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CLIMATE CHANGE ADAPTATION IN GRENADA:

WATER RESOURCES, COASTAL ECOSYSTEMS *and* RENEWABLE ENERGY

2012

Climate Change Adaptation in Grenada: Water Resources, Coastal Ecosystems and Renewable Energy

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FOREWORD

This publication is the product of an international study led by the Division for Sustainable Development (DSD) of the United Nations Department of Economic and Social Affairs (UNDESA) in cooperation with the Ministry of Environment, Foreign Trade and Export Development of Grenada. The completion of the report on *Climate Change Adaptation in Grenada: Water Resources, Coastal Ecosystems and Renewable Energy* is the result of an intensive effort by experts from Grenada, consultants and personnel from the United Nations who actively have participated in meetings, workshops, field trips, data collection and analysis since 2010. The study is part of a larger project being conducted by the DSD on "Integrating Climate Change into National Sustainable Development Strategies and Plans in Latin America and the Caribbean," funded from the United Nations Development Account.

The assessments performed and projects proposed in this study represent an attempt to move forward with the practical implementation of climate change adaptation programmes and their integration into national plans for sustainable development. The study supports the global efforts on defining national strategies for sustainable development and on addressing some of the main critical issues affecting Small Island Developing States (SIDS) and highlighted at the 2012 United Nations Conference on Sustainable Development (Rio+20 Conference).

No study on climate change adaptation for sustainable development can be final and definitive. To be useful, the assessment process must evolve over time to fit ever-changing climate change impacts, conditions, priorities and national sustainable development criteria. This publication summarizes initial analysis, findings and proposals of three critical areas for Grenada. The study serves as a starting point for the development of a more in-depth and comprehensive analysis of climate change impacts and adaptation programmes for Grenada and other SIDS. It is hoped that the experiences and lessons learned from this study will provide valuable information and knowledge to other countries interested in addressing climate change and in achieving progress towards nationally defined sustainable development goals and objectives. It is also hoped that future studies will contribute to refinements in the proposed assessment and approach adding their own unique perspectives to what has been learned herein.

Acknowledgements

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The publication was prepared for the Ministry of Environment, Foreign Trade and Export Development of Grenada in the context of the implementation of the project "Integrating Climate Change into National Sustainable Development Strategies and Plans in Latin America and the Caribbean," and funded from the United Nations Development Account.

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1. Introduction

The global debate on climate change has shifted from whether the climate is changing, and what is causing the change, to how to deal with the changes that are now inevitable. There has also been a shift from the short-term approach of developing isolated projects, to a long-term planning approach and assessment that defines critical priority areas and integrates climate change adaptation into national sustainable development strategies. Grenada is among the Small Island Developing States (SIDS) that needs to adapt to the changing climate and make the necessary shift to long-term integration of adaptation into national development planning.

The Division for Sustainable Development (DSD) of the United Nations Department of Economic and Social Affairs (UNDESA) is supporting Grenada in its effort to address climate change issues under the project entitled "Integrating climate change into national sustainable development strategies and plans in Latin America and the Caribbean." The UNDESA project seeks to strengthen the capacity of countries to integrate climate change policies and actions, especially with regard to adaptation, into their national sustainable development strategies and other planning processes. The project focuses on impacts on ecosystems, water resources, agriculture, coastal zones, human health, natural disasters, and energy systems.

This report presents the results of a study conducted for Grenada under the UNDESA project. The pilot study focuses on three priority areas: water resources, coastal ecosystems and renewable energy systems. The priorities were selected following a systematic approach using analytical tools to help Grenada in the comprehensive assessment of potential impacts from climate change. It identifies the best potential courses of action to hedge for and adapt to these critical impact areas. The analytical work contributes to the knowledge base to support implementation of climate change adaptation/mitigation projects and the elaboration of project proposals for financial and technical assistance.

Chapter two outlines the comprehensive assessment and analytical process followed in evaluating the impacts of climate change in Grenada and the selection of the three critical priority areas.

Chapter three assesses the quantity and quality of water in the Northern Grenada watersheds and offers options for the design of an efficient architecture for storage of water for communities in the northern part of the island during floods and droughts in light of the projections for changes in rainfall patterns. It contains recommendations in relation to minimization of costs, enhancement of the efficiency of the water system, and use of appropriate green technologies in this field.

Chapter four provides an assessment of the current status and the major factors affecting coastal ecosystems. The assessment also serves as baseline data and identifies additional data needs. The report suggests options for restoration and maintenance of the natural coastal ecosystems and proposes policy options including the role of community groups and resource users.

Chapter five presents the current status of energy sources for medical and community centres in Grenada and their ability to provide the necessary services to communities during and after a disaster. It discusses the most appropriate renewable energy systems that can be built as backup systems for use immediately after natural disasters and the cost and benefits from the installation and use of these systems. Policy options to support and maintain renewable energy systems particularly designed for operation during disaster situations are also presented.

Chapters six and seven contain a summary of the conclusions, recommendations and policy options for integrating climate change into national development planning.

2. Selecting Critical Priority Areas

The priority areas for the project were selected at a three-day workshop held in St. George's, Grenada on 4-6 August 2010 (UNDESA, 2010). The main objective of the workshop was to train participants in the use of analytical tools that help to identify and prioritize links between sustainable development and climate change, specifically focusing on vulnerability reduction and adaptation options for Grenada using the Action Impact Matrix (AIM) methodology developed by the Munasinghe Institute for Development (MIND).

The AIM is a strategic analytical tool which helps to study the inter-linkages that exist among seemingly independent policies, activities and issues (Munasinghe, 2010). The AIM implementation process involves the development of matrices that promote an integrated view, meshing development goals and policies with critically vulnerable areas and impacts from climate change.

The workshop included 34 participants of which 24 were from Grenada. The Grenadian participants were selected to represent a wide variety of stakeholder categories including: decision makers, policy analysts from governmental and non-governmental organizations, climate change focal points, economists, environmentalists, ecologists and other researchers. In addition, there were 10 foreign experts from Guatemala, UNDESA and ECLAC, one regional advisor and two AIM trainers from MIND.

Participants selected the development goals and priorities for Grenada from the responses to a questionnaire circulated to attendees before the workshop. These goals and priorities were primarily drawn from available policy documents of the Government. They include: economic growth, poverty eradication, reducing unemployment, food security, reducing debt and budget deficit, improving trade and businesses, education and social development, health, disaster management, and natural resource management. Participants also agreed on the key vulnerable areas that were put together from the prior responses received from attendees. These areas included: water resources; agriculture; human settlements / poor communities; human health; infrastructure, transport and communication; industry, commerce and tourism; wetlands and coastal zones; forest resources; and biodiversity (flora and fauna).

The resulting ranking matrices from the AIM implementation process in Grenada were used to determine the priority policies and strategies in the economic, environmental and social dimensions of sustainable development that support climate change adaptation and mitigation efforts. The AIM methodology resulted in the prioritization of the most important links between sustainable development strategies, climate change interactions and their sustainability impacts. The overall conclusion was that vulnerability reduction and adaptation policies and projects should focus on: water resources, with special emphasis on the nexus with economic growth and food security; tourism; and infrastructure, transport and communication.

Further analysis by Grenadian experts resulted in the selection of three more specific critical priority areas within the main categories selected from the use of the AIM analytical tool. These priority areas included: (1) assessment of water resources in Northern Grenada; (2) restoration of coastal ecosystems; and (3) use of renewable energy for medical and community centres after natural disasters.

The availability of water resources is considered a main critical priority area in Grenada. Water was also selected as a priority area in the National Climate Change Policy and under the Pilot Programme for Climate Resilience (CIF, 2011). The Grenadian experts selected for assessment in this study the issue of water resources availability and management in Northern Grenada. It was considered important to study options for introducing Rain Water Harvesting (RHW) and to identify information gaps for the implementation of a water resources programme in Northern Grenada.

Coastal and marine ecosystems are critical for tourism activities in Grenada. In particular the assessment of the status and options for restoration of ecosystems such as mangroves, beaches and coral reefs is a major priority for the country. This issue was also identified as a priority for Grenada in the National Climate Change Policy and the Pilot Programme for Climate Resilience.

The use of renewable energy represents a major opportunity for Grenada and one of the specific priority areas to be considered for development under infrastructure. Furthermore, the availability and reliability of renewable energy for use in medical and community centres during and after natural disasters was identified as the third critical priority area to assess in this study.

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3. Water Resources in Northern Grenada

3.1 Introduction

Water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. The fundamental role that water plays in food security, energy security, economic growth, maintaining health and reducing poverty means that there is a constant and ever increasing pressure on it as a natural resource (The Royal Academy of Engineering, 2010). There are great differences in water availability from region to region even in small islands. In addition there is variability of supply through time as a result of both seasonal variation and inter-annual variation. In Grenada and its dependencies the magnitude of variability and the timing and duration of periods of high and low supply are not predictable particularly during the dry season and droughts. This poses great challenges to local water managers in particular and to consumers in general. In the past the water provider in Grenada has concentrated mainly on the supply of water for domestic purposes. However, there are growing concerns about the need to manage the water resources in an integrated manner and the demand for water by other sectors like ecotourism, sports and leisure, agriculture, and commercial (bottled water).

Potable water supply in Grenada remained rudimentary and isolated until the 1960s when the first significant plan for the whole island, "A plan for water development in Grenada 1965-1990," was developed (NAWASA, 2004). As a result of the plan, a number of projects were implemented including treatment plants at Annandale, Peggy's Whim, Douglaston and Petite Etang. Since then, there have been a number of studies and initiatives geared towards the improvement of the production and distribution of safe drinking water. In 1984, it was recognized that there was a rapidly growing demand for potable water to satisfy the growing tourist and light manufacturing industries in the south of the island and the demands of the expanding housing sector. In 1984, an externally funded study proposal for the "St. George's and St. John's Water Supply" to provide water to St. George's via 34 cm diameter ductile pipeline was found to be too expensive. In 1987, another proposal "Grenada Water Supply Sector Development Plan 1987-1997" (de Waal, 1987), was not accepted by the Government. In 1995 a study of water for the southern St. George's and St. David's area was funded by the French Government to investigate Unaccounted for Water (UFW) and the potential for metering and leak detection and repair. A direct outcome of this study was the implementation of metering of all water connections in 1995. In 2001, the northern water supply study was completed by a British Consulting Firm STANTEC (Stantec, 2001). The study was intended to generate a master plan for the development of water supplies to the northern part of Grenada where the National Water and Sewerage Authority operated 17 individual water systems.

The water resources in Northern Grenada are varied. This region boasts of beautiful scenery, with rainforests, fast-flowing streams, hot springs and lakes. Water for domestic purposes is harvested in dams in the mountain ranges of the northern region and is distributed to households through gravity systems. Water for agriculture is typically pumped from the downstream of rivers for larger operations, while for small backyard type gardening treated water from public mains is the main water source. The potential demand for water is expected to grow as there are many proposed hotel and housing projects for the northern part of Grenada.

3.2 Northern Grenada water district

The Grand Etang Forest Reserve is in the northeastern district (Figure 3.1). Grenada is divided into two main water districts; the Southern district includes the town of St. George and the tourism and industrial areas to the south of the city and the northern district is north of a line from the Grand Bacolet Point on the east of the island to Halifax Harbour on the west. This division is somewhat misleading since a substantial amount of water from this defined Northern district is exported to the Southern district. Further, when the divisions are too large, development plans incorporate too many ventures which provide a recipe for inaction. For example, a Water Study of the North Grenada in 2000 recommended a number of projects which have not been implemented as the financing of these was beyond the capacity of the National Water and Sewerage Authority (NAWASA).

Figure 3.1: Map of Grenada showing the study site (Northern Grenada-east and north of broken line)

In addition, the western part of the traditional Northern Water District is distinctly different in topography and rainfall from the eastern part of the Northern Water District. The western part on the windward side of the island has higher areal rainfall and a much smaller proportion of flat lands. Over 94% of the western part of Northern Grenada has average annual rainfall of more than 2,000 mm per annum and can be classified as a wet area; however, in the eastern portion on the leeward side of the Northern Water District, almost 50% of the area experiences an annual rainfall of less than 2,000 mm. The differences in topography and annual areal rainfall suggest that different water resources management strategies and practices may be required.

For the purposes of this study, the Northern Grenada is equivalent to Northern Grenada - Eastern Sector described in the "Stantec 2000 Study" and covers the parish of St. Patrick and the majority of St. Andrew's as far south as Munich, but not including the service area of Mamma Cannes water systems. This is represented by east and north of the blue broken line in Figure 3.1. About 37% of the island's population lives in Northern Grenada.

3.3 Water resources in Northern Grenada

3.3.1 Rainfall

Rainfall on the island of Grenada varies from 1,000 mm from the coast to 4,600 mm or more in the central mountains. Spatial variation is greater in the east and south of the island than on the west where orographic rainfall conditions exist (Figure 3.2).

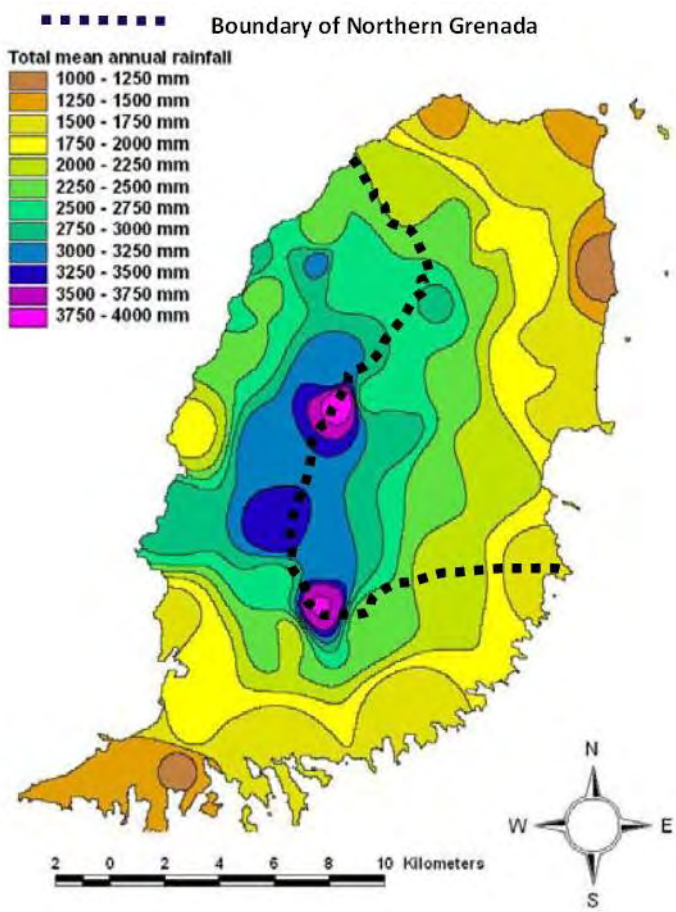

Figure 3.2: Mean annual rainfall on mainland Grenada (source: adapted from Land Use Division, Ministry of Agriculture).

Using the Thiessen method, the average areal rainfall for the northern part of Grenada was estimated at 2,230 mm annually. Many areas, however, have rainfall below 2,000 mm. For example, the average annual rainfall at Levera, River Antoine Estate and Marli for the period 2000 to 2010 was 1,324 mm, 1,500 mm and 1,660 mm, respectively.

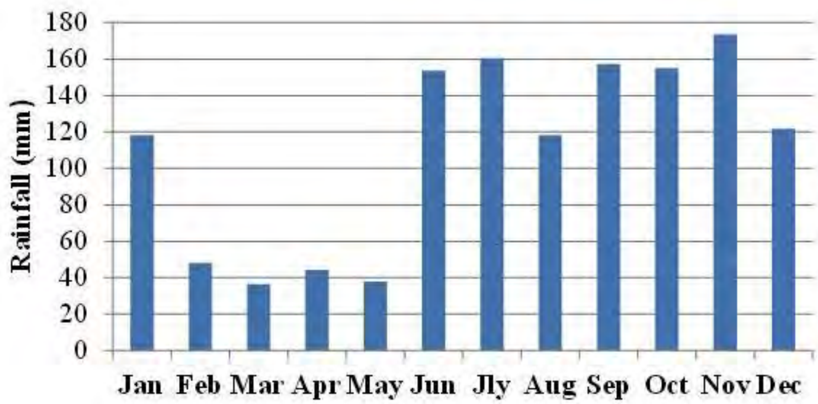

Figure 3.3a: Average monthly rainfall at Levera

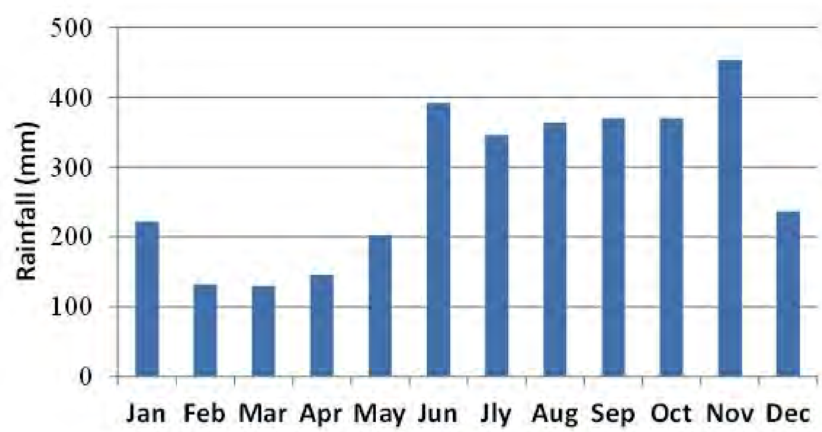

Figure 3.3b: Average monthly rainfall at Grand Etang

Temporal variation of rainfall in Northern Grenada is similar to that of the whole island with only about 20% to 30% of the annual rainfall during the dry season from January to May (Figures 3.3a & b). Evaporation rates, particularly in the dry season, are high. During the driest months estimated yields from mean monthly rainfall can be negative (the difference between the monthly rainfall and potential evapotranspiration) as shown for March in Figure 4. As a result, these areas are vulnerable to droughts and from time to time can experience severe water shortages due to extremely low rainfall.

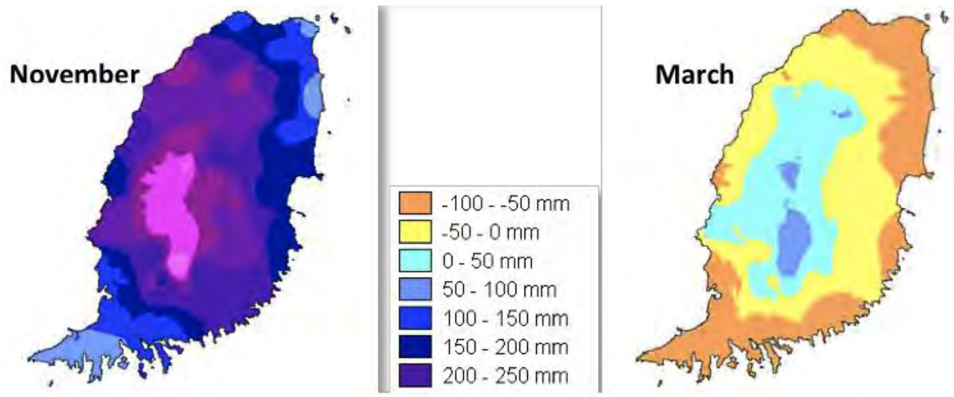

Figure 3.4: Monthly mean rainfall deficit/surplus for Grenada (difference between rainfall and potential evapotranspiration) [Source CEHI, 2006]

Projections of mean annual rainfall from different models consistently indicated decreases in rainfall for Grenada (ECLAC, 2011). The annual projected decreases for the 2090s vary between 23% and 61%, with median changes of 13% to 21%. The results of models' simulation also show that the proportion of total rainfall that falls in heavy events decreases, changing by 20% to 7% by the 2090s. The models project decrease in maximum 5-day rainfalls (ECLAC, 2011).

3.3.2 Sources of water

Grenada is generally endowed with an abundance of surface water resources, due mainly to its mountainous interior characterized by numerous rainfall fed rivers and streams (Parsran 2010). Fresh water in Northern Grenada is obtained from three sources – surface water from rivers and springs, two natural lakes at Grand Etang and Lake Antoine district and some Rainwater Harvesting (RWH). Most of the surface flows originate from the high rainfall areas in the central mountain ranges of the island. Overall, there are 71 watersheds on the island with 21 in Northern Grenada. Four of the largest eight watersheds (Table 3.1) are located within Northern Grenada with the Great River watershed, with an area of over 4,500 hectares, representing about 15% of the island's land mass.

