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Water Security and Services in the Caribbean

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Abstract: The efficient management of water resources and services continues to be a concern in many of the small island states of the Caribbean. There are growing concerns over the ability of governments in the region to ensure the good management and provision of water without jeopardizing economic growth and the maintenance of social well-being. This paper provides an overview of the major factors influencing the water security facing the Caribbean Region and how the emerging concerns are being addressed. The key challenges and vulnerabilities may be summarized as lack of data and barriers to making available what information there is. Forward planning has been largely neglected and is symptomatic of a lack of appreciation of the need for having national water policies. In this respect Jamaica's development of a national master water plan serves as a good example of what is needed. Water service providers have to be efficient, well managed and allowed to do their job. This means that they have to be on a sound financial footing. The challenge is to find the balance between appropriate political and regulatory oversight and the autonomy of water managers and service providers.

Keywords: Caribbean; water resources; water resources management; water services; climate change; affordability

1. Introduction

In October 2012 at the 8th High Level Ministerial Forum of Ministers with responsibility for water, the importance of ensuring long-term water security as a driver for economic and social development and the urgent need to address water scarcity in the Caribbean region [1] were recognized. There was a clear understanding that insufficient political attention was being paid to ensuring water security.

Furthermore, there were growing concerns over the ability of governments to ensure the good management and provision of water without jeopardizing economic growth and the maintenance of social well-being. Of concern were: the impacts of climate change, tariffs and the financial sustainability of service provision, the need to upgrade existing water infrastructure and improve resource use efficiency, the prevention of pollution of water sources, and the management of resources and services in the face of natural hazards.

The purpose of this paper is to provide an overview of the major factors influencing water security in the Caribbean Region, see Figure 1. Given the diversity of the region, this will necessarily entail a “broad brush” approach. The paper outlines the state of water resources and service provision and discusses the factors affecting the supply and demand. The potential impact of future changes, such as demographics, climate change and economics, are explored. In the first section what might be meant by water security is explored, and this has been used to propose an organizing framework for the salient factors constituting water security, which is expanded in the following sections. The final section draws together the possible implications of the previous sections and examines the future prospects for water resources and services management in the region.

Figure 1. Map of the Caribbean Region (Source: [2]).



2. Water Security

Water scarcity can be a product of the conditions that determine demand and supply; social conditions influence demand (patterns of behavior, social norms and expectations) whilst the nature of the available resources, the provision of infrastructure and the condition of ecosystem services can all impact supply. At the Rio+20 Conference in 2012, the themes of water security and sustainable development were very much in evidence, even though there were “no agreements on any ambitious treaties or deadlines for dealing with pressing issues such as climate change, food and water scarcity” [3].

Of increasing concern in the international community are the effects of “population growth, uncontrolled urban expansion, extensive land use changes, degradation of water quality, growing impacts of floods, droughts and of hydrological effects of global changes” [4] all of which are also present in the Caribbean. Evidence of the growing importance attached to water security can be found in the call on the UN Security Council “to recognize water as one of the top security concerns facing the global community.” [3]. In other words, there are fears that growing water insecurity could lead to social unrest and conflict within and between states. Hence the importance of achieving a water secure world as necessary condition for the realization of social well-being and equitable economic development. Responses to this are already beginning to emerge, for example the International Hydrological Programme aims to prioritize the improvement of water security in response to local, regional and global challenges [4].

Water security is seen increasingly as an integral part of human security and central to the achievement of other rights such as the right to life, to education, to health and to adequate housing [5]. Thus, access to enough safe water at an affordable price is necessary for a person to lead a healthy, dignified and productive life whilst at the same time maintain the health of ecosystems that provide water [5].

Grey and Garrick [6] propose that “Water security is defined as a tolerable level of water-related risk at any scale and for any actor.” and go on to say that it includes “every interaction between society and water”. They emphasize that water security operates across the dimensions of values, scale and actors, suggesting that water insecurity impedes social and economic development and leads to environmental degradation. More straightforwardly, the Global Water Partnership has defined a water secure world as one that:

“...integrates a concern for the intrinsic value of water together with its full range of uses for human survival and well-being.....harnesses water’s productive power and minimises its destructive force.....where every person has enough safe, affordable water to lead a clean, healthy and productive life.” and “It is a world where communities are protected from floods, droughts, landslides, erosion and water-borne diseases [7].”

