VULNERABILITY AND CAPACITY ASSESSMENT AND A NATIONAL ADAPTATION STRATEGY AND ACTION PLAN TO ADDRESS CLIMATE CHANGE IN THE WATER SECTOR FOR GRENADA

NATIONAL ADAPTATION STRATEGY AND ACTION PLAN FOR GRENADA, CARRIACOU AND PETIT MARTINIQUE

FINAL REPORT
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Final National Adaptation Strategy and Action Plan for Grenada, Carriacou and Petit Martinique

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For more information visit:

- The Global Climate Change Alliance website: http://www.gcca.eu/
- The African, Caribbean and Pacific Secretariat website: http://www.acp.int/
- The Caribbean Community Climate Change Centre website: http://www.caribbeanclimate.bz

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LIST OF ACRONYMS AND ABBREVIATIONS

AMJ	April-May-June
AMO	Atlantic Multidecadal oscillation
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
ASO	August-september-October
CARIFORUM	Caribbean Forum
CCCCC	Caribbean Community Climate Change Centre
CDD	Consecutive Dry Days
CWD	Consecutive Wet Days
DEM	Digital Elevation Model
DJF	December-January-February
FMA	February-March-April
GCCA	Global Climate Change Alliance
GCM	Global Climate Model
GOG	Government of Grenada
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
JAS	July-August-September
JFM	January-February-March
JJA	June-July-August
MAM	March-April-May
MJJ	May-June-July
MM	Millimetres
NAH	North Atlantic High
NASAP	National Adaptation Strategy and Action Plan
NAWASA	National Water & Sewerage Authority
NDJ	November-December-January
NGO	Non-Governmental Organization
OND	October-November-December
PPE	Perturbed Physics Experiment

PRCPTOT	Annual Precipitation
PRECIS	Providing Regional Climates for Impact Studies
R10MM	Days above 10 mm
R95P	Very Wet Days
R99P	Extremely Wet Days
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RX1DAY	Maximum 1 Day Precipitation
RX5DAY	Maximum 5 Day Precipitation
SDSM	Statististical Downscaling Model
SON	September-October-November
SRES	Special Report on Emissions Scenarios

GLOSSARY

Adaptation The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptive Capacity The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Cisterns An under-ground storage tanks for holding water typically integrated as a structural part of a building

Climate Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate Change Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate Variability Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Demand management Demand management involves measures that promote the efficient use of water, including load management and load reduction or conservation. It is the purposeful and beneficial manipulation of the level and timing of water usage. Demand management deploys various techniques for conserving water and improving the efficient use of water by end users.

Drought A drought occurs when there is an extended period of deficiency in precipitation (relative to what is considered normal), which is then insufficient to meet economic, social and environmental demands.

Flood	An overflow of water from a river, lake or other body of water due to excessive precipitation or other input of water.
Groundwater	Water beneath the surface of the earth which saturates the pores and fractures of sand, gravel, and rock formations
Gross Domestic Product	The market value of all the goods and services produced by labour and property located in a particular country or region.
Rain Water Harvesting	This is the accumulation and deposition of rainwater for reuse on-site, rather than allowing it to run off. Its uses include water for garden, water for livestock, water for irrigation, water for domestic use with proper treatment, and indoor heating for houses etc.
Scenario	A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections but are often based on additional information from other sources, sometimes combined with a “narrative storyline.”
Seawater Intrusion	Aquifers in island and coastal areas are prone to seawater intrusion. As seawater is denser than freshwater, it will invade aquifers which are hydraulically connected to the ocean. Under natural conditions, fresh water recharge forms a lens that floats on top of a base of seawater. This equilibrium condition can be disturbed by changes in recharge and/or induced conditions of pumpage and artificial recharge.
Sensitivity	The degree to which a built, natural or human system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature).
Surface water	Water collecting on the ground, in a stream, river, lake, wetland, or ocean
Watershed or basin or catchment	A geographical area drained by a particular surface water and/or groundwater system. The basin boundaries are demarcated so that there is generally no flow from one basin into another.
Water Management Unit	A single or group of watersheds that have been grouped together for the purposes of management.
Well	A well is a borehole, adit tunnel, or any other excavation constructed or used for the abstraction of water.

EXECUTIVE SUMMARY

Grenada, like other small island developing states in the Caribbean, has certain inherent characteristics that make it vulnerable to the adverse impacts of climate variability and change. The sectors in Grenada that are most susceptible to the impacts of climate change include: water resources, coastal infrastructure, human health, agriculture and tourism. Previous projects have also highlighted these areas for development programs and activities. Demand for water is continually increasing with the country's growing population, changing consumption patterns and food requirements. Climate change is expected to exacerbate this even further. This study was aimed at determining the impact of climate change and climate variability on Grenada's water sector, determining the vulnerability of the water sector to climate related hazards and developing a National Adaptation Strategy and Action Plan to address the anticipated adverse effects of climate change on the water sector.

In order to carry out this study, climate change scenarios/ projections had to be completed first. This involved analyzing the literature and historical data and deriving RCM data at scale for Grenada were derived from PRECIS A1B Perturbed Physics Ensemble. Following this, the water sector was studied to determine the vulnerability issues and threats. The climate data was used along with the results of the analysis of the water sector to determine what the impacts of climate change would be. The institutions, policy and legislation related to the water sector in Grenada were also analyzed in order to determine the weaknesses and the opportunities for strengthening to deal with climate change. Finally, a review of the socio-economy of the tri-island state was done in order to determine how the impacts of climate change on the water sector would affect the society and economy of the country.

As with any study, there were several limitations which affected the strength of the analysis. Most of these limitations related to data, both access and availability. A major suggestion of this study relates to how climate and hydrological data is collected. It is important that small islands such as Grenada collect all the variables necessary for climate statistical downscaling methods for more accurate projections to be made.

The climate projections from this study indicate generally that Grenada may experience increases in annual mean temperature, annual maximum and minimum temperatures, reduction in rainfall and rainfall intensity. Wind speeds are expected to increase which affects rainfall and hurricane development, hurricane intensity is expected to increase but not necessarily frequency and sea level rise in the Caribbean is projected to increase. Given the projections, the water sector in Grenada is going to be further challenged.

The major threats to the water sector in Grenada are droughts and floods-the two common extremes of the hydrological cycle. For Carriacou and Petit Martinique, drought is the more significant threat. Saline intrusion into wells on the island of Grenada is also becoming a threat to the water sector, however this is a combination of over abstraction as well as sea level rise due to climate change. With the projected changes of climate change, the water sector will come under even greater stress requiring strategies for resilience building. In analyzing the water sector, and evaluating its existing resilience, the consultants have concluded that:

- There is a deficiency in the methodology for acquiring meteorological and hydrological data for meaningful climate projections to be made.
- There is a need for much more comprehensive databases to inform appropriate decision making.
- Water budgets for each major watershed have not been fully developed and are a basic requirement for the appropriate allocation of water resources.
- A fundamental challenge to the adequacy of water resources is the need for additional and upgraded water storage catchment systems.
- Given the adaptation challenges faced by the water sector in Grenada, serious consideration needs to be given to the need for a water resources agency with a mandate for integrating and managing all aspects of the water sector.

The institutions responsible for the water sector have several inadequacies which are partially a function of how they are structured but also because of the absence of supporting legislations and regulations. This compromises their ability to effectively achieve their potential in contributing to the adaptation strategies required for climate change. The consultants have concluded that the important issues to be addressed are:

- Completion of the National Land Policy;
- Implementation of the National Water Policy;
- Updating and Implementation of the National Climate Change Policy and Action Plan;
- Cabinet approval for National Hazard Mitigation Policy;
- Cabinet approval of National Waste Management Strategy;
- Enforce Regulations for controlling water quality;
- Finalize and enact draft Public Health Act;
- Finalize and enact draft Environmental Management Policy;
- Prepare and finalize Pollution Regulations;
- Finalize and enact draft Protected Areas Forestry and Wildlife Act;
- Strengthen mechanisms for greater enforcement of existing legislation, through the provision of the necessary support from relevant government agencies and establish training programmes for enforcement offices in all agencies;
- Establish inter-agency collaboration among agencies for enforcement of legislation;
- Legislation regarding development of land needs to be reviewed, with the accompanying creation of a National Development Plan;
- The need to make EIAs mandatory for all projects likely to impact significantly on the environment. Strengthen the mechanism for the EIA process including inter-agency collaboration for evaluating and monitoring EIAs;
- The establishment of an agency with a clear mandate to manage all water resources for Grenada including a mandate to develop and manage, in particular, all watershed areas.

In analyzing the socio-economic conditions in Grenada and relating it to the water sector, the consultants used available data to determine that sectoral contributions to GDP in 2013 were; agriculture- 5.6%, industry- 15.8% and services-78.5%. Each of these depend on water. However, it is difficult to establish a direct relationship between the water sector and the economy.

To get some perspectives on the relationship between the economy and the water sector, an alternative, less direct and more speculative approach became necessary due to the unavailability of the certain types of data from NAWASA. Essentially, the approach was to address if the water sector adequately meets the likely needs of the Grenadian economy. Based on estimated claims on annual water withdrawal, Grenada has 3,500,000 m^3 or 25 % of total water withdrawals that was not taken up by the economy in 2014. This is before transmission losses are taken into account. Water lost during transmission is estimated by NAWASA to be between 20% and 25%.

Based on estimated claims on annual water withdrawals of 14,000,000 m3 Grenada has limited distributable water to support the likely consumption demands if the economy expands rapidly. Sectoral demand is estimated at 10,500,000 m^3 and with an estimated 25% loss of total water withdrawals or 3,500,000 m^3 annual withdrawals of 14,000,000 m^3 seem marginal. Further this is before private rain water harvesting or other private extractions are taken into account.

NATIONAL ADAPTATION STRATEGY AND ACTION PLAN

The final objective of the project was to develop a National Adaptation Strategy and Action Plan (NASAP) to address the anticipated adverse effects of climate change on the water sector. This NASAP is to prepare Grenada to meet the challenges of climate change on the water sector. This strategic action plan is designed to guide implementation of, and track progress toward, national water sector goals and targets in Grenada. The strategy covers the period 2016-2021 and outlines three national outcomes for the water sector of the tri-island state. Expected results (output) are presented along with the actions to meet the defined objectives. The suggested timeline for the commencement of each activity is given, along with an indicative cost where possible and the responsible agencies (lead and partner). The strategies were denoted under four main headings:

- Policy
- Legislation
- Capacity (Physical/ Infrastructural, Institutional and Technical)
- Training and Awareness Building

They were used to define the following strategic outcomes:

1. Improved policy, legal, regulatory and institutional framework for the water sector.
2. Improved technical and institutional capacity for the water sector.
3. Enhanced and improved training and awareness in relation to climate change and the water sector.

These three strategic outcomes have twenty-three (23) objectives, most of which have short to medium term activities. There are a few long term activities. The objectives within each outcome have multiple activities, some of which have only been costed for partially:

STRATEGIC OUTCOMES	NO. OF OBJECTIVES	INDICATIVE COSTS US$
Outcome 1	9	130,000
Outcome 2	9	15,155,000
Outcome 3	6	2,257,500
TOTAL		17,542,500

The National Adaptation Strategy and Action Plan (NASAP) for the water sector of Grenada requires that within the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment, the Environment Unit be responsible for ensuring that the action items set out in this Strategy and Action Plan are carried out by the respective lead and partner agencies. The implementation of the NASAP for the water sector has to be monitored and evaluated to ensure that the activities are successfully on track, and to ensure transparency and accountability. This will entail the monitoring of the actual implementation of the NASAP, and also evaluating and assessing the cause of any changes, both external and internal to the NASAP, to determine what corrective actions, if any, are needed. The results of this monitoring can then be incorporated into future planning and improvement of the NASAP. The NASAP is expected to be a 'living' document and should be monitored, evaluated and updated regularly.

1 INTRODUCTION

1.1 Purpose and Objectives

The Caribbean Community Climate Change Centre (CCCCC) received grant funding from the European Union (EU) under Grant Contract **FED/2011/267-392** for the implementation of an action entitled: Support to the Global Climate Change Alliance (GCCA) under the 10th EDF Intra-ACP financial frame work in the Caribbean. The European Union Global Climate Change Alliance (EU GCCA) project is a Caribbean Forum (CARIFORUM) regional project designed to assist the sixteen (16) participating countries to develop capacity to design and implement climate change adaptation policies and measures.

The overall objective of the Grant is to support the sustainable development of the Caribbean region and preserve the progress of the countries towards the Millennium Development Goals (MDGs). The specific aims of the Project include:

1. To enhance national and regional institutional capacity in areas such as climate monitoring, data retrieval and the application of space-based tools for disaster risk reduction;
2. To develop climate scenarios and conduct climate impact studies using Ensemble modeling techniques;
3. To conduct further vulnerability assessments that can assist with the identification of local/national adaptation and mitigation interventions;
4. Building regional and national capacity to access carbon financing; and
5. To implement adaptation pilot projects that may be subsequently replicated.

The EU GCCA Project, seeks among other things, to incorporate and mainstream climate change adaptation issues into national development and planning processes and mechanisms in order to enhance the economic and social development of the individual participating countries in particular, and the Caribbean region as whole.

Grenada, like other small island developing states in the Caribbean, has certain inherent characteristics that make it vulnerable to the adverse impacts of climate variability and change. These include, a limited reserve capacity to handle the effects of natural hazards, as well as, its location in the path of tropical cyclones of the Atlantic and Caribbean Sea. Additionally, most of the islands' infrastructure is located within the coastal zone, making it particularly vulnerable to the impacts of sea level rise and coastal flooding. The sectors in Grenada that are most susceptible to the impacts of climate change include: water resources, coastal infrastructure, human health, agriculture and tourism. Previous projects have also highlighted these areas for development programs and activities.

As a result of their vulnerability, the Government of Grenada (GOG) received grant funding from the CCCCC under the EU GCCA Project to conduct two main studies. These include:

a. A Vulnerability and Capacity Assessment (VCA) study in the Chemin Watershed in the St. David parish in the south eastern quadrant of Grenada ; and

b. A national sector-based Impact Assessment that will provide relevant data and information leading to the preparation of a National Adaptation Strategy and Action Plan (NASAP) for the water and agriculture sectors.

Environmental Solutions Ltd (ESL) was contracted by CCCCC to implement the project for the Government of Grenada (GOG). CCCCC worked collaboratively with the GOG through the Environment Unit of the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment (MALFFE), to achieve the objectives of the project.

This document presents the second component of the project. The Impact Assessment was used to inform the NASAP. The purpose of the NASAP is to address the anticipated adverse effects of climate change on the water sector and to prepare the tri--island state of Grenada to meet the challenges of climate change on the water sector.

The strategic action plan is designed to guide implementation of, and track progress toward, national water sector goals and targets in Grenada. The strategy covers the period 2016-2021 and outlines the national outcomes for the water sector. Expected results (output) are presented along with the actions to meet the defined objectives. The suggested timeline for the commencement of each activity is given, along with an indicative cost where possible and the responsible agencies (lead and partner).

This Final Report has benefited considerably from the inputs of stakeholders at the consultation meetings held to discuss the Draft Final Report. The comments at the meetings and follow up discussions with some stakeholders enabled important improvements. The Consultants were grateful for the opportunity to improve this report and it also validates the importance of stakeholder participation in all stages of the study.

1.2 Background

The state of Grenada consists of three islands; Grenada, Carriacou and Petit Martinique (Figure 1-1). It lies between Trinidad and Tobago to the south, and Saint Vincent and the Grenadines to the north. It is the southernmost of the Windward Islands with the largest island being Grenada which is 34 km (21 miles) long and 18 km (12 miles) wide. The three islands taken together have a land area of 345 sq. km (133 sq. miles) (PPCR, 2011).

The country has a humid tropical climate, with an average annual temperature of 26 degrees Centigrade. The dry season occurs between January and May and the rainy season from June to December. On average, Grenada receives 1150 mm of rain per year. Carriacou and Petit Martinique generally receive lower levels of rainfall and during the dry season both islands can experience severe drought conditions (Simpson et. al, 2012).

Water is key to the continued success of all aspects of the state's economy. However, the advancement of Grenada's social development is being put at risk by the current water sector arrangements. The state of Grenada is already experiencing some of the effects of climate variability and change through damage from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns. The island of Grenada has not had an extensive history of drought, but the smaller islands of Petit Martinique and Carriacou are more susceptible to drought conditions during the dry season. Two major droughts were recorded in 1995 and between 2009 and 2010. However, June and July 2013 were recorded as the driest months in Grenada in two decades. A growing population, changing consumption patterns, and increasing food demands have placed increased stress on the water supply of Grenada. Increasing climate variability from changes in the parameters of climate, has now induced Grenadians to try to combat the water supply challenges.

Figure 1-1: The state of Grenada

General climate model projections for the islands (Simpson et. al, 2012) indicate that there will be:

- an increase in average atmospheric temperature;
- reduced average annual rainfall which will result in further decreases in the available surface and ground water (-40 to +7 mm per month by 2080);
- increased Sea Surface Temperatures (SST) (from +0.9˚C and +3.1˚C);
- a potential for an increase in the intensity of tropical storms. Observed and projected increases in SSTs indicate potential for continuing increases in hurricane activity. Model projections indicate that this may occur through increases in intensity of events but not necessarily through increases in frequency of storms.

With these projections; it will become even more important for an improvement in water catchment and storage facilities. Surface flows are the main source of potable water accounting for approximately 90 percent of the supply. There are 23 gravity flow surface water treatment plants on the island of Grenada that handle, at a minimum, approximately 6,395,000 gallons per day (gpd). Supplemental sources which include wells, boreholes (main sources in Carriacou) and springs, account for the remaining 10 percent of the water consumed. In addition, three public and three private desalination facilities have been constructed in the tri-island state (Department of Economic Affairs, 2001).

As a result of this heavy reliance on surface water, when the dry season persists, supplies fall sometimes by 40 percent. Additionally, in spite of Grenada's abundance of surface water, the country has always struggled with distribution. The country needs to increase surface storage and reduce leaks. In 2001, it was estimated that distribution losses were between 45 –50% of production (Department of Economic Affairs, 2001). Salt-water intrusion is also of great concern in Grenada. Most wells are within 100 meters of the coastline. Several ground water wells in the south of the main island and several in Carriacou have been identified as vulnerable and a few have had to be abandoned (Department of Economic Affairs, 2001).

The island of Grenada is divided into seventy-one (71) watersheds, and Carriacou and Petite Martinique have twenty (20) (Department of Economic Affairs, 2001) (Figure 1-2). The Chemin Watershed, which is the focus of the VCA, is one of the 12 largest watersheds on the island of Grenada. Significant issues have been identified and some of these include:

- A trend of declining static water levels towards the lower end of the Chemin River, and signs of salt water intrusion;
- The potential for degradation of surface water quality due to salt water intrusion, domestic soak-away pits, agricultural pollution and industrial developments ; and
- Threats to the watershed recharge areas from improper land use and insufficient development planning. The result is watershed degradation including deforestation

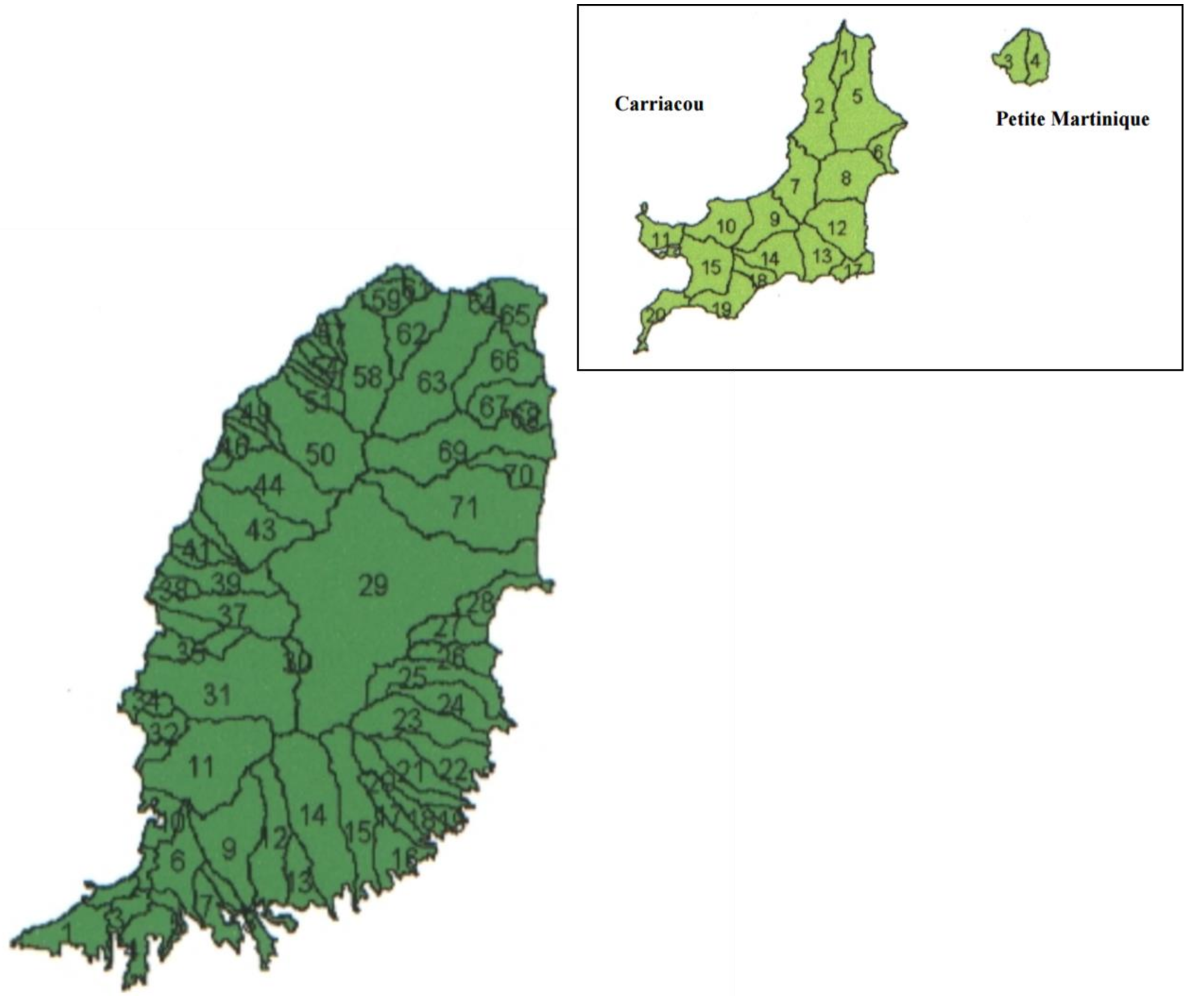


Figure 1-2: Watersheds of Grenada, Carriacou and Petite Martinique (LUD, 2000)

Generally, several national constraints have been identified in relation to the water sector, that if not addressed in a proper and timely manner, will impose additional costs on the economy. Three key challenges for the sustainability of integrated water resources management have been identified: technical, institutional and financial. Climate change will only exacerbate these current challenges. It will invariably directly affect both the quantity and quality of the country's water supply.

The availability of water is impacted by climate signals, with low average rainfall and high rainfall variability being the two key factors. There will be challenges in meeting the quantity and quality of water needed to meet human and development needs. Grenada has recently developed a Water Policy, and is in the process of developing supporting legislation. It has also developed a draft drought mitigation plan. Both of these initiatives are means of adapting to the projected adverse impacts of climate change, and will be further examined in the VCA and Impact studies.

1.2.1 The Water Sector and Climate Change

The water sector includes source and supply of water, wastewater, and associated infrastructure. Climate change is defined by IPCC (2013) as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Water is involved in all components of the climate system (atmosphere, hydrosphere, cryosphere, land surface and biosphere). Therefore, climate change can affect water through a number of mechanisms. There is abundant evidence from observational records and climate projections that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems (IPCC, 2008).

1.3 The Scope and Approach

The NASAP is organized into four main components as illustrated in the Figure 1-3 below.

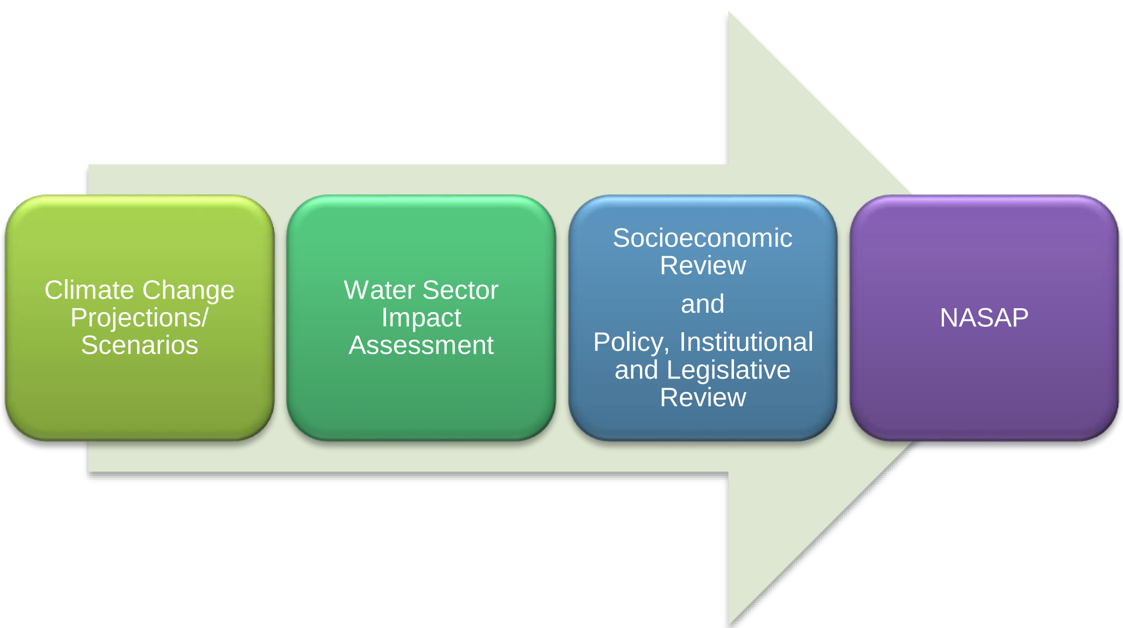


Figure 1-3: Organization of the NASAP

The sector strategy is informed by climate change projections; vulnerability and capacity assessment of the sector; an analysis of the institutional framework within which the sector operates; an assessment of the economic impact of climate change on the sector; and a review of current policies and legal instruments. The aim is to prepare Grenada to meet the challenges of climate change on the water sector.

The strategic action plan is designed to guide implementation of, and track progress toward, national water sector goals and targets in Grenada. The strategy covers the period 2016-2021 and outlines the national outcomes for the water sector of the country. Expected results (output) are presented along with the actions to meet the defined objectives. The suggested timeline (Immediate, Short term= 1-3 yrs; Medium= 3-5 yrs; Long term= > 5 yrs) for the commencement of each activity is given, along with an indicative cost where possible and the responsible agencies. The NASAP also discusses implementation and monitoring and evaluation.

The following subsections describe the overall approach taken.

1.3.1 Climate Change Projections/ Scenarios

The development of climate profiles through statistical downscaling was done with special emphasis on rainfall. The climate change projections/ scenarios involved the following activities:

- Historical data was analysed to produce tables and diagrams for temperature, rainfall (precipitation), wind-speed, sea levels and hurricanes that represent the current climate of Grenada.
- The future possible changes in the state of the climate of Grenada were gleaned from available GCM data; this was represented using tables and diagrams. This was done for the variables such as temperature, rainfall, wind speed, sea level rise and hurricanes.
- RCM data at scale for Grenada were derived from PRECIS A1B Perturbed Physics Ensemble of which 6 representative members of the 17 were chosen. From this data, tables for future changes in the variables of temperature, rainfall and wind speed were created.
- A review of authoritative works on climate change was done in order to examine the state of knowledge about climate change for Grenada climate. These included, but were not limited to, reports from the Intergovernmental Panel on Climate Change, Caribbean Community Climate Change Centre and Climate Studies Group, Mona, UWI.

1.3.2 Water Sector Impact Assessment

The following approach was taken for determining the impacts of climate change on the overall water sector of Grenada:

- Review of existing reports on Grenada, Carriacou and Petit Martinique water sector involving availability of water, demand and supply of water for domestic, agricultural and industrial sectors.
- Analysis of the rainfall data, daily and monthly mean and variability of rainfall pattern in the island and calculation of rainfall return periods and drought and flood assessment.
- Use of Landsat data to see changes in vegetation cover and estimate its impact on drought and flood.
- Analysis of surface and groundwater levels where data is available. Analysis of temporal monthly mean and creation of groundwater contours to analyze the seasonal change in groundwater levels.
- Review of available sectoral water availability reports, data and demand and supply forecasting by using the change factor in rainfall and temperature determined from climate models. Change factor in population can also be used for the demand and forecasting models.
- The DEM utilized a horizontal resolution of 30m and vertical resolution of 1m, as the base layer for determining the topography that would be used for the hydrological modeling and analysis for the island. Data is pending on other input parameters, which limits the further development of the model at this stage. The Aster DEM was smoothed using 9x9 grid filter, and sinks were filled to eliminate areas of artificial depression in the DEM. This was based on the recommended procedure commonly used before performing any hydrological analysis with DEM (Zhu et al, 2013).

1.3.3 Policy, Institutional and Legislative Review

This section of the report involved the following main tasks:

- A thorough review was carried out of all the GOG agencies, other relevant agencies and organisations involved in research, regulations, provision or enforcement within the water sector and especially with relation to climate change.
- Interviews and meetings were held with key stakeholders individually and within meeting settings to gather information and obtain tangible inputs.
- Current legal instruments, regulations and policies were reviewed, analyzed and recommendations made where gaps were identified.

1.3.4 Socio- Economic Review

To carry out the socio-economic review, the main approaches taken were:

- Secondary source material provided by stakeholders in Grenada and online resources were reviewed and analysed.
- Discussions and meetings were held with key stakeholders (Grenada, Carriacou and Petit Martinique), and inferences drawn from the assembled data. There was close consultation across the team's professional disciplines and with the technocrats within the water sector.

One objective of this assessment was to arrive at some quantitative indicators of the main economic relationships that exist with the water sector. This approach was severely limited because available data did not allow the consumption of water by the main contributors to GDP to be accurately determined. The alternative approach adopted, relied on estimating from available, or estimated data, demands made on total water withdrawals. The results were inconclusive as to whether the economy was constrained by the lack of water or was just being satisfied, at current water production levels. This laid the foundation for further concluding that the forecast impacts of climate change on the water sector required an aggressive approach to increasing accessibility to available water resources.

The second objective was to examine the social context of the water sector and the vulnerabilities to which a national adaptation strategy and plan must be sensitive in relation to health. It is generally accepted, that the particular socio-economic characteristics that typify Caribbean SIDS namely: economic vulnerability; poverty; unemployment and inequality; human development challenges, as well as, generally poor governance capabilities, gives an added importance and urgency to issues of water and health.

There was limited statistical data available on water borne diseases and the implications of climate change on vectors such as mosquitoes and rats. Dengue, Chikungunya and leptospirosis have been major areas of concern for Caribbean islands.

Therefore, the main lenses through which the relationship between health and water were viewed was through linking agriculture and food production to food security and nutritional purchasing power. This required analysis on the per capita value of domestic agricultural production and its contribution to total food consumption as an indicator of food security. Once this was established, poverty line indicators and food budgets at the poverty line level were examined in relation to the minimum daily household expenditure deemed necessary to meet essential needs. Water stressed agricultural production, with its heavy reliance on surface flows, is then implicated in the food security chain and nutritional health at the level of the most vulnerable.

The results of these two main lines of investigation were used to illustrate the vulnerability of Grenada to the impact of climate change on the water sector.

The NASAP

The purpose of the NASAP is to address the anticipated adverse effects of climate change on the water sector and to prepare the tri-island state of Grenada to meet the challenges of climate change on the water sector. The strategic action plan was designed to guide implementation of, and track progress toward, national water sector goals and targets in Grenada. The national outcomes were created out of discussions with key stakeholders. Some of these had been previously identified as important action items and so it was important to include these.

1.4 Limitations/ Constraints

A major limitation of the project was the short time frame of 150 days instead of the 180 days as stipulated in the Terms of Reference for the project. The stakeholders in Grenada were hard pressed to supply the requested data in the first month of the project and this seriously affected the time required to complete the analysis for the report. This challenge arose mainly because annual time series data sets were not readily available in consolidated documented form. The compression of the project timeline and the resulting compression of fieldwork time available made some tradeoffs in data collection inevitable.

Other limitations to the project which affected the type and extent of analyses that were completed for the project include:

- Limited hydrological data for Carriacou and Petit Martinique: Data was received on the area and location of the different watersheds of Carriacou only. No data was received for any hydrological parameters for Petit Martinique. No data was received on rivers, lakes for either island. Limited data was available for a few wells of Carriacou. Data on rivers, lakes and water sources and storage systems were received for Grenada and this helped in the analysis for the water resources for Grenada.
- No meteorological data for Carriacou and Petit Martinique: Only daily rainfall data was obtained for MBIA for Grenada. Daily temperature data was also received for the MBIA station. Monthly totals were received for some stations of Grenada; Cardi, Mt Home, Anandale, Grand Etang, Vendomme, Paradise, Clozier and Marli for a considerable period of time (1953-2013). Absence of rainfall data for Carriacou and Petit Martinique limited the analysis for these islands.
- Soil and land use data was available for Grenada and Carriacou but not for Petit Martinique. The soil data received for Grenada did not have any detailed information on the soil type i.e. texture, composition but additional literature and references of soil types of Grenada helped in understanding the spatial variation of soil types across the island. Similar, was the case for Carriacou, soil data received as shape files which were used to create the soil map. However, lack of additional information on soil type, as mentioned above, for Grenada was supplemented by using the geology data and inferring from them the possible soil types. The geological data for Grenada was sufficient enough to identify the different lithologies and their distribution across the island. Soils are weathered residues of bedrock and hence absence of data on soil types, mineralogy, texture was supplemented by using the geology data for both Grenada and Carriacou. No data was received on any of these parameters for Petit Martinique.
- With respect to land use data, sufficient data was received for Grenada. The land use data had information on the different types of land use pattern i.e. agriculture, barren land etc. as well as the types of agriculture. This thus helped greatly in the analysis. Similar, was the case for Carriacou, but no data was received for Petit Martinique.
- No data on the abstraction from the wells or water demand and consumption received from Carriacou. As it relates to availability of data for water resources and storage and supply systems,

it was a challenge for Carriacou and Petit Martinique. Whilst detail data on location of water sources, storage systems (tanks, dams) and supply systems (pipelines) were received for Grenada, it was absent for Carriacou and Petit Martinique. Only data on 2-3 wells of Carriacou were received which relates to their monthly production data and not on demand and consumption. Overall demand and consumption data was not available for any of the three islands, but available population data for Grenada helped in estimating rough demand to do a basic analysis.

- No data was available on the demand and consumption for each parish, economic sector or community.
- The socio-economic analysis was conducted primarily using data bases covering the years between 2008 to 2014 or 2015. In some other instances, data was very outdated. Some agricultural statistics by production systems and farm types being one example. The very important 2012 Agricultural Census has been completed but was not due for official release till mid-July 2015 and therefore unavailable to the consultants. It was decided to use whatever current data was available rather than data from the last census in 1995. In any event, care was taken to ensure that the need for consistency and comparability determined the final range of data selected.
- The most serious impediment to the more detailed analysis of the impact of climate change on the water sector and the economy was the unavailability of relevant water consumption time series data by economic sectors. This would normally be available from the water agencies customer billing data bases. The unavailability of this information, made it impossible to do a value added contribution to GDP per unit of water consumed, for each sector. That is, the contribution to GDP on a sectoral basis per unit of water consumed by that sector. The relationship between the economy and water withdrawals demand is more complex than suggested by the fitting of NAWASA's water withdrawal data to inferred end users. This is because the transactional value of water is neither fully tracked nor known. Further the contribution of unaccounted for water is unknown whether through none metering or in the informal economy. An informative extension of this analysis would have been associated water revenues by customer type.
- Although historical investment expenditure in the water sector by Government and aspects of the capital and recurrent budget of NAWASA was graciously signaled as available (not often the case in government agencies) the Consultant's decided not to pursue this. While therefore not a limitation, the Consultants wished to acknowledge this willingness. The original purpose of such an analysis was to provide some measure of seriousness and intent concerning the Government's commitment to the water sector. The reality of the Governments budgetary constraints meant that such a judgment would have been spurious rather than insightful.
- The derivation of a correlation between water demand and GDP, as a tool for forecasting consumption demand in the future, suffered from the general limitations of water data availability identified in the foregoing paragraph. However some indication of future water withdrawal need and population growth and GDP were graphed using the standard ESRES methodology developed for the Third Assessment Report of the Intergovernmental Panel on

Climate Change (IPCC's) on Emission Scenarios (2000) but currently undergoing review. A more Grenada based forecast of these relationships must await considerably more new information such as net water balances based on evapotranspiration rates, assessments of environmental water requirements and the further disaggregation of existing information on water withdrawals etc.

- Generally, in comparing GDP over time, it is the preferred practice to use constant dollar prices so as to anchor the value of GDP to a pre inflation state. However, this presents several difficulties for comparability when using pricing values that are not similarly anchored. This is partly why GDP data using current prices was retained. The economic section looked mainly at the demand side of the water sector. The supply side, which would have enabled some inferences about the net water demand under climate change conditions, was too challenged by the absence of critical surface water flows and ground water data at every point in the survey.

2 CLIMATE VARIABILITY AND CHANGE

2.1 General Climate

The nation of Grenada is located in the Windward Island chain at approximately 11° 58′ North latitude and 61° 20′ West longitude. The nation is composed of three islands, namely Grenada, Carriacou and Petit Martinique. Grenada, the largest of the three islands, is 34 km long and 18km wide, and rises to its highest point of 833m at Mt. St. Catherine. It is characterised by a mountainous land mass surrounded by extensive coral reefs. The climate of Grenada is typical of a small tropical island. Location, topography and limited coastal area contribute to the influence of many large scale climatic systems of the north tropical Atlantic on the island's weather (Nakicenovic et al., 2000).

In the course of a year, the country's climate is strongly modulated by the migration of the north Atlantic subtropical high, the eastward spread of the tropical Atlantic warm pool, the fairly steady easterly trades, and the passage of tropical waves, depressions, storms and hurricanes. The resulting climate regime is one characterized by a dry winter-wet summer pattern and high and fairly uniform temperatures year-round. Inter-annual variability in the climate of the islands is also influenced strongly by the El Niño Southern Oscillation. El Niño events bring warmer and drier than average conditions during the late wet-season and La Niña events bring colder and wetter conditions at this time.

2.2 Rainfall

2.2.1 Climatology

The precipitation climatology of Grenada, which is the average monthly rainfall over a number of years, is characterized by a generally unimodal pattern of monthly variation (Figure 2-1), with one rainy season from June to November and one dry season from January to May. Though there is a slight decrease in rainfall in September preceding the peak in November, the main rainy season delivers approximately 75% of total annual rainfall, while approximately 16% of rainfall is received during the dry period at the start of the year. Rainfall observations at the Maurice Bishop International Airport indicate that the island receives a total of 116cm of rainfall per year (Table 2-1).

As is the case for the rest of the insular Caribbean, peak rainfall occurs during the Atlantic Hurricane season and seasonality is strongly influenced by large scale atmospheric and oceanic systems. The rainfall pattern over Grenada is largely conditioned by the North Atlantic High (NAH) pressure system which is a large subtropical sermi-permanent centre of high atmospheric pressure typically found south of the Azores in the Atlantic Ocean between 30˚ N and 35˚ N. During the northern hemisphere winter the NAH is southernmost with strong easterly trades on the equator side of the system. Coupled with strong trade inversion, cold sea surface temperatures (SSTs) and reduced atmospheric humidity, the Caribbean generally is at its driest during the winter. Precipitation during this period is generally due to the passage of mid-latitude cold fronts and moisture advection (weak low level convergence). By May, the NAH moves northward, the trade wind intensity decreases and the Caribbean Sea becomes warmer and the the southern flank of the NAH becomes convergent (Taylor and Alfaro 2005). The primary source of rainfall from June to November is the passage of easterly waves which traverses the Atlantic Ocean from the west coast of Africa to the Caribbean. The waves are themselves a source of convection and can develop into depressions, storms, and tropical cylcones under conducive conditions. Near July, a temporary southward movement of the NAH is associated with diminished rainfall and the occurrence of a mid summer drying in much of the region. Enhanced rainfall occurs with the return of the NAH to the north and the passage of the Inter Tropical Convergence zone (ITCZ) northward. When the NAH treks south again at the end of the year, it marks the onset of the dry season. Another atmospheric feature important to rainfall variations during the rainfall season(s) is the Tropical Upper-level Tropospheric Trough (TUTT), a trough situated in the upper level (200 hPa) tropics.

2.2.2 Trends

Over the years, there has been a change in the amount of rainfall observed throughout the year, particularly during the wet season in the late part of the year. The result has been a shift in the rainfall climatology of Grenada across decades (Figure 2-2). Though the beginning of the wet season has not shifted substantially, there has been fluctuation in the number and timing of rainfall peaks observed. The driest decade for Grenada since 1986 occurred in the 1990s, when monthly rainfall did not exceed 14 cm, throughout most of the main rainy season. However, the November peak has become more consistent over time. Overall, the unimodal climatology of the island has varied, but the general pattern of dry early months and wet late months of the year has been retained.

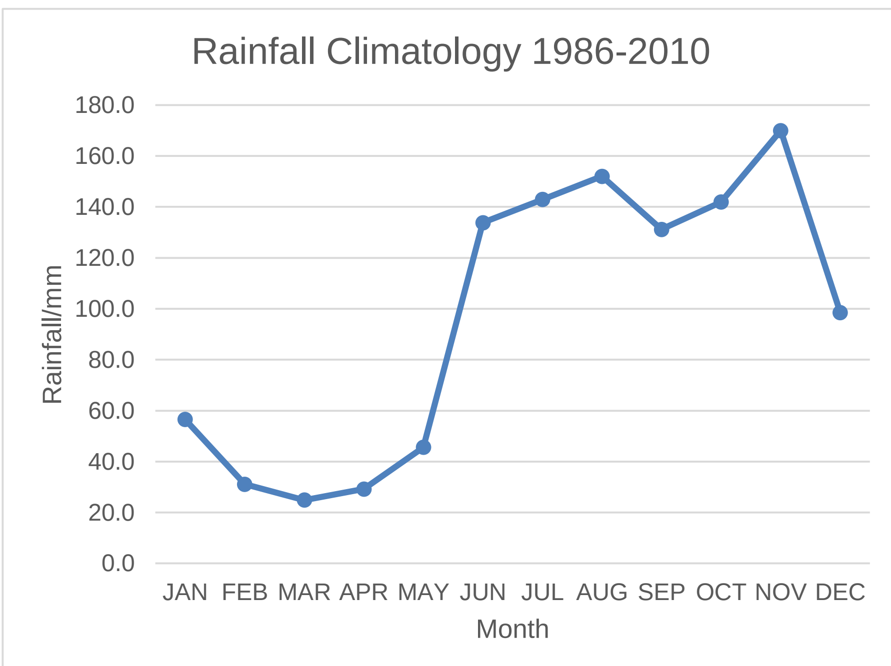


Figure 2-1: Monthly rainfall climatology for the Maurice Bishop International Airport in Grenada

Table 2-1: Monthly rainfall climatology for the Maurice Bishop International Airport in Grenada. Values are in mm

	Maurice Bishop International Airport
	Coordinates: 12°N, 61°W
Jan	56.5
Feb	31.1
Mar	24.9
Apr	29.2
May	45.6
Jun	133.8
Jul	142.9
Aug	152.0
Sep	131.2
Oct	141.9
Nov	170.0
Dec	98.5

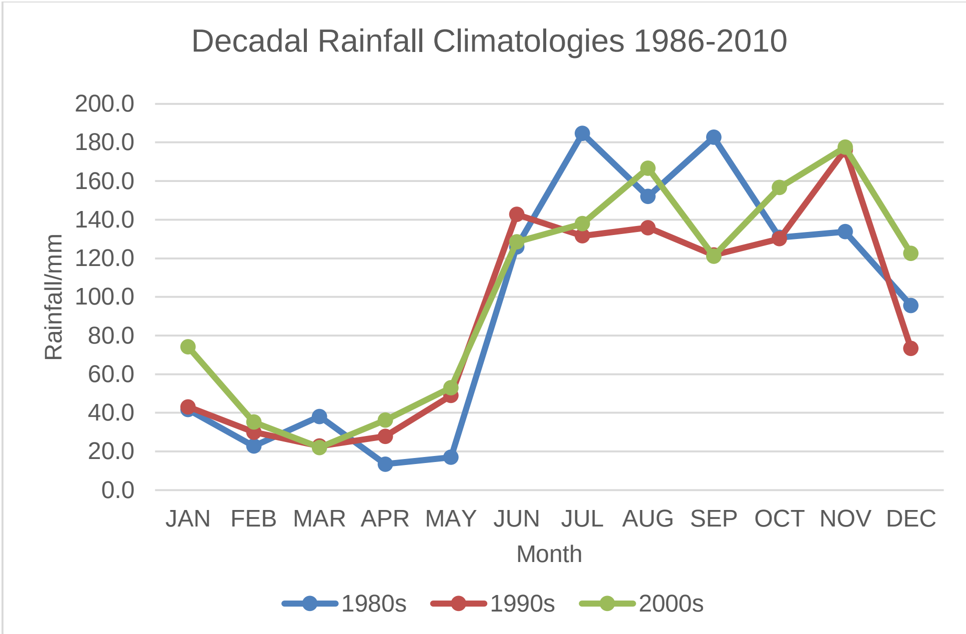


Figure 2-2: Average monthly rainfall by decade for the 1980s, 1990s and 2000s at the Maurice Bishop International Airport.

2.3 Temperature

2.3.1 Climatology

The temperature climatology of Grenada is characterized by summer warming that begins to escalate in April and winter cooling beginning in December (Figure 2-3). The average diurnal temperature range is 6.2°C, with temperatures peaking during summer months. Maximum temperature values may exceed 31°C in these months, while minimum temperature values may fall below 20°C in January/February. The 2000s was the hottest decade on record (Figure 2-4) with the years 1998 and 2010 being the hottest years on record.

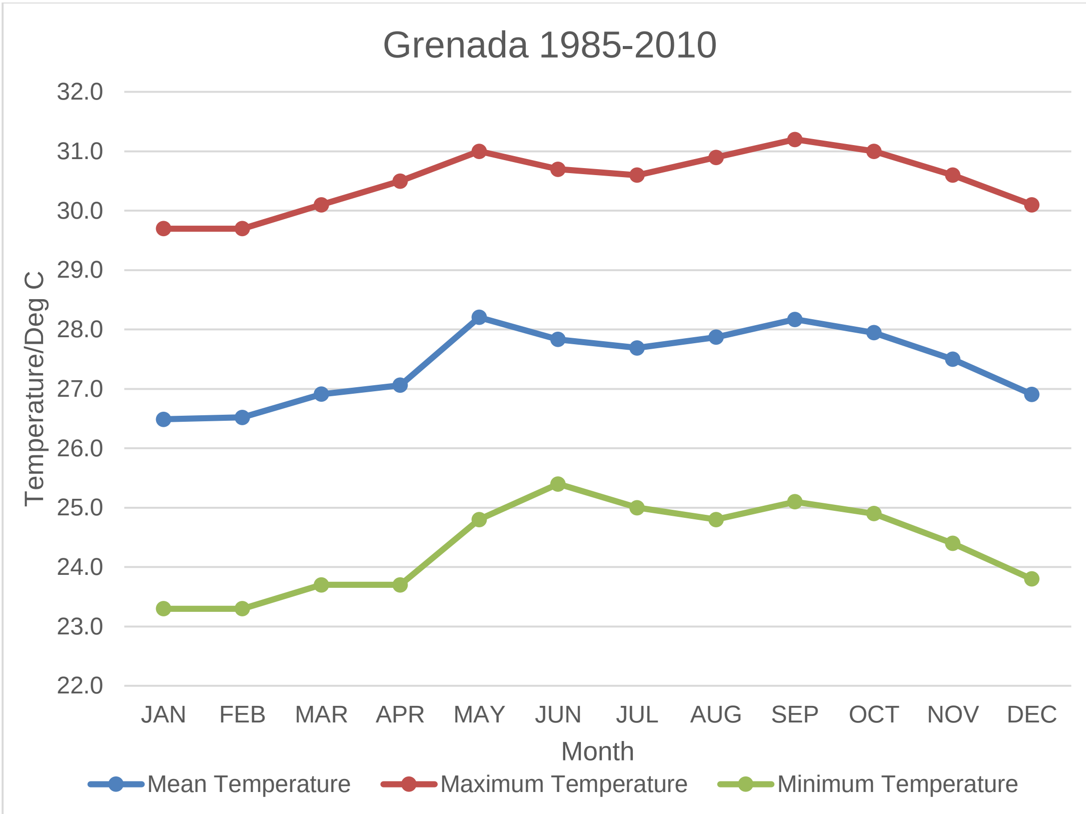


Figure 2-3: Monthly temperature climatology for the Maurice Bishop International Airport in Grenada.

2.3.2 Trends

Decadal temperature climatologies show that temperatures have risen steadily over time, but have remained somewhat consistent since the 1990s (Figure 2-4Figure 2-4). The warmest early summer temperatures were recorded in the 1990s, but the warmest late summer temperatures occurred in the 2000s.

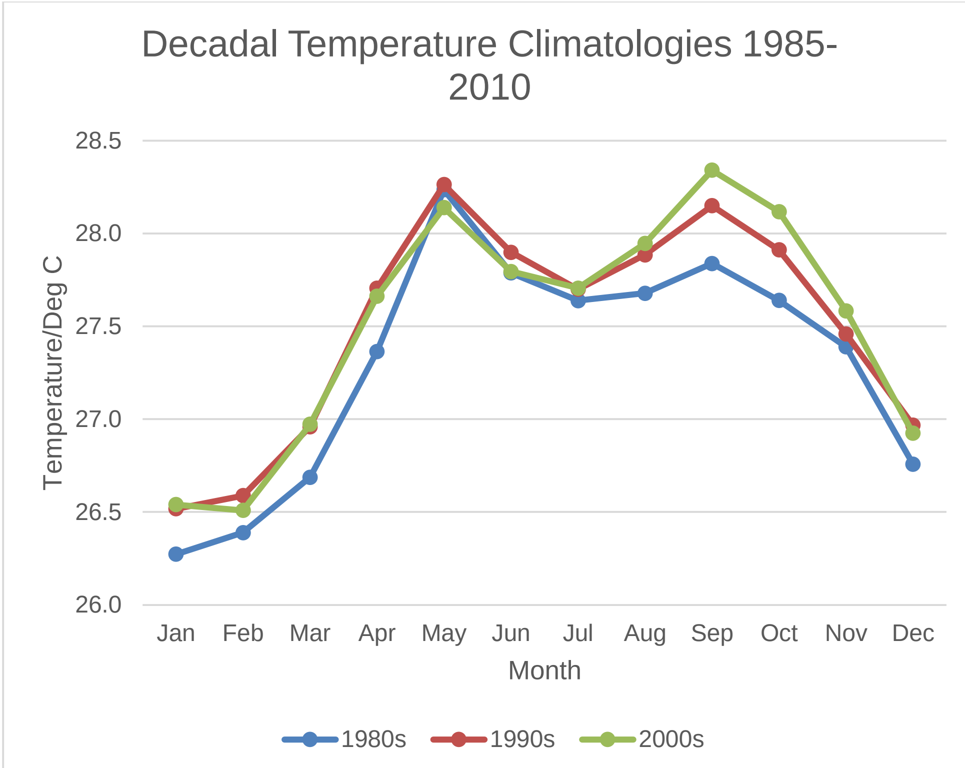


Figure 2-4: Average monthly temperature by decade for the 1980s, 1990s and 2000s at the Maurice Bishop International Airport.

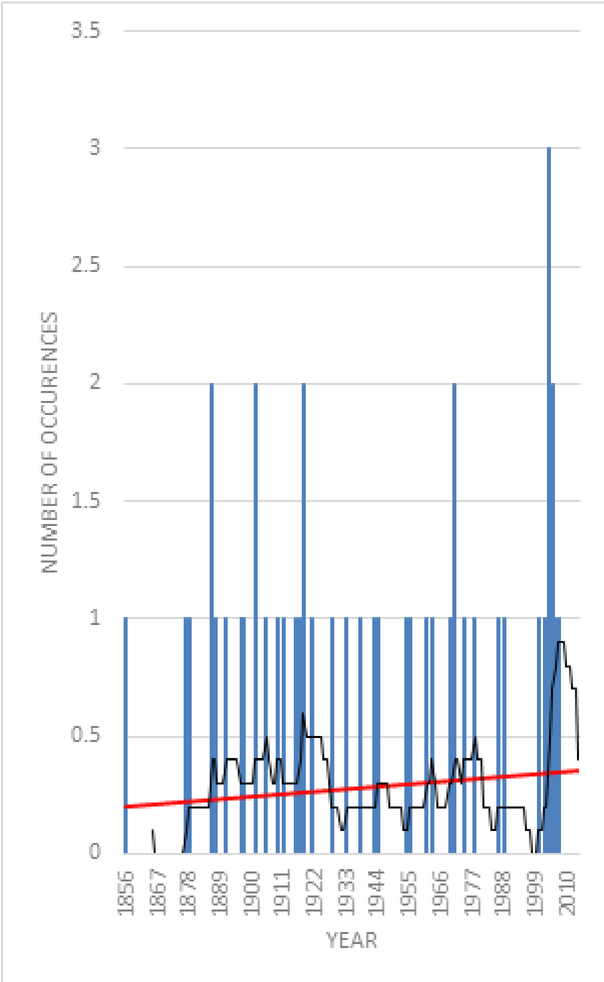
2.4 Tropical Cyclone Activity

2.4.1 Current trends in North Atlantic tropical cyclone activity

Intensity measures in historical records are especially sensitive to changing technology and improving methodology. Over the satellite era however, increases in the intensity of the strongest storms in the Atlantic have been quite robust (Kossin et al., 2007; Elsner et al. 2008). Time series of cyclone indices such as power dissipation show upward trends in the North Atlantic since the late 1970s (Emanuel, 2007), but interpretation of longer-term trends is constrained by data quality concerns (Landsea et al., 2012). The Intergovernmental Panel on Climate Change's AR5 Report notes that evidence suggests a virtually certain increase in the frequency and intensity of the strongest cyclones in the Atlantic since the 1970s. Wu et al. (2008) suggest that the magnitude of the statistically significant linear trend in PDI over 1975-2004 is 0.024 m3 s-3 year-1. It is further noted, that the average lifetime of North Atlantic tropical cyclones shows an increasing trend of 0.07 day year-1 for the same period which is statistically significant. The variability and trend in power dissipation can be related to sea surface temperature and other local factors such as tropopause temperature and vertical wind shear (Emanuel, 2007), but there is debate as to whether local sea surface temperature or the difference between local sea surface temperature and mean tropical sea surface temperature is the more physically relevant metric (Swanson, 2008). The distinction becomes important when making projections of changes in power dissipation, based on projections of SST changes, particularly in the tropical Atlantic where SST has been increasing more rapidly than in the tropics as a whole (Vecchi et al., 2008). ACE has shown declines globally since reaching a high point in 2005, and is currently at a 40 year low point (Maue, 2009) (IPCC SREX 2012).

2.4.2 Current Trends in Tropical Cyclone activity for Grenada

Landfalling hurricanes are taken to be hurricanes passing within a 100-km radius of Grenada. The historical trend suggests an increase in the number of hurricanes making landfall in Grenada. The 10-year running mean indicates a period of increased hurricane activity beginning in the year 2000 (Figure 2-5). However, at this scale, no discernible patterns in TC activity can be concluded. A closer look at the index reveals that recent peaks in TC activity are on account of increases in major hurricanes (Figure 2-2). There is a sharp increase in the number of Category 4 and 5 hurricanes starting in 2002, signifying an increase in the more intense storms. The records indicate a small increase in Category 1 hurricanes, but a decline in Category 2 and Category 3 hurricanes.



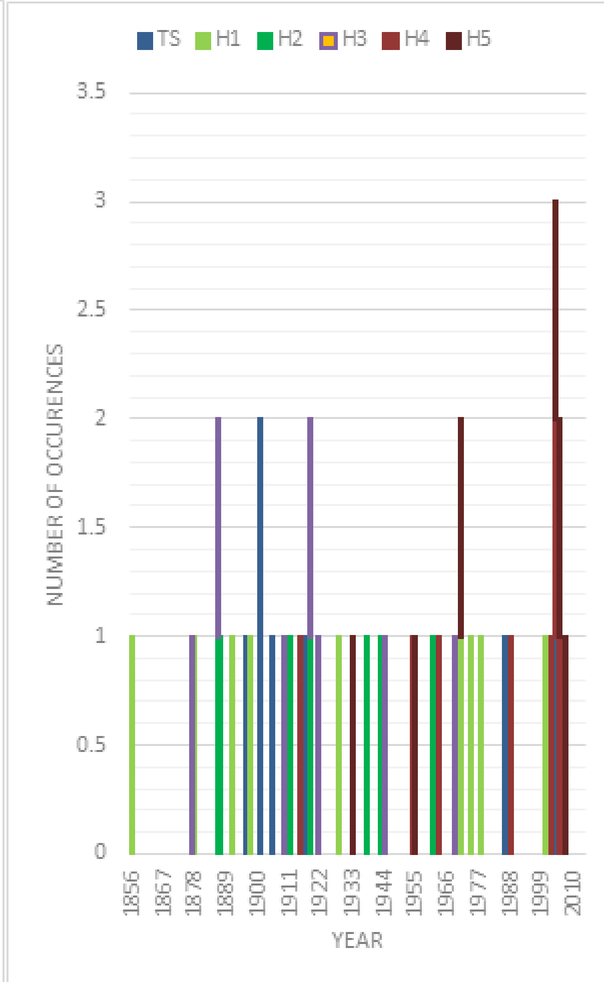


Figure 2-5: The annual number of tropical cyclones passing within a 100-km radius from Grenada's centre from 1856 to 2012. The red line indicates the linear trend in the data and the solid black line indicates the 10-year running mean. The colour codes indicate t number of occurrences of each storm category (TS = tropical storms, H1 = hurricane 1, H2 = hurricane 2, H3 = hurricane 3, H4 = hurricane 4, H5 = hurricane 5).

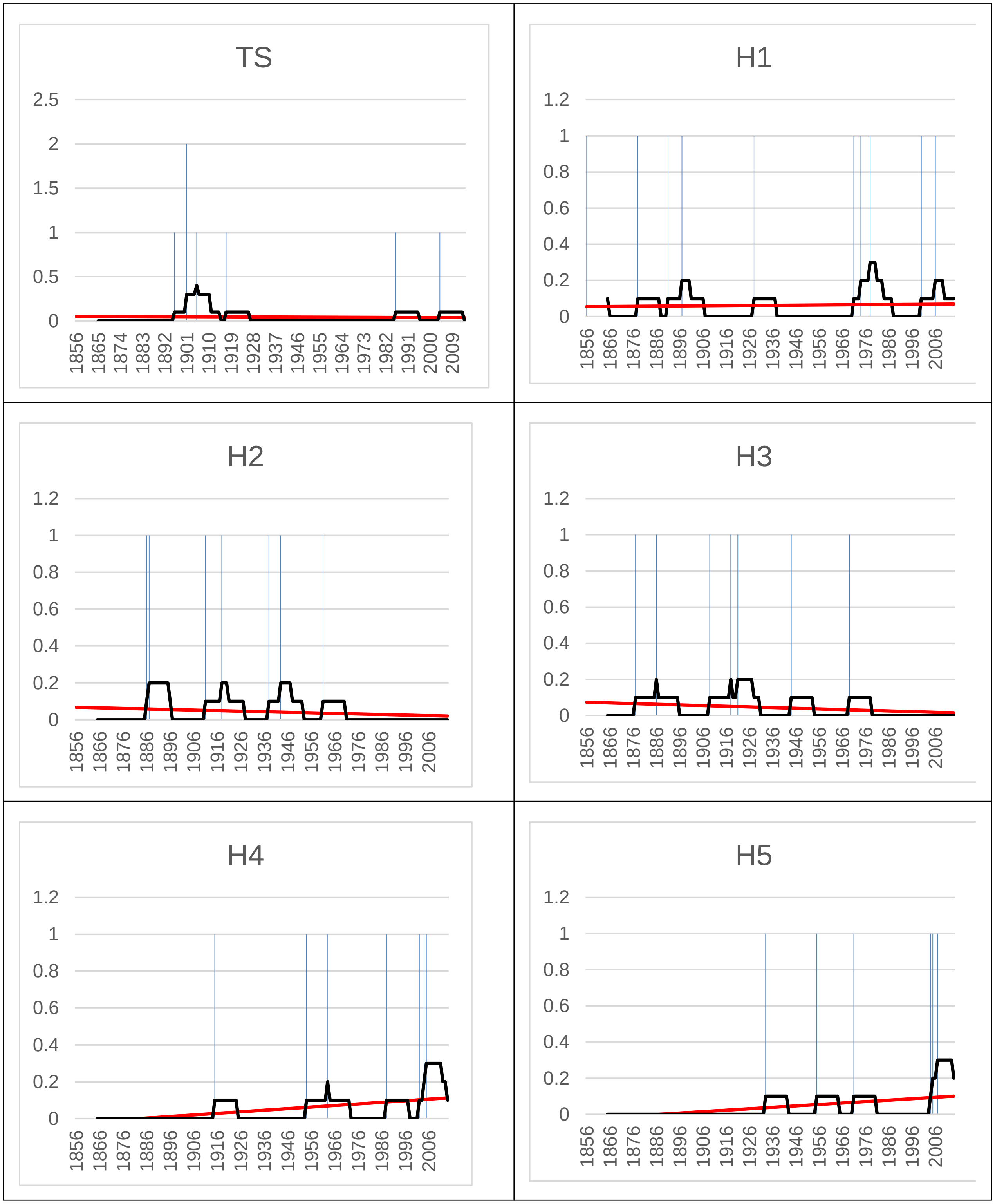
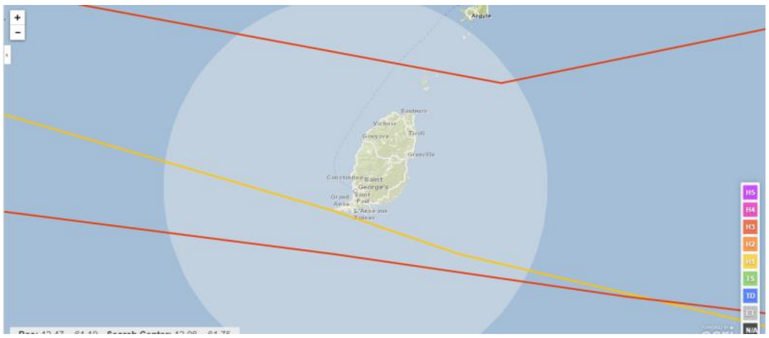


Figure 2-6: 2 Annual number of occurrences of each category of storm. The red line indicates the linear trend across the time series and the solid balck line indicates the trend of the 10-year running mean.