Table 3.1: Grenada's eight largest watersheds (highlighted are watersheds in Northern Grenada)

River Basin	**Number**	**Area (ha)**
Grand River	**29**	**4574**
Beausejour	31	3793
Pearls	**71**	**1500**
St. Patricks	**63**	**1253**
Bailes Bacolet	14	1233
Antoine	**69**	**1102**
St. Johns	11	1208
St. Marks	50	835

3.3.3 River flows

All of the major watersheds have perennial flows, though these are greatly reduced during the dry season. The main rivers in Northern Grenada vary in lengths from 2 km to 30 km (Table 3.2) and most of the river valleys are narrow and steep. Consequently, artificial impounding of water on the rivers in Northern Grenada is limited.

Table 3.2: Main Rivers in Northern Grenada

Watershed#	River Name	Watershed area (ha)	Length (Km)
29	Great River	4574	30.02
29	Grand Bras River	4574	7.46
29	Balthazar River	4574	4.77
71	Simon River	1500	10.16
71	Loria River	1500	4.73
69	River Antoine	1202	10.69
67	Catabsae River	431	2.29
66	River Salle	544	4,97
63	St. Patrick River	1253	8.80
63	Great Arm River	1253	4.12
62	Little River St.Patricks	445	4.60
58	Duquesne River	835	7.12

Rivers have traditionally provided an important source of rural household water supply in Northern Grenada. The continued importance of the source of water supply is manifested during severe dry seasons and in the aftermath of hurricanes and tropical storm induced disasters. It is still a common practice for families to do their laundry on the river stones in rural districts. The quality of the water in the rivers is threatened by uncontrolled development on the river banks. Although there are laws that restrict development on river banks, it is not uncommon to see patches of bamboo removed along the banks to make way for farming. In addition, notwithstanding public awareness programs, rivers are used in some communities for the disposal of household waste.

3.3.4 Stored surface water

Grand Etang Lake

The Grand Etang Lake (Figure 3.5) is 550 m above sea level and is approximately 6 m deep. It has a surface area of about 8 ha and is within a watershed of 86 ha of tropical rainforest. The rainforest around the lake holds a stupendously rich diversity of flora and fauna. Colourful tropical birds, tiny frogs, lizards and rare orchids punctuate the dense rainforest vegetation. It is the only exploitable natural storage reservoir for surface water. Until the 1990s, the water at Grand Etang Lake was not exploited for public water supply but was used only for ecotourism purposes. The natural dry season outflow has been measured at more than 2,270 m^3 per day. During extreme dry seasons, water from the lake has been used to supplement water supply.

Figure 3.5: Grand Etang Lake at surface water source

The Grand Etang Lake is located within a protected area and hence anthropogenic activities in its adjoining catchment area are limited. Therefore, the potential for pollution is minimized. Nonetheless, the potential multi use of the lake to produce water for the water supply system, for recreation and as a premiere ecotourism site requires the continued integrated approach to the management of this water resource.

Lake Antoine

Lake Antoine (Figure 3.6) is 6.5 m above sea level and reaches a maximum of 30.48 m deep. The lake was formed 12 to 15 thousand years ago during the final stage of volcanic activity in the area. With a privately owned catchment area of 59 ha and a surface area of 6.5 ha, average inflow to the lake is about 305,327 m^3 annually. This is sufficient to irrigate about 15 ha. For a number of years, lands around the lake have been cultivated. In the late 1990s, the water from the lake was identified to be used in irrigation for organic bananas. The project was unsuccessful, partly due to the poor quality of the water which is contaminated from agrochemical use in the fields around the lake.

Figure 3.6: Lake Antoine, Grenada, a freshwater source

This shallow crater lake, like Grand Etang, is host to a wide variety of wildlife. The wild species associated with this lake include *inter alia*: Tilapia and other freshwater fish, Red-legged tortoise, Fulvus tree-duck, and the Everglade kite (Government of Grenada, 2001). The lake's perimeter trail, a beautiful walk in itself, is another of Grenada's excellent attractions for bird watchers. The potential multi-use (agriculture, sporting, ecotourism) of Lake Antoine suggests that it is a good candidate for an integrated approach to its management.

Levera Lake/pond

An ancient volcanic crater has become filled with a mixture of fresh and salt water creating Levera Pond with a surface area of 9.3 ha (Figure 3.7). The importance of this lake lies in its support of a rich bird and aquatic wildlife. The pond is surrounded by red and white mangroves. Coconut palms, cactus and woody shrubs grow in the upland regions next to the pond. While this lake holds no major importance for water supply, except for the occasional watering of livestock, it is critical to coastal zone sustainability.

Figure 3.7: Levera Lake and the surrounding mangrove swamp

3.3.5 Groundwater

In Southern Grenada, ground water sources are used to augment surface water sources during the dry season. This is important to meet the demand since surface water yields drop by 25% during the dry season (NAWASA, 2000). The current exploited groundwater is approximately 1,890 m^3/day, with a potential capacity of approximately 3,973 m^3/day (ECLAC, 2011). The potential increase of 2,083 m^3/day would be mostly from Northern Grenada. In the past, no serious attempts have been made to exploit the groundwater in Northern Grenada. Given that some of the largest catchments are located in Northern Grenada, there is a great possibility that the groundwater potential is good. The main groundwater aquifers are likely to be the Great River, Pearls-Paradise and Antoine watersheds. It must be noted that while at this time there may not be strong motivation for exploring and or exploiting the groundwater potential in Northern Grenada, efforts must be made to quantify the potential and to ensure that the quality of any unexploited aquifer is not contaminated.

3.3.6 Rainwater harvesting

RWH in Northern Grenada, which was practiced widely in earlier times, has declined with the improvement of public water supply. However, in some remote high elevation areas, where the public water supply is inaccessible due to low pressure, rooftop RWH is often the main source of potable water (Figure 3.8). Recently, in some residential buildings, rainwater tanks are installed to supplement the public supply. RWH ponds have been used in livestock production and, in a few cases, for the provision of water for intensive vegetable production. There are currently six such ponds in Northern Grenada.

The extent of RWH in Northern Grenada has not been quantified; however, public awareness of the technology is high among the people and the potential for growth is real.

Figure 3.8: Rainwater harvesting in Northern Grenada

3.4 Water production systems in Northern Grenada

3.4.1 NAWASA's production

NAWASA exploits 23 surface and six groundwater potable supply sources on mainland Grenada, which yield 54,600 m^3/day in the rainy season and a maximum of 31,800m^3/day in the dry season. The water demand in the rainy season is 45,500 m^3/day and in the dry season, 54,600 m^3/day (CEHI, 2007). In addition to the main exploited sources, NAWASA, in collaboration with the community, harvests small amounts of water from a number of springs. In Northern Grenada, the main NAWASA facilities (Figure 3.9 and Table 3.3) include a few water production sites and a number of storage facilities at central village locations.

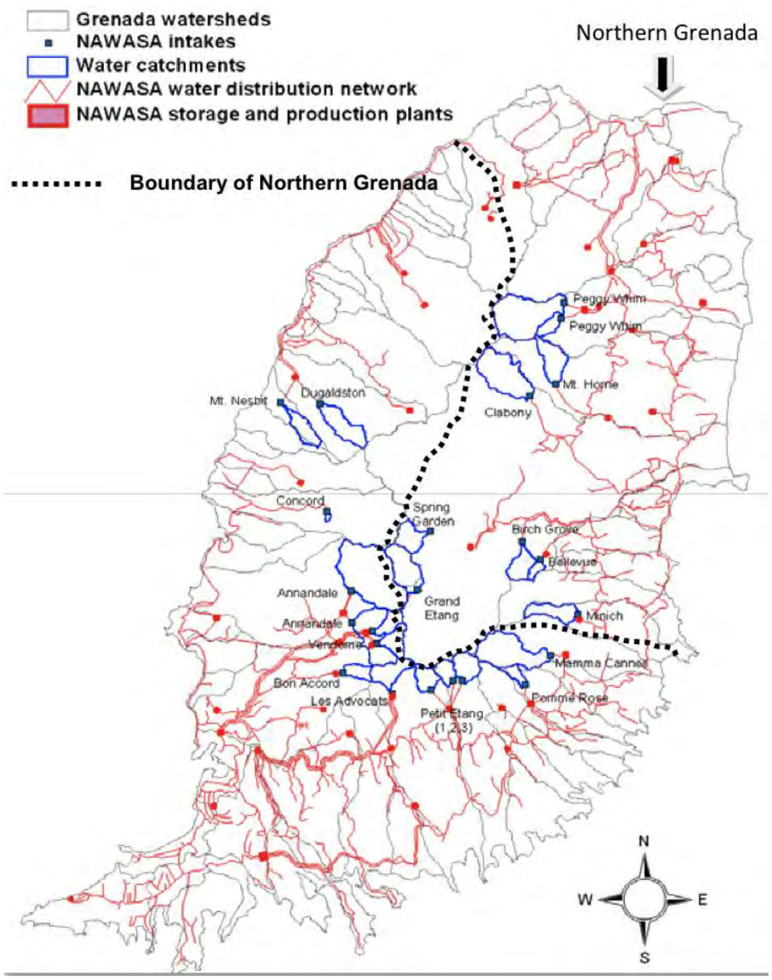

Figure 3.9: Grenada's water supply and distribution network
(NAWASA and Land Use Division, Ministry of Agriculture)

In 2000 the average potable water demand in Northern Grenada was about 13,573 m^3 per day. This is supplied from a storage capacity of 4,896 m^3 and a daily production of 10,775 m^3. In Northern Grenada, all potable water is obtained from rivers or springs. There are two spring sources, managed jointly by NAWASA and the community at Morne Longue and St. James.

A first estimate of the water production potential of water producing catchments can be done by carrying out a water deficit mapping for these catchments. This is done by taking the difference between rainfall and the evapo-transpiration for the period of interest (Table 3.4). A water deficit mapping for Northern Grenada shows that some of the water producing catchments have a positive water yield except at Bellvue, Birchgrove and Munich where the yield could be negative in the dry season. This indicates that in these catchments during the dry season and particularly during severe dry periods, stream flows could be low resulting in the inability of NAWASA to provide reliable supplies in these areas. Water shortages have been reported in many communities, particularly during the dry season. The most serious shortages are usually in Northern Grenada (Stantec, 2001).

Table 3.3: Summary of the main water facilities in Northern Grenada (compiled from NAWASA internal documents)

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**

Table 3.4: Water yields for selected catchments in Northern Grenada (GoG, 2008)

Catchment	Dry season yield (March) m^3/day	Rainy season yield (November) m^3/day
Grand Etang	1688	11810
Spring Garden	747	6581
Claboney	1225	14408
Bellvue	-24	1690
Birchgrove	-130	5390
Mt. Horne	711	7016
Peggy Whim A	2413	19494
Peggy Whim B	360	2739
Munich	-248	5549

3.4.2 Bottled water

The first bottled water operations in Grenada, Glenelg Spring Water, began in Mt. Rueil, St. Patricks (Northern Grenada). Pure water flowing from a rock spring in an undeveloped forest area is bottled after sterilization. Another bottled water is Claboné water. Claboné is the only natural mineral water produced on the island of Grenada, emanating from the foothills of an evergreen mountain range. It has its origins partly in the geothermal seismic activities in a dormant volcanic area. It is bottled from a spring source. This product contains a number of minerals including calcium, potassium, chlorine and manganese, all of which are claimed to be beneficial to the human body.

3.5 Water quality issues

Very little data are available on the quality of the water resources in Grenada. Current key gaps in the knowledge base status of the quality of water resources include: exposures to environmental pollutants such as persistent organic pollutants (POPs), heavy metals and pesticides; the chemical and microbial quality of freshwater sources such as rivers and springs. Water collected by RWH systems for domestic use is not usually treated. Peters (2011) reported such water is often presumed to be safe as it has not flowed on the ground and come into contact with any liquid or solid materials which can alter its quality and that this presumption is reasonable as the detailed tests results showed negligible levels of contamination of raw rainfall.

However, there is growing interest in closing water data gaps. A study on Marine Recreational Water Quality for the South-western Coastline was conducted by the Windward Islands Research and Education Foundation (WINDREF) in collaboration with St. Georges University and the Fisheries Division of Grenada (Forde et. Al, 2011). It has been shown that fecal coliform indicators and opportunistic pathogens are present in the coastal waters of Grenada (WINDREF, 2010). This is due to inappropriate deposition of sewage which can introduce a number of drug-resistant organisms into coastal waters. While the contamination of coastal waters is not necessarily a result of onshore activities, it is well established that watershed patterns and anthropogenic factors play a major role in impacting on the variability of water quality.

The quality of coastal waters and beaches can be a proxy for the quality of inland runoff. In the case of Northern Grenada where research on the beaches has not yet been carried out, a judgment on the quality of runoff can be made based on an assessment of anthropogenic activities in the upper watershed. Anthropogenic activities that cause environmental degradation in the upland watershed impact on water supply intakes. They can also negatively impact the quality of the lower reaches of the rivers which are important to recreation on the rivers and the coastal marine environment.

The major threats to the water supply and recreational water in Northern Grenada include the following:

- Encroachment by farmers in protected water producing catchment;
- Pollution from agricultural chemicals and waste - Agricultural practices in the watershed areas of these water bodies have the potential of introducing chemical residues into the rivers and lakes;
- Siltation of rivers and dams from erosion causing activities in the watershed;
- Inadequate land use practices;
- Pollution from poor solid waste management and poor sanitation - direct and indirect discharge of sewage, grey water and solid waste;
- Pollution from small manufacturing plants and garages through inadequate disposal of lubricants and other effluents;
- Unplanned and unauthorized developments; and
- Lack of control of forest clearance.

There have been numerous reports about the washing of gears and equipment laden with agricultural chemicals in rivers which has resulted in frequent fish kills in the streams. In some cases, persons have been known to use chemicals and explosives to catch fish in the rivers in large quantities.

The impact of agriculture on the water quality was evident in the production of bananas which required frequent and intense applications of agrochemicals to maintain high yields and blemish free fruits. During the mid 1980s, studies in Costa Rica found that residues of agrochemicals in rivers from banana production were at concentrations two times the amount known to cause adverse impacts on fish (Astorga, 1998). Similarly in Grenada, during the 1980s when banana production was at its peak, it was observed that the quantity and size of crayfish and other fish species in the rivers diminished. Banana production also prompted deforestation and soil degradation as farmers moved to higher and higher forested areas in the watershed. These negative impacts were subsequently diminished after the collapse of the banana industry.

3.6 Wastewater management in Northern Grenada

Although wastewater management is not under direct consideration in this document, the management of water resources is an important issue for Grenada. There are no centralized sewerage systems in Northern Grenada which is serviced by septic tanks and pit latrines. During the 1990s, 74% of households used pit latrines (Ministry of Finance, 1996). There have only been small conversions of pit latrines to septic tank systems. The impacts of the indiscriminate location of pit latrines on groundwater are well established. Poor placement and maintenance of the large number of pit latrines in Northern Grenada can impact on surface water quality. To minimize the potential impacts of sanitation, programmes that can lead to upgrading of the pit latrines now used and improving the current septic tanks systems should be undertaken.

3.7 Current and future water demand

3.7.1 Factors influencing demand

The increased understanding of the impacts of seasonal variations in supply and the increased demands have, over time, heightened levels of awareness of watershed management issues. While the population in Northern Grenada has not changed significantly in the past 10 years, the improved standard of living of households has resulted in lifestyle changes that result in greater water use. The demand for water is projected to increase further due to a growing population as well as plans for developments related to irrigated agriculture and the expansion of the tourism sector. Over the past ten years, the reliability of potable water supply has improved and the number of Grenadians who enjoy access to safe and clean water has increased. Despite this general improvement, concerns remain over levels of pollutants and watershed degradation, water shortages during the dry season, the state of water storage and distribution infrastructure, inadequate financial and technological resources and poor human resources capacity, all of which place constraints on sustainable water management.

The demand for water in Grenada as a whole is continuously increasing due to population changes and the growth of the service sectors industries, particularly tourism. The traditional function of the water provider has been to service domestic, commercial and light manufacturing demand. NAWASA has never provided water for agriculture or leisure purposes although, implicit in its mandate, it is responsible for the production and provision of all water for all purposes. Some of the main areas of demand are listed in Table 3.5.

Table 3.5: The main future water use, sources and associated activities

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.

3.7.2 Potable water demand

The demand for potable water in Northern Grenada is projected to come from two sources, namely, the indigenous population and the tourism sector. New hotel plants are expected to be constructed. These new developments would need large volumes of water and, like in the tourism belt in the south, water and wastewater infrastructure would require large capital investments.

With a current population in Northern Grenada of about 37,000 and using a modest population growth of 1.5% over the next 15 years results in a projected population of 50,000 which would require 10,500 m^3/day. If losses in the system of 33% are assumed, then the daily demand would increase and the required production would be approximately 15,000 m^3 daily.

A major tourism plant which is actively discussed is the proposed Levera Resort Development project. In 2011, MDA International provided a feasibility and cost proposal for this large, mixed use resort development which is expected to include some 200 villas, restaurants, beach club, club house, health club and spa. Work was due to commence early 2011 but has been delayed. Although details of the plans are not available, the proposed development is expected to increase the demand for water. Using average per capita use in hotels of 750 liters-day (Singh and Clouden, 1999), the water requirement for this resort, excluding irrigation, is approximately 300 m^3 per day. With a projected number of hotel rooms of 1,100 by the next 15 years, the daily demand would be approximately 825 m^3/d.

3.7.3 Non-potable water for tourism

Water resources in Northern Grenada play an important role in the tourism industry as it forms part of the current ecotourism products and would be required in the large golf course resort proposed for the Levera area. There are several hot springs in the mountain ranges of Northern Grenada. The most accessible of these is Claboney hot springs a few miles from the town of Grenville. These springs are claimed to have healing powers and as such are good tourism products.

In addition, rivers, lakes and waterfalls (Seven Sisters, Mt.Carmel and Tufton Hall) provide opportunities for swimming, river tubing and rafting. Other activities like hiking and picnicking also bring tourists in contact with these water resources. The demand on these waters is meaningless in quantitative terms as insignificant amounts are actually consumed. However, the quality of the water must be high in order to safeguard against potential illnesses that can have negative effects.

Maintenance of the proposed hotels and golf courses for Northern Grenada would require substantial amounts of water. While an 18-hole golf course has been proposed for Northern Grenada, a 9-hole course is more likely as there can be a space constraint. The average size of a 9-hole golf course is about 4 ha and, based on the proposed site, it would require approximately 60,000 m^3 of water. This would be a strain on even an improved water supply system in Northern Grenada. Therefore, for such a project similar restrictions that exist in Barbados on the use of potable water for these purposes would need to be implemented. To satisfy this demand, RWH using lined ponds would be required at appropriate sites in the Levera area. Examples of such ponds already exist under similar circumstances in Barbados.

3.7.4 Water for irrigation and agriculture

Between the 1950s and 1960s, plantation agriculture dominated and irrigation practices flourished particularly in the production of bananas in Grenada. Overhead boom sprinklers were widely used on estates such as Paradise, Grand Bras, River Antoine and Mt. Rueil where water was sourced from river diversion or pumped directly from the rivers. The decline of the plantation system during the 1970s reduced the use of large-scale irrigation. From 1979 to 1983, renewed emphasis was placed on irrigation as a way of increasing productivity of the State Farms Systems (a number of government acquired estates) using Eastern European and Cuban sprinkler systems. After 1983, many of the state farms were divided into small units and the government looked towards Israel, Taiwan, the United Nations Food and Agriculture Organization (FAO) and the European Union for irrigation technology which included micro sprinklers and drip irrigation. Notwithstanding the availability of water, the success of the irrigation program was low due to poor implementation.

