local level government**<br><br>Maintain a local level governance network with Councillors and Ward Development Councillors and partnership with other stakeholders and within NCDC itself. | Sea level rise / coastal inundation | Construction of sea wall initiated by former Moresby South MP Dame Carol Kidu | Protect coastal villages |
| | | | Mangrove planting at Pari Village in partnership with an environmental NGO | Natural protection |
| | | Extreme rainfall and increased precipitation | Assist in relief supplies (food and money) in times of disaster at flood prone areas like Laloki river settlements, Goldie and some parts of Morata settlement | Compensate for loss of property and protect livelihoods of people affected as part of political directive |
| | | Landslides / soil erosion | Assist in relief supplies (food and money) to settlers at Gordons and 2 Mile-Hill | Compensate for loss of property and protect livelihoods of people affected as part of political directive |
| | | Loss of biodiversity | Mangrove planting at Meduna village-Bootless Bay | Restoration of degraded sites |
| | | | Partnership with Badu ILG (Meduna village) to develop Bootless Bay as a Reserve and to become a Locally Managed Marine Area (LMMA) through financial assistance from Ausaid | Marine diversity in the Bay is ideal for scientific study and tourism: Taurama inlet, known as a tuna spawning ground, needs protection and conservation |
| | | Poor waste management | Participate in annual clean-up exercise<br>Incorporate waste management issues into training programs of ward councillors and ward development officers in the 3 electorates. | Community awareness to educate and transform attitudes |
| | **Waste Management**<br>Effectively manage all waste related functions of the city as prescribed under the NCDC Act 2001. | Sea level rise / coastal inundation | Clean-up exercises in the city in partnership with other stakeholders in coastal and inland areas | Discourage discharge of waste into the ocean |

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| | | Extreme rainfall and increased precipitation | Effectively collect and manage all sorts of waste | Prevent clogging and blockages to existing waterways and drainage in the city |
| | | Strong winds / tropical cyclones | Participate in post-disaster activities and relief operations | To safeguard people and community well-being. |
| | | Poor waste management | Assess situation based on known parameters to evaluate and improve the quality of services through awareness rising | Change local attitudes and mindsets |
| | **Parks and Gardens** Cleaning and beautification exercises through Clean and Green programmes, backyard gardening, mangrove rehabilitation, bare hill tree planting, park development and children's playgrounds. However, most of these programs have been outsourced to PNG Gardener. | Sea level rise / coastal inundation | Mangrove restoration at Kanudi, Idubada and Manubada Island | Natural buffer in times of extreme events |
| | | | Awareness programs in coastal urban villages | Importance of coastal resources |
| | | Extreme temperature | Hill-slope tree planting | Help to regulate rainfall, temperature, wind and cloud regimes, while also storing large volumes of carbon (carbon storage house) |
| | | Extreme rainfall and increased precipitation | Hill-slope tree planting | Discourage and stop illegal settlers and hill-slope gardening while acting as a buffer against soil erosion during the wet season |
| | | Strong winds / tropical cyclones | Control height levels of trees (approx. 5-7 m) | To protect properties and public safety |
| | | Landslides / soil erosion | Tree planting on bare hill slopes | Act as buffers against soil erosion during the wet season |
| | | Loss of biodiversity | Planting of trees on bare hill slopes and coastal degraded sites | Restoration of tree and mangrove species |
| | | Poor waste management | Participate with environmental NGOs in cleanathon exercise | Keep Port Moresby clean and green |
| Regulatory Services | **Strategic Planning** Forward planning through preparation of local development plans | Sea level rise / coastal inundation | Provision of 250m buffer set in the Draft Dogura/Taurama LDP for restricted development | Protect environmental value of waterways and bay-front areas |