2.4.3 Historical Hurricane Activity

Grenada, like most islands of the Caribbean, is prone to experiencing Tropical Cyclones, Storms or Depressions between June 1 and November 30th each year. This is a phenomenon that is closely related to Grenada's rainfall pattern described in section 2.2. Given the difference in size and extent between Grenada and its territories, analysis in this section will independently examine the impact of Tropical Cyclones and Storms on Grenada and its territories.

(A)



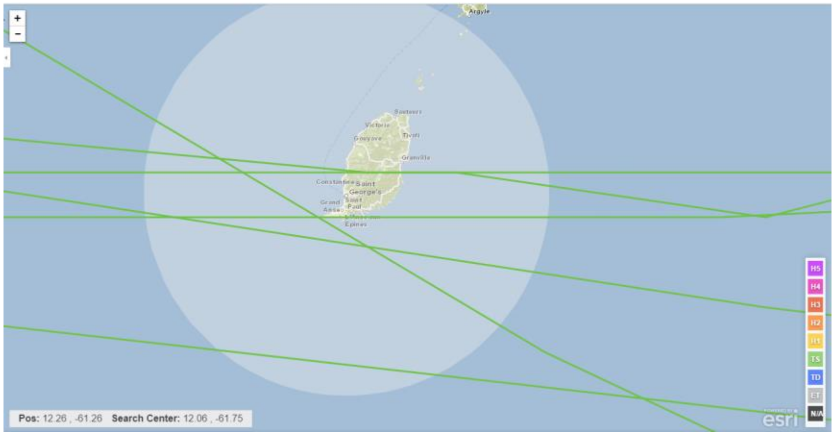
(B)

Hurricane	Year	Category
JANET	1955	3
IVAN	2004	3
EMILY	2005	1

Figure 2-7 - Diagram Showing (A) the number of Hurricanes and their associated paths and (B) their names and maximum category each storm had as it passed within a radius 50Km Grenada's Capital City St. George's. The period of interest is 1950 – 2014.

As illustrated by Figure 2-5, between the years 1950 to 2014 Grenada was impacted by 3 Hurricanes that passed within 50 Km of its capital city St. Georges. The island of Grenada went approximately 50 years without having being impacted by a Hurricane in the specified time period. However, it was impacted twice in 2 years in the last decade of the time period. None of these hurricanes had a path that traversed directly over the island of Grenada.

(A)



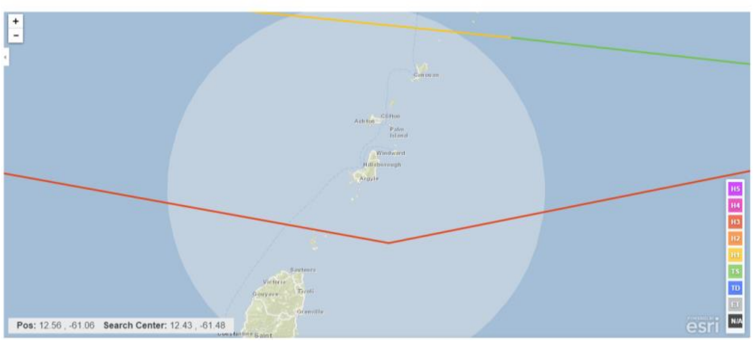
(B)

Tropical Storm	Year
ANNA	1961
CORA	1978
JOAN	1988
ARTHUR	1990
EARL	2004

Figure 2-8 - Diagram Showing: (A) the number of Tropical Storms impacting Grenada and (B) the respective names and years of impact or activity of each storm. Only Tropical Storms occurring between 1950 and 2014 and passing within 50Km of St. George's are considered.

An examination of the impact of Tropical Storms on Grenada, as seen in Figure 2-6, reveals that apart from Anna in 1961, the 5 other Tropical Storms that impacted the island of Grenada all came with a 10 km radius of its capital city. In fact, 3 of the 6 Tropical Storms experienced by Grenada over that time period, made direct landfall. The only decade in which Grenada was not impacted by a Tropical Storm was at the start of the time period of interest, the 1950's.

(A)



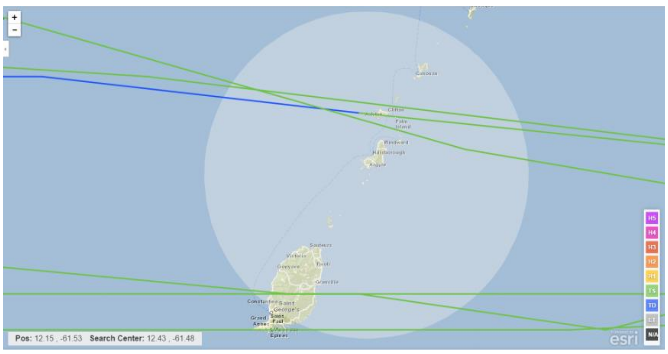
(B)

Hurricane	Year	Category
HAZEL	1954	1
JANET	1955	3

Figure 2-9 - Diagram showing the number of hurricanes - as well as their category - passing within 50Km of grid point 12.34N and -61.48W between 1950 and 2014.

Figure 2-7 shows that the islands of Carriacou and Petite Martinique have only been impacted by 2 hurricanes that passed within a radius of 50km of grid point centre of their locations. One of these hurricanes, Janet, also impacted the larger Island of Grenada. Hurricane Janet also made landfall on the islands of Carriacou. Aside from the starting decade of the time period of interest, the islands of Carriacou and Petite Martinique have not been impacted by a hurricane in the last 60 years.

(A)



(B)

Tropical Storm	Year
GERTRUDE	1974
CORA	1978
DANIELLE	1986
JOAN	1988
LILI	2002
FELIX	2007

Figure 2-10 - Diagram showing the number of Tropical Storms passing within 50Km of grid point 12.34N and -61.48W between 1950 and 2014.

All the tropical storms that had a path which directly impacted the isle of Grenada also impacted its territories. No storms directly impacted Carriacou, in fact, there was an even split in the number of storms passing north and south of Carriacou.

2.5 Sea Level Rise

2.5.1 Global

Using proxy and instrumental data, it is virtually certain (i.e. with 99-100% probability) that the rate of global mean sea level rise has accelerated during the last two Centuries, marking the transition from relatively low rates of change during late Holocene (order tenths of mm yr^{-1}) to modern rates (order mm $year^{-1}$). Rates and absolute changes in global mean sea level pressure are shown in Table 2-2.

Table 2-2: Rates and absolute change in mean sea level pressure. Rates are obtained from IPCC (2013).

PERIOD	RATE (MM YR^{-1})	TOTAL SEA LEVEL RISE	IPCC LIKELIHOOD
1901 – 2010	1.7 ± 0.2	0.19 ± 0.02	Very likely
1971 – 2010	2.0 ± 0.2	-	Very likely
1993 – 2010	3.2 ± 0.4	-	Very likely

The rate represented in the 1993-2010 period reflects data obtained from tide-gauge and satellite altimeter sources. It is likely that rates similar to this period also occurred between 1930 and 1950. It is also likely that global mean sea level has accelerated since the early 1900s, with estimates ranging from 0.000 to 0.013 [-0.002 to 0.019] mm yr^{-2} (IPCC, 2013). Accelerations in the rate of increase over the 20^{th} Century have been detected in most regions. See for example, Woodworth et al. (2009), and Church and White (2006).

2.5.2 Caribbean

Estimates of observed sea level rise from 1950 to 2000 suggest that sea level rise within the Caribbean appears to be near the global mean. Table 2-3, shows the rates of sea level rise for a number of locations in the Caribbean. All values suggest an upward trend. It is important to note that due to shifting surface winds, expansion of warming ocean water and the addition of melting ice, ocean currents can be altered which, in turn leads to changes in sea level that vary from place to place. Additionally, more localized processes such as sediment compaction and tectonics may also contribute to additional variations in sea level.

Table 2-3: Observed rates of sea level rise for some Caribbean stations. Source: The State of the Jamaican Climate (2013).

TIDAL GAUGE STATION	OBSERVATION PERIOD	RATES (MM YR^{-1})
Bermuda	1932 –2006	2.04 ± 0.47
San Juan, Puerto Rico	1962 –2006	1.65 ± 0.52
Guantanamo Bay, Cuba	1973 –1971	1.64 ± 0.80
Miami Beach, Florida	1931 –1981	2.39 ± 0.43
Vaca Key, Florida	1971 –2006	2.78 ± 0.60

2.6 Future Projections

2.6.1 Presenting the Model Data

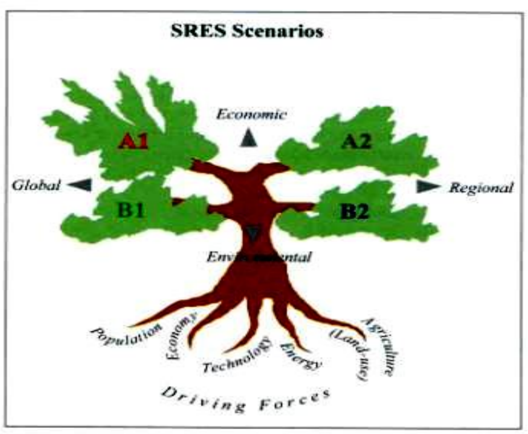
Global Circulation Models (GCMs) are useful tools for providing future climate information. GCMs are mathematical representations of the physical and dynamical processes in the atmosphere, ocean, cryosphere and land surfaces. Their physical consistency and skill at representing current and past climates make them useful for simulating future climates, under differing scenarios, of increasing greenhouse gas concentrations (scenarios are discussed further below).

Projections of rainfall and temperature characteristics for Grenada to mid-century are extracted from the CMIP3 project (McSweeney et al. 2010). Data from 15 GCMs were analyzed and projected change averaged over Grenada for the 2030s and 2060s, under three emissions scenarios, are presented in summary tables. An inherent drawback of the GCMs, however, is their coarse resolution relative to the scale of required information. The size of Grenada precludes it being physically represented in the GCMs, and there is a need for *downscaling* techniques to provide more detailed information on a country or station level. The additional information that the downscaling techniques provide, do not however devalue the information provided by the GCMs, especially since (1) Grenada's climate is largely driven by large-scale phenomenon; (2) the downscaling techniques themselves are driven by the GCM outputs[and (3) at present, the GCMs are the best source of future information on some phenomena e.g. hurricanes.

Data from d*ynamical* downscaling methods are also used. This downscaling method employs a regional climate model (RCM) driven at its boundaries by the outputs of the GCMs. Like GCMs, the RCMs rely on mathematical representations of the physical processes, but are restricted to a much smaller geographical domain (the Caribbean in this case). The restriction enables the production of data of much higher resolution (typically < 100 km). Available RCM data for Grenada were obtained from the PRECIS (Providing Regional Climates for Impact Studies) model (Taylor et al. 2007). The PRECIS model resolution is 25 km.

2.6.2 Emission Scenarios

The GCMs, RCM, and statistical downscaling model are run using the Special Report Emission Scenarios (SRES) (Nakicenovic et al. 2000).[1] Each SRES scenario is a plausible storyline of how a future world will look. The scenarios explore pathways of future greenhouse gas emissions, derived from self-consistent sets of assumptions about energy use, population growth, economic development, and other factors. They however explicitly exclude any global policy to reduce emissions to avoid climate change. Scenarios are grouped into families according to the similarities in their storylines as shown in Figure 2-11.



- A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Figure 2-11: Special Report on Emission Scenarios (SRES) schematic and storyline summary (Nakicenovic et al, 2000)

[1] In 2000, the Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emissions Scenarios (SRES), presenting multiple scenarios of greenhouse gas and aerosol precursor emissions for the 21st century.

Since there is an equal probability of each storyline becoming the future, the results presented in the following section cover a range of scenarios, namely the A2, B1, B2 and A1B (see again Figure 2-11). A2 and B2 are representative of high and low emissions scenarios respectively (Figure 2-12), and A1B is a compromise between the two. The A1B scenario is characterized by an increase in carbon dioxide emissions through mid-century followed by a decrease.

The future climate is presented as absolute or percentage deviations from the present day climate which is in turn represented by averaging over 30 year periods, usually 1961-1990 or 1971-2000. Results are presented for 10 year bands centered on 2030 and 2060 and for the end of the Century (2100).

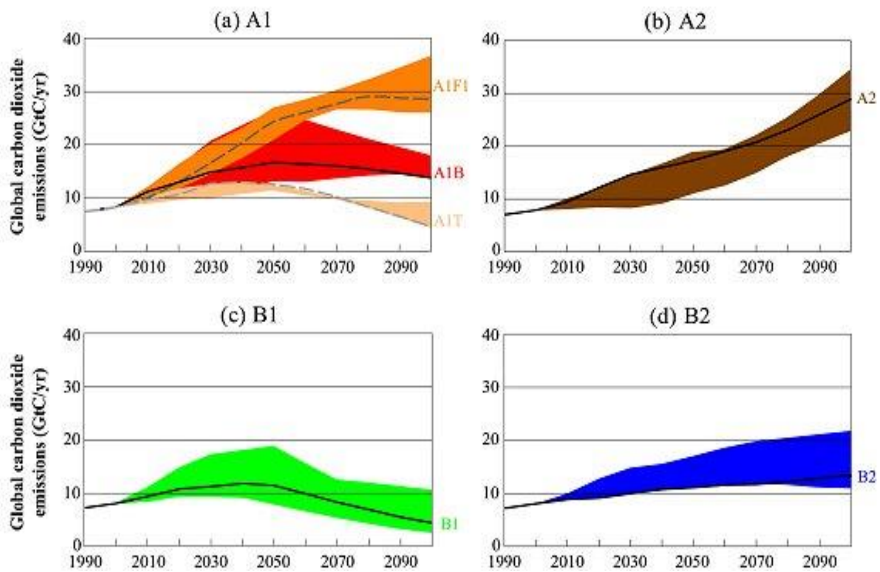


Figure 2-12: Total global annual CO_2 emissions from all sources (energy, industry, and land-use change) from 1990 to 2100 (in gigatonnes of carbon (GtC/yr) for the families and six SRES scenario groups (Nakicenovic et al, 2000).

2.6.3 RCM Perturbed Experiments

RCM results are derived from PRECIS driven perturbed physics experiments (PPE). Created using the A1B SRES scenario, PPE's provide an alternative to using several driving GCM boundary conditions (McSweeney et al 2012). PPE's comprises a 17 member ensemble (HadCM3Q0-Q16), however for the purposes of this study a subset of 6 representative of the overall range of key climate features were used. The 6 in question are the ensemble members Q0, Q3, Q4, Q10, Q11 and Q14.

Figure 2-13, shows how the island of Grenada is represented by the PRECIS RCM. The island is covered by two grid boxes. The results presented below will seek to detail temperature (mean, maximum and minimum), precipitation and wind speed changes associated with each grid box for the 2030's. For each of these variables the average of the 6 perturbations is presented, as well as, the minimum and maximum associated change in the monthly, seasonal and annual time scales.

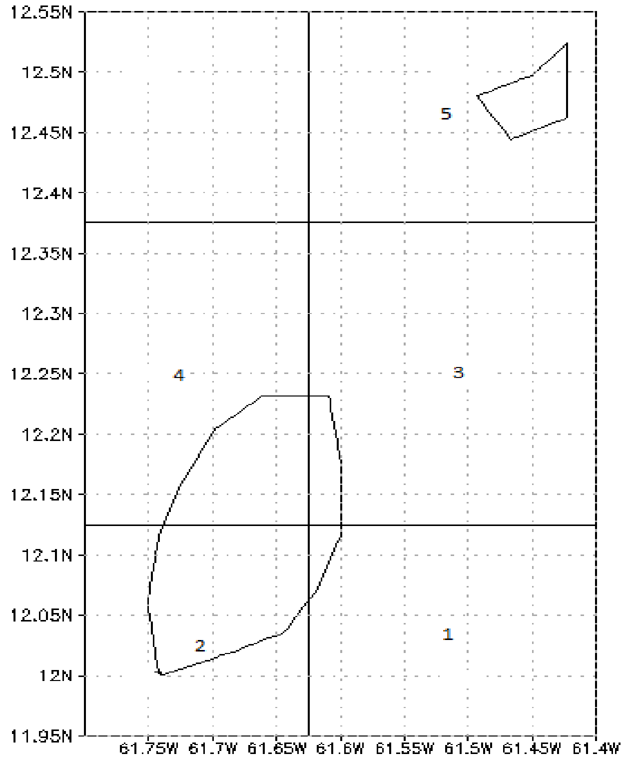


Figure 2-13: Grenada as represented by the PRECIS model

2.6.4 Temperature Projections

2.6.4.1 Mean Annual Temperature

The annual mean temperature of Grenada is projected to increase irrespective of scenario, model or methodology used.

<u>GCM</u>

The mean annual temperature is projected to increase by 0.3 to 1.6˚C by the 2030s and 0.7 to 2.6˚C by the 2060s (Table 2-4). The projected rate of warming is similar throughout the year, but slightly more rapid in June-August (JJA) and September-November (SON). Projections indicate a potential increase of 0.3 to 1.5 ˚C in JJA and 1.8 to 1.8 ˚C in SON by the 2030's. By the 2060s, this escalates to 0.7 to 2.5 °C in DJF and 0.8 to 2.8 ˚C in SON.

Table 2-4: Projected changes in annual and seasonal temperature for GCM grids over Grenada. Changes are relative to a 1970-99 baseline

		Projected change by the 2030s			Projected change by the 2060s		
		Min	Median	Max	Min	Median	Max
		Change in °C			Change in °C		
Annual	A2	0.8	1.0	1.4	1.6	1.8	2.6
	A1B	0.5	1.0	1.6	1.0	1.8	2.5
	B1	0.3	0.9	1.2	0.7	1.4	1.7
DJF	A2	0.7	1.0	1.3	1.5	1.8	2.7
	A1B	0.5	0.9	1.7	1.0	1.9	2.6
	B1	0.3	0.8	1.2	0.7	1.3	1.7
MAM	A2	0.6	0.9	1.2	1.3	1.8	2.4
	A1B	0.5	0.9	1.5	0.9	1.7	2.3
	B1	0.2	0.8	1.2	0.5	1.3	1.7
JJA	A2	0.8	1.0	1.3	1.5	2.0	2.5
	A1B	0.5	1.1	1.5	1.1	1.9	2.5
	B1	0.3	0.8	1.2	0.7	1.4	1.6
SON	A2	0.8	1.0	1.5	1.6	1.9	2.8
	A1B	0.7	1.0	1.8	1.2	1.9	2.7
	B1	0.5	0.9	1.3	0.8	1.4	1.7

RCM

At higher resolutions relative to the GCMs, the projected changes in mean temperature over the nation of Grenada differ slightly (Table 2-5). Warming is projected to occur at a slightly faster rate in the south than in the north, though warming is projected across the entire group of islands. Although there is a lack of uniformity on the warming associated with the northern and southern extent of the country, key points still hold true; August-September-October (ASO) and November-December-January (NDJ) still represent the seasons in which the largest mean warming signal is noted. December is projected to have the largest projected increase in temperature when the monthly timescale is considered, and the average projected increase in annual temperatures is approximately 1.1°C.

Table 2-5: Projected change in mean temperature for RCM grids over Grenada. Changes are relative to a 1961-90 baseline

		GRID BOX 1			GRID BOX 2			GRID BOX 3			GRID BOX 4			GRID BOX 5	
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
JAN	0.606	1.046	1.296	0.727	1.166	1.395	0.553	0.989	1.249	0.606	1.041	1.291	0.553	0.986	1.244
FEB	0.608	1.048	1.300	0.729	1.168	1.399	0.554	0.991	1.253	0.607	1.043	1.295	0.555	0.988	1.249
MAR	0.611	1.050	1.304	0.733	1.170	1.403	0.558	0.994	1.257	0.611	1.046	1.299	0.559	0.991	1.253
APR	0.615	1.052	1.308	0.736	1.172	1.406	0.562	0.996	1.260	0.615	1.048	1.302	0.563	0.993	1.256
MAY	0.619	1.054	1.311	0.740	1.173	1.408	0.566	0.998	1.264	0.619	1.050	1.305	0.567	0.995	1.260
JUN	0.624	1.057	1.314	0.745	1.176	1.411	0.571	1.000	1.267	0.624	1.052	1.308	0.572	0.998	1.263
JUL	0.630	1.059	1.319	0.749	1.178	1.415	0.577	1.003	1.272	0.630	1.055	1.313	0.578	1.001	1.268
AUG	0.637	1.063	1.324	0.755	1.182	1.420	0.584	1.007	1.277	0.636	1.059	1.318	0.585	1.004	1.273
SEPT	0.642	1.067	1.330	0.759	1.185	1.427	0.591	1.011	1.283	0.642	1.062	1.324	0.591	1.008	1.279
OCT	0.647	1.070	1.336	0.763	1.188	1.433	0.595	1.013	1.288	0.646	1.065	1.330	0.596	1.011	1.284
NOV	0.652	1.072	1.339	0.768	1.190	1.435	0.600	1.016	1.292	0.651	1.067	1.333	0.600	1.013	1.288
DEC	0.656	1.074	1.341	0.772	1.192	1.438	0.603	1.017	1.294	0.654	1.069	1.335	0.604	1.015	1.290
NDJ	0.638	1.064	1.325	0.756	1.183	1.423	0.585	1.007	1.278	0.637	1.059	1.320	0.586	1.005	1.274
FMA	0.611	1.050	1.304	0.733	1.170	1.403	0.558	0.993	1.256	0.611	1.046	1.299	0.559	0.991	1.253
MJJ	0.624	1.057	1.315	0.745	1.176	1.411	0.571	1.000	1.268	0.624	1.052	1.309	0.572	0.998	1.264
ASO	0.642	1.066	1.330	0.759	1.185	1.427	0.590	1.010	1.283	0.642	1.062	1.324	0.591	1.008	1.279
ANNUAL	0.629	1.059	1.319	0.748	1.178	1.416	0.576	1.003	1.271	0.628	1.055	1.313	0.577	1.000	1.267

2.6.4.2 Maximum Temperature

RCM

The near term projections of maximum temperature for the grids associated with Grenada suggest an average increase of approximately 0.6°C to 1.3°C annually in maximum temperature (Table 2-6). Again, the southernmost areas of the island of Grenada are projected to warm at a slightly faster rate than the north. However, these differences in rate of warming are relatively small.

Table 2-6: Projected change in maximum temperature for grids over Grenada for the 2030's. Changes are relative to a 1961-1990 baseline.

	GRID BOX 1			GRID BOX 2			GRID BOX 3			GRID BOX 4			GRID BOX 5		
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
JAN	0.599	1.033	1.280	0.724	1.140	1.357	0.544	0.982	1.243	0.602	1.031	1.278	0.543	0.978	1.239
FEB	0.601	1.035	1.284	0.726	1.142	1.360	0.545	0.984	1.247	0.603	1.033	1.282	0.545	0.980	1.243
MAR	0.604	1.037	1.288	0.730	1.144	1.364	0.549	0.986	1.251	0.607	1.036	1.286	0.549	0.982	1.247
APR	0.608	1.039	1.290	0.733	1.145	1.364	0.553	0.988	1.255	0.611	1.037	1.288	0.553	0.984	1.251
MAY	0.611	1.040	1.293	0.735	1.146	1.364	0.557	0.990	1.259	0.614	1.039	1.291	0.557	0.987	1.255
JUN	0.616	1.043	1.295	0.740	1.149	1.366	0.562	0.993	1.262	0.619	1.041	1.293	0.562	0.989	1.258
JUL	0.622	1.046	1.300	0.743	1.151	1.369	0.568	0.996	1.266	0.625	1.044	1.297	0.568	0.992	1.262
AUG	0.629	1.049	1.305	0.749	1.155	1.375	0.576	0.999	1.271	0.632	1.048	1.303	0.575	0.996	1.267
SEPT	0.634	1.053	1.311	0.753	1.159	1.381	0.582	1.003	1.277	0.637	1.052	1.309	0.582	1.000	1.273
OCT	0.639	1.056	1.317	0.758	1.162	1.388	0.587	1.006	1.283	0.642	1.055	1.315	0.586	1.002	1.279
NOV	0.643	1.058	1.319	0.762	1.163	1.388	0.591	1.008	1.286	0.646	1.057	1.317	0.591	1.005	1.282
DEC	0.647	1.060	1.322	0.764	1.165	1.392	0.595	1.010	1.289	0.649	1.059	1.320	0.594	1.007	1.285
NDJ	0.630	1.050	1.307	0.750	1.156	1.379	0.577	1.000	1.273	0.632	1.049	1.305	0.576	0.997	1.269
FMA	0.606	1.037	1.287	0.729	1.144	1.363	0.549	0.986	1.251	0.607	1.035	1.285	0.549	0.982	1.247
MJJ	0.619	1.043	1.296	0.740	1.149	1.366	0.562	0.993	1.262	0.620	1.042	1.294	0.562	0.989	1.258
ASO	0.633	1.053	1.311	0.753	1.159	1.381	0.581	1.003	1.277	0.637	1.052	1.309	0.581	0.999	1.273
ANNUAL	0.617	1.045	1.300	0.743	1.152	1.372	0.567	0.995	1.266	0.624	1.044	1.298	0.567	0.992	1.262

As is the case for mean temperature, the seasons with the highest projected increases are the summer (August-September-October (ASO)) and boreal winter (November-December-January (NDJ)).

2.6.4.3 Minimum Temperature

RCM

Unlike the changes in maximum temperature, minimum temperatures are expected to increase by 0.6° to 1.3°C by the 2030's on average across Grenada (Table 2-7). Similar to the projected changes in maximum temperature, the projected changes in minimum temperature indicate a difference in warming rates in the north and south. Again, the south is projected to be warmer than the north for all seasons. Once again, NDJ and ASO are projected to have the greatest increases. Additionally, the month of December shows the highest change in mean minimum temperature.

Table 2-7: Projected changes in minimum temperature for RCM grids over Grenada for the 2030's. Changes are relative to 1961-1990 Baseline

		GRID BOX 1			GRID BOX2			GRID BOX3			GRID BOX 4			GRID BOX5	
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
JAN	0.622	1.070	1.326	0.749	1.218	1.466	0.561	0.997	1.256	0.616	1.059	1.314	0.560	0.992	1.249
FEB	0.624	1.072	1.330	0.751	1.220	1.471	0.562	0.999	1.260	0.617	1.061	1.318	0.561	0.994	1.253
MAR	0.627	1.074	1.335	0.755	1.222	1.475	0.566	1.001	1.264	0.621	1.064	1.323	0.565	0.997	1.257
APR	0.631	1.076	1.339	0.759	1.225	1.481	0.570	1.003	1.268	0.625	1.066	1.327	0.569	0.999	1.261
MAY	0.636	1.079	1.343	0.765	1.227	1.485	0.575	1.006	1.271	0.630	1.068	1.331	0.574	1.001	1.265
JUN	0.641	1.081	1.347	0.769	1.229	1.489	0.579	1.008	1.275	0.635	1.071	1.334	0.579	1.004	1.268
JUL	0.647	1.084	1.351	0.774	1.232	1.493	0.586	1.011	1.279	0.641	1.074	1.339	0.585	1.007	1.272
AUG	0.654	1.087	1.357	0.780	1.235	1.499	0.593	1.015	1.285	0.647	1.077	1.344	0.592	1.010	1.278
SEPT	0.660	1.091	1.363	0.785	1.239	1.505	0.599	1.018	1.290	0.653	1.081	1.350	0.598	1.014	1.284
OCT	0.664	1.094	1.368	0.790	1.242	1.511	0.603	1.021	1.296	0.657	1.083	1.356	0.603	1.017	1.289
NOV	0.669	1.096	1.372	0.796	1.245	1.515	0.608	1.023	1.300	0.662	1.086	1.360	0.607	1.019	1.293
DEC	0.674	1.098	1.374	0.802	1.247	1.517	0.611	1.025	1.302	0.666	1.088	1.362	0.610	1.021	1.295
NDJ	0.655	1.088	1.358	0.782	1.236	1.499	0.593	1.015	1.286	0.648	1.078	1.345	0.592	1.011	1.279
FMA	0.627	1.074	1.335	0.755	1.222	1.476	0.566	1.001	1.264	0.621	1.064	1.323	0.565	0.997	1.257
MJJ	0.641	1.081	1.347	0.769	1.229	1.489	0.580	1.008	1.275	0.635	1.071	1.335	0.580	1.004	1.268
ASO	0.659	1.091	1.363	0.785	1.239	1.505	0.598	1.018	1.290	0.653	1.080	1.350	0.598	1.014	1.284
ANNUAL	0.646	1.083	1.350	0.773	1.232	1.492	0.584	1.011	1.279	0.639	1.073	1.338	0.584	1.006	1.272

2.6.4.4 Extreme Temperature

<u>GCM</u>

The GCM projections all indicate substantial increases in the frequency of days and nights that are considered 'hot' in the current climate (Table 2-8). The annual frequency of warm days and nights is expected to increase by 33-66% by the 2060s relative to current climate. In contrast, the percentage frequency of occurrence of cool days and nights, falls to near zero by the 2060s. A very hot day (night) is defined as one with temperatures greater than the hottest 10% of days (nights) in the current climate. Similarly, very cool days (nights) are those with temperatures less than the coolest 10% of days (nights) in the current climate (McSweeney et al. 2010). Days that are hot are projected to increase most rapidly in September to November.

Table 2-8: Projected changes in seasonal and annual temperature extremes for GCM grids over Grenada for the 2060s.

		Frequency of hot days			Frequency of hot nights		
		Min	Median	Max	Min	Median	Max
		Future % frequency			Future % frequency		
Annual	A2	44	55	66	46	64	83
	A1B	45	58	64	45	66	81
	B1	33	42	50	33	53	68
DJF	A2	63	79	91	66	80	97
	A1B	65	82	93	62	86	96
	B1	37	62	75	35	60	80
MAM	A2	63	73	88	60	79	94
	A1B	66	77	90	65	81	97
	B1	35	57	78	29	65	82
JJA	A2	58	75	93	74	89	99
	A1B	61	77	91	80	88	98
	B1	46	55	77	52	77	93
SON	A2	62	83	93	80	93	99
	A1B	66	83	96	83	93	99
	B1	33	69	89	57	80	96

RCM

Projected temperature extremes confirm the likelihood of warming over the island of Grenada (Table 2-9). Trends in maximum and minimum temperatures are projected to increase under both A2 and B2 scenarios, with the greatest rate of change occurring mid to late century. The percentage of cool days and nights will also decrease under either SRES scenario, in contrast to an increase in warm days and nights.

Table 2-9: Projected changes in trends in temperature extremes for RCM grids over Grenada (12°N, 61.5°W) for the time slices 2020-2040, 2040-2060, 2060-2080, 2080-2010 and 2071-2099. Changes are relative to 1961-1989 baseline. Values in bold are statistically significant at the 95% level.

			2020-2040		2040-2060		2060-2080		2080-2100		2071-2100	
Indices	Name	Units	A2	B2	A2	B2	A2	B2	A2	B2	A2	B2
TMAXmean	Mean Monthly Maximum Temperature	°C	*0.01*	*0.02*	*0.03*	*0.04*	*0.04*	*0.01*	*0.03*	*0.02*	*0.03*	*0.01*
TMINmean	Mean Monthly Minimum Temperature	°C	*0.01*	*0.01*	*0.03*	*0.03*	*0.04*	*0.00*	*0.03*	*0.01*	*0.03*	*0.00*
TN10P	Cool Nights	% days	*-0.21*	*0.11*	*-1.00*	*-1.11*	*-1.10*	*-0.32*	*-1.33*	*-0.36*	*-0.87*	*-0.02*
TN90P	Warm Nights	% days	*0.85*	*0.82*	*1.63*	*1.30*	*1.61*	-0.05	*1.11*	*0.79*	*0.71*	*0.45*
TX10P	Cool Days	% days	*-0.46*	-0.08	*-0.62*	*-0.92*	*-0.88*	*-0.18*	*-0.64*	*-0.33*	*-0.64*	*-0.02*
TX90P	Warm Days	% days	*0.12*	*0.79*	*1.01*	*1.20*	*1.20*	*0.40*	*0.94*	*0.75*	*0.74*	*0.32*

2.6.5 Rainfall

2.6.5.1 Mean Rainfall

There is much less consensus in the projected rainfall patterns for Grenada.

GCM

Through the 2030's, the projected change in mean annual rainfall ranges from +12% to -25% dependent on model and scenario and projected changes of +6 to -41% by the 2060's (Table 2-10). Very little can be confidently said about changes in the rainy seasons due to the wide variations in the projected change, dependent on model and scenario. However, median changes are negative for all seasons, suggesting drier conditions.

Table 2-10: Projected percentage changes in annual and seasonal precipitation for GCM grids over Grenada. Changes are relative to 1970-1999.

		Projected change by the 2030s			Projected change by the 2060s		
		Min	Median	Max	Min	Median	Max
		% Change			% Change		
Annual	A2	-25	-11	6	-39	-19	0
	A1B	-20	-7	10	-41	-15	1
	B1	-23	-4	12	-37	-10	6
DJF	A2	-18	-9	11	-34	-12	9
	A1B	-23	-7	51	-24	-11	2
	B1	-19	-3	36	-25	-9	2
MAM	A2	-36	-5	13	-42	-14	14
	A1B	-48	-3	30	-64	-9	19
	B1	-17	-1	34	-56	-7	12
JJA	A2	-38	-14	3	-61	-17	5
	A1B	-34	-13	14	-62	-23	6
	B1	-36	-4	12	-62	-14	13
SON	A2	-29	-9	12	-40	-17	9
	A1B	-26	-4	21	-49	-16	4
	B1	-20	-7	7	-29	-3	6

RCM

In agreement with the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4), Table 2-11 shows a projected mean percentage decrease in precipitation. The maximum decrease in monthly average percentage values is projected to occur in dry months of January-March (14%). However, on the seasonal scale the largest decreases are seen in February-March-April (FMA) (13%). All mean monthly percentage decreases are no less than 3% for Grenada.

Table 2-11: Projected percentage change in monthly, seasonal and annual precipitation for RCM grids over Grenada relative to a 1961-1990 baseline.

		GRID BOX 1			GRID BOX 2			GRID BOX 3			GRID BOX 4			GRID BOX 5	
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
JAN	-19.781	-16.003	-12.106	-20.628	-12.692	-7.578	-16.989	-13.145	-6.010	-21.651	-14.654	-8.604	-17.865	-10.460	-4.179
FEB	-19.841	-16.079	-12.074	-20.645	-12.705	-7.549	-17.170	-13.258	-6.149	-21.731	-14.708	-8.467	-17.936	-10.514	-4.235
MAR	-19.999	-16.046	-12.023	-20.674	-12.685	-7.425	-17.516	-13.250	-5.961	-21.784	-14.683	-8.275	-17.962	-10.473	-4.043
APR	-20.009	-15.948	-11.989	-20.428	-12.556	-6.979	-17.609	-13.129	-5.847	-21.547	-14.581	-7.839	-17.621	-10.359	-3.920
MAY	-20.424	-15.949	-11.707	-20.440	-12.460	-6.536	-18.003	-13.084	-5.340	-21.655	-14.486	-7.447	-17.663	-10.232	-3.263
JUN	-20.722	-15.933	-11.355	-20.276	-12.350	-6.071	-18.503	-13.120	-5.002	-21.629	-14.394	-6.996	-17.552	-10.163	-2.859
JUL	-20.856	-15.817	-11.070	-19.515	-12.184	-6.025	-18.843	-13.183	-5.405	-21.036	-14.211	-6.911	-16.902	-10.138	-3.019
AUG	-20.841	-15.868	-11.144	-19.320	-12.138	-5.993	-18.824	-13.302	-5.843	-20.817	-14.179	-6.885	-16.562	-10.088	-3.193
SEPT	-21.025	-15.932	-11.221	-18.921	-12.190	-6.094	-18.956	-13.482	-6.349	-20.389	-14.205	-7.075	-16.199	-10.200	-3.446
OCT	-21.189	-16.014	-11.363	-19.024	-12.309	-6.190	-19.130	-13.574	-6.725	-20.305	-14.236	-7.182	-16.026	-10.304	-3.746
NOV	-21.243	-15.895	-11.296	-19.152	-11.960	-5.384	-19.178	-13.418	-6.640	-20.329	-13.881	-6.231	-15.931	-10.019	-3.225
DEC	-20.964	-15.752	-10.804	-19.071	-11.746	-5.135	-18.960	-13.306	-6.382	-20.207	-13.707	-6.294	-15.590	-9.864	-3.342
NDJ	-20.665	-15.884	-11.404	-19.619	-12.135	-6.150	-18.365	-13.291	-6.344	-20.730	-14.084	-7.049	-16.464	-10.116	-3.709
FMA	-19.950	-16.024	-12.029	-20.583	-12.649	-7.318	-17.416	-13.213	-5.986	-21.687	-14.658	-8.194	-17.840	-10.449	-4.066
MJJ	-20.667	-15.900	-11.379	-20.077	-12.332	-6.210	-18.449	-13.129	-5.249	-21.440	-14.364	-7.118	-17.372	-10.178	-3.047
ASO	-21.018	-15.938	-11.243	-19.088	-12.213	-6.138	-18.970	-13.453	-6.306	-20.504	-14.207	-7.047	-16.262	-10.197	-3.462
ANNUAL	-20.576	-15.937	-11.514	-19.842	-12.332	-6.463	-18.301	-13.271	-5.972	-21.091	-14.328	-7.352	-16.985	-10.235	-3.571

2.6.5.2 Extreme Rainfall

GCM

The proportion of annual total rainfall that falls in heavy events decreases in most model projections, changing by -12% to +8% by the 2060's (Table 2-12). Annual Maximum 1- day rainfall totals show a tendency towards remaining constant as suggested from the equal bands and zero and near-zero median values under the range of scenarios. The maximum 5-day rainfall is projected to decrease by up to 4 mm across the annual and seasonal timescales as suggested by the median change values.

Table 2-12: Projected changes in rainfall extremes for GCM grids over Grenada for the 2060's. Changes are relative to a 1970-1999 baseline.

		% total rainfall in Heavy Events (R95P)			Maximum 1-day rainfall (RX1day)			Maximum 5-day Rainfall (RX5day)		
		Min	Median	Max	Min	Median	Max	Min	Median	Max
		% Change			Change in mm			Change in mm		
Annual	A2	-10	0	5	-9	0	2	-17	-1	5
	A1B	-11	-3	8	-9	0	5	-17	-2	5
	B1	-12	0	7	-4	0	5	-18	1	7
DJF	A2	-12	-3	2	-2	0	0	-3	-2	0
	A1B	-11	-1	4	-2	0	1	-5	-2	3
	B1	-13	-1	3	-2	0	1	-5	-1	1
MAM	A2	-7	-4	9	-1	0	3	-4	0	8
	A1B	-10	-2	11	-2	0	6	-4	0	12
	B1	-14	-2	4	-4	0	3	-13	0	1
JJA	A2	-13	0	4	-8	0	1	-30	-1	4
	A1B	-10	-1	7	-6	0	4	-23	0	4
	B1	-13	0	7	-9	0	2	-30	-2	7
SON	A2	-10	-3	7	-7	0	2	-17	-1	10
	A1B	-12	-3	8	-5	0	3	-14	-4	8
	B1	-13	-4	7	-5	0	4	-13	-1	7

<u>RCM</u>

RCM projections of extreme rainfall indicate a brief mid-century increase in the amount of rainfall followed by overall drying towards late Century, though most of these trends are not significant at the 95% level (Table 2-13). Despite the likely drying trend, the number of consecutive dry days will also decrease in this time, indicating the possibility of less intense rainfall events accompanied by shorter dry spells.

Table 2-13: Projected changes in trends in rainfall extremes for RCM grids over Grenada (14°N, 61°W) for the time slices 2020-2040, 2040-2060, 2060-2080, 2080-2010 and 2071-2099. Changes are relative to 1961-1989 baseline. Values in bold are statistically significant at the 95% level.

			2020-2040		2040-2060		2060-2080		2080-2100		2071-2100	
Indices	Name	Units	A2	B2	A2	B2	A2	B2	A2	B2	A2	B2
CDD	Consecutive Dry Days	days	0.86	0.77	-0.10	0.59	0.38	0.26	-0.21	0.37	0.12	0.52
CWD	Consecutive Wet Days	days	0.48	0.06	0.55	0.13	0.41	-0.16	-0.21	-0.34	***-0.21***	-0.13
PRCPTOT	Annual Total Wet-Day Precipitation	mm	1.83	-0.15	8.25	0.31	6.13	-0.04	4.17	-2.59	-1.30	-2.31
R10	Number of Heavy Precipitation Days	days	-0.10	-0.12	0.19	0.10	0.10	-0.17	-0.06	-0.13	-0.16	-0.02
R95P	Very Wet Days	days	-0.75	-3.46	2.91	0.60	0.81	-1.77	1.21	-2.69	-1.35	-1.02
R99P	Extremely Wet Days	days	-0.10	-3.06	0.88	0.49	0.98	-0.19	1.06	-1.30	-0.48	-0.47
RX5day	Max 5-Day Precipitation Amount	mm	-0.13	-1.93	0.52	0.44	0.42	-0.02	0.17	-0.70	-0.16	-0.12

2.6.6 Wind Speed

There is a high degree of agreement on the projected changes in wind resources across the island, with mean increase of 0.14 m/s (Table 2-14). Projections indicate consistency of change in wind resources across the country.

Table 2-14: Projected changes in wind speeds for grids over Grenada for the 2030's. Changes are relative to a 1961-1990 baseline.

		GRID BOX 1			GRID BOX 2			GRID BOX 3			GRID BOX 4			GRID BOX 5	
	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
JAN	0.069	0.137	0.199	0.081	0.141	0.221	0.062	0.138	0.196	0.071	0.135	0.207	0.061	0.147	0.208
FEB	0.065	0.136	0.200	0.079	0.141	0.223	0.065	0.137	0.199	0.068	0.134	0.210	0.065	0.145	0.203
MAR	0.064	0.136	0.198	0.078	0.140	0.221	0.065	0.137	0.196	0.067	0.133	0.208	0.064	0.145	0.207
APR	0.065	0.135	0.201	0.078	0.140	0.224	0.062	0.135	0.199	0.067	0.132	0.210	0.060	0.143	0.204
MAY	0.065	0.134	0.200	0.078	0.139	0.224	0.065	0.135	0.198	0.068	0.132	0.210	0.063	0.143	0.202
JUN	0.066	0.133	0.202	0.078	0.138	0.226	0.061	0.133	0.199	0.069	0.131	0.211	0.059	0.141	0.203
JUL	0.066	0.132	0.201	0.078	0.137	0.226	0.060	0.132	0.198	0.068	0.129	0.211	0.057	0.139	0.202
AUG	0.067	0.131	0.203	0.078	0.137	0.228	0.060	0.131	0.200	0.068	0.129	0.212	0.057	0.138	0.204
SEPT	0.068	0.131	0.204	0.079	0.137	0.229	0.062	0.131	0.201	0.069	0.129	0.213	0.059	0.138	0.206
OCT	0.066	0.130	0.207	0.078	0.137	0.230	0.061	0.130	0.204	0.068	0.128	0.216	0.058	0.136	0.208
NOV	0.068	0.132	0.213	0.079	0.138	0.234	0.059	0.131	0.211	0.070	0.129	0.221	0.055	0.138	0.216
DEC	0.067	0.133	0.212	0.079	0.138	0.234	0.057	0.132	0.209	0.069	0.130	0.220	0.054	0.139	0.214
NDJ	0.068	0.134	0.208	0.080	0.139	0.230	0.059	0.134	0.206	0.070	0.131	0.216	0.057	0.141	0.210
FMA	0.065	0.136	0.200	0.078	0.140	0.223	0.064	0.136	0.198	0.068	0.133	0.209	0.063	0.144	0.204
MJJ	0.066	0.133	0.201	0.078	0.138	0.226	0.062	0.133	0.198	0.068	0.131	0.211	0.060	0.141	0.203
ASO	0.067	0.131	0.205	0.078	0.137	0.229	0.061	0.130	0.202	0.068	0.128	0.214	0.058	0.137	0.206
ANNUAL	0.066	0.133	0.203	0.079	0.139	0.227	0.062	0.134	0.201	0.069	0.131	0.212	0.059	0.141	0.205

2.6.7 Tropical Cyclone Activity

2.6.7.1 Current trends in North Atlantic tropical cyclone activity

Intensity measures in historical records are especially sensitive to changing technology and improving methodology. Over the satellite era however, increases in the intensity of the strongest storms in the Atlantic have been quite robust (Kossin et al., 2007; Elsner et al. 2008). Time series of cyclone indices such as power dissipation show upward trends in the North Atlantic since the late 1970s (Emanuel, 2007), but interpretation of longer-term trends is constrained by data quality concerns (Landsea et al., 2012). The Intergovernmental Panel on Climate Change's AR5 Report notes that evidence suggests a virtually certain increase in the frequency and intensity of the strongest cyclones in the Atlantic since the 1970s. Wu et al. (2008) suggest that the magnitude of the statistically significant linear trend in PDI over 1975-2004 is 0.024 m3 s-3 year-1. It is further noted that the average lifetime of North Atlantic tropical cyclones shows an increasing trend of 0.07 day year-1 for the same period which is statistically significant. The variability and trend in power dissipation can be related to sea surface temperature and other local factors such as tropopause temperature and vertical wind shear (Emanuel, 2007), but there is debate to whether local sea surface temperature or the difference between local sea surface temperature and mean tropical sea surface temperature is the more physically relevant metric (Swanson, 2008). The distinction becomes important when making projections of changes in power dissipation based on projections of SST changes, particularly in the tropical Atlantic where SST has been increasing more rapidly than in the tropics as a whole (Vecchi et al., 2008). ACE has shown declines globally since reaching a high point in 2005, and is currently at a 40 year low point (Maue, 2009) (IPCC SREX 2012).

2.6.7.2 Grenada

Landfalling hurricanes are taken to be hurricanes passing within a 100-km radius of Grenada. The historical trend suggest an increase in the number of hurricanes making landfall in Grenada. The 10-year running mean indicates a period of increased hurricane activity beginning in the year 2000 (Figure 2-14). However, at this scale, there are no discernible patterns in TC activity can be concluded. A closer look at the index reveals that recent peaks in TC activity are on account of increases in major hurricanes (Figure 1.2). There is a sharp increase in the number of Category 4 and 5 hurricanes starting in 2002, signifying an increase in the more intense storms. The records indicate a small increase in Category 1 storms, but a decline in Category 2 and Category 3 hurricanes.

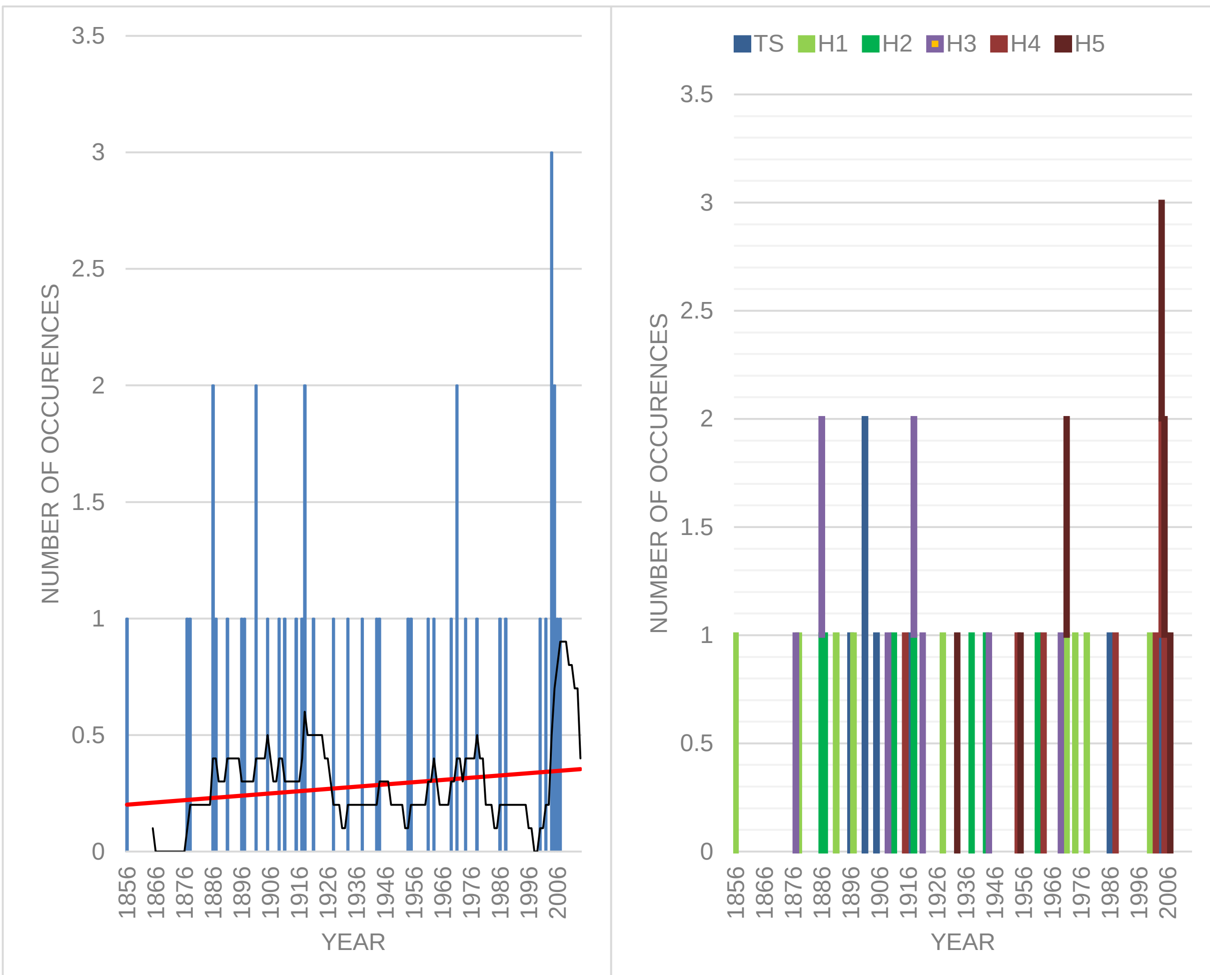


Figure 2-14: The annual number of tropical cyclones passing within a 100-km radius from Grenada's centre from 1856 to 2012. The red line indicates the linear trend in the data and the solid black line indicates the 10-year running mean. The colour codes indicate the number of occurrences of each storm category (TS = tropical storms, H1 = hurricane 1, H2 = hurricane 2, H3 = hurricane 3, H4 = hurricane 4, H5 = hurricane 5).

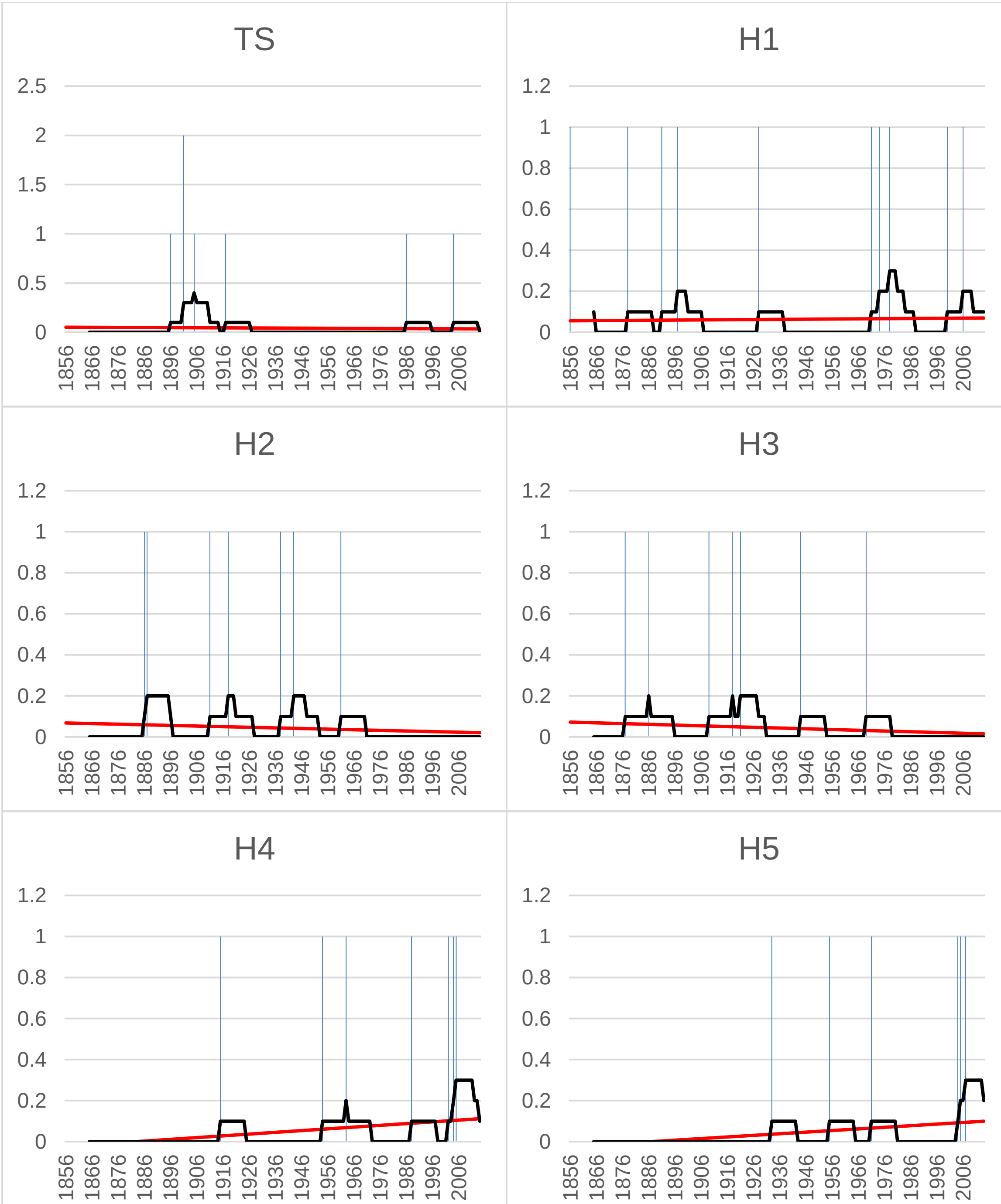


Figure 2-15: Annual number of occurrences of each category of storm. The red line indicates the linear trend across the time series and the solid balck line indicates the trend of the 10-year running mean.

2.6.7.3 Projections of trends in tropical cyclone frequencies and intensities

The AR4 concluded that a range of modelling studies project a likely increase in peak wind intensity and near storm precipitation in future tropical cyclones. Simulations with high resolution dynamical models (e.g. Oouchi et al., 2006; Bengtsson et al., 2007; Gualdi et al., 2008; Knutson et al., 2008; Sugi et al., 2009; Bender et al., 2010) and statistical-dynamical models (Emanuel, 2007) consistently find that greenhouse warming causes tropical cyclone intensity to shift towards stronger storms by the end of the 21st Century (2 to 11% increase in mean maximum wind globally).

Applying 21st Century sea surface temperature projections to a relationship between local SST and tropical cyclone power dissipation (constructed by Emanuel, 2007), power dissipation is projected to increase by about 300% in the next Century (Vecchi et al., 2008; Knutson et al., 2010). Alternatively, when using a similar strong relationship between power dissipation and relative SST (which represents the difference between local and tropical mean SST), projections indicate almost no change in power dissipation in the next Century (Vecchi et al., 2006). Both relationships can be reasonably defended based on physical arguments, but it is not clear which, if either, is current (Ramsay and Sobel, 2011).

When simulating 21st Century warming under the A1B SRES scenario, the present models and downscaling techniques suggest increases in intensity and fractional increases in the number of most intense storms. The frequency of the most intense storms is very likely to increase by more than +10% (IPCC 2013, AR5), while the annual frequency of tropical cyclones is projected to decrease or remain relatively unchanged for the North Atlantic (See Figure 2-16). Of concern, however, is the limited ability of global models to accurately simulate upper-tropospheric wind (Cordero and Forster, 2006), which modulates vertical wind shear and tropical cyclone genesis and intensity evolution.

Knutson et al. (2013) conclude that there is likely to be an increase in radius-averaged precipitation rainfall rates near the hurricane core. The conclusion follows from an expected increase in atmospheric water-vapour content, and thus an increase in moisture convergence that results in convective systems, such as hurricanes. Increases of approximately 20% are projected for radii within 100km from the hurricane core. However, identifying an accurate quantification of positive changes for smaller radii has proven difficult due to complex dynamics near the centre of the hurricane (Knutson et al., 2010).

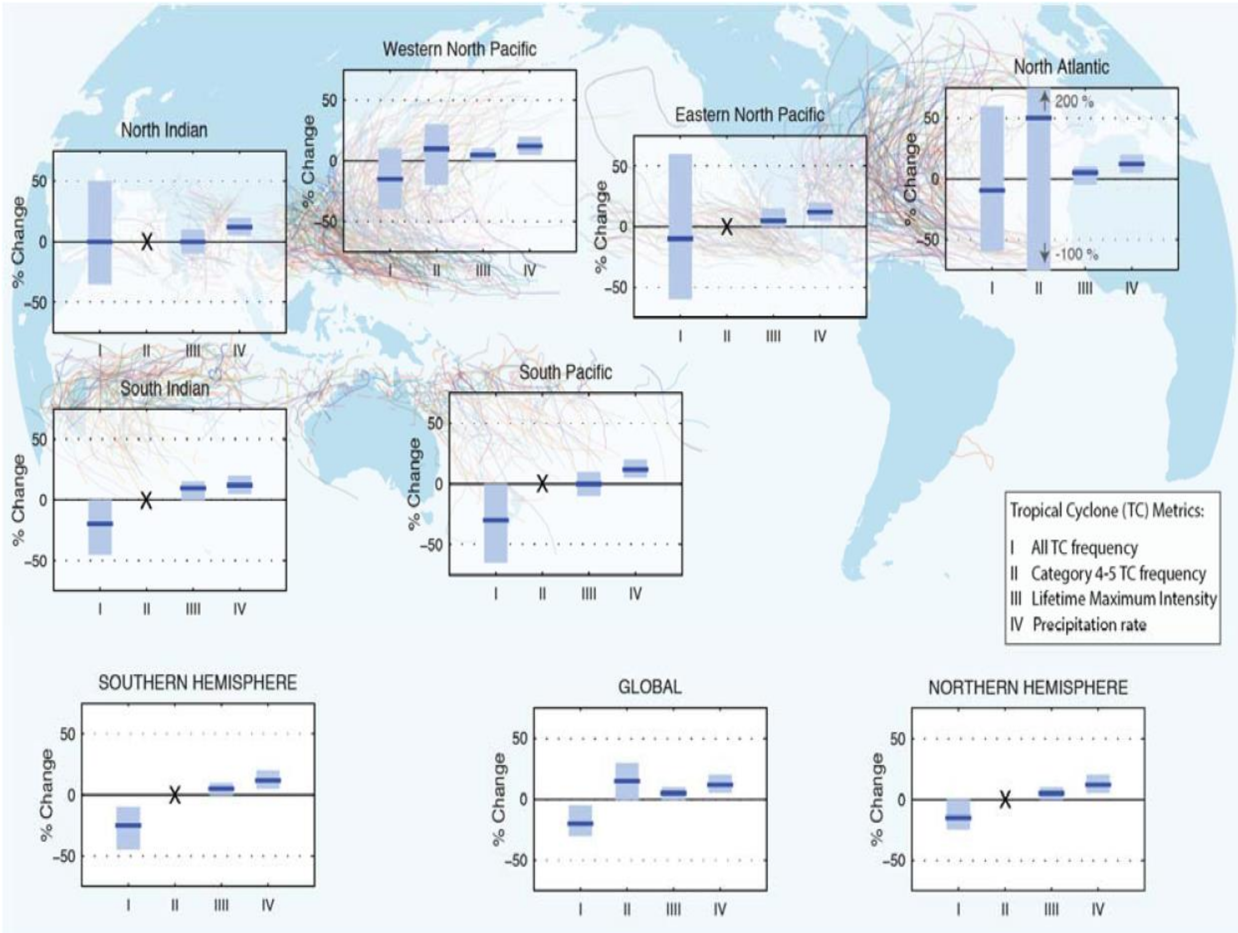


Figure 2-16: Projected changes in tropical cyclone statistics. All values represent expected change in the average over period 2081-2100 relative to 2000-2019, under an A1B-like scenario, based on expert judgement after subjective normalisation of the model projections. Four metrics were considered: the percent change in I) the total annual frequency of tropical storms, II) the annual frequency of Category 4 and 5 storms, III) the mean Lifetime Maximum Intensity (LMI; the maximum intensity achieved during a storm's lifetime), and IV) the precipitation rate within 200km of storm centre at the time of LMI. For each metric plotted, the solid blue line is the best guess of the expected percent change, and the coloured bar provides the 67% (likely) confidence interval for this value (note that this interval ranges across -100% to +200% for the annual frequency of Category 4 and 5 storms in the North Atlantic). Where a metric is not plotted, there is insufficient data (denoted "X") available to complete an assessment. A randomly drawn (and coloured) selection of historical storm tracks are underlaid to identify regions of tropical cyclone activity. Source: IPCC AR5.