Considering the various definitions of water security there are common elements that provide a framework within which to examine the Caribbean situation. The common elements identified are Adequacy, Accessibility, Assurance and Affordability:

- Adequacy addresses conditions governing water resource availability in time and space that satisfies often competing demands and the nature of the demands that drive exploitation.
- Adequacy is complemented by physical accessibility, ensuring that water is available when and where it is needed in such a way that is not an undue burden.
- Assurance concerns the ability to secure safe and sufficient resources to cope with potential system shocks such as extreme events, security threats and contaminated resources.
- Affordability applies to providers of water services and for those who have to access those services and is related to how water management and services are to be paid for, the financial position of state agencies and of businesses and citizens.

Table 1 provides a proposed listing of the various drivers that may be associated with water security, though it does not necessarily capture the overlapping nature of some.

Table 1. Water security—the 4 A's.

Water Security			
Adequacy	Accessibility	Assurance	Affordability
Climate change	Water demands	Water management	Public policy
Resource availability	Water policies & legislation	Hydrological variability & Shocks	Financing
Demographics	Service provision and coverage		Economic instruments
Economic development	Service management		Tariffs

3. Adequacy of Resources

The Caribbean is a humid tropical region; the climate varies with both elevation and the size of the land mass. Temperatures are strongly elevation-dependent, in coastal areas they vary on average between a high of 32 °C and a low of 24 °C but with increasing elevation, temperatures can drop to 10 °C. There are two distinct seasons during the year, a dry season and a wet summer hurricane season. Throughout the region, precipitation varies greatly with windward sides of the islands receiving much more rain than the leeward sides. Thus, water resources vary spatially and are determined by the interaction of climate, geology and topography. At sea level, temperatures tend to vary little throughout the year so that for a significant part of the year evapotranspiration rates exceed precipitation.

3.1. Climate Change

According to the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report [8] small islands are especially vulnerable to the effects of climate change, and furthermore, Caribbean islands are likely to experience increased water stress as a result of climate change. The main pathways through which climate change affects water resources are: sea level rise, temperature, and changes in precipitation patterns. Changes in hurricane activity will also have an effect through impacts on infrastructure and through extreme rainfall events. Sea levels in the Caribbean have been projected to rise at a rate of between 5 and 10 mm per year. However, this effect is complicated by the occurrence of vertical crustal changes on some Caribbean islands as a result of tectonic processes [9]. Nevertheless, such changes are likely to impact coastal aquifers.

Climate change projections for the Caribbean have indicated changes in temperature of between +0.7 °C and +4.0 °C depending on the emission scenario chosen [10]. More recent climate modeling work [11], using the A1B emissions scenario, projects a 2.5–3 °C rise in temperatures for the northern and southern Caribbean and 2–2.5 °C for the eastern Caribbean for the time period 2075–2099. This warming occurs alongside an increase in the number of days and nights where temperatures exceed 35 °C during the day and 25 °C at night. A greater warming is observed in the northwest Caribbean (Jamaica, Cuba, Hispaniola and Belize) than in the eastern Caribbean island chain; and a greater warming is observed in the summer months than in the cooler, drier early months of the year.

Work by Hall *et al.* [11] projects a decrease in annual precipitation of 10%–30% by 2080, and for the months of the wet season a 30% decrease in monthly precipitation for the northern and 20% for the eastern Caribbean is projected. However, over Belize and Guyana increases of between 20% and 30% during the wet season are projected. Analysis of the mean daily precipitation indicates a 10%–15% decrease in higher intensity rainfall for the northern Caribbean and an increase in intensity of at least

15% for the southern Caribbean with no change for the eastern Caribbean. The projected significant reduction in wet season rainfall across most of the insular Caribbean is particularly problematic for water resources, especially when coupled with higher temperatures. This suggests that there is the potential for a major reduction in freshwater flows and groundwater recharge. Anecdotal evidence from Dominica appears to suggest that this may already have begun [12] with decreases in stream flows being observed.