In 1989, estimates of the agricultural water demand were placed at 15% of the total demand (Weaver, 1989). The potential irrigation sites in Grenada were investigated in 2001 (Madramootoo, 2001) and it was found that eight areas were potentially suited for irrigation in Northern Grenada (Table 3.6). These include Paradise, Grand Bras, Snell

Hall, Chambord, Mount Reuil, Poyntzfield, Boulounge and Pearls (Madramootoo, 2001). A simple rainfall-runoff model was used to analyze the water availability for irrigation at the potential irrigation sites (Madramootoo, 2001). The estimated annual runoff represents water that is available if it could be stored by in-stream storage facilities. For example, considering Grand Bras (Table 3.6), if the annual runoff (1,106 mm) from 100 ha ($10x10^4 m^2$) of the catchment could be stored, then the total volume in the storage would be $1.106x10^6$ m^3 (1.106 m x $100x10^4$ m^2). The estimated dry season runoff represents how much water can be pumped directly from the rivers at the site for irrigation purposes. For example, at Grand Bras, if 30% of the water from the river were pumped during the dry season, a total volume of $44.45x10^6$ m^3 (30% x 4,295 ha x 345 mm) of water would be available (Table 3.6). This is sufficient to irrigate 686 ha. If storage facilities are developed in the catchment, then the irrigated area can increase to 1,800 ha.

Table 3.6: Potential irrigable lands in Grenada (adapted from Madramootoo, 2001)

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.

Currently, irrigated agriculture is largely undeveloped in Grenada. In 2011, 218.5 ha, or 1.5% of the total land area under cultivation, was under irrigation compared to 4.8 ha in 1973. The micro irrigation technique is utilized in more than 90% of all irrigated land areas, with the remaining area under sprinkler irrigation. The irrigation potential based on land availability is about 1,056 ha (Madramootoo, 2001). Water for such irrigation can become available from a number of surface, groundwater and RWH sources which can be developed in the future. This would require about 10 million cubic meters of water annually

Water for aquaculture

While the aquaculture sector in Grenada is very small, there is potential for freshwater fish farming in the areas of the Great River and the Antoine River. The quantity of water for fish ponds may not be significant; however, the need for high quality water from the rivers to fill the ponds is critical for success. In the past, ponds were located mainly along the Great River. The need for and pursuit of a diversified economy can require future development of the aquaculture sector.

A summary of current and projected water demand in Northern Grenada is presented in Table 3.7.

Table 3.7 Summary for current and projected water demands in Northern Grenada

Item	***Size of usage***	***Unit consumption***	***Current demand in Mm***^{3}	***Projected demand in Mm***^{3}
Domestic consumption including leakage	37,800 (Yr 2012) 50,000 (Yr 2028) projection)	210l/c/d (Assuming 33% & 40% losses current future respectively)	2.76	3.84
Institutions		17l/c/d		
Commercial and industrial				
Hotels	98 rooms (2012) 1098 rooms (2028)	678 l/bed night	0.02	0.30
Golf courses	40 ha	1.6m/yr	0.0	0.64
Agricultural irrigation	219 ha (Yr-2012) 1056 ha (Yr-2030)	1.5m/yr 1.9 m/yr (assuming the impact of Climate Change)	3.3	19.04

3.8 Vulnerability of water resources in Northern Grenada

3.8.1 Hurricanes

Over the past 100 years Grenada experienced less than 10 hurricanes. However, the two most devastating events for Grenada in the last ten years were Hurricanes Ivan in 2004 and Emily in 2005. Ninety five per cent of the water supply was disrupted after Hurricane Ivan and it took up to one month to restore 95% of the pre-hurricane supply. With the advent of climate change, the frequency of these hurricanes is expected to increase. Grenada's water resources are vulnerable to these hurricanes as the experiences of Ivan and Emily have shown. The water supply can be affected through a number of sources. The impacts of Hurricane Ivan on Grenada's water resources were identified (Peters, 2010), including:

- 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.

Water supply deficiencies over extended periods after disasters like Hurricanes Ivan and Emily can have potentially serious adverse public health and sanitary implications. Consequently, the need to secure adequate potable water supplies to assist with the post-disaster restoration and recovery efforts cannot be understated.

A key lesson from the Hurricane Ivan experience is that households that practised RWH and had minimum storage capacities of around 4 m^3 were able to meet their needs during the first few weeks after the hurricane. The severity of the water shortages at emergency shelters was less in those shelters that had water storage facilities replenishable from rooftop catchments. This suggests that communal rainwater storage systems, using schools and community centers, could be established to provide a reliable system for communities during the early periods after a hurricane disaster.

3.8.2 Droughts

Since 1970, the intensity and duration of droughts has increased around the world, particularly in the tropics and subtropics, where higher temperatures have also been recorded (IPCC, 2007). Small islands are among the hotspots which have been identified by the Global Water Partnership, where climate change impacts are forecasted to be felt within the next few years and where urgent attention is needed in the water sector. Between November 2009 and June 2011, Grenada experienced one of the driest periods recorded in history. This was attributed to climate change. The Northern parts of the island were the hardest hit during this drought. During the 2009/2010 drought, the main water production centres experienced reductions of up to 65%. The monthly production for five years up to the drought is shown in Figure 3.10. The water production during the drought months showed that NAWASA struggled to meet demands.

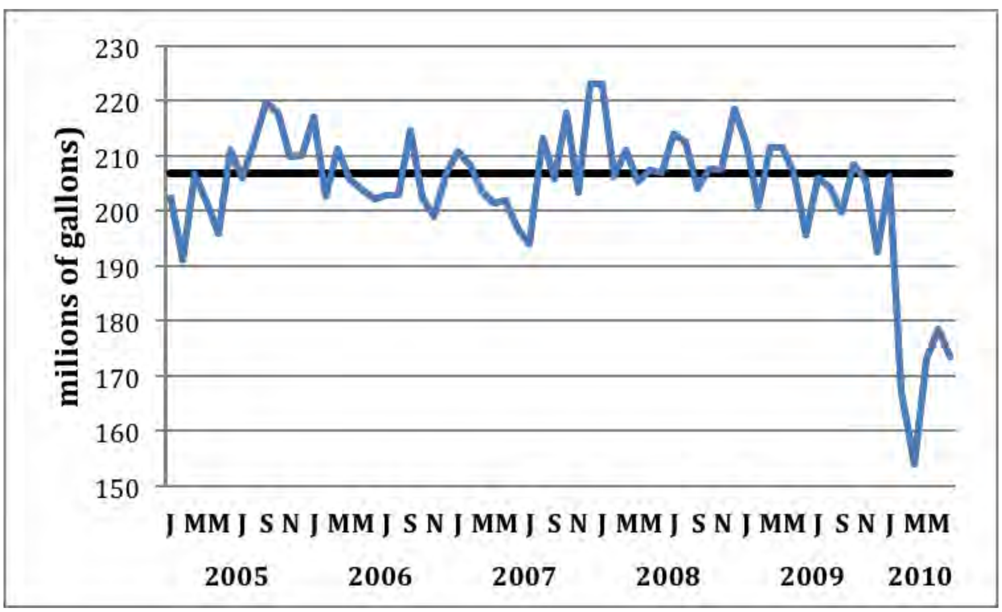

Figure 3.10: Monthly water production of NAWASA from 2005 and the effect of the drought in 2010 (Peters, 2012)

3.8.3 Sea level rise

It is not yet possible to project sea level rise for Grenada to a high degree of accuracy. Nonetheless it is expected to be similar to the wider Caribbean where changes are expected to be near the global mean. Under the A1B scenario of the Intergovernmental Panel on Climate Change (IPCC), sea level rise within the Caribbean is expected to be between 0.17 m and 0.24 m by 2050 (IPCC, 2007). Together with a projected decrease in rainfall, rising sea levels will lead to salinity intrusion into coastal and groundwater aquifers and thus reduce freshwater availability (ECLAC 2011). While no groundwater exploitation occurs in Northern Grenada, as most of the groundwater deposits are within 1 km of the coast, the potential of this untapped water would diminish over time. Using the results of saltwater intrusion from sea level rise on islands elsewhere (Wong et. al. 2007), it is estimated that the potential groundwater aquifers in Northern Grenada could lose between 23 m and 60 m through landward movement of the interface between seawater and freshwater. This result could translate into a 15% to 30% reduction of the current ground water potential in the next 50 years.

3.8.4 Flooding

There is not a history of frequent or widespread flooding in Northern Grenada. The town of Grenville (Figure 3.11), however, has been experiencing an increasing number of floods in the last 20 years. As the town is already almost at sea level, there is a potential for increased floods from the combined effects of sea level rise and more intense rainstorms. A number of studies have been carried out on flooding in Grenville. In 2010 the Government of Grenada commissioned a project that sought to investigate the current flood problems in Grenville as part of the "Greater Grenville" project; rooftop RWH by households in the town can mitigate the severity of flooding by lowering the peak flow by 25% (Peters, 2011). Elsewhere in Northern Grenada, poor maintenance of some of the rivers and streams has been cited for causing flooding particularly during heavy rains and tropical storms. These floods have had negative impacts on some farming communities.

Before After

Figure 3.11: Grenville before and after a flood event in 2012 (Photo from Mikey Hutchinson)

3.9 Water governance in Northern Grenada

3.9.1 Traditional approach

NAWASA has overall responsibility for all water production in Northern Grenada. The Act which governs NAWASA mandates that unless unavoidable, NAWASA shall be responsible for the provision of a satisfactory supply of potable water for domestic purposes and an otherwise satisfactory supply of water for agricultural, industrial and commercial purposes. However, to date NAWASA has not devoted resources to the provision of water for irrigation and agriculture. In some cases, small-scale farmers use treated water from NAWASA for agriculture and irrigation and pay the domestic rates for such water. Consequently, the Ministry of Agriculture had to shoulder the responsibility for water with respect to irrigation and other agricultural uses.

Many agencies share the responsibility for water and watershed management throughout Grenada. There is no independent entity that is responsible for water management in Northern Grenada; hence, the management structure is the same as that for Grenada. The organizations that have some level of responsibility for water management are shown in Table 3.8.

These agencies have different core mandates which can overshadow their role in the cohesive management of water. Most of the agencies are not located in Northern Grenada and, as it is often the case, that part of the island is of low priority and can be neglected. In 2007, a stakeholder meeting on water management issues highlighted this dysfunctional approach in water governance (CEHI, 2007). To reduce the piece-meal approach to water management and in order to attain sustainability in the management of the water resources in Grenada, particularly Northern Grenada, greater coordination and cooperation among the different agencies are needed.

3.9.2 Integrated Water Resources Management (IWRM)

The current and the foreseeable trends indicate that water problems of the future will continue to become increasingly more and more complex in Northern Grenada. Hence, water can no longer be viewed in isolation by one institution or any one group of professionals but must be viewed in a holistic or integrated manner. The concept of integrated water resources management (IWRM) has been around for more than 60 years but was rediscovered by some in the 1990s (Biswas, 2004). In Grenada the conversation on IWRM is at an advanced stage. A recent draft water policy, for Grenada, sets out a framework for the governance of the water sector and the allocation of duties, responsibilities and powers as well as the respective roles of the public and private sectors. The policy objectives include:

- The provision of a framework for integrated use, management and regulations of water resources and associated services; and
- The establishment of an institutional framework for IWRM.

Given these new developments, the future governance structure for water resources management is expected to be reformed to meet the potential water needs of Northern Grenada.

Table 3.8: Organizations responsible for the management of water resources

Agency	Structure	legislation
NAWASA	Statutory: Multi-sectoral Board of Directors with Chairman. General Manager responsible to Board	NAWASA ACT (1990) and Amendments (1991 and 1993)
Land Development Control Authority	Statutory: Multi-sectoral membership	LDC Act (1968 and Amendments (1983); Land Development Regulations (SRO No.13, 1988
Land Use Division		Crown Lands Ordinance (Cap. 78, 1896);Crown Land Rule (SRO No. 36, 1934); Crown Lands (Amend.) Rules (SRO Nos. 3,19,1965
Department of Forestry and National Parks	Division in Ministry of Agriculture	Forest, Soil and Water Conservation Ordinance (Cap. 129, 1949 Amendments (1984); Crown Lands Forest Produce Rules (1956); Protected Forest Rules (SRO No. 87, 1952 National Parks and Protected Areas Act Cap. 206(1990)
Environmental Health Department	Division of the Ministry of Health Headed by the Chief Environmental Health Officer	Public Health Ordinance (Cap. 237, 1925 amendments and Regulations (SRO No. 218, 1957)
Grenada Bureau of Standards	Statutory Body	Standards Act No. 6 (1989)
National Science and Technology Council	Broad-based scientific Technical Committee	Science and Technology Council Act Cap 298(1982)

3.9.3 Main goals

To meet the various demands of water in Northern Grenada and to ensure water security a combination of supply and demand management techniques need to be applied. In Grenada, engineers can play a leading role but must engage policy makers, economists, financiers, farmers and development agencies in order to build the public-political consensus needed to approach the challenge of making the water resources in Northern Grenada sustainable. The consensus building has already begun. Therefore, improvement and consolidation in the implementation of effective governance, financing and regulation are required to allow technical solutions to take effect.

The main goals of this public-political consensus for Northern Grenada water resources should be:

- Sustainability - meeting the needs of Northern Grenada without damaging or depleting the water resources (using appropriate storage facilities);
- Promoting the use of renewable water (rainwater harvesting);
- Reducing waste and pollution by changing production and consumption patterns; and
- Creating economic activities that can support the growth of green water.

3.10 Storage options for sustainable water resources in Northern Grenada

3.10.1 Architecture for improved water storage

The natural river channels in Northern Grenada are too steep and narrow to develop large enough structures that can provide additional storage for economically viable centralized water supply systems. While large storages can be technically engineered on the flatter areas located close to some river channels, it is difficult to indentify many suitable track of land for this purpose. Issues of existing developments, land tenure and the quality of the surface water in these locations would make the construction of large storages economically unfeasible. A more practical approach is to use small natural or excavated impoundments on the lower lands where the topography is suitable. To overcome this limitation, smaller decentralized storages could be considered. Such smaller storages would also be suited to RWH.

3.10.2 River engineering to increase dry season storage

River diversions in Northern Grenada as a way of maximizing the flows in the rivers and streams are faced with the difficulties of existing developments, land tenure issues and costs. Therefore, this option is not recommended. It is possible to dam these streams by constructing weirs across them (Figure 3.12a). These weirs could be temporary or permanent and would be used mainly during the dry season to create small reservoirs so that water can be pumped to adjacent fields. Suitable sites can be located on the Grand Bras River in the vicinity of the Great House, the Simon River in the vicinity of the old cocoa propagation station and Pearls, the Lorio River in the vicinity of La Poterie and Conference and the St. Patricks River in the vicinity of Marli.

Figure 3.12a: A typical weir that can be used to increase on-river storage in Northern Grenada

In limited cases some river clearing can increase storage for use by farmers. This approach is being pursued by the Ministry of Agriculture in the Northern Grenada (Figure 3.12b). In a 1 km stretch of river, as much as 0.4M m^3 of water can be stored.

Figure 3.12b: River clearing to increase on-river storage in Northern Grenada

3.10.3 Decentralized rooftop RWH storage

A second approach to improved water storage is to capture the water at site through RWH from rooftops. This would be particularly useful in the case of disaster mitigation. It would also have the benefit associated with decentralization of the supply system. Such storage facilities can be used for both public supply and rooftop. The storage for a particular building should be sufficient to meet the basic needs of the occupants for at least 15 days. This should be sufficient for the period of time to rehabilitate 70% of public water supply system following a hurricane disaster (the period is based on the experience of Hurricane Ivan).

Table 3.9 shows some of the buildings that should be targeted for storage facilities. All these facilities can be fitted with solar power for pumping the water from the tanks.

Table 3.9: Potential use of rooftop RWH for potable use in Northern Grenada

Buildings type	**Type of storage**	**Size of storage**	**Comments**
All community centers	Reinforced concrete tanks with connection to roof	150 m^3	All community centers are now designed to be used as shelters
Schools non-shelter Schools – designated shelter	Secured PVC tank Reinforced concrete tanks with connection to roof	25 m^3 150m^3	Exposed PVC tanks are vulnerable to flying debris during hurricanes
Medical Centers	Reinforced concrete tanks connected to roof	30 m^3	Water purification facility should be available
Government Offices	Secured PVC tank **OR** Reinforced concrete tanks with connection to roof	25 m^3	
Police stations	Reinforced concrete tanks connected to roof	150m^3	This would be used by the police and can be rationed to people in the immediate vicinity
Princess Royal Hospital	Reinforced concrete tanks connected to roof	300 m^3	The hospital storage capacity needs to be increased Water purification facility should be available
Households	Secured PVC tank **OR** Reinforced concrete tanks with connection to roof		

3.10.4 Storage for agriculture and irrigation

RWH ponds:

Some small farmers use small tanks (2 m^3 to 10 m^3) to store water from the public mains for intensive vegetable production. In some cases, farmers use RWH from their house roofs to fill these tanks. This should be encouraged through technical assistance from the Ministry of Agriculture. However, these storages are insufficient to expand agriculture as envisaged. The practice of using RWH ponds should be promoted. Farmers with five to ten acres can construct ponds in areas like Chambord, Paradise, Conference and Levera. These ponds can be excavated in or near small water courses and should be lined with low-density polyethylene LDPE polythene material. These materials are now readily available and can be affordable to small farmers. Ponds could range in capacity from 50 m^3 to 450 m^3 depending on availability of land. The first option should be to engage groups of farmers to work together in developing these ponds in such a way that one pond can be used by a number of farmers and hence minimum land area is lost. To ensure the sustainability of this process, land tenure issues must be resolved. Solar pumping could be conveniently and cost effectively used to carry water from the pond to the field. Larger RWH storage ponds, similarly lined, can be used for irrigation of future resort and golf course development. This approach has been successful in Barbados.

RWH Tarpaulins:

Emerging technologies in RWH utilize tarpaulin structures in providing water for agriculture. This is quite suitable for greenhouse production where the water can be harvested from the roof of the greenhouse (Figure 3.13). This technology is currently applied by some farmers in Jamaica and is suitable for both rainy and dry seasons in Northern Grenada.

Tarpaulin RWH pond (Barbados)

Tarpaulin RWH from greenhouse (Jamaica)

Figure 3.13: Tarpaulin RWH for agriculture

3.10.5 Soil-water management

In addition to the construction of storage structures, the storage of water in soils for agriculture can be enhanced by a number of soil-water management practices. The amount of water stored in a soil depends inherently on its ability to hold water, the ease with which water can enter the soil and the protection of the stored water from evaporation and other losses. There are several ways to enhance soil water availability:

- Conservation tillage;
- Mulching and compost use;
- In-field water conservation; and
- Improving overall soil water by avoiding deep drainage (IFAD, 2011).

Soil-water management practices are well-known but are not widely applied in Northern Grenada. The Extension Division of the Ministry of Agriculture can develop and implement a suitable programme based on Best Management Practices (BMPs) in soil-water for increasing soil water storage. This would reduce the need for the structures discussed above.

3.10.6 Water supply and distribution

Water supply and demand management, through the reduction of water losses and higher tariffs that would encourage water conservation, can postpone the need for additional storage or even make it unnecessary. Increasing the availability of water requires actions on supply and demand management. On the demand management side, the aim would be to reduce the per capita use by reducing the losses in the distribution system and by improving the efficiency of water use through conservation.

Water losses in the distribution systems in Grenada can be as high as 45% and if reduced can decrease the need for additional storage. NAWASA already has a programme for leak detection and repair. However, inadequate resources are available to maximize the benefits from such a programme.

Improving efficiency of use through water conservation at the user point is important. Changes in water consumption at an individual level will be crucial to tackling water scarcity. Raising awareness and changing customer attitudes are major challenges in achieving a significant reduction in demand. The choice to adopt technologies and practices to reduce consumption lies, to a certain extent, with the individual who needs to be encouraged or incentivized to change behaviours. This would require a programme that incorporated some of the following activities:

1. Replace old fixtures with new LOW FLOW products including: high-Efficiency toilets that flush 1.28 gallons or less, when compared to a 3.5-gallon toilet. This can save up to 16,500 gallons of water per toilet, per year; Water-Conservation Green Technology Showerheads or Hand-showers that use 1.75 gpm and can achieve up to 35% water savings over traditional ones; and faucets with Water-Saving Aerators which deliver up to 45% water savings over traditional faucets.
2. Buy only appliances with water saving features such as clothes washing machines and dishwashing machines (not yet common).
3. Implement public education to develop a "Water Saving Consciousness" programme that encourage measures such as turning off the water while shaving or brushing teeth and taking a fast shower instead of a full bath.
4. Rainwater harvesting at the household level. Households can use RWH for landscaping and kitchen gardens, washing of cars and driveways.