2.6.8 Sea Level Rise

Global sea levels rose through the 20th Century. The rising levels are expected to accelerate through the 21st century and beyond because of warming temperatures, but their magnitude remains uncertain. Key uncertainties include the possible role of the Greenland and West Antarctic ice sheets and the amplitude of regional changes in sea level. In many areas, non-climatic components of relative sea level change (mainly subsidence) can also be locally appreciable. Cooper and Pilkey (2004) suggest that factors that cause changes in the morphology of coasts are numerous and include sediment supply, variations in wave energy, tidal currents, wind action, sediment type, tidal inlet dynamics, morphological feedback, etc. Therefore isolating the influence of sea level rise (SLR) from these other factors is perhaps the biggest challenge in discerning the impact of sea level rise.

2.6.8.1 Causes

Two main factors contribute to SLR: (i) thermal expansion of sea water due to ocean warming; and (ii) water mass input from land ice melt and land water reservoirs. Thermal expansion is the physical response of the water mass of the oceans to atmospheric warming. Ocean temperature data collected during the past few decades indicate that ocean thermal expansion has significantly increased during the second half of the 20th Century. Thermal expansion accounts for about 25% of the observed SLR since 1960 (Domingues et al., 2008) and about 50% from 1993 to 2003 (for e.g. IPCC, 2007; Nicholls and Cazenave, 2010). Ice sheets have the largest potential effect, because their complete melting would result in a global sea level rise of about 70 m. Yet their dynamics are poorly understood, and the key processes that control the response of ice flow to a warming climate are not included in current ice sheet models. The interplay of these factors and their action on different timescales makes understanding of global sea level rise dynamics very difficult.

The mechanism of thermal expansion can be gauged relatively accurately through an analysis of global temperatures and their rate of increase through GCMs. However, there is a great uncertainty in predicting the melting rate of the ice sheets and ice caps. Analysis of observed data suggests that the decay rate of ice sheets is non-linear. Simpson et al. (2009) further highlights that prior rapid collapses of ice sheets bear no correlation, whether contemporaneous or lagged, to any climate forcing that may have triggered them.

2.6.8.2 Current Trends

Global

Using proxy and instrumental data, it is virtually certain (i.e. with 99-100% probability) that the rate of global mean sea level rise has accelerated during the last two centuries, marking the transition from relatively low rates of change during late Holocene (order tenths of mm yr-1) to modern rates (order mm year-1). Rates and absolute changes in global mean sea level pressure are shown in Table 2-15

Table 2-15: Rates and absolute change in mean sea level rise. Rates are obtained from IPCC (2013).

PERIOD	RATE (MM YR^{-1})	TOTAL SEA LEVEL RISE	IPCC LIKELIHOOD
1901 – 2010	1.7 ± 0.2	0.19 ± 0.02	Very likely
1971 – 2010	2.0 ± 0.2	-	Very likely
1993 – 2010	3.2 ± 0.4	-	Very likely

Tide-gauge and satellite altimeter data both reflect the rate represented in the 1993-2010 period. It is likely that rates similar to this period also occurred between 1930 and 1950. It is also likely that global mean sea level has accelerated since the early 1900s, with estimates ranging from 0.000 to 0.013 [-0.002 to 0.019] mm yr-2 (IPCC, 2013). Accelerations in the rate of increase over the 20th century have been detected in most regions. See for example Woodworth et al. (2009), and Church and White (2006).

Caribbean

Estimates of observed sea level rise from 1950 to 2000 suggest that sea level rise within the Caribbean appears to be near the global mean. Table 2-16 shows the minimum, maximum and mean sea level changes for the Caribbean states over the period 1992-2012. Table 2-17 shows the rates of sea-level rise for a number of locations in the Caribbean. All values from both tables suggest an upward trend in Caribbean sea-level rise, with the exception of the Bahamas. It is important to note, that due to shifting surface winds, expansion of warming ocean water and the addition of melting ice, ocean currents can be altered, which in turn leads to changes in sea level that vary from place to place. Additionally, more localized processes such as sediment compaction and tectonics may also contribute to additional variations in sea level.

Table 2-16: Minimum, maximum and mean sea level rise trends per CARICOM country (mm yr^{-1} as modelled by AVISO based on Topex/Poseidon data). Source: Chatenoux and Wolf (2013).

COUNTRY	MIN (MM YR^{-1})	MAX (MM YR^{-1})	MEAN (MM YR^{-1})
Antigua and Barbuda	2.5	2.8	2.8
Bahamas	-1.8	0.8	-0.5
Belize	0.7	1.4	1.0
Barbados	2.5	2.6	2.5
Dominica	1.9	2.1	2.0
Grenada	**2.8**	**3.0**	**2.9**
Guyana	3.3	4.2	3.6
Haiti	-0.5	0.6	0.0
Jamaica	0.0	1.1	0.8
Saint Kitts and Nevis	2.5	2.7	2.6
Saint Lucia	2.2	2.4	2.3
Montserrat	2.7	2.7	2.7

COUNTRY	MIN (MM YR^{-1})	MAX (MM YR^{-1})	MEAN (MM YR^{-1})
Suriname	3.3	4.1	3.6
Trinidad and Tobago	2.8	3.7	3.4
Saint Vincent and the Grenadines	2.6	2.8	2.7

Table 2-17: Observed rates of sea level rise for some Caribbean stations. Source: The State of the Jamaican Climate (2013).

Tidal gauge Station	Observation Period	Rates (mm yr^{-1})
Bermuda	1932 –2006	2.04 ± 0.47
San Juan, Puerto Rico	1962 –2006	1.65 ± 0.52
Guantanamo Bay, Cuba	1973 –1971	1.64 ± 0.80
Miami Beach, Florida	1931 –1981	2.39 ± 0.43
Vaca Key, Florida	1971–2006	2.78 ± 0.60

2.6.8.3 Projected Trends

Global and Caribbean

Estimates of future global mean sea level were obtained from observations and GCM results reported by IPCC Working Group1 for IPCC Fourth and Fifth Assessment Reports (IPCC 2007, IPCC 2013). According to the Fourth Assessment Report by the end of the Century, sea levels are also expected to rise by 0.21m to 0.48m under an A1B (medium emissions) scenario or by 0.26-0.59 m under the highest emissions scenario, A1F1, but the models exclude future rapid dynamical changes in ice flow. One study suggests that the rate of rise may actually double as noted for A1B (Science Daily, Feb. 12, 2008).

Higher projections of sea-level rise are noted in the IPCC Fifth Assessment Report (AR5) in comparison to the Fourth Assessment Report (AR5). This is considered to be primarily due to the improved modeling of land-ice contributions. There is also higher confidence in the projections of sea-level rise in the latter report due to improved understanding of the components of sea level, improved agreement of process-based models with observations, and the inclusion of ice-sheet dynamical changes. Projections and Graph are shown below. In the RCP projections, thermal expansion accounts for 30 to 55% of the 21st century global mean sea level rise, and glaciers for 15 to 35%. AR5 notes, that the basis for higher projections of global mean sea level was considered, but it was concluded, that there is currently insufficient evidence to evaluate the probability of specific levels above the assess likely rate. Finally, the point is made in AR5 that sea-level rise will not be uniform. It is very likely, that sea level will rise in more than about 95% of the ocean area. Approximately 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change.

It is useful to note, that for the SRES A1B which was assessed in AR4, the likely range bases on the science assessed in the AR5 is 0.60 [0.41-0.79] m by 2100 relative to 1986-2005 and 0.57 [0.40-0.75] m by 2090-2099 relative to 1990. Compared with the AR4 projection of 0.21-0.48 m for the same scenario and period, the largest increase is from the inclusion of rapid changes in Greenland and Antarctic ice-sheet outflow.

Table 2-18: Projected increases in global mean surface temperature and global and Caribbean mean sea level from the IPCC (2007) contrasted with those of Rahmstorf (2007). Projections are by 2100 relative to 1980-1999. Source: CARIBSAVE Climate Change Risk Atlas – Jamaica (2011).

Scenario	Global mean surface temperature (°C)	Global mean sea level rise (m)	Caribbean mean sea level rise (±0.05 m) relative to global mean
IPCC B1	1.1 – 2.9	0.18 – 0.38	0.14 – 0.43
IPCC A1B	1.7 – 4.4	0.21 – 0.48	0.16 – 0.53
IPCC A2	2.0 – 5.4	0.23 – 0.51	0.18 – 0.56
Rahmstorf, 2007	-	Up to 1.4 m	Up to 1.4 m

Table 2-19: Projected increases in global mean surface temperature and global mean sea level. Projections are taken from IPCC (2013) and are relative to 1986-2005.

		2046 – 2065		2081 – 2100	
Variable	Scenario	Mean	Likely range	Mean	Likely range
Global Mean Surface Temperature Change(°C)	RCP2.6	1.0	0.4 – 1.6	1.0	0.3 – 1.7
	RCP4.5	1.4	0.9 – 2.0	1.8	1.1 – 2.6
	RCP6.0	1.3	0.8 – 1.8	2.2	1.4 – 3.1
	RCP8.5	2.0	1.4 – 2.6	3.7	2.6 – 4.8
Variable	Scenario	Mean	Likely range	Mean	Likely range
Global Mean Sea Level Rise (m)	RCP2.6	0.24	0.17 – 0.32	0.40	0.26 – 0.55
	RCP4.5	0.26	0.19 – 0.33	0.47	0.32 – 0.63
	RCP6.0	0.25	0.18 – 0.32	0.48	0.33 – 0.63
	RCP8.5	0.30	0.22 – 0.38	0.63	0.45 – 0.82

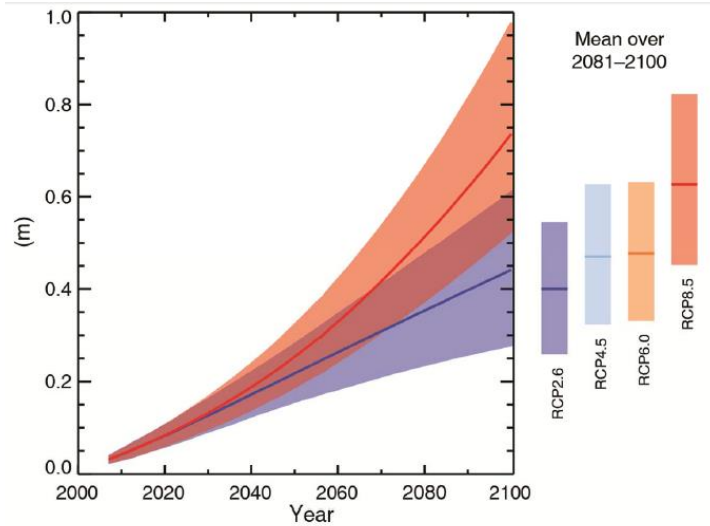


Figure 2-17: Projections of global mean sea level rise over the 21st century relative to 1986–2005 from the combination of the CMIP5 ensemble with process-based models, for RCP2.6 and RCP8.5. The assessed *likely* range is shown as a shaded band. The assessed *likely* ranges for the mean over the period 2081–2100 for all RCP scenarios are given as coloured vertical bars, with the corresponding median value given as a horizontal line.

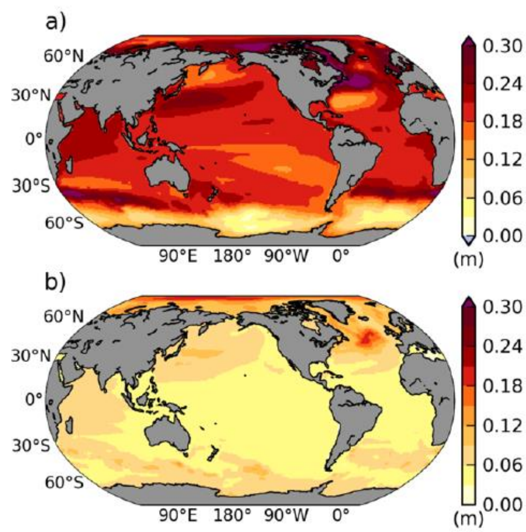


Figure 2-18: (a) Ensemble mean projection of the time-averaged dynamic and steric[2] sea level changes for the period 2081–2100 relative to the reference period 1986–2005, computed from 21 CMIP5 climate models (in m), using the RCP4.5 experiment. The figure includes the globally averaged steric sea level increase of 0.18 ± 0.05 m. (b) RMS spread (deviation) of the individual model result around the ensemble mean (m). Source: IPCC AR5.

[2]The term 'steric' pertains to the temperature, salinity and pressure dependent specific volume of the ocean. (Lauderer et al. 2006)

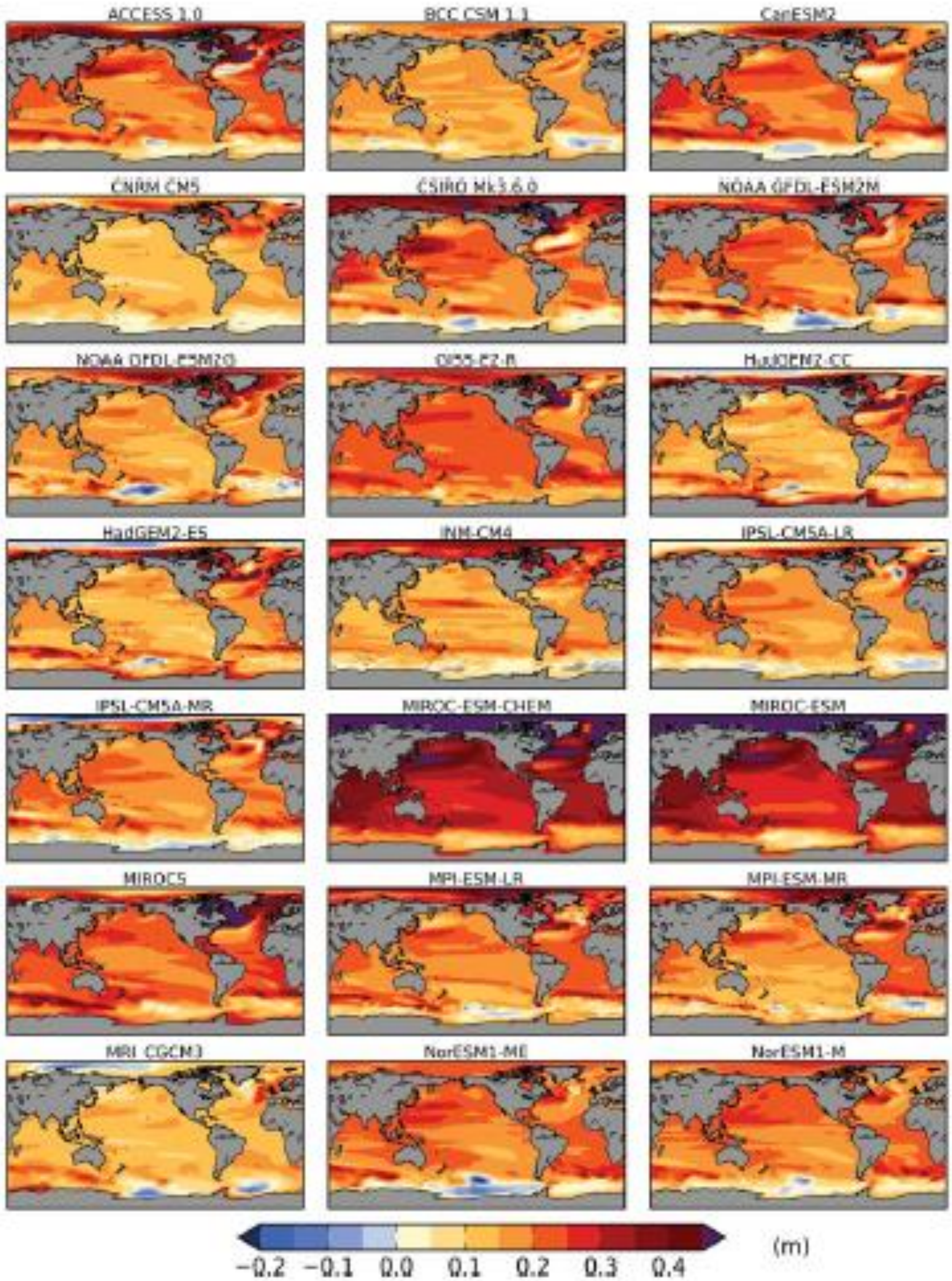


Figure 2-19: Projected relative sea level change (in m) from the combined global steric plus dynamic topography and glacier contributions for the RCP4.5 scenario over the period from 1986–2005 to 2081–2100 for each individual climate model used in the production of Figure 2.2 Source: IPCC AR5.

2.7 Summary

The following are some of the main points that may be noted:

Section 1

- Grenada has experienced fluctuation in rainfall levels in past decades, along with a change in rainfall pattern through the year.
- Annual mean maximum and minimum temperatures at the Maurice Bishop International Airport exhibit a statistically significant warming trend.
- Estimates of observed sea-level rise from 1950 to 2000 suggest that sea-level rise within the Caribbean appears to be near the global mean (2.0 ± 0.2 mm/year for 1971-2010).

Section 2

- The annual mean temperature of Grenada is projected to increase irrespective of scenario, model or methodology used.
- GCMs suggest that the mean annual temperature over Grenada will increase by 0.3 to 1.6˚C by the 2030s and 0.7 to 2.6˚C by the 2060s relative to 1970-99.
- The PRECIS RCM projects that warming will occur at a faster rate in the south of the island than in the north by the 2030's.
- Annual maximum temperature is projected to increase by an average of 0.6°C to 1.3°C across the island in the near term. The annual minimum temperature is expected to increase by 0.6° to 1.3°C.
- September-October and December-January are common periods for which strongest warming is projected across GCM and RCM.
- An increase in the frequency of warm days and warm nights and decrease in cool days and cool nights is projected by both GCM and RCM and across scenarios for near and long term time slices.
- Through the 2030's, median changes in rainfall projections deduced from GCMs are all negative, which may suggest drier conditions.
- RCM ensemble mean suggest decreases in annual rainfall by greater than 3%.
- The proportion of annual total rainfall that falls in heavy events decreases in most GCM projections, changing by -12% to +8% by the 2060's. Annual maximum 1- day rainfall totals show a tendency towards remaining constant while the maximum 5-day rainfall is projected to decrease by up to 4 mm across the annual and seasonal timescales.
- Consistent with the GCM projections, the PRECIS RCM suggests a decrease in rainfall intensity towards the end of the century. The RCM, however, suggests that this decrease in rainfall intensity may be accompanied by a decrease in mean dry spell length.
- RCM ensemble means suggest an increase in wind speeds annually by up to 0.06 m/s
- Hurricane intensity over the north tropical Atlantic is likely to increase (as indicated by stronger peak winds and more rainfall) but not necessarily hurricane frequency.
- Caribbean sea levels are projected to rise by up to 0.24 m by mid-century under the A1B scenario.

3 WATER SECTOR VULNERABILITY ISSUES AND THREATS

This section of the report presents the existing hydrology and water resource challenges and discusses how climate change will impact it. Some brief descriptions of the main geological, hydro-geological and hydrological features of Grenada, Carriacou and Petit Martinique are presented as important considerations in the water sector. These provide some background information for the assessment of the water sector vulnerabilities to climate change. The other subsections deal with water quality, supply and demand, and vulnerabilities of the water sector to existing climate change.

3.1 Hydrological and Water Resource Characteristics of Grenada, Carriacou and Petit Martinique

3.1.1 Topography and Drainage of Grenada

The elevation of Grenada varies from 809m in the central highlands to 0m along the coast (Figure 3-1). The island is characterized by a central ridge which marks the watershed divide for the watersheds in the east and the west. The central ridge trends from the north east to the south west and is marked by the location of the Grand Etang Crater Lake. The central highland is the origin of the major drainage channels which flow from there and drain towards the sea. Thomas (2004) also identifies the presence of mountainous peaks, steep ridges and deep, narrow valleys.

Generally, the western side of the island is more rugged as the ridge is nearer to the coast here. The slopes are gentler to the east, and there are some extensive coastal plains. The northeast and southwest parts of the island are marked by the presence of low hills. About ten percent of the land surface comprises slopes below 10%; twenty percent between 10 - 20%; forty five percent between 21 - 30% and twenty five percent of the land area consists of slopes in excess of 30% (Thomas, 2004). As a result of the steep slopes, heavy rainfall leads to excess runoff from the central ridge causing flooding in the lowland areas along the coast.

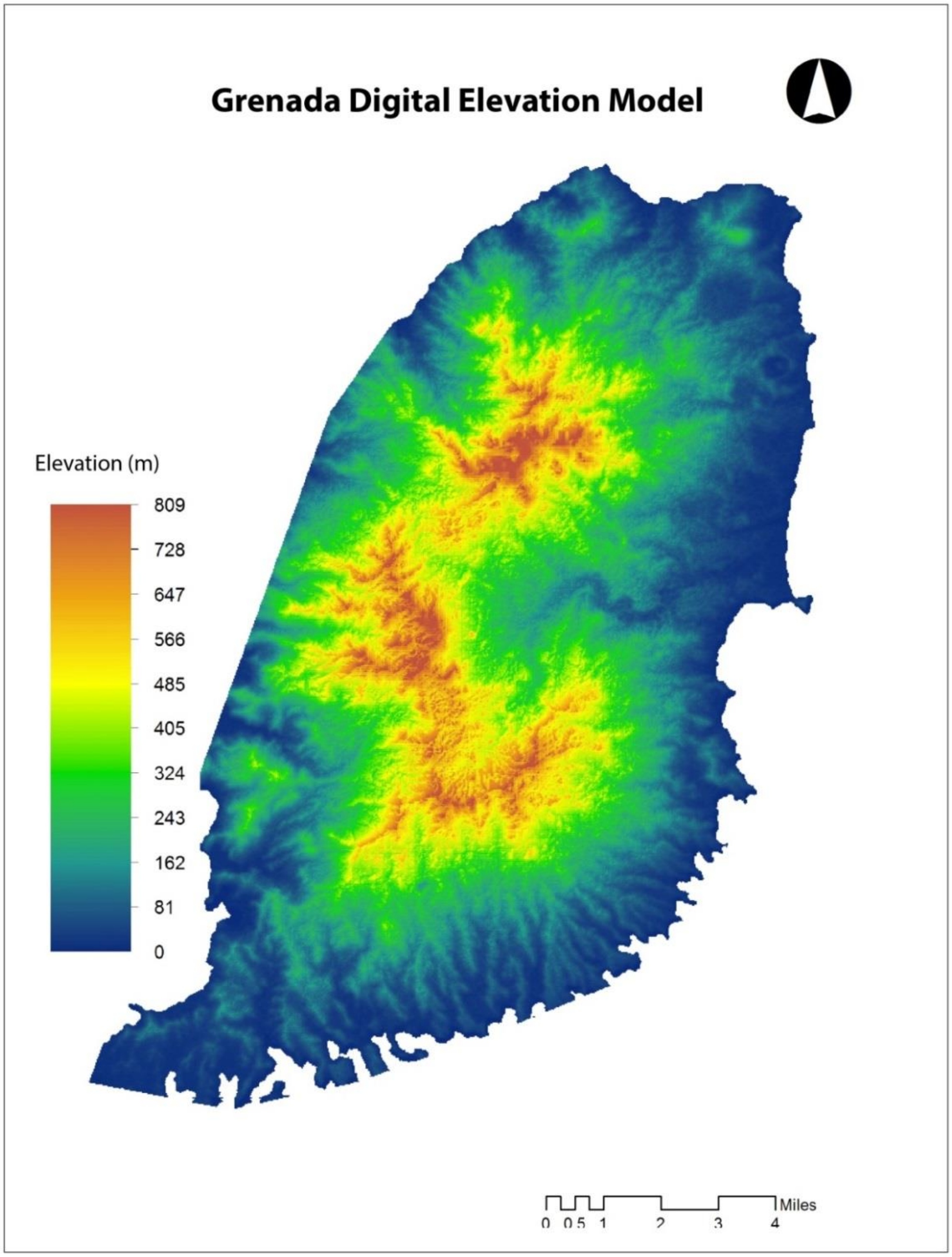


Figure 3-1: Digital Elevation Model for Grenada. Source: ASTER, Earth Explorer. USGS

The DEM was used to create the watershed model for the island using the ARC Hydro operating tool in ARC GIS, which extracts the watersheds and the drainage lines based on the flow direction and flow accumulation grid derived from the DEM. In most cases, the drainage lines extracted from the DEM corresponded with major, existing river networks, but the density from DEM is less than the existing river channels. A similar result, occurred in the case of the number of catchments extracted from the DEM. Results showed a maximum of 290 outlined catchments around the DEM derived drainage channels

(Figures 3-3 and 3-4). This figure is more than the actual number of watersheds in Grenada which are 71 in number, as derived from data from Ministry of Agriculture. Catchments of smaller size were also identified. Drainage lines that displayed the same points of convergence (drainage points) were normally merged to create a wider area catchment. As can be seen from Figure 3-3, the central ridge or highland is the source of the drainage network flows from the ridge to the coastal areas. Most of the drainage points which are points of convergence of river systems are in areas of low elevation and along the coastlines. Therefore, based on the topography it can be concluded that high runoff from rainfall associated with tropical storms and hurricanes would result in flooding in the watersheds of the lowland areas.

Since Grenada is a volcanic island, surface runoff will be greater than infiltration due to the presence of non-porous, impermeable soil. Hence, the vulnerability to flooding and landslides are higher for watersheds of medium to low elevation. This will be further discussed in later sections along with the spatial variability of rainfall, soil and land use.

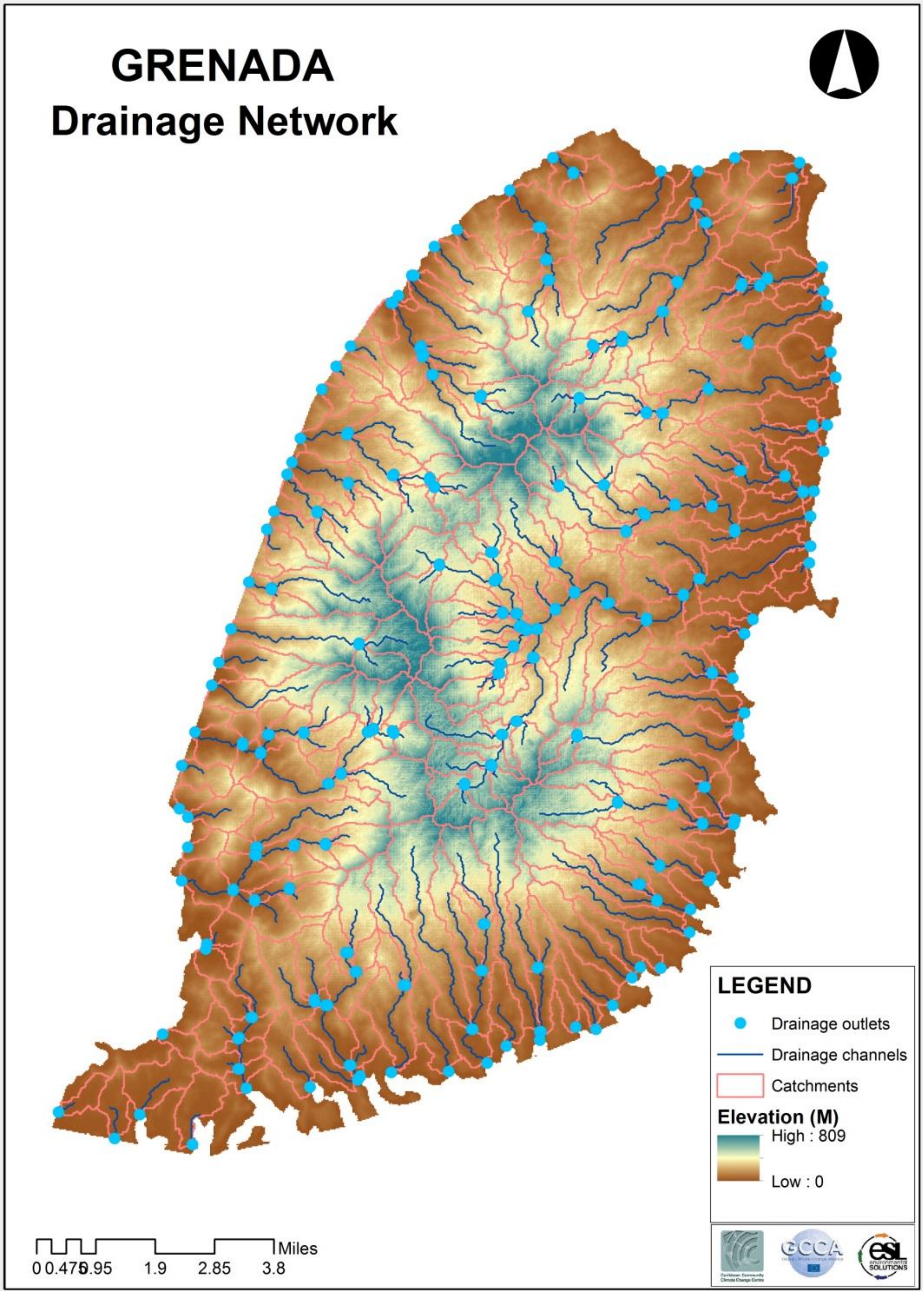


Figure 3-2: Digital Elevation Model for Grenada along with the drainage lines, drainage points and catchments as extracted from the DEM. Source: ASTER , Earth Explorer, USGS

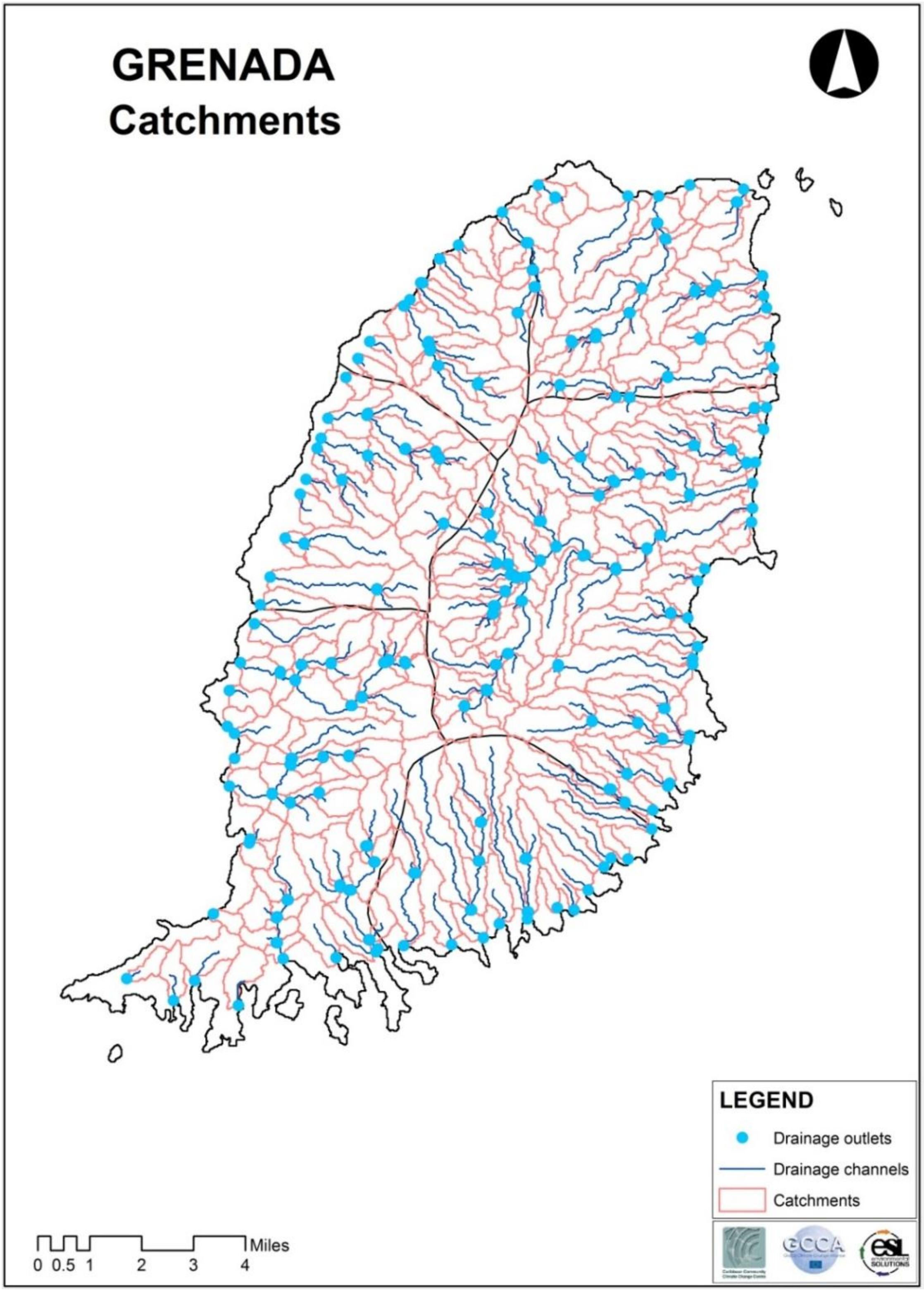


Figure 3-3: Map showing the drainage lines, drainage points and catchments as extracted from the DEM. Source: ASTER, Earth Explorer. USGS

3.1.2 Topography and drainage of Carriacou and Petit Martinique

The island of Carriacou is located 24 kilometres to the north east of Grenada and has an area of 34 square kilometres (13 square miles). The island is rugged with three dormant peaks- High North (291 m), Top Hill (236 m) and Chapeau (291 m). As in Grenada, the topography of Carriacou was derived from the ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer). Elevation ranges from sea level to 297m. The island is characterized by a central NW- SE trending ridge which is the source of the river system. The drainage lines for Carriacou were extracted from the DEM using the same procedure discussed in the previous section (Figure 3-4).

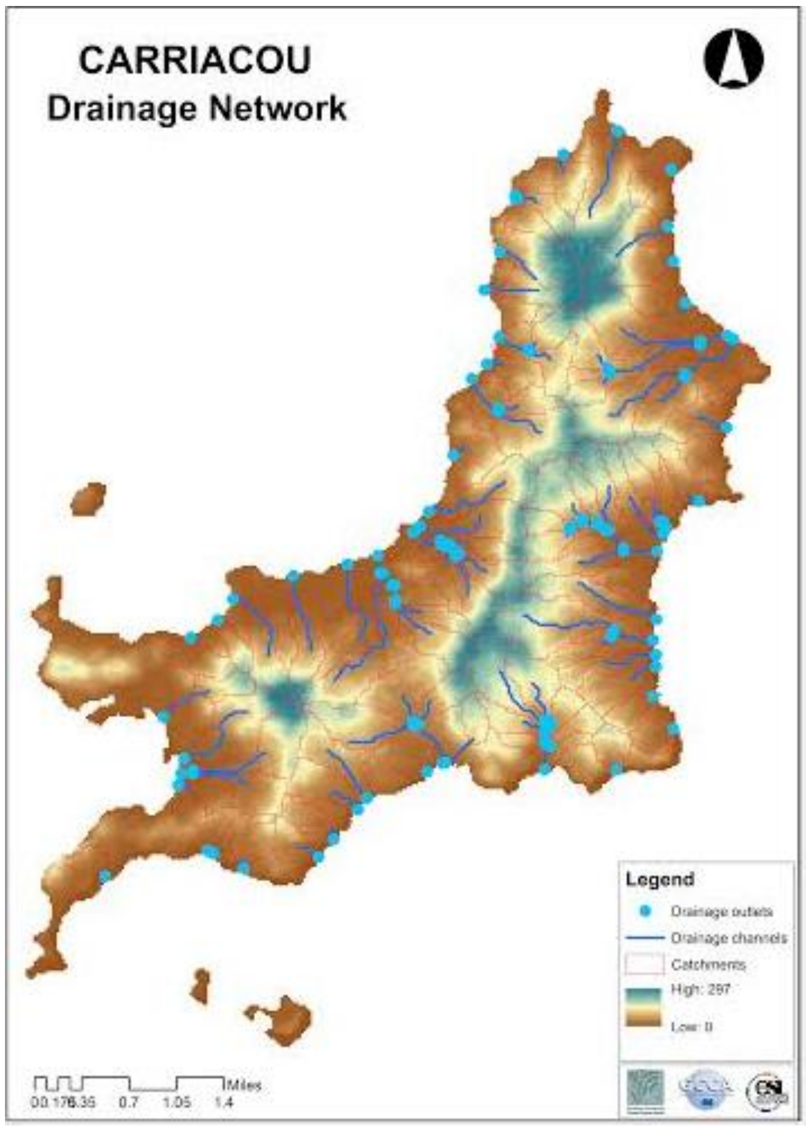


Figure 3-4: Digital Elevation Model for Carriacou showing the drainage channels, catchments and drainage points. Source: ASTER, Earth Explorer. USGS (http://gdex.cr.usgs.gov/gdex/).

The island has a radial drainage pattern with rivers originating in the central highlands and draining towards the coast. This pattern is similar to Grenada's network. The watersheds in lowland areas are vulnerable to erosion and flooding from high runoff along steep slopes. The latter is further facilitated by the presence of impermeable rock surfaces which causes surface drainage rather than high infiltration. Surface water is the main water source in Carriacou with only 5 groundwater wells present on the entire island.

Petit Martinique is 2 ½ miles away from Carriacou with an area of 0.9 square miles. It is volcanic in origin with a cone shape. From the coastline, the land rises smoothly to an elevation of 257 feet, at Sugar Hill in the north and 738 feet at Piton in the south. The drainage pattern follows the natural land form into gullies and ravines. There are no rivers. Not much more data is available on Petit Martinique.

3.1.3 Rainfall Pattern for Grenada

The orographic effect is significant to rainfall in Grenada with the hilly inland areas recording higher rainfall than the coastal areas. This also results in drier areas in the northern and southern sections of the island. Figure 3-5 shows the annual rainfall pattern for the island created from station data reported in the Government of Grenada's Road Map towards Integrated Water Resource Management Planning for Grenada (2007).

Annual rainfall for Grenada varies from 1000mm along the coast to as high as 4600mm or more in the central highlands. Figure 3-5 shows that spatial variability of rainfall as higher on the western side of the island when compared to the east. In examining Figure 3-3, there is also a higher density of drainage lines near to the central section of the island which coincides with the areas of high rainfall.

The UN DESA (2012) report also applied the Theissen method to show the monthly rainfall pattern for certain sections of the island. Results showed that the average, annual, areal rainfall for the northern part of Grenada was estimated at 2,230mm while the average for Levera, River Antoine Estate and Marli were 1,324 mm, 1,500 mm and 1,660 mm, respectively, for the period 2000-2010. Rainfall at Grand Etang and Levera showed a bimodal pattern with a significant peak in the months of September –October and another peak in the month of June, early in the rainy season. The month of January also experiences relatively high rainfall, which corresponds to the winter rains that sometimes affect the Lesser Antilles, causing extensive flooding.

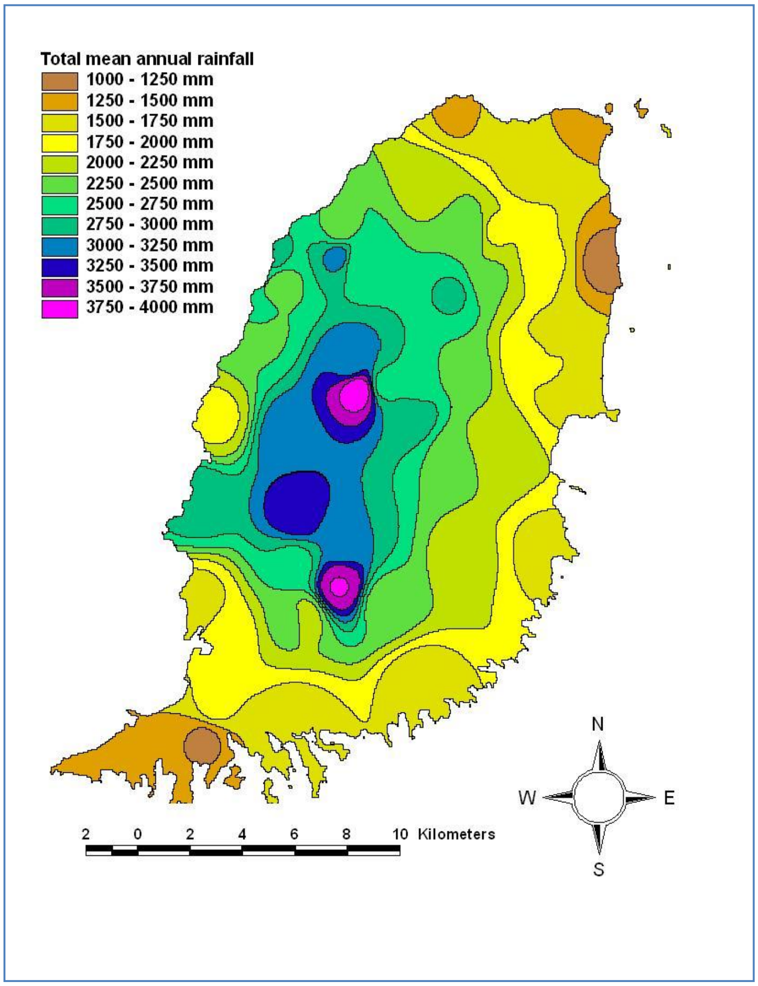


Figure 3-5: Mean annual rainfall on mainland Grenada. Source: Land Use Division, Ministry of Agriculture, cited in the Government of Grenada's Road Map towards Integrated Water Resource Management Planning for Grenada (2007)

For this study, rainfall data was obtained from eight gauging stations across the island (Figure 3-6). All of the rain gauge stations, except for CARDI and MBIA, are located in areas of medium to high elevation. The list of the stations and their available data from the Meteorological Service of Grenada is shown below:

- Maurice Bishop International Airport (MBIA): daily rainfall data from 1986-2010;
- Mt Home : Monthly total from 1953-2013;
- Grand Etang Forestry : Monthly total from 1987-2013;
- Grand Etang National Park: Monthly total from 1927-1959 and from 1987-2013. Gap in data from 1960 -1986;
- Anandale: Monthly total from 1941-1959 and from 1985-2013. Data gap from 1960-1984;
- Vendomme: Monthly total from 1992-2013;
- Paradise: Monthly total from 1986-2013;
- Maribeau: Monthly total from 1961 – 2013;

- Marli: Monthly total from 1941 – 1959 and from 1991 – 2013. Data gap from 1960 – 1990;
- Clozier: Monthly total from 1990 -2013;
- CARDI: Monthly total from 1984-2010.

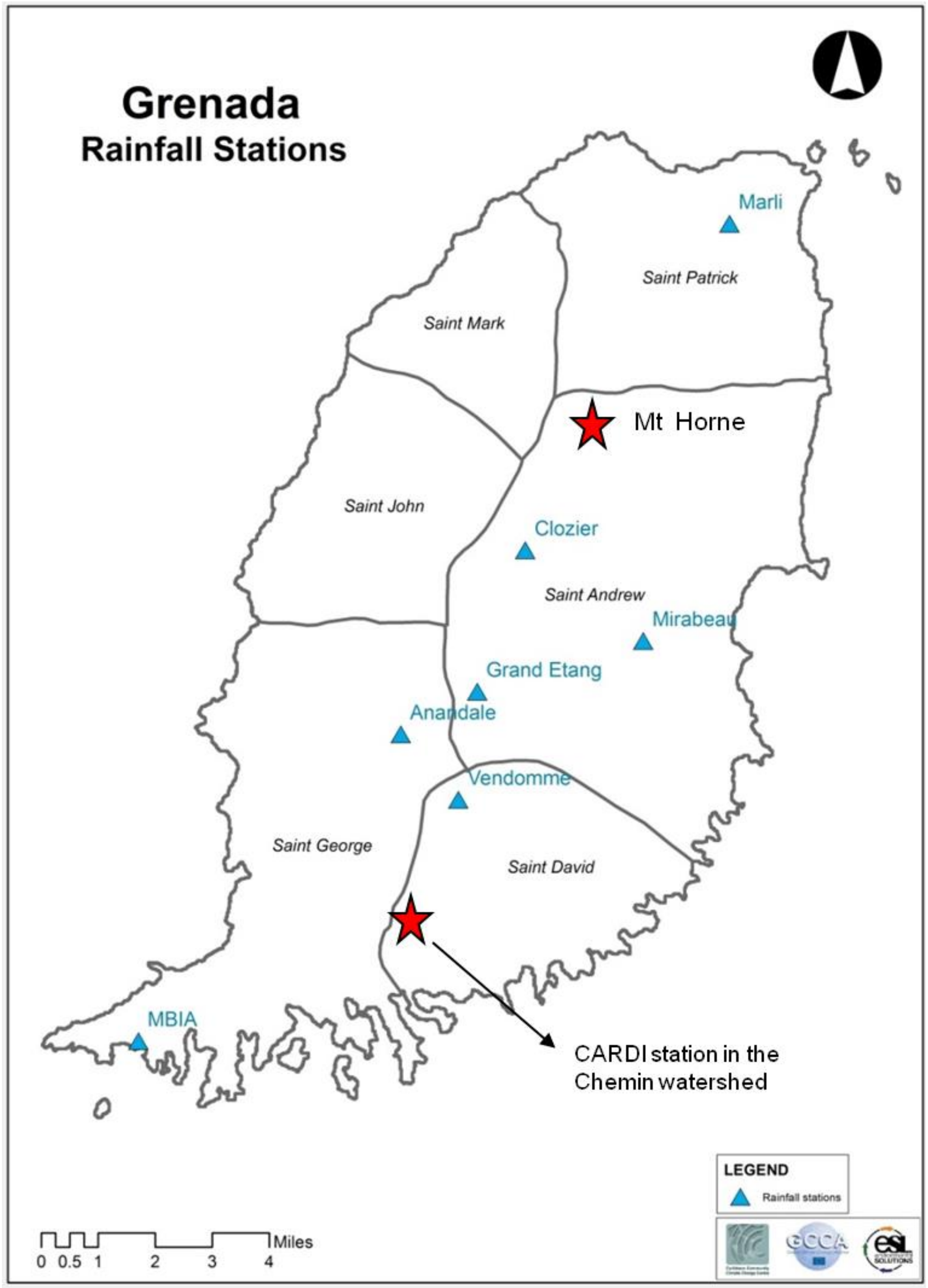
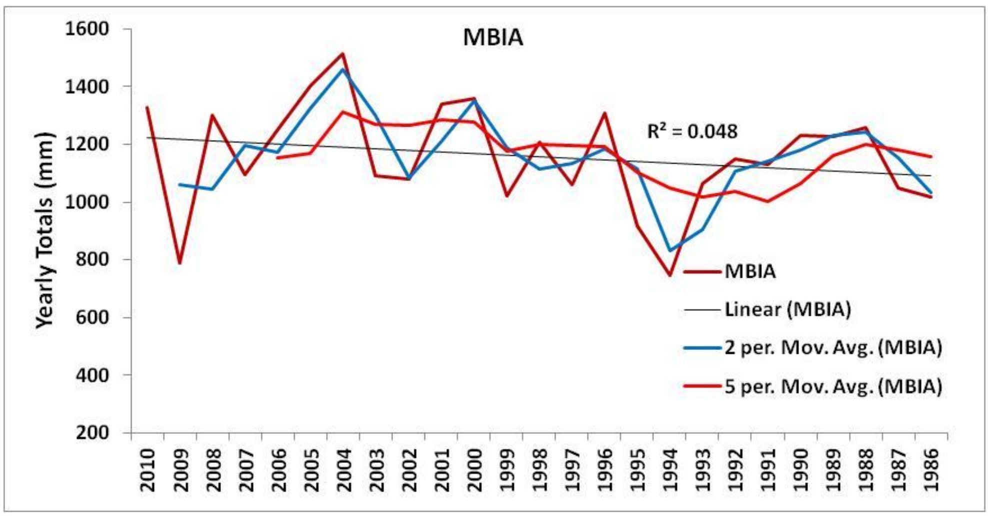


Figure 3-6: Locations of rainfall stations in Grenada. Possible location of Mt Horne and CARDI station marked with a "STAR" in the Chemin watershed.

Analysis of the available data from above stations was completed to show the temporal variation in mean monthly and yearly totals. Since daily data was only available for the MBIA station, the mean monthly rainfall was calculated for this station alone. Daily variations give more accurate results when calculating monthly averages than dividing the monthly totals by the number of days in the month. Seasonality in the rainfall pattern was also determined using the mean monthly values for all stations as listed above.

The total yearly rainfall for MBIA ranged from a low of 744 mm in the year 1994 followed by 749mm in 2009 to a maximum of 1513 mm in the year 2004. There is a weak declining linear trend in the yearly totals. The mean annual rainfall for MBIA (1986-2010) showed a weak increasing trend with a R^2 of 0.048 (Figure 3-7).



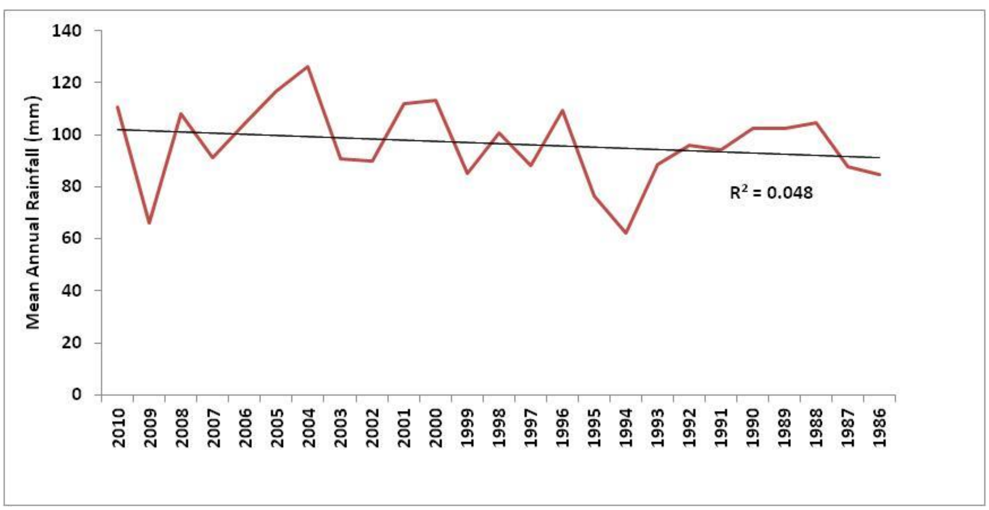


Figure 3-7: Total yearly rainfall and mean annual rainfall (mm) for MBIA.

The trend is very insignificant and overall the average rainfall ranges from a low of 65mm per year in 2009 to as high as 126 mm for 2004. The two point and five point moving averages for the total yearly rainfall show a steady range from 2006-1996 followed by a decline and then showing an increase in the later years to 1986 (Figure 3-7).

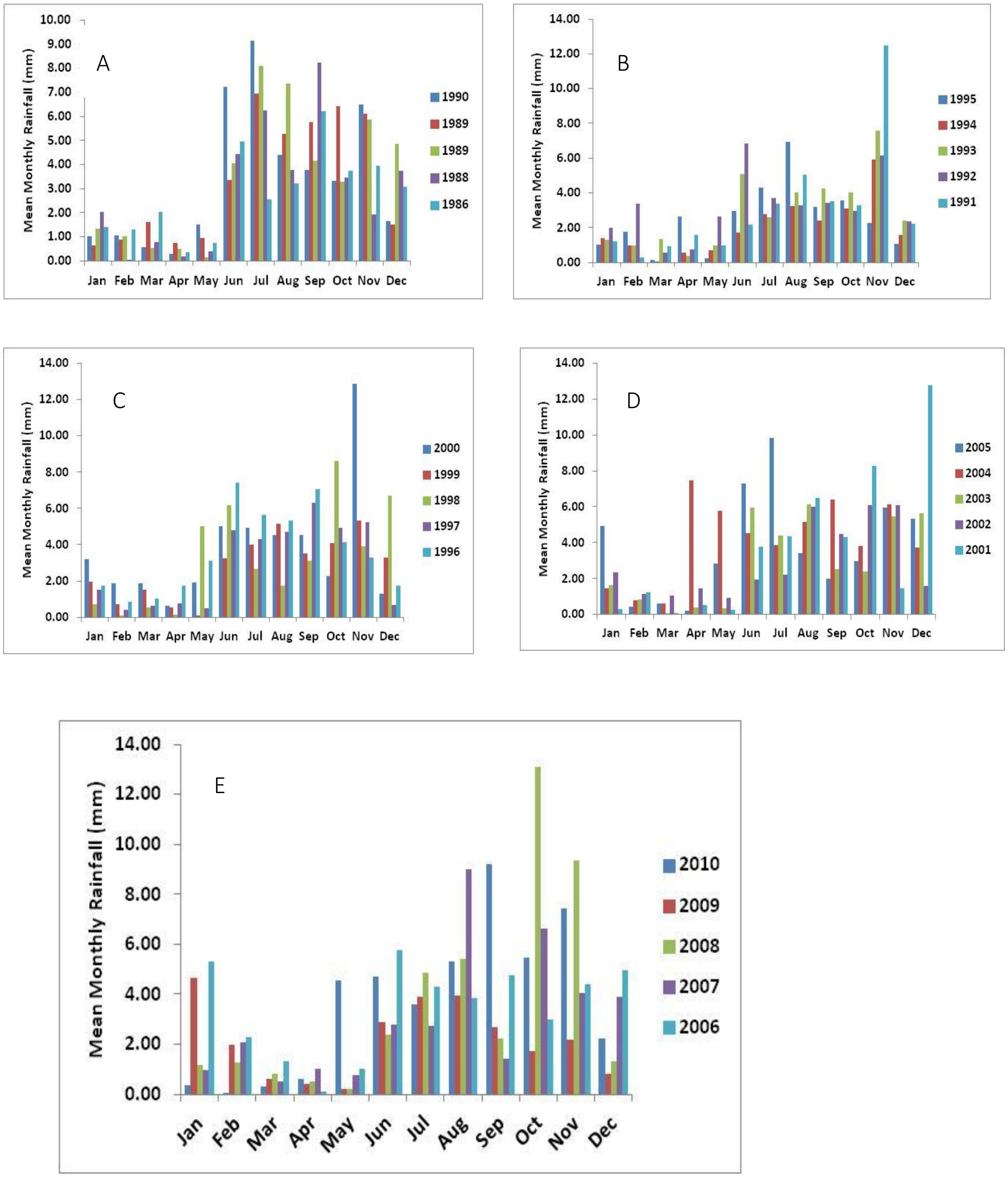


Figure 3-8: Mean Rainfall for MBIA

The years which have had significant impacts on the water sector are 2004 and 2009/2010 which correspond to the passage of Hurricane Ivan (Sept 2004) and the drought (Oct 2009-Mar 2010). The severe drought of 2009-2010 affected the entire Caribbean region and was as a result of the El Niño phenomenon. Most of the Caribbean islands experienced widespread water shortages, with Jamaica and Antigua and Barbuda being amongst the most severely affected. Trotman and Farrell (2010) reported that the rain gauge stations in Grenada, Trinidad, St Vincent, Jamaica, Dominica and Barbados recorded their lowest ever February rainfall totals. Stations in the same islands also recorded their lowest ever three month rains from January to March 2010. The data available from the MBIA station corresponds to the aforementioned. This shall be discussed in more detail subsequently.

In 2004, Grenada experienced the devastating effects of Hurricane Ivan. It resulted in widespread destruction across the entire island, resulting in 12 deaths and damaging 90% of houses. It was a category 3 hurricane when it hit Grenada before making its way to the Greater Antilles. Hurricane Ivan was the most powerful storm to hit the Caribbean since Hurricane Gilbert in 1988. Daily rainfall data from the MBIA station showed that a total of 133mm was recorded on 7-8 September, 2004, which represented 69% of the 192mm of total rainfall that was recorded at the MBIA station for the entire month of September 2004. If all the stations on Grenada had daily rainfall data, it would have been possible to illustrate and evaluate the impact that Hurricane Ivan had on the entire island.

It must be mentioned, that MBIA lies in the low rain zone of Grenada, hence it would record lower rainfall than watersheds in the central highlands (Figure 3-8). Figures 3-9 (a-e) and 3-10 (a-e) show the mean monthly rainfall pattern for the years 1986-2010 and maximum daily rainfall for the same time period for MBIA station. Seasonality in the rainfall pattern is evident from the mean monthly rainfall analysis for MBIA. The mean monthly rainfall pattern for the years 1986-2013 shows a bi-modal pattern of rainfall with the first peak in the months of May-June for the early rainy season. The second major, and in most cases highest peak, is the late rainy season from August to November which coincides with the Atlantic hurricane season. The pattern is pretty consistent however, some deviations do occur, such as the presence of a major peak in the month of December for the years 2001 and 2006. Although the official hurricane season for the Caribbean ends on 30th November, in the recent past there have been instances of heavy rainfall in the month of December.

As seen from the MBIA daily data, the dry season runs from January to April and is characterized by very low rainfall. The years 1986-1990 show a dry season marked by the early onset of the wet season. The year 1990 also had high rainfall in July as opposed to the traditional August- November rains. Rainfall was lower over the next five year time span from 1991-1995 with only one major peak in the month of November in 1991. The bi-modality of rainfall is relatively moderate from 1996-2000 with a single major peak in November 2000. Thus, overall the 1991-2000 decade shows a low, late rainy season when compared to the preceding decade.

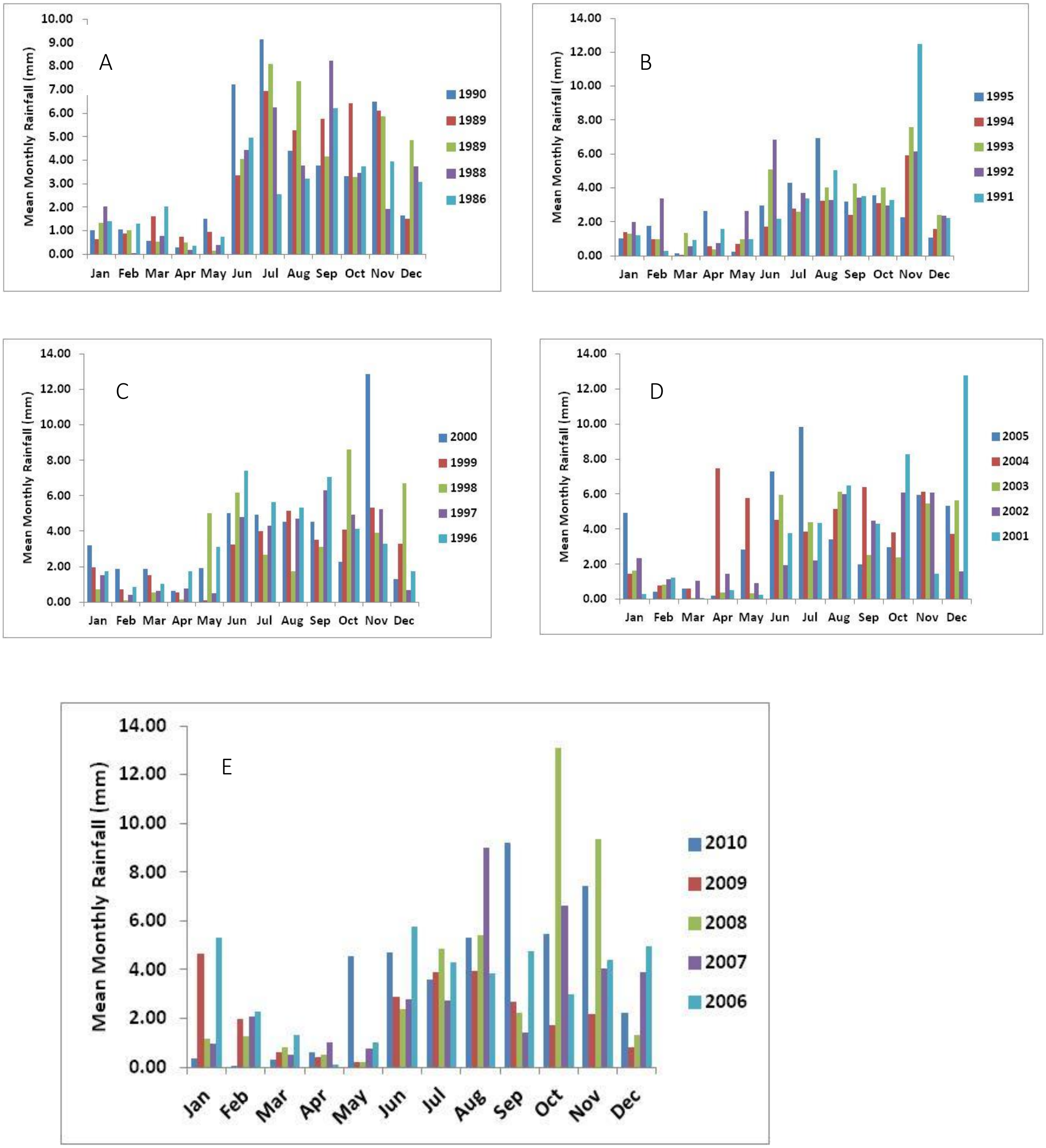


Figure 3-9: Mean monthly rainfall for station at MBIA

From 2001- 2010, the first five years show the standard bi-model pattern, however, a prominent rainfall peak is present in April- May 2004. There is also a peak in the dry season month of January 2005. The rains in Dec-Jan and April-May are ascribed to stationery troughs as well as local depressions. Of particular significance, in this decade, is the lowest ever rainfall for the months October- December in 2009, followed by the lowest ever February rainfall in 2010- Caribbean-wide drought. Furthermore, Grenada recorded its lowest wet season in 2009. The aforementioned trends were also reported by Trotman and Farrell (2010).

