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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE WATER SECTOR IN SAINT VINCENT AND THE GRENADINES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACCC	Adaptation to Climate Change in the Caribbean
ARIMA	Autoregressive Moving Average
BAU	Business as Usual
CCA	Cancouan Construction Association
CCCCC	Caribbean Community Climate Change Centre
CEHI	Caribbean Environmental Health Institute
CWSA	Central Water and Sewage Authority
DFID	Department for International Development
DJF	December January February
DO	Union Island District Office
ECLAC	Economic Commission for Latin America and the Caribbean
ENSO	El Niño Southern Oscillation
ESD	Environmental Services Unit, Ministry of Health and Environment
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Fund
GHG	Green House Gases
GIS	Government Information Services
JJA	June July August
IPCC	Inter-Governmental Panel on Climate Change
MACC	Mainstreaming Adaptation to Climate Change
MoGA	Ministry of Grenadines Affairs
NAO	North Atlantic Oscillation
NCSP	National Communications Support Program
PMC	Project Management Committee
RECC	Review the Economics of Climate Change in the Caribbean

SC	Steering Committee
SIDS	Small Island Developing States
SLR	Sea Level Rise
SON	September October November
SRES	Special Report on Emission Scenarios
SVG	Saint Vincent and the Grenadines
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHO	World Health Organization
VINLEC	Saint Vincent Electric Company

EXECUTIVE SUMMARY

Water security which is essential to life and livelihood, health and sanitation, is determined not only by the water resource, but also by the quality of water, the ability to store surplus from precipitation and runoff, as well as access to and affordability of supply. All of these measures have financial implications for national budgets.

The water sector in the context of the assessment and discussion on the impact of climate change in this paper includes consideration of the existing as well as the projected available water resource and the demand in terms of: quantity and quality of surface and ground water, water supply infrastructure - collection, storage, treatment, distribution, and potential for adaptation. Wastewater management infrastructure is also considered a component of the water sector.

Saint Vincent and the Grenadines has two distinct hydrological regimes: mainland St Vincent is one of the wetter islands of the eastern Caribbean whereas the Grenadines have a drier climate than St Vincent. Surface water is the primary source of water supply on St Vincent, whereas the Grenadines depend on man-made catchments, rainwater harvesting, wells, and desalination. The island state is considered already water stressed as marked seasonality in rainfall, inadequate supply infrastructure, and institutional capacity constrains water supply.

Economic modelling approaches were implemented to estimate sectoral demand and supply between 2011 and 2050. Residential, tourism and domestic demand were analysed for the A2, B2 and BAU scenarios.

In each of the three scenarios – A2, B2 and BAU Saint Vincent and the Grenadines will have a water gap represented by the difference between the two curves during the forecast period of 2011 and 2050. The amount of water required increases steadily between 2011 and 2050 implying an increasing demand on the country‘s resources as reflected by the fact that the water supply that is available cannot respond adequately to the demand.

The Global Water Partnership in its 2005 policy brief suggested that the best way for countries to build the capacity to adapt to climate change will be to improve their ability to cope with today‘s climate variability (GWP, 2005). This suggestion is most applicable for St Vincent and the Grenadines, as the variability being experienced has already placed the island nation under water stress. Strategic priorities should therefore be adopted to increase water production, increase efficiency, strengthen the institutional framework, and decrease wastage.

Cost benefit analysis was stymied by data availability, but the ―no regrets approach" which intimates that adaptation measures will be beneficial to the land, people and economy of Saint Vincent and the Grenadines with or without climate change should be adopted.

Table 1: Priority Investments with Indicative Costs

Ranking	Strategic Response	Adaptation Option	Indicative Cost US$
First order of Priority	Increasing production/supply	Integrated Water Management to increase planning and storage over 3 yr period 2012-2014	4,000,000
		Strengthen rainwater harvesting resources at the local level. Over 3 year period 2012-2014	1,000,000
	Sub Total		5,000,000
	Increasing efficiency	Waste Water Treatment 3 year period 2012-2014	3,000,000
		Develop water efficient program for agriculture 3 year program 2012- 2014	5,000,000
	Sub Total		8,000,000
	Institutional Framework	Strengthen rainwater harvesting resources at the local level 3 year 2012-2014	1,000,000
	Sub Total		1,000,000
	Decrease Wastage	Integrated water resource Management 4 year period 2012-2016	4,000,000
	Sub Total		4,000,000
	TOTAL		**18,000,000**
Second Order of Priority	-Promote Environmental Management system for tourism sector. A two year project 2012-2013. - Design and implement public information program to garner political & civil support for efficiency & protection of resource. A 2 year program 2012-2014.		1,000,000 2,000,000
	Sub Total		3,000,000
	TOTAL		**3,000,000**
Third Order of Priority	None of these projects have as yet had an indicative cost derived.		Nil
SUM			**$21,000,000**

A study on the costs of inaction for the Caribbean in the face of climate change listed Saint Vincent and the Grenadines among the countries which would experience significant impacts on GDP between now and 2100 without adaptation interventions. Investment in the water sector is germane to building the capacity of Saint Vincent and the Grenadines to cope with the multivariate impact of changes in the parameters of climate.

I. INTRODUCTION

A. PURPOSE

This document presents an economic assessment of the potential impact of climate change on the water sector in Saint Vincent and the Grenadines projected to 2050. It is expected that the results of the assessment will stimulate governments, institutions, private sector and civil society to craft effective climate change adaptation and mitigation measures to ameliorate the projected impacts within the respective sectors and the economy.

The availability of water is pivotal in the dialogue on climate change, as changing precipitation patterns and temperature relate directly to water resources and water security. Water security which is essential to life and livelihood, health and sanitation, is determined not only by the water resource, but also by the quality of water, the ability to store surplus from precipitation and runoff, as well as access to and affordability of supply.

B. THE WATER SECTOR DEFINED

For the purposes of this report, the water sector in the context of the assessment and discussion on the impact of climate change includes consideration of the existing as well as the projected available water resource and the demand in terms of:

- quantity and quality of surface and ground water
- water supply infrastructure - collection, storage, treatment, distribution
- potential for adaptation
- wastewater management infrastructure

Analysis of the changing ratios between water availability and demand needs to consider not only changes in parameters of climate and socioeconomic variables expressed through demand and supply, but also measures to be employed for strengthening the resilience of the sector to the threats posed by climate change. The study involved three scenarios: a) Business as Usual (BAU) in which the status quo in Grenada is maintained in terms of no action by the Government on climate change adaptation and mitigation

b) the A2 scenario in which the global trajectory figures continue as is ; and c) the B2 scenario in which mitigation measures lead to modified emissions and reduced rates of warming.

The approach to the study included:

a. review of relevant regional and national reports on climate threats, climate change projections, natural hazard vulnerability, and water sector issues such as demand and supply and approaches to economic modelling, and proposed investments in adaptation measures to meet changing supply;

b. data collection and analysis as elaborated in Appendix I .

The sector review is informed by an understanding of the current socio-economic situation in Grenada as it relates to water demand and supply, and the key climatic threats - floods, drought, extreme tropical weather systems (storms, hurricanes), storm surge, changes in rainfall patterns and rising sea levels - under the various scenarios and carbon emission trajectories for the 40 year period.

C. CONTEXTUAL BACKGROUND

The small island developing states (SIDS) of the Caribbean are regarded as hotspots for climate change, and a significant aspect of climate change is the impact on water resources. Several territories within the region already suffer from the extremes of flood and drought and at varying times throughout any given year, access to adequate water supply in both urban and rural areas may elude a significant proportion of the population. In many instances natural occurrence exceeds demand, but supply is conditioned by spatial demand particularly with increasing urbanisation, agricultural needs, and growth in the tourism sector.

The primary and secondary impacts associated with repeated incidence of flood producing rainfall events, hurricanes, storm surge, and drought wreak frequent havoc on surface flows and groundwater as well as the supply systems. Sea level rise, saltwater intrusion and salinisation of freshwater lenses in the coastal aquifers will further limit natural water availability, and pollution of resources will exacerbate the declining resource. The effects of global warming and climate change are projected to exacerbate these conditions (ESL, 2008).

It is worthy of note that although the islands of the Caribbean generally report widespread access to water and sanitation facilities, and good progress toward meeting Target 7C of the Millennium Development Goals (MDG) to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation, there is an apparent disconnect between access and use, and little consideration of the seasonality and variability which also affects quantity and quality of the resource. According to a report by the Caribbean Environmental Health Institute (Caribbean Environmental Health Institute [CEHI], 2007a), the Caribbean subregion has the least water available per capita as compared to other SIDS regions (CEHI, 2007a).

SVG, situated about 160 km west of Barbados, comprises an archipelago of several islands and cays stretching for about 129 km between St Lucia and Grenada in the Windward Islands of the eastern Caribbean. The country is among the island states considered already water stressed. The main island is

St Vincent, and the Grenadines comprise eight smaller main islands and several islets and cays extending south of St Vincent for approximately 45 miles (75 Km). In the Grenadines the major islands, north to south, are Young Island, Bequia, Mustique, Canouan, Mayreau, Union Island, Palm Island, and Petit Saint Vincent (figure 1).

Figure 1: Saint Vincent and the Grenadines

Source: http://www.intute.ac.uk/worldguide/html/1008_map.html

Seasonality and variability in rainfall can cause up to 40% reduction in available resources during the dry season (Cashman and others, 2010). Agriculture and tourism, two major consumers of water are significant economic activities in Saint Vincent and the Grenadines. Tourism is the mainstay in the Grenadines, and agriculture, though declined considerably with the loss of banana export preferences, is still important on Saint Vincent. On Bequia and other islands in the Grenadines, where the main source of supply is rainwater harvesting or —roof water," variability in rainfall patterns means that as local supplies run dry the government has to send in water via —water boats" to meet the shortfall (Durrant, 2007). There is an underinvestment in water infrastructure, (CEHI, 2007a) but constraints of cost recovery and competing demands on the national treasury deter redress (Cashman and others, 2010).

The Global Water Partnership in its 2005 policy brief suggested that the best way for countries to build the capacity to adapt to climate change will be to improve their ability to cope with today's climate variability (GWP, 2005). Further it has been suggested that among the portfolio of water sector actions for SIDS should be integrated water resources management, demand management, water quality capacity-building; water governance and hydrological cycle observing systems (Overmars and Gottlieb, 2009). The principles of IWRM are instructive for adaptation considerations. They include the following:

Recognition that water is a finite resource and an integral part of ecosystems;

- ✓ Human activities affect the productivity and functioning of water resources;
- ✓ Water resources need to be managed at an appropriate level geographically and through the active participation of stakeholders;
- ✓ Women have a central role to play in water management;
- ✓ Water should be equitably accessible; the management of water needs to be coordinated and integrated across different levels, sectors, and institutions; and
- ✓ Water has an economic value and should be recognized as an economic as well as a social good (Pangare et.al., 2006).

In the 2010 National Environmental Summary of Saint Vincent and the Grenadines the issue of climate change was identified among six key issues. The other five issues namely deforestation, land degradation, loss of agricultural lands to development, pollution of coastal water and river systems and solid waste are all also significant for the country's water sector, and are interrelated with, and impacted by, climate change. The impact of climate change on Saint Vincent and the Grenadines in general has been assessed through various global climate models. However the economic impact is significant to the country's sustainable development and assessment of that impact needs to consider vulnerabilities of the sector and the requirements for building resilience.

The introductory section outlines the mandate for the consultant and the contextual background for the study. Section II summarises the review of literature related to assessment of the projected impact of climate change on the water sector and approaches to simulation modelling and assessment of impacts. Section III provides and analysis of the water sector. Section IV describes the socioeconomic setting, vulnerabilities of and threats to the water sector, and Section V presents an analysis of climate for water sector guidance. Section VI presents the results of the modelling in terms of the BAU, A2 and B2 scenarios. Section VII recommends adaptation and mitigation strategies and findings and recommendations are summarised in Section VIII.

II. LITERATURE REVIEW

Assessment of the economic impact of climate change on the water sector of Saint Vincent and the Grenadines has been informed by a review of literature on the subject of measuring the impact of climate change, as well as papers on the vulnerabilities and threats to the Caribbean water sector in general and Saint Vincent and the Grenadines in particular. The approach to the study involved a survey of previous studies and data on economic models that could assist with selection/development of an appropriate model to conduct the analysis of the sector in SVG reports on existing parameters of climate and projected climate scenarios; and significance of the sector to the country‘s economy.

A. APPROACHES TO MEASURING IMPACT OF CLIMATE CHANGE ON THE WATER SECTOR

1) Overview

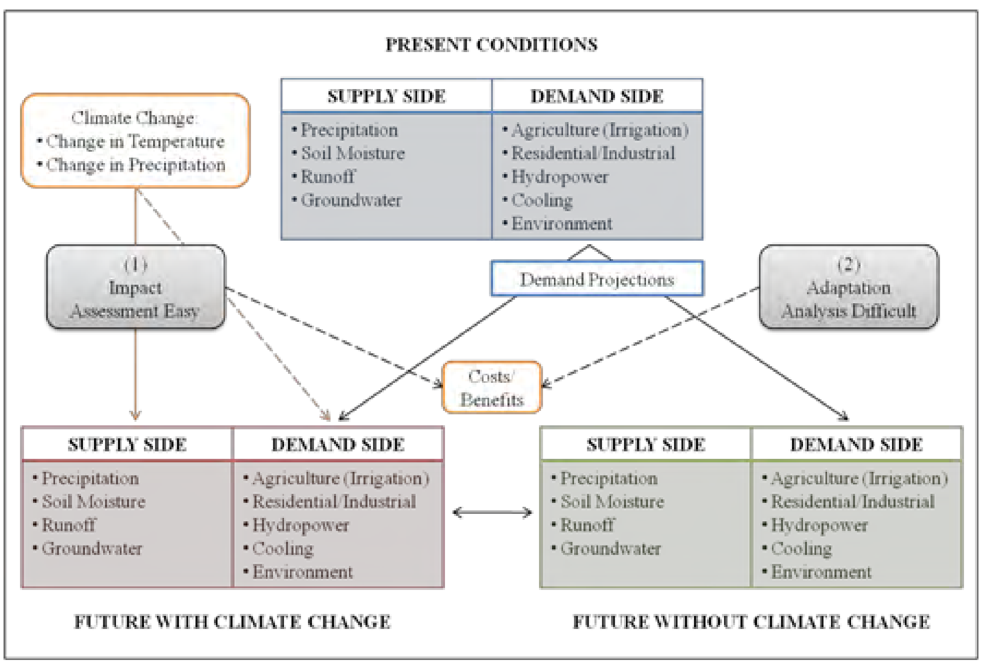
The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, identified the water sector, along with agriculture, as being the ―most sensitive to climate change-induced impacts" (cited in Yanda and others, 2006, pp. 14). Bates and others (2008), in a 2008 IPCC technical paper, confirmed, *inter alia*, that:- (a) higher water temperatures are likely to affect water quality and exacerbate water pollution (p. 43), (b) increased precipitation variability are likely to increase the risks of flooding and drought (p. 56), (c) several gaps exist in knowledge related to climate change and water (p. 133), and (d) current water management practices may not cope with the impact of climate change (p. 63). In the light of (c) and (d), particularly, Hansen and others (2009) (also Mavromatis and Jones 1998) suggest that research into the risk that climate variability and change pose to water resources needs to be integrated into all related programmes and projects through: - (a) observations and analyses, (b) model simulations, (c) seasonal water outlooks, (d) climate scenario constructions, and (e) assessments of the hydrological sensitivity of catchments. The resulting improved understanding of long-term climate variability and change should (a) assist water management practices and productivity, (b) facilitate improved water supply systems (c) maximise opportunities for sustainable ecosystem management, and (d) improve water resource management options and policy response (Gleick and others, 2000; Gleick and others, 2001; Ringler 2008).

2) The Economic Valuation of Water

Water is a complex resource. The boundaries of the sector are unclear; it enters almost every economic and ecological good and process; the good is typically not priced in the market (often subsidized); and values are unstable (seasonal/spatial variation; ADB, 2010). The economic value of water is therefore, not easy to establish (Rodgers, 2010b). This, no doubt, compromises the reliability and validity of the projections for climate-change associated costs and benefits (the future status of the resource and its price as determined by the interaction of demand and supply functions), a position solidified by Turner and others (2004). As the IPCC reports and technical papers have only indicated the ‗likely' impact of climate change on water resources, it is clear that there exists a wide range of underlying uncertainties and risks. Despite this, researchers have coalesced around two key points, crucial for establishing a premise for the discussions contained herein:-

- climate risks exacerbate the existing stresses on water resources due to rapid economic development, demographic changes, and associated increases in water demand (Bakker and van Schaik, 2010; Cashman and others, 2010; Rodgers 2010b; ECLAC, 2010), and
- the sustainability of water, irrigation and farming systems is dependent on climate variability and their future viability are threatened by climate change (Diaz and Morehouse, 2003; Yano and others, 2007; Chakanda and others, 2008; UN-ECLAC, 2010).

Figure 2: Conceptual framework for impact evaluation)



Source:Adapted from: Rodgers 2010a, p. 23

Many of the studies aiming to evaluate and quantify the impact of climate change on specific resources such as water have failed to outline a conceptual framework for achieving their stated objectives, important for understanding the preferred approach to the discussions/analyses. Figure 2, adapted from Rodgers (2010a) attempts to fill this need.

On the one hand, the author proposes that impact evaluation within a climate change scenario is easier when the analysis is done from the supply side. On the other hand, adaptation analysis is more difficult when done from the demand side. At a very basic level, what may also be extrapolated from this conceptual framework is that both demand and supply sides must be analyzed, and so too should the costs and benefits of a future with climate change. Patterning this framework and for the purposes of this review, the studies will be categorized into supply- and demand-side approaches to understanding the issues concerning the economic valuation of water as well as changes in its total economic value (TEV) brought about by climate change.

3) Supply-Side Approaches

Since the early 2000s, a number of studies forecasting the impact of climate change on water resources and the various methods that can be used to cost same have emerged. At present, demand-side approaches appear to outnumber supply-side approaches and are better articulated. Despite this, a considerable number of researchers have attempted to model the economic effects of climate change on either specific resources or specific industries. Though two slightly variant angles on supply-side analyses, Rose and others (2000) and Moore and others (2010), examined the impact of projected changes in precipitation, soil moisture and runoff on the economy of the Mid-Atlantic Region of the United States (US) and on exogenous economies (US and the world), and the impact of these changes, particularly sea level rise, on the profitability and viability of the tourism industry in Barbados, respectively.

North America: Based on the premise that (a) a translation of the physical impacts of climate change into dollars provides a convenient basis for comparison of impacts and a bottom-line unit of account, and (b) the ultimate welfare effects of the physical impacts of climate change depend on economic choices made from available response options, Rose and others (2000) provided models for analyzing how climate change will affect the economy of the Mid-Atlantic Region (MAR)[1] of the United States of America. Using input-output (I-O) models along with the Impact Analysis for Planning (IMPLAN) System[2], the authors were able to generate intermediate inputs for sectors such as agriculture and forestry, mining and utilities (water and electricity) as well as derive demand functions for personal consumption, government, investment/inventory and exports. Additionally, the authors calculated three types of impacts using the I-O models:- (1) demand-driven multiplier impacts (the standard I-O multipliers that measure upstream stimulus to the MAR economy through the chain of suppliers to each affected subsector), (2) supply-driven multiplier impacts (the downstream stimulus to the MAR economy through the chain of customers of each affected subsector), and (3) price impacts (the cost-push inflation for the MAR

[1] The MAR includes states such as New York, New Jersey, Washington, D.C.

[2] The IMPLAN System was developed by the US Forest Service of the Service, Federal Emergency Management Agency, and several other federal government agencies. IMPLAN consists of an extensive national and regional database, algorithms for generating non-survey I-O tables for any county or county grouping in the US, and algorithms for performing impact analyses (IMPLAN 1997).

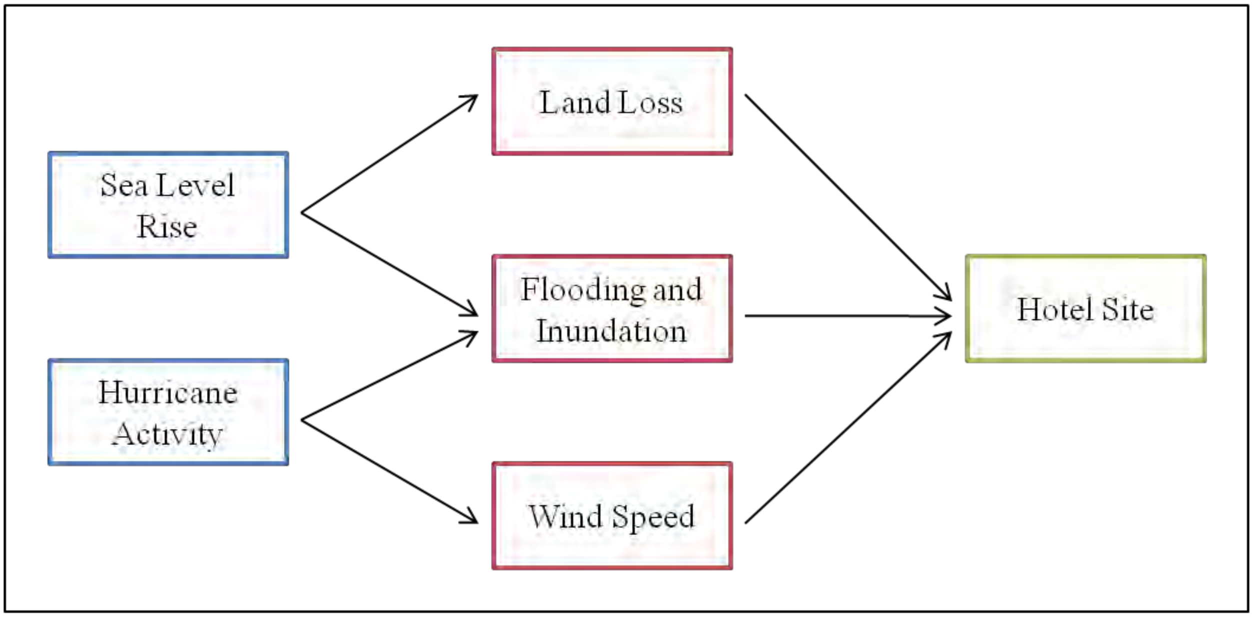
economy as a result of productivity losses in each affected sector) (Rose and others, 2000, pp. 180-181). The supply-driven analysis, over the demand-driven analysis, revealed larger direct impacts and more significant total impacts amounting to -US$150.1 million where most of the impacts affected the agriculture and forestry industries. The authors also highlighted the possibility of muting the supply-driven impacts while bringing attention to the fact that ―i[t] may be difficult if other supplying regions are impacted by climate variability at a level equal to or greater than the MAR" (Rose and others, 2000, p. 181).

<u>The Caribbean</u>: Using data from one hundred and eighty one establishments, Moore and others (2010) examined the potential effects of climate change on the tourism industry in Barbados by generating supply-side simulations conducted particularly ―in relation to the impacts of rising sea levels and greater storm activity on the ability of the island to supply accommodation services" (p. 5). By way of the model captured in figure 3 and the equation the authors were able to corroborate the general findings of Chandler (2004), which showed storms in North Carolina, United States of America, resulting in physical damage and loss revenues of between US$96-US$125 million to the lodgings industry between September and October 1999. Though disadvantaged by the limited availability of historical data on hurricanes impacting Barbados (p. 11), the study found that possible losses from future extreme climatic events would far outweigh the possible losses from potential sea level rise. When modest assumptions were employed regarding storm activity in the region, the potential losses to the industry were estimated at US$356 million, or almost twice the amount obtained under the worst case scenario for land loss (p. 19). Given the potential level of reduced revenue and value-added combined with the number of job losses, it was determined that there is a relatively high risk to the tourism sector and the economy as a whole due to extreme climatic events (p. 19). Figure 3 illustrates a schematic representation of the supply-side simulation model.

4) Discussion of Supply-Side Approaches

Where the Rose and others (2000) study is concerned, the major strength of the I-O model is its potential for disaggregation, which can readily delineate climate-sensitive sectors such as agriculture and forestry and, by extension, water. Other strengths include, as the authors had put it, ―the comprehensive accounting of resource inflows, which helps determine the economy‘s carrying capacity needs; the general equilibrium nature, which is able to trace multiplier or feedback effects; the technological basis, which provides a solid grounding in production requirements; the socioeconomic dimensions, which offer the capability to perform distributional impact analysis; and the empirical orientation, which provides an immense data and computational software base" (p. 177).