3.11 Energy options for water management

Grenada has promoted capitalization of its natural resources by using renewables such as wind and solar energy. The effort is partly in the water sector with solar energy being used mainly for water heaters in hospitals and residences. The potential for hydropower was explored during the 1980s but nothing beyond 500 kW potential was discovered.

NAWASA's operations in Northern Grenada are already green. All the transmission and distribution systems are gravity operated. Energy consumption is restricted to lighting and small equipment consumption in buildings associated with the plants' operations. As such the limited opportunities for improving the greening process for NAWASA at the Northern Grenada operations would be associated with replacing outdoor and indoor electrical lighting with solar lighting.

Since 2002 the Government agreed to establish a national solar water heating awareness initiative to target both the residential and the commercial sectors. That initiative was linked to providing financial incentives such as tax rebates for the purchase of solar water heaters (GoG, 2002). A number of local companies are now providing services in solar energy installation. Some households in areas of low water pressure from the public supply now use electrical pumps for boosting pressures. While there is not yet very wide use of these pumps, increased demand on the system in the future can cause these pumps to be utilized in everyday activities.

Improving efficiency of water use in irrigation is another area for potential energy savings. The irrigation systems can benefit from the use of micro sprinklers and drip irrigation, best management practices in soil water management and solar or wind pumps to replace diesel and gasoline pumps.

For many years, water tariffs in Grenada remained low, making cost recovery impossible so that the sector depended on government subsidies. Water has traditionally been regarded as a free resource and the only costs are usually associated with processing and delivery alone. Public awareness of the inherent value of the water resource can change this perception. Appropriate water pricing can reduce demand as well as generate revenue to cover the cost of providing water supplies and maintaining infrastructure. Appropriate tariffs are essential for the success of the new governance approach of utilizing IWRM and can ultimately contribute to enhanced water supply and quality and can contribute to the reduction of storage demands.

3.12 Conclusions and recommendations

The future demand of water in Northern Grenada would require a shift in the water management paradigm as the responsibility for sustainable water and water security in Grenada does not rest on one group or institution. It is a multifaceted issue and many people would need to participate. This requires a genuine integrated approach to the management of the resource under a revised governance structure.

The physical, socioeconomic and cultural make up of Northern Grenada require that adequate time be given to a transformation of water resources management. A number of national and regional initiatives (including the National Water Policy, the roadmap towards IWRM), and the efforts to mainstream water resources management into the development of a green economy can potentially facilitate this transformation. While the relevance of increasing storage capacities is important, this by itself is not sufficient. The various water storage options have comparative advantages but the development may be affected by social constraints. Hence, storage systems that combine and build on complementarities of different storage types and are responsive to local conditions should be favorably considered for implementation.

A number of opportunities lie ahead in integrating water and energy which can be identified through analyses of the key sectors: agriculture, tourism, and domestic supplies. This would be in keeping with the philosophy of IWRM. Unlike the earlier approaches of using large projects, these opportunities are likely to be more successful through small projects that can be managed by individuals or at the community level with the support of central agencies.

There is a general scarcity of good data for decision making in the water resources sector in Grenada. In particular, the need to improve the availability of data on water quality in Northern Grenada is critical for determining optimal solutions that can ensure sustainability. It is therefore recommended that a framework for monitoring the chemical and biological quality of the main rivers, lakes and waterfalls be developed and implemented.

Given the constraints to a natural expansion of water resources in Northern Grenada to meet future demand, applications that can postpone the need for additional storage must be used where possible. It is therefore recommended that the concept IWRM, which is well accepted by Grenadian policy makers, be mainstreamed.

RWH has many advantages in meeting the everyday water supply needs of agriculture and drinking, in mitigating water shortages during disasters and in the mitigation of flash floods as sometimes seen in Grenville. It is therefore recommended that adequate resources and incentives be provided for an enhanced promotion of RWH in Northern Grenada.

To meet the growing demands of water for agriculture and landscaping in the tourism industry, a programme to improve the technical know-how in the design and installation of RWH ponds should be developed.

To reduce the demand for water at the household level, it is recommended that a package of incentives for the procurement of low volume and low energy facets be provided by the government.

To improve the efficiency of irrigation, farmers should be encouraged to use micro-sprinklers and drip irrigation. It is recommended that the Irrigation Unit at the Ministry of Agriculture be strengthened to provide better extension services to farmers.

Overall, water resources management in Northern Grenada has a low level of energy requirement. It is nonetheless recommended that greening be achieved by replacing current lighting with photovoltaic sources in NAWASA plant facilities and solar powered pumping for irrigation.

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4. Restoration of Coastal Ecosystems

4.1 Introduction

Healthy coastal and marine ecosystems are at the heart of food security, livelihoods and economic prosperity for the coastal communities of Grenada. Coastal ecosystems of Grenada include mangroves, beaches, littoral forests, coral reefs, seagrass beds, rocky shores, and rivers, estuary and wetlands.

The coastal zone serves as the focal point for economic growth, hosting the majority of human infrastructure, transportation and trade, energy processing, tourism, and recreation. Tourism is one of the most important sources of external revenue in the Caribbean, and a majority of tourism development is located in the coastal zone. It will continue to be a challenge for governments to balance the use of the coastal areas for commercial use, whilst conserving it for the social, protective and ecological functions it can provide. While the Grenadian economy has benefited from coastal development, the health and integrity of its coastal and marine areas have been severely compromised by human activities, including mangrove clearance, over fishing and pollution. Given the importance of marine and coastal ecosystems to poverty alleviation, and the health and safety of coastal communities, effective management of these resources is of central importance.

As with most Small Island Development States (SIDS), the effect of climate change is evident in Grenada. In the last decade three major hurricanes, Lenny 1999, Ivan 2004 and Emily 2005, have all devastated the man-made and natural systems of Grenada. Extreme weather patterns are more frequent in Grenada, resulting in periodic flash flooding and forest fires in dry periods. Over the last 20 years the eastern coastline has lost many miles of sandy beaches to the sea and in the last decade Sandy Island cay in Carriacou was pounded by powerful sea surges, which reduced the island to a narrow spit bare of vegetation. These disasters resulted in a huge cost to the Grenada economy, and hundreds of millions of dollars were spent in rebuilding coastal and other public infrastructure.

Scientists are forecasting that there will be rising sea levels, more frequent and intense storms, dying coral reefs, reduced fish stocks, and increased floods and droughts. These events are predicted to not only continue but also to worsen. According to CARIBSAVE (Simpson, M., et al, 2010), in their report on modeling the transformation impacts and cost of sea level rise in the Caribbean, Grenada's annual and capital cost to sea level rise scenario 2050 is estimated at US$489 million. Based on present day realities and these predictions, there is urgent need for Grenadians to find ways to adapt to the very real effects from climate change that they are already seeing.

Grenada has played an important role in the international community in addressing the issues of climate as a SIDS. Since hurricane Ivan the Government of Grenada has been actively working to develop responses to climate change. Grenada participates in local, regional and international biodiversity initiatives, including the Convention on Biological Diversity's Program of Work on Protected Areas, the Caribbean Challenge, National

Protected Area Systems Plans, and has been the chair of Alliance of Small Island State (AOSIS) for two consecutive terms.

This chapter provides the assessment of the current status of coastal ecosystems in Grenada and the major factors affecting them, proposed actions for restoration and maintenance, and policy options to support conservation efforts. Primary and secondary sources were used to assess the current state of each ecosystem. Data sources include peer reviewed literature, technical reports, government reports, technical meetings, fisheries data, interviews and personal communications with governmental organizations, NGOs and community groups across Grenada.

4.2 Status of coastal ecosystems in Grenada

In Grenada, a great deal of human activity and development occurs in the coastal zone, placing pressure on the associated ecosystems. Additionally, land based pollution from further inland is transported to the coast, contributing to this pressure. The following section provides an assessment of Grenada's coastal zone by ecosystem type. It must be recognized that these ecosystems are highly connected and cannot be managed in isolation.

4.2.1 Mangrove

In Grenada mangroves are generally considered as wastelands that could be converted into something for immediate use (Barriteau, 2000). Several general estimates of mangrove acreage exist, but these estimates are out of date and were not based upon the high resolution aerial imagery and survey techniques available today (Moore et al, 2012). Grenada has an estimated 385 hectares of mangrove (Moore et al, 2012). This value puts Grenadian mangrove acreage greater than the three other Windward Islands combined.

Figure 4.1: Levera mangrove and associated ecosystems

Grenada has 22 mangrove sites (Bacon, 1991). Mangroves are prominent in Lauriston Airport, Petite Carenage and Tyrrel Bay in Carriacou and on the northern, eastern and southern coastlines of Grenada. Other significant areas include Levera Pond, Conference Beach, Westerhall – Fort Judy and Woburn. Levera and Conference/Telescope and Carriacou mangrove areas are known to be used for charcoal production, construction (land and sea) purposes, cattle grazing and crabbing.

As a result of the size and productivity of Grenadian mangroves, they play a role in restocking the offshore fisheries not only in Grenada but across the Caribbean region. In Grenada, they are known to provide income and food to rural families and a wide cross-section of Grenadians who purchase charcoal, crabs, fish, poles and oysters that originate from mangrove areas of Conference, Tyrell Bay or Levera.

Figure 4.2: Encroachment into mangrove forest

At the turn of the century the Forestry Department made great strides into mangrove conservation and developed a policy and strategic plans for its management. At present there is draft forest legislation that provides protection for mangroves; however, this legislation has been in its draft stages for the last 10 years.

Mangrove protection efforts are presently being achieved by the limited patrol activities undertaken by forest rangers and in areas where they occur within actively managed marine protected areas, such as Sandy Island Oyster MPA in Carriacou, which has two sites. The Grenada Fund for Conservation (GFC) is the leading organization in the restoration of mangrove ecosystem and has had many years of experience growing mangrove in Carriacou and Grenada and can provide guidance to this project with future restoration work.

4.2.2 Beaches

On the eastern coastline of Grenada a high rate of erosion is noticeable in Levera, Conference, Telescope and Pearls, where several meters of land are lost annually from beach erosion. In Carriacou a local cemetery in the coastal community has receded to the sea, largely due to the removal of sand in the area. Grenada has made strong efforts to stop the use of beach sand in construction and presently there is limited extraction of beach sand by that state agency.

Figure 4.3: Beach erosion at Conference

It is a normal practice to build hard infrastructures, such as seawalls and groins, for coastal defenses. Many of these can be seen on the western coastline of Grenada. These static features are in conflict with the dynamic nature of the coast and impede the exchange of sediment between land and sea.

4.2.3 Littoral forest

In Grenada littoral forests, unlike mangroves, grow on sandy ground above sea level. The vegetation that grows will depend on soil type and height above sea level. The beach forests, which are dominated by almond and sea grapes, are of fundamental importance to the coastal area because of the services they provide in shoreline stabilization. Other services provided include mitigation of storm damage, reduced sedimentation and reduced run-off. Hurricanes Ivan and Emily devastated the littoral woodlands of Grenada and since then there have been little efforts to do any major replanting. In the 1990s there was a campaign by the board of tourism to remove "the poison tree" from the coast, which resulted in the removal of many manchineel trees, one of the largest trees occurring on the coast.

Figure 4.4: Littoral forest being cleared for development, Levera

4.2.4 Coral reefs

The Grenada (and the Grenada Bank) reef system is an area of ecological significance as it supports the most extensive coral reefs and related habitats in the South-eastern

Caribbean. The Grenada Bank is thought to play a vital role in supplying the Northern Caribbean with larval coral and fish.

Figure 4.5: Coastal protection being provided by barrier reef

Current conditions of high ocean temperatures are accelerating the destruction of the Caribbean's coral reefs, and sea level rise is expected to exacerbate inundation, storm surge, and coastal erosion. These threats jeopardize the region's natural and cultural heritage, threaten food security, reduce employment opportunities, and constrain economic growth, placing biodiversity and human well-being at risk. Emerging studies show that major shifts in fisheries distribution due to climate change will adversely affect food security in tropical regions. Global climate models predict that the oceans will continue to warm. The region has seen two serious coral bleaching events and occurrences of fish kills in the last 10 years caused by increased sea temperature.

The fisheries across the Grenada Bank are currently lacking in management and regulation and over fishing is a serious threat to not only the biodiversity in the area but also to the livelihoods of the people of Grenada. Over the past 30 years Carriacou has been exporting over 200,000 pounds per annum of reef fish (demersal) to the island of French Martinique. Of this total, over 100,000 pounds per annum is parrotfish, an important reef grazer and sand producer. One parrotfish is known to produce seven tons of sands in its lifetime. The recent discovery of the lion fish in the water of Grenada and continued use of the illegal gilled net to trap lobsters by the Sauteurs fishermen adds further stress to reefs.

4.2.5 Seagrass beds

Seagrass beds are located mostly in shallow sheltered areas throughout the coastal waters of Grenada, Carriacou and Petite Martinique. The species of seagrass found in Grenada include turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).

Seagrass beds are most prominent in lagoon areas where clusters are located and play an integral role in the well being of a marine ecosystem. Seagrass beds trap and stabilize sediment, resulting in better water clarity and light penetration, which are necessary conditions for coral reefs to flourish. The extensive root system of seagrass beds limits erosion by holding the sand substrate together, preventing extensive shifting of sand during storms. Seagrass also provides important habitat and refuge from predators for juvenile reef fish. Furthermore, green sea turtles, several herbivorous fish, echinoderms, mollusks, and birds feed on the seagrass.

Seagrass beds are destroyed by fishing practices, especially by the use of destructive gears such as trammel nets. Most fisher and yachter anchoring areas throughout Grenada occur in seagrass areas, where there is no established mooring systems except for a few areas. As a result seagrass areas extensively suffer from mechanical damages caused by indiscriminate dropping of anchors and grounding of boats. The use of sand for construction and dredging have also reduced seagrass habitat. In addition siltation, eutrophication and effluent caused by land clearing, deforestation, run-off from cultivated lands, grey water and sewage reduce the resilience of seagrass habitat.

4.2.6 Rivers, estuaries, and wetlands

While rivers themselves are not strictly coastal ecosystems, they discharge into coastal ecosystems and can have significant impacts on them. Grenada has over 40 rivers, which act as the main source of land-based pollution discharged into coastal ecosystems. Freshwater discharge will influence the physical, chemical and biological processes in coastal regions. Effects can include changes in circulation and vertical stability, modification of mixing and nutrient exchange processes, and regulation of primary production. Rivers will carry organic and inorganic compounds as well as living organisms to coastal ecosystems.

Figure 4.6: Sea Moons River draining to the eastern coast, GR.

Due to the rugged topography of Grenada and inappropriate agricultural practices, particularly the indiscriminate use of fertilizers, runoff loaded with nutrients and soil ends up in the rivers and subsequently coastal areas. In addition rivers are a medium for grey water and other discharge from houses and factories.

Technical experts and other stakeholders in Grenada strongly believe that river-based pollution is one of the main contributing factors to the degradation of the coastal environment, and coastal restoration efforts will be limited or ineffective if land based sources of pollution are not addressed. Five rivers have been identified as contributing high levels of pollution and siltation to the coastal environment. Based on monitoring carried out by St. George’s University (SGU) on some of these systems, it was revealed that these rivers contribute high levels of nitrification to the sea, which could impede coastal restoration efforts on coral reef and mangrove areas. These rivers are St. Johns and Beausejour on the western coast, Richmond Hill and Chemin on the southern coast and Soubise on the eastern coastline

Some estuaries have developed into unique wetlands systems in Grenada. In these few areas, such as Beausejour and Perseverance rivers, the vegetation adapts to the wet conditions and grows buttress roots and physiological features to survive. Common flora include terocarpus sp., almond, silk cotton, mangroves and herbaceous trees. These areas help in regulating the flow of water and nutrients into the marine environment. River estuaries provide tremendous opportunities for eco-tourism and education and their importance must be highlighted in order to prevent their alteration.

The Forestry Department, being responsible for coastal woodland, has some jurisdiction over these areas. However, most of these areas are on private land, which affects the management and use of these areas.

4.3 Major factors affecting coastal ecosystems

There are a variety of threats affecting Grenada's coastal ecosystems. It is important to recognize that threats not only occur directly in the coastal zone; they can also be indirect, occurring further inland but still having a negative impact on the coastal zone. A single threat may have multiple impacts, depending on factors such as ecosystem type and health of the ecosystem. The threats that need to be addressed most critically in Grenada are listed in Table 4.1.

Deforestation that occurs when mangroves and littoral forest are converted leads to increased sedimentation, loss of coastal protection ability, loss of habitat for associated species, etc. New development or encroachment from existing developed areas is also responsible for loss of vegetation/deforestation.

Litter is prevalent in many coastal communities. It may either be directly deposited along all coastlines, at dumping sites, or be transported by rivers, wave action or other natural processes. The garbage collection system has improved over the years; however, there is no recycling system for plastics, glasses, cardboards or organic matter.

Fish are one natural resource of particular concern because of the dependence of communities on fisheries. Caribbean reefs, including Grenada's, are experiencing major declines in populations of economically significant species including the Spiny Lobster, Queen Conch and predatory fish species such as the grouper and members of the Lutjanidae (snapper) family, due to overexploitation for human consumption (Bellwood et al, 2004; Hawkins et al, 2007; Sadovy & Domeier, 2005). These reef species are, however, not only of economic importance but play a significant role in the overall health of coral reef systems as well as highly interrelated systems such as mangrove forests and seagrass beds (Linton & Warner, 2003). In Grenada export of fish to Martinique is responsible for a large amount of the catch. There are also issues resulting from the use of illegal, destructive gears, which is destroying reef habitat.

In Grenada land-based pollution from residential, agricultural, business and others sources are affecting the coastal ecosystems. These issues have been raised for a long time, but there has been little effort to address the problem. Whilst the National Water and Sewage Authority (NAWASA) has the right to extract water, no other state agencies are responsible for managing rivers. The Forestry Department could address issues in upland watershed areas; however, there is no planning for river management activities. Surface run off and river discharge transport pollutants to coastal ecosystems. Of particular concern are persistent organic pollutants, which are highly toxic, stable chemicals (e.g. pesticides) that accumulate in organisms and persist in the environment for years. Agriculture is often a major contributor of nutrients into water systems. Sewage, resulting from human waste, is in many cases not adequately managed. This is of concern because of the high nutrient content of this waste. It is not uncommon for sewage to be directly discharged into coastal waters leading to eutrophication. Additionally, sewage may contain other contaminants, such as chemicals used in household cleaning products.

Figure 4.7: Die back at Woburn

In some cases, when a large portion of mangrove forests and littoral woodlands starts wilting, the leaves turn yellow, followed by death of a portion of the forest. This happens when there is undue stress on the system from a nearby or far removed source. Nearby factory effluent, runoff from development and/or upland sources of pollution are often the cause.

Beaches are naturally dynamic ecosystems, with sand being eroded and deposited by wave action. One of the predicted impacts of climate change is increased frequency and severity of storm events; this brings the associated threat of increased rates of erosion. As vegetation is removed from the coastline, it leaves sediment more vulnerable to erosion, increasing the impacts associated with wave action.

Invasive lionfish (*Pterois volitans* and *Pterois miles*), were introduced to the Western Atlantic Ocean in the mid-1990s (Schofield, 2009). Since that time they have become established across the Caribbean Sea and were first reported in 2011 in Saint Vincent and the Grenadines and Grenada. Lionfish are effective predators that pose several ecological and socioeconomic threats if their populations go unmanaged.

Pollution of the marine environment occurs both directly and indirectly. Direct causes include oil discharge and spills, sewage, ballast and bilge discharge, and dumping of human waste from ships (Burke & Maidens, 2004).

Direct damage is caused at construction sites. Depending on the ecosystem type, vegetation will need to be removed, which results in loss of wildlife habitat, loss of vegetation, reduced productivity and reduced biodiversity. Because vegetation helps to stabilize soils and slow surface run off, its loss is associated with increased levels of erosion and rates of sedimentation.

Figure 4.8: Coastal construction post hurricane Lenny, South-west coast Grenada

Post Hurricane Ivan in 2004, people in the south of Grenada have been back filling mangroves and settling in these areas. With increases in sea levels, mangrove will need new areas to accrete to if they are going to continue to provide services to communities. Construction of jetties in the mangrove area in the south is also common. Lands below the high water mark and mangroves in these areas should be protected. However there seems to be a lack of enforcement of this legislation. As vegetation is removed the coastal protection services it provided are also lost.

