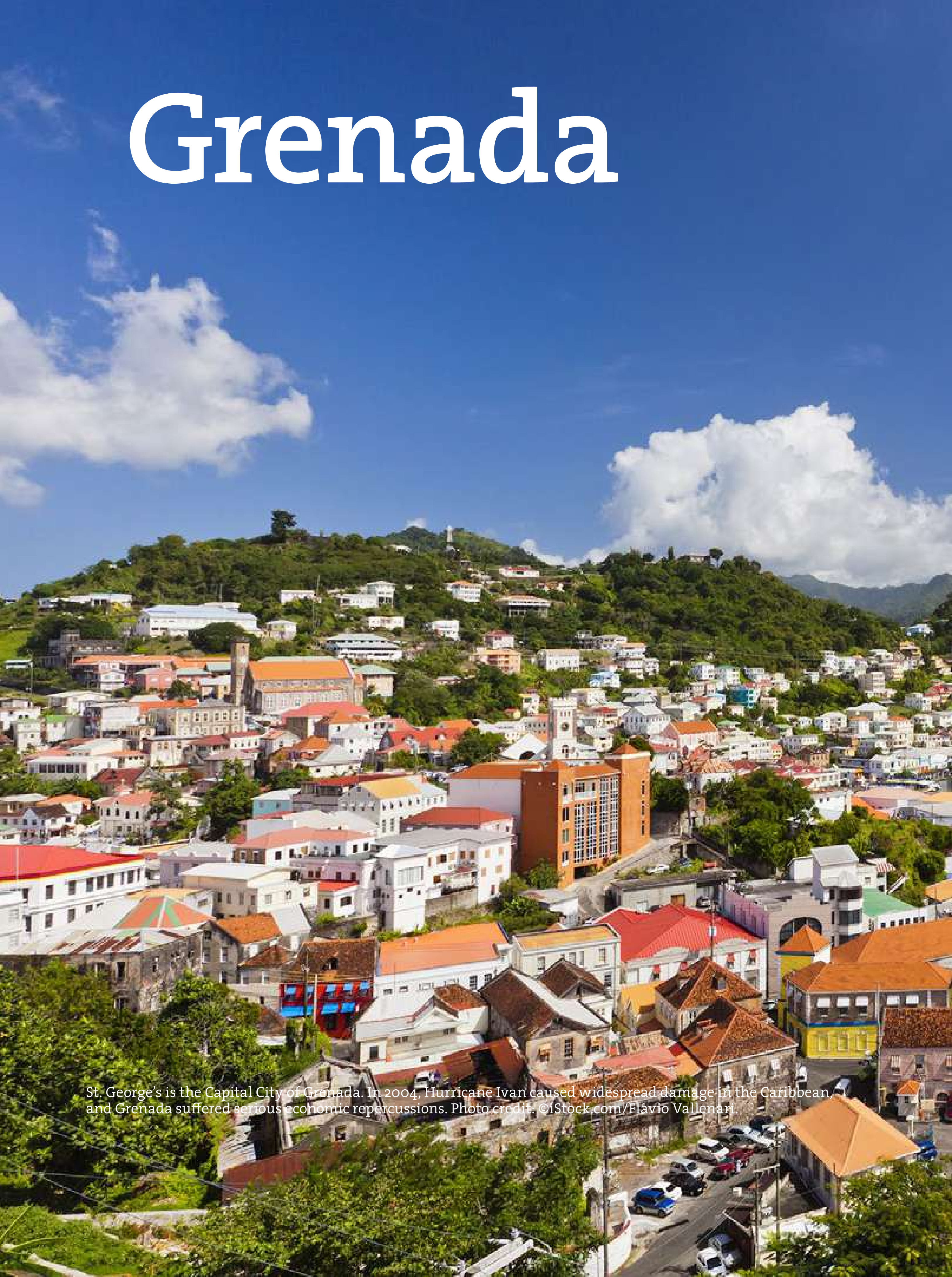
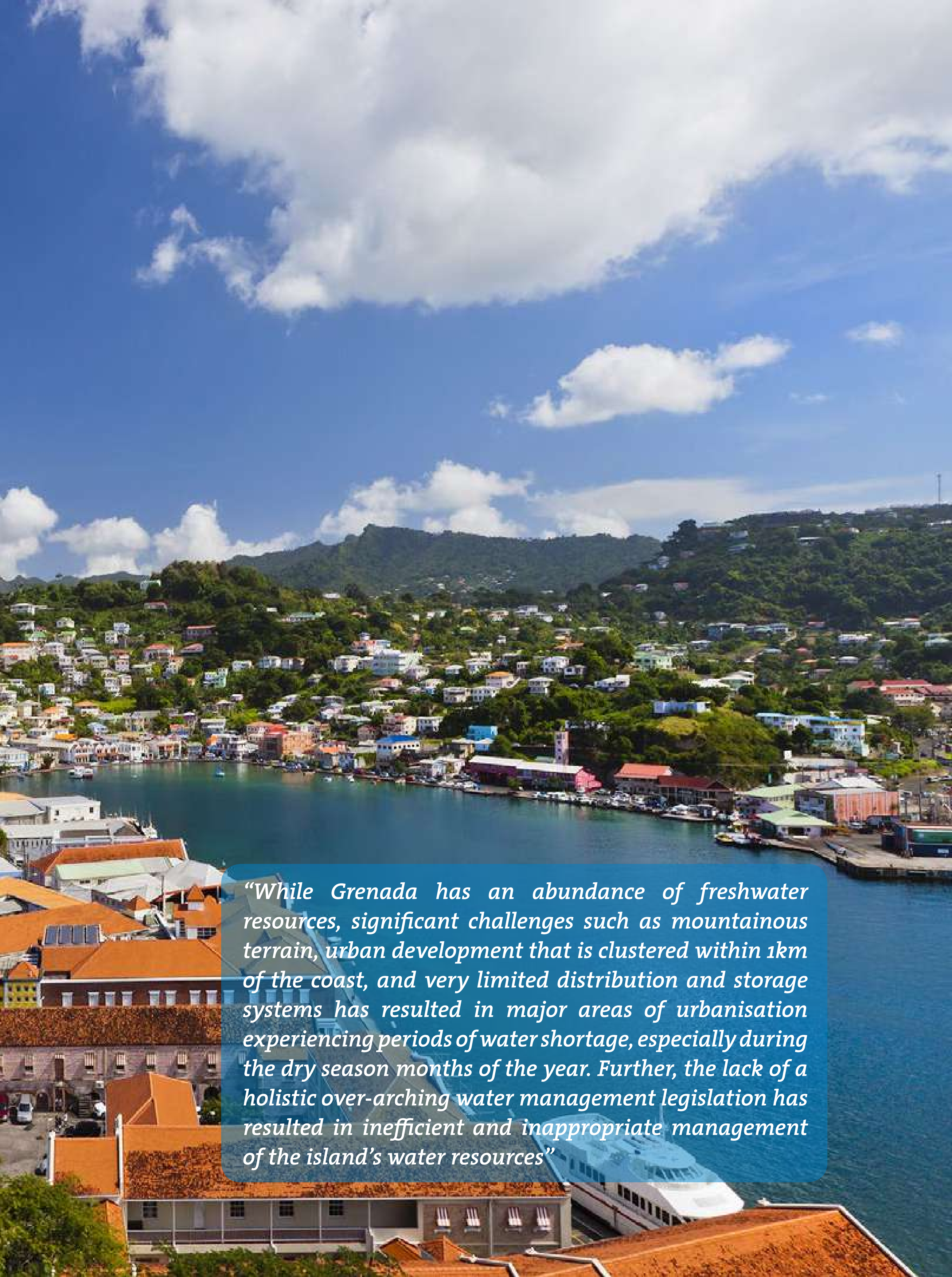
Grenada



St. George's is the Capital City of Grenada. In 2004, Hurricane Ivan caused widespread damage in the Caribbean, and Grenada suffered serious economic repercussions. Photo credit: ©iStock.com/Flavio Vallenari.



"While Grenada has an abundance of freshwater resources, significant challenges such as mountainous terrain, urban development that is clustered within 1km of the coast, and very limited distribution and storage systems has resulted in major areas of urbanisation experiencing periods of water shortage, especially during the dry season months of the year. Further, the lack of a holistic over-arching water management legislation has resulted in inefficient and inappropriate management of the island's water resources"

Impact of Development on Water Supply and Treatment in Grenada

Martin S. Forde and Brian Neff

Summary

Urbanization is not a phenomena limited to developed countries but is also occurring in many developing nations such as Grenada which is located within the Caribbean region. While defining clear-cut urban areas for an island that has a population of approximately 100,000 spread over a very small area (312 km^2) may be somewhat challenging, clear evidence of increasing rates of development and clustering of human activities can be identified on the main island of this tri-island country. Two parishes in particular on the main island –St. George's and St Andrew's– can be considered as 'urban' parishes since about 60 percent of the population lives in these two parishes.