Figure 3: Schematic representation of the supply-side simulation model



Source: Moore and others,2010, p. 13

The following equation (Moore and others, 2010, p. 13) was used to estimate national loss :

$$NL = I \times P \times L$$

Where[3]:-

NL = National Loss Estimates

I = Storm Intensity

P = Probability of Storm Impacts

L = Loss Factor (Storm Type)

The major weakness of the I-O models, as pointed out by authors such as Leontaritis and Billings (1985), Duchin (1992) and Miller and Blair (2009), is that they lack standard statistical properties. Additionally, the inherent linearity of basic input-output models and the absence of market and price considerations have caused researchers, especially at the national and international levels, to favour computable general equilibrium (CGE) models. These are multi-market simulation models based on the simultaneous optimizing behaviour of individual consumers and firms, subject to economic account balances and resource constraints (Shoven and Whalley, 1992). With only a few exceptions examining the

[3] The simulation also utilized data on the number of rooms and the proximity of each hotel to the shoreline.

general equilibrium impacts of climate-induced increases in agricultural production costs, electricity rates, and coastal protection measures (e.g. Scheraga and others, 1993), most of the climate-related applications of CGE models have been to mitigation policy (e.g. Jorgensen and Wilcoxen, 1993; Kamat and others, 1999). Recent applications have included impacts of short-term climate variability e.g. riverine flooding and longer-term climate change affecting agriculture (Rose and others, 1999).

Where the Moore and others (2010) study is concerned, the equation used to quantify the effects of climate change on the tourism industry is a simple approach. The results generated from the simulations tended to magnify the uncertainties associated with climate change. Cases in point are the inclusions of the probability of extreme weather events affecting Barbados and the likely devastation that could be caused. The need to resolve the top-down, bottom-up quagmire in impacts evaluation was underscored as important to the reliability of the results.

5) Demand-Side Approaches

In recent years, water demand, particularly residential demand, has been extensively analysed (Martínez-Espiñeira, 2007). In many of these studies, though the focus is the United States of America (e.g. Renwick and Green 2000; Taylor and others, 2004; Bell and Griffin 2005), water demand is inelastic. There are, however some exceptions - Hansen (1996), Höglund (1999), Nauges and Thomas (2000), and Martínez-Espiñeira (2002; 2007), for example, use European data. Due to differences across the world in how water is used and priced, as acknowledged by authors such as Hentschel and Lanjouw (1997), there are geographic variations in price elasticities of demand, especially between North America and Europe (Arbués and others, 2003; Dalhuisen and others, 2003) and between Australia (Hoffmann and others, 2005). Three of these studies are summarised in table 2, and are expanded on thereafter.

North America: Renwick and Green‘s 2000 study had two major objectives, to (1) assess the potential of price and alternative demand side management (DSM) policies such as water restrictions, water allocations and public conservation campaigns as a tool for the management of urban water usage and supply, and (2) develop an econometric model of residential demand, using cross-sectional monthly time-series data, for an area representing 24% of California‘s total population (7.1 million). The study concluded that (a) price and non-price (alternative) DSM policies are effective in reducing aggregate residential water demand but these reductions vary in magnitude, and (b) aggregate single-family household demand is responsive to price changes. These results laid the groundwork for the Bell and Griffin (2005) study of the determinants of demand for water used in Texas communities, which reiterated two important concepts (a) water demands are not fixed requirements; they have varying total and marginal economic values (Harou and others, 2009), and (b) price elasticity may not be constant from month to month, though constant price elasticity forms are common in water management models that include the computation of consumer surplus (Griffin 1990; Jenkins and others, 2003).

Australia: Using linear and non-linear regression techniques, deriving descriptive statistics such as sample means, standard deviations, skewness, kurtosis and *p-values*, and using one dependent (quantity of water consumed) and four independent variables (e.g. marginal price of water and household size), Hoffmann and others (2005) modelled household water demand with fixed volumetric charging in Brisbane between 1998 and 2004. The study resolved that:- (a) residential water supply is both price and income inelastic, (b) price inelasticity of demand is larger than previously thought, (c) price and income elasticity of demand in owner-occupied households is higher than in renter households (-0.681 and -0.509; 0.267 and 0.290, respectively), (d) factors exogenous to water authorities also have an influence on residential water demand, and (e) weather (especially the number of warm days) is likely to exert more influence on residential water consumption than any other factor subject to the usual demand management strategies.

Europe: Martínez-Espiñeira (2007), in modelling residential water consumption and demand in Seville, Spain, between 1991 and 1999, used co-integration and error correction techniques - unit root tests and time-series monthly data - the first of its kind in Europe. The dynamic properties of the series (for example, water use) were analysed and found to be non-stationary. The study also found that:- (a) the estimates of the price effects obtained are less than one in absolute value, thus confirming the inelasticity of household demand with respect to the price of water, and (b) long-run price elasticity (estimated at -0.5) is greater in absolute terms than its short-run counterpart (estimated at -0.1).

Discussion of Demand-Side Approaches: The referencing of the above studies indicates that the trend in econometric approaches to estimate price-response and marginal benefits for the consumer is towards the use of cross-sectional data as well as time series and panel data (Arbués and others, 2003). The discussions in the literature have focused on which variables to include in the model in addition to water quantity and price, the best functional forms for statistical estimation, data, and magnitudes of the estimated price and income elasticities (Dalhuisen and others, 2003). There is no widespread support in the literature for the use of all the variables listed in each of the studies. The incorporation of household size, for example, a variable deemed statistically significant by Hoffmann and others, (2005), has been critiqued elsewhere; Arbués and others (2000) found that water use is less than proportional to an increase in household size because of economies of scale in discretionary and nondiscretionary usage such as cooking and cleaning.

Other major challenges to econometric estimations of water price elasticity is the simultaneity problem posed by block-rate schedules, the level of disaggregation, dataset size, and the price specification (Harou and others, 2009; Young 2005). Typical econometric applications include specifying a marginal price variable, a Taylor–Nordin difference variable (as was approach taken by Renwick and Green, 2000, and Martínez-Espiñeira, 2007), demographics, and climate data as regressors for water use (Griffin and Chang, 1991). Additionally, a number of indirect methods have been proposed to estimate economic costs of urban water scarcity based on optimization models that select the least-cost mix of residential water-saving techniques (Alcubilla and Lund, 2006; Rosenberg and others, 2007), to be achieved through contingent valuation surveys of willingness to pay in order to avoid shortages (Griffin and Mjelde, 2000).

Following the Martínez-Espiñeira (2007) study, the measure of the impact of pricing policies on the behaviour of households, depending on changes in tariff structures, remains an open area of research.

What is evident is that the long-run effects of water pricing on water may need to be investigated using other datasets (Rosenberg and others, 2007). The author even suggested a comparative approach using the different regions and longer time-series/panel data but was clear in recommending that water demand studies should be conducted on an individual level (i.e. country) with observations particularly linked to ownership (for example, water as a public versus private good; owner-occupied versus renter households). This point is firmly corroborated by Bell and Griffin (2005) who reiterated that meta-analysis, while offering a hint of the potential properties of water demand, is no substitute for exacting studies.

B. TOWARDS SELECTING A MODEL

What is certain, though, is that any future study should aim to address a fundamental conundrum in the literature – the effectiveness of price relative to non-price controls. As would have been observed, a majority of the studies developing hydro-economic models in an effort to increase understanding of the inter-relationship between climate change and water resources, do not take into account the effect non-price controls such as water use restrictions and legislation. Additionally, Turner and others (2004) called on researchers engaged in evaluating the impacts of climate change on specific resources to pay special attention to: (a) geographic/temporal scale – the extent of the population affected and changes in direct use (both existing and potential), and the present value of costs and benefits, respectively,(b) aggregation and double counting, (c) allocation over time, (d) the impact of data limitations and/or budgetary constraints wherein the derived results should be understood in view of these (if any), (e) irreversible change, and (f) risk and uncertainty.

1) Model

Particularly in respect of (d) and the data situation (i.e. shortage or inaccessibility) in the Caribbean, a model that takes this into consideration along with the financial woes experienced by governments may be better served. Shahateet (2008), in studying the water sector in Jordan, developed a model that took into account the country‘s increasing population size, declining rainfall, deepening shortage of supply and increasing demand for water, production of agricultural and industrial sectors, price of unit exports, and lack of financial resources, most of which are functions of climate change. The model comprised a system of equations that represents the production sector and the water sector, making it possible to conduct both supply-side and demand-side analyses. The author, on the one hand, used three behavioural equations to represent the production sector. All Greek letters are parameters to be estimated and all u‘s are stochastic disturbance terms. Total production is divided into three categories: (1) agricultural, (2) industrial, and (3) others. It is assumed that production in these sectors are greatly affected by the credit facilities that are extended by banks (and also government subventions as the case may be in the Caribbean) along with per unit price of agriculture exports, water supply to the sector, and quantity of rainfall (applicable only to the agriculture/forestry sectors).

Figure 4: Equation for modelling the production sector

$$AP_t = \alpha_0 + \alpha_1\,ACF_t + \alpha_2\,APE_t + \alpha_3\,AS_t + \alpha_4\,RF_t + u_\alpha \qquad (1)$$

$$IP_t = \beta_0 + \beta_1\,ICF_t + \beta_2\,IPE_t + \beta_3\,IS_t + u_\beta \qquad (2)$$

$$OP_t = \gamma_0 + \gamma_1\,OCF_t + \gamma_2\,OL_t + u_\gamma \qquad (3)$$

Source: Shahateet 2008, p. 266

Where:

AP = Agricultural production at basic prices

ACF = Agricultural credit facilities issues by banks

APE = Agricultural unit price of exports

AS = Agricultural water supply

RF = Rainfall

IP = Industrial production at basic prices

ICF = Industrial credit facilities issues by banks

IPE = Industrial unit price of exports

IS = Industrial water supply

OP = Other types of production at basic prices

OCF = Other credit facilities issued by banks

OL = Other types of labour

On the other hand, three behavioural equations and two identities were used to express the water sector. These are given as figure 5. The supply of water comprises the supply of water for three purposes: (1) agricultural, (2) industrial and (3) municipal. Each type of these supplies is influenced by a set of socio-economic variables, also given in the figure 5 equations. Like the production sector model, all Greek letters are also parameters to be estimated and all u's are stochastic disturbance terms.

Figure 5: Equation for modelling the water sector

$$AS_t = \delta_0 + \delta_1 AP_t + \delta_2 RF_t + u_\delta \qquad (4)$$

$$IS_t = \zeta_0 + \zeta_1 IP_t + \zeta_2 RF_t + u_\zeta \qquad (5)$$

$$MS_t = \eta_0 + \eta_1 POP_t + \eta_2 RF_t + \eta_3 GDPPC_t + u_\eta \qquad (6)$$

$$GDP_t \equiv AP_t + IP_t + OP_t \qquad (7)$$

$$SW_t \equiv AS_t + MS_t + IS_t \qquad (8)$$

Source: Shahateet 2008, p. 267

Where:

POP = Population

GDP = Gross domestic product at basic prices

GDPPC= Gross domestic product per capita

MS = Municipal water supply

SW = Other water supply

2) Data/Estimation Techniques

The data requirements for the model include time-series data for the variables given in the two sets of equation above. The estimation process should comprise two consecutive steps. The first step involves ―selecting [a] model from a rough class of models that better describes the behaviour of the variables under study" (Shahateet, 2008, p. 267). This tentative model should then be ―fitted to the data and the estimated parameters are obtained by applying the method of ordinary least squares (OLS)" (ibid). In the second step, the ―rough estimates that are obtained by OLS, with or without correction of the autocorrelation, should be used as starting values for estimating the parameters of the model using the full information maximum likelihood (FIML) estimation approach" (ibid). Where OLS is concerned, though, this method has been known to yield poor results. For ECLAC (2010) that applied the OLS method to modelling the impacts of climate change on small island states in the Caribbean, for example, each sector temperature was found to be significant for only about half of the countries, and rainfall data was rarely significant. These results run contrary to the probabilities espoused by the IPCC and the general consensus already arrived at by researchers. Care should, therefore, be taken when using OLS.

C. PROJECTED IMPACTS OF CLIMATE CHANGE ON THE WATER SECTOR OF THE CARIBBEAN

Concerns over the status of freshwater availability in the Caribbean region and in particular the eastern Caribbean states have been expressed for at least the past 30 years (Caribbean Environmental Health Institute (CEHI), 2002). In spite of the significant progress that has been made in extending the coverage of water supply and sanitation services, there are increasing challenges in maintaining access, coverage, and quality standards. In the face of population pressures, urbanization, economic development, and growth in tourism, pressures on water resources have increased significantly. Many Caribbean states are increasingly vulnerable to the dual challenges of increasing demand for water and climatic variability where even a slight reduction in rainfall would have serious consequences (IPCC, 2007a; UNEP, 2003). Climate modelling for the Caribbean region under a range of scenarios suggests a continuation of warming in average temperatures, a lengthening of seasonal dry periods, and increases in frequency of occurrence of drought conditions. Major emerging concerns with respect to climate change include: a limited capacity to adapt, flooding, saltwater intrusion, limited storage capacity, all of which contribute to increased water scarcity (Arnell, 2004).

The IPCC's fourth assessment report mentioned above, projects a bleak future for water resources availability in regions such as the Caribbean. The report suggests that decreases in mean annual precipitation (in some cases by as much as 20%) are likely in the regions of the subtropics (figure 4 for the Caribbean basin). The report also indicates unequivocally that on account of human-induced thermal expansion of the ocean surface and the melting of land ice, global mean sea level will continue to rise at a rate of 1.0 to 7.0 mm/year for many decades into the future (IPCC, 2007a). This rate of rise is approximately 10 times higher than the average rate of rise in the previous 3,000 years.

With respect to the Caribbean subregion, a model that runs under a variety of climate scenarios suggests that sea level will continue to rise for the next several decades between 5.0 and 10.0 mm per year (table 2) (IPCC, 2007a). Though this rate of rise may appear to be quantitatively small, the effect will be disproportionately great on low-lying coastal areas, such as those in the Caribbean, where aquifer size is partly controlled by the size of the land mass. Grenada is one such area possessing these characteristics.

In the Caribbean, sea level has risen at a rate of approximately 1 mm/year during the 20th century. Ocean expansion (due to warming) and the inflow of water from melting land ice have raised the global sea level over the last decade. Large deviations among the limited set of models addressing the issue, however, make future estimates of sea level change uncertain, including those for the Caribbean. As for hurricanes, it is the IPCC's projections which are relied on.

Whereas it is not presently possible to project sea level rise for Saint Vincent and the Grenadines, changes in the Caribbean are expected to be near the global mean. Under the A1B scenario, sea level rise within the Caribbean is expected to be between 0.17 m and 0.24 m by 2050 (IPCC, 2007). For comparison, global sea level rise is expected to average 0.35 m (0.21 to 0.48 m) under the same scenario by the end of the century (relative to the period 1980 to 1999). It is important to note, however, that changes in ocean density and circulation will ensure that the distribution of sea level rise will not be uniform across the region.

Recent studies accounting for observations of rapid ice sheet melt (Greenland and Antarctic) have led to greater and more accurate estimates of SLR than in the IPCC AR4 projections. There is an approaching consensus that SLR by the end of the 21st Century will be between 1-2m above present levels (UNDP, 2010). The Caribbean is projected to experience greater SLR than most areas of the world due to its location closer to the equator and related gravitational and geophysical factors (see table 2).

Table 2: Summary of global sea level rise projections for 21st century (UNDP)

	2050*	**2100**		
		Low Range	**Central Estimate**	**High Range**
Continuation of current trend (3.4mm/yr)	13.6 cm	-	30.6cm	-
IPCC AR4 (2007)	8.9 cm to 23.8 cm	18 cm	-	59 cm
Rahmstorf (2007)	17 cm to 32 cm	50 cm	90 cm	140 cm
Horton and others (2008)	~30 cm		100 cm	
Vermeer and Rahmstorf (2009)	~ 40 cm	75 cm	124 cm	180 cm
Grinstead and others	-	40 cm	125 cm	215 cm

	2050*	2100		
		Low Range	**Central Estimate**	**High Range**
(2009)				
Jevrejeva and others (2010)	-	60 cm	120 cm	175 cm

***Where not specified, interpreted from original sources**

Together with a projected decrease in rainfall, rising sea levels will lead to saline intrusion into coastal and groundwater aquifers and thus reduce freshwater availability. However, the effect of eustatic sea-level rise on the adjacent land mass is complicated by the fact that vertical crustal changes are occurring on some Caribbean islands, as a result of tectonic processes (Farrell, and others, 2007). For example, available records suggest that in Trinidad the sea level in the north of the island is rising at roughly 1 mm/year (the average for the region); however, in the south, sea level appears to be rising at approximately 4 mm/year. This must be of great concern to the small islands of the Caribbean, given that global sea levels are projected to continue rising by up to 7 mm/year-1 during the 21st century.

Results from studies carried out by the Institute of Meteorology in Cuba and the University of the West Indies (Taylor and others, 2007) have indicated that the mean temperatures of individual Caribbean territories have demonstrated an upward trend during the last three decades. This trend is driven largely by the steady increase in daily minimum temperature values (figure 3). The studies also showed that the frequency of droughts has increased significantly, whereas the frequency of other extreme events in the region seems to be changing with flooding events and hurricane passage through the region increasing since the mid-1990s (Taylor and others, 2007).

From the results of the regional climate modelling project for the Caribbean region, which was undertaken jointly by the University of the West Indies and the Institute of Meteorology using the United Kingdom Hadley Centre‘s PRECIS model, the main conclusions about changes in average temperatures were that by 2080 an annual warming of between 1° and 5° C would be experienced through the Caribbean, depending on the region and scenario. The warming would be greater in the northwest Caribbean territories of Cuba, Jamaica, Hispaniola, and Belize than in the eastern Caribbean island chain. Also, there would be greater warming in the summer months than in the cooler and traditionally drier earlier months of the year.

Recent projections from a macroscale hydrological model using the IPCC SRES scenarios suggest that many Caribbean islands are likely to become increasingly water stressed in the future, as a result of climate change (figure 4), irrespective of the climate scenario employed (Arnell, 2004; Taylor and others, 2007). The A2 Scenario is based on a world of independently operating, self-reliant nations;

continuously increasing population; regionally oriented economic development; and slower and more fragmented technological changes and improvements to per capita income. The B2 Scenario is based on assumptions of continuously increasing population, but at a slower rate than in A2; emphasis on local rather than global solutions to economic, social, and environmental stability; intermediate levels of economic development; and less rapid and fragmented technological changes. The A1B Scenario is based on the assumption of a balanced emphasis on all energy sources (IPCC, 2007a).

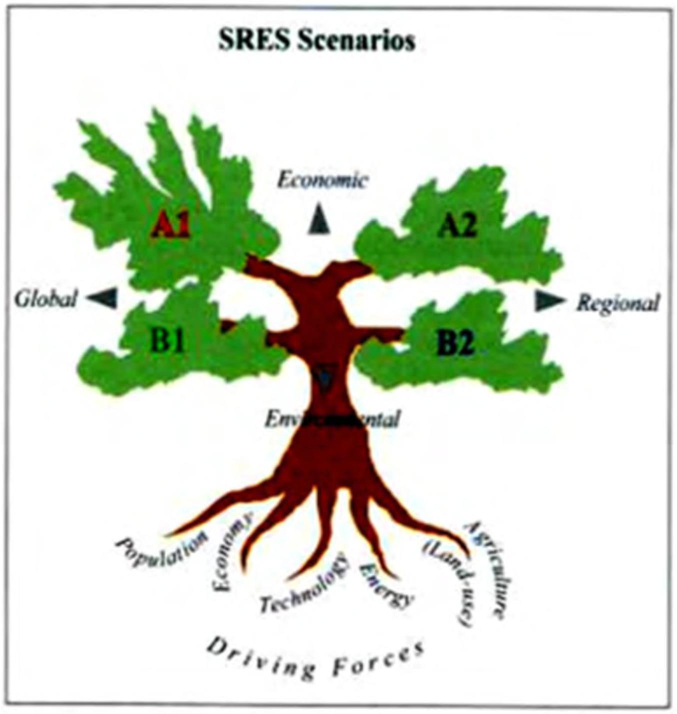
D. IPCC SRES SCENARIOS

Scenarios are alternative images of how the future might unfold. It is an appropriate tool to analyse how driving forces may influence future emission outcomes. SRES scenarios are used to assess associated uncertainties, to assist in climate change analysis, including climate modelling and the assessment of impacts, adaptation, and mitigation (IPCC, 2000).

Four different narrative storylines have been developed to describe the relationships between emission driving forces and their evolution and add context for the scenario quantification (table 3). Each storyline represents different demographic, social, economic, technological, and environmental developments. The scenarios cover a wide range of the main demographic, economic, and technological driving forces of GHG and sulphur emissions and are representative of the literature (IPCC, 2000). The main driving forces of future greenhouse gas trajectories will continue to be

- demographic change
- social and economic development
- and the rate and direction of technological change.

Figure 6: Special Report on Emission Scenarios (SRES) Schematic



Source: Nakicenovic and others, 2000

Monthly rainfall patterns for particular IPCC SRES scenarios have been derived using the PRECIS model (Cashman and others, 2009; figures 7 and 8). The changes are shown as a percentage deviation from the mean monthly precipitation using the period between 1960 and 1999 as the baseline. The percentage deviations are shown in 10% intervals and are differentiated in the figures by increasing colour intensity; that is, the deeper the colour the greater the deviation from mean monthly precipitation (Cashman and others, 2009). The increasing intensity of blue indicates the projected percentage increase in monthly precipitation, mapped across the Caribbean Region, whereas an increasing intensity, from yellow to brown, indicates decreasing precipitation, mapped across the Caribbean region (Cashman and others, 2009).