A major factor affecting the status of mangroves is perceptions or beliefs about them. To an average Grenadian a mangrove area is “that smelly, useless, mosquito infested swamp”. This is further compounded when they are converted into ‘something more immediately useful’ by politicians for short-term economic gain, ignoring the long-term ecological and socio-economic consequences (Barriteau, 1998).

Table 4.1: Summary of threats and impacts affecting coastal habitats in Grenada

Threat	Impact(s)	Habitat Affected
Loss of vegetation/deforestation	Increased erosion Loss of habitat Increased sedimentation Reduced productivity Degraded nursery habitat Loss of coastal defense services	Mangrove Littoral forest Seagrass bed
Litter	Entanglement/smothering of marine animals Reduced productivity	Mangrove Beach Littoral forest Coral reef Seagrass beds Rivers/Estuaries/Wetlands
Fishing	Declining/overexploited fish populations Local loss of species Loss of livelihood opportunities Habitat destruction (from gear)	Mangrove Coral reef Seagrass beds
Pollution from inland sources	Increased algal growth Loss of productivity Nutrient loading/ eutrophication Contamination of water	Mangrove Beach Littoral forest Coral reef Seagrass beds Rivers/Estuaries/Wetlands
Die backs (sudden tree death)	Increased rates of erosion Loss of habitat Loss of coastal defense services	Mangroves Littoral forest
Storm surges & wave action	Increased rates of erosion Damage to infrastructure Coastal flooding	Mangrove Beach Littoral forest Coral reef Seagrass beds
Introduction of invasive species	Loss of native species (predation or competition) Alteration of trophic webs	Coral Reef
Marine based pollution		Mangrove Coral Reef Sea Grass Bed
Coastal Development	Loss of habitat Generation of pollution and litter Loss of turtle nesting sites Eutrophication Sedimentation Loss of coastal defense services	Mangrove Beach Littoral forest Coral reef Seagrass beds

4.4 Actions needed to restore and maintain coastal ecosystems

The concept of managing for resilience is based on the premise that unstressed coastal ecosystems are naturally resilient to climate change, but human-induced degradation erodes the ability of ecosystems to resist the impacts that result from climate change. Therefore improved management or mitigation of human induced impacts on ecosystems is one strategy to address the threats of climate change.

Projects aimed at building ecosystem resilience should strive to address the causes of ecosystem degradation. Too often restoration projects fail because they focus on site level impacts rather than the causes of ecosystem degradation. For example, a mangrove restoration project that focuses on replanting cannot be effective in the long-term, because it does not address the issue of over harvesting which causes deforestation in the first place.

Without support from the government of Grenada, sporadic community driven organizations have gone on the offensive in their efforts to adapt to the effects of climate change. A local NGO in Carriacou, the Carriacou Environmental Committee (CEC) and the Sustainable Grenadines Inc. (SusGren), reforested Sandy Island to a now stable vegetated island and established the Sandy Island Oyster Bed Marine Protected Area (SIOB MPA). In the South of Grenada the Grenada Fund for Conservation (GFC) raised continued funding and started restoring the mangrove ecosystem in that area. These initiatives have resulted in the emergence of many other localized community groups with the interest of restoring their coastal ecosystems throughout Grenada.

4.4.1 Mangrove focused projects

Mangrove restoration

Mangrove restoration programs can take two general approaches: direct planting of propagules, or transplanting of saplings (Kario, 2010). Factors influencing the success of programmes include species selection, seed/propagule quality, nursery quality and management, site preparation, and transplantation techniques. Ideally, natural revegetation can be taken advantage of through secondary succession. Natural regeneration is documented to occur over 15-30 year periods, if certain conditions are maintained, namely normal tidal hydrology and availability of water borne seedlings. Mangrove sites can be rehabilitated by removing the stresses that cause decline (Gilman et al, 2007).

Projects can involve mangrove nursery development (Kripa et al, 2002), where propagules are planted and grown before being transplanted to the restoration site. Nurseries have been utilized as a mechanism for increased community participation in restoration projects.

Some mangrove restoration projects have already been initiated in Grenada; however, some of them have not produced the desired results. It is believed that land based sources of pollution are affecting the success of mangrove restoration and to effectively address restoration the land based sources of pollution needed to be known and reduced.

Litter and Debris Removal

Garbage disposal and littering continue to be important environmental concerns facing the Grenadines Islands and, as such, littering has evolved from an aesthetic problem to a broader environmental and social issue.

Marine debris and litter can cause injury or death to marine life through drowning, smothering, entanglement, internal injuries, or starvation following ingestion. Birds, marine mammals and sea turtles are particularly vulnerable to marine litter. Furthermore, the presence of litter deters human users and negatively impacts the potential for nature based tourism and recreation in coastal environments (Derrial, 2002).

Regulations and laws addressing marine debris in the Caribbean exist, as do international and regional treaties and conventions, but enforcement is difficult. Marine litter is a challenge that has been recognized by Caribbean governments and, accordingly, various institutional arrangements have been developed at national levels, yet the marine litter problem persists.

It has been found in other jurisdictions that community based initiatives are often the most effective means to address issues such as marine debris and litter (Derrial, 2002). In most nations there are not the financial resources to completely address marine litter. Such initiatives require support for success, a role that is frequently played by NGOs (Derrial, 2002).

Sustainable harvesting programs

Many communities still harvest and utilize natural resources based on traditional methods. Two specific examples are mangrove for charcoal production, and land crabs for human consumption. There is a risk for overexploitation that results from a lack of regulation and enforcement and a poor understanding of sustainability. Sustainable harvesting programmes would help resource users to self-regulate in order to ensure that resources are not overexploited. It is also noted that there are communities that have been harvesting mangroves for many years. For example, the Conference community has developed indigenous technical knowledge (ITK) that has allowed them to harvest on a sustainable yield basis. These techniques can be adapted through participatory means to allow for protection of livelihoods whilst maintaining resilient ecosystems. Table 4.2 is a list of mangrove focused project ideas.

Table 4.2: Mangrove focused project ideas

Action	Location	Partners involved
Mangrove restoration	Woburn / Calivigny	Grenada Fund for Conservation (GFC); Woburn / Calivigny Development Organization
	Fort Judy / Westerhall	GFC; Westerhall Petite Bacaye Disaster Mgt. Group
	Levera	GFC; SPECTO; Rosehill eco-friendly and sustainable dev. Organization
	Petite Carenage and Mang (PM)	KIDO; GFC; Petite Martinique Development Org.; SusGren
Litter/debris removal	Woburn Calivigny Fort Judy / Westerhall	Groups related to these areas
	Oyster Bed	Sandy Island Oyster Bed MPA Board / Boating Community / Dive Operators of Carriacou; SusGren
Sustainable harvesting programs	Conference	Charcoal farmers; Crab collectors
	Levera	Crab collectors; Fishers of the pond; Framers of Area; SPECTO; RESDO, GFC; Ocean Spirit
Mangrove monitoring programs	Woburn Calivigny Fort Judy / Westerhall	Groups related to these areas
	Levera	GFC; SPECO; Rosehill eco-friendly and sustainable dev. Organization
	Oyster Bed	Sandy Island Oyster Bed MPA Board

4.4.2 Rivers, estuaries and wetlands

Mapping of pollution sources

Efforts to do any kind of community restoration on the coast could be impeded by upland sources of pollution. A community led mapping exercise of upland sources of pollution is one approach to identifying specific sources of upstream pollution, which in turn can provide information that is critical for improved management or mitigation of this pollution. Table 4.3 presents a list of focused project ideas related to rivers, estuaries and wetlands.

Table 4.3: River/wetland/estuary focused project ideas

Action	Location	Partners Involved
Mapping of pollution sources	Woburn Calivigny Fort Judy / Westerhall	Groups related to these areas
	Chemin Watershed	GFC; GFC; Westerhall Petite Bacaye Disaster Mgt. Group
	Richmond Hill Watershed	GFC; Woburn / Calivigny Development Organization
	St. John and Beausejour Watershed	Molinierre-Beausejour MPA Board
	Soubise	GFC; Soubies Community
Watershed monitoring	Chemin Watershed	GFC; GFC; Westerhall Petite Bacaye Disaster Mgt. Group
	Richmond Hill Watershed	GFC; Woburn / Calivigny Development Organization
	St. John and Beausejour Watershed	Molinierre-Beausejour MPA Board
	Soubise	GFC; Soubies Community

4.4.3 Littoral forest focused projects

Coastal forest restoration

Reforestation projects can make use of either natural secondary forests or planting and plantations (Lamb et al, 2005). When working with natural secondary forests, methods can include: protection and management of natural regrowth, or enrichment with key species. When working with planting and plantations, the methods employed will depend on the program objectives (Lamb et al, 2005). Options to restore biodiversity include: restoration planting using a number of short-lived nurse trees, planting a large number of species from later successional stages, or direct seeding. If the objective is to supply goods and ecological services, options include: monoculture of exotic species, monoculture of native species, tree plantation used as nurse crop with underplantings of natives not otherwise able to establish at the site, and tree plantation of mixed native species. Table 4.4 presents a list of littoral forest focused project ideas.

Table 4.4: Littoral forest focused project ideas

Action	Location	Partners Involved
Coastal forest restoration	Major Beaches: Levera, Bathway; Conference, Seamoon, Telescope; Sobies; Marquis; Grand Anse; BBC–Point Saline	Boy Scout; Rotary; Lion Club
	Sandy Island	SIOB MPA

4.4.4 Beach focused projects

Beach stabilization

Shorelines are naturally dynamic, undergoing erosion and accretion as the result of wind, waves, storms and tectonic process. Coral reefs, mangroves, and seagrass beds all work to reduce erosion by reducing wave energy. At sites where vegetation has been removed, reforestation/revegetation is one potential option for restoring the stabilization services that plants naturally provide.

In order to protect existing developments and infrastructures, it is common for artificial methods of stabilization to be employed. Artificial methods of shoreline protection include groins, jetties and seawalls. While these structures may be successful at protecting a component of the shoreline, they do not provide capacity for natural ecosystem dynamics. Projects aimed at working with nature and people to develop ecosystem based initiatives also should be examined.

Figure 4.9: Artificial groin, South-west coast, Grenada

Soil bioengineering utilizes living plant materials to perform an engineering function (Polster, 2002), such as erosion prevention. Colonization of coastal soils by vegetation whose roots act to bind sediment makes the soils more resistant to erosion.

There is a nonlinear relationship between wave attenuation and wetland size, so that even small wetlands can play a substantial role in wave protection (Gedan et al, 2010). Revegetation is an attractive option because it provides long-term shoreline integrity, and also the ability for the coastline to adapt (Gedan et al, 2010).

Groin reinforcement

Artificial groins are susceptible to erosion, and maintenance can be very costly. By replanting vegetation, groins can be reinforced in a more cost efficient manner. Additionally, vegetation provides a variety of ecosystem services that are not available from artificial materials. Table 4.5 is a list of beach focused project ideas.

Table 4.5: Beach focused project ideas

Action	Location	Partners Involved
Beach/coastal stabilization	Eastern Coastline of Grenada (Conference to Marquis)	GFC; Communities of these areas
	Sandy Island	SIOB MPA Board
Beach monitoring	Same as above	Science and technological council
Groin reinforcement (with trees)	Along the Melville Street Coastline, St. George’s	Willi-Redhead foundation

4.4.5 Coral reef focused projects

Improved fisheries management

The lack of planning or coordination and unsustainable practices are leading to the decline of fisheries across the Caribbean. Specific goals and objectives should be set for near shore fisheries, and appropriate measures should be implemented to achieve them. Examples of measures that could be considered include quotas, area restrictions, seasonal closures, etc. Enforcement, or the lack thereof, is a major impediment to the implementation of sustainable fisheries management and will need to be addressed when developing a fisheries management plan. Guidance documents to facilitate the development of community fisheries management plans have been developed and can be adapted to suit the Grenadian context.

Fisheries co-management

The reef fishing stock of Carriacou and Petite Martinique is being exploited for export to French Martinique. This trade is more than 30 years old and an average of 200,000 lbs of reef fish go to Martinique every year. Marines resources users, government, universities and other stakeholders have been working on a multiuse-zoning plan for the Grenadines. This plan outlines a new approach to managing the coastal ecosystem around Carriacou. The plan needs to be implemented to address the fisheries management issues in Carriacou and Petite Martinique.

Coral reef restoration

There are several methods for coral restoration: coral transplantation, in situ and ex situ coral nurseries, use of artificial reefs, and substrate stabilization. Coral transplantation uses established coral colonies from an external source in denuded areas. New coral colonies are expected to accelerate natural recovery. This approach depends on adequate source colonies and will inevitably cause some level of damage to those source colonies.

To avoid damaging source colonies, in situ and ex situ coral nurseries can be developed; this involves transplantation of colonies or fragments that are maricultured for this specific use. Artificial reefs can be installed to provide habitat; common examples include the sinking of ships.

Substrate stabilization can be used to create conditions more favourable to coral growth. Substrate that has been turned into ruble is dynamic and can easily shift during storms or from currents, and fine fractions are continuously suspended. There are varied methods that can be employed, such as the use of concrete reinforced with steel.

Lionfish eradication

Through active management, the negative impacts of lionfish can be mitigated. Studies predict that populations can be maintained at acceptable levels, if active removal measures are put in place. Keeping populations low will require sustained fishing pressure (Christensen et al, 2011).

Control programmes involve the active removal of lionfish from the marine environment. There are several aspects of control that must be addressed when designing a management plan, including: collection and handing protocol, training, protocol for the handling of specimens, reporting and documentation. Training should be provided on topics such as safe handling and removal, the use and/or construction of removal gear and first aid/medical response.

Aside from removal, other components of lionfish management programmes include: education and outreach campaigns, reporting and monitoring programs, marketing for food consumption, policy and regulations.

Alternative gear technology

Protecting coral associated benthic ecosystems in the southern Grenadines involves moving away from illegal lobster fishing to more sustainable methods and livelihoods. The spiny lobster fishery is fully or overexploited throughout much of the Caribbean region (Cochrane & Chakalall, 2001). Although traps, gillnets, and SCUBA are common lobster fishing methods, illegal or banned trammel nets are the most prevalent gear utilized by lobstermen fishing around Isle de Rhonde. Trammel nets consist of suspended netting that entangles marine organisms and habitat. Use of this unselective gear thus results in reduced spiny lobster populations, extensive habitat destruction, and wide-ranging loss of by-catch species including turtles, rays, and sharks. Table 4.6 lists coral reef focused project ideas.

Table 4.6: Coral reef focused project ideas

Improved fisheries management	Location	Partners Involved
Co-management of fisheries	Carriacou	Sandy Island Oyster Bed MPA; SusGren
Lionfish eradication	Moliniere-Beausejour MPA Woburn Clark Court Bay MPA Sandy Island Oyster Bed MPA	Boards of the these MPAs; Dive operators; Communities
Reef Monitoring	Moliniere-Beausejour MPA Woburn Clark Court Bay MPA Sandy Island Oyster Bed MPA	Boards of the these MPAs
Alternative gear technology	Sauteurs / Isle De Rhonde Community	SusGren SPOD, St. Patrick's Organization for Development
Coral reef restoration	Sandy Island Oyster Bed MPA	MPA Boards

4.4.6 Seagrass bed focused projects

Mooring installation

Anchoring can cause major damage to reefs or other benthic habitat if unregulated (Tratalos & Austin, 2003). Anchors may be cast down on top of the reef or seagrass. For this reason the use of mooring buoys is widely encouraged. The installation of mooring buoys in strategic sites (e.g. MPAs) will help to mitigate such damage.

4.4.7 General project ideas

Sustainable harvesting guidelines

Failure to utilize natural resources within sustainable limits is often attributed to a lack of education and/or misinformation. Introducing sustainable harvesting guidelines is one mechanism for mitigating the negative impacts associated with consumption of natural resources. By engaging communities in the development of these guidelines, they are more likely to be adopted and self-enforced by stakeholders.

There is opportunity to implement a mechanism for co-management when developing these guidelines. Co-management simply refers to the sharing of power and responsibility between government and local resource users. Co-management has the potential to provide social learning opportunities to stakeholders, as well as generate knowledge.

Promotion of ecotourism

Ecotourism aims to be environmentally and socially conscious, providing some benefit to the natural environment as well as the tourists who are involved (Holden, 2003). Ecotourism has the potential to provide alternative livelihoods and encourage resource users to improve the management of ecosystems and natural resources, to ensure that their tourism product can be sustained.

Education and awareness

Improved environmental education is key to better management of our natural environment. From a forest policy survey this was rated as more important than conservation of biodiversity, wildlife, mangroves, forest recreation, seedling provision or timber production. Without improved environmental education all the many existing environmental degradation problems that could be reduced by responsible behaviour by the general public will continue (Wilan, 1998).

Education and awareness is needed for the enlightenment of a wide variety of groups, including the general public, in order to increase their understanding of environmental issues and solutions. This greater understanding should lead to a reduction in environmental damage and pollution and support for all aspects of conservation. This will impact on the general public and particular resource users so that not only is their awareness of environmental issues increased but also so feel a greater ownership of the country's natural resources which should lead to increased respect.

In a case study of coastal restoration projects, it was found that community participation was necessary to avoid human disturbance from the adjacent landowners (Gilman & Ellison, 2007). Stakeholders are more likely to support a program and comply with restrictions if they understand the rationale behind them, which is achieved through direct participation.

Monitoring programmes

The status and trends of ecosystem health is important information for designing effective management programmes and policies. Currently there are major information gaps, which can be addressed through monitoring programmes. Monitoring programs for all ecosystem types could be implemented to fill this gap. Monitoring and evaluation plans are essential mechanisms for improving project impacts and performance and for obtaining the maximum benefits from a project. Monitoring programmes are one way to involve a variety of community members in projects and provide them with the opportunity for first hand experience with the natural environment. Table 4.7 presents a list of general project ideas.

Table 4.7: General project ideas

Action	Ecosystem	Location	Partners involved
Sustainable harvesting guidelines	Mangrove Beach Littoral forest Coral reef Seagrass beds Rivers/Estuaries/Wetlands	General	Target all relevant marine resource user groups
Education and awareness	Mangrove Beach Littoral forest Coral reef Seagrass beds Rivers/Estuaries/Wetlands	General public	
Promotion of ecotourism	Mangrove Beach Littoral forest Coral reef Seagrass beds Rivers/Estuaries/Wetlands		GFC Beausejour – North west dev. Comm.. Meadow/Conference community Bacolet; Perseverance; Requin; La Sagesse community

4.5 Policy options

In order to support the implementation of community based coastal restoration projects, support is necessary from the government. The following section lists policy options that would support the type of community based restoration projects discussed in the chapter. These policy options include both specific actions, such as amendments to legislation, as well as more general principles that could be developed by government agencies.

- Support capacity building programs for civil society, targeting community groups and NGOs. Capacity building should focus on areas such as strategic planning, project management, communications and fundraising skills.
- Establish safety net programmes or public funding to support community groups/NGOs in their efforts to address climate change programmes.
- Support turning existing draft forestry legislation into law that confers protection to mangroves.
- Develop co-management legislation that will support mechanisms for management of mangroves and marine protected areas by community led organizations.
- Examine the possibility of reclaiming encroached lands that were once mangrove areas and restore these areas by planting mangroves.
- Enforce the high water mark legislation, which confers protection to mangroves by clearly demarcating high water mark at fringing mangrove sites to ensure that mangroves are not cleared (illegally).
- Develop a clear policy/guidelines for establishing ownership and rights to used coastal areas (particularly in the tidal zone).
- Develop policy for building jetties and backwalls in vegetated (mangrove/littoral forest) areas. The approval process for building jetties should go through the land control authority and be subject to environmental impact assessment.
- Formalize opportunities for meaningful public input and stakeholder involvement in natural resource/ecosystem management.
- Introduce a set-back policy for construction in beach/coastal areas.
- Clearly establish authority/jurisdiction over rivers; introduce policy for the reduction/mitigation of pollution.
- Strive for comprehensive development control guidelines and policies across sectors, with an overarching goal of maintaining the quality of coastal resources.
- Adopt an ecosystem based approach to management (Ecosystem Based Management, EBM). EBM is a holistic approach to coastal and marine management that considers the entire ecosystem, including humans and human uses, and that integrates the management of multiple uses, rather than managing those uses on a sector-specific basis, in order to holistically address cumulative impacts.
- Adopt an integrated approach to management (Integrated Coastal Zone Management, ICZM). ICZM is a process which aims to preserve coastal resources, their ecological functioning and ultimately their values by applying adequate land use planning within a social, institutional and economic context.
- Establish sustainable financing mechanisms. Set up a national environmental fund from which communities and NGOs can assess funding for community based programs.
- Establish best practices compensation: Communities/individuals who follow prescribed guidelines in their practices and in so doing protect or build coastal ecosystem resilience should be rewarded/supported.
- Government must pursue partnership agreement with private land owner of significant coastal ecosystem for the management of these areas.