Analysis of the maximum daily rainfall data also shows a bi-modal pattern with two major peaks- one in the early rainy season (May-June) and the latter in the months August-November (Figure 3-10). There is no available data on the exact causes of these maximum rainfall peaks except the one for September, 2004 which coincides with the dates of passage of Hurricane Ivan. This figure is also the highest recorded maximum daily rainfall for the 2001-2010 decade for the MBIA station.

Total monthly rainfall data from the other stations in Grenada were analyed for the variation in yearly totals and mean monthly rainfall. Figure 3-11 shows the locations of the different stations along with their mean monthly rainfall. The trends were further illustrated in Figure 3-12.

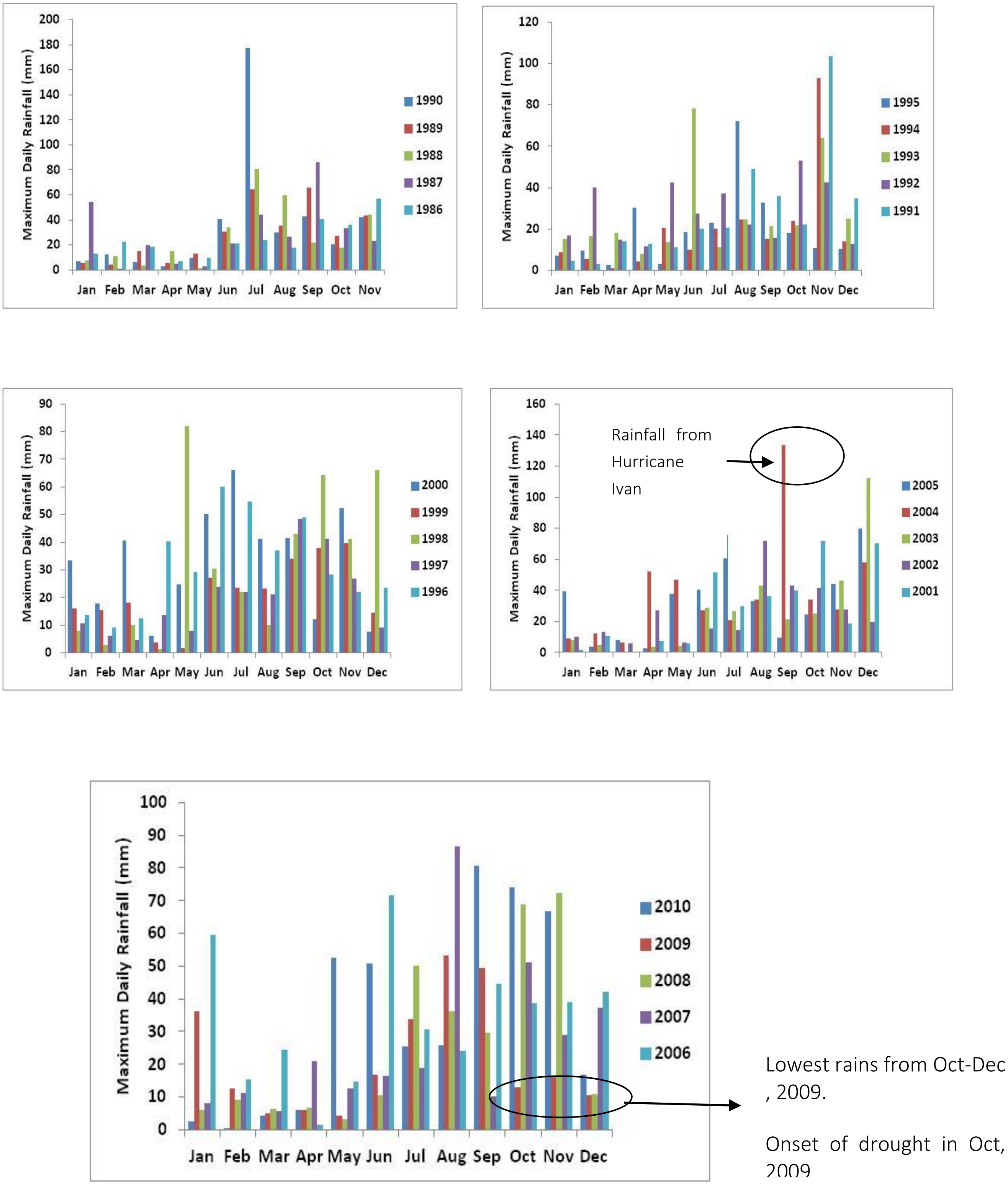


Figure 3-10: Maximum daily rainfall for MBIA.

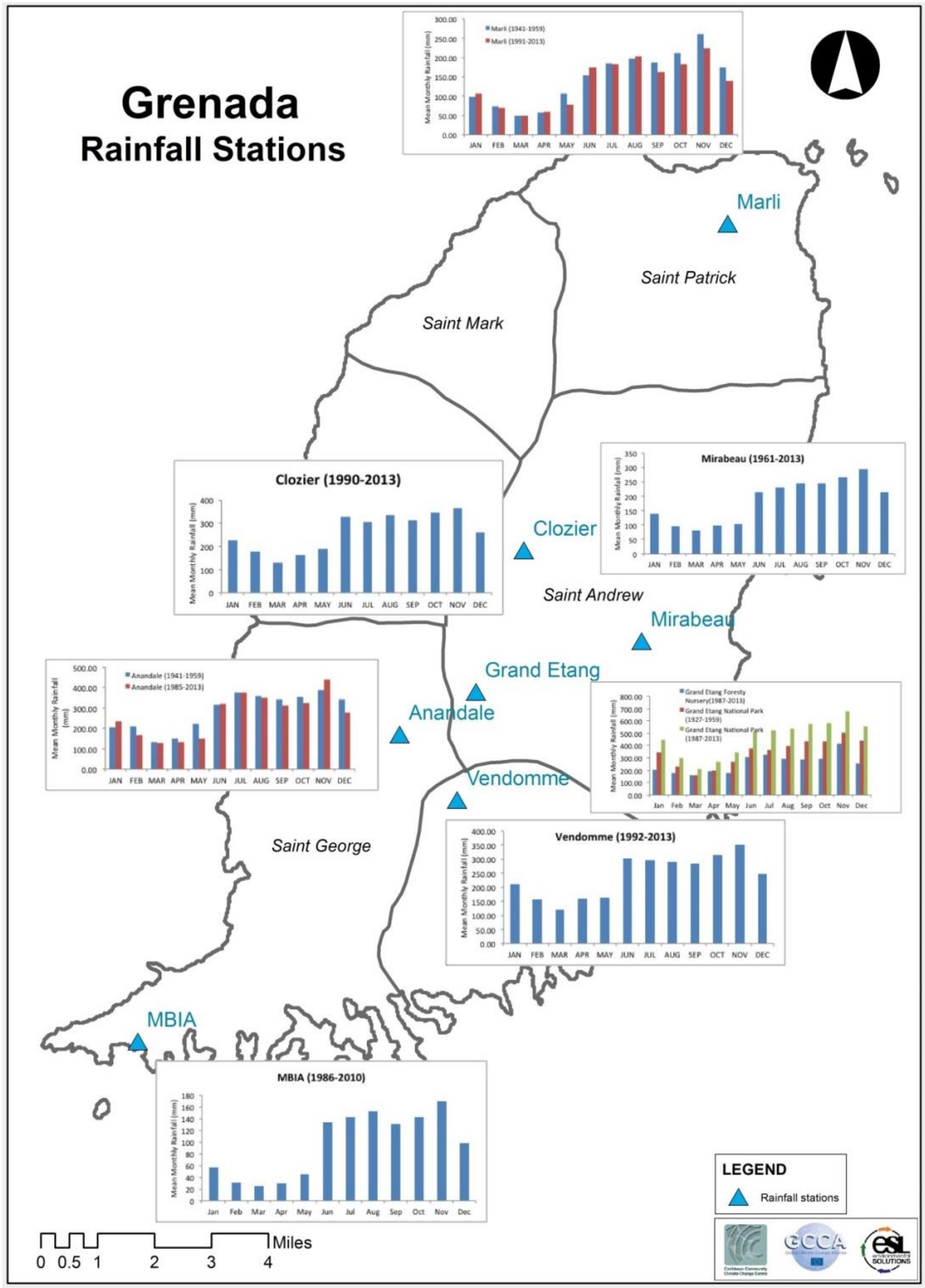


Figure 3-11: Mean monthly rainfall at rain gauge stations across Grenada

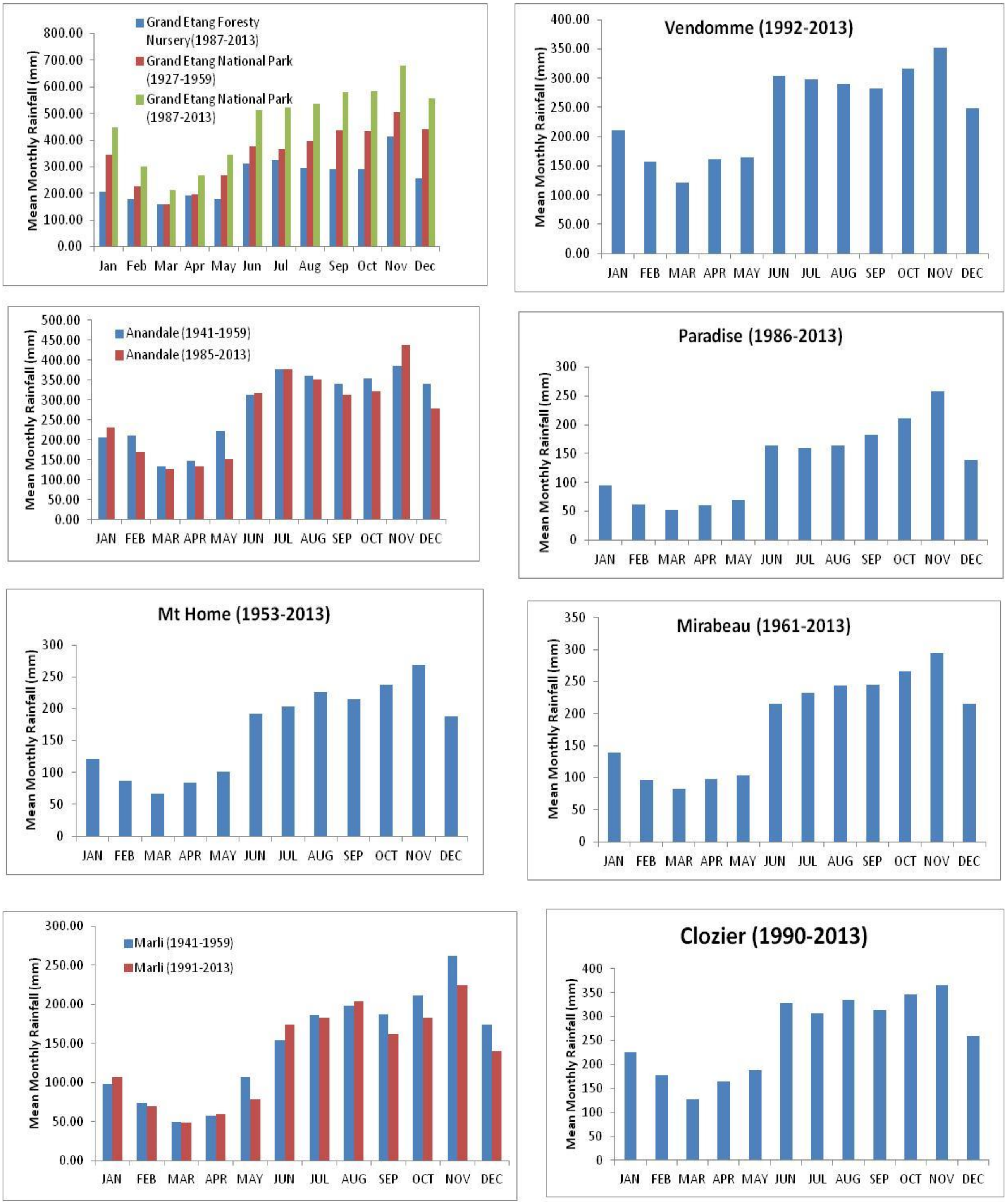


Figure 3-12: Mean monthly rainfall pattern for stations across Grenada.

Monthly total rainfall data received from the other stations in Grenada was analysed for the variation in yearly totals and mean monthly rainfall. The results are shown in Figures 3-13 (a-c), 14 (a-c) 15 (a-c) and 16.

The rain gauge stations vary in their temporal and spatial rainfall pattern. Seasonality is seen at all the stations with two main peaks in the early rainy season (May-June) and then late in the rainy season (September- November). There are also occasional peaks in the December. The Grand Etang (Forestry and National Park) station, which is located in the central highlands, recorded the highest rainfall in Grenada. The evidence of the orographic effect is clearly seen in the rainfall pattern for the stations, where the highest rainfall is recorded at Grand Etang and the lowest at MBIA, which is located in the shadow of the mountains. Historical data from 1927-1959 is available for the Grand Etang station. Analysis of this data along with that from 1987-2013 shows an increase in rainfall during the latter time period where a maximum of approximately 700mm was recorded in November during the 25 year period (Figure 3-13a).

The station at Annandale is also located in the central highland area. Here, a mean monthly rainfall of approximately 450 mm was recorded during the 1985-2013 time period. The stations at Vendomme, Mirabeau, Mt Home, Paradise and Clozier are located in close proximity to each other and show similar rainfall variability. For these stations the maximum mean rainfall was 350-400 mm for the months of October-November. Marli and MBIA which are located in the extreme north and south of the island, respectively, recorded lower amounts of rainfall when compared to the other stations. MBIA, however, recorded the lowest rainfall for the entire island.

The total annual rainfall for the rain stations does not show any distinct trends for the years of available data. The total annual rainfall for Grenada ranges from 6500 mm (1927-1959) for the Grand Etang National Park to as low as 744mm for the MBIA station- this further attests to the orographic effect. The total annual rainfall for the eight stations are shown in Figures 3-14, 3-15, 3-16, 3-17. The 5 point moving average which is a 5yr moving average for the yearly totals shows a weak decline from 1953-1965 followed by a steady rise in the next decade i.e. 1965-75 continuing until 1990 when the highest yearly total was recorded in 1990 (1788mm). This is followed by a gentle declining trend until 2015.

Rainfall for Grand Etang Forestry shows an overall weak declining trend in the 5yr moving average until 2005 followed by a gentle increase until 2013. Yearly total rainfall patterns for the remaining stations do not show any characteristic trend, but overall show alternating decades of high and low rainfall values which would imply alternate years of a longer dry season followed by a weaker wet season. This would have likely had an impact on the water availability since Grenada relies heavily on surface water for its main potable water supply.

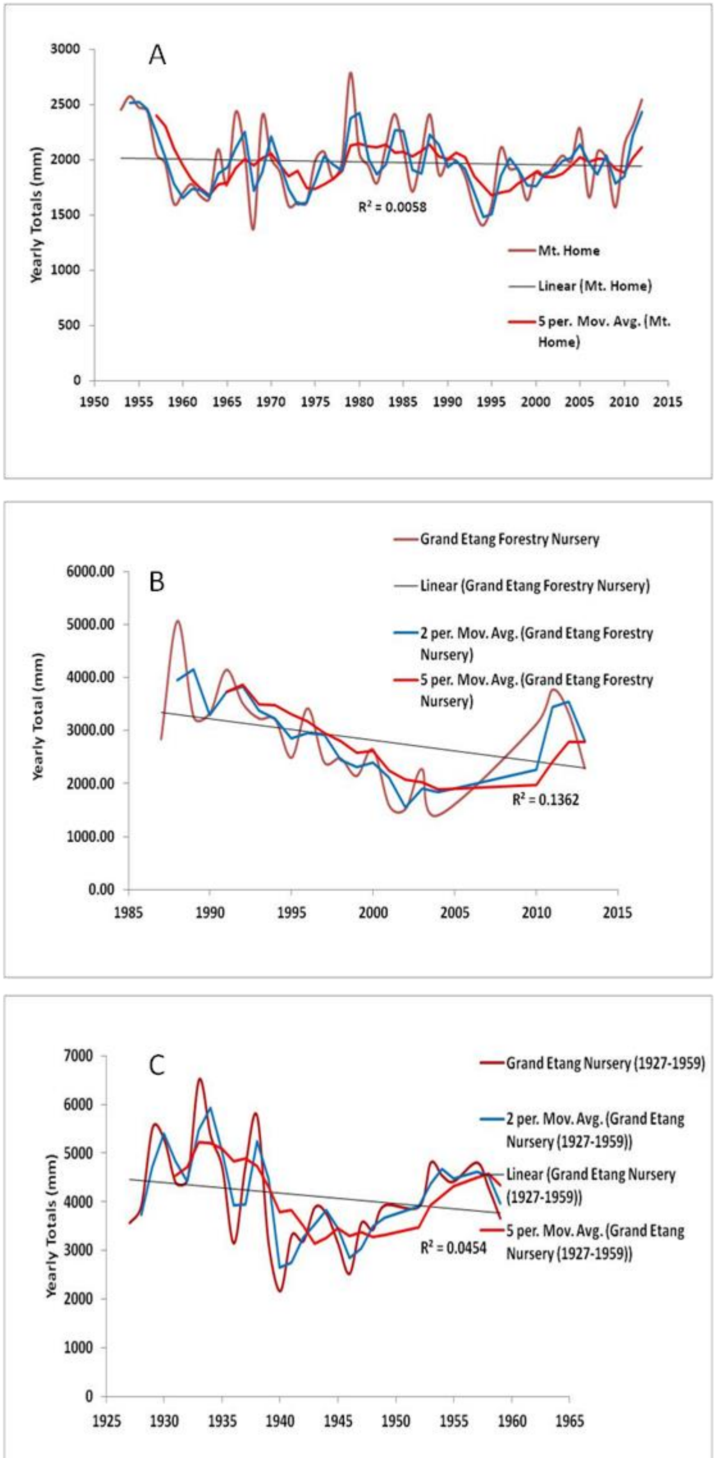


Figure 3-13: Total yearly rainfall for a)Mt Home b)Grand Etang Forestry (1987-2013) c) Grand Etang National Park (1925-1959).

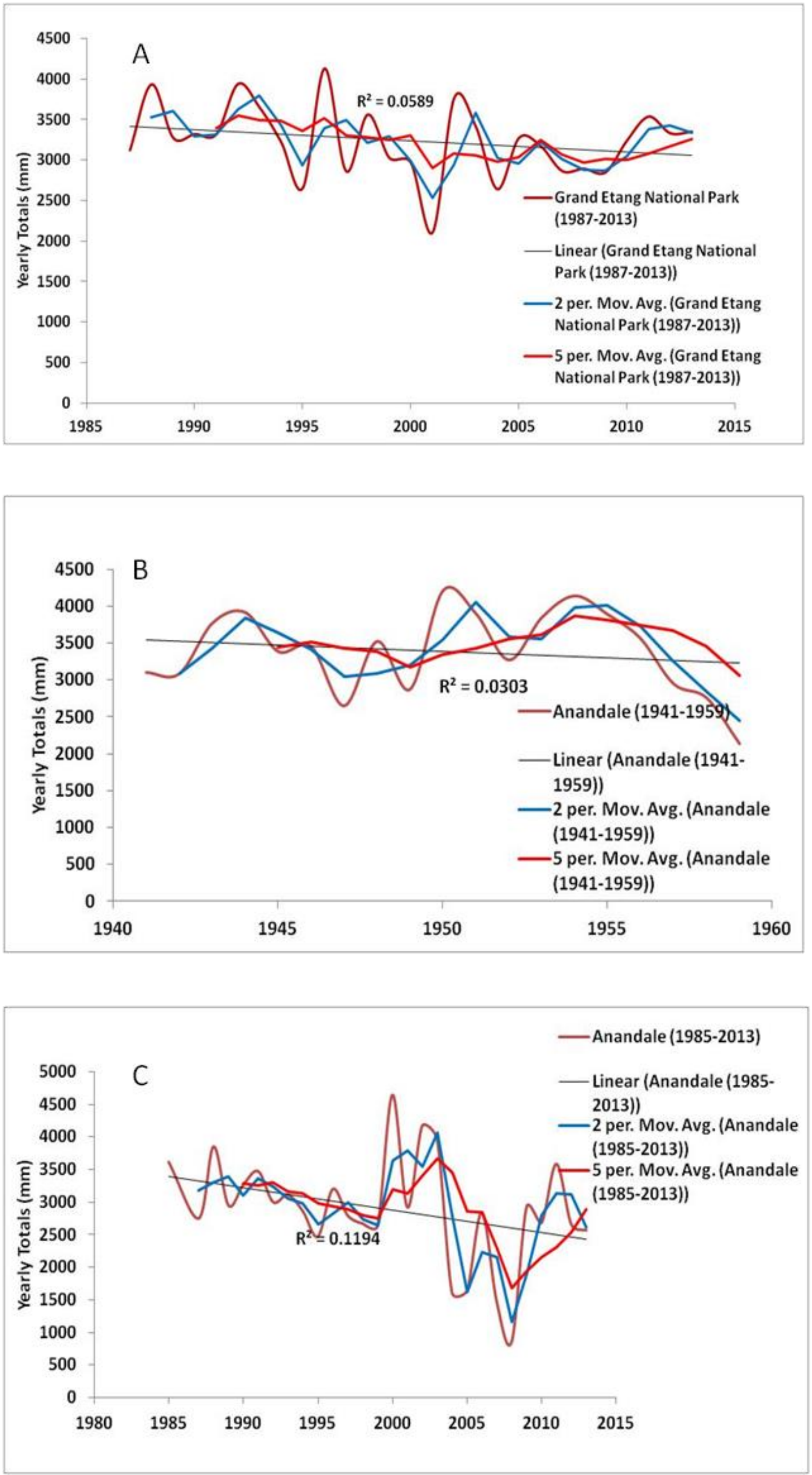
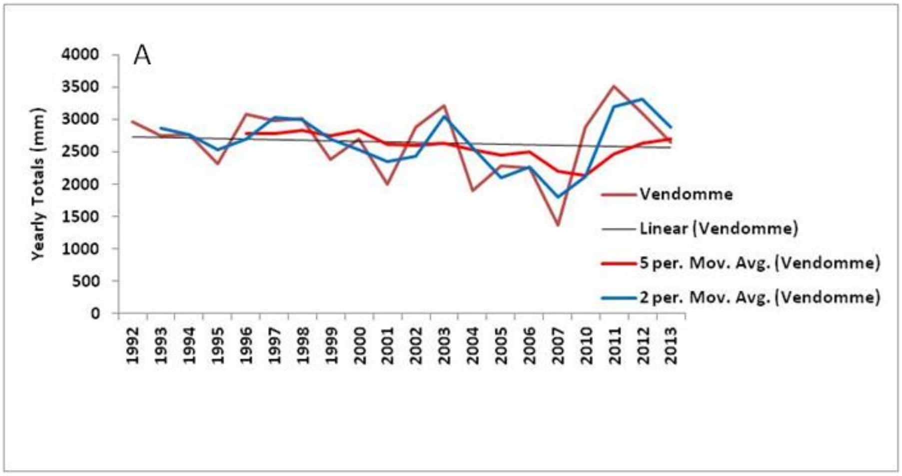
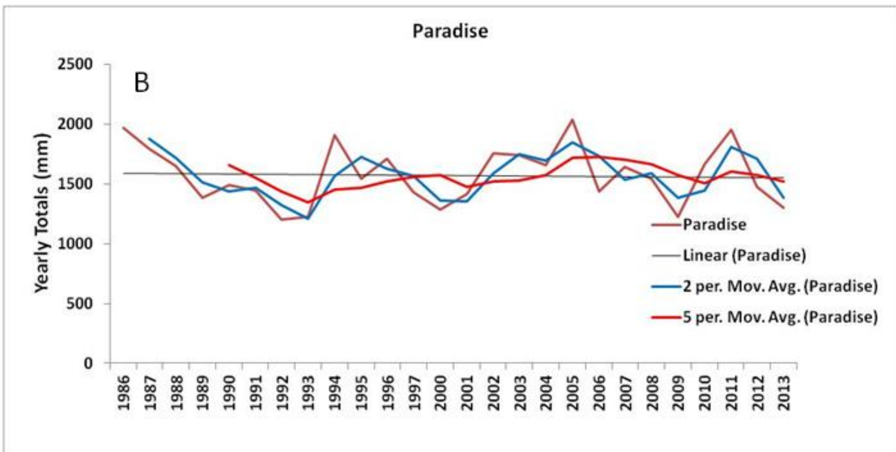


Figure 3-14: Total yearly rainfall for a) Grand Etang National Park (1987-2013) b) Anandale (1941-1959) c) Anandale (1985-2013).





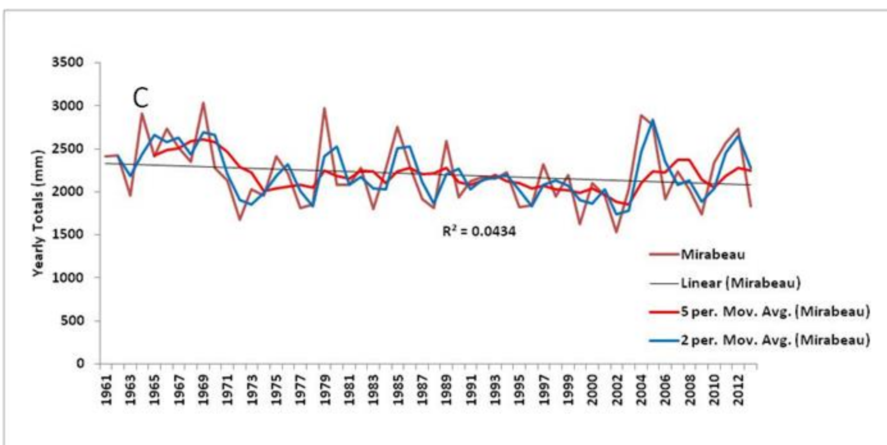


Figure 3-15: Total yearly rainfall for a) Vendomme (1992-2013) b)Paradise (1986-2013) c) Mirabeau (1961-2013).

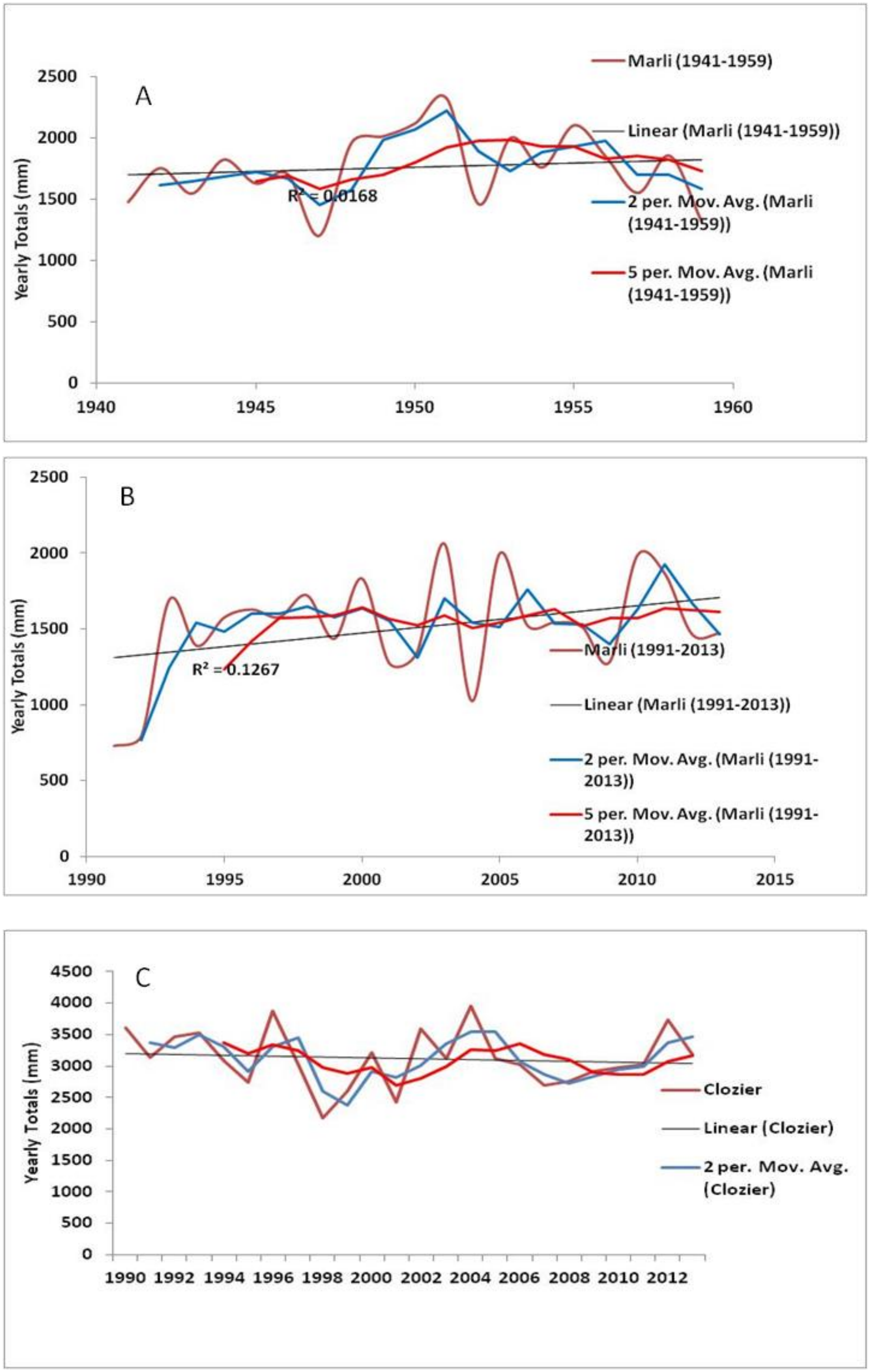


Figure 3-16 : Total yearly rainfall for a) Marli (1941-1959) b)Marli (1991-2013) c) Clozier (1990-2013)

The rainfall data was further analysed to show the effects of the El Niño and the 2009 drought. As previously stated, the drought commenced in October 2009 and continued until March, 2010. The rainfall data for the late wet season and the dry season, was analysed separately, against the previous years for which continuous data was present for all the stations across the island. The monthly totals for the years 1992-2010 was chosen, as it had the continuous set of data for all the stations. The total monthly rainfall was calculated and plotted for Oct-Dec and Jan- Mar for each year, for each station. The results are shown below in Figures 3- 19 and 3-20.

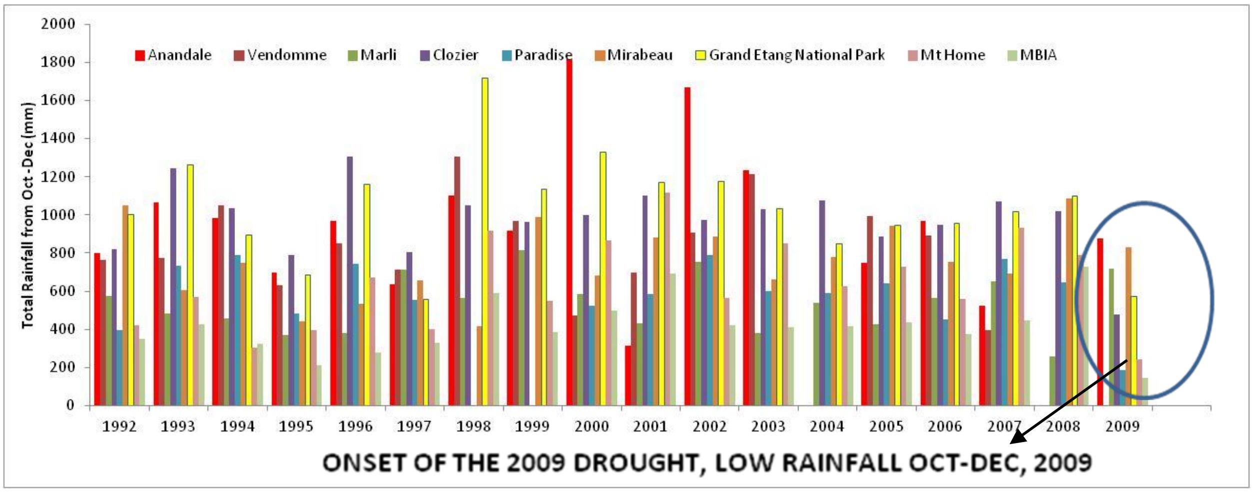


Figure 3-17: Total rainfall (Oct-Dec) Grenada rainfall stations

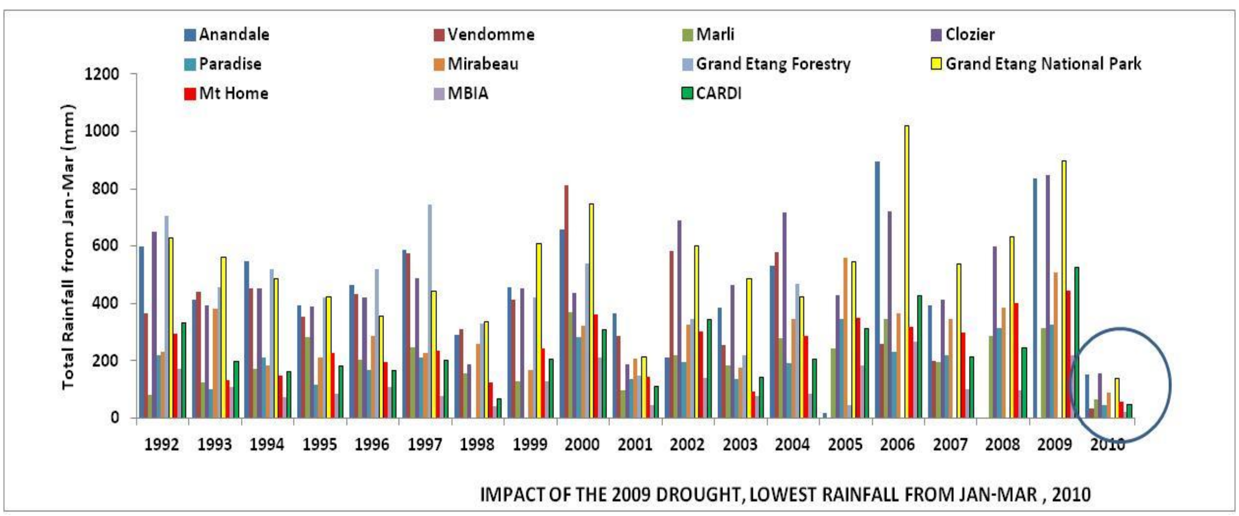


Figure 3-18: Total rainfall (Jan – Mar) Grenada rainfall stations

From Figures 3-17 and 3-18, all the rain gauge stations recorded their lowest total rainfall for the months October-December in 2009 when compared to the previous years with rainfall from October 2009 to

January 2010 being 19%-37% of the normal amount. In addition, the recorded rainfall for March-September 2009 was about 50% of the normal amount. Furthermore, February 2010 had the lowest rainfall for all stations across the island. This decrease was lowest for the MBIA station. Annandale and Grand Etang showed a decline of 682 mm from October to December 2009. This probably had a negative effect on water supply as Annandale is the country's largest source of water.

Figure 3-19 shows the population distribution map for Grenada. When compared to the distribution of rainfall, it is evident that the southern, northern portions as well as the eastern section of the island which have low mean annual rainfall also have medium to high population. Hence, these areas will be adversely affected by drought due to low rainfall and higher demand and consumption of water. This will be discussed in more detail in the section on water resource availability.

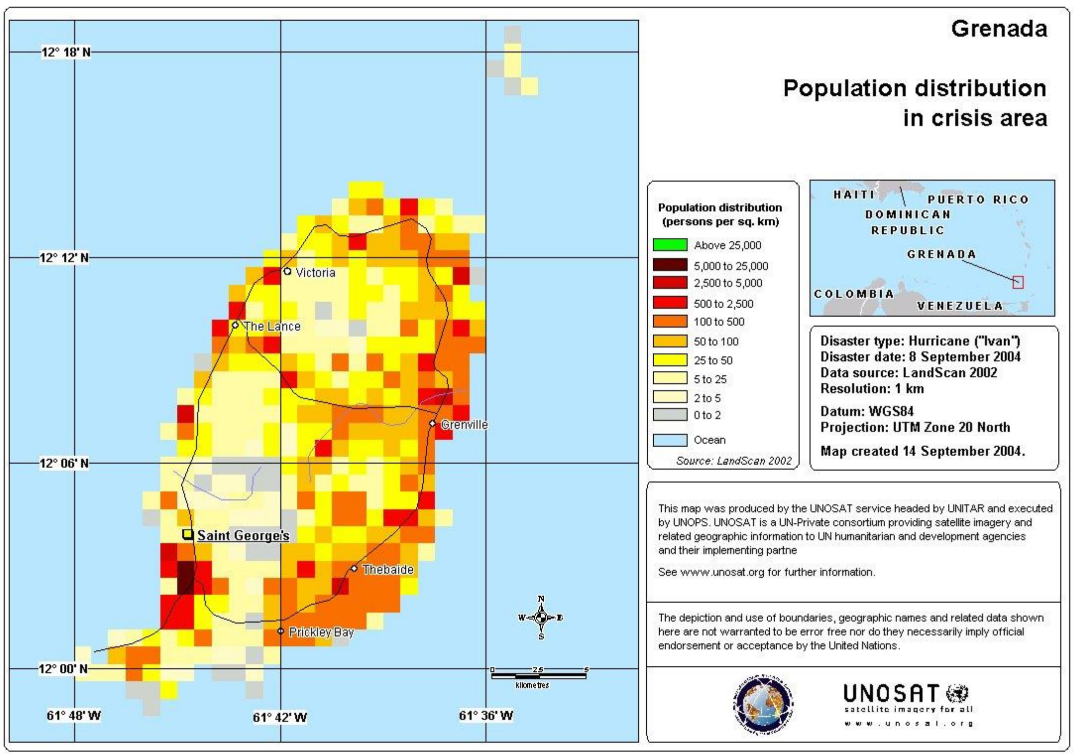


Figure 3-19: Grenada's population distribution (2002)

http://img.static.reliefweb.int/sites/reliefweb.int/files/resources/FEB12E92FF2AEED1C1256F2D00484D4B-unosat_ivan_grd140904.jpg

3.1.4 Watershed Conditions and Trends

3.1.4.1 Grenada

Grenada is divided into 71 watersheds[3] (Figure 3-20). Figure 3-21, shows the area of each watershed while Figure 3-22, shows the watershed areas as a percentage of the Grenada's total area. Grenada has a well-defined system of watersheds, which dissects the landscape, resulting in steep hilly topography almost everywhere except in the south west and north east where it grades into low hills.

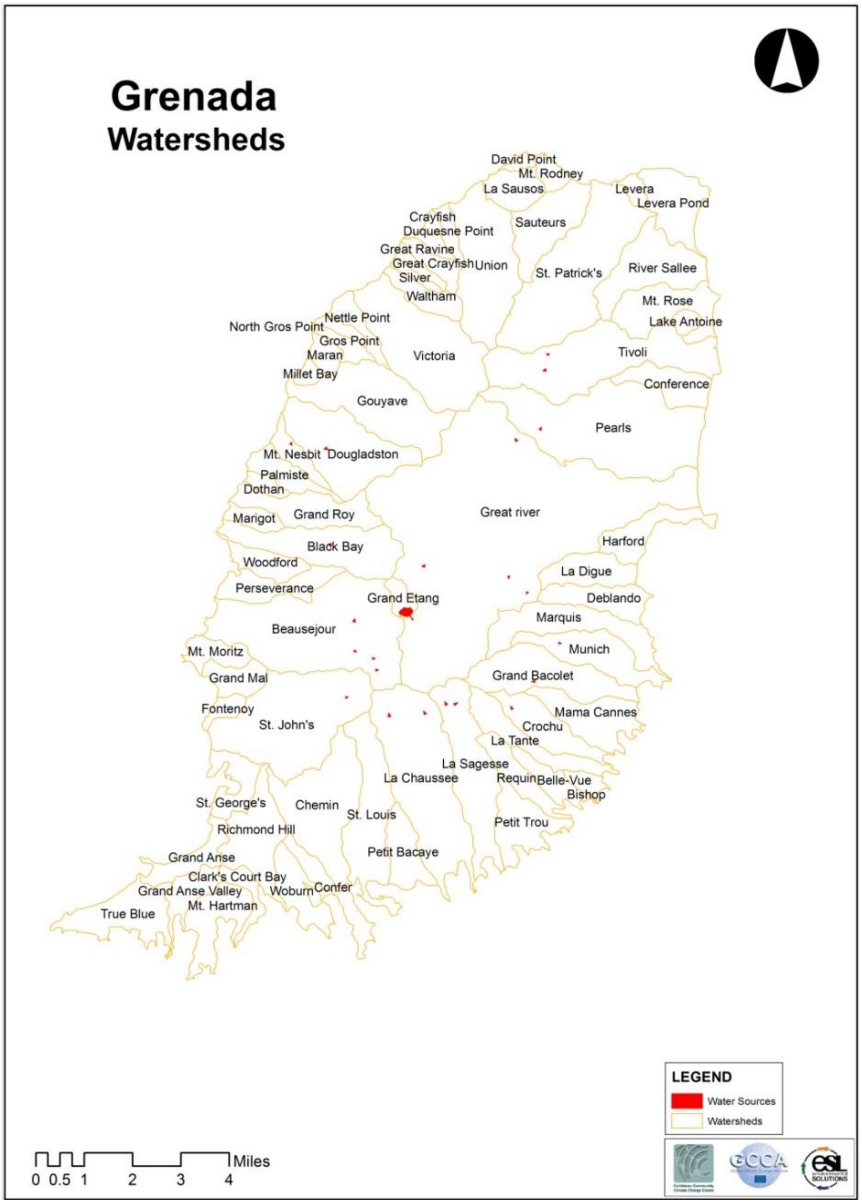


Figure 3-20: Grenada showing the 71 watersheds and the main water sources

[3] Land Use Division (2000): Watersheds of Grenada. Ministry of Agriculture Lands and Forestry and Fisheries. Government of Grenada

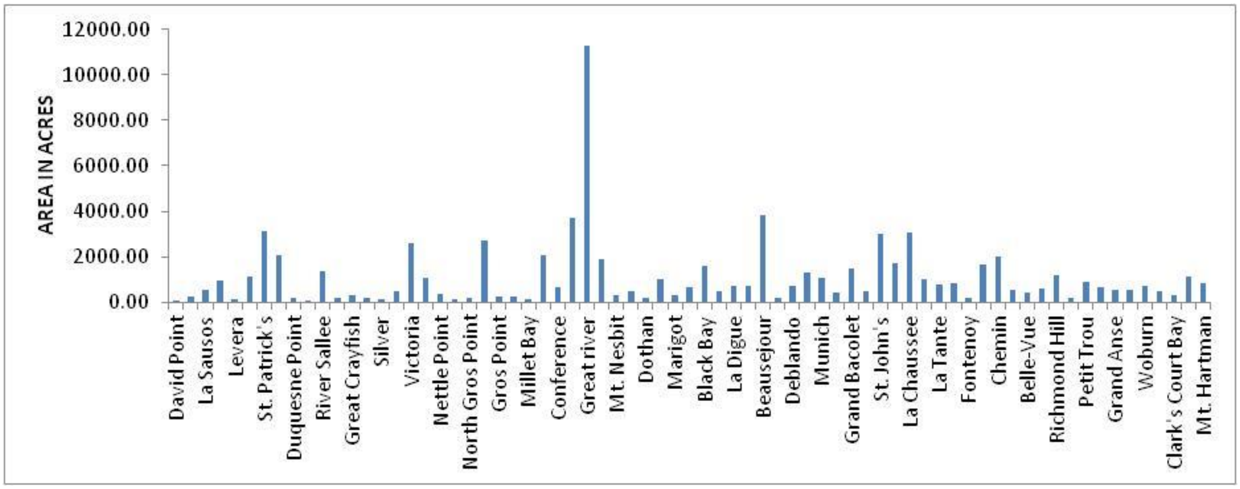


Figure 3-21: Area of Grenada's watersheds (acres)

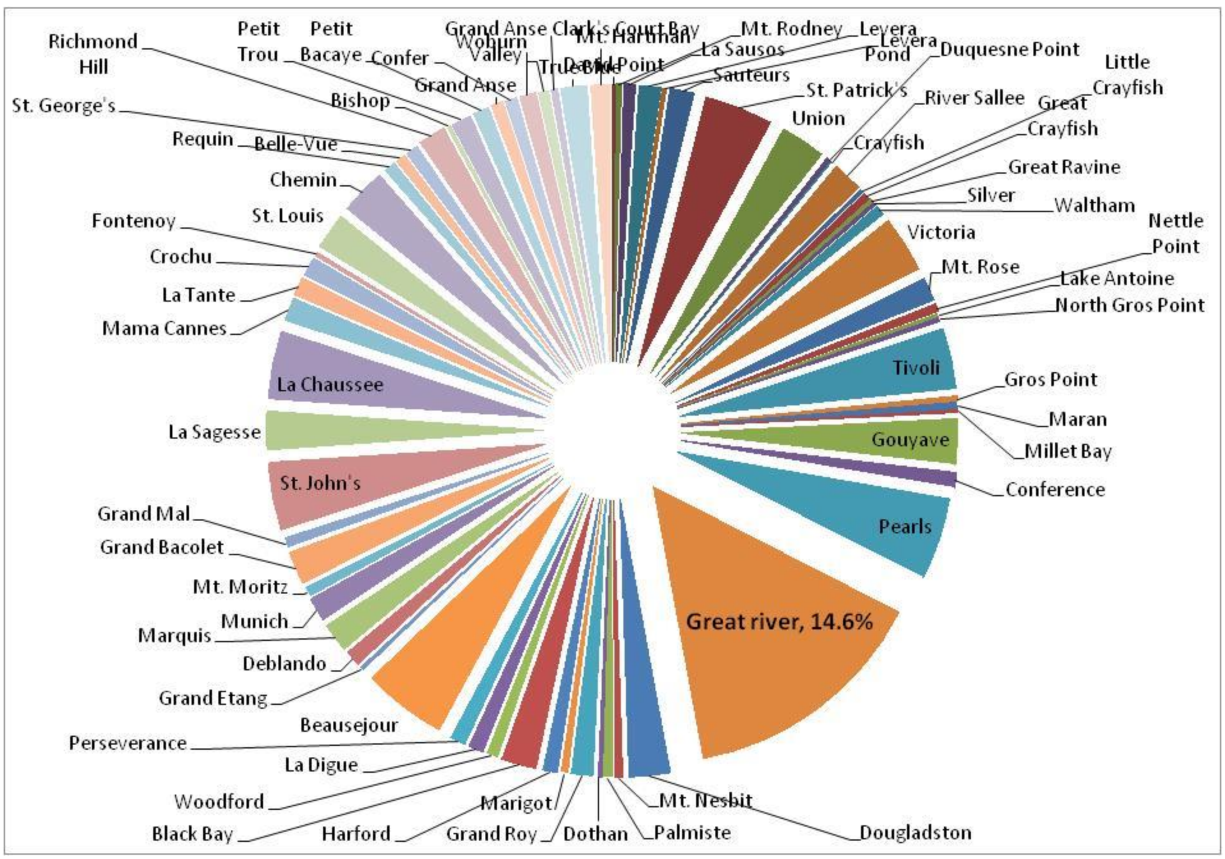
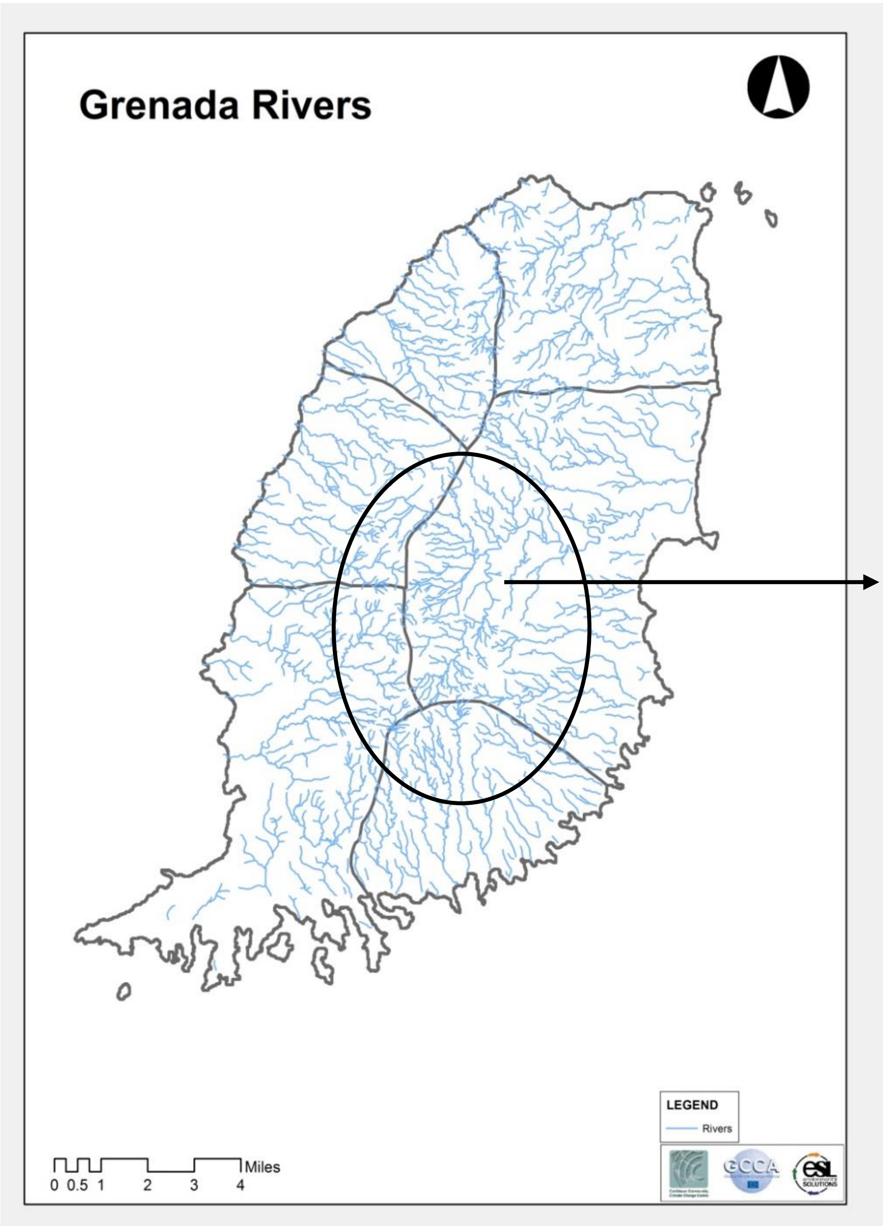


Figure 3-22: Area of each watershed as a percentage of the total area of Grenada

The largest watershed in Grenada is the Great River which is located in the central portion of the highland area in the high rain zone (Figure 3-23). It has an area of 11,303 acres and occupies 14.6% of the total area of Grenada.

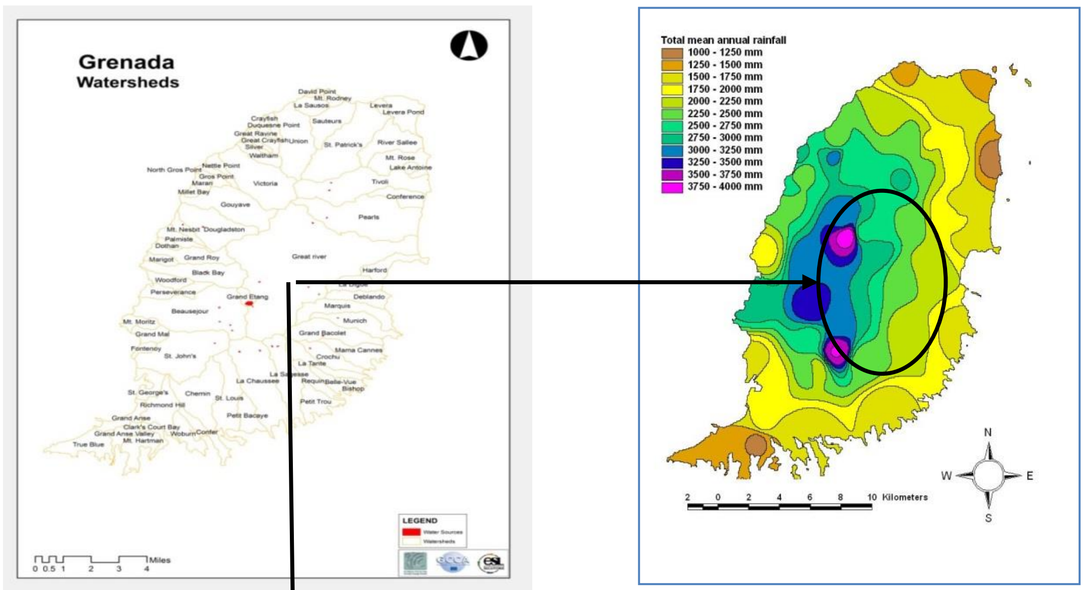


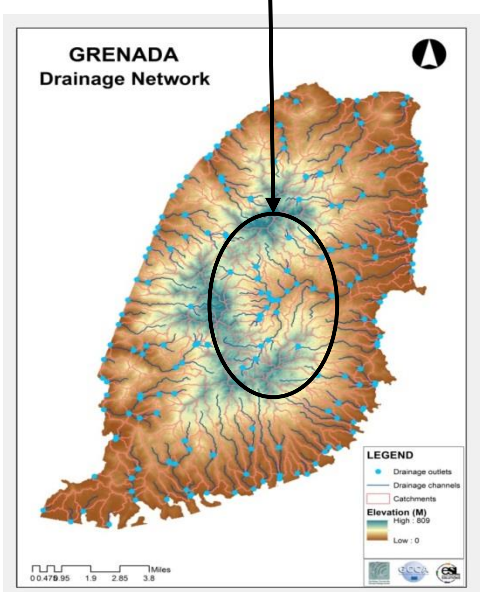
Area covering the Great River watershed- Origin of the highest number of rivers and located in the high rain zone. Highest elevation on the island. Zone with impervious geology, less infiltration and more surface runoff.

Figure 3-23: Grenada's river network showing the extent of the Great River watershed

The **Great River watershed** along with its high density of river systems, impervious geology (andesitic rocsk, pyroclastic flows, scoria and ash), and location of water storage systems (dams) is significant to Grenada's water resources. The longest river originates from the Great River watershed. The Great River watershed produces higher surface runoff than the watersheds in the southern portion of the island. Consequently, this watershed is an excellent potential location for rain water harvesting (RWH) to combat periods of drought.

All the major watersheds have perennial rivers whose discharge is greatly reduced in the dry season. The river network, shown in Figure 3-23, is similar in direction of flow and origin, as compared to the drainage channels extracted from the DEM (Figure 3-24).





Comparison of DEM, watershed and rainfall map, as shown above, thus supports the discussion made earlier on the importance of the Great River. The DEM shows it is located in areas of elevation as high as 750m and with rainfall as high as 3000-4000 mm per year

Figure 3-24: Comparison of watershed, DEM and rainfall maps

Although all of the watersheds are affected by anthropogenic activity, the effect of said activity is more pronounced on the privately owned lands rather than in the central highlands which are protected areas. The major threat to watershed management results from a combination of the following activities:

- Encroachment by farmers;
- Use of agro-chemicals (fertilizers, pesticides, weedicides);
- Siltation of rivers and dams;
- Inadequate land use practices;
- Pollution;
- Land tenure rights;
- Unplanned developments;
- Lack of control of forest clearance.[4]

Watersheds of SIDS which suffer degradation from unsustainable land management practices because of agriculture and/or urbanization are heavily impacted after the passage of a tropical storm or hurricane. This can lead to massive erosion and landslides in the upstream areas and flooding in the downstream sections of the watersheds. Silt and debris-laden high storm flows often choke the water intake infrastructure, while landslides often cause breakages in the distribution lines, forcing supply interruptions to many communities for weeks and in some cases months.

Of particular significance was the damage from passage of Category 3 Hurricane Ivan in 2004 and Category 1 Hurricane Emily in 2005. Hurricane Ivan caused many deaths and damages amounting to 900 USD million while damages from hurricane Emily amounted to USD 107 million (NADMA, 2005; UNDP, 2004). Although the effects of Hurricanes Ivan and Emily on the upland watershed are not well documented, its impact on the vegetation was still evident even two after years of the events (Figure 3-25). Reports of increased river flows following heavy downpours after the hurricanes could be the result of damaged watersheds having reduced retention capacity causing significant increases in runoff.

[4] National Report on Integrating Watershed Management and Coastal Areas (2001)

Figure 3-25: Hurricane damaged forests in upland watershed areas of Grenada

Increasing drought conditions have resulted in forest fires in several watersheds, for e.g. during the drought of 2009. This is further exacerbated by the changing biodiversity within the watersheds. Bamboo has spread across the island changing how much surface water is infiltrated. The shallow root system of bamboo encourages surface runoff instead of percolation into the soils which in turn affects the water supply. This is more visible in the forest reserve. A tree replanting program in the past, encouraged the planting of Blue Mahoe. This has now become predominant in some watersheds. However, this also affects percolation rates because of the fairly shallow root system, in turn affecting how much is stored in soils and dams etc.

3.1.4.2 Carriacou

Table 3-1 and Figure 3- 26 shows the watersheds in Carriacou. Craigstone and Limlair-Dover occupy around 11% and 13% of the total area, respectively.

Table 3-1: Watersheds in Carriacou and their total area in acres

WATERSHED	AREA (ACRES)
Petit Carenage	206.83
Craigstone	835.26
Limlair-Dover	1029.50
Tarleton Point	185.58
Hillsborough	564.58
Mt. Pleasant	687.20
Six Roads	484.00
L'Esterre-Lauriston	510.29
Grand Bay	632.47
St. Louis	304.00

WATERSHED	AREA (ACRES)
La Resource	402.66
Dumfries-Great Bretache Bay	476.95
Harvey Vale	584.24
Kendeace	175.68
Belle-Vue -Black Bay	156.66
Belmont	393.87
Hermitage	263.13

There is not much data available on the water resources for Carriacou. Available data from NAWASA, LUD-MOA are mainly related with the land use and soil type along with the watershed map. Soil data, although available, does not refer in details to the soil types and soil classification as that for Grenada. Neither, was data available on the geology of Carriacou, which could have been used to interpolate for the soil types. Hence analysis for Carriacou is very limited. No data on any of these parameters was available for Petit Martinique. As like Grenada, the major threats to the watershed management for Carriacou are:

- Encroachment by farmers;
- Use of agrochemicals;
- Siltation, pollution and unplanned management.

However, these activities are not practiced in the protected areas which are mainly the watersheds to the north west, central and small sections along the coastal areas of Carriacou.

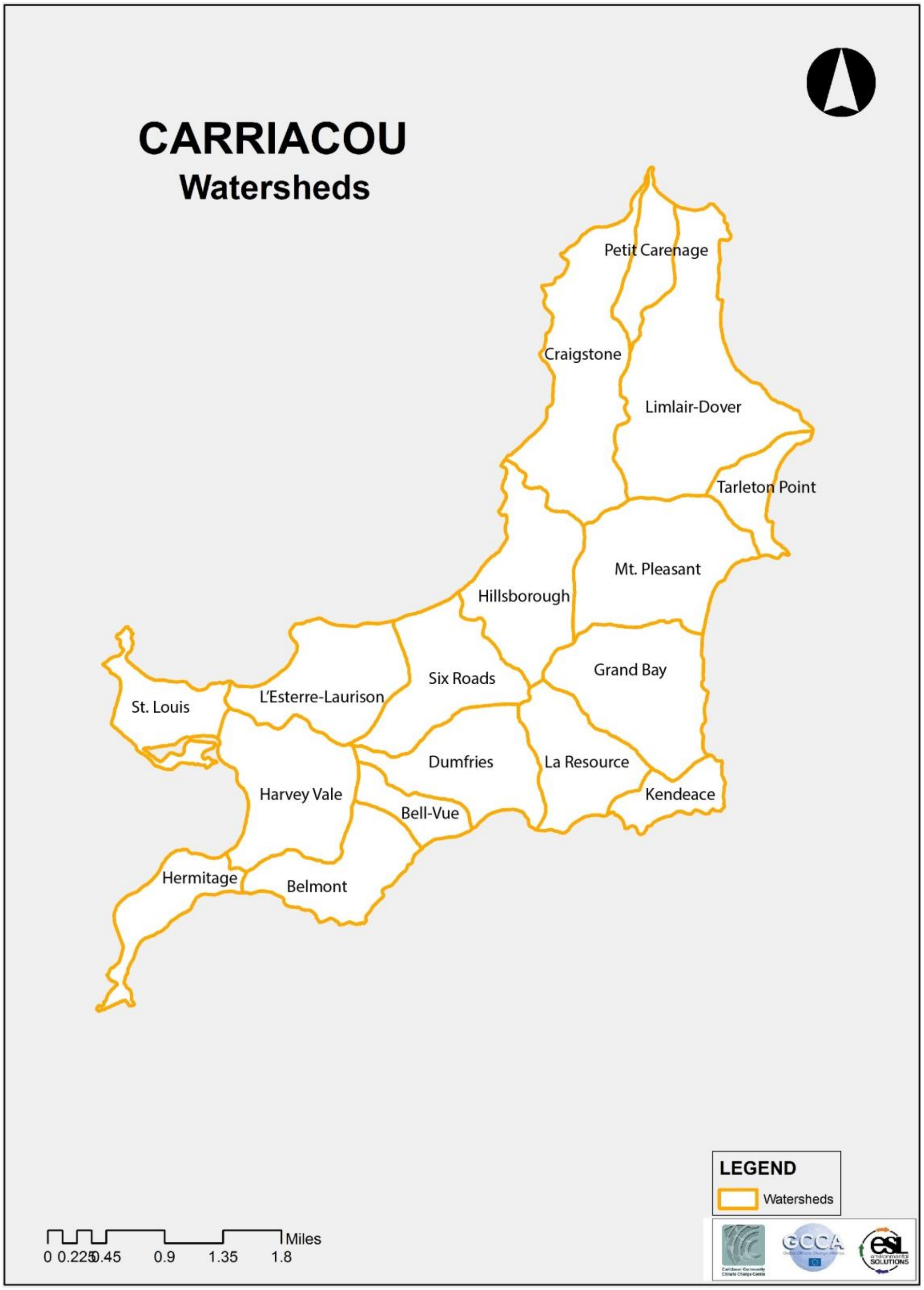


Figure 3-26: Watersheds of Carriacou

3.1.5 Geology and Soils

3.1.5.1 Geology

Geological data was not available for Carriacou and Petit Martinique except for the fact that the islands are volcanic. Therefore, the discussion below focuses on the island of Grenada.