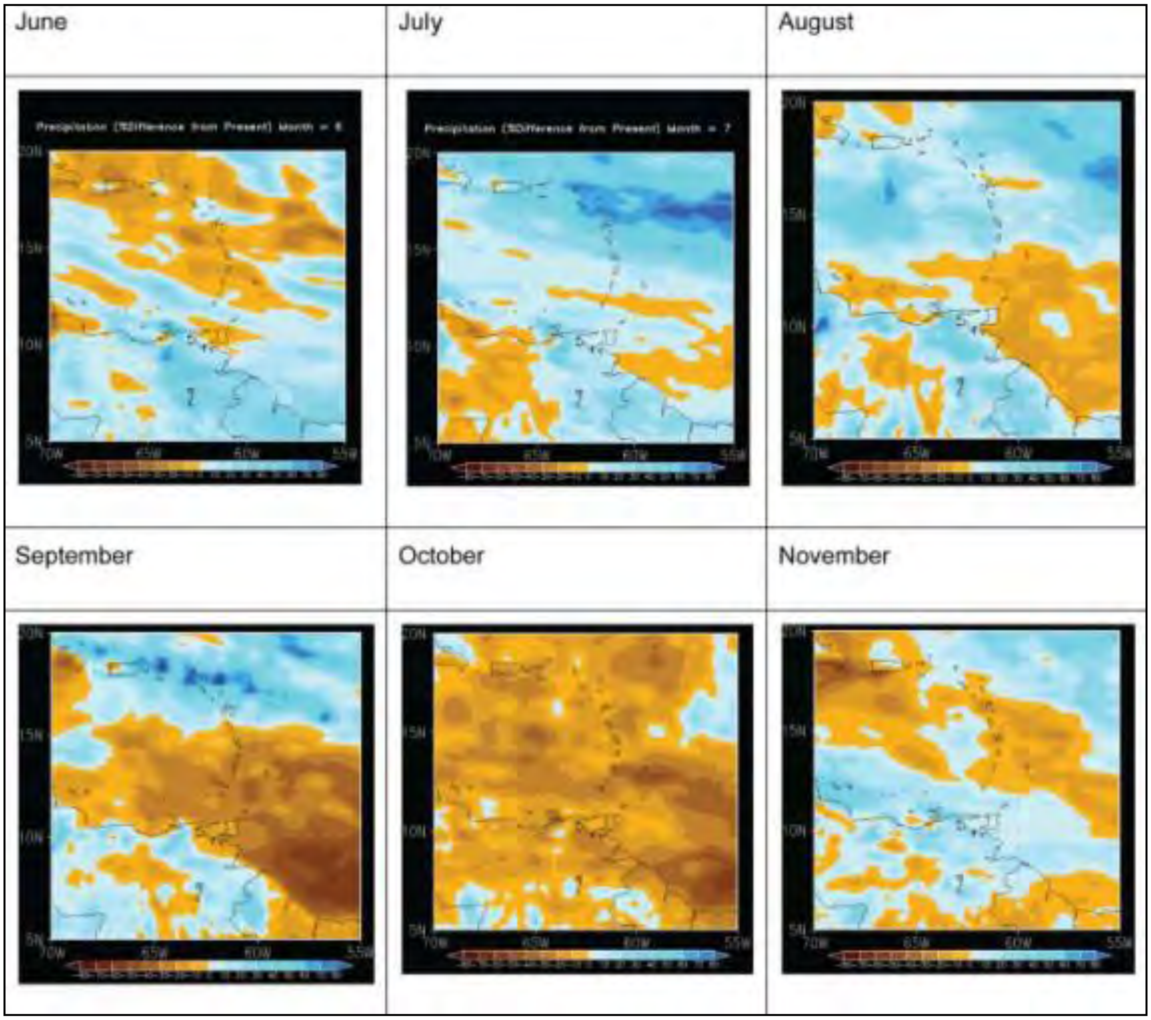
Table 3: IPCC storylines

The A1 storyline and scenario family	**The A2 storyline and scenario family**	**The B1 storyline and scenario family**	**The B2 storyline and scenario family**
A future world of very rapid economic growth Global population peaks in mid-century and declines thereafter Rapid introduction of new	A very heterogeneous world Self-reliance and preservation of local identities	A convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline Rapid changes in	A world in which the emphasis is on local solutions to economic, social, and environmental sustainability A world with continuously

The A1 storyline and scenario family	The A2 storyline and scenario family	The B1 storyline and scenario family	The B2 storyline and scenario family
and more efficient technologies Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions A substantial reduction in regional differences in per capita income. Three groups describe alternative directions of technological change in the energy system fossil intensive (A1FI) Non-fossil energy sources (A1T) a balance across all sources (A1B)	Fertility patterns across regions converge very slowly, which results in continuously increasing global population Economic development is primarily regionally oriented and per capita economic growth Technological change are more fragmented and slower than in other storylines	economic structures toward a service and information economy, with reductions in material intensity Introduction of clean and resource-efficient technologies Global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives	increasing global population at a rate lower than A2 Intermediate levels of economic development Less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

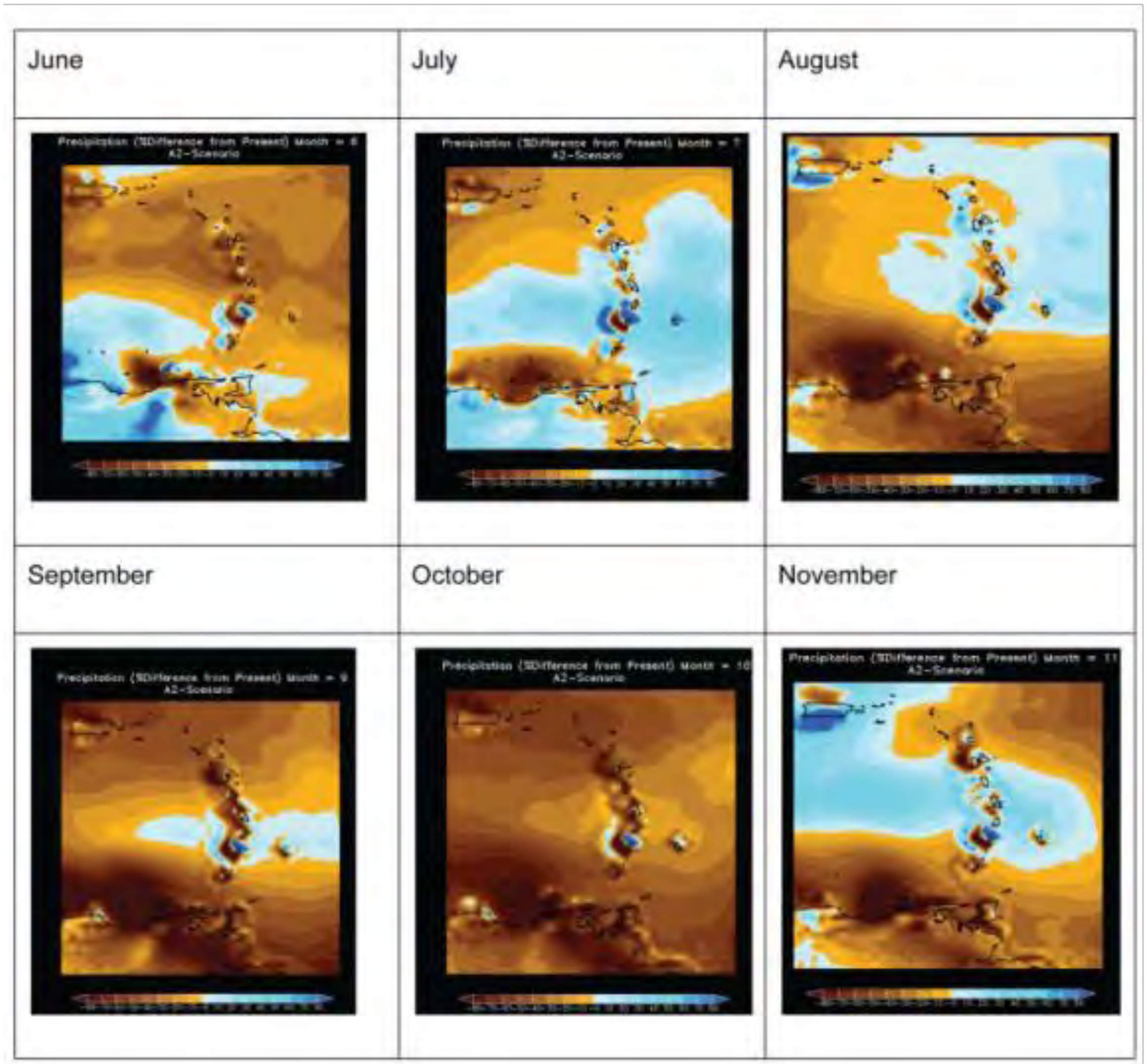
(IPCC, 2000)

Figure 7: Changes in monthly rainfall patterns, A1B Scenario 1990s-2070s (earth simulator's super-high resolution GCM; Japan's Meteorological Research Institute).



The pattern that is emerging from the modelling work into changes in annual average precipitation suggests a drying across the Caribbean basin. The decreases in rainfall range from 25% to 50% depending on the scenario, and the section of the Caribbean basin. For example, using the 1960-1999 baseline climate period, the model shows that the southern Caribbean region and the islands from Saint Kitts to Martinique will have the largest percentage of decreases relative to the mean precipitation by the 2080s (Cashman and others, 2009). On the other hand, the exception to the overall drying trend is in the far north of the Caribbean, including western Cuba and the southern Bahamas plus Costa Rica and Panama, all are up to 25% wetter under the scenarios. The effect of climate change appears to be to enhance the existing climatic pattern, making the wet and dry zones wetter and drier, respectively, during the first 4 to 6 months of the year (Cashman and others, 2009). However, for the months from May to October, the entire Caribbean region is up to 25% drier. The changes in average rainfall show a pronounced north–south gradient in rainfall change during the January-to-April dry season, whereas the summer drying is set to become more severe during the wet season (Taylor and others, 2007).

Figure 8: Changes in monthly rainfall patterns, A2 Scenario 1990s-2070s, as simulated by the U.K. Hadley Centre's PRECIS regional climate model.



Despite the widely varied conditions that drive the different climate scenarios, there is a large degree of agreement between the different climate models with respect to rainfall patterns in the Caribbean. In the case of the Eastern Caribbean under all three climatic scenarios examined (A1B, A2, and B2), the projections are for a substantially drier wet season (July to November) an even drier dry season (March to April), and a marginally wetter spell at the end of the year.

E. SUMMARY OBSERVATION

Research from Caribbean and other jurisdictions has shown that climate-related extreme events are also likely to have an adverse effect on the availability of freshwater supplies (Cashman and others, 2009).

The effect of warm spells and heat waves (e.g., during El Nino events) could lead to higher evaporation losses and reduced water quality due to an increase in the incidence of various phenomena, for example, algal blooms (IPCC, 2007b). Similarly, an increase in the frequency of drought projected for the Caribbean region will also serve to exacerbate existing water stress (Arnell, 2004; IPCC, 2007). It is also well established that salinity intrusion into groundwater lenses resulting from a combination of sea-level rise and over abstraction is already posing a threat to the quality and availability of freshwater supplies on many islands.

Moreover, contamination of ground and surface water frequently occurs following the passage of tropical storms, cyclones, and heavy precipitation episodes, sometimes rendering the available water unfit for human consumption for long periods, particularly in regions such as the Pacific (Terry, 2007), the Caribbean (Arnell, 2004; IPCC, 2007), and South Asia (Manton and others, 2001; Mirza and Ahmad, 2005). In the case of countries like Barbados, Grenada and the Bahamas, more than 80% of the potable water is abstracted from groundwater aquifers and pumped to the reservoirs; supply is almost periodically disrupted due to power outages caused by tropical storms, and other extreme weather events would also add to the challenges already faced by local water resource managers (Cashman and others, 2009).

More intense rainfall events, in addition to potentially giving rise to increased flooding, including likely flooding in urban and peri-urban areas, will adversely affect water quality, with consequent implications for public health. Changes in both patterns of flow and residence time of water in catchments affect water quality regardless of quantity. Increased levels of turbidity through increased erosion would mobilize higher levels of contaminants and pollution, requiring greater levels of treatment that water utilities may not be able to cope with during increasingly frequent extreme (high run-off) seasons. This could exacerbate existing difficulties due to lack of sanitation as well as adequate and appropriate drinking water treatment. As noted (IPCC, 2007b; chapter 3) there are no studies that analyze the impact of climate change on biological water quality from the developing countries‘ perspective.

As the rate of demand is already exceeding the rate of supply, most of the islands are likely to experience increasing water deficits. It is worth pointing out that climate change–induced water scarcity is likely to be a feature of most small islands, not just those in the Caribbean. For instance, a study commissioned by the World Bank (2000) shows that a 10% decrease in mean rainfall by 2050 would be equivalent to a 20% reduction in the extent of the freshwater aquifer on the Tarawa Atoll, Kiribati in the Pacific. Furthermore, model outputs for Bonriki Island, Tarawa, and Kiribati indicated that a 25% decrease in rainfall combined with a 50 cm rise in sea level could cause the freshwater lens to contract by approximately 65% (World Bank, 2000).

The changes in precipitation patterns will also affect run-off characteristics. Less overall rainfall and higher rates of run-off would lead to a corresponding decrease in water available for recharging groundwater aquifers as well as higher transport and pollutant loads. A decrease in overall rain and higher run-off will not only affect groundwater aquifers but also those reliant on other forms of rainwater capture and harvesting. This would either be due to quality considerations or an inability to capture sufficient amounts of the run-off. This would affect among others countries such as Antigua & Barbuda, Barbados, the Grenadines, Jamaica, and Saint Kitts and Nevis.

Assessments of the projected impact of climate change on the water sector in Aruba, Barbados, Dominican Republic, Guyana, Montserrat, Jamaica, Netherlands Antilles, Saint Lucia, and Trinidad and Tobago were pursued (LC/CAR/L.260; ECLAC, 2011) . The studies reviewed the effects of the BAU, A2 and B2 scenarios. The general finding was that climate change will affect all countries, and that relative to 2006, water demand will decline up to 2030, but will again increase reaching a projected level by 2100 of five times the 2006 figure. However, it was noted that unavailability of time series data constrained the analyses, and the use of proxies which did not fully match the respective country led to outcomes that were not as robust as they could be.

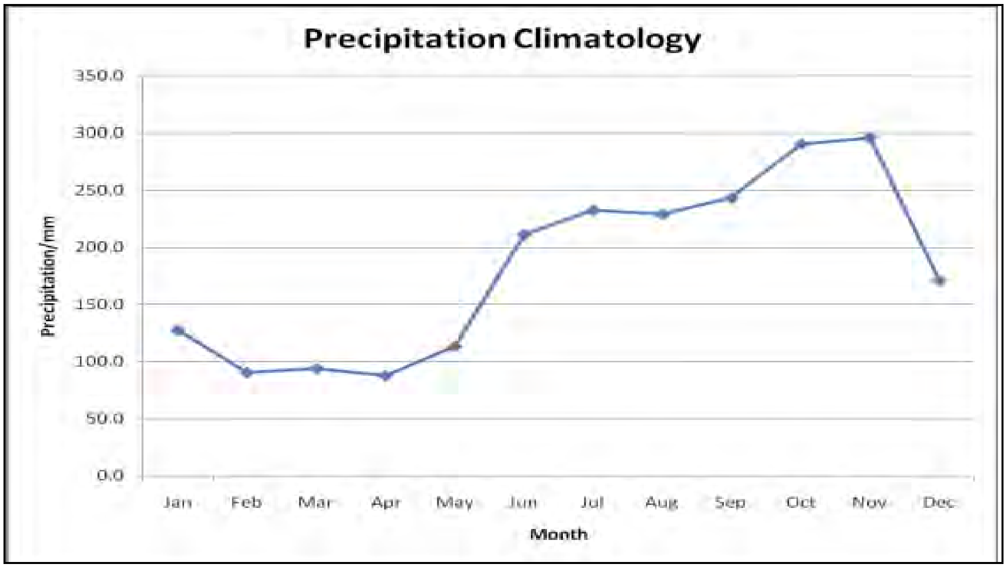
III. ANALYSIS OF CLIMATE FOR GUIDANCE TO THE WATER SECTOR

A. RAINFALL

The location and size of Saint Vincent and the Grenadines make it highly susceptible to climatic influences. On average, Saint Vincent receives 219 cm of rainfall per year, making it one of the wetter islands of the Eastern Caribbean. Figure 9 shows an almost unimodal pattern in the island‘s rainfall climatology, with the wet season occurring between June-November and the dry season between December and May. The rainy season, during which the island receives ~70% of total annual rainfall, coincides with the period of highest tropical storm activity in the region and peaks in September, October, November (SON) (~40% of total rainfall).

The Grenadines have a drier climate than St Vincent. In stark contrast to the forested mountains of Saint Vincent which may have as much as 5100 mm of rain per year, the Grenadines may have as little as 460 mm. The average annual rainfall recorded on Bequia and Canouan is 1,412 mm and 955mm, respectively (Gumbs, 1992). The Grenadines depends on their source of water supply from man-made catchments (concrete collection area on an embankment with a storage tank at the bottom – community catchments), rainwater harvesting, wells, and desalination.

Figure 9: Mean annual monthly rainfall for Saint Vincent (ET Joshua Airport 1987 -2008). (Units are mm/month).



Source: Joyette, Antonio and Joslyn, Ottis 2011

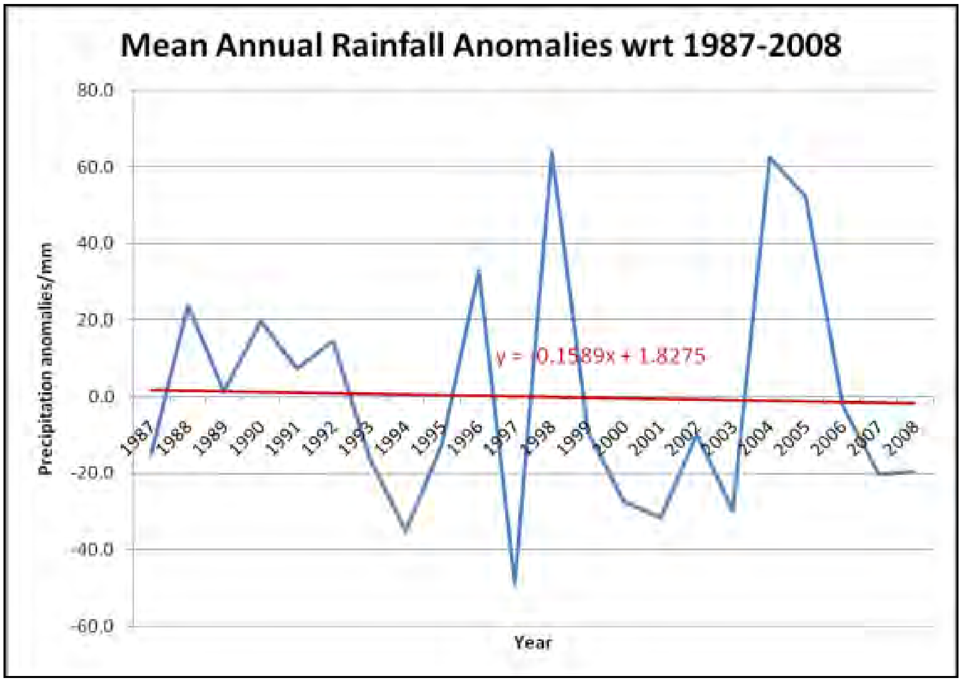
There is also considerable inter-annual variability in the rainfall record with the year 1997 being among the driest years on recent record (~160 cm). This was then followed by one of the wettest years, 1998, (~295 cm). There is evidence that some of the variability is driven by global climatic fluctuations such as the El Niño-Southern Oscillation (ENSO) or by large scale gradients in tropical Atlantic and Pacific sea surface temperatures or the locality of the Inter Tropical Convergence Zone (ITCZ).

There is no statistically significant trend in the increasingly wetter or drier conditions, for the period of record available, though dry and wet year spells exist (figure 10). Peterson and others (2002) found this pattern of significant year to year variability but no statistically significant long term trend is generally true for Caribbean precipitation over the past 50 years.

B. TEMPERATURE

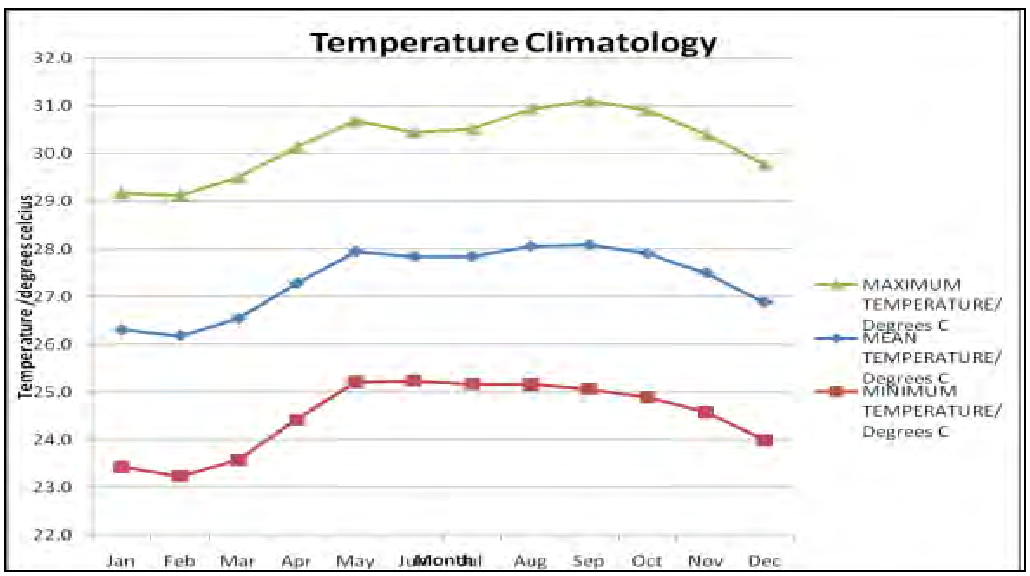
Figure 11 shows the annual variation in maximum, minimum and mean temperatures. Mean temperatures vary by 2^0C throughout the year and peak between May and October. Maximum temperatures can reach a high of 31^0C during these months and minimum temperatures reach a low of around 23^0C in February. Highest temperatures on record were seen in 1998 which is consistent with global estimates.

Figure 10: Annual precipitation anomalies for Saint Vincent (ET Joshua Airport 1987 - 2008). Anomalies are with respect to a 1987-2008 baseline period. Trend lines added.



Source: Joyette, Antonio and Joslyn, Ottis 2011

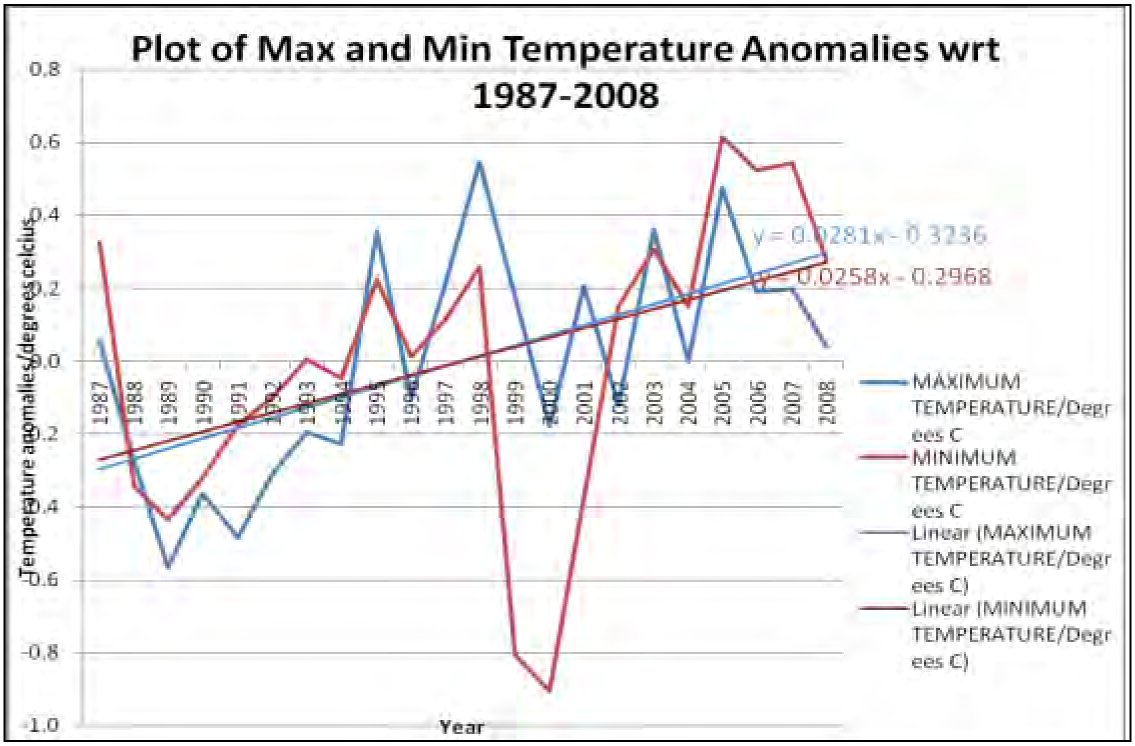
Figure 11. The climatology of minimum, maximum, and mean temperature for Saint Vincent (ET Joshua Airport 1987 -2008). Units are degrees Celsius.



Source: Joyette, Antonio and Joslyn, Ottis 2011

Both the maximum and minimum temperature records show a warming trend over the past 22 years. (The trend is however not statistically significant at the 95% level). The warming is consistent with the rest of the Caribbean (Peterson and others, 2002) and the globe (Alexander and others, 2006). Also, similar to the global averages, maximum temperatures for Saint Vincent are increasing at a slightly faster rate (0.2^0C/decade) than minimum temperatures (0.15^0C/decade; figures 11 and 12).

Figure 12: Annual maximum and minimum temperature anomalies for Saint Vincent (ET Joshua Airport 1987 -2008).



Source: Joyette, Antonio and Joslyn, Ottis 2011

C. OTHER CLIMATE VARIABLES

Relative humidity across the country tends to be generally high year round (above 70%) and predictably highest during the main rainfall period. Winds are generally east to east-south-east, and wind speed is strongest (>9 metres per second) through the dry period to the beginning of the rainy period (December-June). During this period the north Atlantic high pressure system is a persistent and dominant influence on the region. Notwithstanding, strong wind gusts are also common from June to November during the passage of tropical waves, depressions, storms or hurricanes.