The projections are particularly troubling given that there are already serious gaps between available supply and demand in many Caribbean countries. Barbados is utilizing close to 100% of its available water resources, St Lucia has a water supply deficit of approximately 35%, and Nevis of 40%, Trinidad has had a water supply deficit since 2000 [13], Jamaica is projected to experience deficits in supplies to areas of important economic activity by 2015 [14], Antigua and Barbuda are reliant on desalination to meet their demands for water whilst in Dominica, Grenada and St Vincent and the Grenadines demand exceeds supply during the dry season due to reduction in stream flows [15]. Belize and Guyana are however faced with a different set of problems to those of the insular Caribbean. For them water resources are more than adequate but they are more prone to the effects of drought and of flooding, and in the case of Belize, the effects of hurricane activity. The situation across the region is compounded by high levels of unaccounted for water e.g., 67% in Jamaica, 40% in Trinidad, and 50% in Barbados. The paradox is that many of these countries have sufficient water resources to meet demand but not the infrastructure or institutional frameworks to close the supply-demand gap.

Some care needs to be exercised as situations are more complex at sub-national levels with disparities between available surface and groundwater resources, their spatial distribution, and the location of centers of demand. This can give rise to situations where, as in the case of Jamaica, some of the water resources are exploited at levels beyond their renewable levels. This is particularly the case for groundwater, where changes in recharge rates due to climate change are likely to have severe supply implications.

The impact of climate change on the infrastructure can be considered to be twofold. Firstly, existing infrastructure may be ill equipped to cope with changes in the hydrological regime and water quality; more treatment may be required to deal with changes in water quality, pumping arrangements may need to be reconfigured and more distribution storage provided. Secondly, it is anticipated that there will be an increase in category four and five hurricanes. Existing hurricane activity already impacts water infrastructure through landslides that compromise storage reservoir integrity and damage pipelines, damage to intake works and boreholes through sediment and debris, damage to pump stations either directly due to floods or loss of power, and damage to wastewater treatment facilities leading to heightened threats to public health. An increase in more severe hurricanes could well have more detrimental effects.

3.2. Surface Water

Countries such as Trinidad and Tobago, Grenada, St Vincent and the Grenadines, St Lucia, and Dominica use surface water for the majority of their freshwater supplies. Though variations between wet and dry season flows can be ameliorated through the provision of large water storage reservoirs

this strategy is relatively underdeveloped. An increasing threat impacting stream flows is the conversion of catchment areas for urban development or for agriculture. For example, the urbanization of the upper watershed areas around Port of Spain, Trinidad and Castries, St Lucia has resulted in higher peak flows, downstream flooding, an overall in decrease in base flows [16,17] and higher sediment loads. The devastating effects of catchment conversion can be most clearly seen in Haiti where denuding of hillsides has resulted in slope instability, mud flows and catastrophic flooding, as happened in Gonaives in 2008 [18]. The decrease in surface resources during the dry season often leads to significant reduction in water production in Dominica, which can amount to a 50% decrease.

3.3. Groundwater

Countries such as The Bahamas, Barbados and Jamaica rely heavily on groundwater resources as their source of water supplies. In Barbados, 90% of the supply is from groundwater, in Jamaica the figure is 84% and for Trinidad and St Kitts the figures are 24% and 70% whilst in Grenada, Dominica, and St Lucia groundwater is hardly utilized, illustrating the variability across the Caribbean [19,20]. Given Jamaica's reliance on groundwater, its available groundwater resources are significant at 10.663 Mm³/day compared to Trinidad's 0.477 Mm³/day, Barbados' 0.205 Mm³/day and going down to Antigua's 1835 Mm³/day. Groundwater storage and recharge mechanisms do attenuate changes in intra-seasonal rainfall making these sources less prone to the immediate effects of variability. However, prolonged periods of low rainfall and prolonged abstraction levels that exceed the sustainable long term aquifer recharge remain a threat to supplies [21]. This is especially the case for coastal aquifers in Jamaica and Antigua where abstractions have resulted in "up-coning" and increased levels of salinity as the fresh-saline water interface has migrated inland. In terms of water quality issues, these vary between countries. Generally, Jamaica has good water quality but apart from saline intrusion there are also problems with pollution from bauxite mining as well as from improper sewerage disposal. High nitrate levels have been recorded in abstraction from the Liguanea aquifer in the Kingston St Andrews area of Jamaica [22] and such contamination of groundwater makes it unusable, unless expensive treatment is provided. Nitrate levels of around 8 mg/L have been found in water supplies from Barbados' main supply aquifer and have been attributed to a combination of agricultural sources and inappropriate sewage disposal. In Trinidad there have been issues with high iron concentrations in groundwater as well a high chloride levels in coastal aquifers. Over exploitation of aquifers above safe yield, saline intrusion, and pollution pose major threats to groundwater resources, turning them into non-renewable sources. A major challenge facing water resource managers as well as service providers is the difficulty associated with being able to determine the safe yields of aquifers and to undertake regular assessments of the yield-demand balance. Often the required hydrogeological data, the models and the skilled personnel are all in short supply.