Grenada is mainly volcanic in origin and its main rock types are andesitic lava, pyroclastic rocks and basalt. More than 60% of the island (approximate figure based on map observation) is composed of reworked volcanics (Figure 3-27). All the different volcanic centres are composed of pyroclastic basalts, andesitic lavas and reworked volcanics, scoria and ash. The Great River watershed falls in the area of volcanic summit 3 (Figure 3-27) and is composed of reworked volcanic ash, pyroclastic flows and basalts. These rock types are the main reason for the impervious nature of the sub-surface which leads to greater surface runoff and hence the higher density of drainage channels and greater source of surface water systems. The dominant rock types are:

a. Mount Craven Volcanics (Early Miocene to Pleistocene) occupying the central section of the island, high rainfall zone and covering parts of the Great River watershed.
b. Undefined reworked volcanics (Pleistocene) covering approximately 60% of the island extending from north to south, south east.
c. South East Mountain Volcanics (Miocene in age).
d. Mouth St Catherine Volcanics (Pliocene – Pleistocene) lying in the northern section of the island and coinciding with areas of protected Rainforest zone.

Some outcrops of the oldest Tufton Hill Formation, are found on the north and north western section of the island. In addition, the southern end of Grenada, along the coastal areas of the Chemin and St. Georges watersheds, show the presence of Point Saline Beds which are mainly alluvium and limestone deposits.

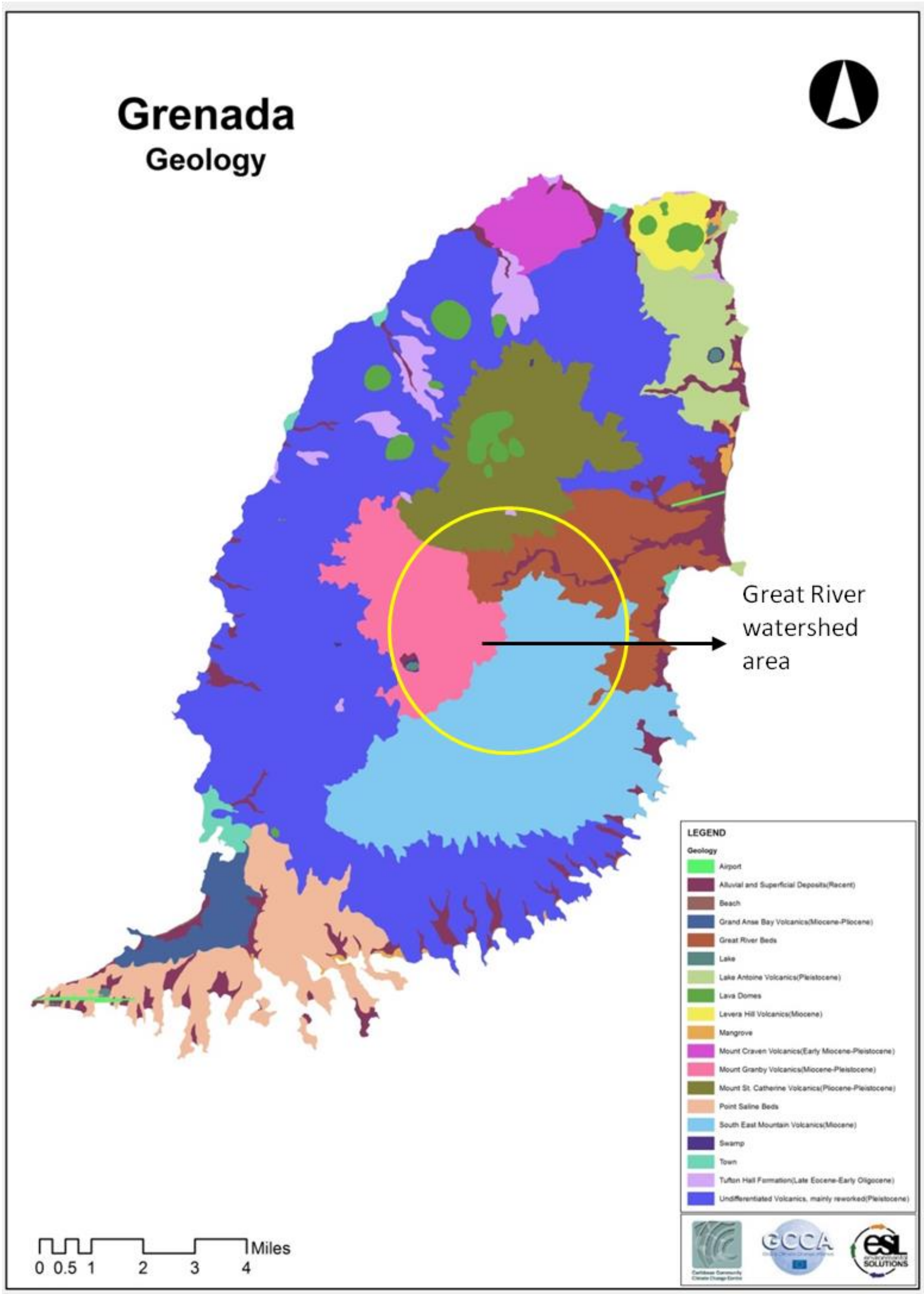


Figure 3-27: Geological map of Grenada. Source: LUD, Grenada

3.1.5.2 Soils

Soils are weathered bedrock residues. Therefore, knowledge of the soil gives an insight into the geology of the island and vice versa. Soil formation depends on local climate, i.e. temperature and rainfall, which controls the level of bedrock weathering. As previously mentioned, Grenada is predominately volcanic in origin and its soils are dominated by clay loams (84.5%), along with clays (11.6%) and sandy loams (2.9%). Agricultural problems tend to arise from the shallowness, high erosion potential and low moisture retention capacity of the clay loams which are present in most of the country[5]. The dominant soil types in Grenada are:

Capital Clay Loam	=	13,354 ha
Belmont clay loam	=	6,479 ha
Woburn clay loam	=	8,276 ha
Total	=	26,089 ha or ~ 82.9% of the total soils

- Capital Clay Loam – fine textured moderately well to well drainage reddish soils of variable depth.
- Belmont Clay Loam – fine textured moderately well to well drainage brownish soils of variable depth.
- Woburn Clay Loam – fine to medium textured well to excessively drained dark brown to gray moderately deep soil.
- Clay Soils – very deep soils drowned from alluvial or colluvial deposits on mainly flat to undulating land.
- Other Soil types – consist of loamy sand and sandy loam. They are medium to coarse textured well-drained soils.

All the soils originate from ash, agglomerate and basic igneous rocks which are the major rock types on the island. Woburn soils are yellowish brown in colour, normally well drained, highly erodible. They are well drained and occur over ash and agglomerate in some areas. They have a medium particle size with <1.5% organic matter. Woburn soils are mainly found on 10-20 degree slopes and are well suited for pasture crops such as sugarcane, cocoa and banana. The upland areas which have slopes angling 10- 25 degrees, 10-30 degrees and 25-90 degrees are characterised by Capital Clay and Belmont Clay. These are also areas of high rainfall. Capitol Clay Loam and Belmont Clay both have good water retention capacity. Like Woburn soils, they are suitable for the growth of cocoa, nutmeg, bananas and food crops. The rocky parts of the Belmont and Capitol Clay soils are found in the high mountainous areas and are prone to erosion from rapid runoff leading to the degradation of the upstream areas of the watersheds.

[5] Grenada National Report on Sustainable Development (2004)

3.1.6 Land Use

3.1.6.1 Grenada

Grenada's land use ranges from forests to woodlands and scrubs to mangroves to built-up areas (Figure 3-28). The built-up areas tend to be located along the coastal areas.

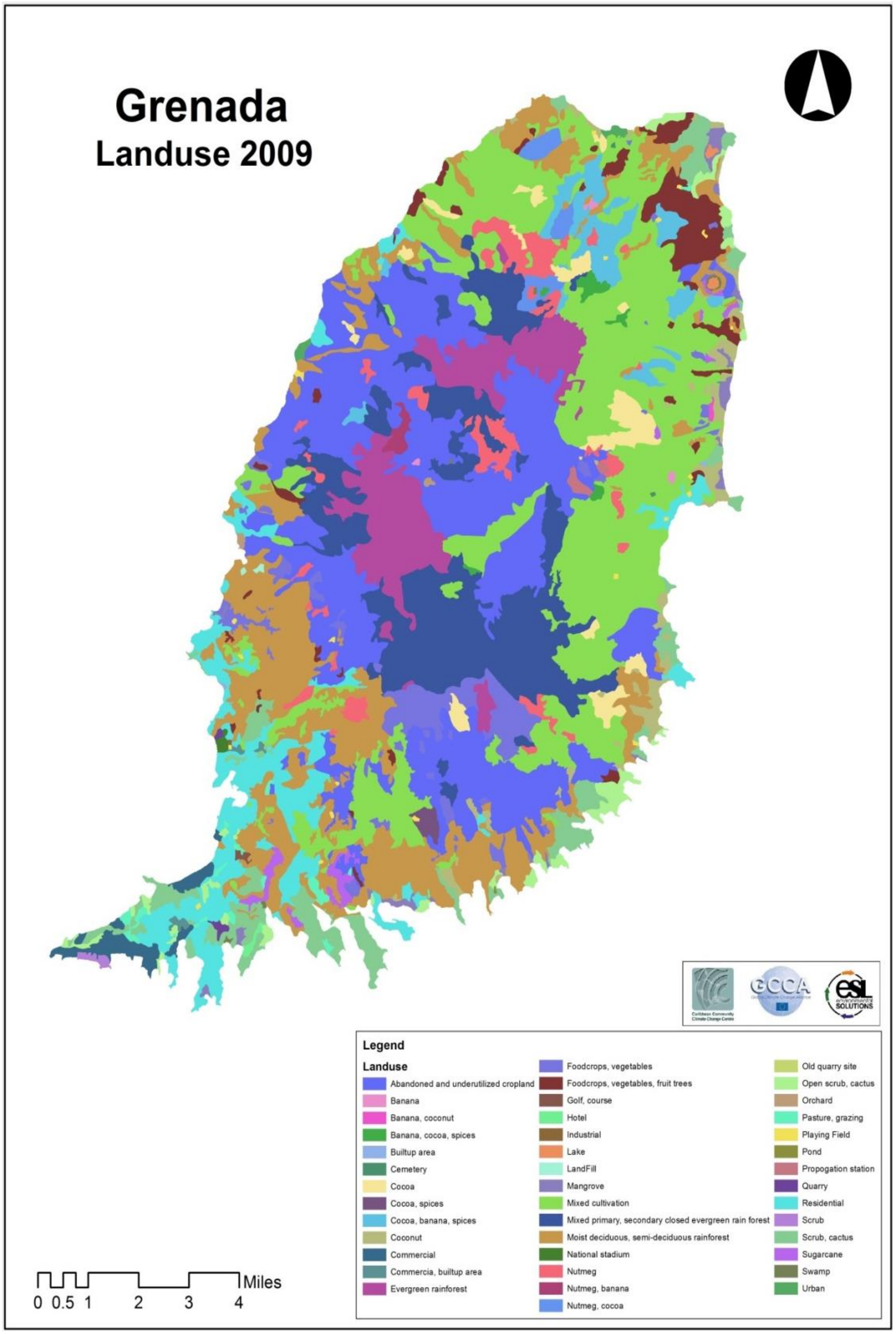


Figure 3-28: Grenada land use (2009)

Forests and woodlands cover approximately 30% of the island. Grenada's forests are classified as follows:

- Cloud forest (Mountain Thicket, Palm Break and Elfin Woodlands)
- Rain Forests and Lower Montane Forest
- Deciduous Seasonal Forests and Dry Woodlands
- Littoral Woodland (scrub and cactus)
- Mangrove swamps

Agriculture is the main type of land use for the island covering approximately 70% of its area. This is mainly in the northern and south-central sections of Grenada in the Great River, Pearls and Tivoli watersheds (Figure 3-28). Forests and abandoned cultivation is the second largest land use type. The urban areas are located in the south west section of the island in the parish of St George and covering the Chemin, Grand Anse, St. George and Richmond watersheds. The Great River watershed comprises mainly abandoned cultivation, mixed cultivation (agriculture) and forest cover (mainly deciduous). The forests in Grenada are mainly moist, deciduous rainforests with some places having scrub and cacti. The Evergreen Rainforests are located in Northern Grenada in the Great River watershed and in the areas marked as protected areas (Figure 3- 29).

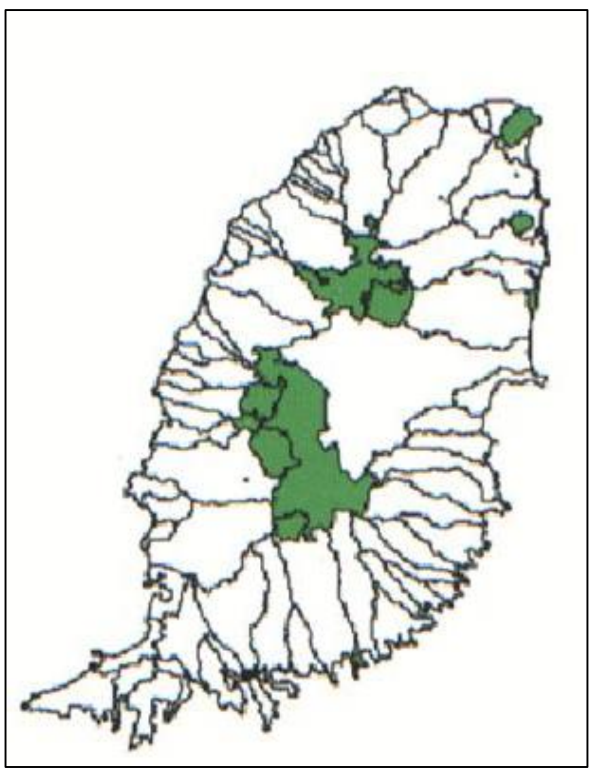


Figure 3-29: Watersheds showing the protected areas. Source: National report on Integrating Watershed Management and Coastal Areas (2001).

Agricultural activities range from coconuts, mixed fruits and vegetables, cocoa, bananas and spices. Most of the cocoa, banana and spices are grown in the northern part of the island on slopes of 10-25 degrees in areas that are dominated by clay, loam and clayey loam soils. The areas of extensive agriculture coincide with the Woburn, Capitol and Belmont Clays and lie both in the high rainfall and drier zones of the island in areas of low rainfall. Mixed cultivation occurs in areas of low rainfall. The location of certain crops in low rainfall zones suggests that these will be severely, adversely affected during periods of drought leading to shortages in the agri-sector. Furthermore, the watershed of St. George is located in the drier areas of the island and is marked by high population density and urbanization. Thus, this area has a higher probability of being affected by hydrological and meteorological drought when compared to the Great River and other inland watersheds.

A generalized analysis of the change in land use-land cover was carried out for the island of Grenada based on satellite imagery. Figure 3-30 shows the land cover change analysis as extracted for Grenada from the ESRI landsat data site (http://changematters.esri.com/compare). This ESRI Landsat image service highlights changes to vegetation areas from 1990 to 2010 using the Normalized Difference Vegetation Index (NDVI). NDVI identifies vegetated areas and their condition while compensating for sun angle and some atmospheric influences. The change map is generated by combining NDVI data derived from Landsat imagery (30m) for three dates, 1990, 2000, 2005, 2010, where R,G,B = 2000 NDVI, 1990 NDVI, 2005 NDVI and 2010NDVI. The data is available at 30 m spatial resolution and hence an islandwide assessment is possible and not at watershed level. Extracting images at the watershed level would result in coarsening of the pixels and lead to errors in image analysis.

NDVI, as determined from satellite remote sensing data, helps in identifying vegetation changes over a period of years and hence can be used as an indicator of drought. It is based on the amount of photosynthetically active radiation that a plant absorbs. Higher absorption implies growing season and less absorption means less productivity. This can be estimated from LANDSAT, MODIS images for a period of at least 20yrs which then can be used to estimate the change in land use-land cover. In this project the IR (infrared image) for Grenada was downloaded from the ESRI site at intervals of 10 and 5 yrs. The time slices available were 1990-2000, 2000-2005 and 2005-2010 and hence these were chosen for best possible scenarios. The ESRI site, shows the maps of NDVI change as “vegetation increase” marked in green and “vegetation decrease” marked in magenta. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Hence, the difference between the two bands (NIR and VIS) divided by the sum of the two gives the index which is called the NDVI. This can then be represented through maps showing the spatial variation of the indices over a region.

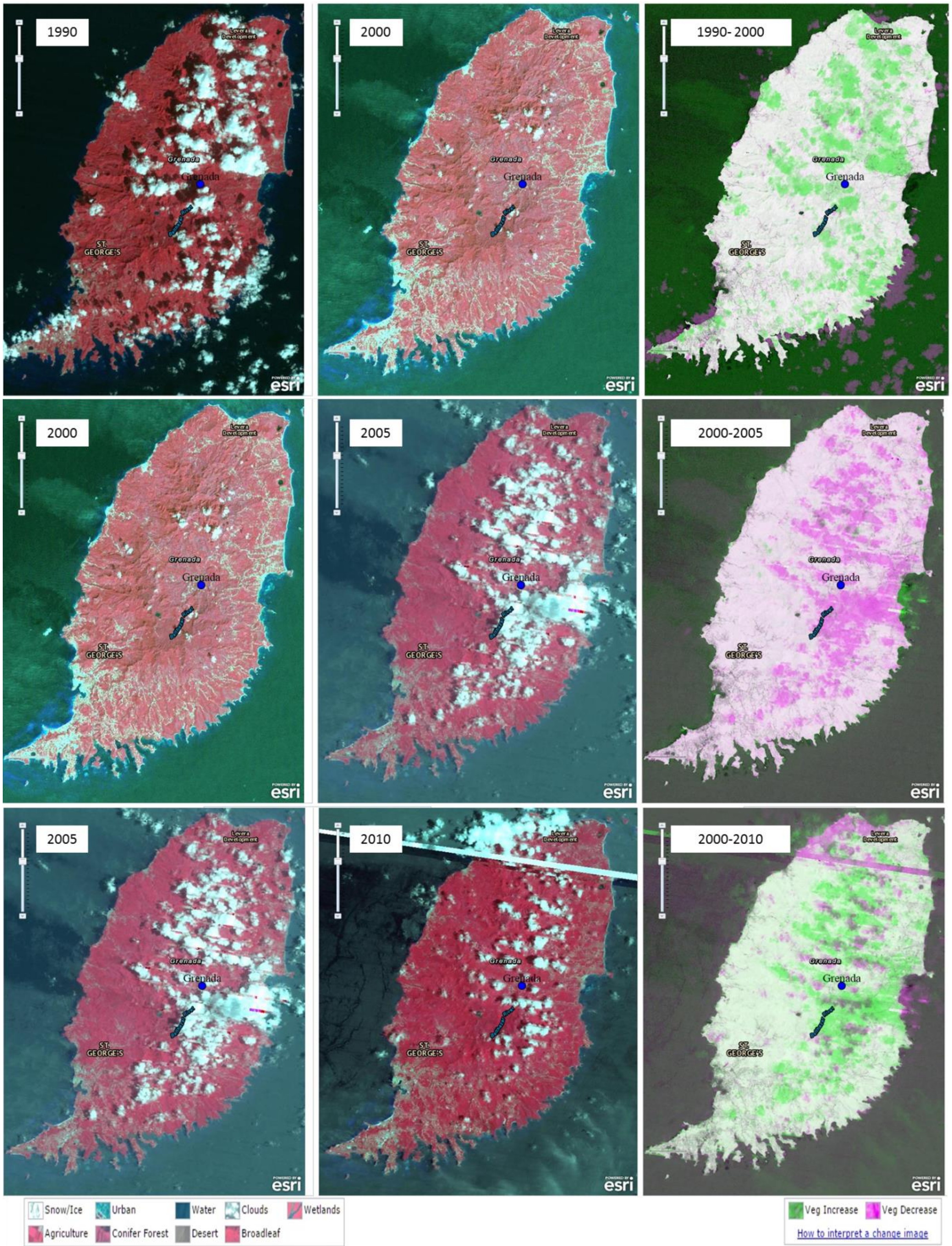


Figure 3-30: Landsat 7 image showing change in land-use land cover type from 1990-2010 along with the NDVI.

The images obtained from the ESRI site are shown in Figures 3-30. Most common land use types are agriculture, broadleaf forests, conifer forests and urban areas. The NDVI images show that most areas in the images for 1990-2000 are grey, indicating no change, because each pixel has relatively the same value in each NDVI dataset. Areas that show up green were brighter in 1990 (meaning more vigorous vegetation), while areas that show up in magenta were brighter in 2000 than 1990. Discontinuity of results between Landsat scenes is generally caused by differences in seasonality, such as scenes acquired in the spring next to those acquired in autumn.

The overall watershed land use and land cover change analysis, shows an increase in vegetation in the years 1990-2000, in the eastern section of the island, as seen from the LANDSAT data acquisition times. The images from 2000-2005 are not clear indicators of change in vegetation due to the presence of thick cloud cover over the central and eastern section of the island. Presence of thick cloud cover obstructs the natural reflectance from vegetation and hence, although areas show magenta coloration implying vegetation decrease, it may not be a true representation of the actual ground condition. The images for 2005-2010 are better than the previous five years as they have less cloud cover and thus the NDVI image shows similar increase in vegetation in the eastern section of the island. This is also seen in the 2009 land use data as received from LUD MOA which shows dominance of agriculture and forests in the central and eastern areas of the island. These areas correspond to the areas of high to medium rainfall, as seen from the rainfall map and rainfall analysis of the stations of Grand Etang, Anandale which record the highest rainfall. High rainfall and volcanic soils provide enough soil moisture for continued increase in vegetation which results in NDVI values corresponding to “green” colour or vegetation increase.

3.1.6.2 Carriacou

In Carriacou, open scrubs and cactus or forested areas are the main types of land use pattern for the island (Figure 3-30). It occupies ~ 58% of the area followed by pastures or agricultural lands (Table 3-3). Residential areas are very limited and occupy ~ 1.5% of the total area. These are mainly located along the coastal and lowland areas of the watershed. The different land use types and their percentages, as compared to the total area are also shown in Table 3-2. No data was received on the water resources for the island, including on the abstraction from the wells or water demand and consumption. However, from the land use pattern it can be inferred that agriculture is the main sector for water demand and it is primarily rainfed as there are irrigation wells supplying water for the farms.

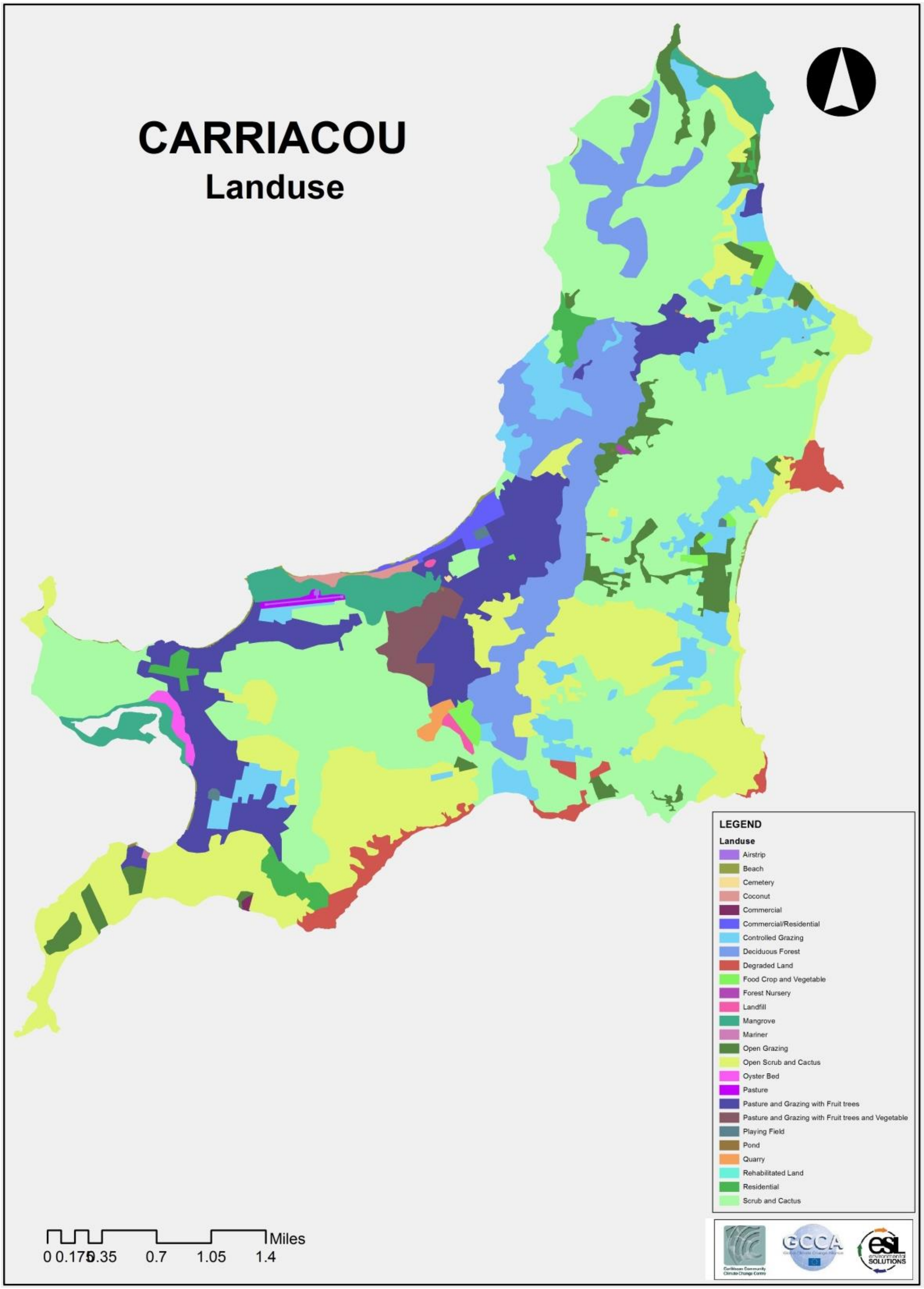


Figure 3-31: Land use map for Carriacou

Table 3-2: Main land use types of Carriacou and the percentage of their areas as compared to the total area.

LAND USE TYPES	AREA IN ACRES
Open Grazing	3.84%
Deciduous Forest	9.37%
Residential	1.39%
Pasture with Grazing with Fruit trees	11.36%
Controlled Grazing	9.01%
Pond	0.02%
Cemetery	0.03%
Open Scrubs and Cactus	57.78%
Forest Nursery	0.03%
Degraded Land	1.96%
Food Crops and Vegetables	0.69%
Landfill	0.14%
Mangrove	3.28%
Quarry	0.22%
Mariner	0.02%
Pasture	0.16%
Airstrip	0.06%
Commercial	0.62%
Rehabilated Land	0.02%

3.1.7 Water Resource Availability

3.1.7.1 Grenada

Grenada relies heavily on surface water from its river systems. At present 23 surface and 6 groundwater potable water supplies (Figure 3-31) yield some 54,600 m^3/day (12 mgd) in the rainy season and a maximum of 31,800 m^3/day (7 mgd) in the dry season (Government of Grenada Road Map Toward Integrated Water Resources Management Planning for Grenada, 2007). Table 3-4 shows the primary types of water sources, their locations and their type (tank, treatment plants or reservoirs). In total, there are 19 tanks, 11 boreholes and 23 treatment plants. There are also additional sources, such as, reservoirs and filter plants. All these sources are maintained and monitored by NAWASA and used for potable water supply, as well as, for irrigation. The boreholes are confined to the southern, coastal aquifer of the island. The UN DESA 2012 report shows the latest data on the existing water sources and their storage capacity (Table 3-5).

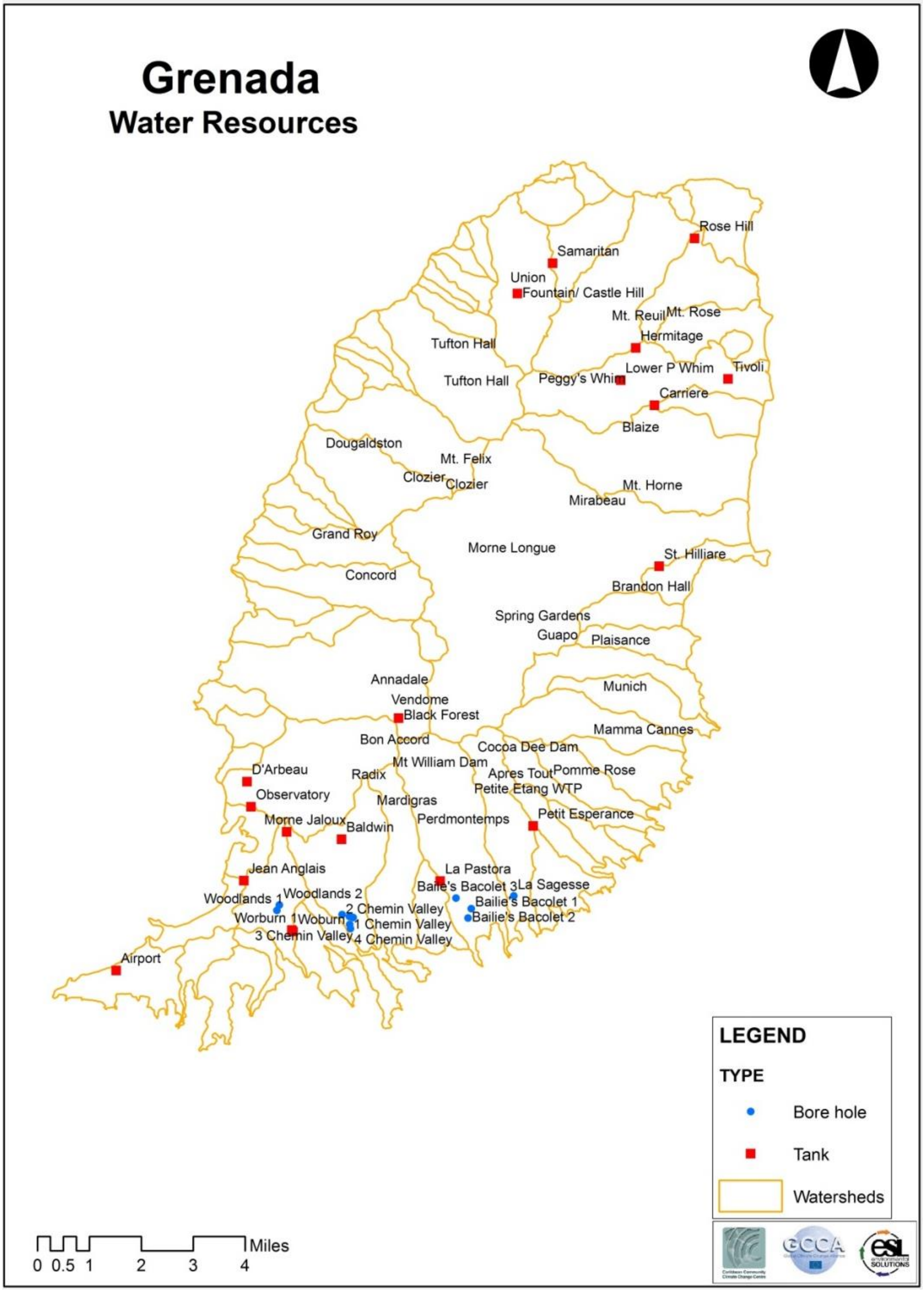


Figure 3-32: Grenada's water sources and storage. Source: NAWASA

The majority of water catchments are around the Grand Etang and in areas that have the highest rainfall and highest elevations. High rainfall in the mountains, paired with impervious geology results in a higher number of streams to transport rain water to tanks and reservoirs.

Figures 3-32 shows Grenada's watersheds along with the different water sources and storage systems. Most of these derive their water from natural sources such as streams and springs. Apres Toute, Blaize, Clozier/Mt. Felix, Fountain, Morne Longue and Union all have spring sources while, Chemin #1, Woodlands #1 and 2, Baillies Bacolet #1 and 2 and Carriacou have borehole sources (Table 3-3). Further, Windsor Forest and Richmond Hill are distribution reservoirs and not Water Treatment Plants. The distribution of tanks and boreholes shows that they are mainly for urban usage, as well as, irrigation since the areas they serve more or less correspond to urban areas and agricultural lands.

Table 3-3: List of water sources and their types as shown in the figure above

TANKS	BORE HOLES	TREATMENT PLANT	REMANING TYPES	NAMES
Airport	Woodlands 1	Petite Etang	reservoir	Mt. Rose
Worburn	Woodlands 2	Apres Tout	filter plant	Dougaldston
Jean Anglais	Bailie's Bacolet 2	Pomme Rose	spring	Cllozier
La Pastora	Bailie's Bacolet 1	Mamma Cannes	reservoir	Tufton Hall
Petit Esperance	La Sagesse	Munich	filter plant	Brandon Hall
D'Arbeau	Baile's Bacolet 3	Bellevue	spring	Morne Longue
Observatory	3 Chemin Valley	Spring Gardens	spring	Tufton Hall
St. Hilliar	4 Chemin Valley	Annadale	dam	Grand Etang
Carriere	5 Chemin Valley	Mirabeau	P filter	Perdmontemps
Tivoli	1 Chemin Valley	Mt. Horne	dam	Spring Gardens
Hermitage	2 Chemin Valley	Peggy's Whim		
Lower P Whim		Mt. Reuil		
Rose Hill		Union		
Fountain/ Castle Hill		treatment pl		
Samaritan		Concord		
Baldwin		Clozier		
Black Forest		Guapo		
Morne Jaloux		Blaize		
Woburn		Radix		
		Bon Accord		
		Les Avocates		
		Mardigras		

TANKS	BORE HOLES	TREATMENT PLANT	REMANING TYPES	NAMES
		Vendome		
		Plaisance		

Table 3-4: Water systems, average production and storage for the water sources of Grenada (Source: UN DESA 2012)

Water system	**Average production (m^3 per day)**	**Storage (m^3)**
Peggy Whim	1514	882
Mt. Horne	720	212
Birch Grove	757	missing data
Spring Garden	1040	946
Grand Etang	4542	missing data
Morne Longe	200	missing data
Munich	941	4.2
Mirabeau	871	272
Bellevue	76	53
Samaritan		378
Rose Hill		378
Hermitage		302
Carriere/St. John		378
St. Hillare		302
Plaisance	378	
Total	**11039**	**4107**

It is also important to note the parishes that the various water supply sources supply, as well as, their variation number with respect to the watersheds and parishes. The main water supply systems of tanks, boreholes and treatment plants serve the population of the island via pipelines. They are linked by ductile and PVC pipes which provide a well-connected supply system (Figure 3-32). The absence of pipelines in the interior is because the steep topography prohibits the laying of pipes. These areas are devoid of urbanization and agriculture, therefore, piped water is not necessary.

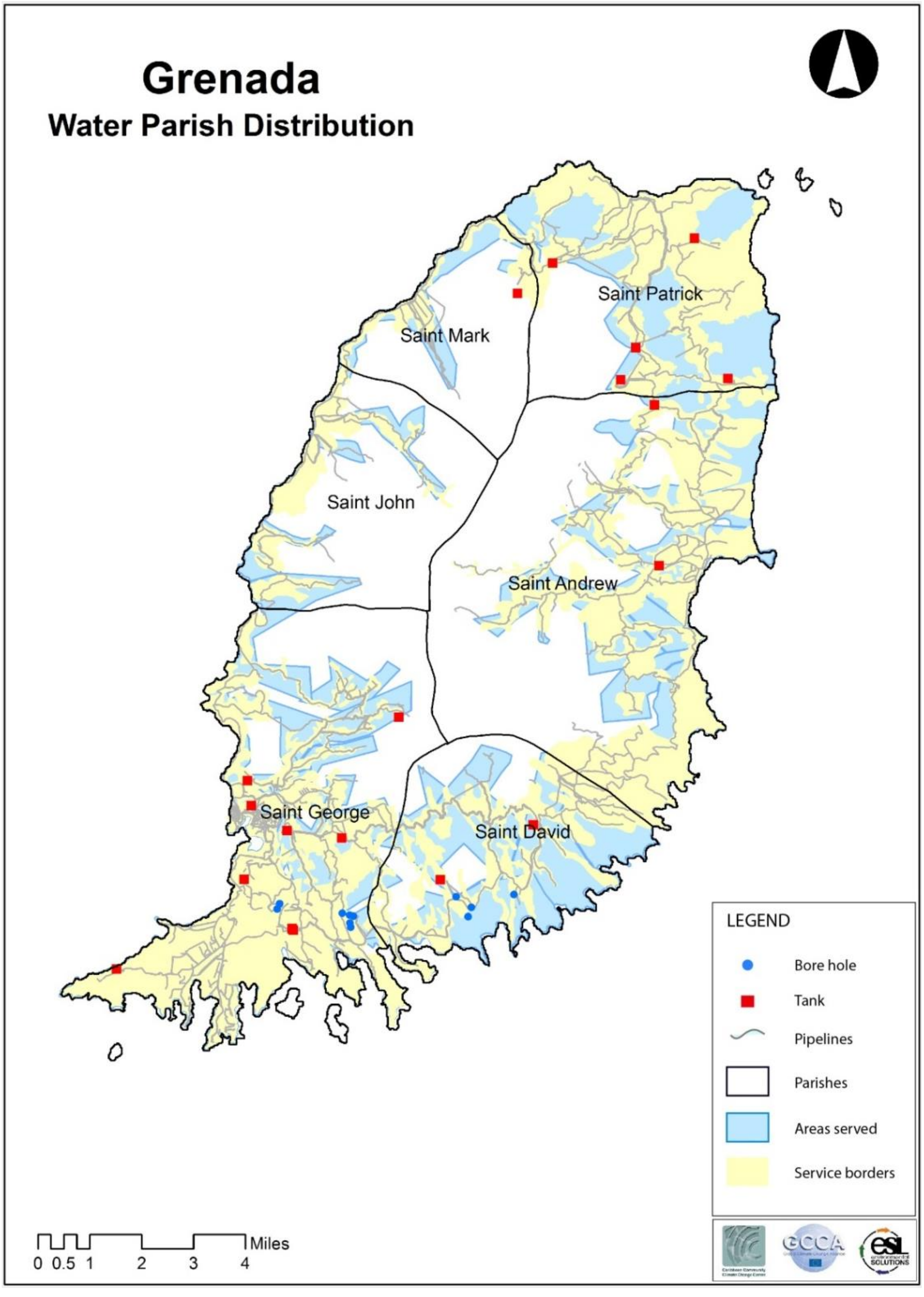


Figure 3-33: The different parishes, water sources and existing pipeline network for Grenada

A comparison of the number of water sources, the parishes they supply and the corresponding population also aids in understanding the sustainability of the existing system. Limited discussion on the effectiveness and sustainability is discussed here, as no data is available on the demand and consumption for each parish and further going down to sectorial and community levels. Data presented here is limited to the number of sources in each parish against its population (Table 3-5 and Figure 3-33).

Table 3-5: List of sources, the parishes they supply and the parish population

SOURCES	PARISH	NUMBER OF SOURCES	POP(1991)	POP (2001)	POP(2011)
Munich	St. Andrew				
Plaisance	St. Andrew				
Brandon Hall	St. Andrew				
Spring Garden	St. Andrew	8	24,135	27,115	26,433
Mount Horne	St. Andrew				
Mirabeau	St. Andrew				
Guapo	St. Andrew				
Blaize	St. Andrew				
Radix	St. George				
Mardigras	St. George				
Annandale	St. George	11	31,994	31,582	35,404
Bon Accord	St. George				
Annandale	St. George				
Woburn	St. George				
Vendome	St. George				
Concord	St. George				
Concord	St. George				
Les Avocates	St. George				
Chemin Pump Station	St. George				
Pomme Rose	St. David	4	11,011	12,634	12,858
Mamma Cannes	St. David				
Petit Etang	St. David				
Beaton	St. David				
Diego Piece	St. Mark	2	3,861	4,675	4,346
Tufton Hall	St. Mark				
Dougaldston	St. John				
Clozier	St. John	2	8,752	9,376	8,404
Mon Plaisir	St. John				
Peggy's Whim	St. Patrick	1	10,118	11,536	10,461

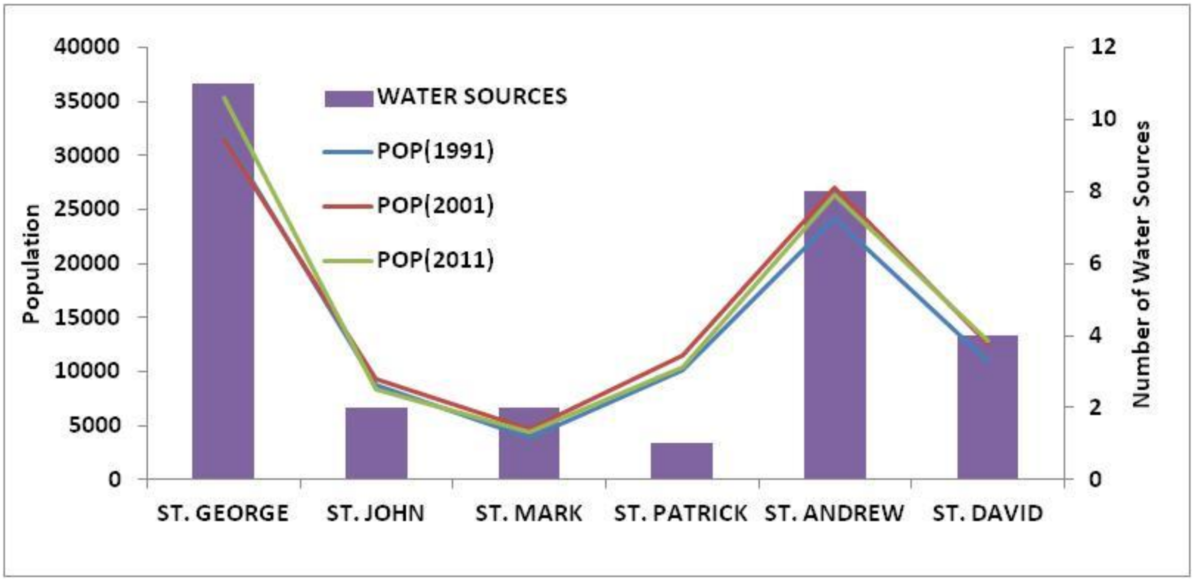


Figure 3-34: Graph showing the parish population from 1991-2011 and the number of water sources.

St. George and St. Andrew have the highest population. St George is located in the south east and is the main urban area for Grenada. It is home to the MBIA and the nation's capital, St George's. According to the data, St George experienced a slight decrease in population from 1991-2001, but an increase from 2001-2011. There has been a very slight increase in population for all of remaining the parishes except for St John and St Patrick which both show slight declines. The reason for the population decline is unclear based on available data.

In terms of water sources, St. George has the highest number (11), comprising of tanks, treatment plants and a borehole. As displayed in Figure 3-33, St. George has maximum coverage unlike others such as St John. As a result, it can be inferred that there has been an effort to provide adequate water supply to the areas with high population and hence high demand. St. Andrew has the second most number of water sources and also has the second highest population. The aforementioned further points to the fact that attempts have been made to balance parish population with the number of water sources and the areas covered. Data on demand per parish per sector was unavailable but looking at the rate of population increase, it can be inferred that demand would also increase. This in turn would imply that either an increase in production or alternative routes for additional water supply needs to be implemented, especially for St George since it receives the lowest amount of on the island.

In northern Grenada, fresh water is obtained from three main sources; the surface waters from rivers and springs, two natural lakes at Grand Etang and the River Antoine district and rain water harvesting (UN DESA (2012). Of the 71 watersheds, four of the largest are located in northern Grenada and are a source for the rain fed rivers and streams. Rivers have traditionally provided an important source of rural household water supply in northern Grenada. The continued importance of this source of water supply is manifested during severe dry seasons and in the aftermath of hurricanes and tropical storm-induced disasters, as well as, pollution and illegal farming.

In recent times, the Grand Etang Lake has become a useful surface water source, particularly in the dry season. It is 550 m above sea level and 6m deep. Since it is located in a protected area, the Grand Etang Lake is protected against anthropogenic activities and thus is much less polluted. Prior to 1990, the lake was used solely for ecotourism rather than as a potable water supply. Presently, it is the largest natural reservoir for surface water on the island. The natural dry season outflow is 2270 m^3 per day. In recent times, the run-off from the later has also been used to supply potable water demand after it is treated at the Annandale treatment plant. Figure 3-34 shows a section of the outflow from the lake which is diverted to the treatment plant. The outflow from the lake helped to overcome the severe drought in 2009/2010.

Figure 3-35: Outflow from Grand Etang Lake taken to Annandale treatment plant for potable water supply

The other two natural surface reservoir lakes, Lake Antoine and Lake Levera are also volcanic crater lakes that are 6.6 m above sea level. Lake Antoine has privately owned catchment areas and its average, annual inflow is 305, 327m^3.These two lakes are primarily used to support birds and other wildlife and not much of their water is used for potable purposes.

Rain water harvesting is not a common practice on the island of Grenada. It is more widely practiced in Carriacou and Petit Martinique.

No data was available for the water resources of Carriacou and Petit Martinique. Hence, for this report the observations made from the field study will be reported which gives a generalized understanding of the existing water resources system in these two islands.

3.1.7.2 Carriacou

Carriacou relies exclusively on rain water catchment because there are no rivers. The volcanic nature of the island promotes surface runoff and therefore the island has a dam at Bellvieu South to capture some of this runoff, but it is heavily sedimented. All homes must have a RWH system. As in Petit Martinique, an important practice is to share water with neighbours who may not have during the dry season.

A new desalination plant located at Bogle's Hell Hole should be completed by September 2015. Construction began in January and in May 2015 it was at the commissioning stage for any correction by suppliers. It has produced 'a little water' with equipment installed between March and May 2015. The rated capacity of its 2 high rate sand filters has a max pressure of 50 psi. It has a total filter area of 12.56 sq. ft. The design flow rate is 5 to 20 G per minute. It has 2 catalytic converters and its intake point is 200 feet offshore and its outfall is 100 feet offshore. The plant's flow rate is 63 to 250 gals /min and it has an overall capacity of 80,000 gals per day.

There are several public catchment systems which are identified below:

- Limlair Farm catchment System- this is a rain water catchment system with a 75 psi pump that serves people from the immediate area. Limlair farm is a 42 acre livestock farm that is in poor condition and showing signs of being very run down. No cattle were seen.
- Bellaire Pond- this is a heavily algae covered pond that badly needs cleaning. It is used for domestic animals and crops. The main public hospital is also at Bellaire and it has its own catchment system which comprises a 12ft x 26 ft. x 80 tank that holds about 100,000 gals.
- Hillsborough street well- this is a cemented over well in Hillsborough located along the main road beside the Permanent Secretary's office. The water is pumped to a catchment tank at elevation and is gravity fed to a few metered places. It serves 25 customers in Hillsborough but NAWASA collects no fees.
- Water Tower - this is somewhat of a land mark structure, water from this well is pumped to catchment tank and gravity fed for general use.
- Prospect Catchment- this is a large and relatively newer storage system operated by NAWASA. It comprises 5 x 2000 gal metered tanks and is served by well water. It is freely distributed.

3.1.7.3 Petit Martinique

In 2015, a new desalination plant was built and commissioned to produce about 50,000 gallons a day. This was just commissioned in 2015. Subsequent to this, residents relied on RWH (tanks and cisterns). During extreme periods of drought, water is barged over to the island from Grenada. People also share water with their neighbours if their storage is greater. The intake for the desalination plant is directly from the sea and there is about 90% recovery. There is no set water distribution network currently in place. One is currently being installed. When this is complete, water will be pumped up hill and then gravity fed to the rest of the population via 2 inch surface pipes. Houses will also be metred, but this will be completed by September 2015.

There are two public catchment cisterns- which has a pipe for persons to collect water. One has been converted for storage for the new desalination plant, the other no longer works as it needs a pump.

Dry periods and drought are becoming more common for the island. This has resulted in wide scale agricultural losses (crops and livestock). The current RWH systems in place are becoming inadequate for the increasing length of the dry season. The new desalination plant is expected to improve the water situation. People have also been coping with the water shortages by building bigger tanks. New cisterns are too expensive to build. To minimize usage of water during the dry season especially, people sometimes use outside toilets. There is no municipal sewage disposal – septic systems are used.

Water is rarely treated, either via chlorination or boiling. Very few people use chlorine tablets and this is occurring more in recent times.

3.2 Water Production, Demand and Consumers

As previously stated, surface water is Grenada's main water source. Unfortunately, the country's water demand and consumption data was not available from NAWASA. Additionally, data on water levels from the Grand Etang and flows from rivers such as the Chemin River, which is one of the main sources for the Chemin watershed was also unavailable. Data was obtained from NAWASA on the amount of production from the water treatment plants (WTPs) and boreholes of Chemin for the period 2005-2014. Consequently, the data presented in this report was from the aforementioned. Table 3-6 shows the yield from the different sources in the wet and dry season as reported in the UN DESA 2012 report.

Table 3-6: Water systems' average yield in the dry and wet season

Catchment	Dry season yield (March) m^3/ day	Rainy Season yield (November) m^3/ day
Grand Etang	1688	11,810
Spring Garden	747	6,581
Claboney	1225	14,408
Bellvue	-24	1,690
Birchgrove	-130	5,390
Mt. Horne	711	7,016
Peggy Whim A	2413	19,494
Peggy Whim B	360	2,739
Munich	-248	5,549

The decrease in the yield corresponds to rainfall data analysis which was conducted on the station data for Grenada. The data in the table follows the trend in mean monthly rainfall for the island which was discussed in a previous section. High rainfall yield corresponds to the wet season (Sept-Nov), while low rainfall yield corresponds to the dry season (Jan-April).

The groundwater wells are mostly located in the watersheds of Chemin and its adjoining La Sagesse in the South-eastern section of the island. Aquifers are mainly sand and sandy loam and are coastal in nature. The list of active wells in the Chemin watershed are seen in Table 3-7. The analysis of the monthly water production data for the water treatment plants are shown in Figure 3- 35.

Table 3-7: Static water level and production data for the active groundwater wells

ACTIVE WELLS	STATIC LEVEL	DRAW DOWN LEVEL	WELL PRODUCTION
Woodlands No.2	15 Feet	60 feet	600 m^3 per day
Woodlands No.3	20 Feet	70 feet	508 m^3 per day
Chemin valley No.1	15 Feet	60 feet	508 m^3 per day
Chemin valley No.2	25 Feet	66.4 feet	409 m^3 per day
Baillies Bacolet No.2	20 Feet	60 feet	613 m^3 per day
Baillies Bacolet No.3	40 Feet	71.44 Feet	1441 m^3 per day
LA Sagesse No.1	20 Feet	47 Feet	390 m^3 per day
Carriacou No.1	15 Feet	70 Feet	66.7 m^3 per day

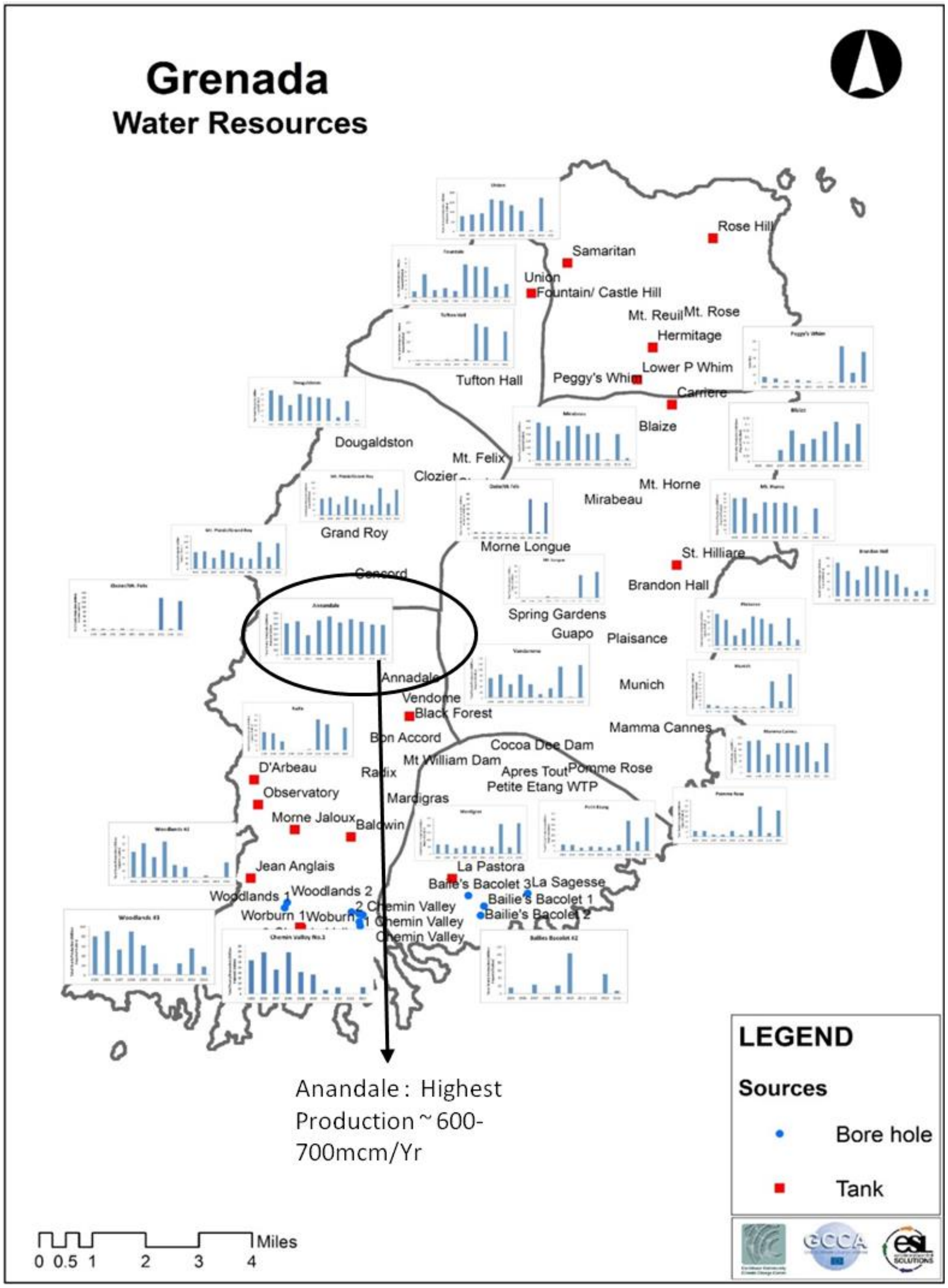


Figure 3-36: Map showing the annual production from boreholes and tanks across Grenada

The wells of the Chemin Valley range in depth from 15-25 feet with the shallower well showing a greater yield as compared to the deeper well. The maximum groundwater production was found to be from the Baillies Bacolet No. 3 well. The shallow water table and coastal aquifers could be a problem for the water quality as it could lead to saline water intrusion with increased abstraction during periods of drought

Table 3-8, shows the monthly variation in the drawdown from the available data on boreholes. Drawdown refers to the lowering of the water table during pumping. The Chemin 2 well shows a lowering of the water table from 73 to 105 ft between Mar-May 2010, which implies increased water pumping during the dry season. A higher rate of abstraction results in the height of the water table decreasing at a faster rate and is very typical of the dry season. A similar trend is seen for the remaining boreholes with a higher drawdown during dry months when compared to the wet months. In addition, it should be noted that the period Jan-Mar 2010 showed the lowest rainfall due to drought. This drought period caused a steep gradient in the lowering of the water table.

Table 3-8: List of boreholes/wells in Grenada and their drawdown (feet)

Borehole Pumps	Date	Draw Down Level D.D.L
Chemin #2	24/03/10	70 feet
	23/04/10	105 feet
	31/05/10	105 feet
Chemin #1	30/03/10	55 feet
	23/04/10	74 feet
	4/5/2010	70 feet
	31/05/10	72 feet
	1/9/2010	66 feet
	3/2/2015	40 feet
	3/3/2015	39 feet
	3/4/2015	42 feet
	4/5/2015	39 feet
Bailles Bacolet #3	3/3/2010	77 feet
	23/04/10	76 feet
	4/5/2010	76 feet
	30/06/11	72 feet
	3/2/2015	90 feet
	3/3/2015	72 feet
	3/4/2015	72 feet
	4/5/2015	73 feet
Woodlands #3	30/03/10	78 feet
	4/5/2010	72 feet
	31/05/10	75 feet
	1/9/2010	68 feet
La Sagesse	30/03/10	47 feet
	23/04/10	46 feet
	4/5/2010	47 feet

Borehole Pumps	Date	Draw Down Level D.D.L
Woodlands 2	30/03/10	74 feet
	23/04/10	69 feet
	4/5/2010	80 feet

The absence of demand and consumption data limits the ability of the data analysis to confirm whether the production is sufficient to meet the needs of the people. However, anecdotal evidence from field visits point to the fact that people are heavily reliant on the Chemin River for their water supply. Reliance on the boreholes is significantly lower than on the river because of salt water intrusion. The shallow water table and possible increased salinity of water limits the abstraction by NAWASA from the boreholes.

The data available for the WTP'S was analysed to determine the overall yearly trend. Results show that the yield from the Annandale treatment plant, is the highest, contributing 26% of the total production from 2005-2014 as compared to the other sources (Figure 3-36).

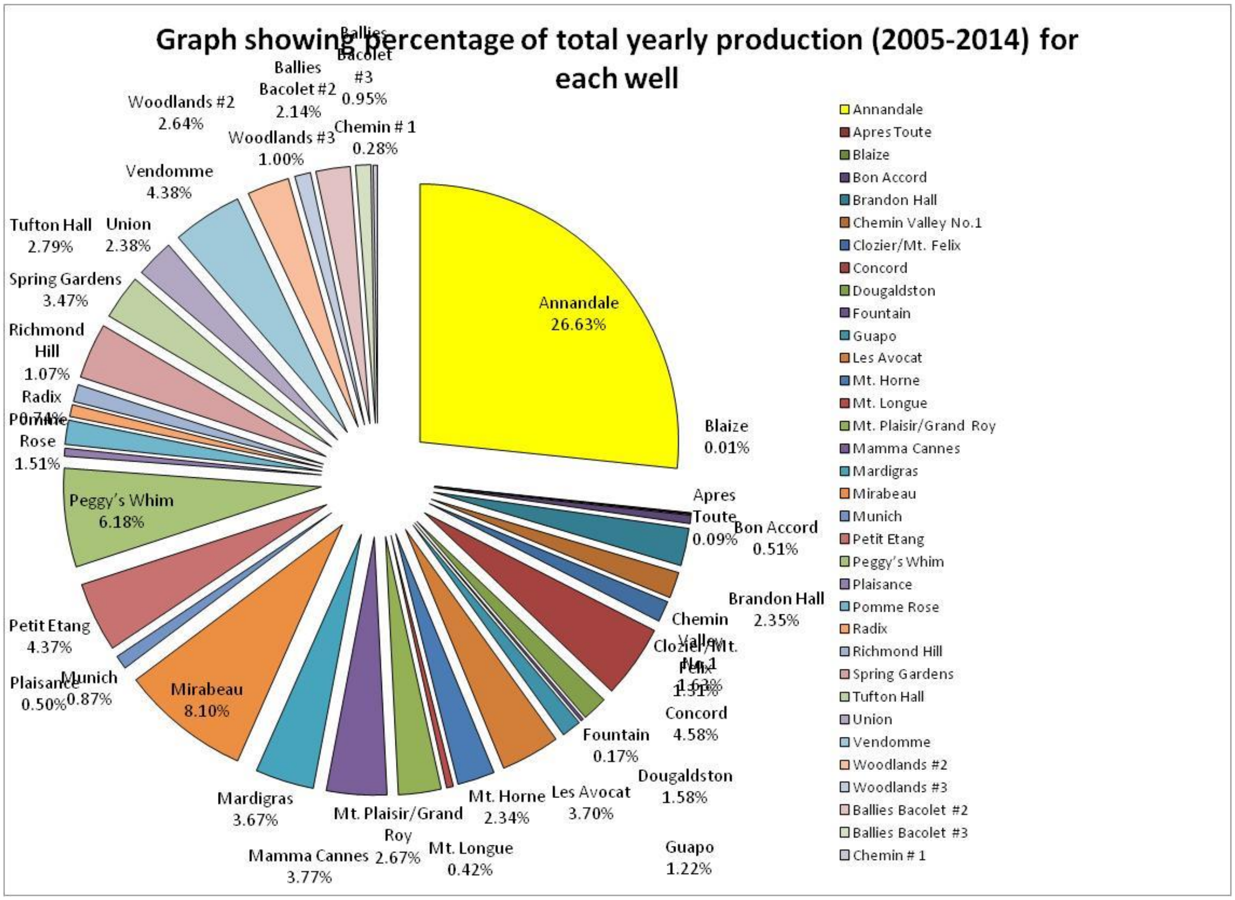


Figure 3-37: Production from all the tanks and boreholes 2005-2014, as a percentage of the total

The total production from Annandale (2005-2014) was ~6000 Million Imperial Gallons followed by Mirabeau (1843 Million Imperial Gallons) and Peggy's Whim (1047 Million Imperial Gallons), making these the three main water sources for the nation (Figure 3-37).