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| and policies to guide land use and infrastructure development in NCD | Extreme temperature | Encourage more Tree Preservation Order (TPO) in NCD | Protection of trees by NCDC and prohibition of cutting down, uprooting, topping, lopping, wilful damage and wilful destruction |
| | Extreme rainfall and increased precipitation | Identification of NCD Drainage Reservesand gardening on road reserves (proposed 2014) | To prevent impacts of flooding on people, infrastructure and properties |
| | Strong winds / tropical cyclones | Control height level of Tree Preservation Order (approx.5-7m) | To ensure that trees are as safe as possible for public wellbeing |
| | Landslides / soil erosion | Provision of >20% slope of ridge top areas set in the Waigani/Tokarara Environmental Feasibility Report for unsuitable development | Poses engineering difficulties in terms of road gradient and geometrics that may be hazardous and should be discouraged in the interest of safety and protection of Port Moresby's scenic environment |
| | Loss of biodiversity | Tree Preservation Order (TPO) | TPO is an order by NCDC (City Council prohibiting the cutting down, uprooting, topping, lopping, wilful damage and destruction of trees |
| | Poor waste management | Participate with other stakeholders in the coastal clean-up exercise | Keep Port Moresby clean and green |
| Urbanization: Settlements and land related matters | Sea level rise / coastal inundation | Sponsor mangrove seedlings to Parks and Gardens Section for mangrove planting | Encourage and promote collaboration within NCDC in providing services to city residents, including urban coastal villages |
| | Extreme rainfall and increased precipitation | Restrict development at flood risk areas, e.g. near drainage reserves as set in plans and policies | To safeguard people and properties |

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| | Landslides / soil erosion | Tree planting on World Environment Day and community awareness campaign | To stop soil erosion and discourage hill slope gardening |
| | Loss of biodiversity | In conjunction with Parks and Gardens, raise awareness through discussions on the importance of coastal resources at Vabukori village | Strengthen partnerships and encourage collaboration within NCDC for better service delivery |
| | Poor waste management | Awareness campaign on healthy livelihood project 2010-2011 at Vabukori village through drama performance by a local theatre group (Watete). | Promote healthy livelihoods to all age groups in the communities through drama |

Source: UN-Habitat

# Annex 2. Key Hotspot Areas

| Hotspot areas | Rationale for selection | Adaptive capacity | Picture |
|---|---|---|---|
| Gordon's market | Gordon's market is the biggest market in the city and is set to undergo a major rehabilitation process, given that the area is known for its petty crime which has become a grave concern, particularly for women and girls. Coupled with this is the poor drainage system, resulting in flooding as a result of careless littering. | NCDC, in collaboration with UN Women, started a project called Safe Market Project in 2011. Their initial project was at Gerehu Market, which was already open, and Gordon's market will be their second market rehabilitation project. This will include redesign of roads to minimize congestion problems, new bus routes to transport women and children only to and from the market, 150 new reservist police to patrol markets and enforce city laws, and a topography survey to look at drainage problems that cause flooding. |  Regular drainage problems at Gordon's market during the wet season. This will be fixed as part of the rehabilitation programme. Photo © Miria, G., 2012 |
| 8/9 Mile planning area (formal and informal) | Due to the high demand for housing and settlements within the city, the 8/9 Mile development plan aims to relocate settlements within the inner city to the outer or periphery of the city boundary. | NCDC developed its 8/9 Mile Local Development Plan with the aim of opening up new sites for development, including settlement upgrading. In addition to the plan, a pilot settlement upgrading project has been initiated at the 9 Mile area. |  Settlers in 8 Mile Settlement using drainage water for laundry. Photo © Susuki, W., and Newalli, J., 2012 |