3.4. Demographics

Population dynamics and rising incomes have been identified as two of the underlying drivers of the demand [23]. Population growth is not as important as the impact of rising standards of living, changes in the age distribution of populations, and urbanization. The majority of Caribbean countries have population growth rates of 1% per year or less and they are experiencing net outward migration

rates of between two to ten persons per a thousand persons. Levels of urbanization are increasing; already 65% of the population live in conurbations. A feature of most Caribbean countries, especially the islands of the Lesser Antilles, is that most of the urbanization has taken place around the coastal fringes with up to 70% of the population living in coastal areas and of this 40% live within 2 km of the coast [24,25]. There are little available data on the percentage of the urban population considered to be living in slums: Jamaica has a reported figure of 61%, Guyana 34% and St Lucia 12% [26].

The impact of demographic changes on demand and consumption patterns has not been studied, but urbanized populations tend to consume more water *per capita* than rural populations. Poverty in rural areas is much higher than in urban areas, and estimates of the degree of inequality in the distribution of income suggests a relatively high level of income inequality as well [27,28]. The effect of an increasingly urbanized population along with improvements in standards of living are likely to drive further increases in both total and *per capita* levels of water consumption.

In 2011 some 17.6 million tourists went to the Caribbean on holidays, staying between 7 and 10 days. Tourism and tourist facilities are large consumers of water with visitors consuming up to three times as much as the local population [29]. Governments across the region remain keen to encourage growth in tourist numbers, and though in some instances hotels are responsible for their own supplies, many are supplied from municipal distribution systems and can account for between 10% and 15% of all water supplied. Although there are some incentives to encourage the efficient use of water in hotels through tax incentives and certification schemes, for the majority of hotels this is not a prime consideration.

4. Access to Services

4.1. Water Supply Services

For many Caribbean countries improved water supplies and sanitation coverage exceed 90%. The problems are not so much associated with the universal provision and access to water services, though this does remain an issue [30], they much more are related to the quality of service and the maintenance and operation of the infrastructure. The challenges include: inappropriate governance arrangements, deficient legislation and regulation, ageing infrastructure, high levels of water unaccounted for, concerns over potable water quality, and poor infrastructure management [31]. Levels of daily water consumption depend not only on population size but also on the degree of industrial activity. Thus Jamaica and Trinidad consume 632,876 m³/d and 904,110 m³/d, respectively, The Bahamas and Barbados 105,710 m³/d and 118,367 m³/d whilst Grenada and St Kitts and Nevis 31,877 m³/d and 13,600 m³/d. These figures include unaccounted for water.

High levels of unaccounted for water include under-reading by domestic and bulk production meters (50% and 15% respectively in Barbados) and bursts and leakage (40% in Barbados) [32]. Many Caribbean countries have an ageing water infrastructure but focus their efforts on the maintenance and extension of supplies to customers. Investment in mains replacement programs as well as in leakage management has not received much attention. This is partly due to management efforts being focused on ensuring that new developments are serviced and on supporting economic activity.

Hurricane Tomás, which affected the Caribbean in 2010, highlighted the impact of extreme events on maintaining accessibility under emergency situations. In St Lucia, as a result of the impact of

Hurricane Tomás, the principle storage reservoir was silted up by a landslide, which damaged the electricity supply and pumping facilities. Some 80% of the population had to cope with limited water supply. The siltation blocked the lower intake significantly, reducing the available storage supply volume. Hurricane Tomás highlighted the multiple facets to maintaining accessibility; water systems cannot operate without electricity and water becomes non-potable if it cannot be properly treated. This suggests that greater attention needs to be paid to scenarios where risk and uncertainty analysis are factored in.

Water is intrinsically heavy and requires energy to be transported through transmission and distribution systems. As a result many water utilities are big consumers of electricity and in some cases are the biggest electricity customers. Electricity generation in the Caribbean relies heavily on the importation and use of fossil fuel, and as this has to be paid for in hard currency, it represents a burden on many countries' balance of payments. Such energy costs in the Caribbean are among some of the highest in the western hemisphere. Realizing that increasing energy use by water companies represents a potential threat to water security there are some initiatives, supported by international financing institutions, aimed at improving energy use and efficiency. It has been estimated that savings of between 30% and 40% could be made by installing energy efficient devices and optimizing pumping equipment [33]. Little use is made of renewable energy sources, other than of hydropower.