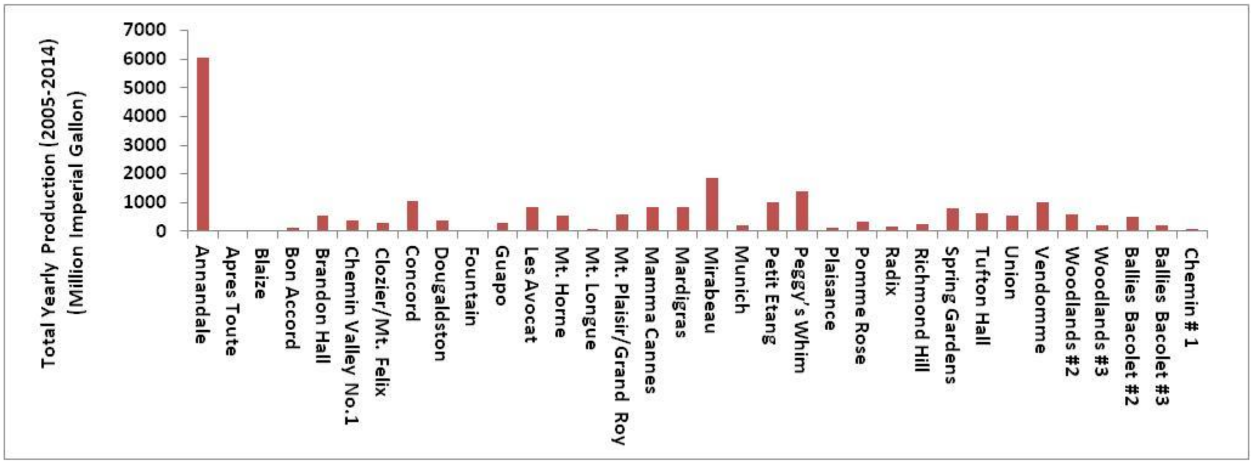


Figure 3-38: Total Yearly Production (2005-2014) for all the water sources for Grenada

The Annandale Treatment Plant mainly gets its water from the Grand Etang. It has the highest yield followed by Mirabeau and Peggy's Whim. All three of the aforementioned sites are located in high rainfall, mountainous areas that also have high density river networks (Figure 3-38).

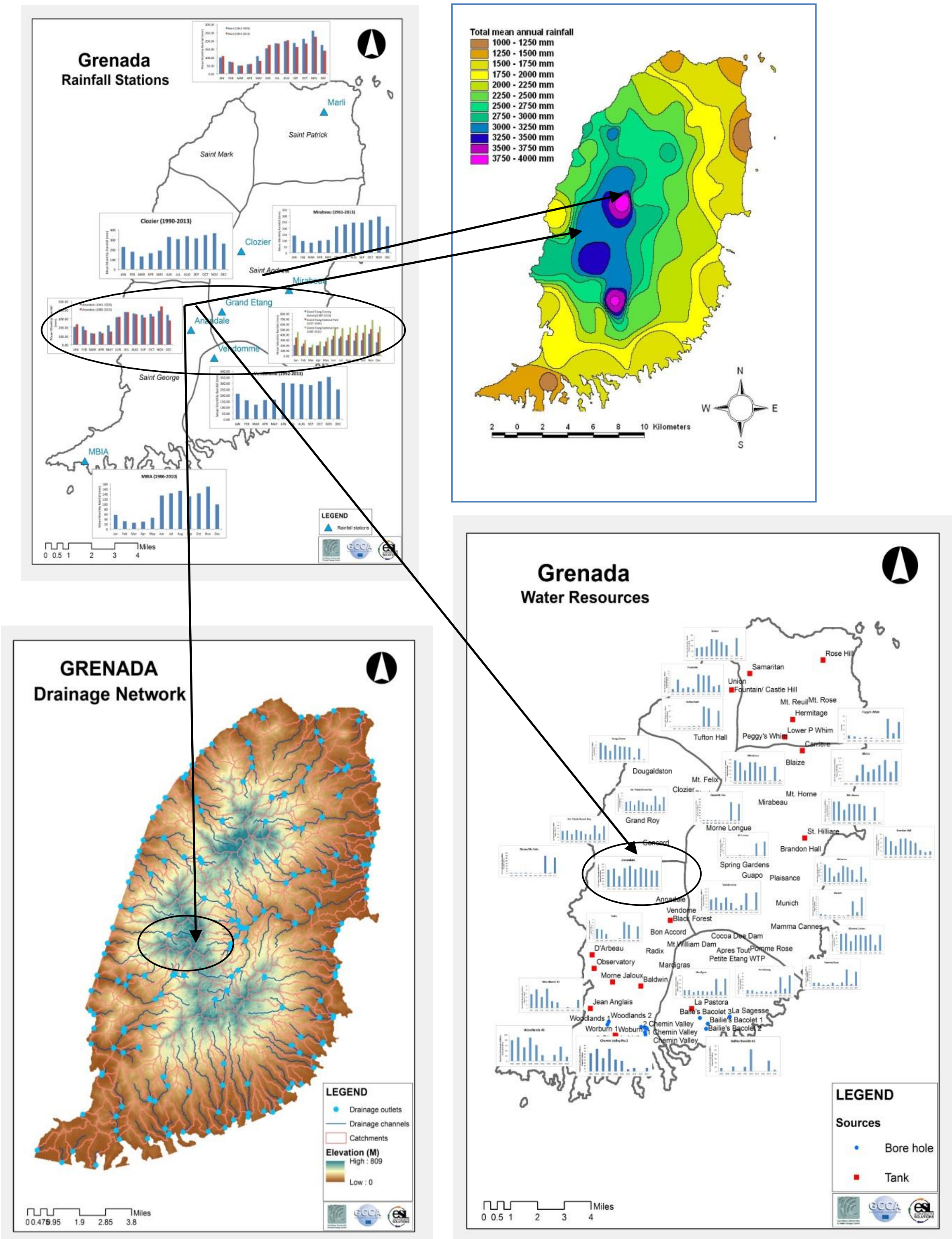


Figure 3-39: Rainfall map, station data for rainfall and water production data, Grenada (fig 42)

Note: Rainfall for Annandale and Grand Etang were the highest (shown by circle), hence, higher water production

Yearly analysis of the water sources, shows that although Annandale has consistently recorded the highest yield, there was a decline in its production over the last decade and particularly, from 2007-2010. The 2010 decline is as a result of the 2009 drought, however, the reason for the 2007 decrease is still unknown. A similar pattern emerges both for Mirabeau and Peggy's Whim (Figure 3-39). Although the other sources all yield less than the top three sites, they all display a similar decline in 2010 which signifies that the 2009 drought impacted water sources islandwide.

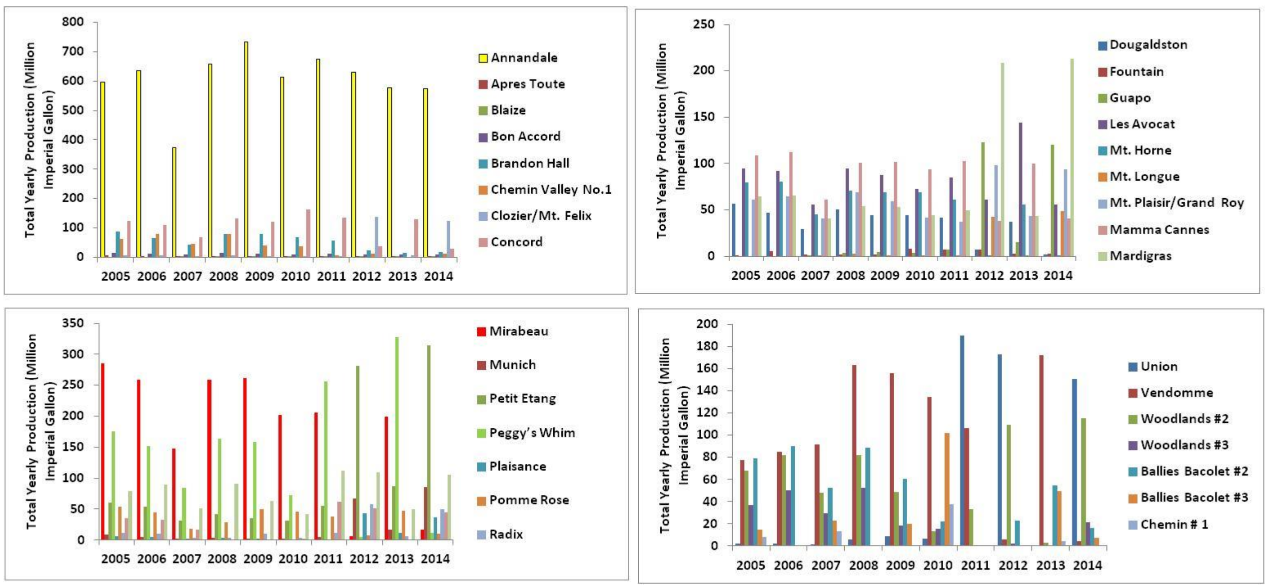


Figure 3-40: Total yearly production for all water sources in Grenada

Existing information on water supply systems have shown that piped water is the main source of potable water for Grenada. As discussed in the earlier sections, there is a well- connected system of pipelines which transport water from the tanks, treatment plants, reservoirs and dams to the households. Although demand data is not available, when population data is correlated with water sources, it is evident that number of water sources corresponds to the population of parishes. Further evidence of this relationship is the fact that decadal population change also corresponds to increases and decreases in the water supply systems (Figure 3-40).

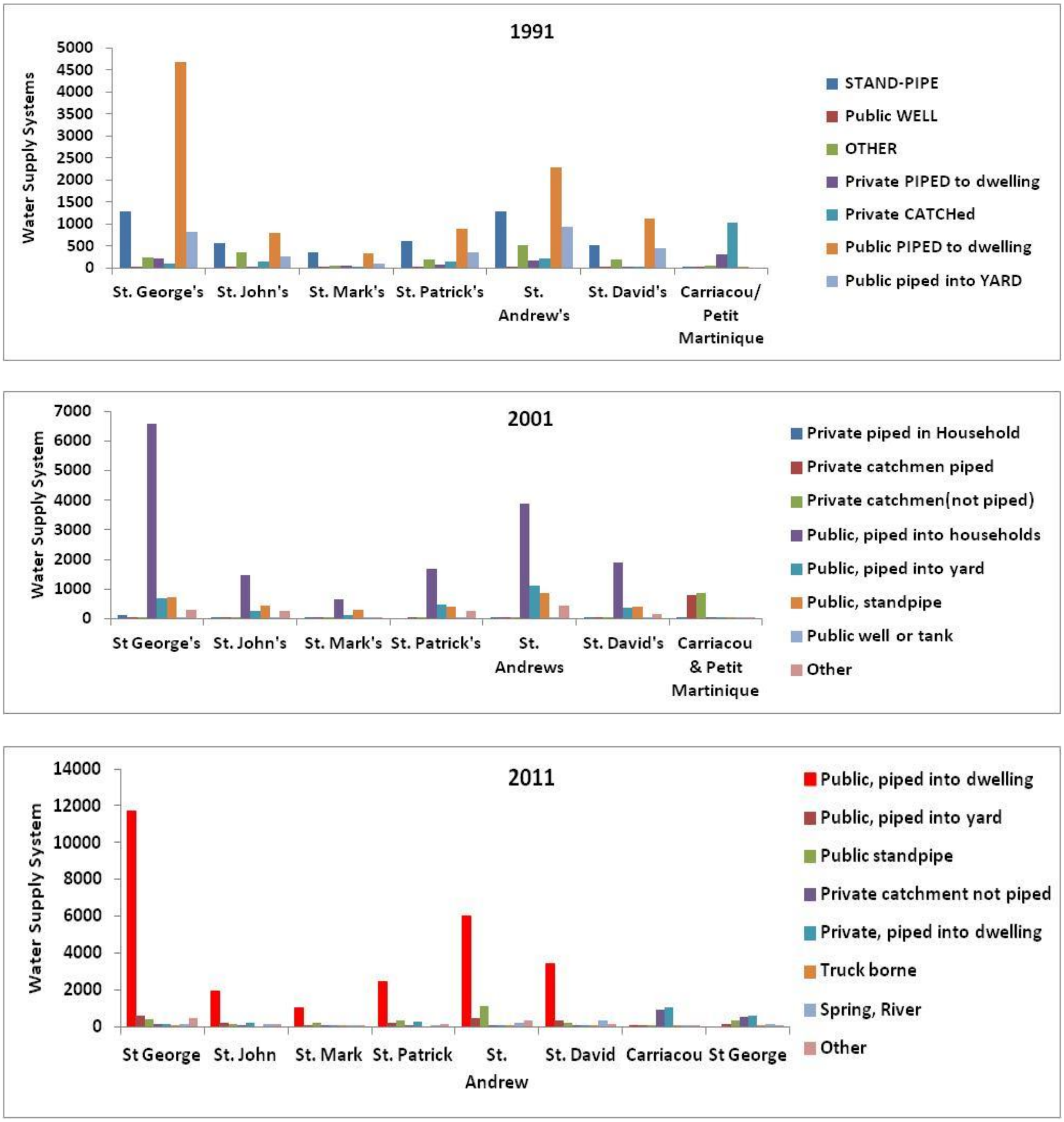


Figure 3-41: Total number of households served by different types of water supply systems

Figure 3-40 shows that "Public piped into dwelling/households" is the major water supply source when compared to the other systems. The parish of St. George has the highest number of "public piped into dwelling/household" water supply system. Additionally, there was an increase in the type of supply systems from 1991- 2011. For example, in 1991 and 2001 there was no supply of water via trucks or from rivers and springs. However, these systems do occur in 2011. This indicates that the demand for water is rising, probably due to lifestyle changes, and when coupled with decreasing rainfall, additional ways of supplying water had to be introduced.

Between 1991-2001 and 2001-2011, the rate of increase in the number of water supply systems was significant for the parishes of St George and St David (13-36% for St George and 17-36% for St David) (Figure 3-41). The increases in the remaining parishes are significantly smaller ranging from 2-6%. This increase may be as a response to the population growth which indirectly increases water demand and consumption.

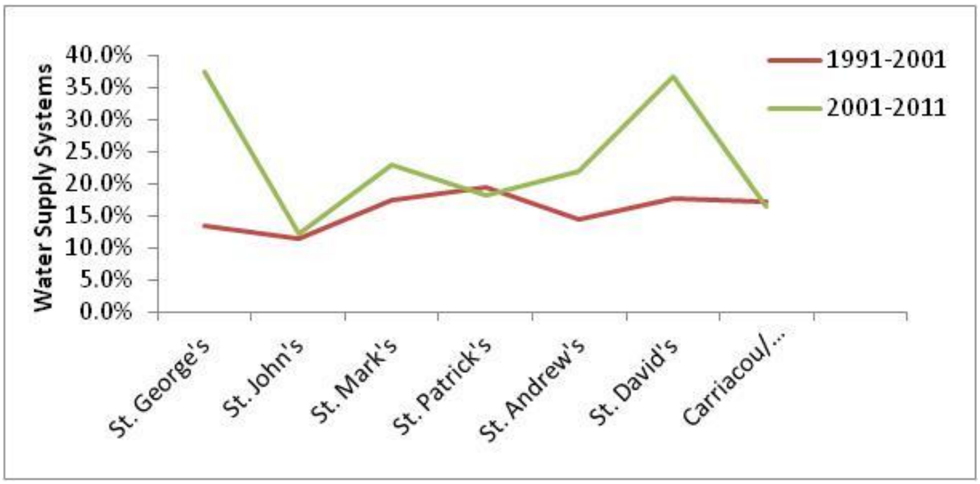


Figure 3-42: The rate of increase in water supply systems from 1991-2001 and 2001-2011

Figure 3-42, displays the total number of water supply systems (piped, trucked, private, public etc.) by parish against the parish population. There has been an increase in the number of supply systems but not a significant increase in population over the two decades. Further, for 1991-2001, the 13% increase in the number of water supply systems in the St George parish was accompanied by a -1.3% decline in population. Now in this instance, the increase in water supply systems could be attributed to more and more households getting access to piped water rather than population increase. In fact, one of the goals of Grenada's IWRM as well as the National Water Policy was to improve access to piped water. It can be inferred that water scarcity is not a serious challenge for St George since, while located in a dry section of Grenada, its number of supply systems has increased. Specific sectorial demand and consumption data, if available would have shed more light on this discussion.

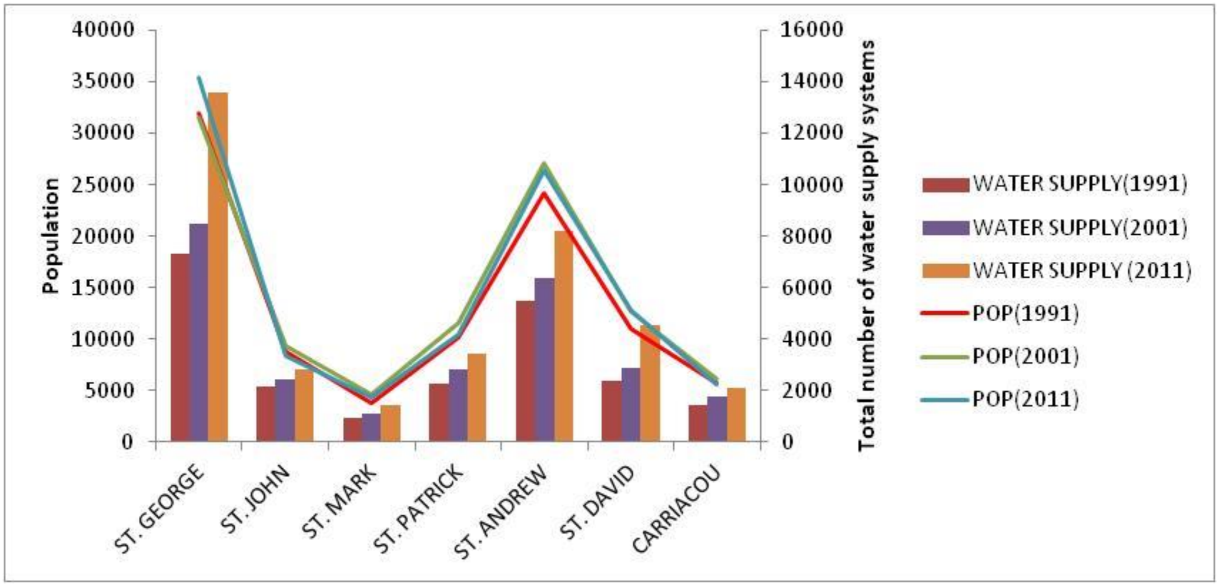


Figure 3-43: Graph showing the change in number of water supply systems and population growth

The remaining parishes in Grenada show similar trends to St George in that they either have very weak declines or increases in population but overall increases in the number of supply systems. The aforementioned does not give a direct supply and demand relationship, but rather highlights the accessibility of potable water by the population. Generally, the supply of potable water has increased and more persons have access to piped water. In fact, from the data, the number of "public, piped into dwelling" water supply systems increased from 4500 in 1991 to 6000 in 2001 to 12000 in 2011 for the parishes of St George and St Andrew- the two parishes with the highest population. The main factors increasing water demand in Grenada are urbanization and improvements in the standard of living of households (UN DESA 2012). The main consumers for water are agriculture, domestic and tourism sectors (Table 3-10).

Table 3-9: Grenada's main sources and consumers of water

Type of use	**Source**	**Activities**
Potable	Rivers, springs, Grand Etang	Drinking, cooking, house keeping
Recreation	Rivers, lakes	Fishing, swimming, river tubing
Ecotourism	Lakes, sulphur springs, waterfalls	Hiking, picnicking, site seeing, health therapy
Resorts Landscaping	RWH, rivers	Irrigation of lawns, golf courses
Agriculture and aquaculture	RWH, rivers	Livestock production, crop production, and freshwater fish rearing.

Source: UN DESA 2012

For the tourism sector, water is provided by the several hot springs in the mountainous areas including the Claboney hot spring which is a few miles from the town of Greenville. Additional water demand is met by the lakes, rivers and water falls (Seven Sisters, Carmel and Mt. Tufton). In 2011, there was a plan for the construction of a new hotel in the Levera area which was expected to increase the demand for water. A study conducted in 2012, estimated a daily demand of 825m^3/day for this 1000 room development over the next 15 years. Other activities that are expected to increase water demand are the maintenance of hotels, as well as a proposed golf course. The latter, is expected to require an additional 60,000m^3/day of water. This would put pressure on the water supply in this area of the country. To satisfy this demand, rainwater harvesting using lined ponds would be required at appropriate sites in the Levera region.

The other main demand for water is agricultural irrigation. Agricultural demand was estimated at 15% of total demand in 1989. The 2001 irrigation sites study showed eight areas as being suitable for irrigation (Madramootoo 2001) (Table 3-10).

Table 3-10: Potential irrigable lands in Grenada

Location	Watershed	Annual rainfall (mm)	Est annual runoff (mm)	Est dry season runoff (mm)	Watershed area (ha)	Catchment above irrigated site (ha)	Max irrigable area (ha)*
Paradise	Great R	1583	1106	345	4521	4295	370
Grand Bras	Great R.	1583	1106	345	4521	4295	370
Snell Hall	St. Patricks	1574	1120	337	1188	713	60
Chambord	River Sallee	1575	1103	358	547	465	42
Mt. Reuil	St. Patricks	1960	1372	492	1188	238	29
Poyntzfield	Tivoli	1680	1176	327	1093	710	58
Boulogne	Pearls	1680	1176	327	1241	745	61
Pearls	Pearls	1680	1176	327	1241	813	66

* Using 30% of river flow without storage.

Source: Madramootoo 2001

It was suggested, that water for irrigation purposes should mainly come from rainwater harvesting, surface and ground water sources. However, these would need to be further exploited to meet the increase in the demand for irrigable lands since the area of irrigable land had increased from 4.8ha in 1973 to 218.5ha in 2011.

3.3 Vulnerabilities of the Water Sector to Existing Climate

The major threats to the water sector in Grenada are droughts and floods-the two common extremes of the hydrological cycle. Saline intrusion into wells is also becoming a threat to the water sector, however, this is a combination of over abstraction, as well as sea-level rise due to climate change. These are discussed below in greater detail.

3.3.1 Drought

The intensity and duration of droughts have increased globally since 1970 (IPCC, 2007). SIDS are more vulnerable to the negative effects of droughts as a result of their limited supply of fresh water systems. Consequently, they have to rely increasingly on alternative sources of water such as desalination.

The island of Grenada experienced its worst drought between October 2009 and March 2010. The period 2009/2010 experienced a reduction in all the water sources across the island and NAWASA had to struggle to meet the demands. All stations across the island recorded the lowest rainfall in these months as compared to the previous years from 1992 onwards. Since Grenada relies primarily on surface water as its main water source, and surface water depends on rainfall for recharge, a drop in rainfall would directly affect the water production. Total annual production in 2010 was lower than the preceding and following years. Further evidence of this is seen when the 2009/ 2010 monthly totals for January-March and then for October-December are compared using the 2005-2010 available data (Figures 3-43 and 3-44.)

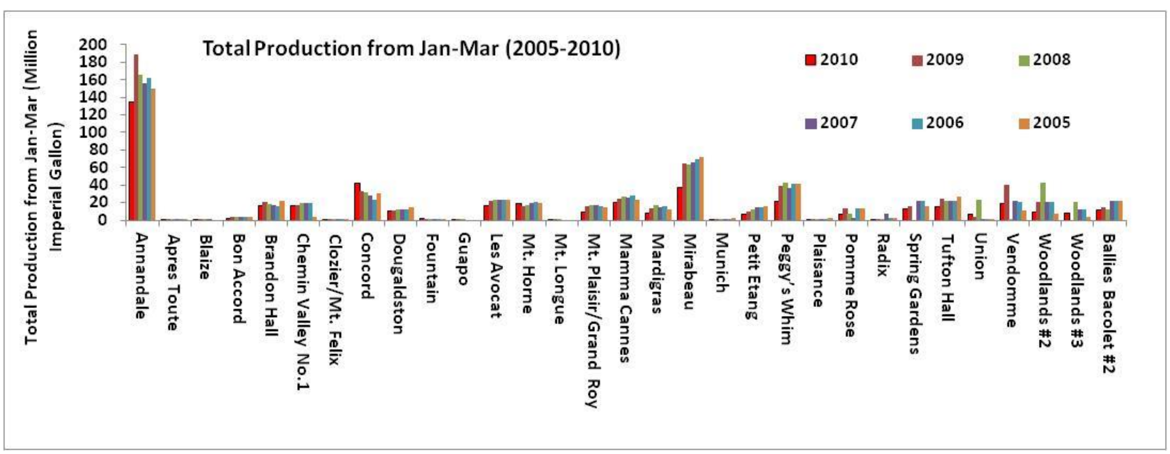


Figure 3-44: Total monthly production January-March

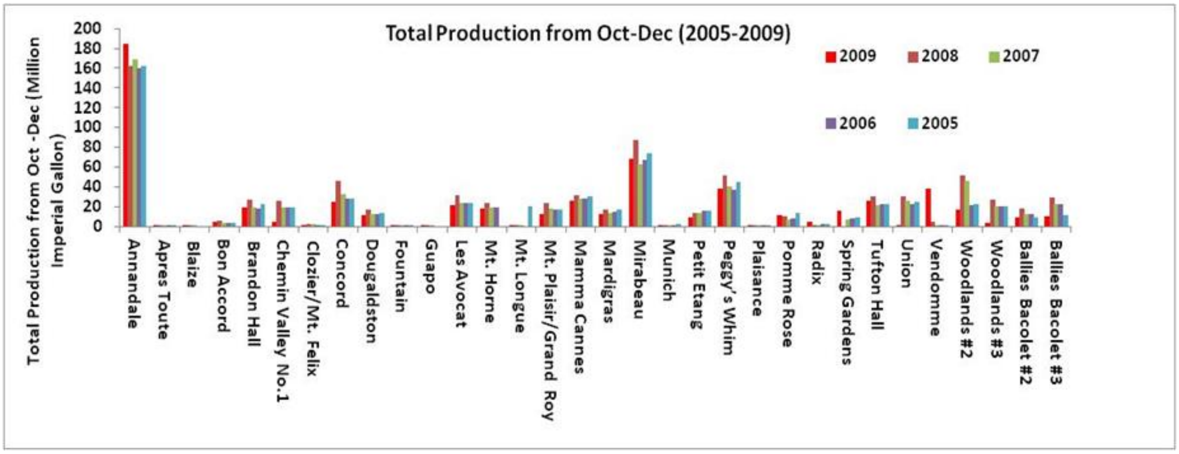


Figure 3-45: Total monthly production October- December

From the graphs it is evident that all water sources recorded low levels of production in the months analysed. October to December is part of the traditional rainy season in Grenada, but water production was low in 2009. This corresponds to the onset of the drought which was further compounded by the dry season in early 2010. Although Annandale still continued to rank highest in terms of water production, even here the drought months showed significant declines in production. This was also the trend in Peggy's Whim and Mirabeau. Table 3-11 outlines the total monthly production from Jan-Mar 2010 along with its comparison to other years for which data is available.

Table 3-11: Total monthly production (Jan-Mar), 2010 for water sources of Grenada as compared to 2005-2014.

	January-March Production Data (Million Imperial Gallon)						Decline in Production (Million Imperial Gallon)				
PLANTS	2010	2009	2008	2007	2006	2005	2009 vs 2010	2008 vs 2010	2007 vs 2010	2006 vs 2010	2005 vs 2010
Annandale	134.6	189.36	165.66	156.2	162	149.6	54.76	31.06	21.6	27.4	15
Apres Toute	0.21	0.64	0.72	1.1	1.6	1.5	0.43	0.51	0.89	1.39	1.29
Blaize	0.03	0.05	0.08	0.06	0	0	0.02	0.05	0.03	-0.03	-0.03
Bon Accord	1.3	3.4	3.76	3.8	3.9	3.5	2.1	2.46	2.5	2.6	2.2
Brandon Hall	17.1	20.2	18.6	16.6	15.9	21.6	3.1	1.5	-0.5	-1.2	4.5
Chemin Valley No.1	16.6	16.8	19.5	19.5	19.5	4	0.2	2.9	2.9	2.9	-12.6
Clozier/Mt. Felix	0.4	1.14	1.77	1.5	1.5	1.5	0.74	1.37	1.1	1.1	1.1
Concord	42	33.2	32.26	27.7	22.62	31	-8.8	-9.74	-14.3	-19.38	-11
Dougaldston	10	11.46	12.8	12.3	11.8	15	1.46	2.8	2.3	1.8	5

	January-March Production Data (Million Imperial Gallon)						Decline in Production (Million Imperial Gallon)				
Fountain	2.1	0.6	0.59	0.8	0.4	0.34	-1.5	-1.51	-1.3	-1.7	-1.76
Guapo	0.74	1.2	0.6	0	0	0	0.46	-0.14	-0.74	-0.74	-0.74
Les Avocat	17.04	22.41	22.63	22.95	22.85	23.4	5.37	5.59	5.91	5.81	6.36
Mt. Horne	18.38	15.5	16.95	19.3	20.7	19.2	-2.88	-1.43	0.92	2.32	0.82
Mt. Longue	0.04	0.2	0.5	0	0	0	0.16	0.46	-0.04	-0.04	-0.04
Mt. Plaisir/Grand Roy	9.4	15.9	16.9	17	15.7	14.6	6.5	7.5	7.6	6.3	5.2
Mamma Cannes	20.53	24.39	26.89	25.99	27.96	22.9	3.86	6.36	5.46	7.43	2.37
Mardigras	8.37	13.71	17.4	15.2	16.29	12.1	5.34	9.03	6.83	7.92	3.73
Mirabeau	36.63	64.18	63.64	66	69.4	71.4	27.55	27.01	29.37	32.77	34.77
Munich	0.3	0.66	0.93	1	1.4	2	0.36	0.63	0.7	1.1	1.7
Petit Etang	6.8	9.5	11.9	14.35	14.6	15.6	2.7	5.1	7.55	7.8	8.8
Peggy's Whim	21	39	43.3	37	41	41	18	22.3	16	20	20
Plaisance	0.18	0.86	0.93	1.1	0.9	2.25	0.68	0.75	0.92	0.72	2.07
Pomme Rose	7.3	13.6	6.9	2.2	13.4	13.6	6.3	-0.4	-5.1	6.1	6.3
Radix	0.74	1.5	1.14	7.9	2.52	2.74	0.76	0.4	7.16	1.78	2
Spring Gardens	12.8	15.65	0	22.4	22.5	16.5	2.85	0	9.6	9.7	3.7
Tufton Hall	15.84	24	22.3	22.4	22.3	26.8	8.16	6.46	6.56	6.46	10.96
Union	6.35	3.3	23.4	0.7	0.6	0.5	-3.05	17.05	-5.65	-5.75	-5.85
Vendomme	18.56	40.4	0.62	22.4	20.6	10.5	21.84	-17.9	3.84	2.04	-8.06
Woodlands #2	8.8	20.4	42.8	20.4	20.4	6.8	11.6	34	11.6	11.6	-2
Woodlands #3	8.07	0	20.4	12.6	12.6	4	-8.07	12.33	4.53	4.53	-4.07
Ballies Bacolet #2	11.27	14.8	12.6	22.5	22.5	22.5	3.53	1.33	11.23	11.23	11.23

The data shows that Annandale recorded a decline of 54 million imperial gallons, in early 2010, when compared to the same period in 2009 and a 31 million imperial gallon decline when compared to 2008. This clearly illustrates the effects of the drought. Peters (2012) also showed a similar trend whereby a sharp decline in production is evident for Jan-Mar 2010 when compared to earlier years (Figure 3-45).

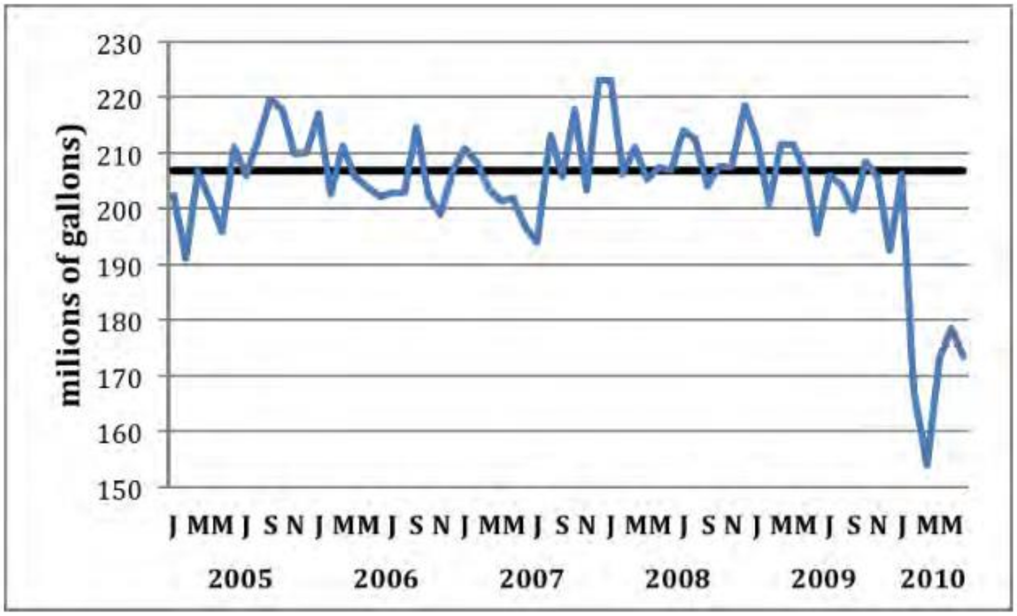


Figure 3-46: Monthly water production from NAWASA and the effect of the onset of 2009 drought

Source: Peters 2012

As reported by Thompson (2013), the impact of the 2009 drought was also observed in the reduced river flows for some of Grenada's major rivers. Although not as drastic as the 2009/2010 drought, 2013 also showed signs of drought which affected the water supply from Annandale (Figure 3-46).

Figure 3-47: Drought of 2013 and reduced water level and siltation for Annandale (shown by arrow)

Source: Thompson 2013

During community consultations around the island of Grenada in May 2015, residents have noticed an increasing drying trend. This has severely impacted farmers especially, but also sometimes preventing residents from being able to perform regular domestic activities. This was similarly recorded in Carriacou and Petit Martinique. Both smaller islands have reported droughts becoming more frequent in the last 15 years. Since, they rely primarily on RWH, the impacts of droughts are more greatly felt in these islands.

During severe droughts, the price of water in Carriacou and Petit Martinique increases significantly which is a serious challenge to the residences of the island.

3.3.2 Flooding

Flooding is very rare for Carriacou and Petit Martinique. However, they are likely to become more severe and regular due to climate change, particularly in Carriacou. When flooding does occur it is temporary and not widespread. In Carriacou, floods tend to be localised in the Hillsborough area and cause relatively insignificant losses. There does not appear to be any impact on water quality.

Even though it is not a common feature of Grenada, the island has been affected by floods. The steep terrain of the island of Grenada, means few areas are prone to flooding and so most of the island falls in the "low" hazard category. However, there are flat areas with slopes not exceeding 0.1%—on which flood hazards can be described as either high or medium. These areas tend to occur within one (1) kilometre of the coast, in the lower reaches of catchments where deposition of sediments, which are transported from the steep upper catchments, occur. Most of these zones tend to predominate on the eastern side of the island which is less steep and where there are several extensive coastal plains, namely in the Conference, Pearls, Grand River, La Chaussee and the La Sagessee catchments. Whereas, the western side of the island is much steeper and rugged and with fewer flatlands, save for that in Beausejour, flooding is less. The hazard to flooding for flatlands north of Pearls Airport is at the medium level mainly because the land cover, which is mainly forest, promotes high infiltration and therefore low runoff quantities from rainfall. South of this airport, the La Sagessee, La Chaussee, Richmond Hill, Grand Anse Valley and Beausejour are each high flood hazard level areas because they lie within catchments with intensive agriculture or suburban development that yield high runoff quantities.

Flooding from hurricanes/ tropical storms can also occur. Grenada does not have an extensive hurricane history due to its location in the southernmost region of the hurricane belt. It has been affected by several tropical storms including Hurricane Ivan, 2004, Hurricane Flora, 1963, Hurricane Janet, 1955 and one unnamed storm in 1921. During hurricanes and major flood events, water supply can be affected through a number of sources. Hurricane Ivan significantly affected Grenada's water resources (Peters, 2010):

- Damage to roads which limits access to water supply infrastructure;
- Damage to underground infrastructure, including water distribution pipes;
- Loss of power at pumping stations thereby increasing the time to restore services;
- Degradation of the water producing watersheds;
- Siltation of water intakes; and
- Damage to treatment facilities.

After hurricanes there may be extended disruptions in water supply which can have serious adverse public health and sanitary implications. Households that have RWH would more likely be able to meet their needs for a few days to weeks after a major hurricane or flood event.

3.3.3 Sea Level Rise and Saline Intrusion: Coastal Vulnerability

Caribbean islands are vulnerable to salt water intrusion. This is caused by the over-pumping of the groundwater wells of coastal aquifers leading to the upcoming of the salt water/ fresh water interface and the gradual inland movement of this interface (Figure 3-48). Most of the boreholes are located along the coastal sections of the island of Grenada (Figure 3-32) and are currently being impacted by saline intrusion due mainly to over extraction. The situation will likely be exacerbated by sea level rise.

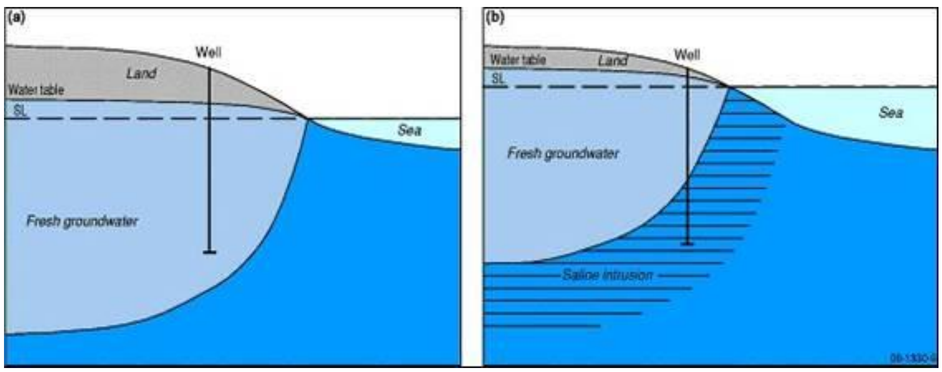


Figure 3-48: Saltwater-freshwater interface in (a) an unconfined (hypothetical) coastal aquifer, (b) the same aquifer under a sea level rise scenario. Source: Geoscience Australia 2010

3.4 Vulnerability to Future Climate Risks for the Water Sector

Grenada, like other SIDS of the Caribbean is seeing the impact of climate related risks which are affecting its water sector. Analysis of the water sector for present climate risks show that floods and droughts are the two main hydrometeorological hazards which have affected the island in the past:

- Flooding, though not a very common event in Grenada, is seen to occur in watersheds along the coast or those in lowland areas due to rapid runoff from the steeper interior sections of the island.
- The island recorded its worse drought in the year 2010 followed by a second phase in 2013. The impact of tropical storms and hurricanes cannot be ruled out either.
- The historical trends for tropical storms and hurricanes for Grenada shows an increasing trend in the number of landfalling hurricanes. The 10-year running mean indicates a period of increased hurricane activity beginning in the year 2000. There is a sharp increase in the number of Category 4 and 5 hurricanes starting in 2002, signifying an increase in the more intense storms. The records indicate a small increase in Category 1 storms, but a decline in Category 2 and Category 3 hurricanes. In the last decade, the island was impacted by two major hurricanes i.e. Ivan in 2004

and Emily in 2005 and by two tropical storms, Earl in 2004 and Felix in 2007. All of these have severely affected the water sector in terms of flooding in the watersheds of Chemin and in the town of Greenville as well as landslips in hilly interiors with steep slopes. Flooding in the Chemin watershed resulted in clogging of the mouth of the river by silt brought down as debris from the upstream section of the watershed, primarily composed of volcanic impermeable lithology. Coastal inundation from hurricanes and tropical storms contributed primarily for the flooding in the town of Greenville. Storms which directly impacted Grenada also impacted its other territories. No storms directly impacted Carriacou, in fact all there was an even split in the number of storms passing north and south of Carriacou.

- Sea level rise and its impact on the coastal aquifers is also a serious concern for SIDS as it directly relates to water quality and coastal inundation. Studies conducted by Smith (2001) on the salt-fresh water interface for the coastal aquifers of Chemin has shown that there is a trend of increase in conductivity in the well waters and the progressive landward migration of the salt-freshwater interface. Records on the sea level rise from 1950 – 2000 for the Caribbean shows that there is an increasing trend and this will further aggravate the inland migration of the interface resulting in production of salty water which would be unsuitable for potable supply.

In this section, the outputs of the climate model (Section 2) are used to analyse its impact on the water sector, primarily with respect to flooding, drought, sea level rise, all of which will affect water availability, water quality and the infrastructures related to water supply systems i.e. tanks and pipelines. Based off of the climate projections discussed in section 2.6 the following effects are likely to be felt on the water sector:

1. **Temperature:** The projections for increased maximum and minimum temperatures for the entire island along with an increase in the number of warm days and nights across the island implies increase in the evaporation and evapotranspiration which are directly related to the T_{mean}, T_{max} and the solar radiative forcing. The months of August – November is the typical wet season as shown from the temporal rainfall pattern across the island. Increase in temperature during these months would imply drier days and higher rate of evaporation. The dry season for Grenada spans from January – March and with an increase in the number of dry days for the rest of the year it will result in chances of increase in drought if rainfall does not show any increasing trend.

   So in other words, higher the temperature, higher the rate of evaporation from rivers, streams, dams and any water bodies which will eventually result in lowering of the water levels for the same if not recharged by rainfall. Dry days also increases demand for water as people need excess water to combat the heat for both drinking and other domestic consumption. Thus it results in increased consumption and with reduced recharge it will further lead to lowering of the existing production and likely result in water shortage. The problems will be more severe for the parishes of St. George and St. David which rank higher in terms of population and hence demand. Furthermore, if the trend in temperature rise shows the southern section of the island being impacted more than the northern, this further aggravates the problem of water availability as St. George and St. David are both in south and south central section of the island.

2. **Precipitation:** Overall there is a projected mean percentage decrease in precipitation for Grenada. The maximum decrease in monthly average percentage values is projected to occur in dry months of January-March (14%). However, on the seasonal scale the largest decreases are seen in February-March-April (FMA) (13%). All mean monthly percentage decreases are no less than 3% for Grenada. Decrease in rainfall directly affects the water sector as rainfall is the main source of water for the island.

   Surface water is the dominant source of water as evidenced from the available data on water resources and supply and from the presence of dense network of natural drainage channels. The largest water supply system is the Anandale tank followed by the tanks and plants at Mardigras, Mirabeau etc. A decrease in rainfall for the island implies reduction in surface runoff and low rate of recharge for the groundwater wells of the Chemin. This would mean decrease in the production of water which would eventually lead to drier conditions or increase in water shortages across the island. A detailed water balance model will be shown in the final report which will show the probable impact of the increase in temperature, decrease in rainfall on the amount of runoff as per the generalised equation: P –E = R (P = precipitation, E = evapotranspiration, R = runoff).

   Existing data on present water supplies has shown that although the Anandale plant was able to provide water during the drought of 2010, but still showed significant lowering in its production levels for the months of Jan –Mar 2010. With climate projections showing further increase in T and decrease in P, the water balance calculations will lead to a decrease in R (runoff) as the E (evapotranspiration) will increase with increase in both maximum, minimum and mean temperatures. Model projections show increase in temperature and drier days for the existing wet season (Aug-Nov), hence this will extend further in the early dry season (Jan – Mar) causing overall yearly reduction in water resources. The existing rainfall data shows that the southern parishes with high population density (St. George, with the capital city) records low rainfall annually as compared to the rest of the island. With models showing further decrease in rainfall this will result in further reduction in the runoff and storage especially in the southern sections of the island. In brief, the climate model projections imply reductions in water supply which will significantly affect the southern parishes which are high in demand owing to its population density.

3. **Sea Level Rise:** Estimates of observed sea level rise from 1950 to 2000 suggest that sea level rise within the Caribbean appears to be near the global mean. Projections in sea level rise for the Caribbean suggest an upward trend in Caribbean sea level rise, with the exception of the Bahamas. As per Chatenoux and Wolf (2013), Grenada shows a mean sea level rise of 2.9mm/yr from 1950-2000. Higher projections of sea level rise are noted in the IPCC Fifth Assessment Report (AR5) in comparison to the Fourth Assessment Report (AR5). It is useful to note that for the SRES A1B which was assessed in AR4, the likely range bases on the science assessed in the AR5 is 0.60 [0.41-0.79] m by 2100 relative to 1986-2005 and 0.57 [0.40-0.75] m by 2090-2099 relative to 1990. Increase in sea level would imply increase in coastal inundation which would

affect the coastal town of Greenville which already shows impacts of coastal flooding. In terms of water quality it would imply increase in the salinity of the well waters of the Chemin, which would eventually lead to closure of the wells, thus increasing the stress on the surface water systems.

4 INSTITUTIONAL, POLICY AND LEGISLATIVE FRAMEWORK REVIEW

It is important to understand the current institutional, policy and legislative framework within Grenada that governs and relates to the water sector. Based on the projected climate variability and change patterns, the institutions will have to position themselves to adapt to the needs that will be generated by these potential impacts. Relevant policies, plans and legislation that guide these institutions have to be reviewed in order to identify gaps, and to realign them to address the situation.

This section discusses the institutions involved in water resources management, the policies, legislation, plans and international conventions that relate to the water sector. It highlights the gaps and makes recommendations for the future.

4.1 Institutional Review

The institutional map takes into account all agencies (public and private) which relate to the several functions and resources considered to form a part of the water sector.

There are several agencies with responsibility for watershed management. They have supporting legislation. There are also existing policies which are related to environmental management and by extension have linkages to watershed management. Table 4-1 shows Grenada's Government Agencies/Ministries and their associated climate related legislation, and policy/plan.

Table 4-1 Government Ministry/ Agency and their associated climate and water-related legislation(s) and policy(ies)/plan(s)

GOVERNMENT AGENCY/MINISTRY	DIVISION/SECTIONS/UNITS/ STATUTORY BODIES	LEGISLATION	POLICY/PLAN
Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment (MALFFE)	• Environment Division • Fisheries Division • Forestry Division • Land Use Division	• Beach Protection Act • Crown Lands Act • Fisheries Act • Forest, Soil and Water Conservation Act • Grand Etang Forest Reserve Act • Land Settlement Act • Pesticides Control Act • Draft Environmental Management Act • Draft Protected Areas and Forestry and Wildlife Legislation	• National Biodiversity Strategy and Action Plan • National Environmental Policy and Management Strategy for Grenada • Grenada National Climate Change Policy and Action Plan 2007-2011 • Grenada's Agricultural Policy • Forest Policy • Draft Drought Management Plan • Draft Forestry and Wildlife Management

GOVERNMENT AGENCY/MINISTRY	DIVISION/SECTIONS/UNITS/ STATUTORY BODIES	LEGISLATION	POLICY/PLAN
			Strategy and Action Plan • Draft Integrated Watershed Management Model Plan • Draft Land and Marine Strategy
Ministry of Finance, Planning, Economic Development, Trade, Energy & Cooperatives	• Grenada Solid Waste Management Authority)	• Grenada, Carriacou, Petit Martinique Strategic Development Plan 2030 • Grenada Solid Waste Management Authority Act • Environmental Levy Act • Standards Act • Solid Waste Management Act	• Medium Term Development Framework: Economic Growth, Poverty Alleviation and Macroeconomic Stability (2005) • Poverty Reduction Strategy • Draft National Waste Management Strategy for Grenada
Ministry of Tourism, Civil Aviation and Culture	• National Parks Department • Grenada Meteorological Service	• National Parks and Protected Areas Act	• Grenada's Plan and Policy for a System of National Parks and Protected Areas • Master Plan for the Tourism Sector – Grenada, Carriacou, Petite Martinique
Ministry of Health & Social Security	• Environmental Health Department	• Public Health Act • Water Quality Act	
Ministry of Communications, Works, Physical Development, Public Utilities, ICT & Community Development	• Physical Planning Unit • National Water and Sewerage Authority (NAWASA	• National Water and Sewerage Authority Act • National Water and Sewerage Authority Sewerage Regulations • National Water and Sewerage Authority Water Services Regulations • Physical Planning and Development Control Act • Water Resources, Supply and Sewerage Bill	• Grenada's Building Code • National Physical Development Plan • Draft National Water Policy • Draft Integrated Physical Development and Environmental Management Plan for Carriacou and Petit Martinique

GOVERNMENT AGENCY/MINISTRY	DIVISION/SECTIONS/UNITS/ STATUTORY BODIES	LEGISLATION	POLICY/PLAN
Office of the Prime Minister	• National Disaster Management Agency	• National Disaster (Emergency Powers) Act	• Grenada National Disaster Plan • National Hazard Mitigation Policy
Drought Early Warning and Information Systems (DEWIS) Committee			• National Drought Early Implementation and Information System Implementation Plan Terms of Reference

4.1.1 Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment (MALFFE)

The mission statement of the MALFFE is "A professional and highly motivated staff providing efficient, effective, quality services to the agricultural community (farming, fishing, forestry) to stimulate maximum production for local consumption, export and increased incomes through the sustainable use of natural resources[6]." The divisions/units within the Agriculture portfolio are Environment, Fisheries, Forestry and Land and Surveys. These are further sub-divided into Agronomy; Agricultural Extension; Agricultural Engineering; Biotechnology and Research; Disaster Risk Reduction; Livestock and Veterinary Services; Pest Management Unit; Produce Chemist Laboratory.

4.1.1.1 Environment Unit

The Units under the Environment Division are – Biodiversity; Climate Change and Multilateral Environment Agreements. The services provided include Environmental Impact Assessment services for investment projects; monitoring of multilateral agreements and protocols; mainstreaming climate change in national planning processes; climate proofing of capital projects; implementation of Community awareness programmes on climate change adaptation and mitigation and preparation of proposals for climate financing.

4.1.1.2 Fisheries Division

The Fisheries Division is responsible for the management of all marine resources throughout Grenada. Marine protected areas management is coordinated by the Fisheries Division[7]. The units under Fisheries are – Marine Protected Areas; Data Management; Resource Assessment and Management; Extension; Quality Assurance; Refrigeration Maintenance and Fishing Technology.

[6] http://www.gov.gd/ministries/agriculture.html

[7] http://www.icriforum.org/about-icri/members-networks/grenada

4.1.1.3 Forestry Division (FD)

The Forestry and Natural Parks Department is responsible for the forest reserves on state-owned lands and any development taking place within them. It overlooks the management of national parks, protected areas and eco-tourism sites. Water related functions include upland watershed management and tree establishment and management. The units under the Forestry portfolio are - Management of Forest Reserve and Protected Areas and the Sub-Units include: Forest Conservation; Tree Establishment and Management; Wildlife Conservation; Environmental Education; Upland Watershed Management; Mangrove Conservation and Forest Recreation.

The Forest Conservation unit is involved with forest protection, and monitoring of activities within forests as well as conducting research. The Upland Watershed Management unit is responsible for identifying and prioritising critical upland watershed areas in need of rehabilitation, and establishing and developing effective working partnerships with landowners and users in priority areas to improve watershed management. The Tree Establishment and Management unit is responsible for developing and managing information systems relevant to public and private sector activities in forestry, and for developing the capacity to provide and assist citizens who are interested in planting and managing trees[8].

There are 70 watersheds in Grenada and 20 watersheds in Carriacou and Petit Martinique. Some of these are forest reserves thus are controlled by the Forestry Division. Some are forested crown lands and fall under the control of the Lands and Surveys Division. However, a large portion of the country's watersheds are on private property and are outside of government management since there is no specific soil or water conservation legislation for environmental management on private lands[9].

4.1.1.4 Land Use Division

The Land Use Division controls the Land Resources Information System whose database contains rainfall data for Grenada gathered from over 60 stations for various lengths of time. Fifty year rainfall data is available for 10 of the stations. The units under the Land and Surveys portfolio are - Lands Unit, Draughting Unit and Surveys Unit.

4.1.2 Ministry of Communications, Works, Physical Development, Public Utilities, ICT & Community Development

The mission statement of the ministry is "To protect and enhance the Nation's investment in infrastructure[10]." Climate related agencies are the Physical Planning Unit and the National Water and Sewerage Authority.

[8] National Report Integrating Management of Watershed and Coastal Areas Grenada, 2001.

[9] National Report Integrating Management of Watershed and Coastal Areas Grenada, 2001.

[10] http://www.gov.gd/ministries/works.html

4.1.2.1 Physical Planning Unite

The Physical Planning Unit consists of two sections – Forward Planning and Development Control. The objectives of the Physical Planning Unit are[11]:

- To guide the future development of the State by establishing a National Physical Development Plan, Local Area Plans and schemes for National Development.
- To ensure the orderly and progressive development of land, in a manner that will protect the environment and conserve the nation's heritage.
- To implement the Grenada Building Code and Guidelines.
- Facilitate improved efficiency in the processing of applications for approval to develop land and monitoring of developments.
- Implement and maintain a Geographic Information System (GIS) in order to enhance the output of the Physical Planning Unit.

4.1.2.2 National Water and Sewage Authority (NAWASA)

The mission statement of this unit is "to provide customers with a safe, adequate and reliable water supply and safe disposal of waste water, in a viable and efficient manner that meets and exceeds customer expectations, and ensures the development of our organization, communities and our nation[12]." The NAWASA is responsible not only for the supply, production and distribution of water, but also for the conservation, preservation and protection of catchments.

4.1.3 Ministry of Finance, Planning, Economic Development, Trade Energy and Cooperatives

The mission of this ministry is to "To effectively plan, generate, allocate and account for resources through the implementation of fiscal and economic policies and the facilitation of social and environmental policies in co-operation with other agencies thereby providing and enabling sustainable growth and development[13]."

4.1.3.1 Grenada Solid Waste Management Authority (NSWMA)

The mission statement of the NSWMA is to "improve the Quality of life of the Grenadian public and the protection and enhancement of the environment through the provision of effective management and an efficient, reliable and acceptable solid waste service.[14]"

[11] http://www.gov.gd/ministries/works.html

[12] http://www.nawasa.gd/about-us/vision-mission

[13] http://www.gov.gd/ministries/finance.html

[14] http://www.gswma.com/

4.1.4 Ministry of Tourism, Civil Aviation and Culture

The mission of the ministry is "to provide a range of administrative and technical services as well as policy leadership for the achievement of sustainable tourism development[15]."

4.1.4.1 National Parks (NP) Department

The NP is responsible for forest reserves on state-owned lands and any development or exploitation schemes taking place within them. The department also manages national parks, protected areas and eco-tourism sites.

The programme objectives of the department are:

- To enhance the physical facilities and beautify the environment of the parks and tourists sites;
- To ensure the efficient and effective management of the resources allocated to national parks;
- To increase revenue collection at national parks and attraction sites[16].

4.1.4.2 Grenada Meteorological Service

The Meteorological Services were established on Oct 28, 1984 at Point Salines International Airport to provide meteorological services for Grenada's aviation sector. The mission of the Meteorological Service is, "to provide users of our Services with timely and accurate information, in the most professional manner ."

4.1.5 Ministry of Health and Social Security- Environmental Health Department (Public Health)

The mission of the ministry is "To promote and provide health services that are appropriate, accessible, equitable and sustainable, by utilizing suitably qualified and motivated staff committed to excellence and professionalism." It also aims "To encourage the improvement, protection, maintenance and preservation, of our fragile ecosystems on a sustainable basis[17]."

The mission of the Environmental Health Department (EHD) is "to promote the practice of good health habits and disseminate information designed at educating people[18]." The EHD is responsible for "monitoring and ensuring the best Environmental Health practices are adhered to at all times." The (E.H.D) also has a Vector Control Unit, which periodically monitors, investigates and terminates various forms of vectors, that threatens human wellbeing.

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[15] http://www.gov.gd/ministries/tourism.html

[16] http://www.gov.gd/ministries/tourism.html

[17] http://www.gov.gd/ministries/health.html

[18] http://health.gov.gd/index.php?option=com_content&view=article&id=100&Itemid=530&lang=en

Public Health Safety Services include, but are not limited to the following: food safety investigation, water quality, waste management, monitor, control and evaluate the spread of infectious diseases and investigate and control the spread of hazardous materials[19]."

4.1.6 Office of the Prime Minister- National Disaster Management Agency (NaDMA)

The mission of NaDMA is "To reduce the loss of life and property within Grenada, Carriacou and Petite Martinique by ensuring that adequate preparedness, response and mitigation measures are in place to deal with the impact of hazards.[20]"

4.1.7 Drought Early Warning and Information Systems (DEWIS) Committee

The Committee comprises the following:

- Ministry of Agriculture (Lead Agency)
- Meteorological Services
- National Water and Sewerage Authority
- National Disaster Management Agency
- Farmers' representatives
- Fire Department of the Royal Grenada Police Force
- Media Representative
- Government Information Systems
- Grenada Chamber of Commerce

The overall goal of the DEWIS Committee is to contribute to efforts to mitigate the effects of droughts in Grenada through the provision of early warning and public education and awareness information.

The scope of work of the Committee is to ensure institutional synergies for the collection, analysis and dissemination of hydrological, meteorological and other forms of drought-related public information as well as the coordination of any necessary action. The proposed structure of drought management in Grenada is presented in Figure 4.1.

[19] http://www.gov.gd/ministries/health.html

[20] http://www.gov.gd/departments/nadma.html

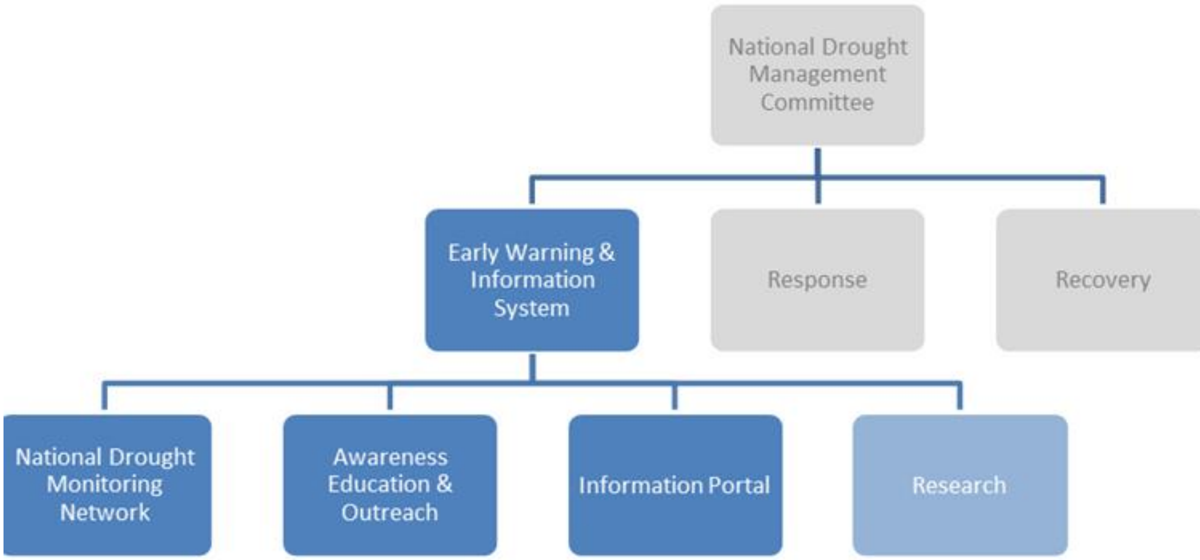


Figure 4-1 Proposed Structure of Drought Management in Grenada with Emphasis on Early Warning

The Terms of Reference for committee are:

- To undertake leadership of monitoring, forecasting and development and dissemination of information on drought and the ultimate development and implementation of a Grenada Drought Plan.
- Review and update existing legislation as it relates to droughts on all corresponding agencies/departments (example: NAWASA, Ministry of Agriculture) to ensure harmonization to develop a Drought Act. Water saving devices and rain water harvesting policy.
- Capacity Building in relevant institutions that will be responsible for the development of relevant Early Warning and Public Education and Awareness information.

A Drought Monitoring Network shall be formed to provide technical advice to, and to implement the policies of the DEWIS Committee. This Working Group would consist of: NAWASA, Ministry of Agriculture, Inter-American Institute for Cooperation in Agriculture (IICA), Farmers Groups, Meteorological Service, National Disaster Management Agency, Inter Agency Group of Development Organisations. (IAGDO), Ministry of Environment. The objective of this Network is to manage climatological and hydrological data and from this produce the necessary climate and water monitoring information and forecasts for Early Warning advice. Other committees include the Awareness, Education and Outreach Committee and the Web Information Portal.

4.1.8 Proposed Land Management Agency (LMA)

Under a Public Sector Modernization Project, the GOG is pursuing the establishment of a new executive agency. This new Land Management Agency will be charged with the task of utilizing an integrated approach to managing land-related issues, which incorporates all agencies whose mandates include land resource management and administration. The Valuation Section of the Ministry of Finance, the Land and Surveys Division of the Ministry of Agriculture and the Registry of the Supreme Court will also be integrated into the new agency. It is anticipated that this agency will be the lead policy and regulatory-setting body for land development processes in Grenada. Establishment was anticipated to be in 2007 (Grenada MSP, 2006).