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| Pari village (Motu-Koitabu village) | The population of Pari is approximately 2,000 and growing due to the influx of urban job seekers. With Pari's location 20 minutes by road from Port Moresby, the pressures from the capital are very acute. The community expressed a serious concern regarding expanding settlements which are putting pressure on the natural resources in the area, namely deforestation for fuel wood and fishing for food. This pressure is compounded by climate change impacts, adding to the social tensions felt in the community. | November 2012 to February 2013 the Coastal Community Adaptation Project technical team carried out participatory risk and infrastructure assessments and mapping in five communities along the Central Coastline of which Pari village is one of them.<br><br>Working closely with the Office of Climate Change and Development, who facilitated risk mapping exercises in the village. The sessions were attended by 22 community members with strong participation from the Pari Women's Development Association.<br><br>Risks were identified and adaptation strategies will be identified. |  <br>in this image. A coconut tree and a substantial amount of soil have been washed away. More images from Pari can be found here: http://www.flickr.com/photos/90755241@N08/sets/72157632566931113/detail/<br>Photo © Auka, J., 2012 |
| Venagi squatter settlement, Badili | Venagi is an informal settlement located along the coast at Badili. It is a small settlement with 87 houses and 220 families. The area has been affected by increased sea level rise in recent years. | The local elected Member for Moresby South, in partnership with the National Department of Planning, funded a mangrove planting project and seawalls made from old used tyres as an adaptive measure to sea level rise. The community has imposed a spot fine of K5.00 for illegal littering. The community chairman is calling businesses to donate old tyres for use in the seawall. | |
| Tree Preservation Order sites | There are currently 5 declared TPO sites in NCD, namely Angau Drive (Boroko), Hunter Street (POM Town), Godwit Road (Gordons), Ela Beach Road and Recreational Reserve (Ela Beach) and Sir John Guise Drive (Waigani City Centre). These protected trees are vulnerable to human use and natural phenomena such as strong winds, extreme temperatures and rainfall. | The Tree Preservation Order Project is an initiative by NCDC to protect trees. The principle effect is to prohibit the cutting down, uprooting, topping, lopping, willful damage and willful destruction of trees. |  <br>Protected tree under TPO being cut at Sir John Guise Drive.<br>Photo © Miria, G., 2012 |

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| Mangroves | Projected increases in the frequency of high water events could affect mangrove health and composition due to changes in salinity, recruitment, inundation and the wetland sediment budget. As rapid population growth and physical development continue in NCD, increasingly heavy demands will be placed on natural resources and the remaining natural habitats along the coast and inland, coupled with the impacts of climate change. | Partnership effort to drive community initiatives such as mangrove planting, LMMA initiative for protection of coastal resources.<br>. |  <br>inlet, Bootless Bay.<br>Photo © Miria, G., 2012 |
| Road infrastructure (Koura Way-Tokara, distributor road in Rainbow, Hohola Tunnel, Poreporena Freeway leading down to Konedobu Oval, Waigani Drive adjacent Car Memorial School) | NCD is already facing huge problems with the flooding of low lying areas, both along the coastline and inland where most residential areas, offices, schools, commercial, industrial and other social and economic facilities are located. Extreme rainfall is also causing hill slope erosion with sediments and other solid waste clogging the storm drains, resulting in storm water spillover causing damage to homes and infrastructures such as roads and drainage systems. | Construction of ramps, grated irons, gabion baskets and fencing of open line drains in NCD by NCDC Engineering Department. More funding is required in this area. |  <br>Poor drainage system resulting in overflow of water onto the road at the Rainbow residential area.<br>Photo © Miria, G., 2012 |

Source: UN-Habitat

UN-Habitat's Cities and Climate Change Initiative promotes enhanced climate change mitigation and adaptation in developing country cities. This document is an initial output of the Cities and Climate Change Initiative activities in Port Moresby, Papua New Guinea. This abridged report is based on the report titled: "Port Moresby, Papua New Guiunea – Climate Change Vulnerability Assessment" funded by the Government of Norway, the United Nations Development Account, and the Cities and Climate Change Initiative.

Starting with a brief background of the city, this report addresses Port Moresby's climate change situation from a climate risk perspective that focuses on hazards, vulnerabilities, and the adaptive capacities of the city. Following the insights gained from clarifying the climate change challenges, the report proposes the key sectors for climate change adaptation and mitigation measures in Port Moresby.

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