Fundamentally, Grenada has an abundance of freshwater resources, however, several challenges currently exist in the management of these resources. As a result, water supply problems exist and prove challenging to resolve. Key challenges associated with managing a growing presence of urban centers, particular in the south of the main island, range from legislative (e.g. no holistic over-arching water management legislation currently exists) to administrative (the sole water provider is also responsible for evaluation of water provisioning services) to difficult geographic realities (e.g., piping water from sources in the North to areas in the South where the demand exists over mountainous terrain).

1. Introduction

Urbanization is not limited to developed countries but is also occurring in many developing nations including those located within the Caribbean region. Indeed, the Caribbean is one of the most urbanized regions in the world with approximately 69% residing in urban settings. By 2015, the Caribbean is expected to see an absolute urban population increase of 4 million.

It should be noted that the highest rates of urbanization are not taking place where the largest cities are located but rather in previously remote or sparsely populated areas. This may be due to national policies which encourage the development of certain areas for tourism purposes.

Among the many reasons why those who live in Caribbean islands are choosing to live in urban areas is the greater availability of public utilities such as piped water, which may be limited or even unavailable in rural areas. The resulting increased demand on water utilities to supply an ever increasing amount of potable water to these growing urban areas can and does impose challenges on water utility providers as they strive to meet this demand while at the same time not compromising on the continuous availability or quality of water delivered.

The Caribbean region consists of a heterogeneous mix of islands that can be differentiated by language, geographies, land geologies, levels of economic development and political history, and culture. Rather than try to present a chapter detailing the impact of urbanization on water resources for the whole Caribbean, this chapter will focus on one English-speaking Caribbean country, Grenada. The issues and challenges experienced by this very small island will obviously not be fully representative of other much larger islands (e.g., Trinidad, Jamaica), however, much of what is discussed here in this chapter for Grenada will also be seen in many of the other English-speaking small island states located in the Caribbean.

1.1 Location of Grenada

Grenada, located between latitude 110 59’ and 120 20’ North and longitudes 610 36’ and 610 48’ West, is the most southerly island of the Windward Islands (Figure 1). The country comprises of three main islands: Grenada, Carriacou, and Petite Martinique. Grenada is the largest of the three islands (312 km^2), followed by Carriacou (34 km^2), which is located 24 km to the North East of Grenada, and Petite Martinique (2 km^2), which lies east of the Northern section of Carriacou. Thus the total area of the island country is approximately 348 km^2 and the total length of the coastline is 121 km. Administratively, the island of Grenada is divided into six parishes. Carriacou and Petite Martinique are administratively managed as the seventh parish.

Figure 1. Map of Grenada, Carriacou, and Petite Martinique

Source: wikipedia.org

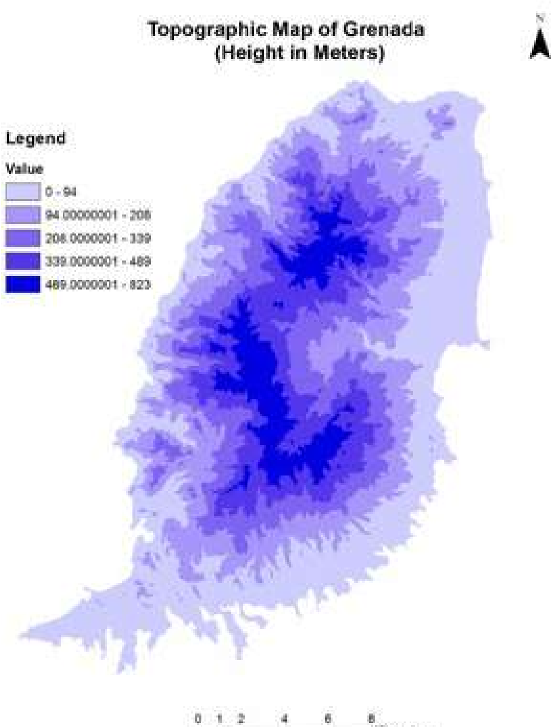
1.2 Geology and Geography

Grenada is located in the Lesser Antilles, which is a long arc of volcanic islands in the Caribbean Sea (Figure 1). Of the three main groups of which the Lesser Antilles is sub-divided into, Grenada belongs to the Windward group of islands, which starts with Dominica in the North and then continues down to Martinique, St. Lucia, St. Vincent & the Grenadines, and finally Grenada in the South.

Grenada is mostly of volcanic origin with a mountainous center which quickly descends towards the flatter coastline (Figure 2). The islands of Carriacou and Petite Martinique are also of volcanic origin and represent the exposed summits of peaks on a single narrow bank of submerged volcanic mountains.

Approximately 70% of the mountain slopes in Grenada have a gradient greater than 20˚ which predisposes terrestrial resources to rapid water runoff and land degradation. The highest peak is Mount St. Catherine at 840 m. Steep mountain peaks, sharp ridges and deep narrow valleys sloping towards the coastline thus characterize the topography of the main island of Grenada. Seventy-five percent of the total land area lies below 305 meters while 23.4 percent lies between 305 meters and 610 meters and 1.6 percent lies above 610 meters. Further, due to the very short 10 km average distance from the mountain peaks to the coast, there is low soil water holding capacity. Clay loams (84.5%), clays (11.6%) and sandy loams (2.9%) are the main types of soils found in Grenada. The coastline itself is ringed by extensive coral reefs.

Figure 2. Topography of Grenada



Source: Government of Grenada

1.3 Climate

Grenada experiences a semi-tropical climate within the Atlantic northeast trade wind belt characterized with an average temperature range from 24˚C to 30˚C. The average temperature is 28˚C. Temperatures at sea level are generally high with little diurnal or spatial variation due to the effect of the adjacent ocean.

Seasonal shifts in the trade winds give rise to two main seasons –a dry season, which runs from January to May, and a wet season which runs from June to December. Approximately 77% of the annual rainfall occurs in the wet season.

The marked spatial variation in rainfall pattern across Grenada is due to the difference in orthographic elevations (Figure 3). The high mountainous areas are cooler compared to the low coastline areas which are warmer. Annual evapotranspiration has been estimated to vary from 1000 to 1500 mm. High rainfall intensities are common and this leads to severe soil erosion on the sloping lands. Mountainous areas can experience an average of about 3,880 mm whereas lower areas along the northern and southern coastline can experience a much lesser average of 1,125 mm annually.

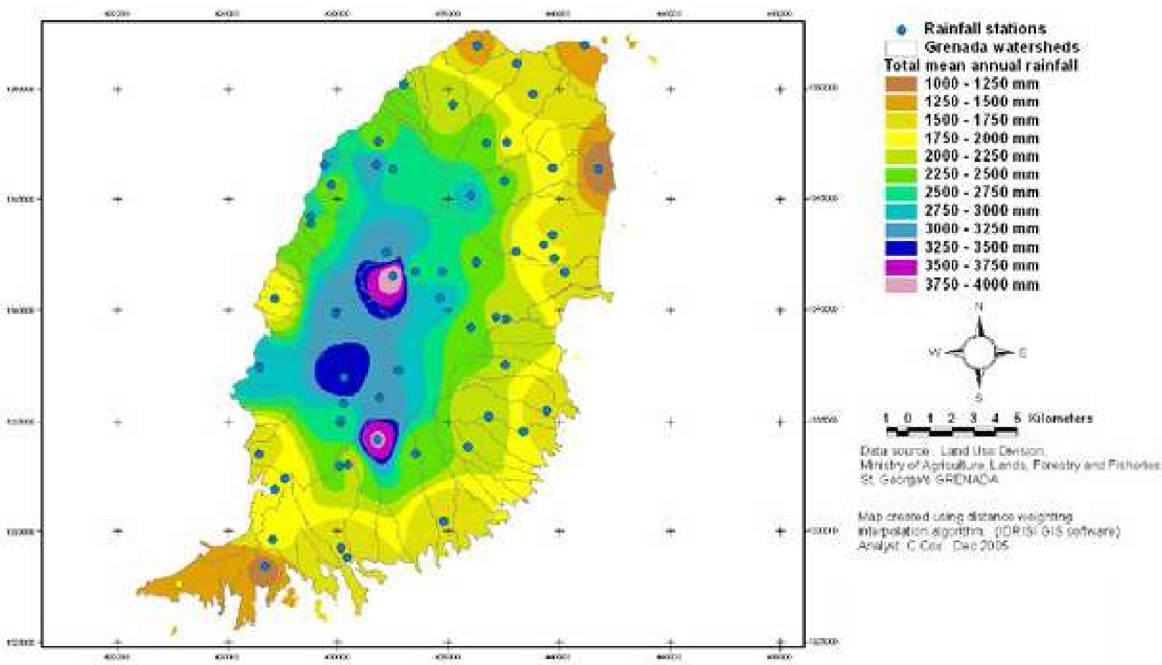
This gives rise to different climatic zones as depicted in Figure 3. Thus, some parts of the island experience moderately warm temperatures between 20˚C and 22.5˚C, no dry season, and rainfall in excess of 4000 mm whereas other parts of the island are characterized by very warm temperatures over 27.5˚C, a long dry season, and rainfall ranging between 700 mm and 1000 mm.