4.2 Policy and Legislative Review

4.2.1 Review of Legislation

4.2.1.1 Weaknesses in Existing Legal Instruments

The structure of the legal framework governing the water resources management can be considered to consist of three levels:

- International level through the myriad MEAs ratified or acceded to by the GoG ;
- Regional environmental protection agreements signed by GoG;
- National laws, policies and plans.

The regulatory framework associated with water resources management is disjointed and embedded in various institutions. Nationally, many pieces of legislation that exists for environmental protection are dispersed among a number of Ministries and national agencies. The dispersion of the legal instruments among various institutions necessitates inter-sectorial coordination and cooperation for attaining sustainable management of water resources.

4.2.1.2 Weaknesses in Existing Legal Instruments Regarding Water Management

The existing sectorial, disjointed system for water management needs to be replaced by a central coordinating agency which will be responsible for the management of water resources in a holistic manner. This will ensure that due consideration is given to the various conflicting uses and allocation of water resources. Successful models already exist in the Caribbean, of which the Water Resources Agency (WRA) of Jamaica is a good example. The newly formed Water Resources Authority, Water Resources Management Act and the Water Policy of St. Lucia provide a template which can be tailored to meet the needs and expectations for Grenada.

Additionally, attaining the goal of implementing IWRM in Grenada will involve four fundamental and required elements:

- A holistic and comprehensive national policy and plan for the management of water resources;
- Development of the legal and regulatory framework for the management of water resources;
- Improving and where necessary developing the institutional and administrative framework for water resources management;
- Enhancing the capacity and capability for the management of water resources.

4.2.2 Assessment of Institutional Framework, Policies and Legislation

4.2.2.1 Weakness in Institutional Framework

The responsibility for land management in Grenada is dispersed among several Government Ministries and Departments: Land Use Division in MOALFF, Lands and Surveys' Division, Forestry and National Parks Department, the Ministry of Health and the Environment, the National Water and Sewage Authority, the National Housing Authority, the Ministry of Communication and Works, the Industrial Development Corporation and the Grenada's Port Authority.

Consequently, there is need for greater coordination and harmonization of actions to combat land degradation. However, it should be noted that currently, there is no National Land Use Policy for Grenada. The need for such a policy has been recognized as one of the priorities for sustainable development, and more specifically land management in Grenada. According to the National Environmental Policy and Management Strategy for Grenada:

"in the absence of such a policy and of specific policy instruments, current trends towards the excessive concentration of development on the south-west of the island of Grenada are likely to continue, with resulting patterns of congestion, migration and inequity."

Water resources management in Grenada is faced with a multiplicity of challenges reflected at many levels such as inter and intra governmental, statutory and private sector agencies. In assessing the main challenges, varying levels of severity have been suggested by different agencies. The challenges and obstacles are as follows:

- Lack of Good Water Governance Severe;
- Multiple institutions, each with their own piece of legislation and mandate, none of which is broad or deep enough;
- Assigned responsibilities for planning; management and operations affecting quantity to units separate from those responsible for quality management;
- Poorly defined responsibilities for departments/section;
- Overlap of responsibilities, resulting in duplication;
- Cost trade-off between the pollution control and water supply treatment in the same watershed is not evaluated, thus the national investment policies and programmes do not reflect the interrelationships between quality and quantity.
- Lack of effective integration and coordination hampered by:
    - The absence of sound and comprehensive national policies on water resources;
    - The multiplicity of institutions that deal with the management of the resources;
    - The multiplicity of laws, each dealing with separate aspects of the management of the resources, thus encouraging compartmentalization;
    - Institutionally divided approach to dealing with environment and development;
    - Poor management of the dynamics of water supply and demand;
    - Inadequate legal and regulatory frameworks for managing the resources;

- The lack of a proper understanding and awareness of the principles of sustainable development and an appreciation of the inseparable linkages between environmental, social and economic issues;
- Institutional arrangements for integrated water resources management are weak/ non-existent;
- Lack/inadequate institutional resources;
- Lack/inadequate human resources;
- Inadequate financing;
- Weak technical capabilities/lack of a critical mass for water resources management;
- Inadequate Data and Information Management Infrastructure;
- Conflict between water supply and demand;
- Poor land use planning and soil management in watersheds;
- Poor pollution prevention and control Limited/poor Stakeholder Participation;
- Limited/little Public Awareness and Education;
- Lack of promotion of the economic, social and ecological values of water;
- Impact of Climate Change and Sea level Rise.

4.2.2.2 Weaknesses in Policy Framework

Whilst there are many policies and plans, many are not effectively implemented. Land use planning plays an important role in the conservation and wise use of natural resources, such as land, by creating a suitable framework within which usage can occur. There is no national land use plan nor is there a land use policy. Instead, there is a draft National Physical Development Plan (2003) for Grenada and its sister islands.

4.3 Recommendations for Policies and Legislation

The reasons why legislation are not implemented vary but include: lack of political will, lack of technical and financial resources, change of Government or change of Government policy, legislation is not on the legislation time table approved by the Attorney General, lack of or inadequate drafting instructions, lack of commitment by the Ministry or Minister, lack of communication by ministry technical officers and the Permanent Secretaries of the Ministry.

In the classic model, legislation should start with the approval of a Policy which then gets Cabinet approval. At the time of approval, the Cabinet would also direct that the legislation be drafted. The legislation is then drafted by the Attorney General or a private draftsman, approved by the Attorney General (in any event the final draft would have to be approved by the Attorney General). Following this, the Cabinet would give approval for the Bill to be tabled in Parliament. In Parliament, the Bill would be debated in accordance with Parliamentary rules and may be referred to a Committee for review. At the Committee stage, the Bill could be varied or major questions asked about it. Once the Bill is in Parliament , it may be amended until finally approved by Parliament. After the parliamentary process is complete the Bill would go to the Governor General for assent.

Thus, there are many hurdles to be overcome before a draft becomes law. A good way of making a good start towards the implementation of legislation is to first settle Government policy and then get that policy approved by Cabinet and also obtaining Cabinet instructions to draft. The preparation of adequate drafting instructions (in which the technical and legal aspects of the proposed legislation are fully explained) is also of critical importance. Often, legislation is drafted without following these steps and therefore nothing happens.

A major difficulty with implementing legislation is often the constant change of staff in the Attorney General's Office. This impacts the volume of legislation that can be implemented and often, only the most pressing legislation that is a high priority on the Government's legislative timetable will be implemented.

As a result of the aforementioned, it would appear that some of the laws in Grenada are both outdated and ineffectively enforced. After consultation with various stakeholders the following recommendations are posited:

- There is a need for a National Land Policy in Grenada. Work started on this in July 2015 and needs to be finalised as soon as possible;
- The current set of laws should be reviewed and amended to ensure that there is rationalization across these laws;
- Legislation regarding development of land needs to be reviewed, with the accompanying creation of a National Development Plan;
- Punitive sanctions for pollution imposed by the current legislation should be revised to make the fines more realistic and enforceable;
- In general, greater enforcement of existing legislation needs to take place, through the provision of the necessary support from relevant government agencies.
- The completion of EIAs needs to be mandatory for all projects likely to impact significantly on the environment.

4.3.1 Policy Recommendations

The policy recommendations are as follows:

- Implementation of a National Water Policy;
- Implementation of a National Climate Change Policy and Action Plan;
- Cabinet approval for a National Hazard Mitigation Policy;
- Cabinet approval of a National Waste Management Strategy;

4.3.2 Legislative Recommendations

The legislative recommendations are as follows:

- Enforce Regulations for controlling water quality;

- Enforce Regulations to establish standards and specifications for effluent discharges into receiving surface, underground or coastal waters;
- Finalize and enact draft Public Health Act;
- Finalize and enact draft Environmental Management Policy;
- Prepare and finalize Pollution Regulations;
- Finalize and enact draft Protected Areas Forestry and Wildlife Act.

4.3.3 Inter-agency Co-operation

There is a significant need for inter-agency collaboration in various sectors. This will be especially significant to the evaluation of EIAs. Although the responsibility for EIAs falls under the Planning Unit, the input of various agencies will be crucial for their successful evaluation and monitoring. Water issues span a number of agencies. Additionally, while NAWASA has primary responsibility for water management, the role of public health (water quality monitoring), the Forestry Division (Watersheds/forest reserves) and the Physical Planning Unit (environmental issues generally) are also of critical importance in the water-sector. Thus, inter-agency collaboration will be of key importance in the effective implementation of critical issues in the natural resources sector.

4.3.4 Institutional Recommendations

A variety of mechanisms will be necessary to strengthen the institutional framework. These include:

- Strengthen the mechanism (s) for greater enforcement of existing legislation, through the provision of the necessary support from relevant government agencies.
- Establish training programmes for enforcement offices in all agencies.
- Establish inter-agency collaboration among agencies for enforcement of legislation
- Strengthen the mechanism(s) for the EIA process including inter-agency collaboration for evaluating and monitoring EIAs.

5 SOCIO-ECONOMIC REVIEW

This section contributes findings on the economic relationships that exist with the water sector. It sets the groundwork for how this relationship may be impacted by changes to the water sector as a result of climate change. The section is broadly grouped into three analyses:

1. The current Grenada Economy.
2. The relationships between the economy and water with a focus on the adequacy or otherwise of the water sector to meet economic activity. Also climate change and water requirements under climate change.
3. The social context of the water sector with a focus on health and food security the vulnerabilities to which a National Adaptation Strategy and Plan must be sensitive in relation to these issues.

5.1 The Current Grenada Economy

In relation to economic performance indicators, the economy of Grenada in this section refers to the tri-island state unless otherwise indicated. There is little disaggregation on the separate economic performance of each island. However, the economy of each of the islands can be sufficiently separated in applied economic terms to appreciate the relationship each has with the water sector, and to some extent the challenge of climate change.

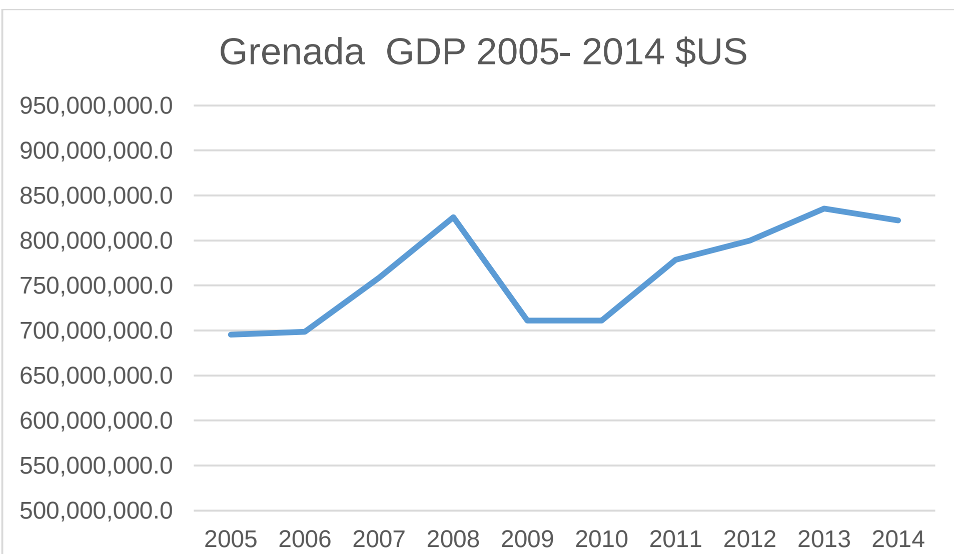


Figure 5-1: Grenada's GDP 2005 to 2014

After the successive set-backs of Hurricane Ivan in 2004 and Emily in 2005, Grenada's economy began a period of marked growth in 2006 which peaked in 2008 having achieved 3 consecutive years of 6% growth. The financial crisis of 2007–08, also known as the Global Financial Crisis then had a very contracting impact on the economy. This crisis resulted from a significant decline in tourism, commerce and the financial markets. The results being that by 2009 the Grenadian economy recorded a growth rate of - 13.9 %. These successive reversals in economic performance are instructive regarding the vulnerability of small open economies, such as Grenada, to external impacts. An experience replicated in several island states in the region.

Unless otherwise indicated, GDP data in this section refers to the tri-island state of Grenada and includes the economy of Carriacou and Petite Martinique. Both smaller islands, reflect close similarity to the economy of the mainland, and have several issues in common except that fishing and services are of greater importance in the smaller islands. Petite Martinique's fishing subsector accounts for over 60% of the national fish export. The services sector in Carriacou and Petite Martinique is essentially tourism and related services. Although less developed than the mainland with a very limited number of hotel-beds available, they both offer home-stay facilities. There is an important Eastern Caribbean island patronage and tourism revenue is also augmented by an occasional cruise stop over and recreational yachting.

Carriacou and Petite Martinique have experienced significant levels of migration over the last century. This has impacted the economic development of the islands. It is estimated that as of 2000, about 50% of the population had migrated. Carriacou and Petite Martinique are considered the least poor district in the country, (Kari Consultants, 2009). This relative position is explained by the high level of remittances through extended family connections. Remittances for both islands may account for more than 30% of the islands' GDP. Over the past 40 years, remittances from North America and the UK were considered high and were estimated to be about 9.2% of GDP for Grenada, including Carriacou and Petite Martinique (World Bank, 2008). Without migration and remittances, the economic situation is not sustainable and the population might be forced to change its system of production, alter social structures, and make other radical transformations in order to survive (Cultural Survival, 2011).

The economies were adversely affected by the impact of the financial and economic crisis, particularly the fall in tourist arrivals and the decline in inflows of Foreign Direct Investment (FDI) and remittances. As a result of the weak economic performance, it is estimated that unemployment levels would have increased. Unemployment is high and is estimated to be over 30% in Carriacou and Petite Martinique.

Agriculture, which accounted for about 20% of Grenada's GDP during the 1970s, accounted for less than 10% by 1995 and was estimated to be about 5.7% in 2013. This reduced contribution from agriculture was due to several factors:

- The longer term shift in the global trading arrangements for sugar and bananas.
- The impact of pest and diseases in particular the Moko disease that severely affected the banana industry.

- The islands' vulnerability to natural hazards, as evidenced by the damage caused by Hurricane Ivan in 2004 and Hurricane Emily in 2005. In particular, Hurricane Ivan completely destroyed the agricultural sector.

The decline in agriculture saw the further ascendency of the services sector and by 2009 services, inclusive of tourism, accounted for more than 80% of GDP. However, this sector was also sensitive to natural hazards and developments in the originating markets for tourists. In 2004, Hurricane Ivan badly damaged a significant proportion of tourism infrastructure and as a result, in 2005 the hotel and restaurant sector, contracted by 42%. Thereafter, as reflected in Figure 5-1, both agriculture and tourism were negatively affected by the global financial and economic crisis which began in 2008.

In the subsequent years 2011 to 2014, the economy has shown its core resilience. Strong performances in construction and manufacturing, together with some recovery in tourism has enabled Grenada's economy to record an annual average 2.6% in GDP (current prices) which by 2013 and 2014 had approximated a return to 2007/8 levels. Sectoral contributions to GDP in 2013 were estimated at:

- agriculture: 5.6%;
- industry: 15.8%; and
- services: 78.5%.

The main agricultural products were bananas, cocoa, nutmeg, mace, citrus, avocados, root crops, sugarcane, corn, vegetables. In industry, the main activities center upon; food and beverages, textiles, light assembly operations, tourism, construction despite its overall contribution to GDP, industrial production growth rate in 2013 had been – 2%. Economic growth recovery remains sluggish and in real terms the 2013 growth in GDP was 0.8%. Grenada was listed at 198 out of 267 countries on the Central Intelligence Agency's 2014 ranking of national economies.

5.1.1 The Agriculture Sector

The tabulated data for this section is mainly drawn from The Agriculture Review 2014 produced by the Ministry of Agriculture, Forestry and Fisheries with assistance from the Food and Agriculture Organization (FAO).

Table 5-1: Agriculture Sector's Annual Growth & Contribution to GDP 2007-2011

Year	Agri-food Sector Percentage of GDP (%)	Agri-food Sector Annual Growth (%)
2007	5.75	6.75
2008	6.25	8.00
2009	6.62	8.50
2010	6.75	10.17
2011	6.92	11.00

Grenada's agricultural sector, contributed between 5% and 7% to GDP over the 5 year period 2007-2011. Its annual growth rate averaged 8.9% in current prices. In real terms the sector had remained fairly static. The Grenadian economy had also depended on exports of commodities, primarily spices and bananas. However, the banana industry on the island virtually disappeared with the loss of European trade preferences in 2006, while Hurricanes Ivan (2004) and Emily (2005) devastated the nutmeg industry, resulting in a decline in agriculture's share of GDP from 24% in 1980 to less than5% by 2013. Green Nutmeg production declined from 12.9 M lbs. pounds in 2004 to 3.5M lbs. in 2005, and by 2011 had further declined to 1.8M lbs.

Table 5-2: Subsector Performance Indicators 2011

Agricultural Subsector	Output 2011 (Lbs.)
Fruit Crop	3,623,165
Vegetable	1,766,741
Poultry	1,561,475

Mixed farming is the predominant type of production system engaged in. It has adapted to changing technology slowly. Although crops have shifted in relative importance over time, there has been little structural change to agricultural production systems or the distribution system. Marketing is a constraint to scale of production and the export market.

The absence of reliable water flows is a major constraint to farming in Carriacou and Petit Martinique. It is also a constraint to farmers in the south western watersheds of Grenada. In the northern and eastern parishes both precipitation and surface water supply are less challenging. Farmers however complain that irrigation, is expensive. Water challenges for farmers, in all areas, remain one of adequate catchment and storage facilities.

Most farmers try to source rivers or tributaries from which to pump water for irrigation. Others employ some form of catchment system with which to drive low technology drip irrigation or sprinkler systems. Very few practice rain water harvesting mainly due to the financing levels required for effective collection. Extension services are regarded as supportive but inadequate.

But agricultural activities in the watershed are also affecting its ability to generate water:

- Clearing of land for farming activity.
- Use of pesticides and fertilizers.
- Solid and liquid waste discharge into the aquifer.
- Some anthropogenic issues such as dumping, commercial waste, effluence and fires combine to exert more pressure on water resources.

With respect to both livestock and crops, cultivation practices generally seem unable to attain viable economies of scale appropriate to the mainly domestic market served and serious exporting remains tentative. Also to be factored, are the extended drought conditions that have characterized recent years.

Table 5-3: Fishing Subsector

YEAR	PRODUCTION LBS (M)	VALUE $EC M
2007	4.87	29.25
2008	5.26	31.56
2009	5.23	31.40
2010	5.40	31.71
2011	4.81	30.15

Fisheries is the most important contributor to the agricultural sector. Its production and value contribution has remained fairly consistent over the 5 year period ending 2011. A new fish complex at Gouyave has contributed importantly to marketing infrastructure. The sector has an important export market into North America and the French Caribbean. The industry faces challenges of overfishing, and retooling its technology, particularly its deep sea fisheries.

In relation to the water sector, nutrient loading and other pollutants (pesticide runoff) around the entire coastal zone has for many years created stressed reefs and damaged onshore fishing nurseries. This has occurred mainly as a result of the following ongoing challenges:

- Use of agro-chemicals (fertilizers, pesticides, weedicides);
- Siltation of rivers and dams;
- Inadequate land use practices;
- Pollution;
- Unplanned developments in the coastal zone;
- Lack of control of forest clearance leading to soil erosion and sediment deposition into the coastal zone.

(Source: National report on Integrating Watershed Management and Coastal Areas (2001)).

Despite the presence of two marine protected areas, there is understocking and overfishing. Global warming also brings with it the threat of invasive species and valued pelagic resources moving out into deeper water, and also the potential loss or reduction of landing site beach area.

5.1.2 Forests

Grenada has approximately four major types of forest ecosystems; evergreen forest, -mixed primary and secondary closed -evergreen, moist deciduous and - semi and moist deciduous rain forest, and dry forest. In addition to their contribution to the economy via timber, Grenada's forest resources are critical for assisting in protecting the water resources of each island. In recognition of this, the Government has implemented a program with the assistance of FAO in developing a Land Degradation Assessment Methodology for determining the extent and severity of the degradation of forests and hence their vital support for watersheds. The following are some preliminary outputs of the project as reported in "The Agriculture Review, 2014" produced by Ministry of Agriculture, Forestry and Fisheries:

- A Draft Livelihood Assessment Report
- Land Use Systems Map of Grenada and Carriacou
- Draft Land Degradation Monitoring System
- Preliminary Land Degradation and SLM maps

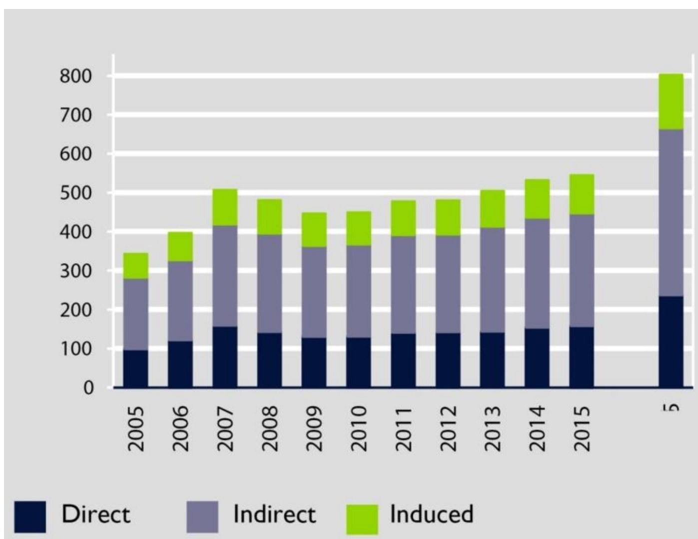
These initiatives will eventually lead to the proposed Implementation of a Sustainable Land Management Project (SLM).

5.1.3 Tourism

In 2014 visitor arrivals to Grenada numbered 368,881; of this number 63.7% were cruise ship passengers, while 36.25% were stopover visitors. The direct contribution of travel & tourism to GDP was EC$154.4mn (US$ 57.1m) 7.0% of total GDP and is forecasted to rise by 2.5% in 2015, and to rise by 4.1% pa, from 2015-2025, to EC$ 237.2m or US$87.85m (8.3% of total GDP) in 2025.

The total contribution of travel & tourism to GDP was EC$ 531.9mn (US$197 m) 24.2% of GDP in 2014, and is forecasted to rise by 2.4% in 2015, and to rise by 4.0% pa to US$186.16m (28.2% of GDP) in 2025. Figure 5-2 shows this graphically.

Figure 5-2: Total Contribution of Travel & Tourism to GDP



Tourism's contribution to GDP declined during the global recession that got underway in 2007 and persisted through 2011 where tourism made some recovery.

5.1.3.1 Water and Tourism

Tourists are particularly heavy consumers of water and this presents a dilemma to NAWASA since Grenada's tourism is centered in the south western part of the island of Grenada which is one of the driest sections. From the data cited below in this section, the consultants estimate that visitor consumption of water per annum is in the order of 101,532 m^3 for 2014. The latter was derived by comparison with tourism water consumption in Antigua and Barbuda.

Important conclusions with regards to water use in tourism, in the context of climate change, have been drawn by Gossling, Peeter, Hall, et.al (2011). These conclusions have particular discussion value for Grenada and have been accordingly paraphrased here to elucidate this relevance:

- Tourism can concentrate traveler flows in small island states like Grenada, where renewable water reserves are likely to be limited. Furthermore, the understanding of tourism's indirect water requirements, including the production of food, building materials and energy, remains inadequately understood, but is likely to be more substantial than direct water use. The article concludes that with expected changes in global precipitation patterns due to climate change, it is advisable, in particular, for already water scarce areas, to engage in water management.

- By 2020, tourism's contribution to water use is projected to increase with i) tourist numbers, ii) higher hotel standards and iii) the water-intensity of tourism activities. In comparison to other economic sectors, such as agriculture, there are no specific regional or national water use statistics for tourism, and tourism-related water use is still relatively little investigated.

- Overall, water use in tourism can be considerable, and higher than currently assumed in the literature. Indirect water use is likely to be more relevant than direct uses, with food consumption and fuel use constituting important consumption categories.

- Water consumption by hotels is far higher than household consumption, due largely to the collective consumption of water in hotels (landscape watering, daily cleaning of rooms, filling of swimming pools, kitchen and laundry services). Furthermore, holidaymakers have a 'pleasure' approach to showering or bathing and generally use more water than they would normally.

- Given these predisposing factors, the concern is whether tourism-related water abstractions are sustainable, and whether these interfere with other uses or users. Where tourism-related fresh water demand is significant, the sector can add considerable pressure on available fresh water resources, particularly when these are concentrated in regions with few or no fossil water resources, low aquifer renewal rates, and few or no surface water sources, such as characterizes the situation in some Island states. (E.g. Gosling, 2002b; Rodriguez Diaz et al., 2007).

- Desalination might currently be the most widely considered option to enhance water resources, but it increases energy consumption and, in many areas not connected to the national grid, the dependence on imports of fuels to run generators, leading to considerable additional emissions of greenhouse gases. Desalination is costly, and can involve energy use of 3 to 12.5 kWh of electricity, corresponding to emissions of 1-10 kg CO_2 per m^3 of water. (Guide et al., 2010; Sadhwani & Veza, 2008).

While the exact implications of this review have not been worked out for Grenada it would be a reasonable conclusion that they are relevant.

5.2 The Relationship between the economy and water

A convenient approach for establishing a working relationship between the economy and the water sector is to take the consumption of water by the customer base of the utility and compare each sector's contribution to GDP with its consumption of water. By deriving some notion of the value added to GDP per unit of water consumed a discussion can follow on the likely impact of climate change on the water sector and the challenges this could pose for that sectors value added performance. This works reasonably well for water sensitive sectors like agriculture which depend on metered irrigation sources, and tourism where water consumption and visitor arrivals can be shown to be correlated. It works less well for health.

Had the data been available, this would have been the option of choice but NAWASA was not able to supply the requested data and therefore, to obtain some perspectives on the relationship between the economy and the water sector an alternative, less direct and more speculative approach became necessary. Essentially, it seeks to address whether the water sector adequately meets the likely needs of the Grenadian economy. To do so, requires a number of building blocks.

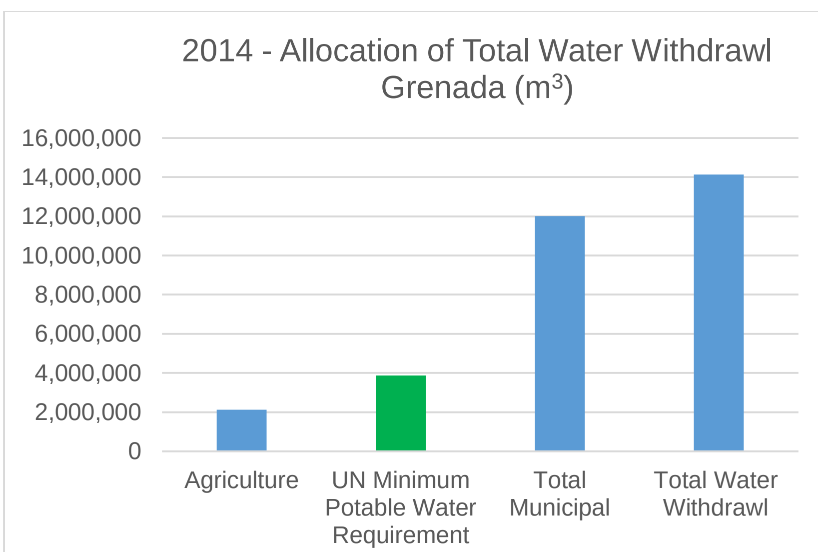


Figure 5-3: Allocation of Total Water Withdrawal Grenada 2014

Although NAWASA has not provided water production data by customer groups, the relative use of water by agriculture in 2013 can be extracted from data bases available *(Aquastat. FAO Greanda 2014),* it is 2000,000 m3. Figure 5-4 reflects that total water withdrawal in 2014 was 14,000,000 m^3. The United Nations minimum recommended per capita potable water need per day at the upper range, is 100 liters. This is for cooking cleaning and drinking. It has been annualized and been calculated for Grenada's population, for comparative purposes.

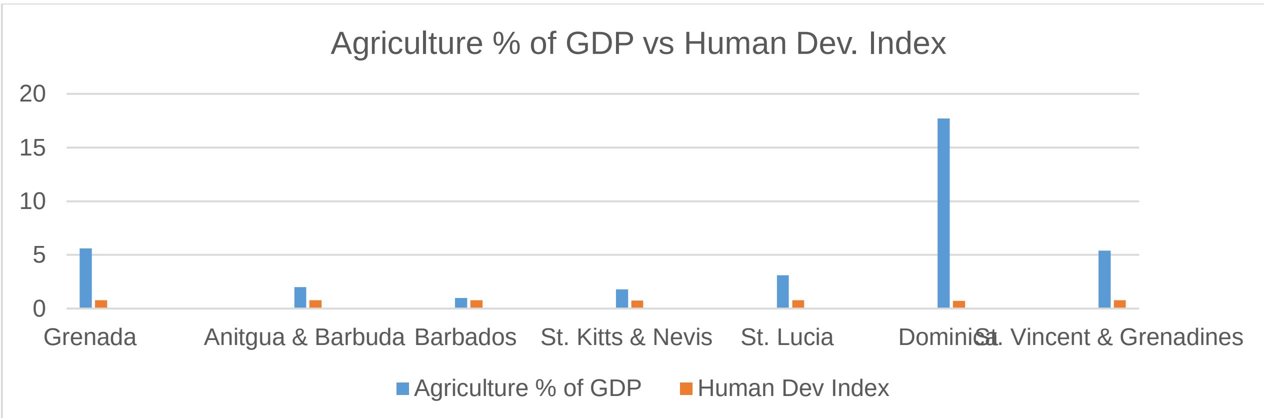


Figure 5-4: Agriculture as a % of GDP and the Human Development Index

Based on the UNDP's Human Development Index, all of the states listed are grouped in the high human development index (Figure 5-4). The index speaks to countries that have managed on the basis of a complex mix of criteria to be considered at a high development stage. With the exception of Dominica, a water rich agricultural led economy, none of the other economies have an agriculture sector contributing more than 6% to their GDP. The average contribution of agriculture to GDP excluding Dominica is 3.15%. In these economies, agriculture's main contribution is to employment not goods and services. Essentially, these are economies whose engines of growth are industry commerce including tourism, services and government. Not being very industrialized this sector is usually a relatively small contributor. In the case of Grenada, the services sector contributes approximately 78% of GDP and Industry 16%. For Antigua and Barbuda the services sectors contributes 81% and Industry 16.4%. In both countries, the end consumers of GDP are for Grenada, the household sector accounting for 92%, and for Antigua & Barbuda, the household sector accounting for 56%.

The economies can reasonably be thought of as being similarly structured and driven by sectors that are themselves fairly similar (and regionally familiar) in composition. In both countries, tourism is an important driver of the services sector and its direct contribution to GDP in Antigua and Barbuda is 58%, whereas, for Grenada it is 24%. In a 2013 study for the CCCCC on climate change and the water sector, the per capita consumption of water by overnight tourists in Antigua and Barbuda was estimated to be about 236,400 cubic meters.

Although in both states, cruise ship arrivals are - greater numerically, stay over visitors contribute more to the economy because they stay on average 9 days or 8 days longer than transiting cruise ship passengers. Their impact on water demand is also proportionately greater.

Assuming that this water per visitor arrivals ratio holds for Grenada's tourism, by applying the required ratio to total visitor arrivals per annum for Grenada an implied tourism claim on water withdrawals can be derived. One assumption being that comparable levels of quality service are offered between both countries, notwithstanding that the numbers of visitors are significantly higher in Antigua and Barbuda. Based on tourism arrivals in 2014, the water demand by tourism on water withdrawals can be estimated at 101,532 m^3. Similarly, domestic water consumption is likely to be fairly similar on an average per capita consumption basis. These figures then become the lynchpin around which Table 5- 4 is derived.

Table 5-4: Grenada's Water Withdrawal Profile by User

USER SECTOR	Consumptive Claims on Annual water withdrawals (m^3)
Total Annual Water Withdrawals	**14,000,000**
Agriculture	2000,000
Domestic potable water	3,517,780 *
Tourism (Prorated to Antigua's)	101,532
Other (Including, Industrial, Commercial. Government and non- potable domestic).	4,880,684
Total Claims on Water Withdrawal	10,500,000
25% Water Loss post withdrawals	3,500,000
Sub Total Water Accounted For	14,000,000
Surplus Accessible Water after Withdrawals & Loss	**Nil**

* World Health Organization standards (upper per capita coefficient) 36,500 liters per annum or 36.50 cubic meters or 8,029 imperial gals/annum.

Table 5-4 suggests that based on the derived claims on annual water withdrawals for 2014, Grenada had a nil surplus after water withdrawals, the consumptive claims by the economy (see table) and losses had been met. This is also before other sources such as private rainwater harvesting or private unaccounted for extractions are factored. This suggests that the accessible extracted water resources are being fully taken up (and perhaps exceeded) by consumptive claims after factoring losses. It therefore raises the question as to whether the economy is being curtailed or just satisfied by the present water situation.

This final answer hinges on limitations that have to be acknowledged but could not be resolved given the data bases available. Firstly although more detailed consumption data is collected by NAWASA it is not presently in a form that could have been made available to the consultants within the time frame required. NAWASA generated water consumption data would have been considerably superior to the use of the proximate data relied on. Secondly while a 25% water loss factor is currently assumed by NAWASA , as referenced in an earlier section of this study, it was estimated in 2001, that distribution losses were between 45 –50% of production (Department of Economic Affairs, 2001). While it is reasonable to accept that significant improvements in distribution leaks have taken place over the years, the 25% perhaps needs to be further justified. Finally, it is again emphasized that the estimates of some sectoral use (tourism, domestic water) have been based on external values extrapolated for Grenada.

Is Grenada facing a water crisis in relation to climate change? It can be so inferred in relation to water access but not water availability. Support for this conclusion is that Grenada's long term annual average precipitation rate is 799,000,000m3 which is considerably in excess of the 14,000,000 m^3 annual water withdrawals. Similarly, that its internal renewable water resources are estimated at 200,000,000 m^3 per annum. Well in excess of estimated annual water withdrawals of 14,000,000 m^3. Further the per inhabitant annual water withdrawal for Grenada is 333 m^3. The UN (World Health) annual potable water standard is 8.09m^3 per capita per annum. So from a simple water accounting perspective, annual domestic potable needs to satisfy UN per capita standards are only 2.4% of per resident annual water withdrawals.

However, despite expected variations due to the comparative approach used with Antigua and Barbuda, the balancing 'Other' which accounts for 4.88M m^3 requires validation by NAWASA when the data is available. It would mean that the commercial sector (of which tourism is a part) is a major consumer of water, just under-par with agricultural and domestic water usage. This would be at variance with the Antiguan experience in which Commercial water usage is about 44% of total domestic and agricultural water use. Better data sets are an important necessity.

In the face of climate change, conservation of water resources must be considered prudent. Particularly, as Grenada's overall vulnerability is assessed as moderate. However, taking into account the claims by farmers, businesses and residents in the drier areas of mainland Grenada, and in Carriacou and Petite Martinique in particular, the objective of policy with respect to adaptation strategies for the water sector, must be towards increasing accessibility to available water resources.

Climate change is expected to impact the water sector of Caribbean Island states as follows:

1. Observed changes in large-scale hydrological cycles include regionally changing precipitation patterns, changes in precipitation intensity and extremes, reduced snow cover and widespread melting of ice, as well as changes in soil moisture and runoff.

2. Climate model simulations project increases in precipitation in the high latitudes and parts of the tropics, and decreases in sub-tropical and lower mid-latitude regions.

3. Models also project an increase in annual average river runoff and water availability in high latitudes and some wet tropical areas, and decrease over dry regions at mid-latitudes and in the dry tropics.

4. Increased precipitation intensity and variability are leading to greater likelihood of flooding and drought in many areas.

5. Higher water temperatures and changes in extremes, including floods and droughts, will affect water quality and exacerbate many forms of pollution.

6. Changes in water quantity and quality also affect food availability, stability, access and utilization.

7. The operation of existing water infrastructure, including hydropower, structural flood defenses, drainage and irrigation systems, will be affected.

(Bates et al., 2008)

Regional modelling shows that already water scarce or water-sensitive regions, such as the Caribbean basin will be particularly affected by declining rainfall (Bates et al., 2008).

More generally, the costs of dealing with current and future water demands under serious climate change scenarios are likely to be considerable (Gossling, Peeter, Hall, et al 2011). Globally, Parry et al. (2009a) estimate that dealing with water scarcity because of climate change will cost an additional US$9-11 billion per year.

The challenge for adaptation strategies is partly the difficulty of predicting the interface of the economy and climate change over long periods. Efforts in this regard have been made by the Global Environmental Facility through its National Communications Support Unit in encouraging and disseminating research efforts at better understanding this interface.

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC's) produced a Special Report on Emission Scenarios (2000) (SRES) Global Environmental Facility's National Communications Support Handbook: Economic Scenarios for Use in Vulnerability and Adaptation Assessments (April 2004). Below, subsequent developments with respect to IPCC climate change approaches will be mentioned.

Economic development is expressed in GNP (Gross National Product). The SRES scenarios span a wide range of future levels of economic activity. Worldwide, the highest overall prediction is for the A1 scenario; an estimated GNP of US$529 trillion (1990 US dollars) in 2100. The lowest overall prediction is for the B2 scenario; an estimated GNP of US$235 trillion in 2100. This means that globalization combined with an emphasis on wealth would generate the highest economic growth. This is mainly because population growth is lower in a global scenario, causing a narrower division of the GNP. The emphasis on wealth rather than on sustainability also increases the GNP. It is estimated that the future income gap between developed and developing countries will be smaller than was initially estimated in the IS92 scenarios. A key element, however, is technological development and the implied energy efficiency of future economic development. (http://www.ess.co.at/METEO/CCS.html).

Population growth is determined by fertility and mortality rates. Global population projections range from 7.1 to 15 billion people by 2100 across the scenarios, depending on the rate and extent of the demographic transition. Regionalization is expected to account for more population growth than will globalization.

The IPCC's B2 scenario is described as follows:

B2: Regionalization, emphasis on sustainability and equity. Mixed assortment of environmental initiatives. Storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

For example the projected population growth curve for Grenada would be shown to take a similar slope as the B2 (UN) population projection in Figure: 5.5 below. This can be generally observed in Figure: 5.7 - Increase in Population Grenada 1990-2100, which is based on 1990 actual population data.

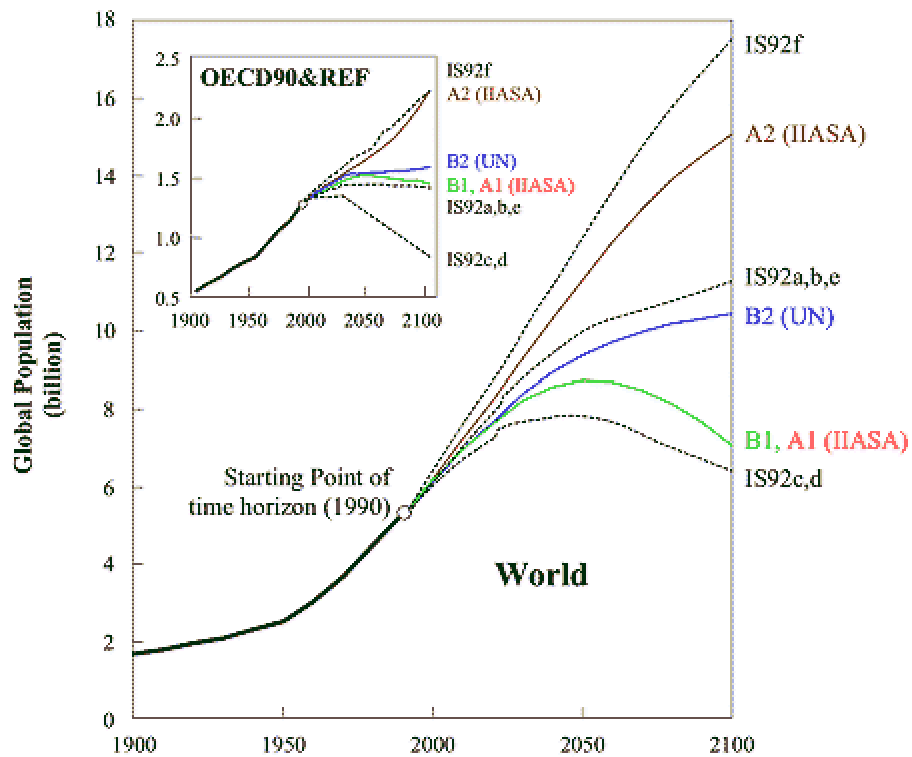


Figure 5-5: **Global Population to 2100 Showing A2, B2 and B1 IPPC SRES Projections**

Source: Population projections - historical data from 1900 to 1990 (based on Durand, 1967; Demeny; 1990; UN, 1998), and SRES scenarios (based on Lutz, 1996, for high and low, and UN, 1998, for medium) and IPCC IS92 scenarios (Leggett et al., 1992; Pepper et al., 1992) from 1990 to 2100.

In Table 5-5,below, the increases to GDP and the increase in population have been developed for the time series 2030, 2050, 2080 and 2100 based on the IPCC's , SRES B2 scenario developed for the ALM region. They therefore embody the assumption that Grenada's future economy and population under conditions of climate change, can best be described under this B2 SRES economic scenario 1990 to 2100 developed for the ALM region.

When the SRES B2 as developed for the ALM regional economy and population, are compared with the actual performance of Grenada in the single year available – 2010, the SRES projected performance of Grenada exceeds that projected for by SRES; in the case of population growth by about 43% over the 20 year period. This is most likely to be explained by local variability to the ALM model. In the case of growth in GDP, the actual - out performed the projected by approximately 48%. In any event, the usefulness of the SRES projections lies in their long term modelling of climate change and the SRES B2 projections are retained in Table 5-5 and remain the basis for the consultants' projections for GDP and population in this section.

Table 5-5: Socio Economic Indices Developed from SRES modelling for ALM Region (A2 B2).

	1990	2010*	2030	2050	2080	2100
Increase GDP (EC$M)	221,100,000	521,796,000	1,373,031,000	3,117,510,000	7,517,400,000	10,922,340,000
Increase in Population (#s)	96,826	150,080	213,017	271,113	321,462	328,240
Min Potable Water Requirements (m3)	2,926,381	4,535,891	6,438,039	8,193,868	9,715,586	9,920,433

Notes:
The first two rows, were derived from given SRES indices. Minimum Potable Water Demand was estimated based on population projections and UN derived minimum per capita potable water requirements, assumed to remain reasonably constant over time. These figures are at best indicative.

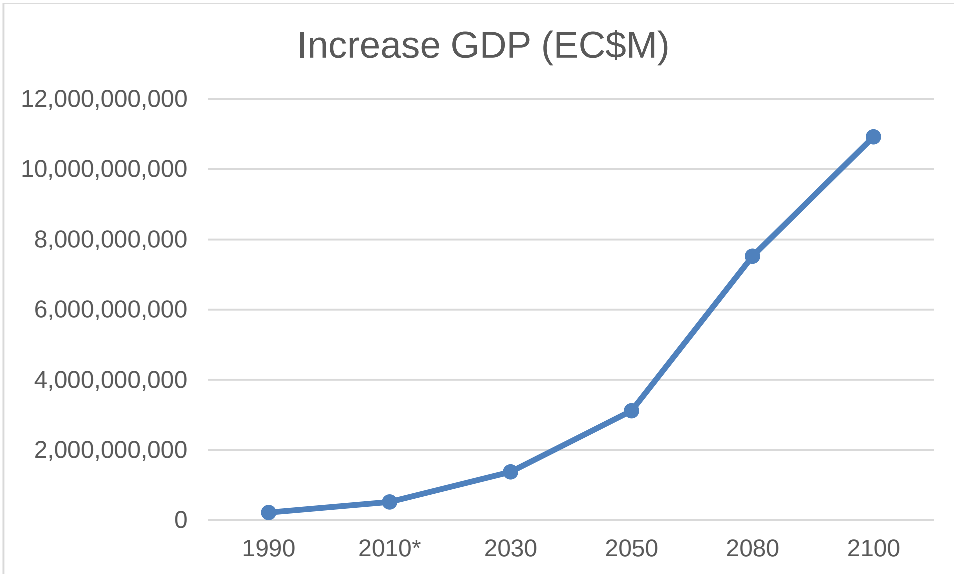


Figure 5-6:Increase GDP in Current Prices (US$M) Projections 1990-2100

On the basis of the SRES B2 scenario, GDP in current prices of Grenada is projected to be US$10.9 in 2100. In the shorter time period, it is projected that GDP will reach US$3.12 b in 2050 or, roughly 35 years from the current period. Although the B2 scenario models the impact of climate change across a significant geographical area of the world, it nevertheless is predicated on very careful and detailed analyses of the social economic technical production functions/potentialities of countries that are considered to possess a commonality of development characteristics. On the climate change side, the scenarios embody the IPCC's forecasts for the main determinants of climate change, precipitation, temperature and greenhouse emissions. The important point being that inherent in the curves are the predisposing climate change conditions.

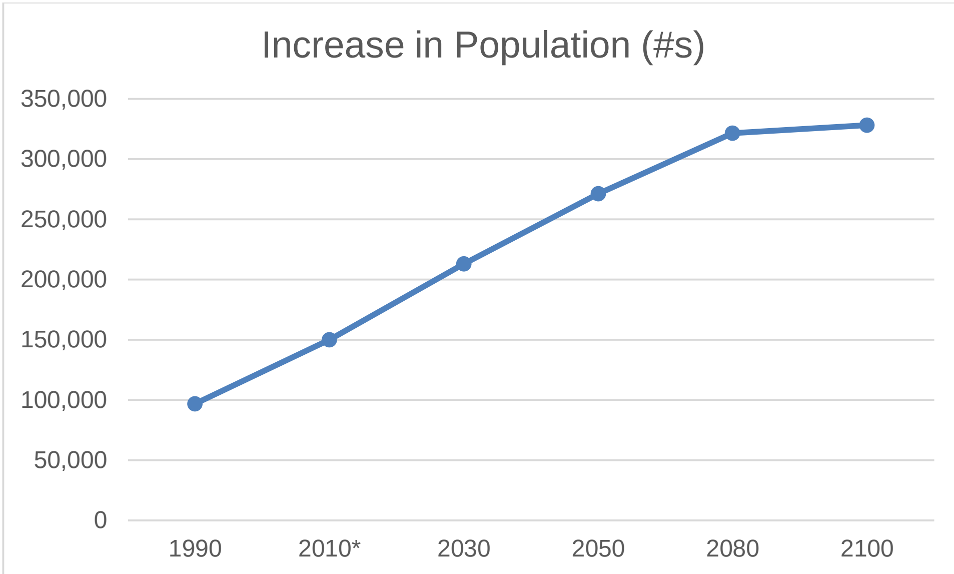


Figure 5-7: Population (#s) Projections 1990-2100

Using the SRES B2 scenario applied to the 1990 population, the population of Grenada is projected to reach 328,000 in 2100 and to reach 271,113 in 2050, roughly 36 years from the current period.

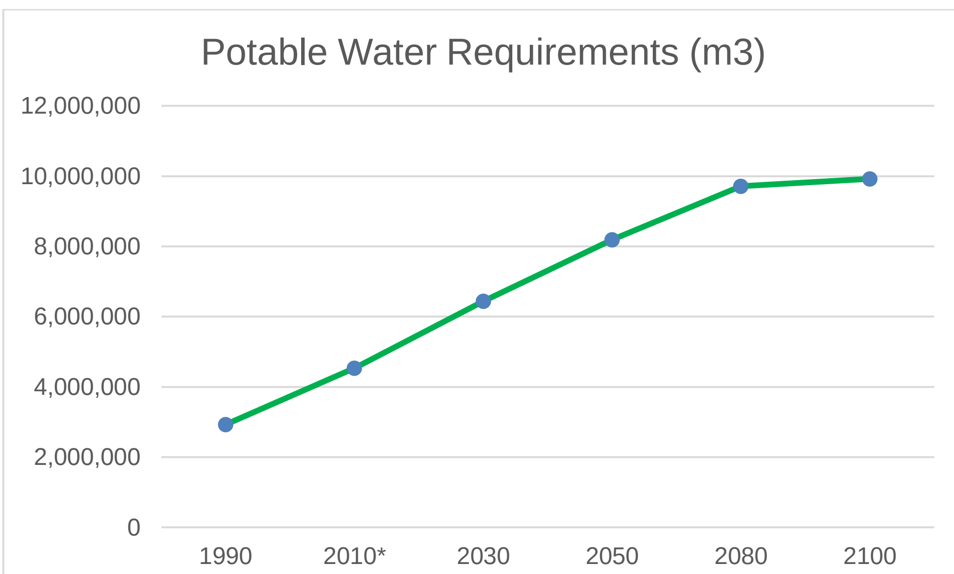


Figure 5-8: Minimum Potable Water Requirements (M3) to Projections 1990-2100

Figure 5-8 projects the future domestic potable water requirements based on UN estimated per capita minimum requirements. It is not directly predicted by SRES B2 scenario but has been derived by the consultants, based on the criteria used.

The curve shows that in the year 2100, the population will require a minimum volume of potable water of 9.9M cubic meters in 2100 and 8.2M cubic meters in 2050. It is important that water management strategies be devised that will recognize the challenge that this level of potable water demand poses for the water sector. Particularly with respect to improving accessibility to water resources.

A study entitled *An Assement of The Economic Impact of Climate Change on the Water Sector in Grenada* – ECLAC Oct 2011, modeled water demand requirements for tourism, agriculture and the residetial sector under the A2 ,B2 and BAU (Business as Usual) during the four decade period 2011 to 2050.

The results available at http://www.cepal.org/portofspain/publicaciones/xml/4/45354/LCARL.329.pdf suggest that water supply will exceed forecasted water demand under B2 and BAU during all four decades. However under the A2 scenario, water demand will exceed water supply by the year 2025.

It is important to note that the forcasting model had been constrained by the omission of several key parameters, and time series for climate indicators, data for which is unavailable. Some of these include time series for discharge data, rainfall-runoff data, groundwater recharge rates, and evapotranspiration. Similar data constraints as confronted the current study.

Interpretation of the results suggests that under the A2 and B2 scenairios water needs will each be approximately 7.5M cubic meters and be satisfied by supply in 2050. Under the BAU scenario water needs will be 7.9M cubic meters, and this is the only scenario in which needs will exceeed supply by 2050. Thereby confirming the importance of implementing adaptation strategies.

At the IPCC 29th Session held in Geneva in September 2008, a decision was initiated to upgrade the socio economic indices developed from SRES modelling for all regions. A target date was set for 2012 but into the present period the Consultants have not been able to access published revisions. It is not clear as to whether the current 2015 IPCC conference in Bangkok will clarify this position. However a significant amount of work has gone into modelling emmissions under conditions of climate change, and this has also spawned a re orientation in describing the likely impacts of climate change. Bangkok is expected to discuss/validate what is referred to as the IPCC complete Synthesis Report.

The following graphics have been taken from the IPCC Report (2014). In the first column of Figure 5-9 the risks associated with Central and South America region (within which the Caribbean is alo nestled) are identified. In the remaining columns Adaptation Issues of particular concern are described leading to a Risk assessment (vulnerability) and the potential for adaptation strategies.

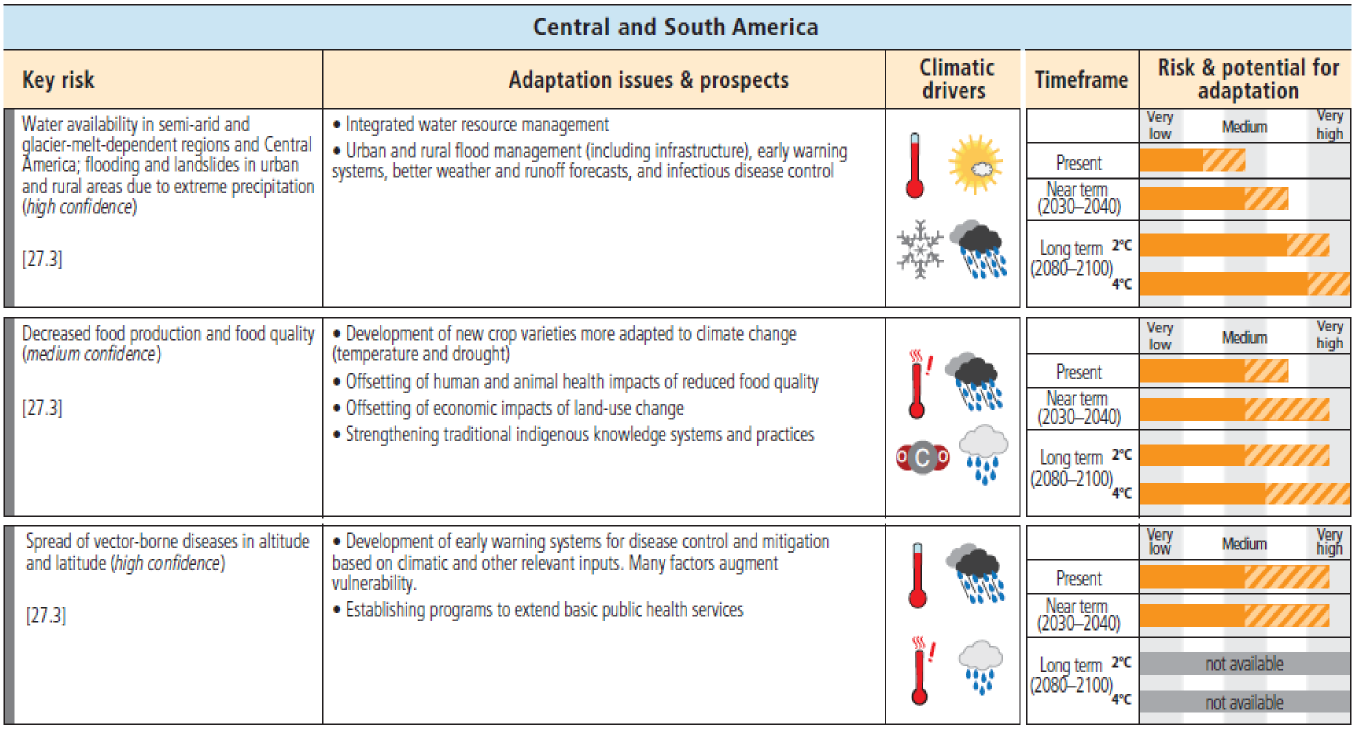


Figure 5-9: Key Risk and Potential for Adaptation Central & Latin America

Figure 5-10 illustrates the same analysis undertaken for Island States.

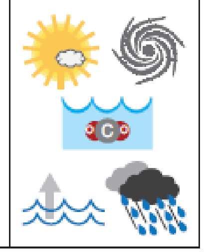
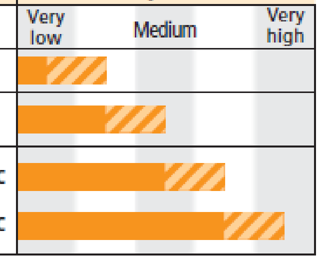
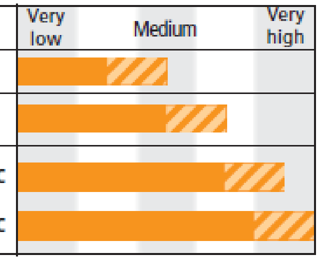
Small Islands				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability (*high confidence*) [29.6, 29.8, Figure 29-4]	• Significant potential exists for adaptation in islands, but additional external resources and technologies will enhance response. • Maintenance and enhancement of ecosystem functions and services and of water and food security • Efficacy of traditional community coping strategies is expected to be substantially reduced in the future.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas (*high confidence*) [29.4, Table 29-1; WGI AR5 13.5, Table 13.5]	• High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. • Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	

Figure 5-10: Key Risk and Potential for Adaptation for Small Island States

It should be emphasized that the current study focuses on the relationship between the water sector and climate change in the tri-island state of Grenada. The issues identified relating to sensitivity adaptation and vulnerability are therefore particular to Grenada. IPCC, Climate Change 2014, Synthesis Report relates to a significantly larger geographical area, with varied climate change challenges. Nevertheless several of the issues raised and addressed in Figs 5.9: and Figs 5.10: will find their counterparts in the NASAP report.

5.3 Health

5.3.1 Health Challenges

The health challenges faced in the Caribbean are very much a feature of the regions geography, culture, size and development. In the region, the challenge includes the world wide rapid development of chronic non communicable diseases, but also the historical presence and periodic recurrence of the communicable diseases such as malaria. These are made more challenging because of the openness of borders to world tourism, and a legacy of low income and relatively vulnerable agricultural based economies. Allied with diseases are the challenges of natural disasters. The Caribbean Health Research Council mindful of this regional profile has prioritized a number of foci for health research in the region. Included are: strengthening health systems, human resource development, environmental health, family and community health, communicable diseases and nutrition (*Health Research Agenda For The Caribbean,* 2011).

In discussions focused on the water sector and health, held with the Public Health Department the following relevant concerns were expressed:

- The Public Health Department was once the Environmental Health Department which managed food safety, water quality, solid waste, OSH. However, they do not do all of these anymore.
- They are the regulatory body for water. Their focus is on ensuring safe water is distributed- they regulate NAWASA. NAWASA provides them with reports on their weekly water quality data. They independently have a water quality programme. It has been suspended for the last 2 years because of lab constraints.
- The epidemiological unit has not captured the type of water borne diseases. They have only been testing feacal coliform and total coliform.
- They have issues related to development affecting water quality- planting along the catchment areas. In the past, a number of agricultural estates have been close to the catchment areas. These have closed and have now become a free for all- river parties, animals grazing.
- They track communicable diseases. They track gastroenteritis (under 5 and over 5 population). Sometimes they have spikes in gastro but cannot be sure to attribute it to climate related events because gastro can be related to food and water issues.
- There is not a very strong correlation between outbreaks and climate related events.

- They manage the cleaning of drains under a contractual arrangement. They have 32 antimalarial drains within and outside of town (drains that have mixing of sea and freshwater tend to be antimalarial).

Table 5-6: Indicators for the impact of climate change on health

INDICATORS	Evidence Exists For response given	Evidence does not exist either way (No) or was unavailable to be used as Indicator (NA)
Are total water resources declining	No	Na
Is there a reduction in annual withdrawal of surface water		Yes for the drought year of OCT –DEC 2009 AND JAN – MAR 2010.
Is there a reduction in annual withdrawal of ground water	No	Yes for the drought year of OCT –DEC 2009 AND JAN – MAR 2010.
Is there an increase in number of watershed restoration programs		NA
Is there improvement in technology or investment for more efficient water use		Not clear based on data available. But no. of piped supply has risen to show efficiency in supply.
Is there an increase in aquifer recharge rates		No
Is there an increase in water use efficiency leading to reduced extraction rate (m3/h/yr. in irrigation)		No specific sector based data to support
Is there an increase in watershed area with appropriate cover	No	
Is there a reduction in water demand?		No data on demand to support this.
Is there an increasing % of the population with access to clean drinking water		NA
Is there increasing water production per capita		NA
Is there increasing water demand per capita	Yes	

There are at least 8 indicators which suggest increased vulnerability for the water sector under conditions of climate change with likely health impacts associated with them. Similarly, there is only 1 indicator that can be interpreted as suggesting some resilience to climate change. These are summarized for convenience in the table below.

Table 5-7: Indicators of Health Vulnerability

Indicators Suggesting Increased Vulnerability	Indicators suggesting some resilience to Climate Change
• No reduction in annual withdrawal of surface water. • No reduction in annual withdrawal of ground water • No increase in the number of watershed restoration programs (except Oct-Dec 2009) • No increase in aquifer recharge rate • No data to support increased efficiency leading to lower extraction rate. • No increase in watershed area with appropriate cover • No indication of a reduction in water demand. • Increasing per capita demand for water.	• Improved technology being employed and increased distribution efficiency

Potable water is another important indicator of public health, both with the assumption of its quality but also its availability. The picture however is not particularly clear. On the one hand NAWASA claims to be the only official provider of potable water. In some areas, particularly the south eastern side of the island, most community members spoken to express skepticism regarding the quality of NAWASA supplied water. Along the North and North Western sections of the Island most members of the public felt the water quality of NAWASA was good to adequate.

5.4 Food Security, Water, Agriculture and Poverty

Grenada's agricultural sector generated approximately EC$126,336,000 towards GDP in 2013. The importation food bill, in 2013 was estimated by the Eastern Caribbean Central Bank to be EC $205,460,000 a factor of 1.63 time's domestic food production. Only 38% of food consumption is produced locally. Four critical issues for the nation's food can be identified; security, availability, accessibility consumption/utilization and stability of supply. These basic requirements set the background conditions to national food security.

It can be argued that the constraints to food availability include: low productivity, short-term land tenures, inadequate water supply, difficulty in accessing credit, loss of arable lands to housing construction, lack of storage facilities, high labour and energy costs, persistent praedial larceny, and over-exploitation of marine food sources.

In considering the issue of food security in the context of climate change and NAWASA, the relationship between health, water, poverty and agriculture suggested themselves for closer examination. An earlier assessment of the data concluded that the agricultural sector was marginal in its direct contribution to GDP. The contribution of domestic agriculture to food security though important is not robust.

In 2013 the per capita value of domestic agricultural production was EC$3.27 per day. This meant that the domestic food basket (inclusive of exports) could potentially contribute EC$3.27 per day per person to national food supply and security. Further, a poverty line indicator of EC$16.0 per day per person was established in a 2007/2008 study (Kari Consultants Ltd). This figure being the minimum daily household expenditure deemed necessary to meet essential needs. The study also established that for Grenada, 37.7% of the population fell below the poverty line. The study also found that at the poorest level households, EC$6.55 per person was consumed as food (indigence line).