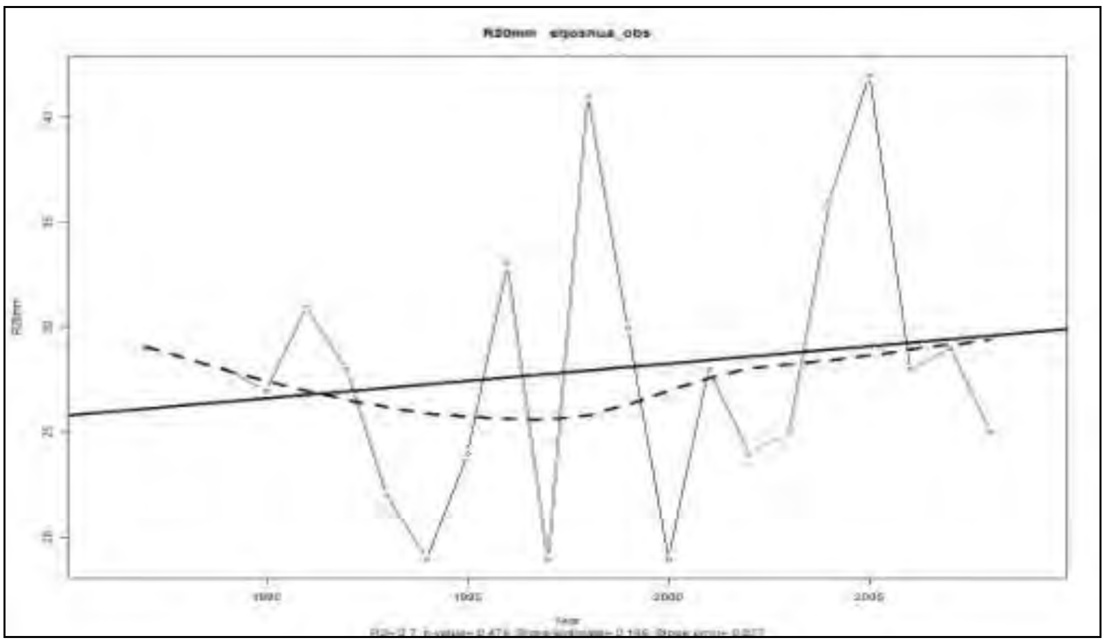
Evaporation rate is highest during the late dry season and into the early wet season. This is consistent with lowest relative humidity, which increases further into the rainy season.

D. CLIMATE EXTREMES

Calculated rainfall indices show an increase in the number of heavy rainfall events that occur in a year. This is reflected in an increase in the number of days with rainfall between 10-20 mm (R10) and the number of consecutive wet days. This trend is also reflected in the increase in some rainfall intensity indices, for example, daily intensity, maximum consecutive five day rainfall and maximum one day rainfall. However, extremely wet days (days with rainfall occurring at levels higher than the 99th percentile, R99) occur with less frequency as the historical record progresses.

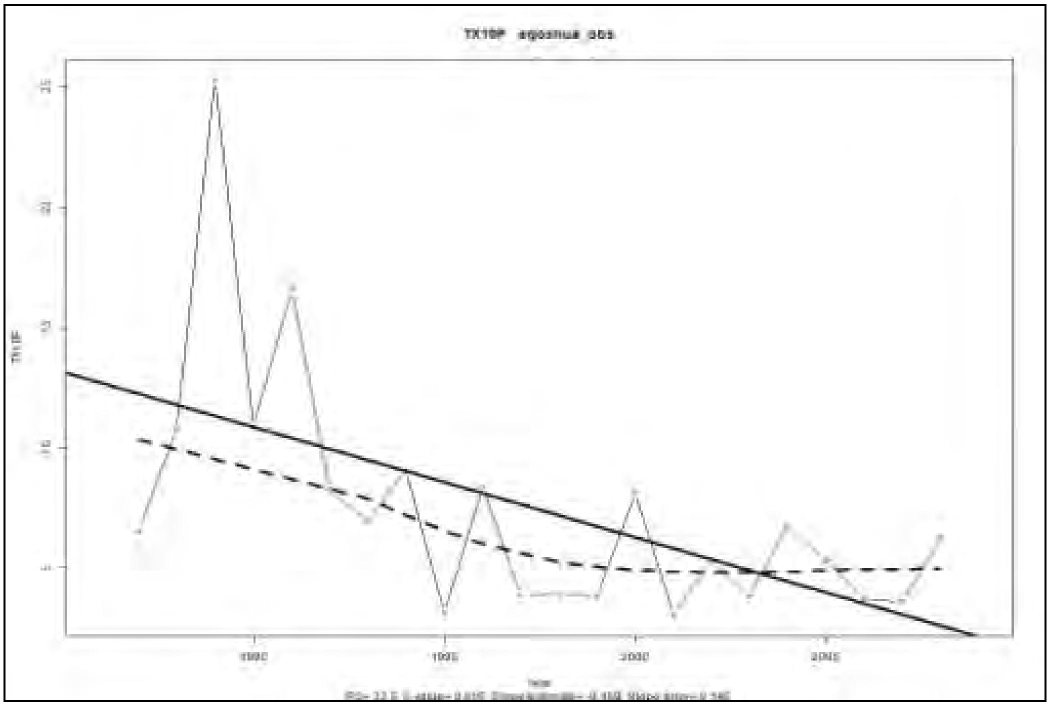
Temperature indices support the conclusion that warm days (TX90) and nights have increased over the last two decades (figure 13) and cool days (TX10) and nights have decreased (figure 14).

Figure 13: Temperature indices for warm days and warm nights



Source: McSweeney

Figure 14: Temperature indices for cool days and cool nights



Source: McSweeney

With respect to hurricanes, in general, north Atlantic hurricane frequency is characterized by a multi-decadal cycle which yields active and inactive phases lasting 10 or more years (Goldenberg and others, 2001). It is noteworthy that since 1995, the north Atlantic has swung into an active hurricane phase. Hurricane variability is also influenced by the ENSO cycles. Fluctuations in Saint Vincent's May-June rains can be statistically linked to anomalies in both Caribbean and tropical Pacific sea surface temperatures. Warm Caribbean waters induced by El Niño events in early spring generally favour rainfall in the region. The drying influence is also very discernible in the country's primary rainy season in some El Niño years (e.g. the early 1980s). The drying is in part due to the strong vertical shear induced in the Caribbean during an El Niño event which proves very unfavourable for tropical convection.

The El Niño phenomenon has become more frequent, persistent and intense during the last 20-30 years. It is not certain whether this is due to natural variation or the effect of increasing greenhouse gases. Other global phenomena such as the North Atlantic Oscillation (NAO) can also modulate ENSO's impact on the Caribbean region (Giannini and others, 2001).

E. CLIMATE CHANGE AND ST VINCENT AND THE GRENADINES

The impact of drought spells on water availability and the sensitivity of the tourism and agricultural sectors to climate extremes point to the usefulness of rainfall, temperature, and seasonality projections. The vulnerability of important water resources infrastructure to storm and hurricane activity (particularly wind and storm surge) indicates the usefulness of projections of future storm activity and sea level rise.

Of particular significance is the vulnerability of coastal aquifers to saline intrusion and of surface resources to coastal flooding.

1) Dynamic and Statistical Models

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

The projections of rainfall and temperature characteristics for Saint Vincent and the Grenadines through the end of the century are obtained, from a consensus of an ensemble of 15 GCMs, using data averaged over the two grid boxes within which the islands fall. The data used represent future change under two greenhouse gas emission scenarios: A2 (high emissions) and B2 (lower emissions).

It is to be noted that an inherent drawback of the GCMs, however, is their coarse resolution relative to the scale of required information. The size of Saint Vincent and the Grenadines precludes it being physically represented in the GCMs, and there is a need for the application of downscaling techniques to provide more detailed information on a country or station level. Downscaled climate information is; however, not currently readily available for Saint Vincent and the Grenadines, though efforts are underway to generate such information. The additional information which the downscaling techniques would provide does not however devalue the information provided by the GCMs especially since (1) Saint Vincent and the Grenadines‘ climate is largely driven by large-scale phenomenon (2) the downscaling techniques themselves are driven by the GCM outputs, and (3) at present the GCMs are still the best source of future information on some large scale phenomena.

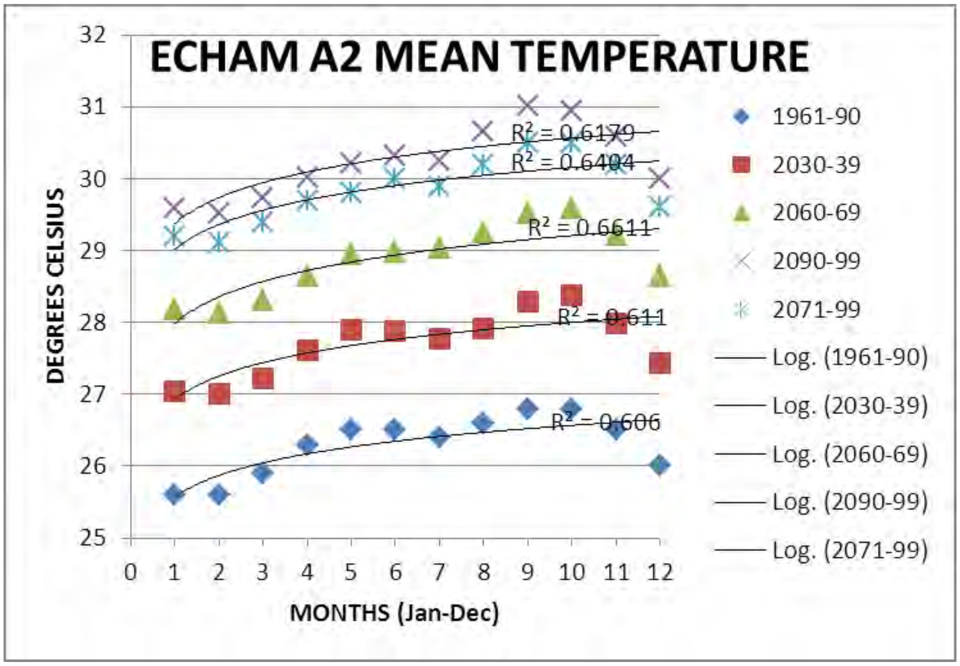
The GCMs are run using the Special Report Emission Scenarios (SRES) (Nakicenovic and others, 2000). Each SRES scenario is a plausible storyline of how a future world will look. The scenarios explore pathways of future greenhouse gas emissions, derived from self-consistent sets of assumptions about energy use, population growth, economic development, and other factors. They however explicitly exclude any global policy to reduce emissions to avoid climate change.

The future climate of Saint Vincent and the Grenadines is presented as absolute or percentage deviations from the present day climate which is represented by averaging over a 30 year period, (usually 1961-1990 or 1971- 2000). Future results are presented for 10 year average time slices for the 2030s, 2060s, and 2090s (GCM data) and for the end of the century (2070-2100) (RCM data).

2) Temperature

Regardless of scenario or model, mean temperatures in Saint Vincent and the Grenadines are expected to increase markedly over the next century, on average by ~0.15^{0}C per decade, as expected from global results. Figures 15 and 16 illustrate the range of increase projected for each time slice noted from the GCMs under A2 and B2 Scenarios.

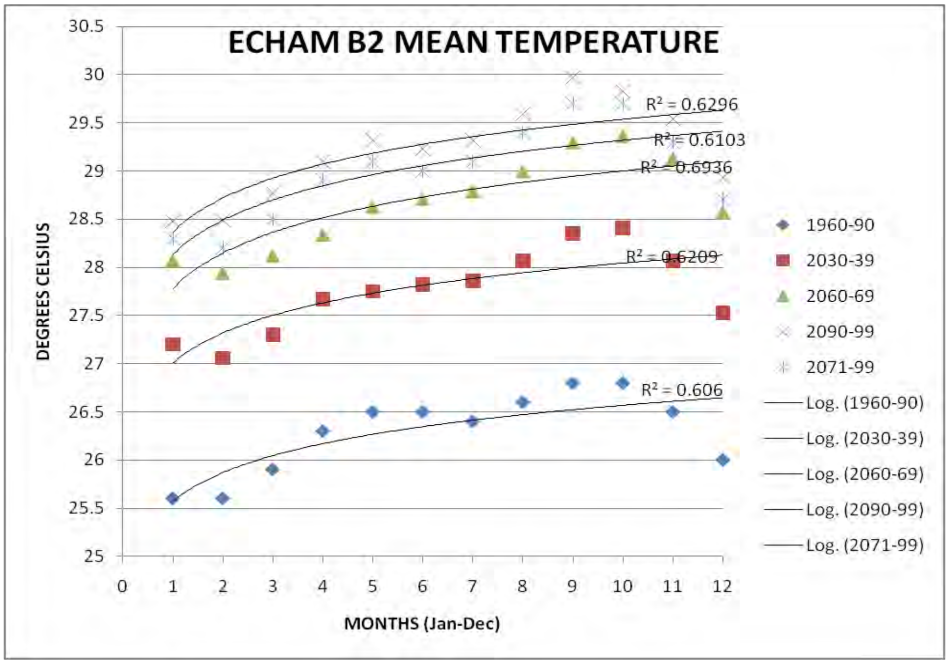
Figure 15: Projected mean temperature changes for specific time slices under A2 Scenario



Source: INSMET, Cuba

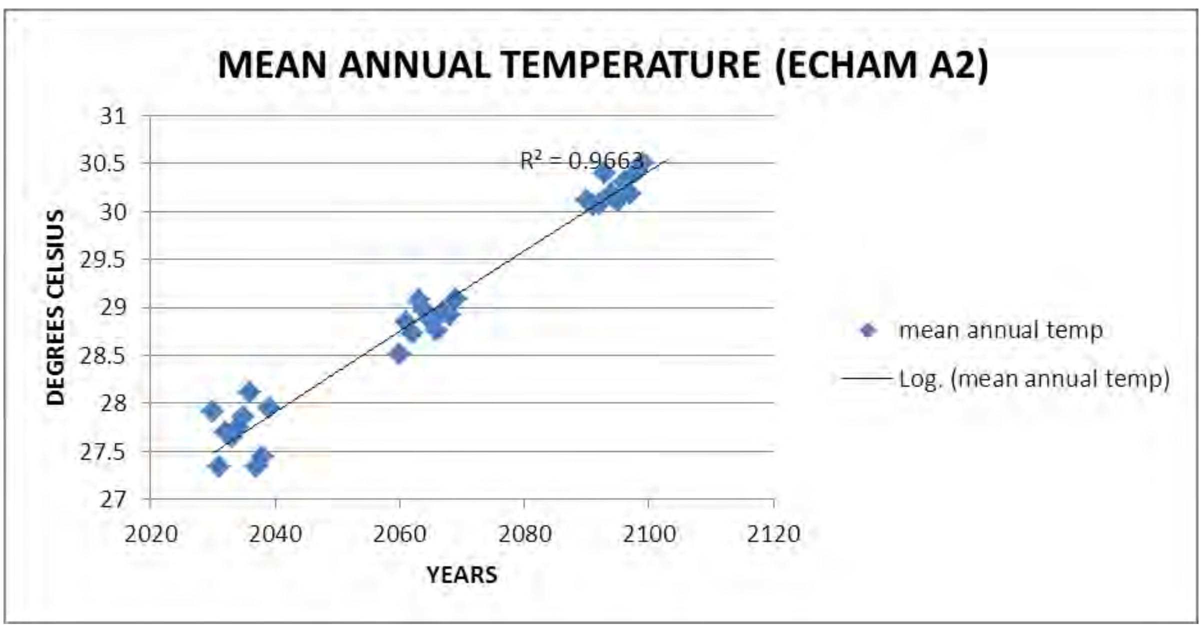
Under the A2 scenario GCMs project mean temperature changes of up to 4 ^{0}C by the end of the century (figures 17 and 18), with median annual increase of up to 1.0 ^{0}C by the 2030s, 1.8 ^{0}C by the 2060s, and 2 ^{0}C by the 2090s. This range of increase is consistent with IPCC projections for the Caribbean which indicates that annual mean temperatures will increase by 1.4°C to 3.2°C, with a median increase of 2.0°C by 2100. The increase is however slightly less than the anticipated global average warming. Seasonal changes show a similar warming trend throughout the century. By the end of the century, GCMs project greatest seasonal warming in DJF under highest emissions by end of century, but June, July, and August (JJA) and September, October and November (SON) show the fastest average rates of decadal change.

Figure 16: Projected mean temperature changes for specific time slices under B2 Scenario



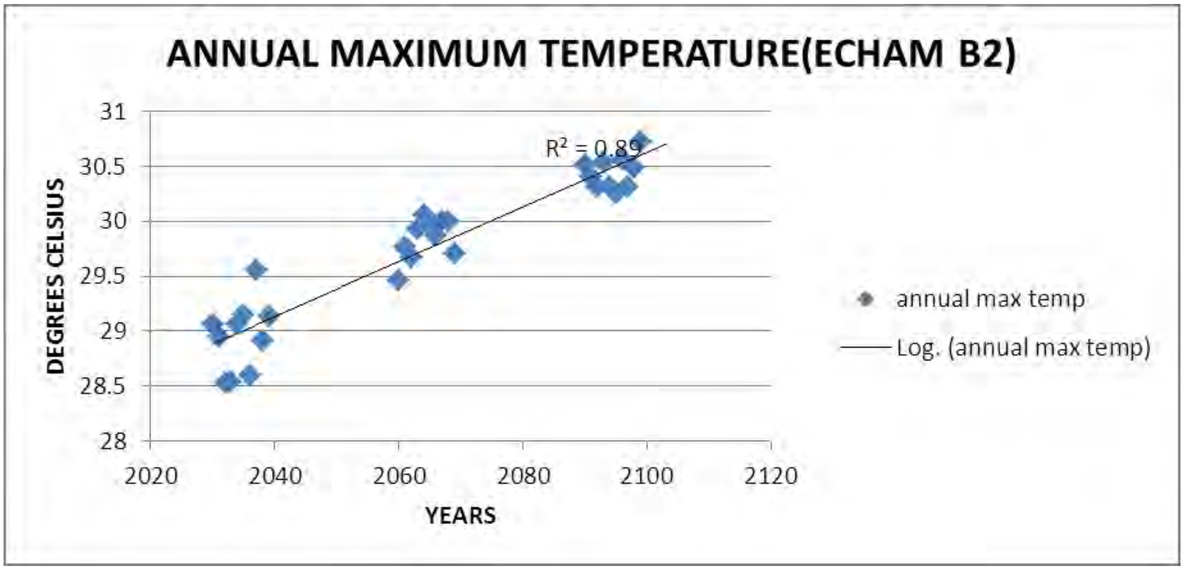
Source: INSMET, Cuba

Figure 17: Mean annual temperature increase under A2 Scenario up to 2100



Source: INSMET, Cuba

Figure 18: Annual maximum temperature up to 2100 under B2 Scenario



Source: INSMET, Cuba

The frequency of hot days and nights will increase by the end of the century according to all models under all scenarios. This is consistent with trends seen in historical data. Annual percentage frequency approaches 75% of nights and 66% of days by the 2060s and up to 99% by the end of the century according to GCMs. Cold days and nights show marked decrease under all models and all scenarios, almost reaching nonexistence by the 2060s. A very hot day (night) is defined as one with temperatures greater than the hottest 10% of days (nights) in the current climate. Similarly, very cool days (nights) are those with temperatures less than the coolest 10% of days (nights) in the current climate. With respect to temperatures and ENSO all models show continued ENSO inter-annual variability in the future. However there is no consistent indication of discernible changes in projected ENSO amplitude and frequency in the 21st century (IPCC 2007).

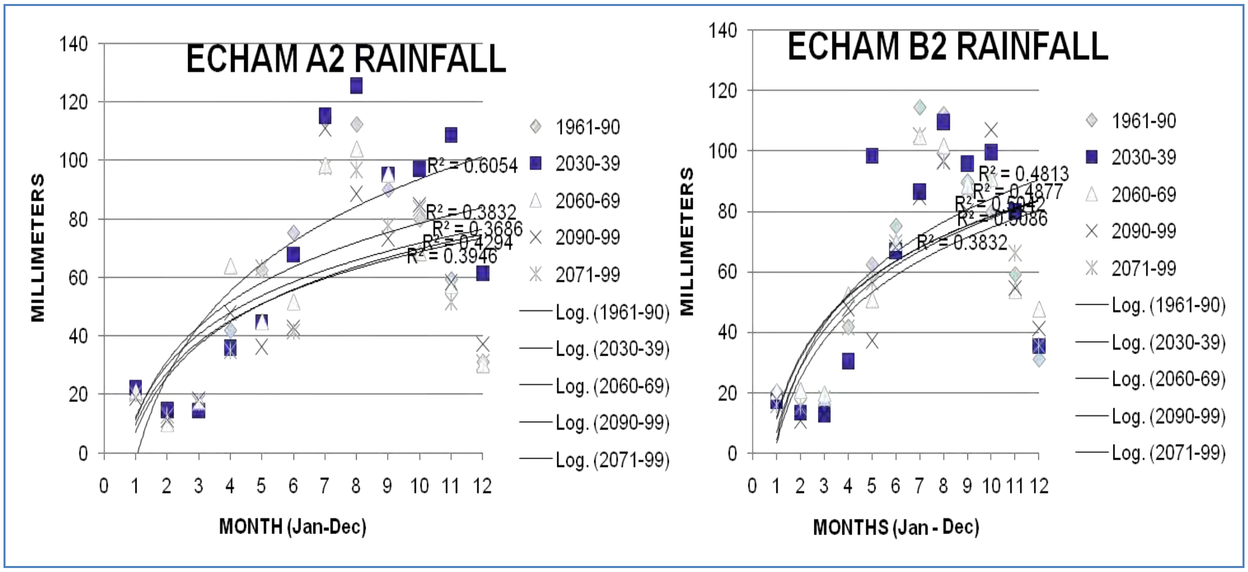
3) Temperature and Water Availability

All the time periods analyzed are consistent in showing that mean temperatures under the Global Climate Model, ECHAM, and storyline/climate scenario A2 are increasing. The variability in this increase is gradual. The trend reflects an increase in mean temperature and this constitutes the increase in the rate of evaporation and transpiration. This will lead to the reduction of available freshwater and therefore creates challenges for water resources' users. The continuous reduction of soil moisture content will be an output/impact as a result of increased evaporation, transpiration and geology of the land in evaluation. As a result, the increase in the mean temperature for various time periods reflects that definitely water quantity will be influenced most likely negatively and water quality is heading down a very similar path.

4) Rainfall

Most current models and ensemble median, point to a drying throughout the year in Saint Vincent and the Grenadines. Negative median values range between 10 to 22% annually by 2090's. Maximum possible changes indicate up to 24% less annual rainfall by 2030's, 41% less rainfall by 2060's and 58% less rainfall by 2090‘s (figure 19). The model results also suggest drying in the main wet season from June to November, with greatest seasonal change seen in the summer months (7.1% per decade). Note the significance of this for water availability for Saint Vincent and the Grenadines. The dry months early in the year are less severely affected in the median, but still show similar downward trends.

Figure 19: Mean annual rainfall changes (Jan- Dec) for specific time slices under A2 and B2 scenarios



The proportion of total rainfall falling in ‗heavy‘ events shows greatest change in MAM, with a decrease of up to 30% under A2, but the possibility of increase by up to 13% under low emissions by end of century. This clearly indicates a reduction in rainfall quantity. The baseline data reflects the highest rainfall quantity and is the earliest time period (1961-90). The latest time period (2090-99) shows the lowest rainfall quantity based on decadal averages and that the projected rainfall climatology for 2071-2100 shows reduction in rainfall quantity (figure 20).

5) Relative Humidity

Under both scenarios (A2 and B2) there is a marked decrease in relative humidity for SVG (figure 21).