Desalination as a source of supply is being used on 14 islands, and in some cases, such as the Cayman Islands and Aruba, there is little other choice available. In other instances, desalination plants supplement existing resources or are a drought proofing measure, such as in Barbados. There has been a growing tendency to push desalination as a solution for water supply difficulties. The attraction is that such plants can be built relatively quickly and are often outsourced to the private sector under long term Build and Operate contracts. Whilst desalination plants do provide a 'back stop' source of water, the continued affordability of such supplies, when reliant on fossil fuels, is open to question. Beyond that, given that they are often reliant on fossil fuel, any expansion of desalination needs to be balanced against commitments to reducing greenhouse gas emissions. Hence there is growing interest in smaller scale desalination plants that use renewable energy, such as that which has been installed on the island of Bequia and on Carriacou in 2015. More needs to be done to improve the efficient use of energy in the water and wastewater sector and to make greater use of renewable sources and the opportunities for resource and energy recovery, especially in the wastewater sector.

4.2. Wastewater Services

The provision of infrastructure for wastewater services lags behind drinking water services. It has been estimated that 85% of wastewater entering the Caribbean Sea remains untreated. The impact of poorly functioning sewage systems, the lack of or improper sewage disposal is causing serious pollution of surface and ground waters. Studies undertaken by Pan American Health Organization (PAHO) [34] found that 51.5% of households lack any kind of sewer connections and only 17% are connected to adequate collection and treatment systems. This is indicative of the difficulties in facing the scale of investment in necessary sewerage infrastructure [35]. In addition to the financial constraints [35], other barriers include: inadequate legal and regulatory frameworks, fragmented

approaches to and responsibility for wastewater management, and limited technical and operational capacity, knowledge and awareness of low cost treatment technologies.

In Trinidad untreated organic matter from domestic sewage contaminates many water bodies and adds to the cost of water supply [36]. In other instances, contaminated water bodies cause health problems, which give rise to the need for medical interventions and loss of productivity [37]. Sewage discharges into the marine environment are considered to be one of the main causes of degradation of coral reefs, eutrophication and of harmful algal blooms. A cost-benefit analysis of proposed sewerage scheme [38] demonstrated that although the public health benefits were relatively minor, costs arising from tourism-related losses and deterioration of the marine environment were in the order of US\$260 million giving rise to benefit-cost ratios of between 1.3 and 1.6. Moreover, advanced wastewater treatment would allow augmentation of scarce water resources and increase availability for agriculture and industry.

The coming into force of the Cartagena Convention's Protocol on Land-based Sources of Marine Pollution (LBS) has had a positive impact as it has allowed the development of innovative approaches to funding the expansion of wastewater services through the Caribbean Regional Fund for Wastewater Management (CReW). The objective of the CReW is to mobilize additional funding for wastewater treatment investments at an affordable cost of capital by leveraging co-financing arrangements. The fund is intended to support the improvement of existing institutional, policy, legal and regulatory frameworks for wastewater management as well as to obtain training and capacity building for the identification, evaluation and maintenance of appropriate wastewater management technologies.

5. Assurance of Supply

Water resources are variable both in time and space. The challenge is to put in place an infrastructure that is capable of meeting present and future needs whilst at the same time being capable of coping with the variability of the water resources. The fact that water infrastructure, especially in urban settings, is expensive to construct, maintain, and is composed of assets that are long-lived compounds, challenges the assertion of adequacy and accessibility.

5.1. Variability and Shocks

There is some evidence that climate-related events have become more frequent and more extreme resulting in an intensification of the hydrological cycle [23]. The greater variability within the hydrological cycle has important implications with respect to the adequacy of existing water infrastructure and future planning and design. It suggests a need to re-evaluate assumptions regarding stream flows, aquifer recharge rates, and sustainable levels of abstraction and assured yields from surface and groundwater resources. The experience across the Caribbean of the 2009/10 drought demonstrated the difficulties associated with assuring supply. Recent work has indicated that both surface and groundwater resources are likely to be adversely affected by climate change and variability [16,36,39] with significant decreases in sustainable yields due to decreases in recharge rates. It does not help that the available information on water resources from which to calculate yields and assess the impact of climate change is sparse and often incomplete, and many states have little idea of what their resources are, how they vary and what controls need to be implemented to ensure reliable long term yields.