The preceding data indicates that the poorest households satisfy their minimum daily food requirements by spending daily an average of EC$6.55 per person on food. Whereas, the domestic agricultural supply chain supplies only EC$3.27 of food value per person per day, and this is before accounting for food exports. At this level 50% of the per capita daily food requirements of the poorest would need to be met by imports.

In the event of a disaster to agricultural production, exceeding that inflicted by hurricane Omar (2008) in which significant agricultural production loss occurred, the dependency on imported food could conceivable approach an unsupportable level of import dependency .

The above, rather bleak assessment of the vulnerability of the poor, but also the wider population to the challenge of food security requires important qualifications. Agricultural production at the household level is unlikely to be reliably represented in the formal economy. Back yard and small farm agricultural production probably escapes the reporting net or is otherwise highly unreported. This will distort the food security threat.

Also direct employment in agriculture accounts for about 24% of total employment and it is this occupational dependency on the sector which primarily maintains its importance.

6 CONCLUSION

Grenada has a humid tropical climate, with an average annual temperature of 26 degrees Centigrade. The dry season is between January and May and the rainy season from June to December. On average, Grenada receives more rainfall than Carriacou and Petit Martinique and relies heavily on surface water from its river systems. The smaller islands have no surface water and depend primarily on rain water harvesting and the newly installed and commissioned desalination plants.

Water is key to the continued success of all aspects of the state's economy. However, the advancement of Grenada's social development is being put at risk by the current water sector arrangements. The state of Grenada is already experiencing some of the effects of climate variability and change through damage from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns. The island of Grenada has not had an extensive history of drought, but the smaller islands of Petit Martinique and Carriacou are more susceptible to drought conditions during the dry season. Two major droughts were recorded in 1995 and between 2009 and 2010. However, June and July 2013 were recorded as the driest months in Grenada in two decades. A growing population, changing consumption patterns, and increasing food demands have placed increased stress on the water supply of Grenada. Increasing climate variability from changes in the parameters of climate, has now induced Grenadians to try to combat the water supply challenges.

Generally, several national constraints have been identified in relation to the water sector, that if not addressed in a proper and timely manner, will impose additional costs on the economy. Three key challenges for the sustainability of integrated water resources management have been identified: technical, institutional and financial. Since the island of Grenada depends primarily on surface water, an extended dry season would considerably affect water supply. Other challenges relate to distribution, surface storage and leaks and saline intrusion affection the wells. In Carriacou and Petit Martinique, the challenges relate primarily to storage and distribution. Rain water harvesting is the primary source of water and during extended dry seasons water has to be imported. These existing challenges identify how sensitive and vulnerable the islands are to the predicted climate change impacts. Climate change will only exacerbate these current challenges. It will invariably directly affect both the quantity and quality of the country's water supply.

The climate projections from this study indicate generally that Grenada may experience increases in annual mean temperature, annual maximum and minimum temperatures, reduction in rainfall and rainfall intensity. Wind speeds are expected to increase which affects rainfall and hurricane development, hurricane intensity is expected to increase but not necessarily frequency and sea level rise in the Caribbean is projected to increase.

The major threats to the water sector in Grenada are droughts and floods-the two common extremes of the hydrological cycle. For Carriacou and Petit Martinique, drought is the more significant threat. Saline intrusion into wells on the island of Grenada is also becoming a threat to the water sector, however this is a combination of over abstraction as well as sea level rise due to climate change.

Based on estimated claims on annual water withdrawals, Grenada utilized all of its annual water withdrawals in 2014 after factoring water leakage. This is a matter of accessibility and not availability since a point of note is that Grenada's long term annual average precipitation rate is 2,300,000 m3 which is only about 22% percent of the 10,500,000 annual water requirements estimated for the user sectors. This data would support the likelihood that Grenada's water priorities must lie in the direction of increasing accessibility.

Legislation, policy and the role of local institutions are very important in increasing the resilience of the country to climate change. There are a number of statutes that have some bearing on water, however, there is an absence or weakness of policies to guide development and management of land use, water resources or the coastal zone. There is a body of national legislation that applies to water resources but it has been developed piecemeal and is scattered through a wide range of legislation. Similarly, there are various institutions that impact importantly on aspects of water resources. However, their ability to fulfill their mandates is sometimes significantly limited by staffing and budgeting issues. This means that their adaptive capacity is limited. With upgraded policy and legislation directed at managing water resources in light of climate change, the adaptive capacity of Grenada will likely increase significantly. This is because local institutions (both formal and informal) will then play an important role in building resilience and reducing vulnerability to climate change. These agencies are also the principal vehicle through which external support for adaptation (e.g., training and capacity building, etc.) is and will increasingly be delivered.

7 NATIONAL ADAPTATION STRATEGY AND ACTION PLAN

7.1 Introduction

The final objective of the project was to develop a National Adaptation Strategy and Action Plan (NASAP) to address the anticipated adverse effects of climate change on the water sector. This NASAP is to prepare the tri-island state of Grenada to meet the challenges of climate change on the water sector.

Adaptation has been defined as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects” (IPCC, 2014). It involves anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise. Well planned, early adaptation action has been shown to save money and lives later. Adaptation measures could include: using scarce water resources more efficiently; adapting building codes to future climate conditions and extreme weather events; building flood defenses and raising the levels of dykes; developing drought-tolerant crops; choosing tree species and forestry practices less vulnerable to storms and fires; and setting aside land corridors to help species migrate. Usage of rainwater harvesting as an alternative is very important for both agriculture and domestic sectors. This could be used to store the excess storm water runoff and can be used during periods of drought when supply systems are dwindling.

Adaptation strategies are needed at all levels of administration: at the local, national, regional, and international level. However, adaptation activities tend to be local – district, regional or national – issues rather than international (Paavola and Adger, 2005). This is because communities possess different vulnerabilities and adaptive capabilities, they tend to be impacted differently, thereby exhibiting different adaptation needs.

This strategic action plan is designed to guide implementation of, and track progress toward, national water sector goals and targets in Grenada. The strategy covers the period 2016-2021 and outlines three national outcomes for the water sector. Expected results (output) are presented along with the actions to meet the defined objectives. The suggested timeline for the commencement of each activity is given, along with an indicative cost where possible and the responsible agencies (lead and partner).

7.2 Strategic Objectives

Several adaptation strategies have been identified for Grenada. These are based on findings from this study and past studies assessing the existing water sector of the islands. The NASAP also incorporates stakeholder perspectives and suggestions as recorded during stakeholder interviews. The recommended strategies were presented to stakeholders at a National Workshop and were subsequently amended to incorporate suggested comments. These strategic objectives are denoted under the following headings:

- Policy
- Legislation
- Capacity (Physical/ Infrastructural, Institutional and Technical)
- Training and Awareness Building

They were used to define the following strategic outcomes:

- Improved policy, legal, regulatory and institutional framework for the water sector;
- Improved technical and institutional capacity for the water sector;
- Enhanced and improved training and awareness in relation to climate change and the water sector.

7.3 Implementation of the Strategy

The National Adaptation Strategy and Action Plan (NASAP) for the water sector of Grenada requires that within MALFFE, the Environment Unit be responsible for ensuring that the action items set out in this Strategy and Action Plan are carried out by the respective lead and partner agencies. However, staffing challenges within the unit would need to be addressed for this strategy to be implemented adequately. To overcome this challenge, in the interim, a committee could be formed to oversee implementation of the strategy. It would comprise representatives from all of the named agencies and ministries in the Action Plan. Each of the three outcomes has a slate of activities to be undertaken over the five year period, and operational plans will need to be developed with appropriate phasing.

The inter-sectoral collaboration required for mainstreaming water resource management can be facilitated through the Environment Unit. It is recommended that this Strategy and Action Plan be shared with all the partner agencies and awareness and capacity building programmes be undertaken. The Committee of Permanent Secretaries and the Cabinet of Ministers will need to accept the imperative for endorsing and implementing the National Adaptation Strategy and Action Plan for the water Sector.

To the maximum extent possible, elements of the NASAP should be integrated into the existing and proposed cooperation programmes of Grenada's bi-lateral and multi-lateral partners. Further funding may have to be sought for specific aspects where these cannot be accommodated within the respective Ministry/agency budgets.

7.4 Monitoring and Evaluation

The implementation of the NASAP for the water sector has to be monitored and evaluated to ensure that the activities are successfully on track, and to ensure transparency and accountability. This will entail the monitoring of the actual implementation of the NASAP, and also evaluating and assessing the cause of any changes, both external and internal to the NASAP, to determine what corrective actions, if any, are needed. The results of this monitoring can then be incorporated into future planning and improvement of the NASAP.

Therefore, an implementation monitoring plan will have to be developed to monitor the progress of the activities and submitted to the Minister of Agriculture, Lands, Forestry, Fisheries and the Environment in Grenada. This will include an annual implementation report that will review the year's activities and make recommendations for planning the activities of the coming year. It will also include reports from all agencies involved in the implementation of the NASAP. This will be initiated by the responsible Ministry.

It is also important to monitor changes in the water sector, and to measure how the activities are contributing to the protection of water resources. A monitoring programme should be developed, and some of the key indicators can be used to determine changes which may include:

- Status and trends of watershed areas, wetland areas, water quality, water availability and water resource management and accountability.
- Changes in the policy and legal framework for water resources, including watershed areas.
- Shifts in human, institutional, and funding capacity, including shifts in cultural perceptions, practices and norms, appropriate orientation of technology, training and education, management information availability, and monitoring capacity.

Once these evaluations are done, the Environment Unit should prepare, or seek to prepare, evaluation reports, including recommendations to be included in the NASAP and submit it to the Minister of Agriculture, Lands, Forestry, Fisheries and the Environment.

OUTCOME 1: IMPROVED POLICY, LEGAL AND REGULATORY FRAMEWORK FOR THE WATER SECTOR

Based on the projected climate variability and change patterns, government institutions in Grenada will have to position themselves to adapt to the needs that will be generated by these potential impacts. It will also require an improved legal and regulatory system to guide and enforce the required actions. The focus of this outcome is therefore to ensure that the legal, regulatory, and institutional framework necessary for the protection of the water sector in Grenada is improved.

Output:

By the end of this strategic planning period, it is expected that the following is achieved:

- A National Land Policy in Grenada
- Promulgate Regulations for controlling water quality
- Promulgate Regulations to establish standards and specifications for effluent discharges into receiving surface, underground or coastal waters
- Rationalization across the laws
- Revised fines for current legislation
- Greater enforcement of existing legislation, through the provision of the necessary support from relevant government agencies
- Improved EIA process
- Watershed Master Plan

Table 7-1: List of Objectives, Activities, Funding and Responsible Agencies for Outcome 1

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To complete preparation of a National Land Policy	Engage Consultant Prepare draft Policy Consultations Revised draft Cabinet approval	Short term	$90,000	Global Water Partnership-Caribbean (GWP)	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment (Land Use Division and Forestry Unit)
To develop a Watershed Master Plan	Completion of detailed mapping of the different soil types of the watersheds, spatial variability and depth range of different soil types. Analyse satellite data for change in soil pattern and ground truth with field data. Improve the land use classification system as per the standards used in the Caribbean and update the land use map for each watershed. Note the change in the land use pattern for the last 10 years from satellite images as well as from aerial photographs Prepare draft Watershed Plan	Short- Medium Term	$195,000	GWP-Caribbean, EU and CCCCC, TNC (The Nature Conservancy)	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment Partner: NAWASA

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	Consultations				
To develop a Water Resource Master Plan	Review and update the existing water resources master plan/report. New water resource report or master plan should take into account the impact of climate variability, land use change and impact of increase in urbanisation and population on the available water resources. Prepare draft Watershed Plan Consultations Implement the new water resource master plan.	Short- Medium Term	$50,000	GWP-Caribbean, EU and CCCCC	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment, Ministry of Communication, Works, Physical Development, Public Utilities, ICT and Community Development Partner: NAWASA
To promulgate regulations for controlling water quality	Engage Consultant Prepare draft Regulations for controlling water quality; consult on draft regulations, prepare final draft regulations	Short-Medium Term	$50,000	GEF- CREW	Lead: Ministry of Communication, Works, Physical Development, Public Utilities, ICT and Community Development
To promulgate regulations to establish standards and specifications for effluent discharges into receiving	Engage Consultant Draft Regulations to establish	Short-Medium Term	$75,000		Lead: Ministry of Health and Social Security

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
surface, underground or coastal waters	standards and specifications for effluent discharges; consult on draft regulations, prepare final version.				
To rationalize the laws	Engage Consultant Prepare legal analysis and review of relevant legislation; prepare background paper to recommend rationalization of existing laws to avoid conflicts, overlaps etc. Prepare necessary legislation to implement the rationalization	Medium Term	$50,000		Lead: Attorney General's Office
To revise fines for current legislation, specifically the Public Health Act and Regulations	Prepare revisions to relevant legislation	Short Term	$20,000		Lead: Attorney General's Office
To improve enforcement of existing legislation (public health, water legislation and other related legislation), through the provision of the necessary support from relevant government agencies	Engage Consultant Institute training for enforcement officers	Short term	$30,000		Lead: Physical Planning Unit, Environmental Health, Forestry Department, Fisheries Department

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To improve EIA process	Engage Consultant Prepare draft EIA regulations Consultations	Short Term	$30,000		Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment, Ministry of Communication, Works, Physical Development, Public Utilities, ICT and Community Development

Note- Commencement of each activity should take place in the following timeframes:

Immediate Short term= 1-3 yrs Medium term= 3-5 yrs Long term= > 5 yrs

OUTCOME 2: IMPROVED PHYSICAL/ INFRASTRUCTURAL TECHNICAL AND INSTITUTIONAL CAPACITY FOR THE WATER SECTOR

Capacity building must be an integral component of any climate change adaptation strategy due to existing uncertainty within the climate models, particularly at local and national levels. Local institutions (both formal and informal) play an important role in building resilience and reducing vulnerability to climate change. They are also the principal vehicle through which external support for adaptation (e.g., training and capacity building, etc.) is and will increasingly be delivered.

Increasingly, local institutions are challenged to respond to increased exposure to risk and vulnerability of the local population as a result of climate change. This is often due to staffing and financial challenges. For there to be effective local adaptation, local institutions need to be responsive, flexible and able to adapt to the uncertainties associated with climate change. However, local governance that is responsive to climate adaptation is constrained by weak technical and managerial capacity, poor funding, poor linkages with other institutions at different levels, weak systems for gathering and disseminating information, and unclear mandates and conflicting priorities between levels and agencies of government. This is often the case in many of the SIDS in the Caribbean. Therefore, the focus of this outcome is to ensure that there is improved physical/ infrastructural, technical and institutional capacity for the water sector.

Output:

By the end of this strategic planning period, it is expected that the following is achieved:

- Establishment of a central coordinating agency which will be responsible for the management of water resources and watershed areas in a holistic manner.
- An improved standardized methodology for acquiring meteorological and hydrological data. Grenada should become a member of the World Meteorological Organization.
- Upgrading the knowledge and data sharing platform for hydrological and meteorological data.
- Increased technical staff at the Environmental Unit.
- An improved standardized methodology for acquiring meteorological and hydrological data.
- An established framework and policy for water access and drainage system.
- Water-balances for the major watersheds ie Great River, Chemin and parishes of St David and St George's which are highest in terms of population and thus domestic water usage.
- Water Quality Monitoring Program restarted.
- Increased surface storage in Grenada and improvements in the distribution system (including leaks).

Table 7-2: List of Objectives, Activities, Funding and Responsible Agencies for Outcome 2

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To create a central coordinating agency which will be responsible for the management of water resources in a holistic manner	Engage consultant, prepare report, obtain Cabinet approval	Medium Term	$70,000	CDB/ EU/ IDB	Lead: Ministry of Communication, Works, Physical Development, Public Utilities, ICT and Community Development Partner: Office of the Prime
To assess the implementation of the National Water Sector Policy for Grenada which was created in 2007. The same should include assessment for Carriacou and Petit Maritinique	Upgrade and improve the functioning of the WRU, Water Resources Unit which was outlined as a part of the CARIWIN initiative in 2008.	Medium Term	$40,000	CDB, IDB, CCCCC	Lead: Office of the Prime Minister, NAWASA, Attorney General, Environment Unit
To develop an improved methodology for acquiring meteorological and hydrological data. Data needs to be collected for Carriacou and Petit Martinique.	Update data on all existing water resources for the three islands (Grenada, Carriacou and Petit Martinique), including both surface and ground water. The mapping should include the exact location rain gauges in each watershed. Develop a policy for how well data is acquired and logged. Staff responsible for well data acquisition should be	Short Term Short Term	Rain gauges: $600-1,200 per rain gauge (2 new ones in each watershed)	USAID/ CDKN/IDB/ CCCCC	Lead: Grenada Meteorological Service, Ministry Of Health, Environment Unit Partner: NAWASA

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	adequately trained with sufficient awareness on the importance of the data. Sufficient staffing in the NAWASA to collect hydrological data. Audit of all assets supporting data collection for rainfall and water resources. Identify gaps and update them. Chemin watershed shows evidence of flooding, but no gauges to measure river discharge. Hence installation of flood gauges to determine the level of flood waters after each event. Community members can be trained to read flood gauge data and of NAWASA, Ministry of Health and Environment staff to create spatial maps from successive flooding events.	Short Term Short Term Short to Medium Term	Approx 100USD for each flood gauge. At least one in each community. These costs do not include maintenance	USAID, IDB, CDKN	
To upgrade the NWIS online data access platform	Conduct an Information Technology Needs Assessment (Infrastructure and Institutional) for	Short term	$120-150,000 (For all Departments)	Climate Investment Fund/IDB/	Lead: Land Use Division Partner: Grenada

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	government departments that handle hydrological and meteorological data. Upgrade a data management platform for each department. Upgrade Information Technology equipment and develop skillsets Develop a Policy on data sharing among government agencies for the purpose of conducting studies and for decision making	 Short term Short term Medium term	 $20,000 (Each) TBD (Will heavily depend on IT Needs) $15-20,000 (individual consultancy)	CCCCC/ International Research Initiative on Adaptation to Climate Change (IRIACC) Challenge Fund	Meteorological Service
To establish a framework and policy for water access	Undertake analysis of the amount of water needed for each housing area monthly, update the present data base and allocate allowance for increase in population for at least a 10 yr period. Analyse the seasonal change in consumption with variation in rainfall pattern.	Short Term to Medium Term	$100,000	CDB/ IDB/ EU	Lead: NAWASA Partner: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment.
To develop water balances for each major watershed.	Calculation of water-budgets for each basin for each month and then final yearly	Short Term- to be	- (If additional	Technical	Lead: NAWASA

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	water budget. Continuous analysis of the water budget using the rainfall, evaporation and storage data for effective management of water availability and projection into short, medium and long term time periods	continuous assessment	technical assistance is required that would have to be costed for separately)	Skills in house	
To develop plan for water quality monitoring program for all three islands (for Carriacou and Petit Martinique monitoring can also take place in coastal waters to determine the effect of septic tanks)	Audit- water quality data is lacking. There needs to be monitoring of the existing supply systems.	Immediate- to be continued for every month.	$5-10,000 To be determined based on the findings of the Audit	GWP-Caribbean	Lead: Environment Unit Partner: NAWASA
To improve maintenance of the drainage system in	Assess the current drainage system and identify drains that need widening and re grading etc. This should be stepwise to prioritize flood prone communities and then major townships. Identify where new drains are needed Undertake preliminary engineering design work Cleaning of the mouth of the Chemin river from silt	Short Term Medium Term	US$15M Cost to arise from design	CDB/ IDB	Lead: Ministry of Health and Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment (specifically Land Use and Environment Unt) Partner: Public Works

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	accumulated during flooding.		work.		
To increase surface storage in Grenada and improvements in the distribution system (including leaks).	Feasibility study to determine the best locations for additional surface storage and the type of storage. Develop a plan for improving the distribution system- identify areas of the islands that need improved infrastructure. Install meters along the distribution network to track areas where water is significant. Quantify losses within the distribution network/ reservoirs Develop a plan for how leaks are managed and fixed.	Medium Term Medium Term Short- Medium Term Short to Medium Term	$45,000 TBD	CDB/ EU/ IDB, GWP-Caribbean	Lead: NAWASA

Note- Commencement of each activity should take place in the following timeframes:

Immediate Short term= 1-3 yrs Medium term= 3-5 yrs Long term= > 5 yrs

OUTCOME 3: ENHANCED AND IMPROVED TRAINING AND AWARENESS IN RELATION TO CLIMATE CHANGE AND THE WATER SECTOR (PRIVATE, GOVERNMENT AND CIVIL SOCIETY).

The management of Grenada's water resources (sector) requires radical changes in many of the attitudes and behaviour of people and institutions. There is a need to develop a greater sense of ownership of, and responsibility towards water and a need to increase the understanding of how climate change has already affected and will continue to affect the water sector.

There must be an increased awareness and sensitivity to climate change and its impacts on the water sector. Meaningful education and awareness programs should not only increase knowledge, but also create a better understanding of the consequences of one's actions and their implications. The focus of this outcome, is therefore to ensure that there is an enhanced and improved education and awareness in relation to climate change and the water sector within the society (private, government and civil society).

Output:

By the end of this strategic planning period, it is expected that the following is achieved:

- Education campaign focused on training farmers, improved farming practices to include water conservation measures and to increase the use of RWH systems;
- Promote the use of water saving devices on a widescale;
- Increasing water supply by expanding RWH domestic storage capacity particularly in Grenada;
- Climate Change education and media campaign for the general public;
- Year round water conservation media and education campaign;
- Revised (increased) water tariff rates;
- Encouraging the use of more drought resistant crops by famers, particularly in the Chemin Watershed;
- Increased implementation of dryland farming techniques around the island.

Table 7-3: List of Objectives, Activities, Funding and Responsible Agencies for Outcome 3

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To develop education campaign focused on training farmers, improved farming practices to include water conservation measures	Development of two training modules centered on 2 half an hour videos in support of agricultural extension services presentations to community based farmer groups. 1. **The first educational video Farming Practices** -will focus on soil conservation practices appropriate for integration into local farming conditions and will address themes such as: Soil Management; Tillage; timing of planting; pest and disease control; crop rotation; plant spacing; and cropping systems. Focus will be on their importance to good cultivation practices. 2. **The second educational video Water Conservation Measures for Farmers –** will focus on a. On-farm water storage; harvested rainwater; surface water (such as streams); sub-surface or ground water; and recycled water.	Short Term	$158,000	CDB/ FAO/ IADB/ IFAD/ UNECLAC/ UNDP/ USAID	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment. Partner: The Agricultural Extension Service and Ministry of Communications, Works, Physical Development, Public Utilities, ICT & Community Development.

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	b. Soil water management systems practices to reduce the effects due to drought and floods; types of irrigation systems; increasing the water holding capacity of soils; conserving and reducing the evaporative loss of water from the soil; Efficient drainage system for the effective removal of flood waters after intense rainfall.				
To develop Climate Change education and media campaign for the general public.	Evaluation the current water conservation program through the use of social surveys Develop an effective media campaign.	Short Term	$26,250 (individual consultancy) $120,750	Climate Investment Fund/IDB EU UNEP	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment, NAWASA Partner: Ministry of Communications, Works, Physical Development, Public Utilities, ICT & Community Development. Planning and Development Unit, Ministry of Education and Human Resource Development.

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To develop the use of more drought resistant crops by famers, particularly in the Chemin Watershed.	Assessment of farming techniques island-wide Devise training programs for farmers introducing all types of dryland farming techniques which would allow for less useage of water beyond drip irrigation-mulching. Introduce farmers to drought resistant crops/ diversify crop production	Short Term	$157,500	CDB/ FAO/ IADB/ IFAD	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment. Partner: The Agricultural Extension Division and CARDI
To increase technological options and solutions for production and post-harvest handling in Agriculture that offer resilience to climate change.	In-service training program targeting public sector crop specialists livestock specialists, and extension officers. Short course tertiary training in modern production and post harvesting technologies applicable to current and targeted farm products and fisheries.	Short Term	$1.575M	CDB/ FAO/ IADB/ IFAD/ UNECLAC/ UNDP/USAID	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment Partner: The Agricultural Extension Division and CARDI
To develop revised water tariff rates	Consultancy to determine water pricing towards sustainable water services. Components will be: 1. Water policy objectives and water pricing;	Immediate		CDB/ FAO/ IADB/ IFAD/ UNDP/ GWP/ EU	Lead: NAWASA Partner: Ministry of Finance, Planning, Economic Development, Trade, Energy

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	2. Water pricing mechanism's and instruments: levies, taxes and charges; Revenue: Analyzing the revenue potential and administrative complexity of alternative pricing instruments, Capacities: identifying and addressing institutional capacities needed for the development and implementation of pricing strategies		$315,000		& Cooperatives Ministry of Tourism, Economic Development, Divestment & Energy Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment
To diversify away from low yield/low return agricultural production.	**Agricultural Export Development Training** Grant to support work experiences in developing countries with a track record of agricultural export development and promotion directed at the export supporting agencies in the government. The main focus would be: • Marketing & Promotions • Product Development • Quality Improvement	Medium Term	$210,000	CDB/ FAO/ IADB/ IFAD/ UNDP/ Bi Laterals/ The European Union	Lead: Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment Partner: Ministry of Economic Development, Trade, Planning, Cooperatives& International Business Support: CARDI

Note- Commencement of each activity should take place in the following timeframes:

Immediate Short term= 1-3 yrs Medium term= 3-5 yrs Long term= > 5 yrs

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ANNEX

ANNEX 1: POLICIES, PLANS AND LEGISLATION REVIEW

Existing Policies and Plans

Forest Policy 1999

The Forest Policy seeks to maximize the contribution of forests to environmentally sound social and economic development. The objectives of the policy are to:

1) Conserve species, ecosystems and genetic diversity; maintain, enhance and restore the forests ability to provide goods and services sustainably
2) Optimise the contribution of forest resources to socio-economic development
3) Maintain a positive relationship between the people and the forest environment.

The policy addresses watershed management and among its strategic directions is the adoption of an integrated approach to watershed management, conservation of all ground and surface water resources and protection from pollution and depletion. However, the policy has not been implemented because of a lack of supporting legislation and regulations.

Grenada's Agricultural Policy

The MALFFE currently has no Agricultural Policy. Recently, efforts have been made to remedy this situation through the development of a number of documents which aim to "fill the policy gap". The Agricultural Policy and Programme of the Ministry of Agriculture 1997-2010 was released in January 1998, but is yet to be adopted and/or acted upon. A draft Agricultural Strategy and Corporate Plan for the Agricultural Sector, 2005 has been developed and is being discussed.

Grenada's Building Code of 1999

The Grenada Building Code is administered under the Land Development Control Authority which was established under the Land Development Control Act. It sets the standards that the Authority will use to determine the suitability of any building or development plan. The Code was developed to establish building safety standards which are applicable for a region that is susceptible to frequent tropical storms and hurricanes. Thus, in all respects the Grenada Building Code addresses adequately, the problems, which may arise from that type of hazard.

The Code provides details on all aspects of construction and health and safety standards to be used in buildings. The safety requirements specifically focus on hurricane and fire resistant buildings. There are also specific design criteria for the construction of sea walls and bulkheads. This Code is comprehensive and detailed enough to cover all the requirements of an appropriate building standard for Grenada. The Code was recently updated to provide standards for buildings, which can effectively withstand hurricanes and flooding.

Grenada, Carriacou and Petit Martinique Strategic Development Plan, 2030

The Strategic Development Plan (SDP) is "a path toward greater national consciousness and competitiveness; greater collective responsibility for our nation's future; smarter and more effective planning for future generations; better use of our national assets and resources; empowerment of our people; development of competitive micro, small and medium sized businesses; a diversified economy built on the collective will of every citizen."

Grenada: National Disaster Plan, 2005

The Plan outlines Grenada's course of action in case of disasters. It describes disaster prevention and preparedness measures against the country's natural hazards and outlines the organization of the national disaster management system. The plan also discusses the responsibilities and functions of the national disaster management committees and various government agencies. Finally, it addresses the role of the private sector and non-governmental organizations and service clubs in cases of disaster.[21]

Grenada Plan and Policy for a System of National Parks and Protected Areas, 1988

The document identifies 27 areas of outstanding natural and cultural heritage in Grenada that should be included in a National Parks System. Included within are upland watershed areas which are important for water resources management.

Land and Marine Management Strategy, 2011

The overall goal of the strategy is to, "achieve integrated national development that is environmentally sustainable." Its vision is:

- Sustainably managed areas, where competing demands and pressures have been taken into account and the social and economic needs of society have been reconciled with the need for conservation of the natural and historic environment.
- A clear policy and regulatory framework into which the principles of a holistic and coordinated approach are embedded.
- A new strategic management approach in the marine environment which is effectively integrated with the management of the land.
- More consistent application of the best management practices and principles of sound holistic and coordinated management around the coast.
- A management approach that builds on existing structures and responsibilities while encouraging organizations to improve relationships coordinate work plans.
- A flexible management approach, which supports local initiatives and solutions to address local circumstances within an overall regulatory framework.
- Appropriate and effective stakeholder and local community involvement throughout management processes."

[21] *www.gov.gd/egov/docs/nadma/**national_disaster_plan**.pdf*

It was developed to address the following challenges to governance in order to enable sustainable Land and Marine Management:

- Outdated legislation not consistent with present socio-economic and cultural imperatives;
- Limited coordination of implementation among agencies involved in environmental management;
- No Land Management Agency or Marine Management Authority;
- Absence of a clear policy statement for utilization of land and marine resources;
- Inadequate regulations, codes of practice and standards for natural resource use;
- Promulgation of a Draft Environmental Management Act;
- No comprehensive zoning or spatial planning since planning is sector or project specific; and
- Tourism dependent economy centred around development in coastal areas."

The Strategy consists of the following four outcomes:

Strategy Outcome 1

- Legislative Policy Framework for Land and Marine Management Developed

Strategy Outcome 2

- Network Administrator Organization (s) Established

Strategy Outcome 3

- Tools for Management of Land and Marine Resources Developed

Strategy Outcome 4

- Framework for Planning, Implementation, Monitoring and Review Developed

Master Plan for the Tourism Sector – Grenada, Carriacou, Petite Martinique, 1997

One of the main objectives of The Master Plan for the Tourism Sector is to ensure that tourism development is consistent with the protection and conservation of the country's natural and cultural resources and the built environment.

Medium-Term Development Framework: Economic Growth, Poverty Alleviation and Macroeconomic Stability (2005)

The GOG has developed a Medium-Term Development Framework entitled Economic Growth, Poverty Alleviation and Macroeconomic Stability which articulates a series of initiatives that were to be undertaken from 2006 to 2008. The broad focus areas of the framework include:

1) Sustainability of high economic output,

2) Restoration of debt and fiscal sustainability

3) Reduction of vulnerabilities and

4) Reduction in poverty

Some specific areas identified for intervention which are relevant to land management within the scope of this MSP include the establishment of an executive land management agency, the strengthening of public sector investment planning and implementation and the enhancement of government service delivery and vulnerability reduction (through implementation of post-Hurricane Ivan reconstruction recommendations).

National Biodiversity Strategy and Action Plan (NBSAP), 2000

Key objectives of the National Biodiversity Strategy and Action Plan (NBSAP) are to:

- Provide broad-based support for conservation and sustainable use of biodiversity.
- Protect key ecosystems from negative human induced impacts.
- Develop and encourage sustainable utilisation of biological resources that are essential to the livelihood of local communities.
- Maintain, recover and promote genetic resources necessary for sustainable agriculture.
- Ensure a fair and equitable sharing of the benefits arising out of the utilisation of genetic and ecosystem resources.
- Provide information on key ecosystems for incorporation into national accounts and decisions on national development projects

National Environmental Policy and Management Strategy (NEPMS) for Grenada, 2005

The vision of the National Environmental Policy and Management Strategy for Grenada is "The Government and People of Grenada, Carriacou and Petit Martinique envision a healthy and productive environment that guarantees the sustainability of development activities and processes and that contributes fully to social and cultural development, to economic prosperity, and to the quality of human life." The goal of the NEPMS "is to provide a coherent framework to ensure that development is environmentally sustainable, while optimising the contribution of that environment to economic, social and cultural development in the short, medium and long terms." The seven objectives of the NEPMS are:

2. Maintain the diversity of ecosystems, species and genes.
3. Maintain and enhance the natural productivity of ecosystems and ecological processes.
4. Optimise the contribution of natural and environmental resources to the production and trade of economic goods and services.
5. Optimise the contribution of natural and environmental resources to social and cultural development.
6. Prevent and mitigate the negative impacts of environmental change and natural disasters, and build resilience relative to these.
7. Maintain and enhance the contribution of the environment to human health.
8. Fulfil regional and international responsibilities and capitalise on opportunities that accrue from regional and international networking.

Among the main policy interventions is, "Maintain and enhance the natural productivity of ecosystem and ecological processes" under which two of the three main instruments are: "Full implementation of the National Forest Policy and Strategic Plan and continued collaboration among relevant agencies to promote integrated watershed management." Additionally, one of the two new instruments to be developed under this strategy is "An emergency programme to enhance the conservation and rehabilitation of highly sensitive areas in key watersheds."

National Hazard Mitigation Policy, 2003

The policy seeks to mainstream hazard risk reduction into national development planning and decision making as a key strategy towards vulnerability reduction. It emphasises proactive approaches to hazard risk reduction by focusing on strengthening national capacity for hazard management while raising awareness on risk management approaches to natural and technological hazards among key stakeholders.

National Physical Development Plan, 2003-2021

The National Physical Development Plan was completed in accordance with Section 16 of the 2002 Physical Planning and Development Control Act. Cabinet approved the Plan for Grenada in 2004. The GOG has implemented environmental aspects of the Plan through planning and development regulations. One example of this is that environmental impact assessments (EIAs) have to be completed in order for approval for development projects to be granted. Projects that will have negative impacts on water can be addressed through the cross-sectorial representation on the EIA committee that is formed to review projects by the Physical Planning Unit.

Poverty Reduction Strategy

The GOG, with the assistance of the International Monetary Fund (IMF) has developed an interim Poverty Reduction Strategy Paper(PRSP). The vision of the PRSP is rooted in the country's commitment to realizing poverty reduction under in the context of the MDGs and focuses on the following priority elements:

- Economic recovery for sustained economic growth;
- Agricultural rehabilitation and development;
- Housing development;
- Reduced unemployment;
- Improved access to social infrastructure;
- Human resource development;
- Modernization of estate service machinery;
- Improved environment management;
- Social safety net programmes.

Pending Policies and Plans

Draft Drought Management Plan

The operational plan will be based on regular monitoring and assessment and the making of adjustments to sustain the water supply. The Plan outlines NAWASA's response to drought.

Draft Model Integrated Water Resources Management Plan (IWRM)

The vision of the Draft Model Plan is "optimal and sustainable use of the Country's water resources to maximize the welfare of the Nation." The Plan considers coastal zone management and fresh water management.

The objective of the IWRM Plan is to identify actions to be taken to facilitate the successful implementation of integrated water resources management. Actions to be implemented must be based on stakeholder participation and public awareness.

Draft National Climate Change Policy and Action Plan 2007-2011

The vision of the Draft National Climate Change Policy and Action Plan is, "an empowered Grenadian population capable of responding to the risks from climate change, at the individual, community and national levels." The strategic objective of this plan is "to lay the foundation for a structured long term response to Climate Change". There are seven inter-related strategies:

1) Climate-proofing present and future national development activities by requiring a climate risk analysis of all ongoing and new development initiatives.
2) Strengthening the collection, analysis and use of climate-related data and impacts.
3) Building local human capacity to assess and respond to climate change, including through the access and use of appropriate technologies.
4) Reducing greenhouse gas emissions through increased energy efficiency and the use of renewable energy.
5) Eliminating unsustainable livelihood and development practices that increase climate change vulnerabilities.
6) Sustained Public Awareness and Education Programming.
7) Foreign policy advocacy for international action on climate change.

Draft National Hazard Mitigation Policy, 2003

The policy seeks to mainstream hazard risk reduction into national development planning and decision making as a key strategy towards vulnerability reduction and emphasizes proactive approaches to hazard risk reduction through focusing on strengthening national capacity for hazard management and raising awareness on risk management approaches to natural and technological hazards among key stakeholders.

Draft National Waste Management Strategy for Grenada (NSWMS), 2003

Once the draft National Solid Waste Management Strategy is passed by the Cabinet it will serve as the blueprint for actions to support the provisions of the Waste Management Act. The NSWMS has 18 action items which were to be implemented in Grenada from 2003 to 2008. The action items represented the priority issues identified through stakeholder consultations. These priorities were divided into the following categories:

- Institutional Arrangements
- Policy and Regulation Development
- Management, Operations, Monitoring and Enforcement
- Public Awareness

The NSWMS was to be reviewed within five years of adoption of the initial strategy.

Draft National Water Policy, 2007

The National Water Policy envisages "optimal and sustainable use of the Country's water resources to maximise the welfare of the Nation." Its goal is "to provide a framework to maximise the contribution of the water sector to sustainable economic, social and environmental development in an efficient and equitable manner." The Policy sets out a governance framework for the water sector, allocates duties, responsibilities and powers, and states the roles of the public and private sectors. The Policy focuses on establishing integrated water resources management; implementing effective and transparent coordination; improving the water resources information base; establishing effective, water and wastewater quality control; regulating water services and tariffs; strengthening human resource capacity; reducing vulnerability to natural disasters; and fostering appropriate cultural and attitudinal change.

The policy objectives are to:

- Ensure that present and future generations have access to water of sufficient quality and quantity for their various uses and an acceptable standard of sanitation;
- Provide a framework for the integrated/rational use, management and regulation of water resources and services, with a view to achieving sustainable development of the sector;
- Foster coordination, collaboration and participation between all stakeholders and thereby greater accountability and transparency;
- Secure water for non-domestic uses including that required to secure ecosystem services, recreation and aesthetics;
- Ensure water is used as efficiently as possible, including promotion of wise use and conservation;
- Ensure that vital ecosystems are maintained and that adverse effects on other natural resources are considered and where possible eliminated or if not practical reduced;
- Ensure implementation of measures to restore and enhance the quality and quantity of usable water and protect the aquifers, watersheds, and other sources of water;

- Provide opportunities for all water users to influence decisions that affect their daily lives;
- Establish an institutional framework for integrated water resources management;
- Establish a National Integrated Water Management Plan encompassing both water resources and water services that shall be reviewed on a regular, periodic basis.

Figure 4.2 illustrates the proposed structure for water resources management under the Policy.

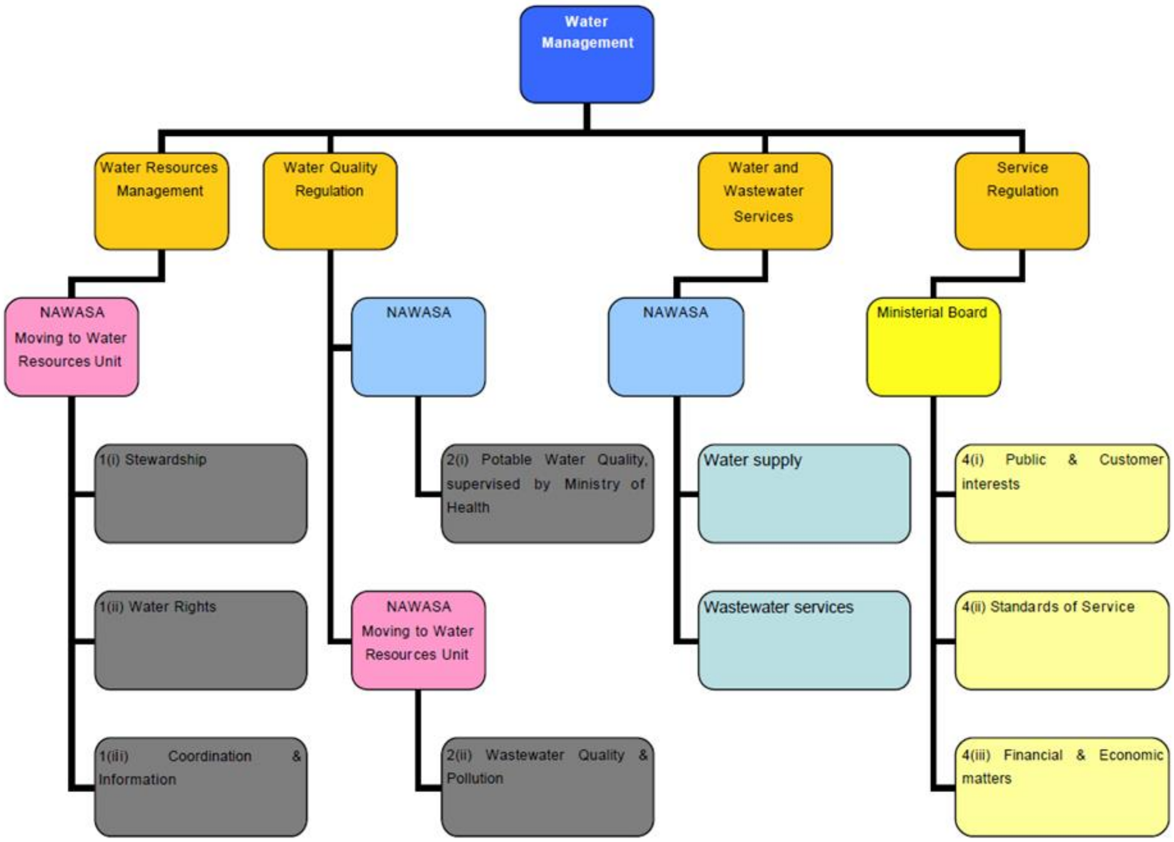

Figure A1: Proposed Arrangements of Functions and Responsibilities for Water Resources Management in Grenada

Existing Legislation

In Grenada, legislation for natural resources management is quite fragmented. This section presents the natural resources and related legislation for the country.

Beach Protection Act, 1979

The Beach Protection Act prohibits the unauthorised removal of sand, stone, shingle and gravel from the seashore. Under the Act, permission is required to remove or carry away sand and other coastal aggregates from the seashore. The Act is specific to the concerns of *inter alia*, coastal erosion and salt water intrusion.

Carriacou Land Settlement and Development Act

The Carriacou Land Settlement and Development Act established and empowered the Land Settlement and Development Board to regulate and control land settlement and development in Carriacou. However, it is unclear as to whether the Board is still active given the date on which the legislation was passed. The major challenge however, appears to be the inability of the Board to adequately administer the Act in spite of the fact that it is important for the orderly control of development and can have a significant positive impact on sustainable land management.

Crown Lands Act, 1896

The Crown Lands Act relates to Crown Lands. Under the Act, the lands vested in the Governor General for public use in Grenada are called "Crown Lands". Subject to the National Parks and Protected Areas Act, the Governor General may grant, sell, exchange or lease any Crown Lands or any right or easement over them for such price or consideration or rent, for such estate or term of years as he/she may think fit. The Act grants the Crown the rights to mines and alluvial deposit as well as deposits of precious metals and minerals. Subsidiary legislations under this Act are the Crown Lands Forest Produce Rules and the Prevention of Squatting on Crown Lands Rules. The Crown Lands Forest Produce Rules provide the procedure for harvesting trees on Crown Lands.

Environmental Levy Act, 1997

The Environmental Levy Act makes provision for the payment of a Levy by persons on goods and services. It serves to support the financial operations of the Grenada Solid Waste Management Authority.

Grenada National Trust Act, 1967

The Grenada National Trust Act is an Act for incorporating the Grenada National Trust with limited liability. The National Trust is a body interested in the preservation of places of historic and architectural interest or national beauty whose objectives are:

- Listing buildings and monuments of prehistoric, historic and architectural interest and places of natural beauty with their animal or plant life;
- The compilation of photographic and architectural records of the foregoing;
- The preservation of chattels of prehistoric, historic or artistic interest and the establishment of museums;
- Making the public aware of the value and beauty of Grenada's heritage;
- The pursuance of a policy of preservation, and acting in an advisory capacity;
- Acquiring property for the benefit of the people of Grenada;

- Promoting and preserving for the benefit and enjoyment of the people of Grenada submarine areas of beauty or natural or historic interest, and the preservation (as far as possible) of their natural aspect, features and animal, plant and marine life;
- Attracting funds by means of subscriptions, donations, bequests and grants for the effective carrying out of those objects, have prayed that an Act be passed incorporating the Grenada National Trust.

The Act determines that lands or tenements (including buildings), submarine areas or lakes or rivers once vested in the National Trust, which have been defined as being held for the benefit of people of Grenada, by the Council, to be inalienable.

Grenada Solid Waste Management Authority Act, 1995

The Grenada Solid Waste Management Authority Act establishes a Solid Waste Management Authority which is charged with the duty of developing the solid waste management facilities and improving the coverage and effectiveness of solid waste storage, collection and disposal facilities.

Forest, Soil and Water Conservation Act, 1949

The Forest, Soil and Water Conservation Act makes provision for the conservation of the forest, soil, water and other natural resources of Grenada. The main objective of the Act is to prevent flooding and soil erosion. Section 3 of the Act also provides a forest policy for, *inter alia,* the preservation of tree cover to prevent soil erosion, flooding and to protect water supplies. Under Section 7, the Governor-General has the power to declare by order, any land other than Crown Land to be a protected forest where in his opinion this is felt necessary for the maintenance of water supplies in springs, rivers and reservoirs. The Act also prohibits squatting on Crown Lands.

Grand Etang Forest Reserve Act, 1906

The Grand Etang Forest Reserve Act states provides for the preservation of forest growth in the vicinity of the Grand Etang Lake by pronouncing the area a forest reserve for the benefit of Grenada. The Act forever declares the Grand Etang Forest Reserve as a part of government land hence, it is strictly reserved and set apart for forest conservation as well as the promotion of rainfall and water supply in Grenada.

Land Settlement Act, 1933

The Land Settlement Act provides for the establishment and location of small holdings for other purposes. The Act establishes the Land Settlement Development Board, a body corporate and vested with power to acquire property by various means for small holdings.

National Disaster (Emergency Powers) Act, 1984

The National Disaster (Emergency Powers) Act makes "provision for the maintenance of supplies and services essential to the life of the community on the occurrence of a national disaster, and for connected matters." The Act gives the Prime Minister the power to "make regulations for the regulation and control of supplies and services essential to the life of the community" during the period of the national disaster.

National Parks and Protected Areas Act, 1990

The National Parks and Protected Areas Act provides for the designation and maintenance of national parks and protected areas, and for connected purposes. The Act aims to protect and preserve environmentally sensitive areas. Under the Act, the Governor General is responsible for the national parks system and is responsible for declaring an area a national park. Lands which may be declared a national park by the Governor-General are government land, leased, purchased or donated land. The Minister responsible for the Act has the authority to declare government land to be a protected area for the purpose of, *inter alia*, preserving the natural beauty, including flora and fauna.

National Water and Sewerage Authority Act, 1990

The National Water and Sewage Authority Act is the principal piece of legislation that deals with the provision of water services and the management of water resources. The Act provides *inter alia* for the establishment of the National Water and Sewage Authority (NAWASA) and states the functions of the Authority. Under the provisions of the Act, NAWASA is charged with two main responsibilities:

1) The power to manage water resources and to issue water licenses
2) The authority to provide water services

Section 3 of the Act provides for the promotion of a national water and sewerage policy which in turn allows for *inter alia*, the conservation and proper use of water resources inclusive of the preservation and protection of catchment areas and the treatment and disposal of sewage and other effluents.

National Water and Sewerage Authority Sewerage Regulations, 1993

The National Water and Sewerage Authority Sewerage Regulations, *inter alia*, prohibits sewerage discharge to natural outlets, prohibits certain discharges (e.g. petroleum spirit, non-purified waste) and requires private sewers to comply with the requirements of general systems.

National Water and Sewerage Authority Water Services Regulations, 1993

These Regulations stipulate that NAWASA "shall keep and provide a constant supply of water, sufficient for the domestic, commercial and industrial use of owners of property who are, in accordance with these Regulations, entitled to be supplied with water by the Authority". They also state that "The Authority may enter into special contracts to provide water supply services to any premises or group of premises for irrigation or other purposes not specified in sub-regulation (1) subject to such terms and conditions as are agreed between the parties or as the Authority determines."

Other subsidiary legislation includes National Water and Sewerage Authority (Water Supply and Sewerage Areas) Order, National Water and Sewerage Authority (In-House Installations) Regulations, Water and Sewerage Rates and Charges Regulations.

Pesticides Control Act, 1973

The Pesticides Control Act governs the importation, sale, storage and use of pesticide, and for connected matters. The Act establishes the Pesticides Control Board whose duties are to advise the Minister on matters relevant to making regulations under the Act and to carry out the provisions of the Act and the Regulations. The Minister with responsibility for the Act is the Minister of Agriculture and the Act gives him/her the power to make regulations for *inter alia*, prohibition of the importation of particular pesticides, control of pesticides used in food production and the setting out of conditions under which pesticides are to be stored.

Physical Planning and Development Control Act, 2002

The Physical Planning and Development Control Act makes provision for the orderly and progressive development of land, the proper planning of town and country areas as well as the control of development. The main objectives of the Act are:

- To ensure that appropriate and sustainable uses are made of all public and private lands in the public interested
- To maintain and improve the quality of the physical environment in Grenada
- To maintain and improve the standard of building construction so as to secure human health and safety
- To protect and conserve the natural and cultural heritage of Grenada. The Minister responsible for the Act may designate a heritage conservation or an environment area.

The Act establishes the Physical Planning and Development Authority which is required to prepare physical plans for Grenada to protect the natural and cultural heritage and for related matters. In the preparing these plans, the Act mandates the Authority to collaborate with other government agencies that have an interest in the matter.

Public Health Act, 1925

The Public Health Act governs matters relating to Public Health. Section 3 of the Act establishes a Sanitary Authority which is responsible for general superintendence and control over all sanitary matters in Grenada. The Authority consists of the Chief Medical Officer, the Chief Technical Officer (Public Health), the Port Health Officer, the Medical Officer of Health, the Port Manager, the Public Health Officer of Carriacou, a representative (appointed by the Minister) from each of the following – National Water and Sewerage Authority, Chamber of Commerce, Trade Union Congress, a representative appointed by the Minister responsible for agro-industries and four other persons to be appointed by the Minister. The

Authority has the power to make rules relating to, *inter alia*, regulating and ensuring the use of drainage channels for surface water and disposal of return flows from irrigation.

Public Health Regulations, 1925

Within the Public Health Regulations are provisions that allow for the protection of water resources and makes it an offence for any person to pollute any stream.

Standards Act, 1989

The Standards Act provides "for the preparation and promotion of standards in relation to goods, services, processes and practices, by the establishment and operation of a bureau of standards and its council, and for connected matters." In relation to water resources, the Grenada Bureau of Standards has published a standard for the collection, processing and marketing of water.

Solid Waste Management Act, 2001

The Solid Waste Management Act provides for the management of waste which conforms to the best environmental practices and any related matters. Under the Act "Authority" is defined to mean the Grenada Solid Waste Management Authority established by the Grenada Solid Waste Management Authority Act.

Waste Management Act, 2001

The Waste Management Act makes provision for a National Solid Waste Management Strategy with components covering, *inter alia*:

- Standards, requirements and procedures for the management of all waste, including the generation, handling, storage, treatment, transport and disposal of all types of waste;
- Outline measures for effective training of staff involved in waste management and effective public education and awareness regarding waste management;
- Establish standards and procedures to be implemented in the reduction, recycling of, recovery, reclaiming and re-use of waste and the use of recycled substances;
- Identify methods by which waste is to be transported.

This Act is important for the prevention of litter, illegal dumping and establishment of waste management facilities. It has implications for the protection of watershed and pollution prevention of natural watercourses.

Water Quality Act, 2005

The Water Quality Act governs matters relating to the quality of water which is intended for human consumption. The Act requires that water for human consumption shall be regularly monitored by an authorized person at the point where it is made available to the user.

Wild Animal and Bird (Sanctuary) Ordinance, 1928

The Wild Animals and Birds (Sanctuary) Ordinance of 1928 provided early legislation for the protection of birds and certain other species in the Grand Etang Forest Reserve. The Bird and Other Wild life (protection) Ordinance of 1957 and amended in 1964 provided wider protection and included all birds other than the game species, and for sea turtles, lobsters and oysters during the closed seasons. Limiting the disturbance of the forest and reducing fauna habitat modification will be of critical importance to maintaining the functionality of the watersheds.

Pending Legislation

Draft Environmental Management Act, 2005

The Draft Environmental Management Act provides a comprehensive framework for environmental management in Grenada. The Act makes provision for the establishment of a Department of the Environment, the establishment of an Environmental Trust Fund, the development of an Environmental Management Plan, the establishment of a Sustainable Development Council (SDC), among other provisions.

Draft Protected Areas, Forestry and Wildlife Legislation, 2003

The draft Protected Areas, Forestry and Wildlife Act is legislation is intended to support the Forest Policy and would govern protection and conservation of forests and watersheds. It would establish a Department of Forestry and National Parks and the functions of the Department would be:

- Ensuring the sustainable development of the forest and wildlife resources of Grenada;
- Protecting biodiversity
- Monitoring the forest and wildlife resources of Grenada and their habitats;
- Managing forests on Crown Land and protected areas established under this Act;
- Managing the wildlife of Grenada
- Managing watersheds in cooperation with ...
- Promoting the practice of forestry in agricultural and other areas and encouraging proper forestry practices on private land;
- Undertaking such forestry and related activities on private land as may be agreed with land owners
- Promoting scientific research, education and training in forestry, wildlife, watershed management and related matters
- Regulating fires on Crown land
- Prosecuting offences under this Act

The Act would also establish a Forestry and National Parks Advisory Council and outlines its functions as advising the Minister on any matter relating to the policy and the implementation of the Act, as well as on any other related matter that the Minister may refer to it. The Act requires, *inter alia*, that the Director of the Department keeps a record of watersheds of Grenada and monitors their state, identifying watersheds which require particular protection for purposes of conservation of water and soil.

Draft Public Health Act

A draft Public Health Act has been prepared to update and modernize the existing public health legislation.

Water Resources, Supply and Sewerage Bill, 2015

The Draft Water Resources, Supply and Sewerage Bill proposes to:

- Incorporate the objectives and guiding principles of the National Water Policy and provide for the management, development protection and use of water resources. The Bill will also seek to regulate the delivery of water supply services throughout Grenada and to provide for incidental matters. The Bill will also repeal the National Water and Sewage Authority Act.
- Provide for certain fundamental principles, which must be applied in interpreting its provisions. It will also seek to establish the State's rights with respect to water.
- Seek to establish a Water Resources Management Unit for the purposes of managing the water resources in Grenada. The Unit will be under the portfolio of the Minister of Agriculture and will be administered by a Director who shall be assisted by a Deputy Director. The functions and powers of the Unit will be clearly defined in the Bill.
- Provide for the protection of gathering grounds and for water related emergencies and the powers of the Minister in that regard.
- Provide for the Unit to prepare and submit for the Minister's approval, a draft National Water Resources and Management Master Plan for Grenada.
- Include provisions will be made in the Bill for water user rights and water allocation throughout the State.
- Make provisions for water supply, abstraction and use and the reservation of the water resources. A licensing process will also be enacted to regulate the abstraction and use of water resources.
- Implement measures in the legislation to allow also for the control and protection of ground water.
- Provide for water conservation and water management practices.
- Establish a regulatory oversight body called the Water and Sewage Commission to regulate the delivery of water supply services and sewage services throughout Grenada. This Commission will act as a watchdog over service providers and establish standards of service in relation to the water sector. This will allow for transparency and good governance.
- Empower the Water and Sewage Commission to establish and approve tariff schemes.

Relevant Regional and International Conventions

Regional

The St. George's Declaration

The St. George's Declaration on Principles for Environmental Sustainability in the OECS is an important agreement for the conservation of natural resources in the sub-region. In this agreement, the Member States of the OECS agreed that the effective management of environmental resources at local, national, regional and international levels is an essential component of sustainable social and economic development, including the creation of jobs, a stable society, a buoyant economy and the sustaining of viable natural systems on which all life depends.

Principle 11 addressed the sustainable use of natural resources and outlines among other things that Member States should manage terrestrial, marine and atmospheric resources, organisms and ecosystems in an appropriate manner in order to obtain the optimum sustainable productivity, while maintaining the integrity of natural and ecological processes and inter-relationships between such systems and processes. Further, States should develop a schedule of development activities for which environmental impact assessments will be required as part of project definition and design and the results of which will be considered in determining whether and how a project will proceed.

The Cartagena Convention, 1983 (The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region) and the Land-Based Sources of Marine Pollution Protocol (1999)

Notwithstanding the reliance of the Caribbean islands on the marine environment, the exploitation, degradation and overexploitation of the sea has plagued the region for decades. The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region was developed to offer some measure of protection to this vital natural resource base. This Convention addresses issues such as pollution from ships, dumping, land-based sources of pollution, seabed activities, airborne pollution, specifically protected areas, cooperation between nations in case of emergencies, and environmental impact assessments. This Convention was signed by Grenada in 1983 and ratified in 1987.

Pollution of the marine environment from land-based sources has been recognized as the most significant stressor on the Caribbean Sea. Hence, the Land-based Sources of Marine Pollution Protocol which complemented the convention is one of the three ancillary instruments for attaining coastal and marine resource protection. IWRM and in particular watershed protection, prevention of land degradation, prevention of pollution of water courses are key elements to reducing the degradation of the coastal and marine resources from land-based activities.

Multi-lateral environmental agreements (MEAs)

Grenada has ratified or acceded to a number of international conventions and agreements which require measures and systems to be implemented at the national level for the protection of the environment.

However, like most other regional States, the challenge of developing the institutional capacity to administer these instruments at the local level have led to delays in the impacts of these instruments at the national and local levels. Table 2 provides a listing of the multi-lateral environmental agreements (MEAs) to which Grenada is party.

Table 2- Grenada's Commitment to International Conventions

CONVENTIONS	COMMITMENT DATA
Convention on Biological Diversity	Sgn 12/06/92 Rtf 11/08/94
World Heritage Convention	Ac 10/07/98
Cartagena Convention	Sgn 24/03/83 Rtf 17/08/87
United Nations Convention on Law of the Sea	Rtf 25/04/91
United Nations Framework Convention on Climate Change	Wef 09/11/94
United Nations Convention to Combat Desertification	Rtf 27/05/97
Sgn – signed; Ac – Acceded; Wef – With Effect from; Rtf - Ratified	

The United Nations Convention to Combat Desertification and Drought

UNCCD was ratified by Grenada in 1997 due to the recognition that land management is essential for sustainable development of Grenada. Under the UNCCD countries agree to develop (or adapt existing) strategies, plans or programmes for the conservation and sustainable use of land, land to integrate land management into the agenda of various sectors and sub-national levels of administration and planning. Implementing the objectives of the convention involves the formulation of a National Action Programme (NPA) which is a product of a national policy to elevate concern for land management to the level of planning and action. It recognizes land management as an important national asset that offers the country manifold economic options (Bynoe, 2005).

A major thrust of the UNCCD is sustainable land management (SLM) the objective of which is to harmonise the complimentary goals of providing environmental, economic and social opportunities for the benefit of present and future generations, while maintaining and enhancing the

- Quality of the land (soil, water and air) resources. Sustainable land management is the use of land to meet changing human needs (agriculture, forestry and conservation), while ensuring long-term
- Socioeconomic and ecological function of the land. SLM combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns to protect the potential of natural resources and prevent degradation of soil and water quality (protection) among other aspects.

United Nations Framework Convention on Climate Change

The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. Grenada ratified the convention in 1994 and in doing so has committed to the preservation of sinks for carbon dioxide which was identified as the nation's leading greenhouse gas culprit.

Management of forests is important to mitigate against climate change. Trees provide the sink by absorbing carbon dioxide from the atmosphere during the photosynthetic process to produce organic carbon. Deforestation of any sort will compromise the ability of the state of Grenada to meet its obligations under this Convention. Furthermore, this is important for the protection of forest reserves, watershed and water resources in the State.

Barbados Programme of Action (1994)

Subsequent to the United Nations Conference on Environment and Development (UNCED) in Rio 1992, the United Nations Conference on Small Island Developing States (SIDS) was convened because it was acknowledged that that special emphasis needed to be placed to these States. The Barbados Programme of Action (BPOA) emerged to guide environmental management in Small Island Developing States and outlined the basis for sustainable development.

A number of issues are associated with environmental management and sustainable development. One such concern is that the major long-term land management issue for SIDS is the degradation of their limited land area due to a variety of factors. These factors include, but are not limited to, overuse because of high population pressure on a limited resource base, deforestation due to unsustainable commercial logging or permanent conversion to agricultural or grazing pursuits as well as other episodic events, such as fire. Natural events, such as catastrophic cyclones, are also major contributors. Land degradation of this kind results in accelerated erosion with an accompanied decline in fertility and productivity, a deterioration in water quality and the siltation of rivers, lagoons and reefs. Deforestation is also linked to a decline in the continuity and quality of village water supply, the depletion of genetic, wood and non-wood plant resources, and the fading away of traditional forest, lagoon and reef-based subsistence life systems.

National programmes for the management of the environment of SIDS include *inter alia*:

- Prepare and/or review land-use plans in conjunction with agricultural, forestry, mining, tourism, traditional land-use practices and other land-use policies, with a view to formulating comprehensive land-use plans and zoning so as to protect land resources, ensure sustainable and productive land-use and guard against land degradation, pollution and exceeding island carrying capacity.
- Encourage appropriate forms of land tenure, improved land administration and a greater appreciation of the integrated nature of land development in order to facilitate sustainable land-use.
- Support appropriate afforestation and reforestation programmes, with appropriate emphasis on natural regeneration and the participation of land owners, in order to ensure watershed and coastal protection and reduce land degradation.
- Increase attention to national physical planning in both urban and rural environments, focusing on training to strengthen physical planning offices, including the use of environmental impact assessments and other decision-making tools.

ANNEX 2: STAKEHOLDER LIST

VULNERABILITY AND CAPACITY ASSESSMENT AND A NATIONAL ADAPTATION STRATEGY AND ACTION PLAN FOR GRENADA

National Consultation Workshop- NASAP

Thursday July 30, 2015

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