Figure 20: Average annual rainfall under A2 and B2 scenarios up to 2100

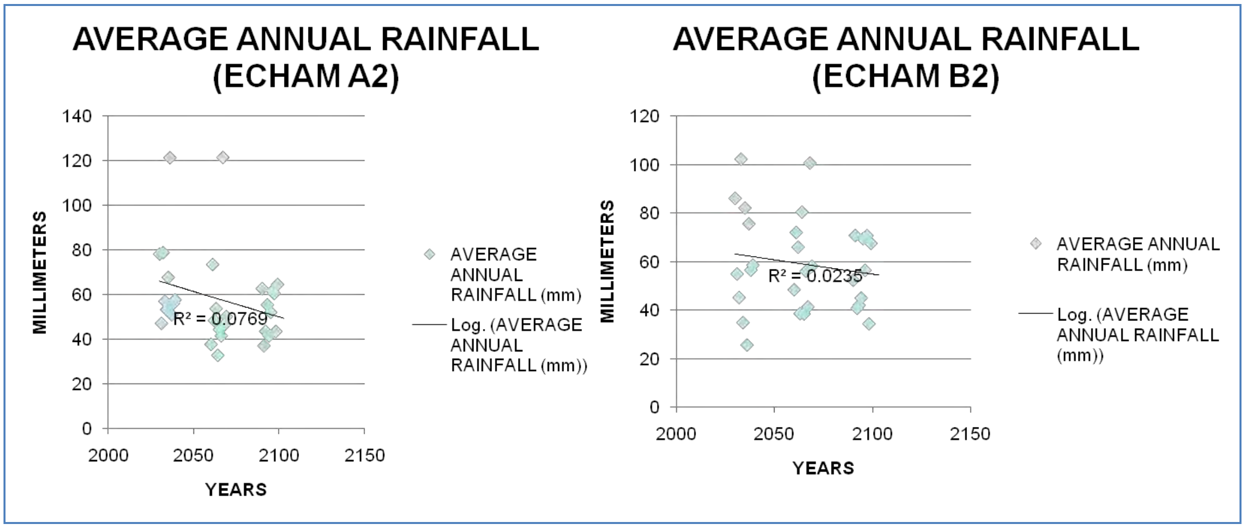
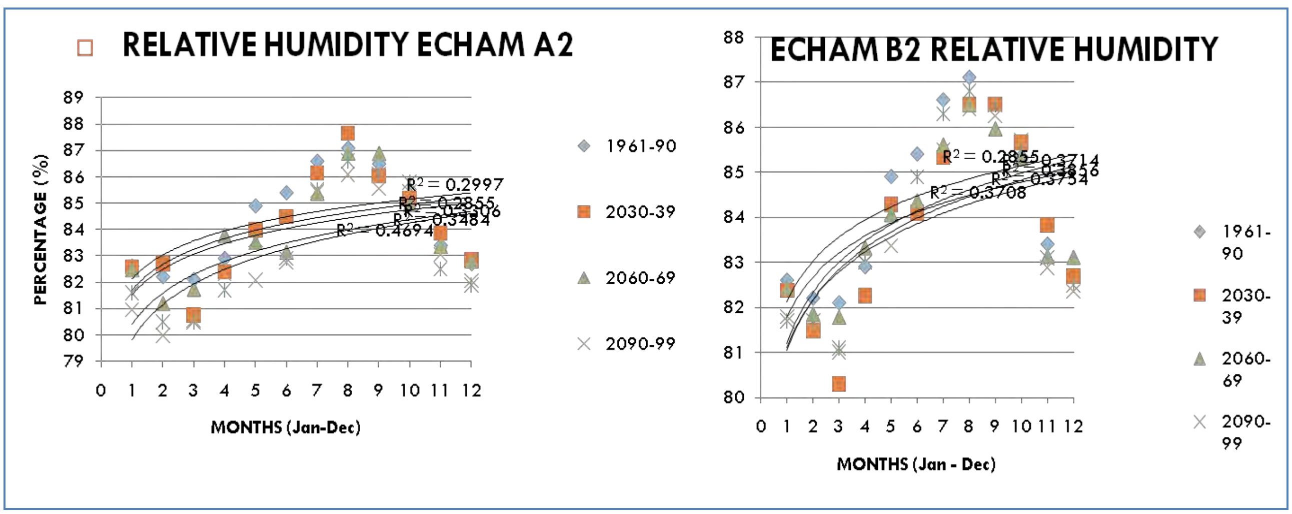


Figure 21: Relative humidity under ECHAM A2 scenario up to 2100



Overall, temperatures (mean, minimum and maximum) show an increase for the global climate model, ECHAM, and the scenarios A2 and B2; relative humidity and rainfall reflect a reduction for the same (model and scenarios/storylines). This is definitely an adverse effect on the water resources sector.

6) Sea Level Rise

Ocean expansion (due to warming) and the inflow of water from melting land ice have raised global sea level over the last decade. Large deviations among the limited set of models addressing the issue, however, make future estimates of sea level change uncertain, including those for the Caribbean. Whereas it is not presently possible to project sea level rise for Saint Vincent and the Grenadines, changes in the Caribbean are expected to be near the global mean. Under the A1B scenario, sea level rise within the Caribbean was expected to be between 0.17 m and 0.24 m by 2050 (IPCC 2007). For comparison, global sea level rise (SLR) is expected to average 0.35 m (0.21 to 0.48 m) under the same scenario by the end of the century (relative to the period 1980 to 1999). It is important to note, however, that changes in ocean density and circulation will ensure that the distribution of sea level rise will not be uniform across the region.

Recent studies accounting for observations of rapid ice sheet melt (Greenland and Antarctic) have led to greater and more accurate estimates of SLR than in the IPCC AR4 projections. There is an approaching consensus that SLR by the end of the 21st century will be between 1-2m above present levels (UNDP, 2010). The Caribbean is projected to experience greater SLR than most areas of the world due to its location closer to the equator and related gravitational and geophysical factors. Table 4 summarises the global sea level rise projections for the 21st century. Large deviations among the limited set of models addressing the issue, however, make future estimates of sea level change uncertain, including those for the Caribbean. Whereas it is not presently possible to project sea level rise for Saint Vincent and the Grenadines, changes in the Caribbean are expected to be near the global mean.

Table 4: Summary of global sea level rise projections for 21st Century (UNDP 2010)

	2050*	2100		
		Low Range	**Central Estimate**	**High Range**
Continuation of current trend (3.4mm/yr)	13.6 cm	-	30.6cm	-
IPCC AR4 (2007)	8.9 cm to 23.8 cm	18 cm	-	59 cm
Rahmstorf (2007)	17 cm to 32 cm	50 cm	90 cm	140 cm
Horton and others (2008)	~30 cm		100 cm	
Vermeer and Rahmstorf (2009)	~ 40 cm	75 cm	124 cm	180 cm
Grinstead and others (2009)	-	40 cm	125 cm	215 cm
Jevrejeva and others (2010)	-	60 cm	120 cm	175 cm

***Where not specified, interpreted from original sources**

F. CLIMATE VARIABILITY AND SUMMARY TRENDS

All models show continued ENSO interannual variability in the future. However there is no consistent indication of discernible changes in projected ENSO amplitude and frequency in the 21st century (IPCC, 2007).

The results of the climate change profile of Saint Vincent and the Grenadines from the National communication as described above (McSweeny and others, undated) are as follows:

1) Trend in Temperature

- Mean annual temperature has increased by 0.7°C since 1960, at an average rate of 0.16°C per decade since 1960.
- This warming has affected all seasons at a similar rate.
- There is insufficient daily observed data available from which to determine trends in climate extremes.

2) Trend in Precipitation

- Average precipitation has shown a decline of ~8.2 mm per month (-5.7%) per decade over the period. This decline in rainfall affects all seasons, but is most marked in the wettest seasons JJA and SON, when the average rate of decline had been 10.6 to 13.5mm per month (4.9 to 7.1%) per decade.
- There is insufficient daily observed data available from which to determine trends in daily precipitation extremes.

GCM projections of future climate for SVG are as follows:

3) Projections in Temperature

- The mean annual temperature is projected to increase by between 0.6 and 2.3°C by the 2060s, and 1.1 to 3.9 degrees by the 2090s. The range of projections by the 2090s under any one emissions scenario is around 1-2°C.
- The projected rate of warming is similar throughout the year, but most rapid in the south than the north.
- All projections indicate substantial increases in the frequency of days and nights that are considered ‗hot'1 in current climate.
  - Annually, projections indicate that ‗hot' days will occur on 31-66% of days by the 2060s, and 39-95% of days by the 2090s. Days considered ‗hot' by current climate standards for their season are projected to increase most rapidly in DJF and SON, occurring on 58-99% of days of the season by the 2090s.
  - Nights that are considered ‗hot' for the annual climate of 1970-99 are projected to increase in frequency more rapidly than hot days, occurring on 31-75% of nights by the 2060s and 55-100% of nights by the 2090s. Nights that are hot for each season are projected to increase most rapidly in DJF and SON, occurring on 67-100% of nights in every season by the 2090s.
- All projections indicate decreases in the frequency of days and nights that are considered ‗cold' in current climate. These events do not occur at all by the 2060s in projections from any of the models in the higher emissions scenarios (A2 and A1B) and do not occur in any projections under any of the three emissions scenarios by the 2090s.

4) Projections in Precipitation

Projections of mean annual rainfall from different models in the ensemble are broadly consistent in indicating decreases in rainfall for SVG. Ensemble median values for all seasons are negative. Annual projections vary between -61% to + 23% by the 2090s with ensemble median values of -13 to -21%. The largest decreases occur in the wet seasons, JJA and SON. Decreases are greater in the south than the north of the region. The proportion of total rainfall that falls in heavy events decreases in most model projections, changing by -22% to +5% by the 2090s. Maximum 5-day rainfalls tend to decrease in model projections, changing by -30 to +14 mm by the 2090s.

G. EXTREME EVENTS

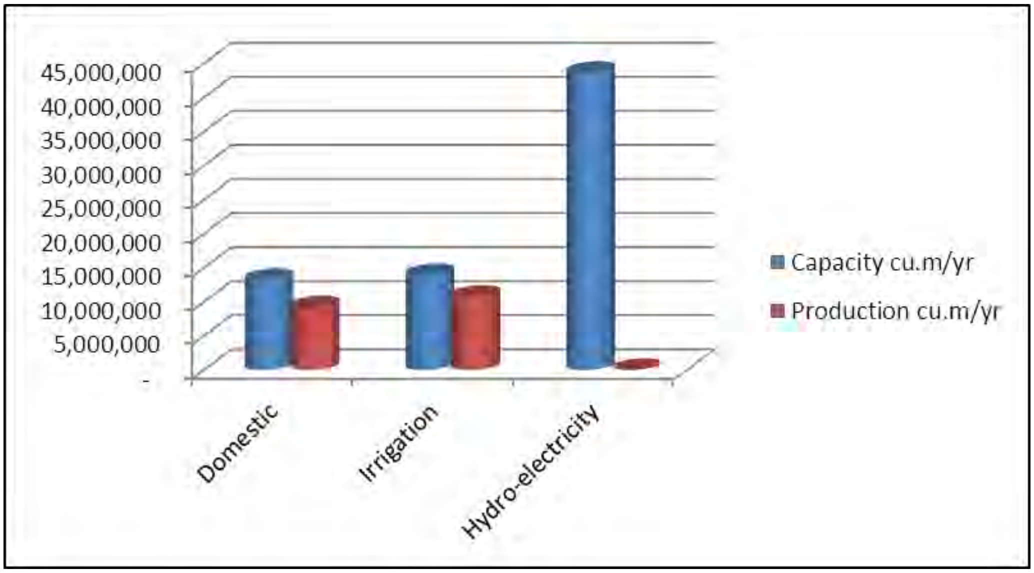
Based on a range of models, the IPCC suggests that future hurricanes of the north tropical Atlantic are likely to become more intense, with larger peak wind speeds and heavier near storm precipitation. It is projected that there will be an increase in the frequency of hurricanes in the categories 3-5 and also it is most likely that a tropical storm will developed into a category 5 Hurricane within a very short time span such as within 24 hours.

Calculated rainfall indices show an increase in the number of heavy rainfall events that occur in a year. This is reflected in an increase in the number of days with rainfall between 10-20 mm (R10) and the number of consecutive wet days. This trend is also reflected in the increase in some rainfall intensity indices e.g. daily intensity, maximum consecutive five day rainfall and maximum one day rainfall. However, extremely wet days (days with rainfall occurring at levels higher than the 99th percentile, R99) occur with less frequency as the historical record progresses.

IV. SOCIOECONOMIC SETTING, VULNERABILITIES AND THREATS

Water supply refers to the availability of the water resource. Water resources in Saint Vincent and the Grenadines are tapped mainly from streams, which flow both perennially and ephemerally. The islands use this resource for the generation of hydroelectricity and for domestic supply, irrigation and industrial/commercial uses. Figure 22 illustrates surface water capacity and for domestic, irrigation and hydro-electricity usage.

Figure 22: Surface water capacity and production for domestic, irrigation and hydro-electricity usage



There were 20 water abstraction areas in the country during 2002, with the major sites located at Dalaway, Hermitage, Majorca and Montreal. In 2002 the total production of water was almost 2 billion gallons with an estimated GDP of EC$12.6 million (current prices). Hydroelectricity generation is also characteristics of water use accounting for about 20% of power generated in St Vincent and the Grenadines. Contribution to GDP is an estimated EC$7 million (Homer and Shim, 2004)

Water quality monitoring is limited to ―spot" measurements of treated water by CWSA staff. No systematic raw water quality measurements are undertaken in rivers. At the present time, mainland Saint Vincent reportedly does not experience severe water stress. The Grenadines, however, are highly stressed during the dry seasons due to the lack of available fresh water resources. The two areas should be considered as hydrologically separate units, due to significant differences in geology and rainfall totals.

A. MANAGEMENT OF THE RESOURCE

Water use and consumption is presently managed almost exclusively in a sectoral manner, each entity involved having its own mandate, and in some instances respective mandates conflict with each other. Institutional responsibility at the state level is also fragmented and conflicting.

―The CWSA Act of 1991 puts all fresh water under the control of the CWSA (a statutory body under the Ministry of Health and the Environment) while the Forestry Conservation Act of 1992 puts all forested crown lands and mangrove under the control of the Forestry Department (a division of the Ministry of Agriculture and Labour). The Lands and Survey Department (a division of the Ministry of Agriculture and Labour) manages Crown lands not under the control of the Forestry Department. The

Central Planning Department (a division of the Ministry of Finance and Planning) gives legitimacy to all development on the island including coastal development and subdivision of lands" (CEHI, 2001).

At present, there is a perceived lack of water stress on mainland Saint Vincent, but it is anticipated that given greater water demands, increasing levels of water pollution and the projected decrease in rainfall quantity in the Caribbean region due to climate change, availability of water resources will be compromised. The Grenadines on the other hand receives far less rainfall and water availability is a challenge. Those islands are currently stressed. The need for comprehensive data on water resource availability and demand is fundamental to inform development and implementation of comprehensive water management in Saint Vincent and the Grenadines.

B. SUPPLY

It is generally believed that the supply (surface water from rivers and springs) on Saint Vincent is more than enough to meet developmental needs. However, climatic and socioeconomic trends call this statement to question. Bishop (1989) and Murray (1993, unpublished) point to a slow but steady decline in flow volume of many rivers in Saint Vincent and seasonality is marked with dry season flow considerably less than that in the wet season.

The major rivers on the mainland are the Richmond, Cumberland, Buccament, Yambou and Colonarie, all originating at high elevations in the centre of the island and flowing in steep river valleys to the coast. The higher rainfall in these upper catchments and the likelihood of these streams being fed by base-flow from coarse, weathered rock debris beneath, may explain not only the greater flow rates of these streams but also their perennial nature. Some of the smaller rivers, particularly on the west coast, are intermittent. More noticeable than the decline in quantity is the deterioration in quality of surface water.

Surface flow is non-existent in the Grenadines and the system for supply and demand is described below. Bceom and Stewarts Engineering Limited (2006) in their water resource management study estimate a water consumption rate for the Grenadines - 20.2 gallons of per capita per day during the wet season and 14.5 gallons during the dry season. Households who buy water mostly do so in the dry season. On average, approximately 0.05% residents buy water in the wet season and 8.1% households buy water in the dry season. In Canouan, 46% of households buy water during the dry season and 2.3% in the rainy season mainly from Cancouan construction Association's (CCA's) desalination water[4] (Bceom and Stewarts Engineering Limited, 2006). In Union island 1.8% and in Mayreau 4.3% of households buy water mainly from neighbours (Bceom and Stewarts Engineering Limited, 2006). Households with booster pumps that pump water from their groundwater tank to their roof top tank consume an estimate of 22% of the electricity bill i.e. $33 per month (at minimum) corresponding to a consumption of 1,300

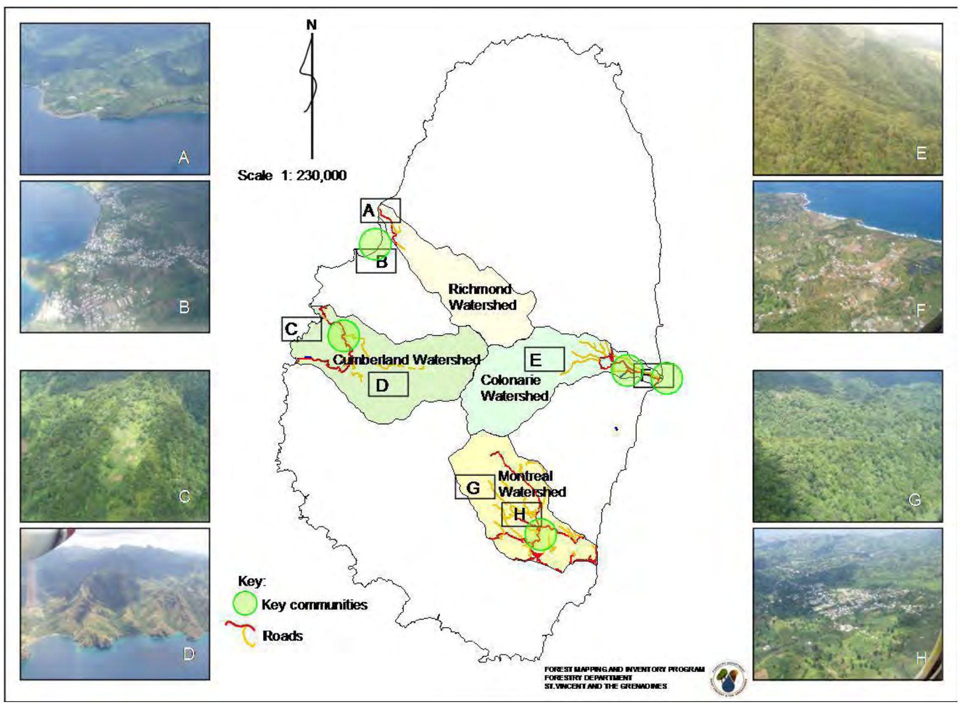
[4] Selling Price applied by CCA to villagers is 8c per gallon (i.e. $80 per 1,000 gallons at source), 15c per gallon (i.e. $150 per 1,000 gallons trucked to property)

gallons per month according to Central Water and Sewerage Authority (CWSA) present tariff[5] (Bceom and Stewarts Engineering Limited, 2006).

C. WATERSHEDS

Forest cover is characteristic of the watersheds, but recent accelerated deforestation has reduced rainfall percolation, soil water retention and hence stream flow. Overall the ability for the several watersheds on mainland Saint Vincent to recharge groundwater has been reduced. Vegetation removal has increased susceptibility to landslides which move volumes of material downslope and into streams, increasing turbidity levels and compromising water quality. Watershed management is a salient need for resilience of the water sector to climate change. Figure 23 illustrates the location of the existing major watersheds in Saint Vincent.

Figure 23: Major watersheds in Saint Vincent and the Grenadines



Source: John, 2009

5) Demand

Sectoral demand for water is discussed below and illustrated in figure 24.

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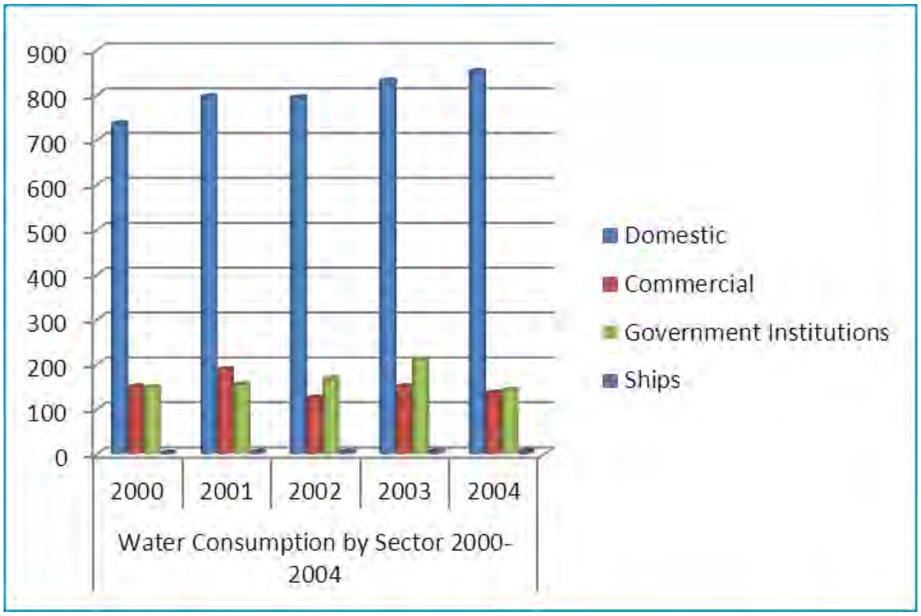
[5] Including a fixed sanitation charge of $15

Figure 24: Water demand by sector



D. AGRICULTURE

Most of the agriculture in Saint Vincent is rain fed. However, over 2000 acres of agricultural lands are currently irrigated utilizing more than 60% of the available dry season river flow. Given the increasing seasonality and variability of rainfall and increasing temperatures, the need for hydrological assessments to inform approaches to support crops during low rain periods is increasingly imperative.

The banana industry is instructive. Although production has fallen by more than 60% over the last 15 years, and exports in 2006 were only 25-30% of the tonnage achieved in the early 1990s, the Government has indicated that the decline must be arrested in the short to medium term. The industry is a critical source of foreign exchange and employment. Recovery of the industry to the level of the 1990s will have an associated demand for irrigation. The banana crop requires between 1300 and 1800 mm of rainfall per year so an adequate water supply is necessary to produce fruit of an optimal size.

E. DOMESTIC DEMAND

Consumption by the domestic sector is the single largest category of water use. Population increase and the concomitant development of housing with changes in life style and housing patterns have increased domestic demand for freshwater. Added demand is being placed on the Central Water and Sewerage Authority to improve its collection, treatment and distribution capacity.

F. THE TOURISM SECTOR

The importance of tourism to the economy of Saint Vincent and the Grenadines has been increasing. Total visitor arrivals increased by nearly 25% over the last 5 years. The focus of the industry is on the

Grenadines, and given its significance, tourism has been accorded priority in the new thrust to diversify the economy.

As the tourism sector in Saint Vincent and the Grenadines develops and expands so too does the demand for high quality potable water. The global per capita demand for fresh water by the tourism sector is about four times that demanded by the local population. This increase in demand is paralleled by an increase in liquid waste which, if not adequately managed will often pollute coastal water bodies. In addition to increased demand for piped water supplies, the growth of the tourism industry has wider implications for pollution control and the maintenance of water quality and quantity.

G. INDUSTRIAL DEMAND

Industrial demand for fresh water includes water for hydro-electricity generation as well as for beverage production. Increased international demand for bottled water has resulted in the formation of at least three companies which exporting bottled water. Economic growth slowed in 2008 to 2.8% after reaching a 10 year high of nearly 7% in 2006. In 2009 with the global economic downturn the Saint Vincent and the Grenadines economy grew by 6.5% despite weak US tourism demand. Success of the economy hinges upon seasonal variations in agriculture, tourism, and construction activity as well as remittance inflows.

Much of the workforce is employed in banana production and tourism, but persistent high unemployment has prompted many to leave the islands. This lower-middle-income country is vulnerable to natural disasters - tropical storms wiped out substantial portions of crops in 1994, 1995, and 2002. In 2007, the islands had more than 200,000 tourist arrivals, mostly to the Grenadines. Saint Vincent is home to a small offshore banking sector and has moved to adopt international regulatory standards. The government's ability to invest in social programs and respond to external shocks is constrained by its high debt burden - 25% of current revenues are directed towards debt servicing. An agreement with Italy to write-off debt reduced the public debt-to-GDP ratio to about 70%.

H. DEMOGRAPHICS AND SETTLEMENT PATTERNS

Total land area of SVG is approximately 390 sq km and the population is 118,000 (2006 estimate). Kingstown, the capital, is located on the south west coast of the main island. It has an estimated population of 15,900 and is the country‘s main port of entry and economic hub.

In 1980, 92.6 percent of the total SVG population resided on mainland Saint Vincent and in 1991 the figure was virtually unchanged, 92.1 percent. However, in 2001, the mainland accounted for 91.9 percent of the total SVG population of 106, 253, registering a slight decrease. Some 85% of Saint Vincent‘s population lives in the coastal zone. The major concentration of the population is in the more developed areas in the south, with 45% of the population in the census divisions of Kingstown: 12.3%; Kingstown suburbs: 11.77%; and Calliaqua: 20.79%.

The average density for the island is 707 per sq mile distributed as follows: Kingstown - 6,954/ sq mile; Kingstown suburbs -1,954/sq mile; and Calliaqua (1872/sq mile). The least dense areas are in the north – Chateaubelair (197/sq mile); Georgetown (311/sq mi); Barrouallie (382/sq mi) and Sandy Bay (512/ sq mi). According to the 2001 Census, there was a net loss of persons from the Kingstown census division (-14.6%) with gains in the suburbs (+16.3%) and Calliaqua (+8.9%). Density levels across census divisions vary significantly, from a high of 6,954 in Kingstown to a low of 197 in Chateaubelair (table 5). Density is directly related to water demand and the ability to supply. As noted earlier the growing population and associated construction has encroached on slopes and watershed areas, thus contributing to accelerated erosion and sedimentation of water sources.