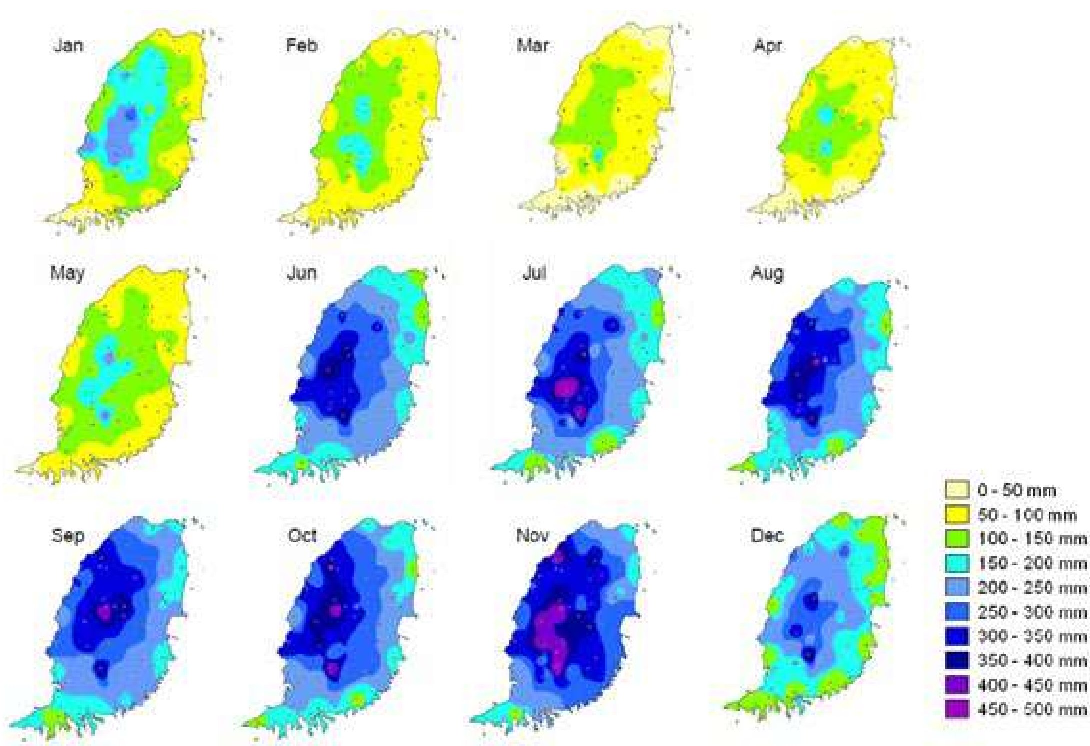
For Carriacou and Petite Martinique, due to their small size and relatively low elevations, both of these islands are significantly drier than Grenada with annual rainfall being only around 1,000 mm. In all three islands, however, extended dry periods and extreme drought conditions during the dry season are not uncommon and indeed over the past decade have become more pronounced.

1.4 Land Use

Grenada's total land area is 31,334 ha. Land use in Grenada is closely linked to its agrarian history as a primary commodity producer of sugar in the

Figure 3. Climatic zones - Grenada





Source: (CEHI, 2006a)

recent past to now where more tree crop products such as nutmeg, cocoa, and bananas are cultivated. Additionally, a lot of subsistence farming now takes place with the land that is being used for such cultivation moving more and more from the lower areas up and onto the mountainsides. As a result, the amount of forest acreage has steadily declined since the 1960s to the present.

Although it is difficult to determine the exact magnitude of land use change over time in Grenada due to unavailable data, over the past two decades, several significant land use changes have been observed. Firstly, the rate of abandoned cropland dramatically increased from 144 ha in 2000 to over 2,428 ha in 2009, which is equivalent to a 1685% increase in the amount of lands abandoned from use for crop cultivation (Roberts, 2013). Secondly, land characterized as urban and built-up areas increased by almost 25% from 1,825 ha (5.8%) in 2000 to 2,267 ha (7.2%) in 2009 (Roberts, 2013). Especially following the passage of Hurricane Ivan in 2004, the rebuilding efforts which followed witnessed a massive expansion of construction activities and conversion of abandoned agricultural estates and pastures in coastal areas into tourism, commercial and residential use. This still ongoing increasing trend in urbanization with its attendant increased demand for land for housing and non-agricultural purposes continues to lead to further encroachment on remaining agricultural lands and key watershed areas.

In Grenada, as well as most other small Caribbean islands, small farmers undertake a significant percentage of the agriculture industry. With the exception of the Grand Etang Forest Reserve, most of the historical large plantation estates have been sold and subdivided into smaller lots allowing for mass private ownership. The typical size of most lands used for agriculture is less than 5 hectares. Nearly 75% of the farm sizes in Grenada are less than 0.8 ha in size. However, this represents less than 15% of the agricultural lands with approximately 50% of the agricultural lands being held in holdings varying from 1 to 10 ha. The FAO in 2007 estimated that though forested land in Grenada has declined to 12% and agricultural land to 35%, only 2% of total land area is designated as protected areas.

Other major land use problems observed in Grenada are listed below:

- Illegal developments and squatter settlements;
- Land use conflicts among the agricultural, tourism and construction sectors;
- More settlements vulnerable to disasters including flooding, land slides and rising sea levels;
- Environmental management concerns;
- Inappropriate and inadequate land tenure arrangements and institutional capacity for land management; and
- Lack of adequate legal and regulatory frameworks.

1.5 Demographics

The island of Grenada is administratively divided into six parishes with the other two islands –Carriacou and Petite Martinique (PM)– being administratively treated as one parish (Table 1). Based on 2011 census data, Grenada's population is estimated to be 105,539 persons with a gender split of 51% females and 49% males. Annual population growth averaged 0.6% annually for the period 1981 to 2001. The current population density is about 307 persons per km^2.

Given Grenada's mountainous terrain, most of the population resides within 1 km of the coastline with many settlements located around the mouths of rivers. The southern parish of St George, where most of the industrial and tourism activities are located, accounts for 36% of the population. The largest parish, St Andrew, accounts for 24% of the population with the rest of the population being fairly evenly distributed among the other parishes (Table 1).

The Grenada population is relatively young with about 50% of the population under 25 years old. The labor force now stands at approximately 42,000 persons. A recent poverty assessment survey (Government of Grenada, 2007b) revealed that 37% of the population is deemed to be poor with 53% of the population deemed to be economically vulnerable.

1.6 Urbanization in Grenada

Two parishes –St. George's and St Andrew's– can be considered as 'urban' parishes since about 60 percent of the population lives in these two parishes. It is estimated that for the period 2001 to present the annual population growth rate was 0.7%. The parish

Table 1. Geographical Distribution (2011 census) and Population Density by Parish

Parishes	Population					
	1991	2001	2011	Land Area (km^2)	2011 Density ($/km^2$)	2021
St. George (town)	4,621	3,628	3,100	1	3,100	N/A
St. George (Rest)	27,373	27,951	34,304	64	536	40,726
St. John	8,752	9,374	8,404	35	241	13,382
St. Mark	3,861	4,676	4,346	25	174	4,654
St. Patrick	10,118	11,537	10,461	42	250	12,218
St. Andrew	24,135	27,114	26,433	99	267	28,508
St. David	11,011	12,637	12,858	44	293	9,891
Carriacou/PM	5,726	6,219	5,633	34	166	6,982
Total	**95,597**	**103,136**	**105,539**	**344**	**307**	**116,361**

Source: Ministry of Finance, 2014

with the fastest population growth is the parish of St. George, which is most likely due to the fact that most of the island's tourism activities are located in this parish and the tourist industry in expanding. The population density for the parish of St. George is approximately 570 inhabitants/km^2 which is significantly higher than the national average of 307 inhabitants/km^2.

In general, the majority of Grenada's 300 towns and villages are located in the coastal areas with linear inland extensions along valleys and ridges. The main urban centers in Grenada are the capital, St. George's, Grenville in the parish of St. Andrews, and Gouyave in the parish of St. John. In Carriacou, the largest settlement is Hillsborough. All of these urban centers are located in coastal areas and are predicted to grow to contain over 60% of the country's population by 2050.

1.7 Water Management in Grenada

In Grenada, although the responsibility for supplying, producing and distributing water throughout the tri-island state has been assigned to the National Water and Sewage Authority (NAWASA), management functions are very fragmented. The responsibility to preserve and protect all water catchment areas has also been given to NAWASA. It should be noted that while NAWASA has a nominal presence in Carriacou and Petite Martinique, both of these islands predominantly rely on self- or communal supplies of water. Water governance and reform efforts are discussed further in Section 3.4.

2. Water Sources and Problems Caused by Urbanization

2.1 Overview of Water Sources in Grenada

The island of Grenada is reasonably well resourced with respect to fresh water (Figure 4). There are many rivers, streams, and lakes on the main island which contrasts with Carriacou and Petite Martinique where no perennial fresh water rivers or streams exist.

Grenada has 71 distinct watersheds of which the largest watershed, the Great River catchment comprises 4,521 ha whilst the smallest is the Crayfish catchment, 27 ha (Figure 5). Most of these watersheds have perennial flows, however, flows can drop significantly during the dry season. Of the 71 watershed catchments, 23 are utilized for water supply.