The ability to withstand shocks (droughts, floods, hurricanes, *etc.*) to water services infrastructure (*i.e.*, robustness and resilience) is a matter that has hereto not received much attention in the region. More attention has been paid to the formulation of drought management measures and sector responses to hurricanes rather than to disaster and emergency response planning across affected sectors. This is changing as greater attention is being paid by water managers to the development of Water Safety Plans [40,41], and more recently by the industry in developing Source Vulnerability Assessments. This entails a systematic identification and assessment of risks and hazards in the production and supply chain from source to point of consumption and the development of monitoring and management plans. The necessity for preparing strategies to deal with a range of possible threats can be clearly seen as lessons from recent regional disaster and emergency events such as the 2009/10 drought that affected the security of water supply to agriculture, towns and cities, Hurricane Tomás' that impacted St Lucia's water and wastewater infrastructure, and the cholera epidemic in Haiti.

It would appear that more needs to be done to internalize the lessons and act accordingly [42]. At the heart of it, the ability to cope with shocks is as much a governance issue as it is an infrastructure issue.

5.2. Management

Poor operation and management of water systems compromise the ability to maintain the integrity of resources and supplies and meet demands. The Global Environmental Facility Integrated Watershed and Coastal Area Management (IWCAM) project prepared Integrated Water Resources Management Plans for Grenada, Barbados, Union Island in St Vincent and the Grenadines, St Lucia, Dominica, St Kitts and Nevis and, Anguilla and Barbuda. Each of these reports contains an evaluation of water management and the challenges facing the countries and suggestions as to how these might be responded to. These reports on the state of water management suggest that water management practices are sub-optimal. A World Bank report [43] noted:

“Institutional arrangements for policy making, planning, and regulation are confusing and weak, and often lead to overlapping and redundant responsibility. For instance, it is often unclear which agency is ultimately responsible for setting water service standards, and how they are enforced. The process for approving government contributions to capital investments is characterized by a game of political forces instead of economic criteria. Arguing that water and sanitation are essential social services, it is common for politicians and politically influenced regulators to keep tariffs below cost. The fact that many Caribbean water utilities are demonstrably inefficient helps rationalize this decision.”

Water management and service tend to be “bottom heavy” employing large numbers of semi-skilled staff and relatively fewer at the professional level. The lack of appropriate human resources and capacity is matched by a lack of investment and use of information and communication technologies (ICT). The effect of this has been to hamper future water management planning, and thus proposed investments are made on the basis of incomplete information and on a project-by-project basis.

Poor management, lack of investment and inadequate water services have led some states to address the problems through forms of franchise or private sector involvement (*e.g.*, Guyana, Trinidad and Tobago, St Lucia and Belize). For a variety of reasons, these initiatives have not been successful and have

been opposed by trade unions and citizen groups. An emerging alternative has been to encourage cooperation between service providers in the region as well as with providers outside of the region, and benchmarking the performance of water service providers. However, the lack of agreed standards of performance, confused and ineffective regulation of utilities [43] and an absence of water policies [31] has allowed poor performance to continue to place security of supply and effective water management at risk.

6. Affordability

There are two sides to affordability: affordability of water management and services to the consumer/customer/citizen that revolves around determining willingness and ability to pay for services and how the costs associated with the services are to be afforded by the provider. Whilst there are many instances of affordability being largely determined by political considerations, within the Caribbean probably only Jamaica has an independent and functional regulatory regime [43] through which such matters can be resolved.

6.1. Consumer/Customer/Citizen Affordability

Of concern is the ability of low-income households to be able to afford to access sufficient water to meet their needs and not spend a disproportionate amount of their income on water in the process. Affordability issues have been addressed through charging a fix amount for a volume of water sufficient to meet basic water requirements 10–15 m³ per month. After this, levels of consumption are charged at progressively higher unit rates in order to discourage excessive usage. Whilst this may address questions of social equity, it is often unclear on what basis tariffs are set. The absence of robust economic regulation provides opportunities for less rigorous approaches to tariff setting. The suggested lack of affordability together with water being a basic need provide powerful arguments to the political classes to keep water tariffs low.