4.6 Conclusions and recommendations

Coastal communities are ecologically and socio-economically vulnerable to the effects of climate change, and these effects are expected to increase in the future. Grenada's coastal ecosystems provide a vast array of goods and services that help with climate change adaptation, such as protection from coastal erosion and mitigation of cyclone damage. The importance of these natural coastal defenses will only grow as sea level rise and the predicted impacts of climate change become a reality around the world.

There are many factors impeding the effective management of coastal ecosystems in Grenada. There is a need for the development of an effective management process, guided by management plans, with accompanying monitoring and enforcement. The resilience of coastal ecosystems should be bolstered to the greatest extent possible, to increase the environment's ability to adapt to changing climate conditions. This will take large-scale changes in the management approach taken in Grenada, but it is important not to lose sight of the role of civil society in environmental management.

The importance of community participation in environmental management must be formally recognized through the implementation of community level restoration, conservation and resource management projects and through supporting policy. Local capacity for addressing climate change impacts should be developed at the community level through targeted capacity development programmes. Key community groups/NGOs that have exemplified their leadership skills in the past should be sought out as facilitators for implementing community scale projects. By using established, reputable NGOs as facilitators and/or project managers, limitations in government resources and manpower can be overcome. Project implementation will include several stages: capacity building, group training, small grants, attachments and exchanges, monitoring and evaluation, and communication and networking.

Effective conservation and management of coastal resources require community involvement. The ecosystem composition and challenges of each community in Grenada are different; therefore, a variety of small-scale projects, targeting specific community needs, should be implemented. Marine resource users need to be empowered to take a leadership role in the restoration and subsequent management of coastal ecosystems. Before leaders can emerge, civil society must understand what the problems affecting their community are. Awareness raising and education will be necessary to support any type of project.

Synergies should be built between actors who are working towards complementary objectives. This will increase the effectiveness of planning and coordination of climate change related initiatives. Many new projects/initiatives are enlisting community involvement. At the national level governmental entity needs to assume leadership of this role. Current projects that would benefit from this type of networking and integration include:

- Forestry Department: Seedlings and monitoring
- Fisheries Division: coral restoration and coastal monitoring programmes.

- The Nature Conservancy: water edge Coastal Resilience project for Grenada and St. Vincent and the Grenadines
- The Vulnerability and Risk Reduction Project
- The Korean Southern Coastline Monitoring project
- Sustainable Finance Mechanism Project
- GEF Star 5 grant
- GIZ, German technical assistance in the area of climate change
- OECS Climate Change programmes.

Capacity development could target a set number of community groups/NGOs in communities of greatest need across Grenada. Assessment of these groups will reveal the capacity gaps that must be addressed. Capacity building, training and other skill development can be delivered to multiple groups at the same time to achieve the most efficient use of resources and get the most value out of resources invested. There are many skills common to all projects, regardless of the ecosystem being targeted or the technique being used. Examples include project management, budget development, design of outreach/communications materials, etc. Individuals from across Grenada can be invited to participate in common workshops, training sessions, exchanges, etc.

Funds should be made available in the form of small grants to create access to the financial resources necessary to implement on-the-ground restoration work. Community/ groups/ NGOs could submit proposals for projects, which address the environmental threats impacting their particular community. These small grants could be administered through the same NGOs that take on the facilitation role of this larger project.

Capacity also needs to be developed within government organizations to allow for enforcement of coastal ecosystem legislation. The Physical Planning Department of the Ministry of Finance, Forestry Department and Fisheries Division of the Ministry of Agriculture all have legislation related to coastal zones management. The Marine Protected Areas within Fisheries have recently conducted enforcement training and arrested offenders within the MPAs; similar training should be made available to other departments. The Forestry Rangers of the Forestry Department are not equipped to perform their management and enforcement related duties, rendering them ineffective.

Grenadians will continue to depend on coastal ecosystems for ecological, socio-economic and cultural reasons. The health of these ecosystems is in decline and climate change will only place further stress on these ecosystems. In order to build resilience to the impacts of climate change, human activities must be better managed. This can be accomplished through a variety of restoration projects, outlined in this chapter. To allow for effective change, civil society must be engaged in restoration and management efforts, as they are the actors who directly depend on, and cause direct impacts to, coastal ecosystems. Finally, project success will require complementary policy reforms to support them.

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5. Renewable Energy for Medical and Community Centres after Natural Disasters

5.1 Introduction

This chapter assesses the current status of energy sources for medical and community centres in Grenada and their weaknesses when called upon to provide support during natural disasters. It also presents an assessment of the most appropriate renewable energy systems that can be built as backup systems for use immediately after natural disasters. Costs and benefits from the installation and use of these systems are discussed. This chapter also presents policy options to support and maintain renewable energy systems particularly designed for operation during and after natural disasters.

The methodology used for completing this chapter of the report involved collecting load data from Grenlec for 2011 actual electricity consumption for a sample of health centres, medical stations and community centres. Fifteen sites were visited throughout the island in February and March 2012 and the building roof type, equipment and land spacing around the facilities were evaluated. The community centres visited are designated shelters.

5.2 Natural disasters risk assessment for Grenada

The main natural disasters which threaten Grenada are summarized in Table 5.1 below. The risk level is conceptualized in terms of displacement of a large percentage of the population.

Table 5.1: Showing risk of hazards threatening Grenada

	Risk level		
Hazard	**Low**	**Moderate**	**High**
Hurricane			√
Volcano			√
Earthquake		√	
Flooding	√		
Wildfire	√		
Tsunamis		√	

Grenada, Carriacou and Petite Martinique are normally just south of the track of many of the storms which pass through the Caribbean hurricane belt. However, the nation was shocked to reality on 22 September 1955 by Hurricane Janet, which caused a lot of destruction. Recently in September 2004 Hurricane Ivan devastated the island. The risk levels for hurricanes are high because they can displace a large number of people and stronger and more frequent hurricanes are expected in the next few decades.

Hurricane Ivan struck Grenada in 2004 as a strong category 3 storm with wind speeds of 111-129 mph (178-201 km/h). It is estimated that 80-90% of the buildings suffered structural damage. In the days following the disaster many people used tarpaulin covering for makeshift roofs. Overall damage was estimated to be as high as 2.5 times the gross domestic product (GDP). Hurricane Emily struck in 2005, but with far less severe effects (University of the West Indies Seismic unit, 2012).

During the relatively short 500-year period of written Caribbean history, tsunamis have inflicted a small amount of losses compared to other hazards such as windstorms, earthquakes and volcanic activity. The impact of a large tsunami can be as devastating as earthquakes or an erupting volcano. The capacity of tsunamis to travel over a wider area in a shorter time than hurricanes gives them the potential to unleash destruction on regional and hemispherical scales, especially if warning systems are not in place. This was convincingly demonstrated by the December 2004 tsunami in the Indian Ocean.

The Eastern Caribbean islands lie in a setting where major structural changes are occurring in the Earth's crust. All known sources capable of causing tsunamis (earthquakes, volcanic eruptions and landslides) can occur within striking distance of the Eastern Caribbean, and there are also distant sources across the Atlantic. Since the islands lie in an area of relatively high earthquake activity for the Caribbean, the most likely tsunamis to affect the Eastern Caribbean are those which can be triggered by shallow earthquakes (<50km depth) in the region, with a magnitude greater than 6.5 on the Richter scale.

Tsunamis caused by large volcanic eruptions at or below sea level also pose a threat to the Eastern Caribbean. The submarine volcano Kick-'em-Jenny, located 9 km north of Grenada, erupts on average every 11 years. At least two of those eruptions, in 1939 and 1965, generated small tsunamis that were witnessed on the north coast of Grenada. Detailed studies of the physical structure of Kick-'em-Jenny conducted in 2002-2004, however, have shown that the volcano does not currently pose an immediate tsunami threat, but it is possible that future eruptions could change this situation. The University of the West Indies Seismic unit constantly monitors this volcano and will change the warning status depending on the state of activity. During the last 50 years there have been volcanic eruptions in St. Vincent in 1979 and in Montserrat in 1997. The risk of volcanic eruptions displacing people in the Eastern Caribbean islands is high.

Figure 5.1: Eastern Caribbean Islands with Volcanic origin shown in red.

Several negative impacts can be expected from natural disasters. The utilities and road infrastructure can be severely damaged. When the electrical distribution system is affected it can take months before remote areas are reconnected and so an appropriate backup supply of electricity is required, especially since diesel and gasoline are usually in short supply after a major disaster. A significant number of solar water heater panels and photovoltaic panels can be destroyed on roofs in a severe storm, and corrugated steel roofing is very vulnerable during a major storm. Water supply is usually disrupted for an extended period, as well as communication by internet and telephone. Social life is disrupted and activities such as banking and teller machines are severely affected.

There will be a need to supply shelter at the community centres for months after a natural disaster. The medical centres need to be supplied with adequate emergency power supply to preserve medication and sterilize equipment. The medical personnel will be under severe stress levels to attend to injuries and also to attend to their personal problems.

Natural disasters will have different effects on the buildings depending on the type of natural disaster. For volcanic activity the health/medical centres and community centres in the disaster area will have to be vacated. Neighbouring centres will be required to accommodate the displaced residents. After a severe hurricane many of the buildings might lose their steel roofings, and tarpaulins will be used to make temporary roofing. After a severe earthquake the building walls can be destroyed. However temporary shelter will still need to be constructed and power will still be needed for critical loads.

Figure 5.2: Showing tarpaulin roof on buildings after hurricane Ivan (Grenada)

Figure 5.3: Haiti 2010 earthquake aftermath

5.3 Survey of existing health centres, medical stations and community centres

There are two categories of health facilities in Grenada. The larger ones are called health centres and the smaller facilities are identified as medical stations. There are five health centres, 27 medical stations and 24 community centres designated as hurricane shelters. All the operational health centres were visited and samples of medical stations and community centres were also visited to have an idea of the activities taking place at these locations. The operational loads under normal conditions were also established so that projections can be made as to the capacity of any renewable energy system that may be recommended. Table 5.2 summarizes the locations of the various centres.

Table 5.2: Listing of health centres, medical stations and community centres (shelters)

Health Centres (5)	**Medical Stations (27)**		**Community Centres / Shelters (24)**	
	St. George	**St. Andrew**	**St. George**	**St. Patrick**
St. George	Good Hope	Birchgrove	Fontenoy (GF)	Chantimelle
St. David	Laborie	Paraclete	New Hampshire(GF)	Mt. Rich
Grand Bras (St. Andrews)	Mourne Jaloux	Mt. Carmel	Mt. Airy (GF)	**St. Mark**
St. Patrick	Grand Anse	Paradise	Good Hope (GF)	Non Pariel
St. John (not operational)	Mt. Moritz	**St. John**	Marian (Model)	Maran
	Happy Hill	Florida	Woburn (GF)	**St. John**
	Snug Corner	Clozier	Cherry Hill (GF)	Clozier
	New Hampshire	Grand Roy	Mt. Moritz (GF)	Black Bay
	Woburn	Gouyave	**St. Andrew**	Mt. Plaisir
	St. Patrick	Victoria	Harford Village	**St. David**
	Union	**St. David**	Upper St. John's	Crochu multi purpose
	Mt. Rich	Perdmontemps	Mirabeau	Corinth (GF)
	River Salle	Vincennes	La Digue	Marlmont Dev Centre
	Tivoli	Westerhall	Pearls	
	Hermitage	Crochu	Union	

Table 5.3 shows the 2011 kWh consumption data collected from Grenlec for 2011 for a sample of the various centres.

Table 5.3: Showing summary table based on actual consumption data supplied from Grenlec.

	2011 data			Ave. Daily
Name	kWh	Floor area (m^2)	kWh/m^2	kWh
St. George's Health Centre	43,517	746.0	58.83	120.88
St. David's Health Centre	5,998	223.0	26.9	16.66
Grand Bras Health Centre	9,135	304.0	30.05	25.38
St. Patrick's Health Centre *	11,885	167.0	71.17	33.01
Mt. Moritz Medical Facility	859	62.0	13.85	2.39
Woburn Medical Facility	1,727	130.0	13.28	4.80
Paradise Medical Facility	3,268	102.0	32.22	9.08
Marian Emergency Shelter	1,676	618.0	2.71	4.66
Mt. Moritz community Centre	6,612	480.0	13.78	18.37
Pearl's Community Centre	390	395.0	0.99	1.08
Chantimelle Community Centre	967	193.0	5.01	2.69
Non Pareil Community Centre	18	231	0.08	0.05

*Floor area chosen for main building but consumption is for at least 4 buildings

5.3.1 Health centres

The health centres all have critical equipment which will be needed in an emergency, including at least one autoclave for sterilization and one or two refrigerators to keep medicines including vaccines. Detailed monthly consumption is given for a sample of facilities.

St. David's:

The St. David's Health Centre has a section of its roof in concrete. There is also adequate space around the building for installing pole or ground mounted solar panels or even small wind turbines. The critical loads in this building are autoclaves, refrigerators, lighting, a nebulizer and other small pieces of equipment. There is no backup generator at the moment in the facility.

Figure 5.4: A section of the roof is concrete and adequate land space around building

Figure 5.5 and table 5.4 indicate that the 2011 average consumption per month fluctuates between 350 to 600 kWh for the year. The average monthly consumption is 500 kWh. A spot reading with an amprobe measured 5.87 amps which equates to 1.2 kW at 230 volts single phase and 0.90 power factor.

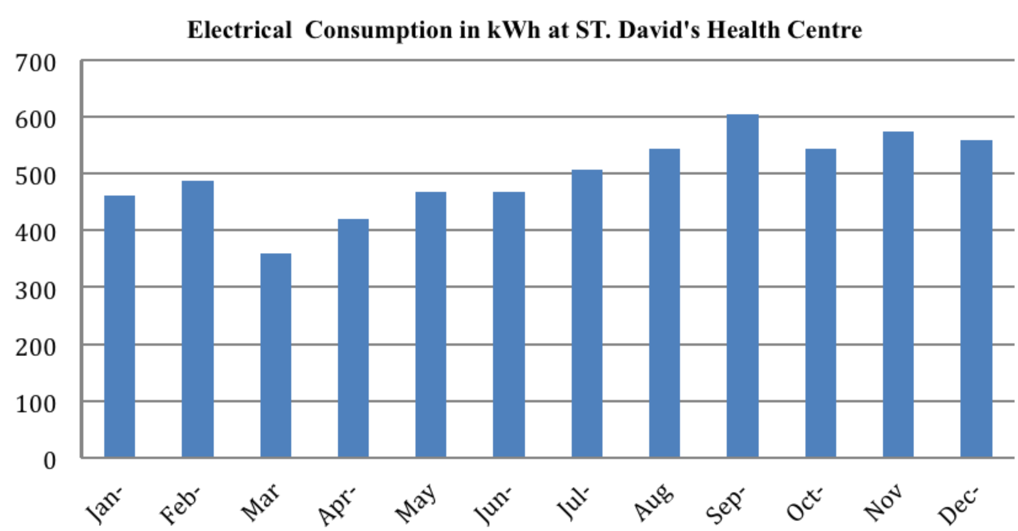

Figure 5.5: St. David's Health Centre 2011 kWh electricity consumption distribution

Table 5.4: St.David's Health Centre 2011 kWh consumption and cost

A. Electrical Energy			Electrical Index (kWh/m²)			
		Electrical Energy	Building	Index	Amount Paid	Energy Cost
Item	Month	Used (kWh)	Area (m2)	kWh/m2	$ EC	EC$/kWh
1	Jan-11	462	223.0	2.07	$620.65	1.34
2	Feb-11	488	223.0	2.19	$500.05	1.02
3	Mar-11	360	223.0	1.61	$582.53	1.62
4	Apr-11	421	223.0	1.89	$654.40	1.55
5	May-11	467	223.0	2.09	$660.21	1.41
6	Jun-11	467	223.0	2.09	$707.66	1.52
7	Jul-11	507	223.0	2.27	$746.42	1.47
8	Aug-11	544	223.0	2.44	$813.57	1.50
9	Sep-11	604	223.0	2.71	$742.47	1.23
10	Oct-11	544	223.0	2.44	$774.91	1.42
11	Nov-11	575	223.0	2.58	$759.26	1.32
12	Dec-11	559	223.0	2.51	$710.42	1.27
	Total	5,998	223.0		$8,272.55	
	2011 (annual)	5,998	223.0	26.90	$8,272.55	1.38
	2011 (month)	499.83	223.0	2.24	$689.38	

St. Patrick Health Centre:

The St. Patrick's Health Centre has its main building roof in concrete. There is also adequate space around the building for installing pole or ground mounted solar panels or even small wind turbines. The critical loads in this building are autoclaves, refrigerators, lighting, and other small pieces of equipment. There is no backup generator at the moment in the facility.

The 2011 average consumption per month fluctuates between 794 to 1,196 kWh for the year. The average monthly consumption is 900 kWh. A spot reading with an amprobe measured 5.55 amps which equates to 1.1 kW at 230 volts single phase and 0.90 power factor.

Grand Bras Health Centre:

The Grand Bras Health Centre has two main buildings. The roof structures on both buildings are corrugated steel sheeting. There is adequate space around the building for installing pole or ground mounted solar panels. The critical loads in this building are sterilizers, refrigerators, lighting, and other small pieces of equipment. There is no backup generator at the facility.

The 2011 average consumption per month fluctuates between 422 to 1,783kWh for the year. The average monthly consumption is 761 kWh. A spot reading with an amprobe measured 5.2 amps which equates to 1.1 kW at 230 volts, single phase and 0.90 power factor.

St. George's Health Centre:

The St. George's Health Centre is a two storey complex located close to the bus terminal and next to the street. The roof structure of the building is corrugated steel sheeting. There is no adequate spacing around the building for installing pole mounted or ground mounted solar panels. This centre is by far the largest and the only one with a three phase supply. There are two dental rooms and a number of other specialized rooms. The critical loads in this building are sterilizers, refrigerators, lighting, and other specialized pieces of equipment. There is no backup generator at the facility.

Figure 5.6: Roof area of St. George's Health Centre

The 2011 average consumption per month fluctuates between 3,011 to 4,118 kWh for the year. The average monthly consumption is 3,626 kWh. A spot reading with an amprobe measured an average of 17.8 amps per phase which equates to 11.1 kW at 400 volts, 3 phase and 0.90 power factor.

5.3.2 Medical stations

The medical stations tend to be located in villages and are a smaller version of the health centres. After a natural disaster they are expected to play a pivotal role in attending to minor medical problems.

Paradise Medical Station:

The Paradise Medical centre has one building. The roof structure is corrugated steel sheeting. There is adequate space around the building for installing pole or ground mounted solar panels. The critical loads in this building are sterilizers, refrigerators, lighting, and other small pieces of equipment. There is no backup generator at the facility.

Figure 5.7: Paradise medical centre

Table 5.5 indicates that the 2011 average consumption per month fluctuates between 219 to 334 kWh for the year. The average monthly consumption is 274 kWh. A spot reading with an amprobe measured 2.0 amps which equates to 0.414 kW at 230 volts, single phase and 0.90 power factor.