Construction (especially house building in the private sector) is one of the main sectors driving the SVG economy at the moment. A ―Cross County Road" is proposed and it is projected to open up previously inaccessible areas to housing and other development. The road along with the new development will introduce potential threats to the integrity of water sources. Measures to monitor and control soil erosion, and washout of pollutants will need to be implemented (Egis Bceom International, 2009).

In 2001 41.6 percent of the total employed population worked in the Agriculture, Construction and Wholesale industries compared with 49.1 percent in 1991 (GoSVG, 2001). This was due to the 37 percent decline in employment in the agricultural industry, although there was positive growth in the construction and wholesale and retail trade sectors. The industries which experienced the most significant decline in employment were fishing (-22.0 percent) and manufacturing (-13.0 percent).

L. NATURAL HAZARD VULNERABILITY

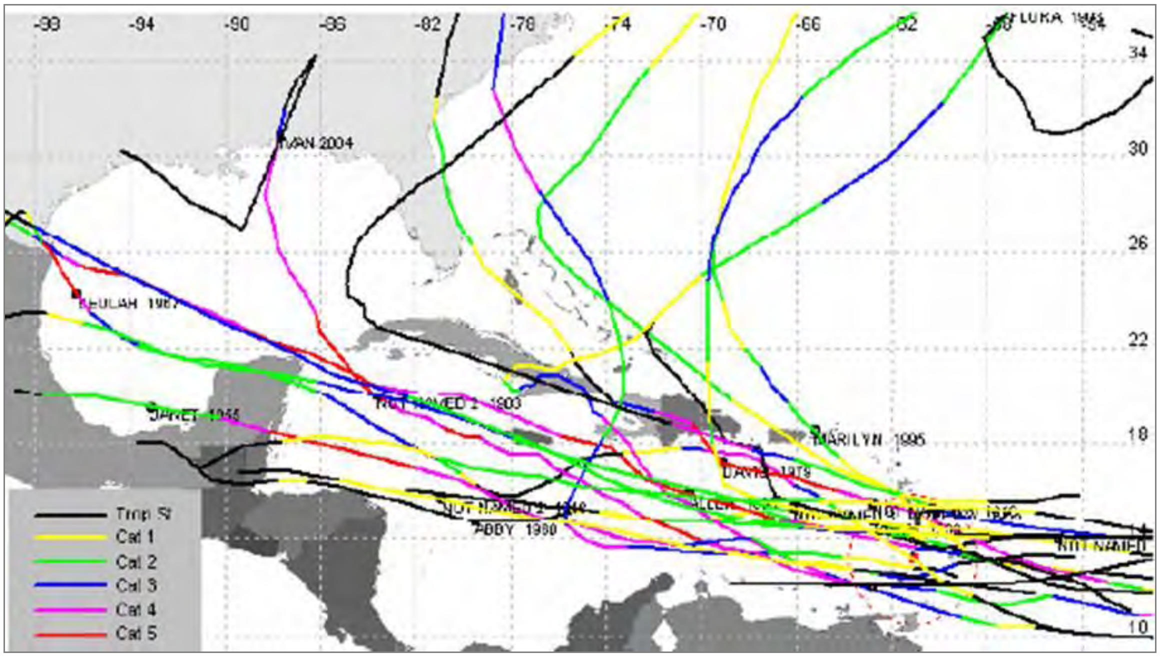
1) Hurricanes

The Caribbean is considered a disaster ―hotspot" and the eastern Caribbean island states are impacted directly from the west and northwesterly tracks of the cyclones crossing the Atlantic Ocean (figure 25). Saint Vincent and the Grenadines is located south of the belt of the most active zone within the eastern Caribbean, but the islands have experienced either the direct impact or the effect of storm waves and heavy rainfall. These hurricanes have had varying impacts on the island‘s coastline, and by extension settlement, water supply other infrastructure. Hurricane Tomas of October 2010 is the most recent storm to have impacted the island. Damage assessment reports indicate some damage to water supply infrastructure.

Table 5: Population density data for SVG 1980 to 2001 (Source: Population and Housing Census 1980, 1991 and 2001)

Census Division	Area	Population			Density		
	Sq. Miles	1980	1991	2001	1980	1991	2001
Kingstown	1.9	16,532	15,466	13,212	8,701	8,140	6,954
Kingstown Suburbs	6.4	8,609	10,757	12,508	1,345	1,681	1,954
Calliaqua	11.8	17,440	20,290	22,095	1,478	1,719	1,872
Mariaqua	9.4	8,408	8,864	8,145	894	943	866
Bridgetown	7.2	6,762	7,532	6,754	939	1,046	938
Colonaire	13.4	7,210	7,890	7,482	538	589	558
Georgetown	22.2	6,494	7,303	6,914	293	329	311
Sandy Bay	5.3	2,867	2,793	2,716	541	527	512
Layou	11.1	5,510	5,993	6,303	496	540	568
Barrouallie	14.2	4,667	5,199	5,422	329	366	382
Chateaubelair	30.9	6,101	6,045	6,087	197	196	197
Total Mainland	**133.8**	**90,600**	**98,132**	**97,638**	**677**	**733**	**730**
Northern Grenadines	9	4,740	5,514	5,389	527	613	599
Southern Grenadines	7.5	2,505	2,853	3,226	334	380	430
Total Grenadines	**16.5**	**7,245**	**8,367**	**8,615**	**439**	**507**	**522**
TOTAL SVG	**150.3**	**97,845**	**106,499**	**106,253**	**651**	**709**	**707**

Figure 25: Caribbean Basin hurricane tracks from 1962 to 2004



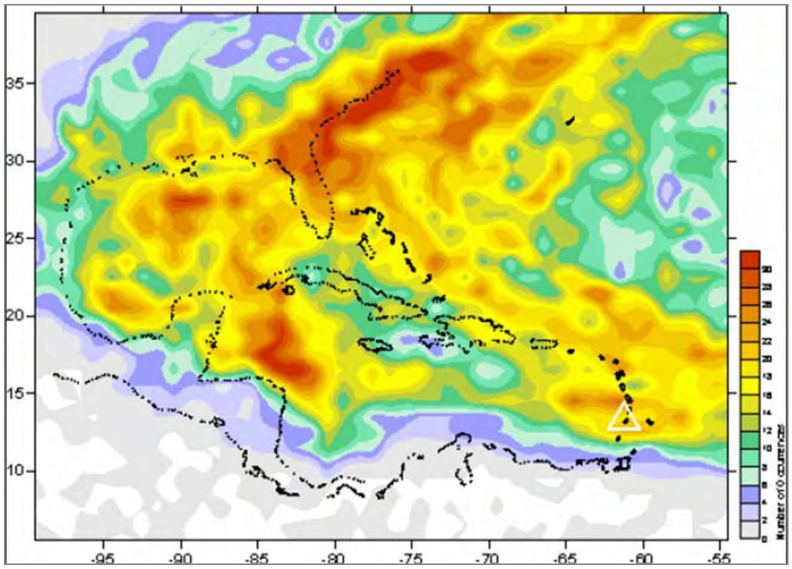
Source: SWIL, 2006

Based on the frequency of events the islands are considered moderately predisposed to hurricane activity of the lesser magnitudes (average exposure of a hurricane every 5-7 years) and is far less exposed to the most severe hurricanes (exposure of a severe hurricane every 25-50 years), in relation to the islands to the north (figures 26 and 27). However, it is significant to note that the country has been assessed as extremely vulnerable to natural disasters. Using data from 1970-2005, researchers compiled an index to convey and rank vulnerability of countries across the globe to Natural Disasters. In terms of land area, Saint Vincent and the Grenadines was ranked the 2nd most disaster prone country in the world. In terms of population, it was ranked 5th (EM-DAT; World Bank, 2006). A single disaster event can be devastating to the entire country because of its small size.

2) Storm Surge

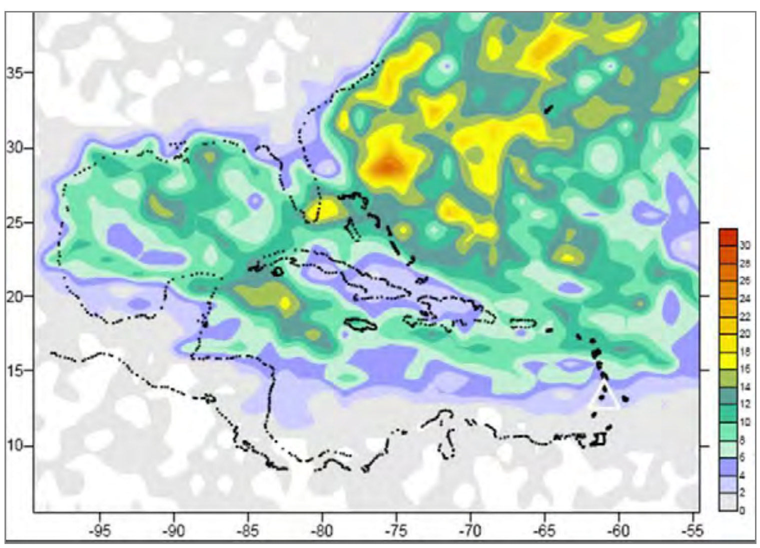
Storm surge refers to the abnormal increase in sea level caused by hurricanes and are technically defined as the difference between the observed water level and the normal astronomical tide. Surge can flood aquifers, surface resources, and wash out water supply infrastructure. A study of coastal vulnerability has identified the eastern and southern sections of the coast of Saint Vincent as most vulnerable to storm surge (figure 28). These coastal areas also house most of the population of the islands.

Figure 26: Spatial distribution of hurricane occurrence in the Caribbean Basin (note Saint Vincent and the Grenadines in the white triangle



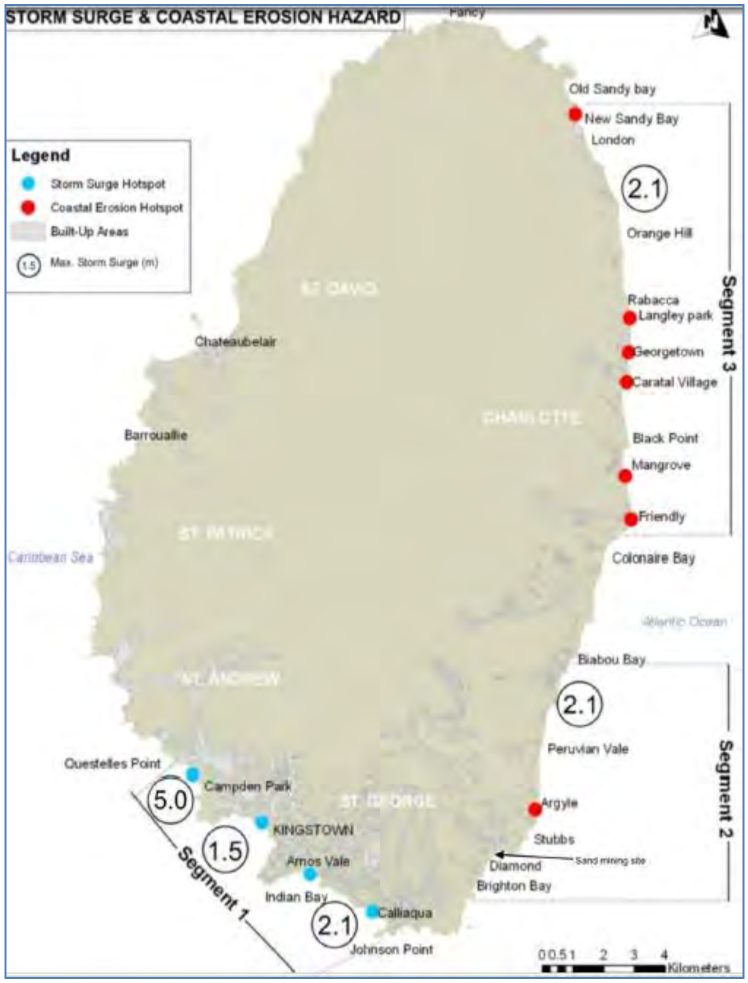
Source: SWIL, 2006

Figure 27: Spatial distribution of intense hurricane (category 3 and over) occurrences



Source: SWIL, 2006

Figure 28: Storm surge and coastal hazard erosion of Saint Vincent



Source: ESL, 2008

3) Drought

Three main drought events have been recorded in Saint Vincent and the Grenadines: 1958, 2002 and the early part of 2010 all due to prolonged dry periods (Boruff, 2006; and VINLEC, 2010). In 2002, the island experienced severe drought conditions for five months. Excessive run off occasioned by deforestation reduced underground storage to a minimum. At the same time, water demands were steadily increasing. This situation has since prompted the irrigation unit to examine its future and the future of agriculture in Saint Vincent. One immediate response from the unit has been the establishment of a water user group. The most recent event in 2010 was felt throughout the Caribbean and was significant to the SVG islands in that it not only impacted water supply but also hydroelectric supply for the country. In 2009 21% of the electricity supply of Saint Vincent and the Grenadines was produced by hydroelectricity

(VINLEC, 2010) but projections for 2010 were expected to be less due to the severe drought experienced in that year.

Table 6: Climate change variables and water sector impact

Climate change variable	Response	Impact on sector		
		Quantity & quality	**Infrastructure**	**The resource**
Increasing length of the dry season	Low flows	Low volume. Pollutants	Broken mains. Low storage, inactive pumps, pipelines. barge, trucks	Loss vegetation on slopes, fires,
Increased frequency of high intensity rainfall events	Rapid runoff, rapid flood-peak Increased erosion, high sediment loads. Landslides and floods.	Increased quantity high turbidity	Washout mains, pumps, siltation of intakes	Slope failure. Debris slides Loss of soil. Siltation of channels - reduced capacity
The likely increase in climatic variability	Flood-drought cycles - impact on agriculture	Variability in flow high & low flows. High turbidity with high flows. Contaminants with low flows	Flood impacts. Low flows. Irrigation. Trucking, barge	Slope failure. Debris slides. Loss of soil
Sea level rise	Coastal Flooding. Saline intrusion	Brackish water	Corroded equipment - loss of use	Habitat alteration
Temp increases	Increased evaporation ocean temps, extreme events	Flood impacts	Wash out	Accelerated erosion. Siltation of channels - reduced capacity

4) Flooding

During the rainy season in Saint Vincent and the Grenadines flooding and landslides are likely to occur. Flooding is also associated with the tropical systems that may traverse the Caribbean bringing several inches of rainfall as they move due west or North West. With these hazards, arise losses within the various sectors. For example, on April 11, 2011 flooding resulted in damaged irrigation system in the north of Saint Vincent.

5) Climate Variables and Impact

Table 6 illustrates**.**

V. CLIMATE MODELING AND WATER SUPPLY 2011-2050

Climate change is expected to alter the livelihood and standard of living for a large portion of the world‘s population. One key aspect of this impact as discussed above is in the area of availability of water resources vis-à-vis the likely changes in the key water demand sectors for these increasingly scarce resources. This section of the report estimates the demand and supply relating to these resources between 2011 and 2050 in order to provide policymakers with possible adaptation and mitigation measures that ought to be implemented. It is important to note that the models are helpful in making projections not predictions.

A. WATER DEMAND

The historical data on national water demand and supply was generally available for Saint Vincent on an annual basis between 1990 and 2009 with some gaps having to be interpolated from the data. These calculations are explained below.

1) Residential Water Demand

Residential water demand was estimated for Saint Vincent was estimated using proxy data from Jamaica. This was necessitated by the absence of a time series of the residential water demand time series for 1990 to 2009. As a result, no econometric model relating the climate to residential water demand was estimated. The methodology that was used to calculate per capita water demand of the population is presented below and implicitly assumes that per capita consumption for water by the residents of Saint Vincent and the Grenadines is the same as those of the Jamaican population. In addition, the forecasts for the A2 and B2 scenario were calculated using the anticipated changes in global population under these two scenarios. The following three steps outline the approach that was employed and the results are presented in figure 25.

Step 1: Estimating the historical Saint Vincent residential water demand for 1990 to 2009

As a result of the discussed absence of the water that was available at the time of the study, residential water demand (consumption) in Saint Vincent had to be estimated by calculating the residential water demand per capita for Jamaica and multiplying it by the total Saint Vincent water demand during the period 1990 and 2009. This provides an estimate of the historical residential water demand.

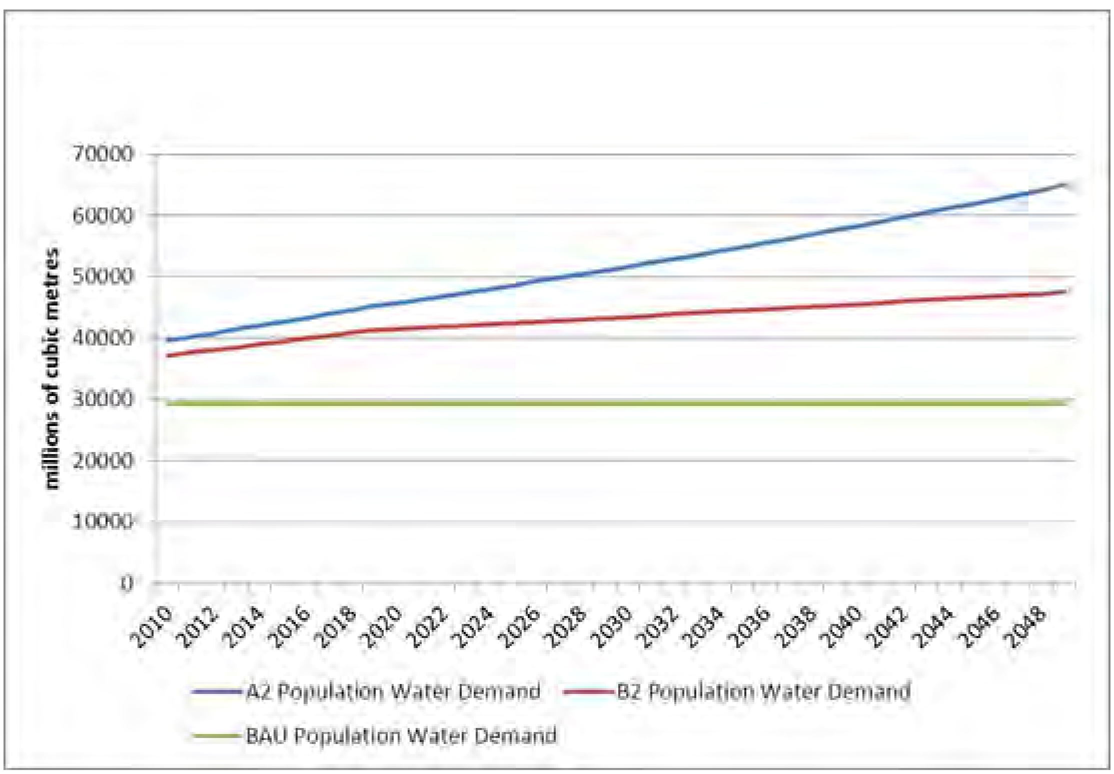
Step 2: Estimating the A2 and B2 forecasts of Saint Vincent residential water demand for 2011 to 2050

The forecasted residential water demand for 2011 to 2050 under the A2 and B2 scenarios were calculated under the assumption that the ratio of the Saint Vincent population to the world population under both A2 and B2 scenarios would remain the same throughout 2011 and 2050 and the 2010 per capita residential water consumption rate applied to the A2 and B2 estimated Saint Vincent population. These global populations for A2 and B2 were obtained from the IPCC webpage.

Step 3: Estimating the BAU forecasts of Saint Vincent residential water demand for 2011 to 2050

The BAU residential water demand for Saint Vincent was calculated as the two-period moving average of the historical residential water demand calculated in Step 1 (figure 29).

Figure 29: Saint Vincent residential water demand 2011 to 2050



Source: Author's compilation

Figure 29 indicates that under both A2 and B2, residential water demand would increase between 2011 and 2050 at a higher level than the comparator BAU series. This is likely to occur in response to the higher temperature and rainfall extremes that are anticipated under the A2 and B2 climate-based scenarios. In addition, population growth figures are larger under the A2 and B2 than under the BAU scenarios as prescribed by the IPCC global estimates of population growth.

B. TOURISM WATER DEMAND

The importance of the tourism sector to the Vincentian economy has been discussed above. It is also a key sector in terms of the demand for water and is therefore assessed as part of this study. The dataset provided by the country did not contain a historical time series on demand for water by the sector as a result, estimates had to be developed. This was done by utilizing the per tourist water demand (consumption) for Jamaica and applying it to the tourist arrivals to Saint Vincent and the Grenadines. The A2 and B2 tourism water demand were calculated on the basis of 2011 (ECLAC, 2011) projections of the likely impact of climate change on tourist arrivals to Saint Lucia a close industry competitor of Saint Vincent and the Grenadines. The methodology is presented below.

Step 1: Estimating the historical Saint Vincent tourism water demand for 1990 to 2009

Given the absence of this time series, volume of water consumed by tourists in Saint Vincent had to be estimated by calculating the tourism water demand per capita for Jamaica as a proxy and multiplying it by the total Saint Vincent water demand during the period 1990 and 2009. This provides an estimate of the historical tourism water demand. The assumption here is that tourists to Saint Vincent and the Grenadines would consume the same amount of water, *ceteris paribus*.

Step 2: Estimating the A2 and B2 forecasts of Saint Vincent tourism water demand for 2011 to 2050

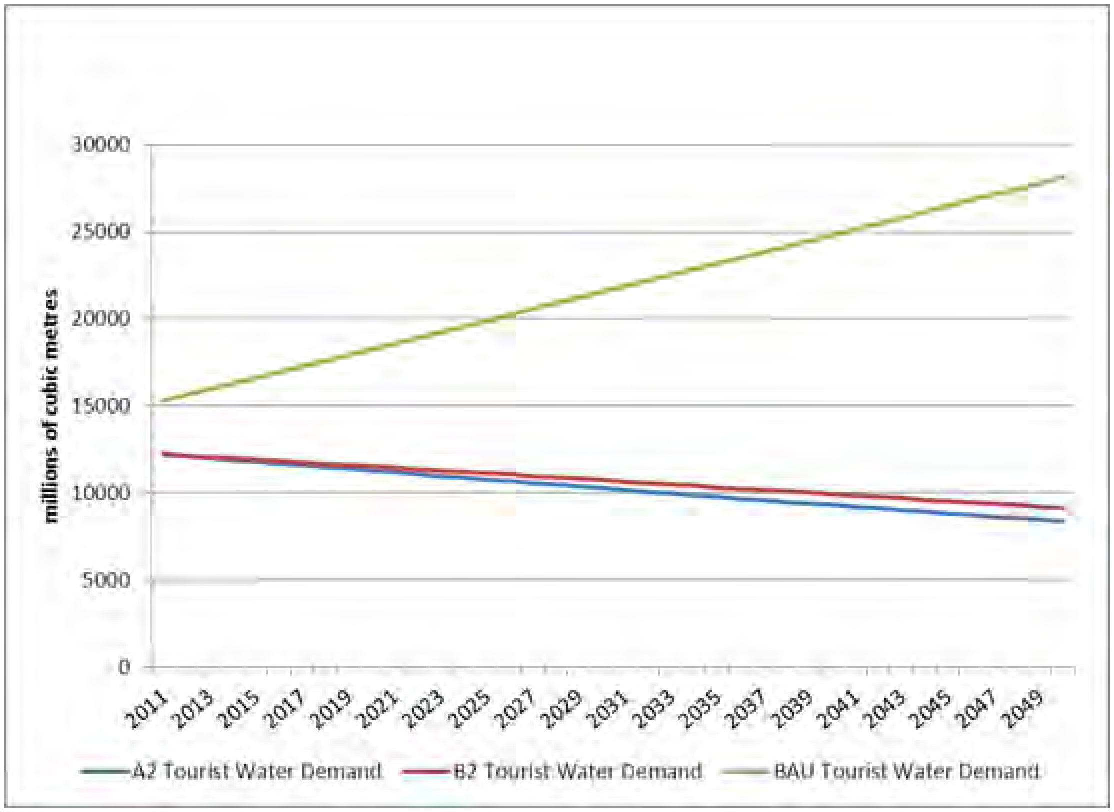
The forecasted tourism water demand for 2011 to 2050 under the A2 and B2 scenarios were calculated in two sub-steps:

- **Sub-step 1*:*** The anticipated number of tourists that are likely to visit Saint Vincent between 2011 and 2050 under the A2 and B2 were estimated using percentage changes in tourist arrivals for Saint Lucia (ECLAC, 2011).
- **Sub-step 2:** Using these A2 and B2 forecasts of the number of tourists that are likely to visit Saint Vincent the volume of water that is likely to be consumed by these tourists has to be calculated next. This is done using the Jamaican data as a proxy (the total volume of water consumed by tourists to Jamaica divided by the number of tourists gives the ―per tourist" water demand) and multiplying this per tourist rate of water consumption by the A2 and B2 number of anticipated tourists. The ―per-tourist" water demand was determined using Jamaican data under the assumption that these rates of consumption ought not to vary systematically across countries.