In Dominica the 15% tariff increase in 2011 was judged to be reasonable by members of the public. However, affordability is clearly an issue in some cases. A high level of outstanding accounts and a lack of effective measures to penalize non-payment are perhaps indicative of this. A further problem has been the *ad hoc* nature of tariff adjustments in many, but not, all cases. However, the mounting pressures on public finances may be having an effect as several countries that have revised their tariffs over the last four years (e.g., Barbados, Jamaica, Dominica, Grenada, and Saint Vincent and the Grenadines).

6.2. Service Provider Affordability

The provision of water services requires financing in order to cover costs, and service providers have to generate sufficient income to cover these costs: If they do not, then services have to be curtailed. The predominate financing model in the Caribbean is one whereby operation and maintenance costs are covered by revenue from tariffs but capital works are funded through loans guaranteed by governments and by government transfers. This “cash needs” approach [44] does not take into account implicit costs such as exchange and inflation risks, environmental costs, bad debts, and costs of foregone operation and maintenance. If tariffs are not regularly reviewed and adjusted, there will be an increasing reliance on taxation transfers. This appears to be the case in Barbados,

Dominica, St Lucia and Trinidad and Tobago, and probably in other Caribbean countries as well, where increasing levels of utility indebtedness have been reported (Note that this can be difficult to determine if the audited Annual Accounts of the service providers are not published). A compounding factor is the lack of a clear institutional framework of policies, legislation and regulations that sets out duties and responsibilities, such as cost recovery policies [31].

A development that appears to be emerging as a result of the current economic challenges is that of off balance sheet financing mechanisms such as public-private-partnerships. To date such arrangements have been used in the provision of desalination plants, but there is no reason why the approach cannot be extended to other aspects of service provision and management such as the provision and management of wastewater facilities.

7. The Regional Outlook

The Caribbean is one of the most vulnerable regions in the world with respect to exposure to the effects of climate change and also to natural hazards. Many of the challenges arise from the macro-economic conditions that prevail in the Caribbean. Countries are heavily indebted with debt to Gross Domestic Product (GDP) ratios unsustainably high [45]. Unemployment, especially levels of youth and female unemployment have been growing, and the high levels of poverty throughout the region pose particular challenges to governments to be able to fund programs and initiatives and maintain levels of services to communities. However, since the mid-20th century the Caribbean region has undergone a remarkable transformation away from predominantly rural, agricultural-based economies to a situation where the majority of the population is urbanized. Nevertheless, there will be challenges for Caribbean states in holding onto the gains that have been made whilst at the same time moving towards sustainable water resources management.

However, even under the current economic circumstances there is a trend of increased investment in infrastructure such as production wells, water treatment works, pumping installations, leakage reduction initiatives, and mains replacement programs. Water utilities in Dominica, Barbados, Grenada, Jamaica and others are investing, sometimes out of their own resources and sometimes with the help of international financing institutions, in works that extend existing supplies or make them more robust. Jamaica is to invest US\$44 million in rural water supply upgrading, benefiting 250,000 people over 3 years in addition to obtaining an Inter-American Development Bank (IDB) grant to carry out a rural water master plan and review of its water sector policy. In the case of Haiti, there is the prospect with investments being made by the IDB and other funding agencies that the next few years will see considerable improvements in water supply and sanitation. Indeed, from Jamaica and Haiti some of the successful models of service delivery involving private sector provision may well find application within the wider Caribbean. The examples of private sector involvement include water services being provided by small companies, community based organizations, and non-governmental organizations.

With respect to climate change, the region is probably unique in adopting a regionally-led response through the development of “The Implementation Plan for Regional Framework for Achieving Development Resilient to Climate Change”. This includes actions which addresses water-related needs and form the basis for attracting funding and investment for the region. It is the result of cooperation across the region coordinated through a regional apex body. Regional cooperation in water is

strengthened at the formal and informal level through various mechanisms that bring together professionals and policy-makers to engage in dialogue.

Efforts to address institutional weaknesses have not been universally successful nor have the key linkages between land and water management been incorporated into policies and planning. This is probably the second biggest challenge after economic development, facing the region. Support and engagement through IWCAM were credited with facilitating the entering into force of the LBS Protocol and thus clearing the way for getting the Caribbean Regional Fund for Wastewater Management (CRew) off the ground. The successor project IW-Eco promises to leverage co-financing for the water sector of US\$118 million. These initiatives have also bolstered efforts to improve data gathering with Barbados, Guyana, Grenada, St Lucia and Jamaica implementing national water information systems. Such systems are fundamental to better water management, the ability to plan and to adapt to increasing climate variability associated with climate change.