Table 5.5: Paradise medical station 2011 kWh consumption and cost

A. Electrical Energy			Electrical Index (kWh/m^2)			
		Electrical Energy	Building	Index	Amount Paid	Energy Cost
Item	Month	Used (kWh)	Area (m2)	kWh/m2	$ EC	EC$/kWh
1	Jan-11	203	102.0	1.99	$207.28	1.02
2	Feb-11	238	102.0	2.33	$249.01	1.05
3	Mar-11	219	102.0	2.15	$236.26	1.08
4	Apr-11	236	102.0	2.31	$263.41	1.12
5	May-11	265	102.0	2.60	$306.08	1.16
6	Jun-11	333	102.0	3.26	$389.28	1.17
7	Jul-11	294	102.0	2.88	$343.49	1.17
8	Aug-11	246	102.0	2.41	$284.83	1.16
9	Sep-11	297	102.0	2.91	$343.44	1.16
10	Oct-11	334	102.0	3.27	$385.18	1.15
11	Nov-11	306	102.0	3.00	$350.88	1.15
12	Dec-11	315	102.0	3.09	$363.19	1.15
	Total	3,286			$3,722.33	
	2011 (annual)	3,286.00	102.0	32.22	$3,722.33	1.13
	2011 (month)	273.83	102.0	2.68	$310.19	

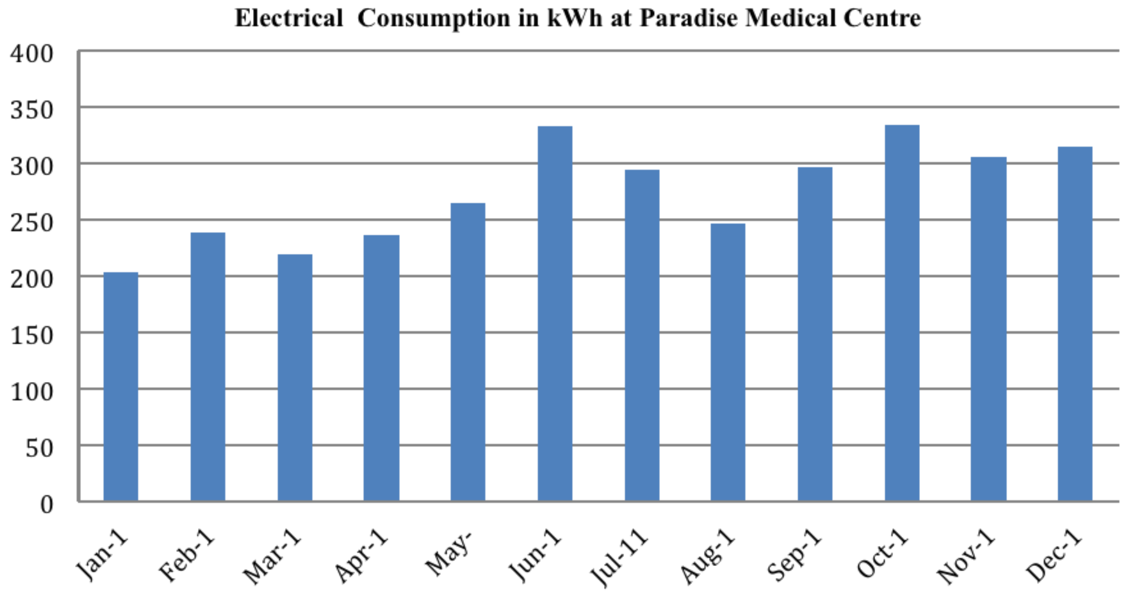

Figure 5.8: Paradise Medical Station 2011 kWh electricity consumption distribution

Mt. Moritz medical station:

The Mt. Moritz Medical centre has one building. The roof structure is corrugated steel sheeting. There is adequate space around the building for installing pole or ground mounted solar panels. The critical loads in this building are sterilizers, fridges, lighting, and other small pieces of equipment. There is no backup generator at the facility.

The 2011 average consumption per month fluctuates between 50 to 81 kWh for the year. The average monthly consumption is 71.6 kWh.

Snug Corner:

The Snug corner has a two storey building. The roof structure is corrugated steel sheeting. There is adequate space around the building for installing pole or ground mounted solar panels. The critical loads in this building are sterilizers, refrigerators, lighting, and other small pieces of equipment. There is no backup generator at the facility.

Woburn medical station:

The Woburn medical station is a single storey building. The roof structure is corrugated steel sheeting. There is adequate space at the back of the building for installing pole or ground mounted solar panels. The critical loads in this building are sterilizers, refrigerators, lighting, and other small pieces of equipment. There is no backup generator at the facility. The 2011 average consumption per month fluctuates between 104 to 177 kWh for the year. The average monthly consumption is 144 kWh.

5.3.3 Community centres (shelters)

There are many community centres in Grenada. Those surveyed in this study are the ones which are dedicated as shelters for the community. Some of them have computers for use by the community and the loads are also needed to operate lights, refrigeration and music systems.

Crochu Multi Purpose Centre:

The Crochu Multi Purpose Centre is a multi storey building. The roof structure is corrugated steel sheeting with a portion of it being concrete (289 sq. ft). There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are computers, refrigerators, air conditioners, and music system. There is no backup generator at the facility. This facility is overlooking the sea and the residents indicate that the wind is always blowing in that area. From all the sites visited for this survey this is the only one which may have potential for wind energy.

Figure 5.9: Crochu Multi Purpose Centre roofing and corrugated steel sheetings

A spot reading with an amprobe measured 6.82 amps which equates to 1.41 kW at 230 volts, single phase and 0.90 power factor.

Pearls Community Centre:

The Pearls community Centre is a multi storey building. The roof structure is corrugated steel sheeting with a portion of it being concrete (1,740 sq. ft). There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are computers, refrigerators, fans and a music system. There is no backup generator at the facility.

The 2011 average consumption per month fluctuates between 24 and 112Wh for the second half of the year. The average monthly consumption is 32.5 kWh. A spot reading with an amprobe measured 0.95 amps which equates to 0.20 kW at 230 volts, single phase and 0.90 power factor.

Chantimel Community Centre:

The Chantimel community Centre is a single storey building. The roof structure is totally concrete (2,080 sq ft.). This building is a fortress for hurricanes. There is adequate space on the site for installing or ground mounted solar panels. The loads in this building are lights, refrigerator and music system. There is no backup generator at the facility. The 2011 average consumption per month fluctuated between 40 and 124 kWh for the year. The average monthly consumption was 81 kWh.

Non Pariel Community Centre:

The Non Pareil community Centre is a two storey building. The roof structure is corrugated steel. There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are lights and music system. There is no backup generator at the facility. The 2011 average consumption per month fluctuates between 1 and 5 kWh for the year. The average monthly consumption is 1.5 kWh.

Clozier Community Centre:

The Clozier community Centre is a single storey building. The roof structure is corrugated steel. There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are lights, computers, refrigerator and music system. There is no backup generator at the facility. This part of Grenada is very rainy and although there will be solar radiation it will be at lower levels to other parts of Grenada.

Mt. Moritz community centre:

The Mt. Moritz Community Centre is a two storey building. The roof structure is corrugated steel. There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are lights, refrigerator and music system. There is no backup generator at the facility. This community is very active and this is reflected in the electricity consumption.

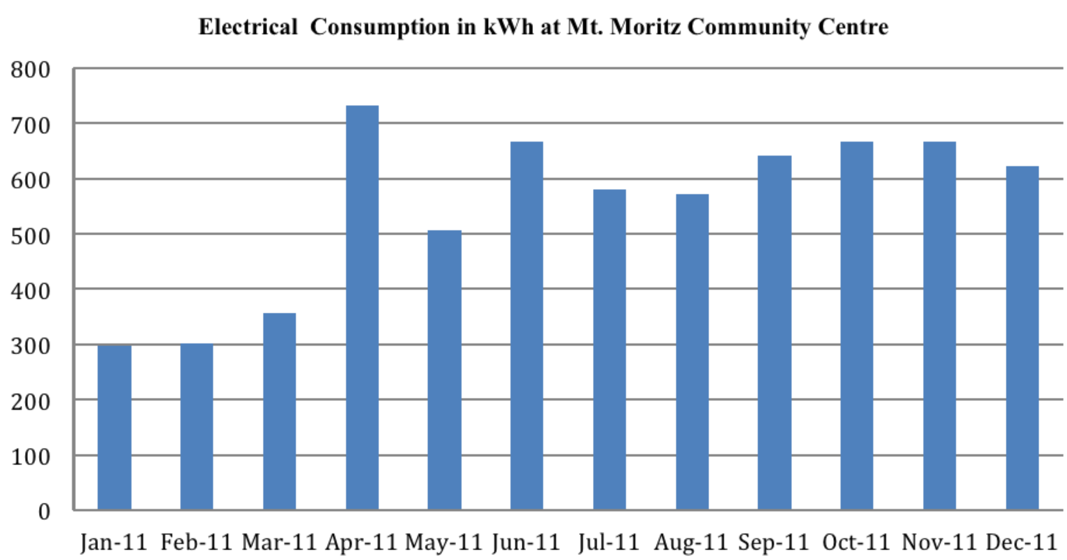

Figure 5.10: Mt. Moritz community centre 2011 kWh electricity consumption distribution

Table 5.6 indicates that the 2011 average consumption per month fluctuates between 301 and 733 kWh for the year. The average monthly consumption is 551 kWh.

Table 5.6: Mt. Moritz community centre 2011 kWh consumption and cost

A. Electrical Energy			Electrical Index (kWh/m^2)			
		Electrical Energy	Building	Index	Amount Paid	Energy Cost
Item	Month	Used (kWh)	Area (m2)	kWh/m2	$ EC	EC$/kWh
1	Jan-11	298	480.0	0.62	$312.07	1.05
2	Feb-11	301	480.0	0.63	$380.77	1.27
3	Mar-11	356	480.0	0.74	$812.17	2.28
4	Apr-11	733	480.0	1.53	$583.69	0.80
5	May-11	506	480.0	1.05	$779.66	1.54
6	Jun-11	668	480.0	1.39	$677.95	1.01
7	Jul-11	580	480.0	1.21	$663.05	1.14
8	Aug-11	571	480.0	1.19	$742.63	1.30
9	Sep-11	642	480.0	1.34	$769.64	1.20
10	Oct-11	667	480.0	1.39	$766.94	1.15
11	Nov-11	668	480.0	1.39	$716.60	1.07
12	Dec-11	622	480.0	1.30	$648.52	1.04
	Total	6,612			$7,853.69	
	2011 (annual)	6,612.00	480.0	13.78	$7,853.69	1.19
	2011 (month)	551.00	480.0	1.15	$654.47	

Marian Model Shelter:

The Marian model shelter community Centre is a two storey building. The roof structure is corrugated steel. There is adequate space on the site for installing pole or ground mounted solar panels. The loads in this building are lights, refrigerator and music system. There is no backup generator at the facility. This community is very active and this is reflected in the electricity consumption. The 2011 average consumption per month fluctuates between 93 and 207 kWh for the year. The average monthly consumption is 140 kWh.

5.4 Assessment of current status and weakness to support natural disasters

In general the structures surveyed are still vulnerable, many of them having steel corrugated roof. Some of the sites have a portion of the facility's roof structure in concrete and there is at least one of them with a totally concrete roof. During a major hurricane roofs are expected to be damaged as they have been in the past. Some of the community centres are designated as shelters only for the lower floor since they have concrete as the flooring for the upper level. In case of an earthquake, there will be extensive damage as most of the buildings are not designed to withstand any major earthquake. Although Grenlec has designed its distribution more robustly since Hurricane Ivan in 2004, prolonged outages are expected in the outer parishes after a major disaster.

None of the facilities surveyed is currently equipped with backup generators. Given the financial constraints of the local government, it is important to seek full financial support for a commissioned project when the project is being designed.

5.5 Practical renewable energy alternatives after a natural disaster

The two most realistic renewable energy alternatives for the sites are wind and solar. Out of the many sites there is only one site with a wind potential. Usually a wind study has to be conducted on a site before committing capital to this option. Grenada's solar isolation profile is very high compared to many countries of the world. This makes solar technology a very attractive proposal for power source after a natural disaster. Therefore, the most practical solution for an alternative energy source to supply the sites after a natural disaster seems to be solar.

5.5.1 Solar PV Homer model

The solar resource for Grenada was estimated using NASA's surface Solar Data Set. A copy of the Homer simulation model was downloaded and used to generate the specific information for Grenada (NASA, 2011). Figure 5.11 presents data on modeled solar resources of Grenada. The information summarizes the daily radiation values in kWh/m^2/d incident on a horizontal surface for each month of the year. The data also show the clearness index for each month. This is a measure of the clearness of the atmosphere. A high value indicates a clear day and a low value a cloudy day.

	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.579	4.953
February	0.585	5.453
March	0.589	5.952
April	0.542	5.720
May	0.538	5.689
June	0.492	5.156
July	0.507	5.318
August	0.523	5.489
September	0.516	5.269
October	0.512	4.868
November	0.510	4.439
December	0.554	4.588
Average	0.536	5.240

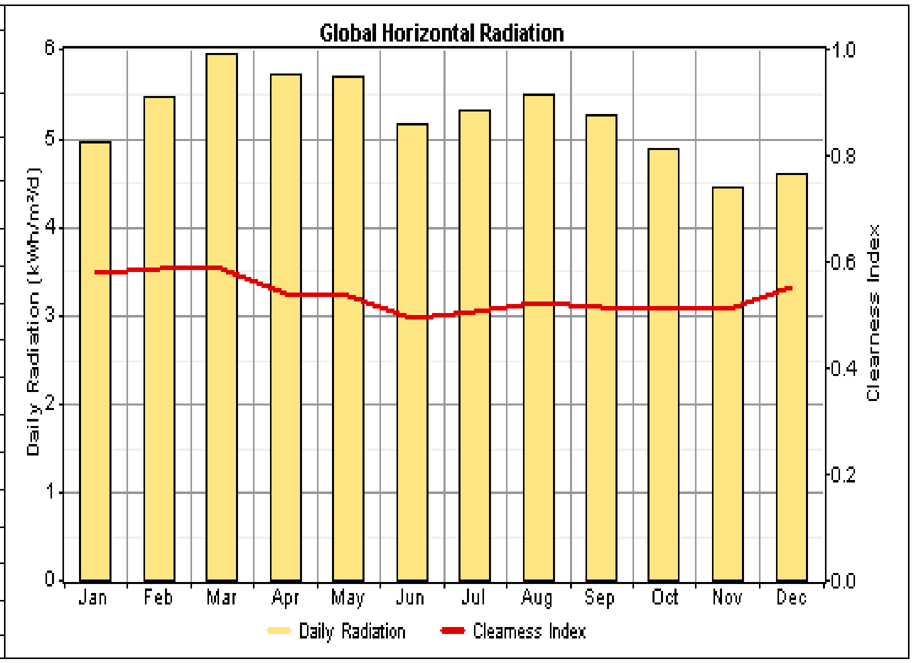

Figure 5.11: Modeled Solar Resource of Grenada

A PV model was created in the Homer software for a PV panel under conditions of Figure 5.11. In this model, the following was assumed:

- 18% panel efficiency based on current commercially available silicon-PV technology.
- DC to AC efficiency of the Inverter is 87%.
- Mounting of the PV panels is fixed.
- Panel tilt of 12° above the horizontal position which is roughly equivalent to the island's latitude.

The model 1 kW PV system has an estimated daily average production of 4.40 kWh/day.

Table 5.7: Simulated performance summary of 1kW PV system on Grenada

Quantity	Value	Units
Rated Capacity	1.0	kW
Mean output	0.18	kW
Mean output	4.40	kWh/dy
Capacity factor	18.3	%
Total production	1605	kWh/yr

5.5.2 Solar system types

There are different options available on the market. For this project the combination of the stand alone system and grid interactive system is most appropriate. The grid interactive system can be modified to have a larger battery pack to compensate for the fact that it will be needed for natural disasters. The different systems available include: Stand Alone, Grid Connected, and Grid Connected with Backup (GrenSol, 2012).

Stand Alone system

During the day, the generation of the solar energy system is usually higher than the consumption in the house. Any excess electricity is used to charge a large battery pack in order to store the energy.

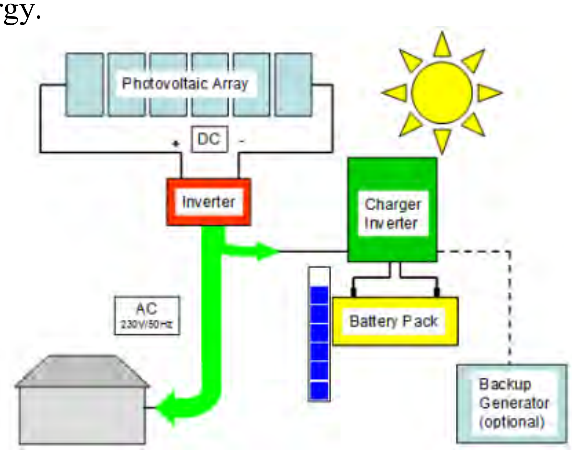

Figure 5.12: Stand alone system during the day
(GrenSol, 2012)

During the night, the solar energy system produces no electricity. The required power is taken from the batteries that were charged during the day.

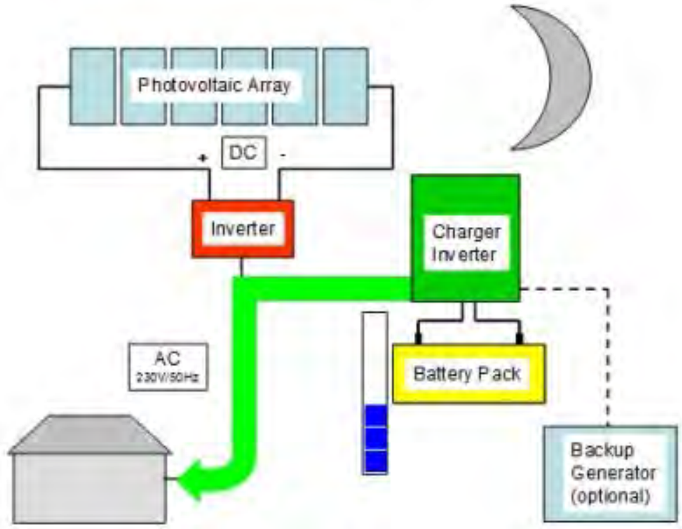

Figure 5.13: Stand alone system during the night
(GrenSol, 2012)

The system consists of:
- Photovoltaic Array (solar panels), usually installed on roof
- Inverter, which converts the DC (direct current) to AC (alternating current)
- Charger Inverter to control charging of batteries
- Battery Pack, sized for the amount of electricity needed for consumption

Grid connected

During the day, the production of the solar energy system is usually higher than the consumption in the house. As a consequence, the excess electricity is fed into the power line, i.e. one gives electricity to the public power company (Grenlec) – the meter spins backwards.

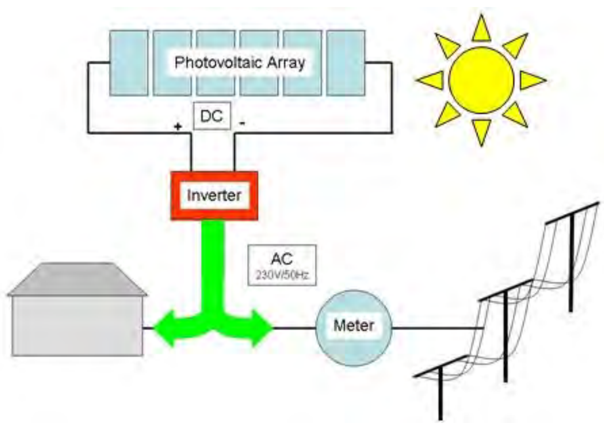

Figure 5.14: Grid connected during the day
(GrenSol, 2012)

During the night, the solar energy system produces no electricity. The required electricity is now taken from the power line, i.e. one gets back electricity from the public power company.

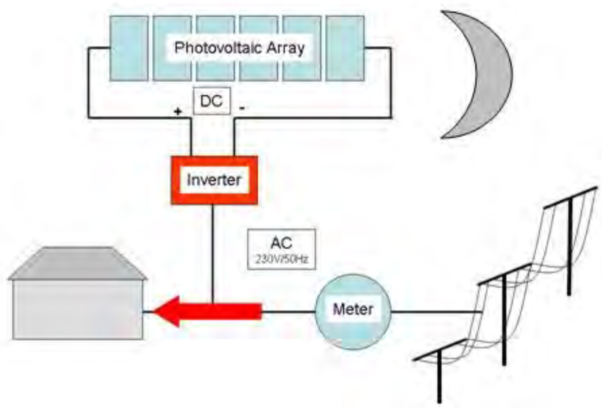

Figure 5.15: Grid connected during the night
(GrenSol, 2012)

The system consists of:
· Photovoltaic Array (solar panels), usually installed on roof
· Inverter, which converts the DC (direct current) to AC (alternating current)
· Charger Inverter to control charging of batteries
· Small Battery Pack for emergencies and fallout of public power supply

Grid connected with backup

Public power supply on: The system works in grid-connected mode with the usual give and take between solar electricity and energy from the power-line.