Carriacou has 20 watershed areas. No differentiation is made for Petite Martinique due to its small size. There are no permanent streams or springs in both of these very small islands. Water supplies in Carriacou and Petite Martinique depend almost exclusively on the harvesting of rainwater in

Figure 4. Rivers, streams and watersheds in the six parishes of Grenada

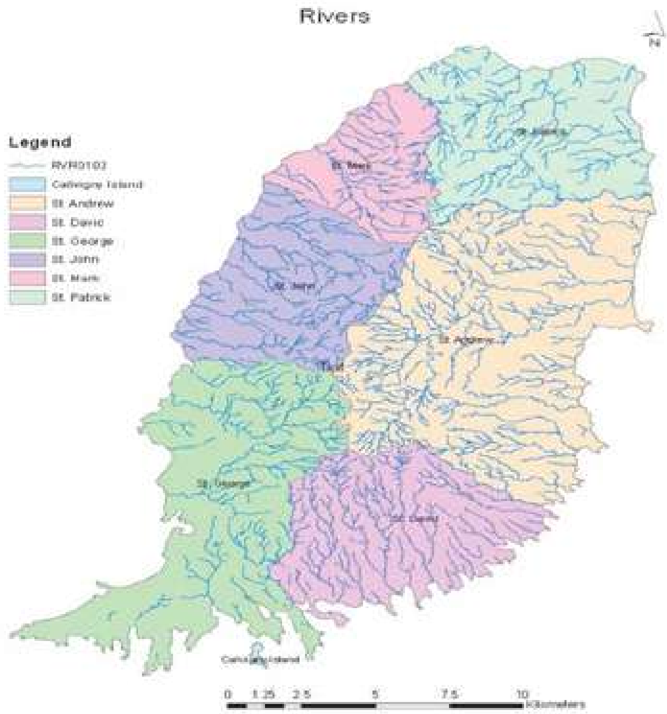
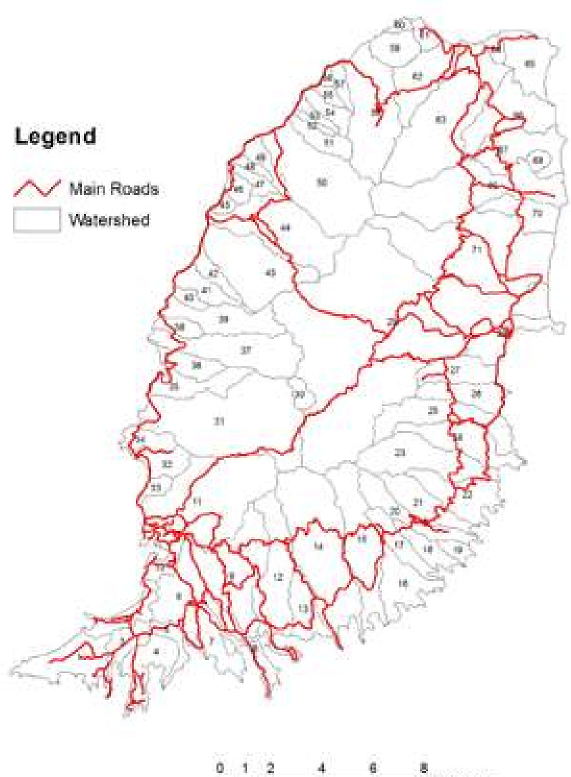


Figure 5. Watersheds in Grenada



Source: Government of Grenada

cisterns, while water for agriculture and livestock comes mainly from the withdrawal of groundwater and surface water stored in ponds. A 2001 water supply study for Carriacou concluded that island-wide community rainwater collection systems totaling 15 ha with provision for a total of 22,000 m^3 of storage is sufficient to meet to the island's water needs.

Although there are estimates of the mean yield from the watersheds used for water supply, consistent, accurate data or a comprehensive assessment of surface water resources is not available. Additionally, there is very little long-term, consistent stream-flow data, especially for low and high flow periods.

2.2 Surface Waters

Arising out of its volcanic past, there are three crater lakes –Grand Etang Lake (8 ha), Lake Antoine (17 ha) and Levera Pond (23 ha)– the most important for providing water to the south of the island being Grand Etang lake, which is located in the center of the island. The natural dry season outflow of the Grand Etang lake has been measured as exceeding 2,270 m^3/day.

Given the increasing demand for water particularly in the urban south of Grenada as a result of construction and investment in the tourism sector, the provision of adequate water supply has become very important particularly in the dry season when there is maximum usage and at the same time reduced stream flow. As a result, the Grand Etang Lake is used as a source in the dry season as well as bore holes located in the south and south east of Grenada. There is also a full time borehole facility in Carriacou.

2.3 Groundwater

Exploitable groundwater resources in Grenada lie in three valleys located in the south of the island: Woodland (448 m^3/day), Chemin Valley (1,648 m^3/day) and Baillie's Bacolet (917 m^3/day) giving a grand total of 3,013 m^3/day. Presently, only about 5-10% of current water demand is met from groundwater supplies, primarily during the dry season to help supplement surface water supplies. Although more groundwater could be exploited, water quality issues, in particular taste, as well as the costs in pumping this water to the surface mean that this source of water is used only on a limited basis.

Another concern regarding the increased use of groundwater is salt-water intrusion. A 2001 study, however, that was conducted to review the potential impact of sea-level rise as a result of global climate change found that this impact was minor when compared with the threat posed by over pumping of the aquifers. Again, as with surface water data, there is currently no consistent data collection program in place that would allow assessment of the quality, quantity, water balance, subsurface flows or outflows of potential groundwater supplies.

2.4 Water Production

NAWASA operates 23 surface water sources mostly located in upper catchment areas to supply the water needs for the island of Grenada. A 2006 review estimated that the rainy season yield of these sources was 54,600 m^3/day which dropped to a maximum of 31,800 m^3/day in the dry season. Again, it is noted that current reports do not provide consistent data which makes it very difficult to evaluate what is the true yield of each water source which, in turn, makes it difficult to design appropriate intake works, water treatment facilities, and pipeline transmission capacities.

A 2006 water deficit mapping exercise indicated that during the statistically driest month of March, the total raw water yields from the 23 catchments utilized by NAWASA were extremely low in cases where the mean monthly rainfall was close to or below the evapotranspiration losses. This fact is very significant since during the month of March the estimated daily national demand exceeds water from surface sources. While utilizing raw water storage, mainly water that has been storage in the Grand Etang Lake, helps somewhat to compensate for this shortfall, this situation highlights the water scarcity situation that prevails during the dry season months.

The same study mentioned above extended the water deficit analysis to generate spatial variation in the number of cases where evapotranspiration exceeds rainfall input and found that the northern and southernmost coastal areas of the island of Grenada have the longest water deficit periods. This is of particular concern since the greatest amount of development and urbanization is taking place in the southernmost coastal areas. Further, this problem is likely to get much worse before it gets better since this very same area is also where the 'tourist belt' lies. Current and projected future plans indicate that the tourism industry in going to continue to steadily expand both in this size and demands in the coming years.

In 1998, a 1,818 m³/day desalination plant was installed in order to help augment the water supply to the southern communities. Similar but smaller plants were also installed in Carriacou (454 m³/day) and Petite Martinique (136 m³/day) but both are currently in various states of disrepair. Several large hotels in the south of the island also have installed their own small desalination plants to augment their water supplies. One institution, St. George's University, which is located on the southern tip of the island, has installed a large desalination plant which has a capacity to produce 908 m³/day. Present consumption ranges from 340 to 450 m³/day, which allows it to take care of all of its current water requirements.

As previously mentioned, rainwater harvesting supplies almost 100% of the demand to households in both Carriacou and Petite Martinique.

2.5 Water Supply and Demand

Currently, 97% of the urban population and 93% of the rural population has access to potable water. Per capita consumption values for Grenada have been estimated to range from 130 L/day to 150 L/day; in Carriacou and Petite Martinique consumption rates are estimated to be 100 L/day. Unaccounted for water (UFW), also referred to as non-revenue water, has been estimated to be 33% of production.

Water demand estimated for the year 2010 for the north and south of Grenada indicate an average daily demand (ADD) of 31,877 m³/day, or annual demand of 11.6 million m³ (Table 2).