Step 3: Estimating the BAU forecasts of Saint Vincent tourism water demand for 2011 to 2050

The BAU tourism water demand for Saint Vincent was calculated as the two-period moving average of the historical tourism water demand calculated in Step 1 (figure 30).

Figure 30: SVG Tourism water demand 2011 to 2050



Source: Author's compilation

Tourism water demand is anticipated to increase continuously between 2011 and 2050 by industry associations such as the World Travel and Trade Council. For this study however, the BAU was estimated as a two-period moving average of the historical 1990 to 2009 data on tourism arrivals. This approach assumes a continuation of the historical trend which does not consider the impact of climate change on the desire of tourists to visit Caribbean countries in the absence of the environmental qualities that they are renowned for. As a result, the number of tourist arrivals and therefore the volume of water demanded by these tourists increases at a rapid rate between 2011 and 2050. In contrast, the findings of ECLAC (2011) in relation to tourism arrivals anticipate that tourism arrivals will decline, rather significantly and contrary to the static forecast assumed under BAU, under the A2 and B2 scenarios (using the rates calculated by ECLAC (2011) and these rates are applied to the BAU levels to get relevant declines in Grenada tourist arrivals. As a result, tourism related water demand is highest under BAU than under A2 and B2.

C. AGRICULTURE WATER DEMAND

Water demand by the agriculture sector for the period 1990 to 2050 was developed using the steps below and the results are illustrated in figure 27. Broadly speaking the analysis uses proxy data for the changes in global water demand needs for irrigation of an additional 2 and 5 per cent of water under the A2 and B2 scenarios, respectively. The analysis assumes that Saint Vincent and the Grenadines will follow the global needs and demand proportionally as much additional irrigation water as other farmers across the world.

Step 1: Estimating the historical Saint Vincent agriculture water demand for 1990 to 2009

Given the absence of this time series, volume of water consumed by farmers in Saint Vincent had to be estimated by calculating the agriculture water demand per acre in Jamaica and multiplying it by the total Saint Vincent water demand during the period 1990 and 2009. This provides an estimate of the historical agriculture water demand.

Step 2: Estimating the A2 and B2 forecasts of Saint Vincent agriculture water demand for 2011 to 2050

The forecasted agriculture water demand for 2011 to 2050 under the A2 and B2 scenarios were calculated using the IPCC estimates of changes in agriculture water demand under the two scenarios[6]. The IPCC reported estimates are based on an analysis by Döll (2002) and Döll and others (2003) who apply the SRES A2 and B2 scenarios and find that net irrigation requirements could increase by up to 2 to 7% by the 2070s. The largest global-scale increases in net irrigation requirements result from a climate scenario based on the B2 emissions scenario.

Step 3: Estimating the BAU forecasts of Saint Vincent agriculture water demand for 2011 to 2050

The BAU agriculture water demand for Saint Vincent was calculated as the two-period moving average of the historical residential water demand calculated in Step 1 (figure 31).

D. CLIMATE DATA: A2 AND B2 FORECASTS

The data available included the total rainfall data for Saint Vincent and the Grenadines which was sourced from the Caribbean Institute of Meteorology and Hydrology (CIMH) for the years 1990 to 2004 with the years to 2010 estimated by the author using a two-period moving average. Some critical variables are missing from projections due to unavailability. These include:

i. Sea level rise
ii. Rain water run-off
iii. Quality and health of water supply

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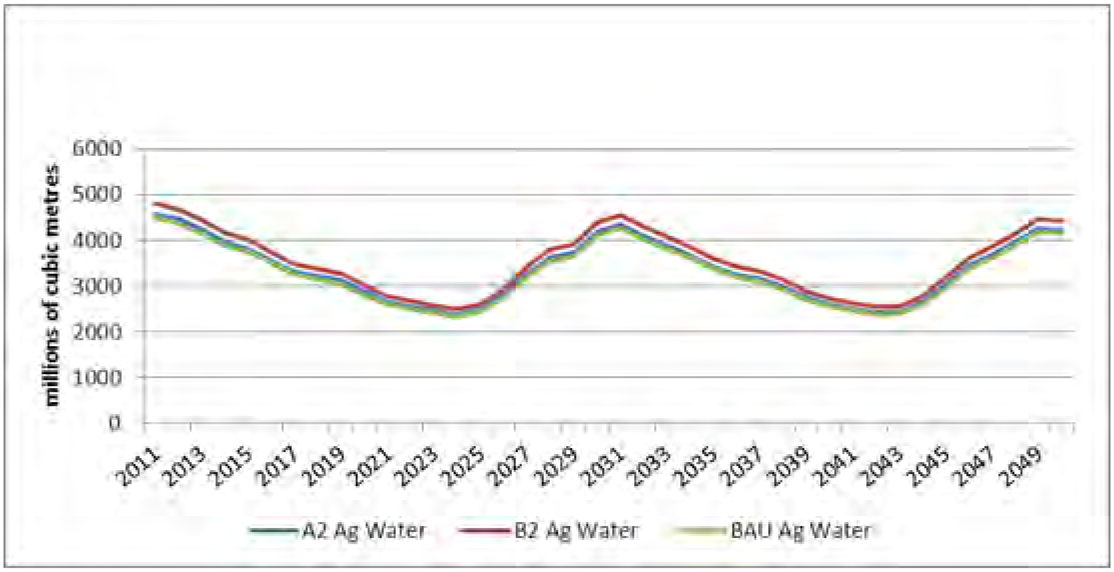
[6] http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3s3-5-1.html

iv. Rise of new demand
v. Seasonality & erratic patterns of rain

Figure 31: SVG agriculture water demand 2011 to 2050



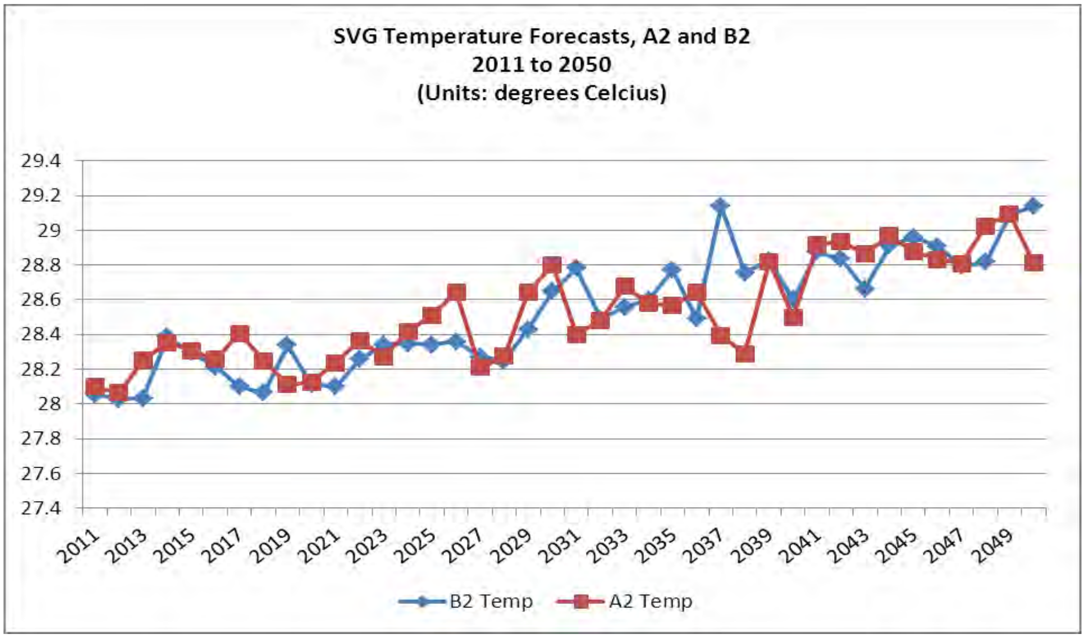
Source: Author's compilation

Water supply data was obtained from Central Water and Sewerage Authority (CWSA) in Saint Vincent and the Grenadines for the years 1990 to 2009. The rainfall forecasts were calculated for the A2 and B2 scenarios (figure 32) using the following steps:

- The temperature and rainfall climatology was calculated by calculating the average of the monthly temperature and precipitation for each month between 1990 and 2009 (figure 33)
- The anomalies that are obtained from the ECHAM model for coordinates 291-17.5 for each scenario – A2 and B2 – were used to downscale the climatology. This yielded the A2 and B2 temperature and rainfall forecasts for the period 2011 to 2050.

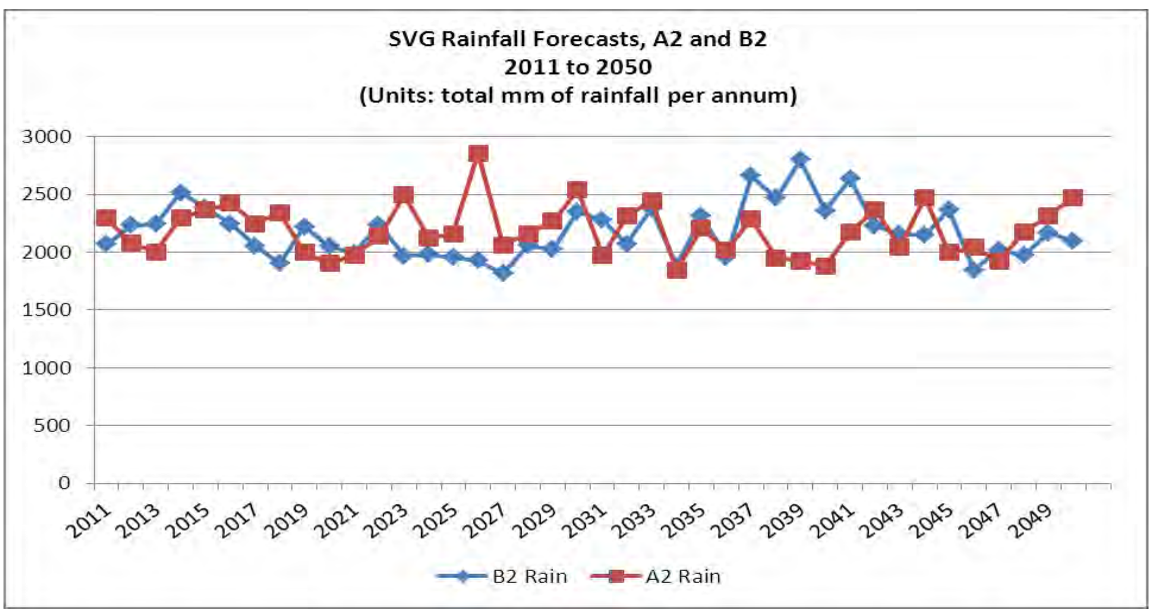
Figures 32 and 33 indicate that the A2 and B2 scenarios both result in higher levels of rainfall and as expected the A2 exceeds B2 in terms of rainfall and temperature during the entire forecast period.

Figure 32: SVG Temperature Forecast A2 and B2 2011 to 2050



Source: Author's compilation

Figure 33: SVG rainfall forecasts, A2 and B2, 2011to 2050



Source: Author's compilation

These forecasts for the A2 and B2 scenarios are the basis for our discussion about the impact of climate change on water supply in Grenada presented in the next section.

E. WATER SUPPLY

The approach used to model water abstraction is an Error Correction Model in which the temperature and rainfall are included to determine their impact on the level of water abstraction undertaken by the Vincentian water authorities. Water abstraction under the BAU is calculated as the linear trend of the historical water abstraction of water. The coefficients from the estimation are presented in table 7.

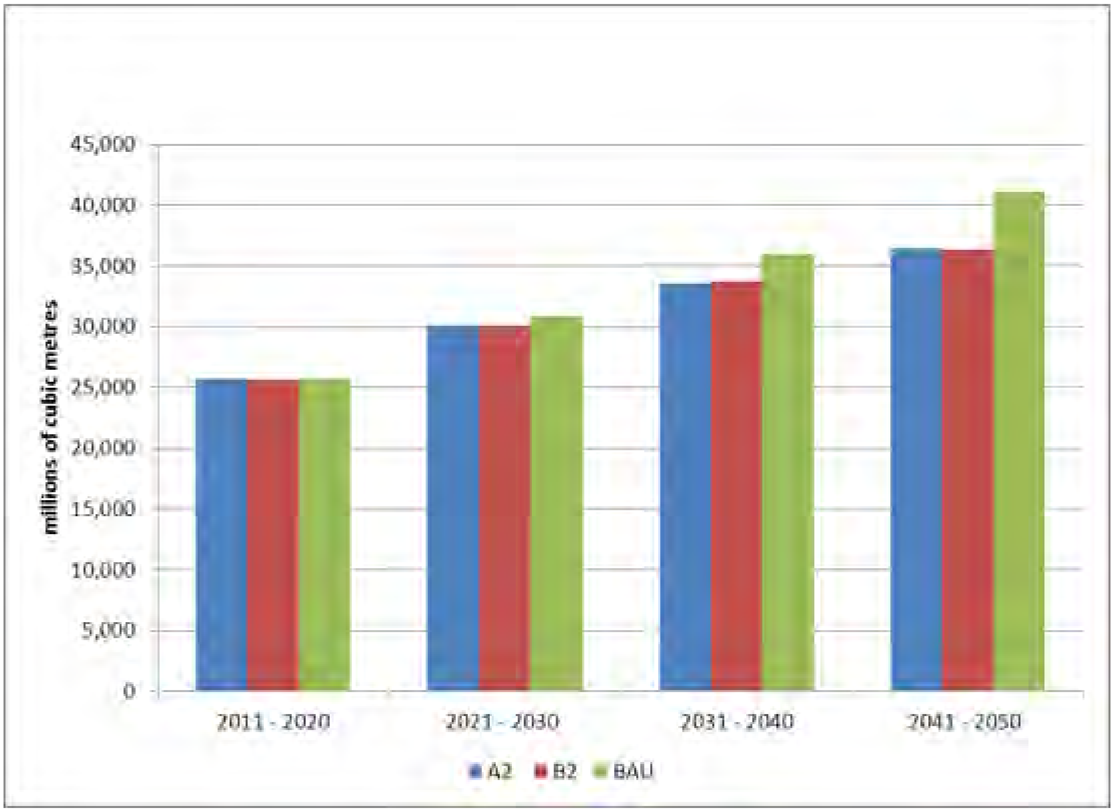
Table 7: Model coefficients for Saint Vincent water supply regression

Model Coefficients for Saint Vincent Water Supply Regression		
Variable	Coefficient	T-value
Error Correction Term	-0.058	-2.811
Rainfall	0.166	0.704
Temperature	-8.854	1.616
R-squared	0.938	
S.E. Regression	0.011	
Jarque-Bera	3.644 (0.162)	
Breusch-Godfrey	0.297 (1.175)	
Breusch-Pagan	0.252 (0.961)	

This model provides the statistically significant relationship between temperature and water supply between 1990 and 2009. The sign and magnitude of the Error Correction Term indicate that the model fits the data and is not likely to provide forecasts that explode over time. In addition the r-squared indicates that the model explains approximately 91 per cent of the variation in the volume of abstracted water in Saint Vincent. Tests for normality, serial correlation and heteroscedasticity also indicate that the linear model is appropriate for the data being analysed.

The forecasts for water supply between 2011 and 2050 were obtained by including the forecasts for temperature as calculated in the previous sector in the model and using the forecast function in Eviews 6. These forecasts are presented in figure 34.

Figure 34: SVG Water supply forecasts 2011 to 2050



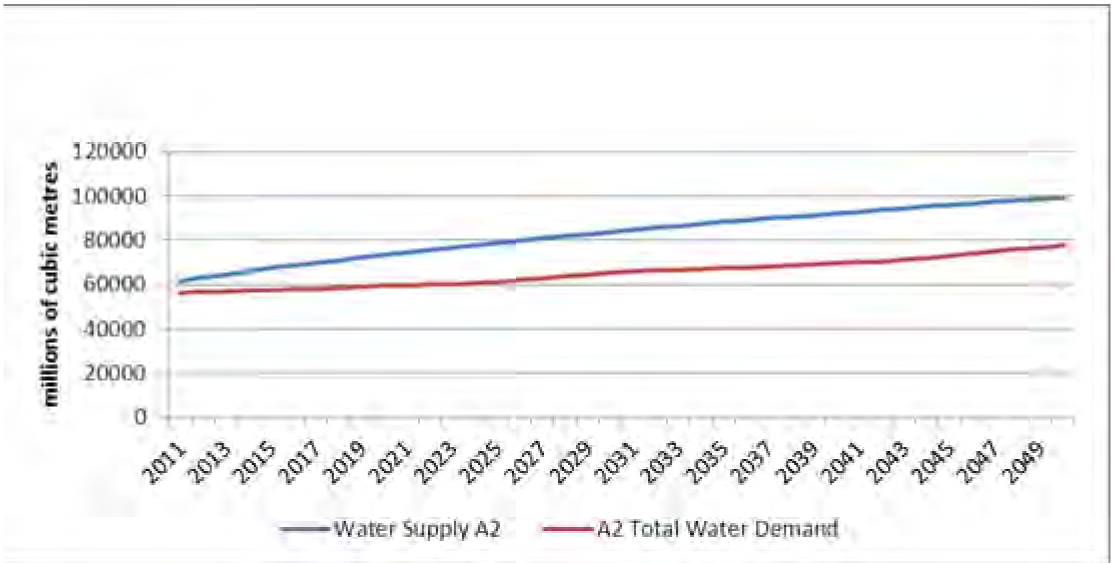
Source: Author's compilation

The B2 water abstraction is forecasted to be approximately the same as water abstraction under the A2 with very little variation between these two scenarios. Under BAU, water abstraction increases steadily over the period in anticipation of increased demand likely associated with providing adequate supplies for the tourism sector.

F. RESULTS & DISCUSSIONS

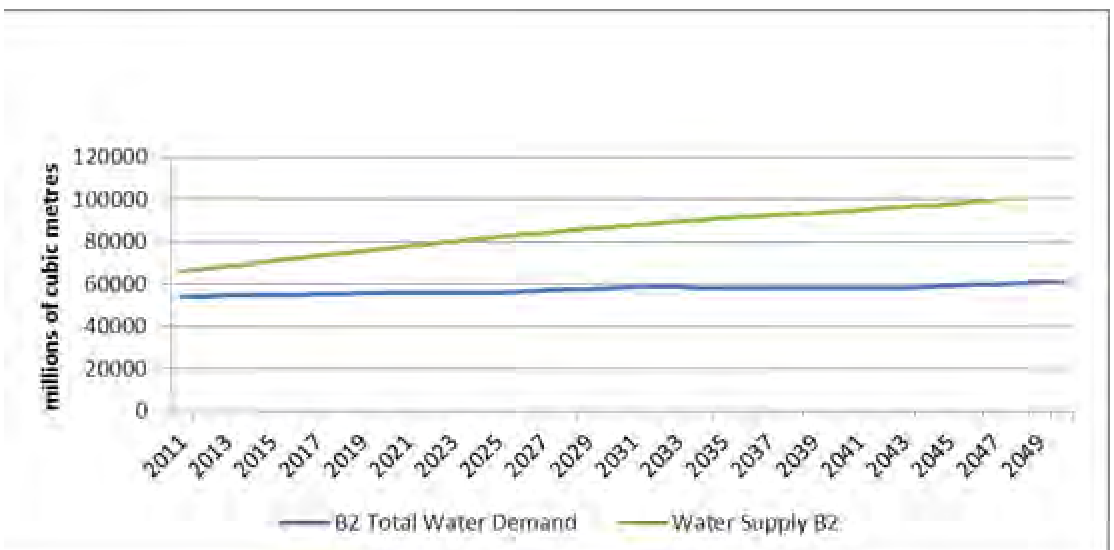
This section presents forecasts of the net water demand (supply) that will be required (available) to Saint Vincent and the Grenadines between 2011 and 2050. Net supply was calculated as the difference between the forecasted water supply and demand for 2011 to 2050 and is presented for each scenario 9in figures 35, 36 and 37.

Figure 35: A2 Net water supply 2011 to 2050



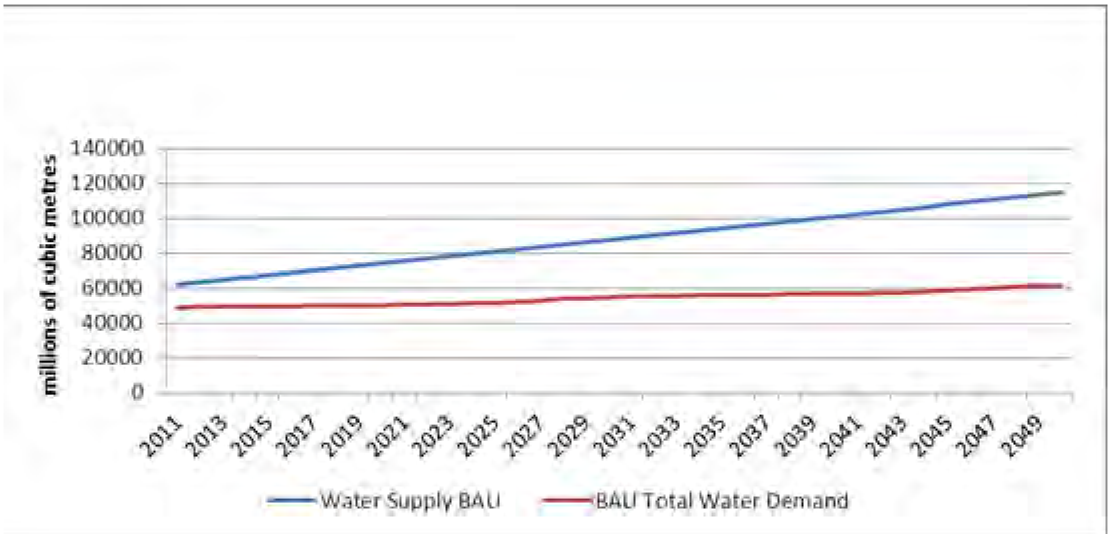
Source: Author's compilation

Figure 36: B2 Net water supply 2011 to 2050



Source: Author's compilation

Figure 37: BAU Net water supply 2011 to 2050



Figures 35, 36 and 37 indicate that in each of the three scenarios – A2, B2 and BAU Saint Vincent and the Grenadines will have net water supplies represented by the difference between the two curves during the forecast period of 2011 and 2050. The amount of water demanded for various uses increases steadily between 2011 and 2050 in all three scenarios; however there is a faster increase in the water supply that enables the countries to have adequate water to supply each sectoral use. It is important, however to ensure that the infrastructure is able to contend with the additional demand and to store the needed additional amounts of water being predicted by the model but exceed current levels of demand. The significance of variability and seasonality is masked in the projections of a positive balance between supply and demand for the period 2011 to 2050. Further, the disparity between mainland Saint Vincent and the Grenadine islands is also subsumed. It is anticipated that variability and seasonality will increase and therefore it is important to ensure that the infrastructure and policy framework are adequate to meet the demand during the periods of crisis.

It is important for policymakers to consider that since water is a complex resource and these projections and conclusions are to be understood as holding many of the factors that could influence water demand and supply constant, the results have to be interpreted in this context. The results reflect the fact that the supply side analysis of the impact of climate change is easier to model than the demand side. However the attempts reflected above were made in order to provide a more informative analysis for the benefit of planners over the medium term. In particular, there are other ecological issues and other anticipated impacts of climate change such as sea-level rise that have not been modelled in this analysis.

SLR is of particular concern for small-island developing states that depend heavily on freshwater supplies and locate major infrastructure on the coast. SLR is anticipated to have a substantial impact on the quality of the available water resources particularly during the forecast horizon. Consider further the issues of the quality and health of these ―excess supplies" that are forecasted based on the analysis. It will be increasingly important for planners to consider this aspect since salt-water intrusion due to sea-level rise and contamination associated with general economic development and debris from natural disasters (Arnell, 2004; Terry, 2007) all of which may require expensive and expansive purification and treatment plants.