The key challenges and vulnerabilities may be summarized as follows. Data gathering and information availability and management are major challenges, which have been highlighted on many occasions. The lack of data compounded by barriers to making data available hampers the understanding of current water vulnerabilities, the ability to plan ahead and to identify appropriate adaptation strategies. Forward planning has been largely neglected and is symptomatic of a lack of appreciation of the need for having national water policies. In this respect, Jamaica's development of a national master water plan serves as an example of what can be done. The reluctance to involve the private sector in a range of activities such as localized water supply, wastewater facilities, and outsourcing needs to be addressed, and a conducive environment to facilitate its involvement needs to be established. This should assist in finding innovative ways to improve the maintenance of water and sanitation infrastructure, introduce demand management, and extend wastewater services. Lastly, the perception has to be addressed that welfare and water are synonymous. Water service providers have to be efficient, well managed, and allowed to do their job. This means that they have to be on a sound financial footing. The challenge is to find the balance between appropriate political and regulatory oversight and the autonomy of water managers and service providers. Compared with 50 years ago, water security in the Caribbean has improved enormously, and the achievements are all the more impressive given where the region has come from socially, politically and economically. There are still many challenges to be faced, and these are acutely apparent through the impact of natural hazards. However, climate change, of itself, is not the most pressing problem but rather the macro-economic conditions. It is the macro-economic conditions that determine the creation and availability of resources—natural, human, intellectual, and financial—needed for a water-secure Caribbean. Water security is realized through sustainable economic development as much as sustainable economic development depends on the achievement of water security.

A strengths, weaknesses, opportunities, and threats (SWOT) [46,47] analysis was used to identify some of the key factors affecting water security and the sustainable management of water resources. These are summarized in Table 2.

One practical step is for countries to develop explicit water policies and regulations based on the principals of Integrated Water Resources Management (IWRM). This approach has been championed by various organizations and through their advocacy efforts there has been a growing realization that this does offer a way to address issues of water scarcity and security. There have been a number of

IWRM Roadmaps prepared for the majority of the insular Caribbean states, which provide a basis on which to develop policies. Recently, the Organisation of Eastern Caribbean States (OECS) has developed a model water policy and model legislation, which can form the basis for its member states to revise and update their existing institutional frameworks. Such a framework is seen as a necessary step in addressing a range of issues, which are constraining moves to a more water secure region. It would focus greater attention on the management of water resources as a balance to the current focus on water supply delivery. It would emphasize the need for data collection and forward planning and also the need to closely link land issues with water management. By adopting such approaches the economic case for better management of water as a critical resource in the Caribbean can be made.

Table 2. Strengths, weaknesses, opportunities, and threats (SWOT) Analysis of factors influencing water security.

Strengths	Weaknesses
<ul style="list-style-type: none"> • Rising standards of living • High level and standard of education • Stable political landscape • Highly motivated and networked water professionals • Regionalized approach to climate change 	<ul style="list-style-type: none"> • Low population growth and aging population • Outward migration leading to loss of educate population • Low economic growth impacting on ability of economies to finance improvements • Aging infrastructure • Poor financial position of water utilities • Weak regulatory frameworks • Poor institutional framework for the management of water sector • Sparse data, data collection and monitoring
Opportunities	Threats
<ul style="list-style-type: none"> • Greater role for the private sector • Greater regional integration of water policies • Development of a common water framework for the Caribbean • Climate change—financing of adaptation measures which would address water security • South-south cooperation • Requirement under the Cartagena Convention Annex III to improve wastewater management • Urbanization—cost effective provision of water services 	<ul style="list-style-type: none"> • Climate change and variability affecting: <ul style="list-style-type: none"> ○ Tropical storm activity ○ Higher temperatures ○ Greater variability of rainfall ○ Sea level rise • Land conversion <ul style="list-style-type: none"> ○ Urbanization ○ Soil erosion ○ Agricultural pollution ○ Deforestation • Low economic growth rate, tied to main European and North American markets • Perception of water as a public good • Political interference

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Conflicts of Interest

The authors declare no conflict of interest.

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