The 23 surface water and 6 ground water supply facilities in Grenada produce 12 million gallons per day (mgd) in the rainy season which drops to a minimum of 8 mgd in the dry season (Figure 6). The demand for water in the rainy season is 10 mgd which rises to 12 mgd in the dry season. Assuming

Figure 6. Monthly surface and groundwater supply (mgd, stacked bars) and demand (line)

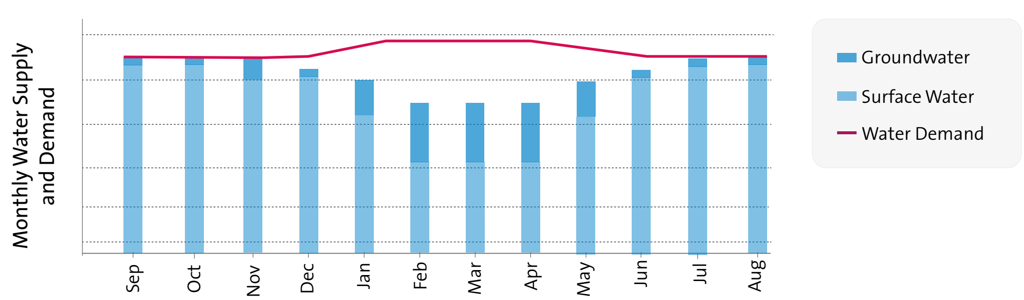


Table 2. Water demand estimates for Grenada 2010

Area	Total Cons. (m³ /d)	UFW (m³/d) *	ADD (m³/d)	Water Production (driest week 1999/2000) (m³/d)	Water Production (avg. annual 1999/2000) (m³/d) **
Northern Grenada	9,094	4,479	13,573		8,835
Southern Grenada	12,076	6,228	18,304	16,540	20,761
Total	**21,170**	**10,707**	**31,877**		**29,596**

Sources : Stantec (2001), Witteveen+Bos (2001). Notes: * Unaccounted for water (UFW) 33% of production for northern Grenada, and 30% for southern Grenada. ** For northern Grenada, plant capacity in 2001.

that no significant change takes place with respect to NAWASA's water production capacity, it can then be concluded that there will be, in particular for the southern region of Grenada, a significant shortage of water during the dry season months of the year.

One way NAWASA is trying to mitigate this shortfall is by increasing water storage capacity. Based on a 2007 (Government of Grenada, 2007b) review of Grenada's water sector, available water storage capacity in the rainwater catchments can just meet the 100-day minimum requirement for dry season demand from the present human population, but the water available from ponds and dug wells can meet only 80% (80 days) of demand from the livestock.

2.6 Problems Caused by Urbanization on the Water Sector

Urbanization, and more generally ongoing economic development, particularly in the tourism industry, coupled with continued demographic growth have led to rising demand for potable water and challenges in managing Grenada's water resources. Over the past 30 years, maintenance and needed upgrades to water resource infrastructure has not kept pace with the demands that have been placed upon them. As a result, the present water supply system is not adequately resilient to ensure that supply for good quality water in the quantities required are met, especially in the dry season. This situation in further compounded by poor enforcement of water resource management regulations and the very weak financial position of the agency, NAWASA, who is mandated to provide and maintenance adequate water resources to the public.

A review of Grenada's water sector done in 2007 identified four key challenges for the sustainability of integrated water resources management and water services:

1. **Financial Sustainability:** The government of Grenada's historically poor and limited access to financial resources has meant that it has been very difficult to source sufficient funds to finance the necessary capital investments needed to ensure the adequate provision of infrastructure for water resources, as well as find the funds to carry out needed maintenance and eventual replacement of water resources as these suffer wear and tear.
2. **Institutional Sustainability:** In Grenada, the same agency –NAWASA– that supplies water to the country also regulates itself. There is thus a need to establish an independent water resources management unit that can do water mapping, demand projection, and water quality assurance testing.
3. **Operational Sustainability:** This is contingent of the pricing of water services to recover full costs and investing the capital raised in operation and maintenance to provide better service standards. As it currently stands, the government sets what rates NAWASA can charge which do not match the costs incurred to produce and deliver to the local population.
4. **Technical Sustainability:** While a range of solutions made be available, these need to be carefully reviewed to ensure that they are financial feasible and meet the needs of the local population taking into account that any solution usually involves behavioral adaptation and therefore it must be cultural acceptable.

The main threats to the fresh water ecosystem are listed below:

- Improper domestic solid waste and liquid disposal
- Over exploitation of species
- Unsustainable agricultural practices including the use of weedicides and pesticides
- Saline intrusion
- Deforestation
- Introduction of alien invasive species
- Extensive use of fresh water for domestic and commercial purposes

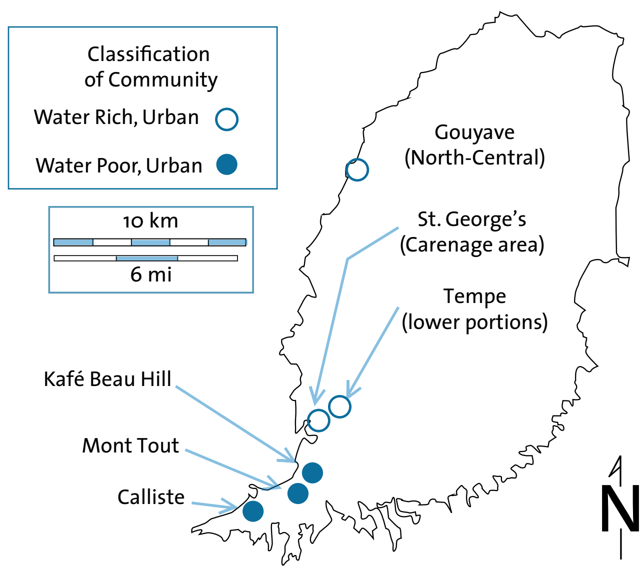
3. Water Supply Services in Urban Areas

Recent statistics indicate that 98% of Grenadian residents have access to improved sources of water and 97% have access to improved sanitation (World Health Organization and UNICEF, 2014). The World Bank parses these data further in their online

Table 3. Description of community classification and communities surveyed

Classification	Description	Community Surveyed
Water Rich	Urban communities with a stable, high quality water supply	St. George's (Carenage area)
		Tempe (lower portions)
		Gouyave (North-Central)
Water Poor	Urban communities with water rationing and/or frequent water quality problems	Calliste
		Kafé Beau Hill
		Mont Tout

Figure 7. Map showing locations of surveyed communities



Base map of Grenada provided by d-maps.com, http://d-maps.com/carte.php?num_car=1707&lang=en

database of world development indicators, which states that as of 2012, 99% and 97.5% of urban residents have access to improved sources of water and sanitation, respectively (World Bank, 2014a). Despite these numbers, many urban residents experience substantial turmoil due to water service irregularities such as intermittent service, poor water quality, and poorly regulated water pressure. The resilience of residents to these water supply challenges is variable, and depends largely on wealth and empowerment.

3.1 Characterization of Water Service

Data have not been published to quantify the proportion of residents who experience water supply problems in Grenada. Although many publications exist which describe various aspects of water management in Grenada, data describing water service is uncommon. One recent survey study, however, of water management in Grenada done by Neff (Neff, 2013) provides a detailed insight into the range of resident experiences with water service in both urban and rural areas. This study utilized surveys of residents in 6 urban neighborhoods, three being classified as having 'good' water service and three as having 'poor' water service (Table 3 and Figure 7).

Key findings from the Neff 2013 survey of residents living in these six communities are listed below:

- Residents reported experiencing several water related problems such as water service interruptions, episodes of 'dirty water,' and other resident-perceived service problems. Data showed that even residents in 'water rich' neighborhoods experienced water service problems, suggesting that some degree of water service problems are likely widespread.

- Water service cutoffs were usually short-term (less than a full day) and ranged from occasional to chronic (Figure 8). Most cutoffs occurred as a result of water rationing or shortage when water demand exceeds water supply. However, during drought conditions, water cutoffs lasting weeks to months, and requiring NAWASA to deliver water by tanker truck, were reported.
- Many residents reported experiencing episodes of receiving 'dirty water' through their taps. The severity of dirty water ranged from slight discoloration to being described by residents as being "like mud" (Figure 9). As a frame of reference, Figure 10 shows a jar of water collected that would be classified as "severe" but not quite "like mud." Dirty water often occurs after breaks in distribution pipes or following intense precipitation events. In the later case, rapid runoff flushes sediment-laden water into water treatment plant intakes.
- One third (33%) of survey respondents identified one or more additional issues with their water supply in both water rich and water poor locations (Figure 11). The most common problems reported by residents other than water service disruption and dirty water were excessive chlorine smell and/or taste, low and high pressure at the tap, and health concerns.
- Health concerns related to potable water were expressed by 12% of the urban residents surveyed. Concerns were spread over such factors as microbial contamination, perceived adverse gastrointestinal reaction to 'heavy' borehole water or excessive chlorine, and general suspicions of the safety of the water.
- Survey participants that elaborated on their concerns over water pressure described episodes of low water pressure during daytime which interfered with water usage and high pressure at nighttime which commonly broken water fixtures.