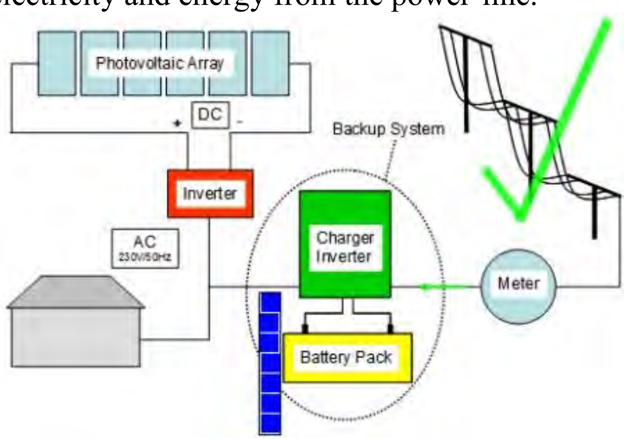

Figure 5.16: Grid connected with backup, public power supply on
(GrenSol, 2012)

Public power supply off: In case of an interruption in the power supply, the system disconnects automatically from the power-line and switches over to stand-alone mode within less than a second (similar to a backup generator).

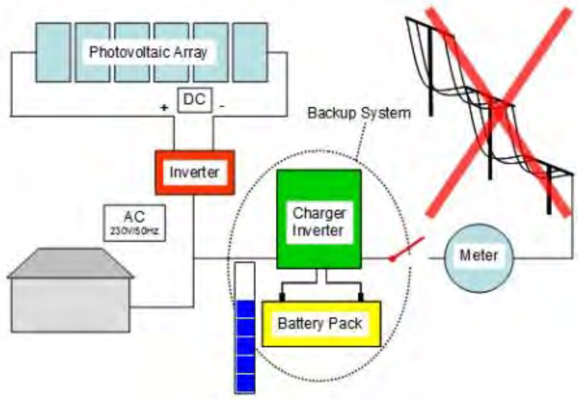

Figure 5.17: Grid connected with backup, public power supply off
(GrenSol, 2012)

The system consists of:

- Photovoltaic Array (solar panels), usually installed on roof
- Inverter, which converts the DC (direct current) to AC (alternating current)
- Charger Inverter to control charging of batteries
- Small Battery Pack for emergencies and fallout of public power supply

5.5.3 Sizing an appropriate unit

The proposed system for use is the one which includes a photovoltaic array, inverter, battery- grid interactive system and battery pack. In this system electricity generated by the PV panels is used to power the building's electrical loads. Any excess (or deficit) is supplied or absorbed by the grid. The batteries are kept fully charged by the charge controller. With this system during an outage the grid-interactive system will continue to supply current to the batteries via the battery storage. The PV panel will continue supplying current to the batteries through the charge controller. When power is restored from the grid the inverter/chargers help recharge the batteries while the grid powers the AC loads.

The following example shows rough sizing of a photovoltaic grid interactive system for typical health and medical centres and community centres (shelters) on Grenada. The loads for the different facilities during 2011 can be expected to increase for the community shelters and medical stations after a major disaster. St. George's Medical Centre is not considered due to the unavailability of ground space to mount the panels and also due to its load as compared to the other facilities. Systems of 15 kWh/dy are proposed.

The peak load on the system to run the medical centres will be at a minimum:
Autoclave = 2.0 kW
Lights (5 T8 florescent fixtures double) = 0.36 kW
2 refrigerators = 0.40 kW
Others = 0.50 kW
Minimum peak load on system = 3.26 kW

The proposed peak load is 5 kW to provide power for facilities to operate fully and to cover expected loads without load shedding.

- Average daily consumption: 15 kWh/dy
- Average daily production from 1kW PV at 12 degree tilt: 4.40 kWh/day (18.3% capacity factor)
- Capacity of PV needed to offset estimated annual consumption: 15/4.40 ≈3.5 kW
- Minimum inverter size = 3.5kW

Battery Sizing:

- Average amp-hours per day at 48 VDC: 15000 Wh per day/48 VDC=312.5 Ah/dy at 48 VDC
- Divided by inverter efficiency≈ (92%): 340 Ah/dy at 48 VDC
- Divided by battery efficiency ≈ (75%): 453 Ah/dy at 48VDC
- Divided by battery depth of discharge≈ (60%): 755 Ah/dy at 48VDC

Battery sizing depends on the desired autonomy. For example a battery system with autonomy of three days (3 x755 Ah=2265 Ah) would be able to provide the facility with power for three days if both the grid and PV panels were disabled. Three days autonomy is the minimum which should be considered to ensure maximum life of the batteries.

An approximation of the area required for the panels is 65 sqft. /kW. Therefore a 3 kW system will require approximately 195 sq ft of space for installation purposes. A 5 kW system will require 325 sq ft.

5.5.4 Panel mounting options

Several options for mounting are possible. The following are the most common of the options:

- Pole Mount (with or without typhoon protection and tracker). Fixed or retractable technology.
  - Automatically folds a tracker wing when tracker not working
  - At night and in case of typhoon or rain. It automatically stops and reclines a tracker horizontally when wind speeds go above 20 m/sec (45 mph)
- Platform mount
- Roof mount: this option is feasible where all the mountings and wiring can be designed for quick disconnection. During a storm the panels can be removed from the roof and secured. The drawback to this option is that there might not be a roof to reassemble the panels after the hurricane. This solution is therefore only feasible for sites with concrete roofing.
- Ground level mount (with or without tracking capabilities)

5.5.5 Security and space considerations

Batteries will need to be secured by installing them in lockable cabinets. Also, because the PV arrays will be ground mounted except where there is a concrete roof, it is recommended that an 8 ft. wall be constructed around the area used for mounting the panels. This will serve as a security feature for the panels to prevent damage and it will reduce the possibility of wind damage during a hurricane. The PV systems recommended for evaluation will be capable of 3 and 5 kW peak power and 15 kWh daily output. Assuming 65 sqft/kW, at least 325 sq ft will be required for installing the panels for the largest system and more space will be required to construct a protective wall around the system.

5.5.6 Solar hot water consideration

In addition to the installation of PV systems for the generation of electricity, at least an 80-gallon solar hot water system can be installed at the facility to provide for hot water demand. This too can be ground mounted for security during high winds. Flat plate collectors or evacuated tube type solar hot water systems are the alternatives. The evacuated tube type is more efficient but will be more expensive to install and also maintain. Water temperatures in these systems can get as high as 140°F (60° celsius). Solar Dynamics is an example of a major supplier in the Caribbean and their 66-gallon unit is certified to provide 863.5 Btu/Sqft of panel sizing. (Solar Dynamics, 2012).

In Grenada the present cost of purchasing and installing a flat panel model of 80-gallon capacity is approximately US$ 2,000.

5.6 Cost and benefits from installation of energy alternatives

Considering only the energy savings (avoided cost of fuel or per kWh cost of electricity) in a cost benefit analysis will be misleading since the payback period will be higher than 10 years.

In the face of a natural disaster, supply of electrical power becomes of paramount importance in a medical centre or community shelter because of the following reasons:

a) It is essential for the preservation of medicines that help to prevent the spread of diseases
b) It will provide power to run essential medical equipment
c) In a community centre it will provide basic lighting and refrigeration services for those who are dislocated from their homes.

In short, the consequences of having no power source can be disastrous. In addition to the huge benefits of having a power source after a natural disaster by installing the units before disasters and protecting then during the actual event, additional benefits can be accrued by having the effect of reducing the cost per kWh of electricity to the facility.

Presently the installed cost of PV units is approximately US$ 7-10 per watt. Grenlec allows users to sell directly to the grid at US$ 0.17 per kWh which is the avoided cost of burning diesel fuel. In one year the 5 kW units can produce at least 20 kWh per day for 300 days or 6,000 kWh which priced at US$0.17 is US$ 1,020. To improve the payback of the project, consideration can be given to disconnecting the facilities from the grid and operating then as standalone systems. In this situation the savings per kWh of electricity will increase from US$ 0.17 to US$0.42.

A budget cost has been provided for two systems which are basically similar and will produce 15 kWh per day with 3 and 5 kW max load (GrenSol, 2012). A system of 5 kWp and 28 batteries and other equipment including installation costs is estimated to be approximately US$ 47,000.

5.7 Policy options to support and maintain renewable energy systems designed for operation during and after natural disasters

The following policy options need to be considered:

- As part of a general policy it is important that a recognized code be used for the construction of buildings in Grenada. These buildings should be built to withstand earthquakes and hurricanes. This should be strictly enforced by the Planning Division. A building code is currently in the process of being enacted by Parliament.

- The use of the most advanced solar panels with the highest efficiency is recommended as this reduces the footprint requirements for installing the panels. Also, normal deep cycle batteries tend to have a life of 4-8 years. Industrial type batteries like the crown and rolls 4ks series can have a life of 10-20 years. Rolls-Surrette premium deep cycle batteries with a life of 7-15 years is an alternative. Longer life batteries should be considered for purchase.

- Grenlec has a policy which can impact on the renewable energy market. Effective in 2012, customers are no longer allowed to use the power from wind turbines and PV systems and sell the excess. Customers must now sell all the power generated once connected to the grid at US$ 0.17 per kWh. The price offered to customers selling power to Grenlec will be based upon an annual average of avoided fuel cost, with a fixed ten-year option and a variable option. A low purchase price by Grenlec will have a negative impact on payback and therefore the attractiveness of the investment (Grenlec, 2012). Consideration can be given to run the systems as stand alone and totally disconnected from the grid. This will mean that the savings from the energy cost would be US$ 0.42 and improve the economic feasibility of renewable energy projects.

- The above policy is a disincentive to development of the alternative energy market. It is important to develop a policy to liberalize and regulate the energy markets. Tariffs should be set by the independent regulator and should be designed to make the market environment competitive and the investment viable.

- NADMA (National Disaster Management Agency) should consider a policy to identify safe zones some distance away from the coast for the locations of medical centres and community centres (shelters). This will reduce the risk of damage during tsunamis, floods or high seas.

- Grenada now has a draft National Energy Policy which is being discussed before being enacted into Law. This will be a key document which can support the implementation of renewable energy technologies.

- Maintenance considerations are important to design into the project. There will be a need to change batteries approximately every 5-10 years and consideration needs to be given to the source of funds for replacement. An alternative consideration is to dry store the batteries and only use them after the actual natural disaster. A responsible institution has to be given responsibility for maintaining the units after installation.

5.8 Conclusions and Recommendations

In Grenada the most immediate threat from natural disasters is the threat of hurricanes. Hurricanes have the potential to displace a large percentage of the population and plans must be in place to mitigate the difficulties which the populace will experience after a natural disaster.

A grid interactive solar PV system with backup batteries is the best energy alternative for use after a disaster. However the PV arrays need to be protected. The best way to protect the panels is to ground mount them and to surround them with concrete barrier walls. Alternatively if a concrete roof space is available then detachable panels with quick disconnect fittings can be used. The protective glass on the PV array can also be selected for resilience.

The recommended size for consideration is one of a maximum capacity of 5 kW and capable of providing 15kWh per day.

To complement the PV electrical supply, solar water heater panels can also be considered for installation at the facilities.

The best option is to use solar PV systems which are grid interactive with battery storage. These could be installed before a natural disaster and its electric generation will assist in reducing the cost to the facilities. A major challenge will be the selection of the stations and community centres.

Initial consideration to be given to selecting the sites for PV installation are as follows:

- Four medical centres. St. George Health Centre is too large and does not have ground space. Additionally St. George is on the priority line to the General Hospital and is the first to be repaired after a disaster.
- Two medical stations per parish for five parishes for a total of 10 units.
- Two community centres per parish for six parishes for a total of 12 units.

- Subject to budgetary availability hot water systems can be installed at the same locations as the PV systems.
- A further selection requirement will be the availability of sufficient and suitable ground space to install the PV modules at the locations or alternative concrete roofing to install the PV system for quick disconnection in case of a hurricane.
- Height above sea level can also be a consideration for community centres.

For synergies in the effort, coordination needs to be done between similar projects for Carriacou and a project being developed by the Ministry of Finance to ensure that economies of scale are employed to get purchasing and installation cost reduced.

Possible projects

Project 1: Renewable Energy Systems for Medical Centres and Community Centres
Aim: Design /install grid-interactive distributed energy systems for all qualifying medical centres and community centres (shelters).
Description: A 5 kW grid interactive solar PV system (with batteries) for facility would require an investment of approximately US$ 50,000. The government should explore grants to fund the installation of these systems for all identified complexes as a matter of urgency for the safety of residents in case of a natural disaster. Ensure that high efficiency and durable systems are considered for the project. Batteries with at least a life of 10 years should be considered.

Project 2: Installation of Solar Water Heaters for Medical Centres and Community Centres.
Aim: Design and install solar water heaters for all qualifying medical centres and community centres (shelters)
Description: A simple solar heater system with 80-gallon water capacity would require an investment of approximately US$2,000. The government should explore grants to fund the installation of these systems for all identified complexes as a matter of urgency for the safety of residents in case of a natural disaster.

These projects need to be sustainable after installation and the responsible institution for the maintenance and care of the units must be identified from the time of installation. Batteries tend to need replacement in approximately 5-10 years depending on the quality and their replacement must be budgeted for. Consideration can be given to disconnecting the smaller facilities from the grid totality so that the feasibility of the projects can be improved. Further investigation can be done to obtain carbon credit funds for these projects.

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6. Conclusions

This chapter provides a summary of the main conclusions of this study on the main priority areas of water resources in Northern Grenada, restoration of coastal ecosystems and renewable energy for medical and community centres after natural disasters.

6.1 Water resources in Northern Grenada

Northern Grenada is endowed with several sources of surface water including rivers, springs and lakes. Ground water resources are limited and have not been explored in Northern Grenada.

Water management and security is a multi-sectoral issue and many groups and institutions would need to participate in order to meet the future demand of water in Northern Grenada. An Integrated Water Resource Management (IWRM) approach is required under a revised governance structure.

The transformation of water resources management will require adequate time, given the physical, socioeconomic and cultural characteristics of Northern Grenada. National and regional initiatives (including the National Water Policy) and the efforts to mainstream water resources management into the development of a green economy can facilitate this transformation. Increasing storage capacities is necessary, yet not sufficient. While various water storage options have comparative advantages their development may be affected by social constraints.

Opportunities in integrating water and energy can improve key sectors such as agriculture, tourism, and domestic supplies. These opportunities are likely to be more successful through small projects that can be managed by individuals or at the community level with the support of central agencies.

6.2 Restoration of coastal ecosystems

Grenada's main coastal ecosystems include beaches, littoral forests, mangroves, coral reefs, seagrass beds, rivers, estuaries and wetlands. These ecosystems offer protection to the coastline against hurricanes, coastal erosion and habitats. They also have the potential to help Grenada adapt to projected sea level rise.

There is no monitoring programme for coastal ecosystems and the data related to the size of these ecosystems may not be accurate. Legislation for the protection of mangroves was drafted more than a decade ago but to date still has not been finalized.

The health of these ecosystems in Grenada is in decline and the negative impacts of climate change can add further stress. There are many direct and indirect threats affecting the coastal ecosystems, including deforestation of mangroves and littoral forests due to encroachment of existing developments or construction of new developments. Other threats include litter, over-fishing, pollution from inland and marine sources, diebacks, storm surge and wave action, and introduction of invasive species like Lion Fish.

Civil society organizations are playing a leading role in the conservation, restoration and management of coastal ecosystems in Grenada, but there is no policy which formally recognizes their role. There is also a need for management plans with accompanying enforcement mechanisms.

Coastal resource users can be empowered to take a leadership role in the restoration and subsequent management of coastal ecosystems. There is also need for capacity building among civil society organizations, community groups and staff of government departments involved in coastal resource management.

Several government departments are responsible for enforcement of relevant coastal zone management legislation. Capacity needs to be developed within government departments to allow for enforcement of coastal ecosystem legislation.

6.3 Renewable energy for medical and community centres

The most immediate threat from natural hazards that could result in disasters in Grenada is the threat of hurricanes. Hurricanes in the past have displaced a large percentage of the population of Grenada, and plans must be in place to reduce the suffering which the vulnerable populace may experience after a natural disaster.

In general the structures surveyed are still vulnerable, many of them having steel corrugated roofs. During a major hurricane, roofs are expected to be damaged in many buildings as they have been in the past.

None of the facilities surveyed is currently equipped with backup electric generators. Although some changes have been implemented to allow a more robust electric system since Hurricane Ivan in 2004, prolonged outages are expected in the outer parishes after a major disaster. Given the financial constraints of the local government, it is important to seek full financial support for a commissioned project when the project is being designed.

The health centres all have critical equipment which will be needed in an emergency, including at least one autoclave for sterilization and one or two refrigerators to keep medicine including vaccines. The medical stations tend to be located in villages and are a smaller version of the health centres. Nevertheless, after a natural disaster they are also expected to play a pivotal role in attending some medical problems.

There are many community centres in Grenada with electric supply systems that might be affected after a natural disaster. Those surveyed in this study, which are the ones dedicated as shelters for the community, have electric loads that operate lights, refrigeration and music systems, and in some cases computers.

An assessment of health facilities in Grenada determined that the grid interactive solar photovoltaic system with backup batteries is the best energy alternative for use in medical and community centres after a disaster.

7. Recommendations

This chapter is a compilation of the recommendations which have been selected to form the basis for project concepts. It is expected that these concepts will be further developed into project proposals.

7.1 Water resources in Northern Grenada

There is a need to improve the availability of data on water quality in Northern Grenada; therefore, it is recommended that a framework for monitoring the chemical and biological quality of the main rivers, lakes and waterfalls be developed and implemented.

Given the constraints to a natural expansion of water resources in Northern Grenada to meet future demand, programmes that can postpone the need for additional storage should be used where possible. It is therefore recommended that the Integrated Water Resource Management road map, which was developed, be implemented. If necessary, storage systems that combine and build on complementarities of different storage types and are responsive to local conditions should be favorably considered for implementation.

Rainwater harvesting has many advantages in meeting the daily water supply needs for agriculture and domestic purposes and in mitigating water shortages during disasters. It is therefore recommended that adequate resources and incentives be provided for an enhanced promotion of rainwater harvesting in Northern Grenada.

To meet the growing demand of water for agriculture and landscaping in tourism, it is recommended that a programme to improve the technical know-how in the design and installation of rainwater harvesting ponds be developed.

To reduce the demand for water at the household level, it is recommended that the government provide a package of incentives for the procurement of low-volume and low energy faucets.

7.2 Restoration of coastal ecosystems

The spatial mapping of coastal ecosystems to determine their size and location and to provide baseline information in order to monitor trends is recommended as a priority action. The mapping exercise will provide information which can then be used to organize a national replanting of littoral and mangrove forests.

A Public Education and Outreach programme focusing on climate change and coastal ecosystems must be implemented if coastal ecosystem restoration activities are to be successful.

The elaboration of a sustainable use plan and guidelines for coastal resources is needed to build resilience of the coastal ecosystems.

A capacity building programme on coastal ecosystems for communities, civil society groups and relevant government departments should be initiated to support the implementation of the sustainable use plan. The plan has to be accompanied by monitoring and enforcement programmes for coastal ecosystems.

A legislative review of laws applicable to coastal ecosystems and rivers has to be one of the priority areas for consideration.

7.3 Renewable energy for medical and community centres

Solar photovoltaic systems that are grid interactive with battery storage is recommended as the best option for providing energy to medical and community centres during and after natural disasters.

If put into operation prior to natural disasters, their electricity generation will assist in reducing related costs to these facilities. Initial consideration should be given to selecting sites for the installation of these solar systems at five medical centres. Further selection criteria should be applied to determine the availability of sufficient and suitable ground space or concrete roofs to install the photovoltaic modules at the selected locations.

The appropriate size for a system depends on the specific size and services the centres provide for the communities. An average size that can be considered is one of a maximum capacity of 5 kW and capable of generating 15 kWh per day.

The assessment also concluded that the best way to protect the solar panels is to ground mount and surround them with a protective concrete barrier wall. For those buildings with concrete roof space available, detachable panels with quick disconnect fittings can be used. Protective glass on the PV array can also be used for resilience.

It is also recommended that hot water systems be installed along with photovoltaic systems in some centres. Consideration should be given to the installation of these systems in at least two medical centres in each of five parishes and at two community centres in each of six parishes.

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