Figure 8. Days of water supply interruption per year reported by residents

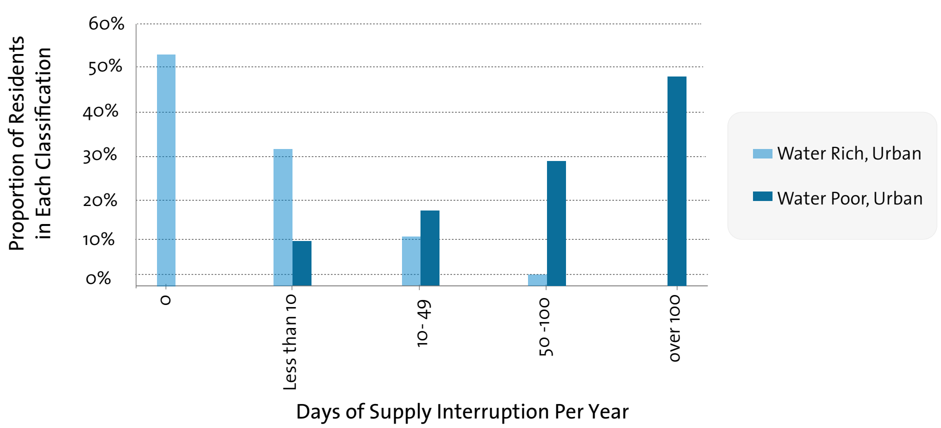
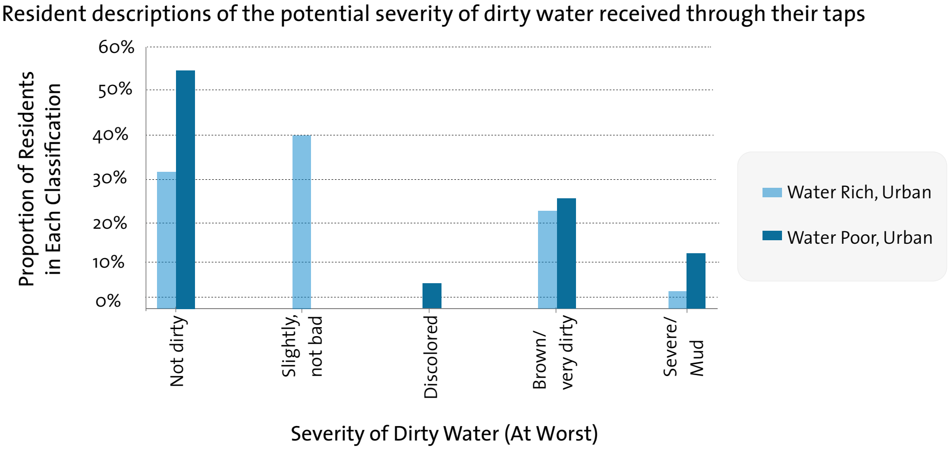


Figure 9. Resident descriptions of the potential severity of dirty water received through their taps



- Despite the shortcomings in water service, residents were generally satisfied with the water service provider NAWASA with a majority perceiving the water supply situation as being either stable or improving over time. Notably, 63% of residents surveyed in urban communities with poor water service reported that water supply interruptions are decreasing over time.

3.2 Poverty and Resilience to Water Service Irregularities

Options exist for Grenadians to reduce or eliminate the impact of water service problems on their daily lives. For example, residents may store water for use during water supply interruptions. Likewise, sediment filters can be installed to reduce or eliminate dirty water and pressure-limiting valves and water pumps can be installed to eliminate problems caused by poorly regulated water pressure. However, resident access to adaptation measures is variable and depends largely on the amount of financial resources available and empowerment.

In the case of water storage for use during service interruptions, different approaches can be taken with varying degrees of effectiveness. Crude storage systems capture and store rainwater using buckets and rain barrels and are not plumbed into the home (Figure 12a). More elaborate systems store piped water using elevated black polyethylene storage tanks of 500 gallons (1,890 L) or more and are plumbed to supply the home with water by gravity when water supply is interrupted (Figure 12b). In some cases, large cisterns, typically holding over 10,000 gallons (37,850 L), are located under the home and may hold either rain water or piped water and are plumbed to automatically supply the home during water service interruptions using a pressurized pump. With a sufficiently large tank and pressurization, residents may be unaware of water supply interruptions.

Data reported in Neff (2013) support the assertion that the ability of residents to adapt to water supply problems is strongly influenced by wealth and empowerment. While the frequency of water supply interruption was the primary factor determining if a household possessed a water storage tank of any type, the type of tank/system (e.g., plumbed/not plumbed) installed was associated with the level of wealth the household possessed (Figure 13). This suggests that residents who need to store water for use during water supply interruptions do so, but relatively wealthy residents own large tanks plumbed into the home, while relatively poor residents rely on simple rain barrels which must be accessed from outside the home.

The lack of financial resources by several Grenadian residents is also an issue in the country. While NAWASA is required to be self-supporting and funds most of its operations with user fee, they try to be flexible with residents who communicate an inability to pay their water bill due to financial hardship and strive to prevent disconnections. Unfortunately, many residents do not take advantage of this flexibility and as a result do have their service disconnected. Nearly 9% of study respondents in urban areas surveyed in the Neff reported having their service disconnected in the past or being at risk of disconnection due to delinquent bills.

Figure 10. Comparison of 'normal' piped water (left) and 'dirty water' (right) collected by Neff from a tap at his residence in Grand Anse, Grenada. The sample at right qualifies as 'severe'

Photo by Brian Neff, 2014.

Figure 11. Other water service problems reported by residents

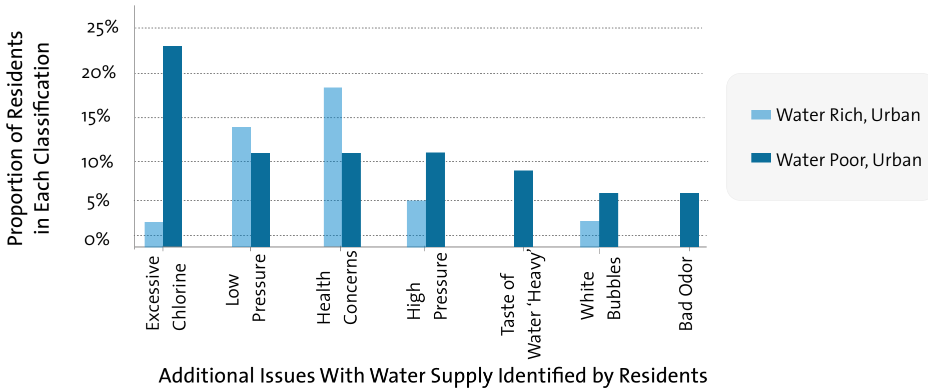
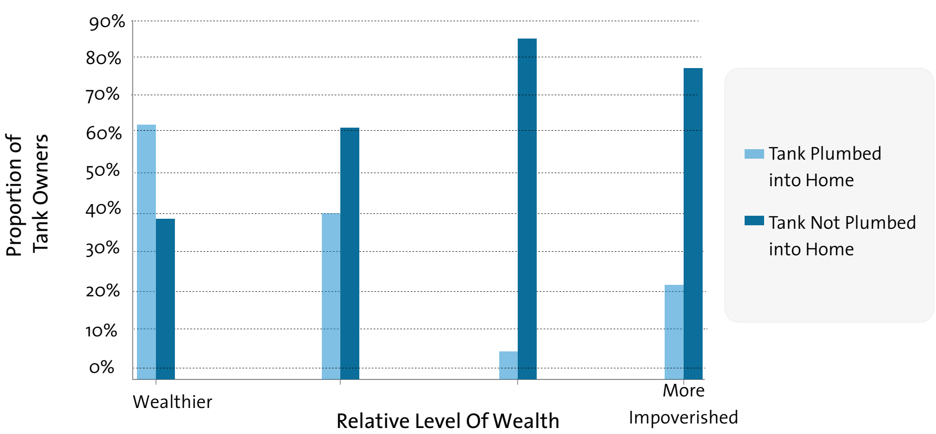


Figure 12. a) Left: Example of an elevated 500 gallon (1,890 L) black polyethylene storage tank plumbed into the home b) Right: Example of a rain barrel not plumbed into the home (Photos courtesy of Brian Neff, 2014)

Figure 13. Relation between poverty and the water tank installation used



3.3 Water Service Challenges and Solutions

Fundamentally, Grenada has an abundance of freshwater resources. In fact, a tropical rainforest exists at relatively high elevation within 10 kilometers of every residence. Urbanization, per se, does not pose a significant challenge for the Grenadian water service. Nonetheless, the management of these resources in Grenada poses several challenges and, as a result, water supply problems continue to exist.

Water is generally supplied to residents through a system of diverting source water from high-elevation streams to treatment plants and then distributing treated water to residents at lower elevations. A distinct advantage of this system is that it utilizes gravity to distribute water and greatly reduces the need for costly pumping. However, the quantity of water which may be withdrawn from streams is vulnerable to seasonal decreases in streamflow during dry season and during droughts. In addition, the rugged terrain also reduces opportunities for easy diversion or distribution of water from one watershed to another. Difficulties in diverting water around the island make areas with high populations, and thus high water demand, vulnerable to water shortages.

An added challenge is that sediment-laden water is frequently flushed into streams and water intakes after significant rainfall events. Most water treatment plants lack the ability to let heavy sediment loads settle out from water being treated. In these cases, plant operators have to choose between closing the treatment plant until the source water clears, which causes a supply disruption to residents, or supplying sediment-laden water to the distribution system.

The mountainous terrain of Grenada and deficiencies in the water distribution system combine to cause difficulty in maintaining consistent water pressure. Spikes in water pressure can rupture household fixtures and cause frequent breaks in the distribution system. This can further exacerbate water quality and quantity problems.

Technical solutions exist to overcome all of these problems, although obstacles exist to implementation. Expanding raw water storage capacity to supply treatment plants during precipitation events could prevent dirty water from entering the treatment and distribution system. If storage is sufficiently expanded, water could be stored during the wet season to supply water treatment plants through the dry season. The rugged terrain precludes easy distribution of water from any central location to other parts of the island, but the feasibility of constructing many moderate size dams or large storage tanks could be explored.

Other technical options to prevent water shortages exist. The water authority NAWASA could utilize additional streams or establish intakes and treatment plants farther downstream than presently located to expand source water supply. Expanding the use of groundwater could provide additional source water during supply shortages and NAWASA's 5-year plan contains plans to study the feasibility of this option (NAWASA, 2009).

Reducing water demand and improving resident resilience to water supply problems are also options for improving the present situation. One technical approach to reduce water demand is to reduce leakage of the present distribution system, as is the main objective of the Southern Grenada Water Supply Project. Policies can be devised and implemented to promote water use efficiency or persuade residents to collect and use rainwater (Box 1). Other policies could make it easier for residents to adopt better adaptation strategies to water supply problems.

3.4 Water Governance and Reform Efforts

In 2008, a formal national water policy for Grenada was ratified, however, the overarching legislation needed in order to replace the existing 14 pieces of legislation that govern water resources in Grenada and their management is still yet to be passed and implemented. This arrangement has led to a poorly coordinated approach to water management and generally to a top-down bureaucratic structure that provides separate agencies with relatively narrow mandates.

Beside the lack of coordination in the current governance structure, a more serious problem that exists is the absence of an over-arching strategic vision for the long-term (multi-decade) water future of Grenada. Long-range, multi-decade planning is not required under Grenadian water management laws and as a practical matter does not occur

Box 6

Rainwater Harvesting as an Urban Water Solution in Grenada

The potential of better implementing and utilizing rainwater harvesting (RWH) systems in Grenada are significant:

- Grenada experiences sufficient precipitation for RWH systems to prove to be economical and effective
- Even small-scale RWH can substantially improve resilience to water shortage
- RWH reduces demand for pipe-borne water and could be used to fill the gap between dry season water supply and demand in urban areas
- Residential RWH systems could be more cost effective in reducing water shortages than infrastructure improvements

Currently, the structure of Grenadian water management is fragmented with multiple silos of responsibility and a lack of an overarching, holistic management approach (see section titled Water Governance and Reform Efforts). No entity has the legal responsibility to consider tools such as RWH as part of a holistic water management strategy. In particular, the water authority, NAWASA, is mandated to supply water, not to reduce demand.

Within recent times, RWH has received renewed interest from NGOs and academics as a resident-driven means to augment or replace municipal supplied water (e.g. CEHI, 2006; Peters 2006; Neff, Rodrigo, and Akpinar-Elci 2012). Notably, the Caribbean Environmental Health Institute (CEHI) drafted and promoted the Grenada National Rainwater Harvesting Programme (CEHI, 2006). However, to date, no aspect of this plan has been adopted by the water authority (NAWASA, 2009). Worse, this program promoted a relatively expensive 'best practices' model of RWH and was ineffective at persuading residents to consider installing RWH systems at their homes.

Observing this setback, Neff, Rodrigo, and Akpinar-Elci (2012) attempted to delineate a potential role for RWH. These researchers concluded that the potential exists to expand the use of basic forms of RWH (e.g. rain barrels), but the best practices model is difficult to promote for several reasons, a conclusion which is consistent with the view of criteria specified by the United Nations Environment Programme (1999) for promoting RWH and conversations between the primary author and persons in the local water authority (Al Neptune, personal communication, 2011).

Ultimately, the use of RWH systems still remains an unrealized potential and a symbol of the limitation of Grenada's fragmented and incomplete water management system.

anywhere in the water governance structure. This situation is true even within the individual 'silos' of water management.

In 2007, the European Union (EU) offered Grenada a US$7.4 million grant to fund a much needed water infrastructure project on the condition that the government formulate and pass a new water policy. The Government of Grenada agreed and rushed toward a new water policy. A brief consultation period was held and consultants produced key documents which sought to identify the deficiencies in current water resources management, define a sensible water policy for future integrated water resources management, and chart a path to implementing the new policy (Government of Grenada, 2007c, 2007b, 2007a). In early 2008 the Grenada legislature approved the 2007 water policy and the EU released funding for the water infrastructure project.

It is one thing to draft and approve an idealistic visioning document describing good water governance with a US$7.4 million ultimatum hanging in the balance; it is quite another thing, however, to draft and enact legislation to supersede the 14 existing statutes and provide a blueprint for implementing such governance. To date, the legislation required to bring life to the 2007 water policy has not been implemented.

Of the 14 current pieces of legislation that govern water resources in Grenada and their management, the most comprehensive is the National Water and Sewerage Authority Act 1990, which vests the right to the use of every body of water to the National Water and Sewage Authority (NAWASA). Further, this Act specifies that one of NAWASA's functions is to provide the public a satisfactory supply of potable water for domestic purposes and provide a potable or otherwise satisfactory supply of water for agriculture, industrial and commercial purposes.

Although NAWASA has been granted the legal authority to manage all water resources within the state of Grenada, there is no single government department that exercises any oversight or responsibility for the formulation of water regulations and policies. The Ministry of Health, Social Security, and the Environment is responsible for waste management, the control/ management of hazardous waste, formulating guidelines, regulations, legislations and other policies in relation to the environment. The Ministry of Agriculture, Lands, Forestry, Fisheries, Public Utilities and Energy though has responsibility for the oversight of NAWASA.

Finally, both the water service provision and the regulation of such service provision is vested in the same entity, namely NAWASA. In effect, in the absence of an independent agency that has oversight over NAWASA's water service provision function, NAWASA in essence self-regulates itself.

4. Treatment of Wastewater in Urban Areas

Currently, 96% of the urban population and 97% of the rural population has access to improved sanitation. Individual septic tanks and pit latrines handle the majority of sewerage with only 5% of the total population connected to one of only two sewerage systems located on the island of Grenada.

The two existing sewerage systems are both located in the south of the island of Grenada (Figure 14). The St. George's system is over 75 years old and serves mainly the capital, St. George's. The other sewerage system, the Grand Anse System, was commissioned in 1992, and serves mainly the hotels and residential areas located in the southwest tip of the island of Grenada. Both of these systems are only primary treatment systems that simply remove by screening large items from the sewerage with the remainder outflowed to two points on the west coast.

5. Effect of Climate Change on Urban Water Users

Forecasting the hydrologic effects of climate change is much different than forecasting the effect of climate change on urban water users. Both are critically important questions to address, but the latter is arguably of greater value to guide management of climate change adaptation. The potential effects of climate change on Grenadian urban water users will be impacted mainly by three factors: (1) the likely hydrologic effects of climate change; (2) the vulnerability of the present water supply system to those effects, and (3) the effectiveness of the current water management system to adapt to these changing conditions.

5.1 Hydrologic Effects of Climate Change

Climate change is likely to disrupt historical patterns of temperature and precipitation, with resulting cascading effects throughout the water cycle. The following discussion is divided into observed and projected changes in climate as they affect water management.

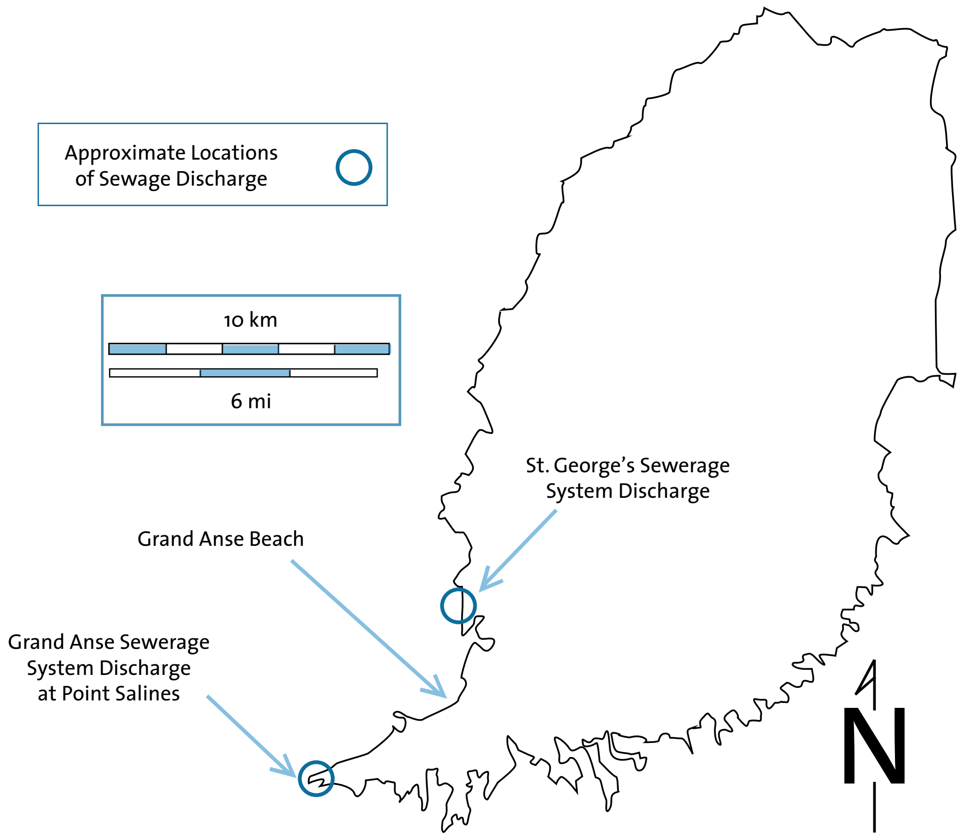
5.1.1 Observed Trends

Since 1960, mean air temperature in Grenada has increased approximately 0.6°C (McSweeney, New, and Lizcano, 2010). In analyses of Caribbean-wide climate trends, both Peterson (2002) and Stephenson et al. (2014) found an increase in the frequency of very warm maximum and minimum daily temperatures over the same time period. The Stephenson research group also found a corresponding decrease in cool days and nights. These observations are consistent with data describing increasing global temperatures (IPCC, 2007).

Since 1960, mean annual precipitation has increased slightly in Grenada, though the change is not statistically significant (McSweeney, New, and Lizcano, 2010). In analyses of Caribbean-wide climate trends, Peterson reported an increase in precipitation intensity and a decrease in consecutive dry days, indicating a more frequent rainfall during the dry season. However, a revised analysis by Stephenson et al. (2014) found that the trend in consecutive dry days had reversed since the late 1990's. In addition, these researchers found no trend in total precipitation in the past 50 years and confirmed the trend toward increased precipitation intensity observed in Peterson (2002).

The El Niño Southern Oscillation (ENSO) is an important wild-card in the discussion the effects of climate change on water supply. Climatic factors that create drought conditions in the Caribbean are complex and incompletely understood, but ENSO appears to be the largest factor (Giannini, Kushnir, and Cane 2000; Stephenson, Chen, and Taylor, 2008). Both the frequency and intensity of ENSO has been increasing since at least the 1500's and the trend appears to be accelerating (Gergis and Fowler, 2009), though this has not been attributed to climate change.

Figure 14. Sewage systems installed in Grenada



Base map of Grenada provided by d-maps.com, http://d-maps.com/carte.php?num_car=1707&lang=en

5.1.2 Projected Changes

Air temperature in Grenada is projected to continue increasing throughout the next century. The exact degree of warming varies depending on which model and climate scenario is used. For example, the 4th IPCC report predicts the Caribbean will warm 1.4°C to 3.2°C by 2100, with a median of 2.0°C (Christensen et al., 2007). The UNDP Climate Change Profile for Grenada projects warming of 0.7 to 2.6°C by the 2060's and 1.1 to 4.3°C by the 2090s (McSweeney, New, and Lizcano, 2010). The point is that widespread consensus exists to document substantial warming in Grenada in coming decades, most likely by approximately 2°C by 2100.

The significance of warming air temperatures to water supply is that evapotranspiration can be expected to increase concomitantly. As evapotranspiration increases, less of the water that falls as precipitation makes its way to the streams used as source water. Of particular interest, groundwater recharge is reduced, causing a reduction in groundwater discharge to streams (baseflow).

Change in total precipitation over the next century is highly uncertain in both global and regional climate models (Karmalkar et al., 2013). Overall, recent studies are tending toward a slight reduction in annual precipitation by 2100. The IPCC Fourth Assessment Report (IPCC, 2007, p. 912) states, "...most models project decreases in annual precipitation and a few increases, varying from –39 to +11%, with a median of –12% [by 2100]." McSweeney, New, and Lizcano (2010) report project annual precipitation deviation ranges between -61 and +23% by the 2090's, with a median of -13 to -21%.

Changes in the seasonality and intensity of precipitation are critical to water supply. Grenada lacks the ability to store streamflow from the wet season so that it can be utilized in the dry season. Total annual streamflow is far less important than daily streamflow, particularly during dry season conditions. Water supply in Grenada may be unaffected if the reduction in precipitation is isolated to the wet season, as some authors have suggested (Government of Grenada, 2011). In addition, McSweeney, New, and Lizcano (2010) project precipitation events will be less intense by 2100. This should enhance infiltration of precipitation, which tends to reduce flooding and increase baseflow in streams, potentially improving water supply during dry seasons and droughts. Reducing the intensity of precipitation events should also reduce erosion and sedimentation of streams, potentially reducing episodes of dirty water in potable supplies. Grenada lacks streamflow data that could be used to confirm these propositions. Other factors, such as land use changes in water supply catchments, will also affect the relation between precipitation, streamflow, sedimentation, and dry season baseflow.

As discussed in section 5.1.1, ENSO appears to be the largest factor driving severe drought in the southern Caribbean. Unfortunately, climate scientists offer little in projections for if and how ENSO will change in the next 100 years. Given the long-term acceleration in ENSO frequency observed by Gergis and Fowler (2009), it may be prudent to anticipate a potential increase in severe droughts, regardless of whether or not ENSO frequency is affected by climate change.

5.2 Water Management and Climate Change

The effect of climate change on water supply is not necessarily a question of hydrology; rather the real question is if and how water management responds to future water challenges. Grenada is blessed with great freshwater resources and water supply is fundamentally more sensitive to water management decisions than to forecast changes in the water resource. Options already exist to expand water supply or to reduce water demand through improving water use efficiency or increasing residential rainwater harvesting (Box 1; Caribbean Environmental Health Institute, 2006; Neff, Rodrigo, and Akpinar-Elci, 2012). The real question is if water managers utilize these options to maintain and improve water supply over the coming decades.

One option to expand water supply to the largest urban areas in Grenada is to divert and treat water from the Concord River, and transfer it 6 km south to the capital city of St. George's through the existing water distribution system. The Concord River is a relatively large stream in Grenada and is largely unused for water supply. There is evidence that the chronic dry-season water supply problems in the southwest part of the island could be easily corrected if this water source was tapped and brought on stream. NAWASA engineer's believes this one project could increase supply to the southwest part of Grenada by 0.8-1.0 million gallons per day (mgd), an increase of ~40% over the current 2.25 mgd capacity to supply this area.

Ultimately, Grenada possesses excellent options for coping with the effects of climate change on water supply. Grenada has an excess of water resources and management options already exist to greatly expand water supply. In addition, it is possible that improving the present system of water governance could illuminate new solutions that are less difficult and costly to implement. The degree to which Grenada implements these options depends largely on political leadership and will. If these two qualities can be found and nurtured, Grenada's resilience to deal with any water management challenges posed by climate change will be greatly enhanced.

6. Conclusions

As is true for many developing countries, the increasing development and expansion of cities and other urban centers in Grenada will bring more and more to the fore the need to significantly improve and enhance the infrastructure needed to deliver water of sufficient quality and quantity to these growing concentrations of population. While Grenada is blessed with adequate freshwater resources, the challenge of harnessing these resources, which currently are located in the mountainous areas of the island, and bringing them to where the key consumption areas are located will need to be addressed.

Additionally, besides improving physical water capture and delivery infrastructures, there is the need to completely overhaul and update the management structures that are in place to manage all water resources in Grenada. Specifically, there is an urgent need to reform and collate the current mishmash of legislative and statutory bodies that currently perform some part of this function into one holistic, over-arching policy and legal framework. It is unlike that needed funding to improve and replaced aging water delivery and storage infrastructures will be sourced under the current legislative and management framework.

Finally, in order to improve water security, especially during the dry season months, polices and programs should be developed that encourage locals, particularly those living in urban centers, to install rainwater harvesting (RWH) systems. RWH systems are a relatively inexpensive way to significantly improve the overall water storage capacity of the municipal system. Furthermore, RWH residential systems can help reduce the demand for water from the municipal system, especially during the dry season months.

7. Recommendations

Based on the experiences of Grenada in trying to provide both the quantity and quality of water for a growing urban population, the following recommendations are made:

1. For the proper and effective management of water resources, holistic, over-arching water-management legislation has to be passed and enacted.
2. The provisioning of water and the regulation of such a service should not be vested in the same entity. The latter needs to set up to act independently of the former to ensure proper oversight and effective monitoring of the quality of water that is being produced for the population.
3. Policies and programs should be implemented to help locals better utilize the potential of Rainwater harvesting (RWH) systems so that these can firstly help reduce the demand load for pipe-borne water, and secondly help provide increased water security to locals especially during periods of water shortage.

8. Acknowledgments

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10. Acronyms

ADD	Annual Daily Demand
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
IPCC	Intergovernmental Panel on Climate Change
L	Liters
mdg	Million gallons per day
NAWASA	National Water and Sewage Authority
NGO	Non-governmental Organization
RWH	Rainwater Harvesting
UFW	Unaccounted for Water
UN	United Nations
UNICEF	United Nations Children's Fund