Water is most vulnerable to climate change, the ability for SVG to store surplus water from runoff, access to water, and affordability of water would all be affected. In order for SVG to achieve water security steps must be taken to increase the water supply and the efficiency of water use. Several issues need to be consideration for SVG when developing adaptation strategies in Section 6.0 which follows. These include:

- The Mainland and the Grenadines have different climatic conditions
- Competing demand exists among sectors- tourism, energy, industry
- Governance and institutional capacity require improvement
- Poor management of flood and drought hazard
- Sustainable supply of good quality water

Although not specified as a variable in the analysis, it is important that the quality and health of the available water supplies be prioritized in the development of catchment and storage capacities. In addition, the analysis does not explicitly contend with the possible rise of new sectors that have an unforeseen impact on the demand for water. Finally, the well-known climatic differences between Saint Vincent and the Grenadines should be brought to bear on the infrastructural response to developing and locating storage infrastructure to facilitate demand.

VI. ADAPTATION STRATEGIES

The Global Water Partnership in its policy brief indicated that the best way for countries to build the capacity to adapt to climate change would be to improve their ability to cope with today‘s climate variability (GWP, 2005).

The dependence of Saint Vincent and the Grenadines on rainfall increases the country‘s vulnerability to future changes in and distribution of rainfall. Low rainfall can lead to reduction in river flows and in turn a reduction in the amount of water that can be physically harvested. This means that it is unlikely that demand will be met during periods of low rainfall. On the other hand, during the rainy season, lack of suitable land areas for dams and high runoff during storms result in significant loss of surface water to the sea. Measures that have been suggested to respond to projected changes in water resources in SIDS include:

- Incentives to encourage the use of water saving devices
- Selecting appropriate drought tolerant vegetation
- Establishing river buffer zones to enhance the resilience of the river and catchment area
- Updating national water policies
- Improving water resources management
- Revising building codes to increase opportunities for rainwater catchment and storage; preparing water resource master plans for islands
- Assessing and improving the water supply system.

Globally some of the approaches taken have included the following:

- Top-down (e.g., expanded irrigation systems) versus bottom-up (e.g., community-based water harvesting or allocation systems).

- Policy level (e.g., integrated water management policies accounting for climate change impacts) versus operational (e.g., location and design of bridges, reservoirs & hydropower facilities) level.

- Traditional (e.g., Water managers would fit a drainage system in an area projected to experience more intense rainfall events with bigger pipes when replacing old ones) versus modern

- A mainstreamed adaptation strategy in the water sector includes measures that address the underlying factors of vulnerability to climate change particularly at the local scale.

The following measures as recommended by L. Nurse at the UNESCO international seminar on climate change education in 2009 can reduce some of the risks on the water sector if implemented in a timely manner:

- Infrastructural - erect coastal and flood protection (SLR & flooding); adopt technologies that improve water use efficiency, e.g. trickle irrigation

- Behavioural - altered habits and choices e.g. alter irrigation practices such as time of day to achieve maximum use of the resource, desist from using treated water for some non-domestic purposes

- Managerial - e.g. altered farm practices such as cultivation of drought-tolerant cultivars; implementation of demand management strategies (e.g. through metering and pricing)

- Government Policy - e.g. planning regulations; building codes; use of appropriate, renewable energy sources –solar, wind, bio-fuels, landfill gas (methane).

A. SELECTING STRATEGIES

Adaptation costs as defined in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change are “the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs”, while the benefits are defined as “the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures”.

The Subsidiary Body for Scientific and Technological Advice of the UNFCCC in its Synthesis Report of 2010 (UNFCCC, 2010) , presented a summary of efforts undertaken to assess the costs and benefits of adaptation options, and views on lessons learned, good practices, gaps and needs. The report indicated that in some cases for adaptation, more can be achieved by using a cost-effectiveness approach – that is, selecting the options that have the lowest cost for achieving a given physical target of supplying key services. The islands of Niue and Tuvalu, for example, identified enhanced water supply and storage as the adaptation priority under the Pacific Adaptation to Climate Change project using such an approach. The aim was not to find alternative adaptation options that might yield a higher adaptation benefit but to find those options that ensure sufficient water quality and quantity for vulnerable communities.

In other cases, a risk-based approach, in which adaptation options are selected that achieve an acceptable risk level at least cost, may be more appropriate. The EU in its submission suggests that risk management approaches, including phased approaches or approaches based on no-regrets or win-win options, can be helpful in coping with uncertainty. Finally, in certain cases multi-criteria analysis may be adopted, to account for the fact that not all aspects can measured or costed. With multi-criteria analysis, a number of objectives are identified and each objective is given a weighting. Using this weighting, an overall score for each adaptation option is obtained, and the option with the highest score is selected. The report further suggests that an assessment of the costs and benefits of adaptation options, can consider either the economic or the financial costs and benefits. Economic assessments consider the wider costs and benefits to the national economy as a whole. In contrast, financial costs are typically assessed within the budgetary framework of each of the options under consideration.

For example, in its submission, the Russian Federation reported on its assessment of the financial costs of enhancing systematic observation in the country. It considered the efficiency of its hydrometeorological services by assessing the costs of producing relevant hydrometeorological data and the benefits in terms of avoided damage achieved by preparatory measures that were made possible by the availability of high quality, timely forecasts. This approach is particularly applicable to Saint Vincent and the Grenadines which has recognised the need to improve the database for water resources management and is in the process of implementing the Water Resources Management Unit and a National Water Information System.

It was also reported that Turkmenistan under a UNDP project, considered only those adaptation options that could eliminate the general risk of an expected water deficit of 5.5 km3 by 2030, following a cost-effectiveness approach. In Turkmenistan, 90 per cent of the total water resources are used for irrigation in agriculture, so the adaptation options assessed include improving water resources management, optimizing agricultural production and increasing the efficiency of irrigation systems. The total cost of adaptation options was calculated to be USD 16.1 billion between 2009 and 2030 (UNFCCC, 2010)

With the projected reduction in precipitation, measures such as desalination may have to be considered in some instances to meet the demand for water. If freshwater supply has to be replaced by desalinated water due to climate change, then the cost of climate change includes the average cost of desalination, which is currently around US\$1.00/m^3 for seawater and US\$0.60/m^3 for brackish water (Zhou and Tol, 2005) while the cost for freshwater chlorination is approximately US\$0.02/m^3.

This estimate may be increased for Caribbean states given the high cost of energy for most energy dependent countries. Further the consumption of energy for desalination counters efforts at climate change mitigation and the move to low carbon economies. Handling these issues requires building individual and institutional ―capacity to change" as new practices and procedures need to be developed and implemented.

B. INCREASING ADAPTIVE CAPACITY

Adaptive capacity is regarded as a prerequisite for the pursuit of effective adaptation strategies in order to reduce the harmful impacts of climate change. It may be influenced by a number of factors: public perception about and acceptance of exposure to risks; dependence on and relationship with natural resources; technical skills and capabilities; social capital and social networks; institutional structures; decision-making and implementing authorities, and governance and political trends.

A positive aspect of adaptive capacity is the fact that it enables sectors and institutions at the same time to take advantage of opportunities and benefits from climate change, for instance longer growing seasons or increased potential for tourism (IPCC 2007: 21). According to the IPCC, the human and social capacities are viewed as key determinants of adaptive capacity on all scales. Further, it is argued that these aspects had the same relevance as income levels and technological capacity (IPCC, 2007: 27).

C. SVG CURRENT WATER MANAGEMENT INITIATIVES

Saint Vincent and the Grenadines is almost entirely dependent on surface waters as its source of supply, making rainwater reliance a major factor in the sector‘s vulnerability to climate change. Low rainfall can lead to reduction in river flow and in turn a reduction in the amount of water that can be physically harvested. This will mean that it is unlikely that demand will be met during periods of low rainfall. On the other hand, during the rainy season, lack of suitable land areas for dams and high runoff during storms will result in significant loss of surface water to the sea.

The Grenadines have over the years had more of a challenge with water resources than the main island, Saint Vincent. With projected decreases in water resources this will no longer be an issue only for the Grenadines but also for the mainland, Saint Vincent. Rainwater harvesting has been a consistent practice in Saint Vincent and the Grenadines. Over the last decade, the initiative has gained momentum mainly in the agriculture sector. Increasingly, home owners are installing collection systems during construction. There is a vigorous tree planting program by the Forestry Department and a Community based Organization (JEMS). These along with demands of the ‗Fair Trade' banana regime are reportedly boosting water management in Saint Vincent.

From the government perspective, water pricing and the development of water user groups are the chosen policy options for water conservation. Ground water exploitation is receiving greater attention as well as protection of catchment areas. Irrigation has become a feature of agriculture as are green houses and farm sheds**.** All of these are designed to reduce water loss and heat stress associated with climate change.

1) National Water Resource Management Study

A National Water Resource Management Study was undertaken in 2007 and was completed in 2010. The project included a water resource assessment, institutional reform and capacity building and an economic assessment of the water sector. One of the principal components of this study was to identify, design and implement a surface water monitoring network which would provide an adequate basis for future resource planning and allocation. The backbone of this network would be the sites of existing major abstractions/use, such as those for CWSA and VINLEC (Egis Bceom International, 2009). This hydrometric system has been established. A part of establishing this network included:

1. The installation of a new station at the Solid Waste Management Unit at Belle Isle since there was no agro-climate station located on the leeward side of the island of Saint Vincent.
2. The upgrade of the existing equipment at Langley Park to be fully automatic.

Both stations have been equipped with the following instrumentation:

- Rainfall Sensor (automatic raingauge or high-tech rain sensor)
- Air temperature/relative humidity sensor
- Atmospheric pressure sensor
- Wind speed sensor / wind direction sensor
- Solar radiation sensor
- Evaporation pan and cup counter anemometer
- Double ring infiltrometer (measure infiltration rate of the soil)

(Egis Bceom International, 2009)

Hydrometeorological equipment was procured based on the hydrometric network design and detailed technical specifications. Owing to the need to adjust the overall procurement budget to permit the incorporation of a ―works" contract (the borehole drilling contract), the remaining budget for procurement of hydrometeorological equipment was reduced to approximately €250,000 from approximately €400,000 (Egis Bceom International, 2009).

Tables 7, 8, 9 and 10 present the estimated costs of establishing and operating the Water Resources Management Authority (WRMA) to support the maintenance of the hydrometric system that has been established. The estimates have been prepared in constant prices (late-2007) and current prices and the latter includes projected inflation of 3.5% per year.

Table 7: WRMA – Prospective capital investment programme

Item	Unit Cost (EC$ 000)	2008		2011		2014		Total	
		Nos.	EC$ 000	Nos.	EC$ 000	Nos.	EC$ 000	Nos.	EC$ 000
Vehicles Pick-ups	2 pickups transferred from EU-funded NWRMS								
Computers									
High spec.	10.0					1	10.0	1	10.0
Storage (HDD)	0.5	2	1.0	1	0.5			3	1.5
Laptops	4.0	2	8.0			1	4.0	3	12.0
Spare parts hydromet equip.				1	15.0	1	15.0		30.0
Printers									
High spec.	2.5					1	2.5	1	2.5
Low spec.	1.0	1	1.0	1	1.0			2	2.0
Photocopier		1	15,000			1	15.0	2	30.0
Office Equip.									
Chairs									
High spec.	0.5					3	1.5	3	1.5
Low spec.	0.25	4	1.0			4	1.0	8	2.0
Desks	1.0	4	4.0			5	5.0	9	9.0
Filing cabinets	1.0	2	2.0			2	2.0	4	4.0
Doc. cabinets	1.0	2	2.0			2	2.0	4	4.0
Total									
Constant Prices			34.0		16.5		58.0		108.5
Current Prices			35.2		18.9		73.8		128.0

(Source: Egis Bceom International, 2009)

Egis Bceom International (2009) outlines that the estimated staff costs were forecasted to increase from an estimated EC$ 155,000 in 2008 to EC$ 225,000 in 2012 in constant prices. In current prices (i.e. including projected inflation), the estimates would rise from EC$ 160,000 in 2008 to EC$ 267,000 in 2012 and EC$ 530,000 by 2015.

Table 8: WRMA – Proposed staffing and annual salary costs[7]

Position	Salary 2007 (1) (EC$ 000)	2008 (nos.)	2009 (nos.)	2012 (nos.)	2015 (nos.)
Chief Executive	67				11
Chief Technical Officer	61				1
Technical Officer	51	1	1	1	1
Finance & Admin. Officer	51				
Hydrologist	46			1	1
Secretary	31			1	1
Gauging Technician	28	2	2	2	2
Technical Assistant	20	3	3	3	3
Total		**6**	**6**	**8**	**11**
Annual Cost					
Constant Prices (EC$ 000)		155	155	225	403
Current Prices (EC$ 000)		160	166	267	530

(Source: Egis Bceom International, 2009)

The figures are summarised in table 9 in both constant and current prices, with the inclusion of annual depreciation for the vehicles, computers, office furniture and hydrometric equipment.

Table 9: WRMA – Estimates of Recurrent Annual Costs (EC$000)

Component	2008	2009	2012	2015
Constant Prices				
Staff	155	155	225	403
Vehicles	24	24	24	24
Office Rent	36	36	36	60
Administration and. Office Expenses	24	24	24	42
Grenadines Field Visits	8	8	8	8
Training	4	5	15	10
Hydrometric Equipment – maintenance		5	8	10
Water Quality Testing	14	3	3	3
Total – Direct Expenses	264	258	343	560
Depreciation	68	68	72	78
Total – Constant Prices	**332**	**326**	**415**	**638**
Current Prices				
Staff	160	166	267	530
Vehicles	25	26	29	32
Office Rent	37	39	43	79
Administration and Office Expenses	25	26	28	55
Grenadines Field Visits	8	9	10	11
Training	4	4	18	13
Hydrometric Equipment – maintenance		5	10	13
Water Quality Testing	15	3	4	4
Total – Direct Expenses	273	276	407	737
Depreciation	72	72	76	91
Total – Current Prices	**345**	**348**	**483**	**828**

(Source: Egis Bceom International, 2009)

[7] (1) Includes: pension contribution, national insurance stamp and other allowances.

The figures indicate the following:

- Constant prices – annual recurrent costs are expected to increase from EC$ 332,000 in 2008 to EC$ 483,000 in 2012 and EC$ 638,000 by 2015. Staff costs will account for 48% to 66% of the annual totals (Egis Bceom International, 2009).
- Current prices – the annual figures are projected to increase from EC$ 345,000 in 2008 to EC$ 483,000 in 2012 and EC$ 828,000 by 2015 (Egis Bceom International, 2009).

Table 10 summarises the projections for WRMA's annual income and expenditure, based on the following parameters and assumptions:

1. Raw water demand projections by agency and sector on St Vincent have been derived from the complementary report prepared by the Study Team, entitled: Water Demand Characteristics and Forecasts, September 2007. The figures indicate that VINLEC is the major abstractor (non-consumptive) accounting for 93% of the total, followed by CWSA (consumptive) with 4%, NIA (consumptive) 3% to 3.5%, plus minor volumes by the three bottled water companies and local livestock.
2. Raw water abstraction charges are set at levels that will cover WRMA's projected annual operating costs (direct expenses + depreciation), based on the following parameters and assumptions:
    a. All abstractors (except VINLEC) – charged at rates rising from EC$ 0.003 per m^3 in 2008 to EC$ 0.0036 per m^3 in 2012 and EC$ 0.0060 per m^3 in 2015.
    b. VINLEC – charged at 50% of the rate for other abstractors to take account of the fact that VINLEC's use of the water is non-consumptive.

(Egis Bceom International, 2009)

Table 10: WRMA - Income and expenditure statements (EC$ 000, current prices)

Component	Unit	2008	2009	2012	2015
Raw Water Demand Projections					
CWSA	m3 000	9,619	9,622	9,402	9,079
VINLEC	m3 000	214,794	222,398	230,270	230,270
NIA	m3 000	6,032	6,032	7,407	8,762
Bottled Water Companies	m3 000	2	3	3	3
Livestock	m3 000	264	264	264	264
Total	m3 000	230,175	238,318	247,346	248,379
	glns mln	50,632	52,424	54,410	54,637
Raw Water Abstraction Charges					
Current Prices					
All Abstractors – except VINLEC	EC$/m3	0.0030	0.0030	0.0036	0.0060
VINLEC	EC$/m3	0.0015	0.0015	0.0019	0.0030
Average	EC$/m3	0.0015	0.0015	0.0020	0.0033
Constant Prices					
All Abstractors – except VINLEC	EC$/m3	0.0029	0.0028	0.0036	0.0046
VINLEC	EC$/m3	0.0014	0.0014	0.0018	0.0023
Average	EC$/m3	0.0015	0.0014	0.0020	0.0025
Income					
CWSA	EC$ 000	29	29	34	54
VINLEC	EC$ 000	322	334	414	691
Bottled Water Companies	EC$ 000	...	...	...	...
Government	EC$ 000	35	36	52	96
Total Income	**EC$ 000**	**386**	**399**	**500**	**841**
Operating Expenses					
Staff	EC$ 000	160	166	267	530
Vehicles	EC$ 000	25	26	29	32
Office Rent	EC$ 000	37	39	43	79
Admin. & Office Expenses	EC$000	25	26	28	55
Grenadines Field Visits	EC$ 000	8	9	10	11
Training	EC$ 000	4	4	18	13
Hydrometric Equip. – maintenance	EC$ 000		5	10	13
Water Quality Testing	EC$ 000	15	3	4	4
Total – Direct Expenses	EC$ 000	273	276	407	737
Depreciation	EC$ 000	72	72	76	91
Total – Expenses	EC$ 000	345	348	483	828
Net Income	**EC$ 000**	**41**	**51**	**17**	**13**

(Source: Egis Bceom International, 2009)

Income – this is divided into two main components:

1. Public and private companies that operate on a commercial basis (i.e. CWSA, VINLEC and the Bottled Water Companies) – would be billed at the proposed raw water charge multiplied by the recorded raw water abstractions.

2. Government – it is assumed that Government would pay the charges and contributions for: (i) NIA – because the Authority is not sufficiently solvent to pay the charges; (ii) livestock; and (iii) Grenadines contribution – set at 5% of the annual costs (Egis Bceom International, 2009).

The resulting annual income rises from EC$ 386,000 in 2008 to EC$ 500,000 in 2012 and EC$ 841,000 by 2015. These sums will also enable WRMA to build up modest surpluses averaging EC$34,000 over the period and ranging from EC$17,000 to EC$54,000 per year that could set aside in a separate fund to finance other equipment purchases and unforeseen expenses (Egis Bceom International, 2009).

2) Desalination

A part of the Water Resource Management Study included a feasibility-level study of water supply to the 3 Grenadine islands of bequia, Canouan and Union Island. Tables 11, 12 and 13 present estimated costings for three islands. The estimates for desalination with road tanker distribution for Union Island and Cancouan is EC$ 10.1 million (US$ 3.7 million or € 2.6 million).

Table 11: Bequia, Canouan and Union Island summary projection 2006 to 2025

Component	Unit	2006	2010	2015	2020	2025
Population						
Bequia	000	4.9	5.0	5.1	5.2	5.3
Canouan	000	1.3	1.4	1.5	1.6	1.7
Union Island	000	1.9	1.9	2.0	2.0	2.1
Total – Population	000	8.1	8.3	8.6	8.8	9.1
Tourism Visitors						
Bequia	000	58.9	63.3	69.4	76.1	83.5
Canouan	000	9.9	11.1	12.8	14.8	17.1
Union Island	000	85.6	91.0	98.3	106.2	114.9
Total – Tourism Visitors	000	154.4	165.4	180.5	197.1	215.5
Water Consumption – Annual						
Bequia	m3 000	215.6	293.7	337.3	369.0	404.5
Canouan	m3 000	132.5	177.8	196.7	205.3	213.9
Union Island	m3 000	111.7	158.9	182.8	194.3	212.7
Total – Water Consumption	m3 000	459.8	630.4	716.8	768.6	831.1
Water Consumption – Daily Average						
Bequia	m3/day	591	805	924	1,011	1,108
Canouan	m3/day	363	487	539	562	586
Union Island	m3/day	306	435	501	532	583
Total – Water Consumption	m3/day	1,260	1,727	1,964	2,105	2,277

(Source: Egis Bceom International, 2009)

The capital cost estimates for the main options and the initial investment in 2010 are summarised below. The estimates for desalination and piped distribution (with or without rainfall contribution) were:

(i) Bequia: EC$ 9.1 million (US$ 3.4 million or € 2.3 million)
(ii) Canouan: EC$ 4.6 million (US$ 1.7 million or € 1.2 million)
(iii) Union Island EC$ 7.4 million (US$ 2.8 million or € 1.9 million)
(iv) Total: EC$ 21.2 million (US$ 7.8 million or € 5.4 million).

(Egis Bceom International, 2009)

The estimates for desalination with road tanker distribution (only with rainfall contribution) were:

(i) Canouan: EC$ 4.3 million (US$ 1.6 million or € 1.1 million);
(ii) Union Island EC$ 5.8 million (US$ 2.1 million or € 1.5 million); &
(iii) Total for two islands: EC$ 10.1 million (US$ 3.7 million or € 2.6 million).

(Egis Bceom International, 2009)

Table 12: Capital cost estimates – initial investment 2010 (EC$ 000 2008 constant prices)

Component	Bequia	Canouan	Union Island	Total
Desalination + Piped Distribution				
No Rainfall Contribution	9.1	4.6	7.5	21.2
With Rainfall Contribution	9.1	4.6	7.5	21.2
Desalination + Road Tanker Distribution				
With Rainfall Contribution	n.a.	4.3	5.8	10.1

(Source: Egis Bceom International, 2009)

The average incremental cost for the provision of desalinated water on the three islands ranges from:

(i) Piped distribution: EC$ 10.3 to 12.7 per m3 (EC$ 47 to 58 per 1,000 gallons)
(ii) Road tanker distribution (2 islands only): EC$ 14.8 to 15.1 per m3 (EC$ 67 to 69 per 1,000 gallons) – all at a discount rate of 8%.

(Egis Bceom International, 2009)

The unit costs of distribution by road tanker are 20% to 30% higher because of the higher operating costs of distribution by road (Egis Bceom International, 2009).

Table 13: Water sales: average incremental cost @ 8% discount rate

Component	EC$ per m3			EC$ per 1,000 gallons		
	Bequia	Canouan	Union Island	Bequia	Canouan	Union Island
Desalination + Piped Distribution						
No Rainfall Contribution	10.3	12.2	11.3	47	55	51
With Rainfall Contribution	11.7	12.7	12.2	53	58	55
Desalination + Road Tanker Distribution						
With Rainfall Contribution	n.a.	15.1	14.8	n.a.	69	67

(Source: Egis Bceom International, 2009)

The following average tariffs and charges would be required to sustain the proposed provision of desalinated water with piped distribution. It is assumed that a common tariff structure would be adopted on all three islands. The average values are presented in current prices (i.e. including projected inflation) and 2008 constant prices. With regard to the illustrated tariffs and charges in table 14, there a number of important issues highlighted below:

- Fixed charge – to be levied as a monthly charge on all connected customers and set at levels that will cover the fixed costs of the service (i.e. staff, administration, depreciation, and interest charges) that will be incurred every year. The levying of an adequate regular fixed charge is also important to cover properties that may be unoccupied for large portions of the year (e.g. retirement and holiday homes, etc.).
- Consumption charge (average) – to be based on metered consumption and set at levels that will cover the variable costs of the service (i.e. electricity, chemicals, repairs & membrane cleaning, cartridge filters and membrane replacement). Note: the calculations are based on average tariffs;

but in future, it may be appropriate to introduce an ―increasing block tariff structure" in order to address affordability issues, especially for low income households.

(Egis Bceom International, 2009)

Table 14: Indicative Water Tariffs and Charges (current and constant prices

Component	Unit	2011	2015	2020
Current Prices				
Fixed Charges				
• Domestic	EC$/conn/month	80	83	85
• Others	EC$/conn/month	160	166	175
Consumption Charges				
• Domestic	EC$ per m3	5.5	6.0	6.9
• Others	EC$ per m3	11.0	11.9	13.8
Constant Prices - 2008				
Fixed Charges				
• Domestic	EC$/conn/month	73	67	60
• Others	EC$/conn/month	145	135	123
Consumption Charges				
• Domestic	EC$ per m3	5.0	4.8	4.8
• Others	EC$ per m3	10.0	9.8	9.7

3) Integrated Water Resources Management Plan

The World Summit on Sustainable Development (Johannesburg, 2002) and the resulting Plan of Implementation (JPoA) called for all countries to develop integrated water resources management (IWRM) and water efficiency plans by 2005. These plans were expected to contribute to the foundation towards achievement of targets set out under the Millennium Development Goals as related to poverty, hunger, health and environment issues.

4) CARIB-GEF Pilot Project

CARIB-GEF proposed a project that involved the implementation of pilot adaptation investments in three countries in the Eastern Caribbean one of which is Saint Vincent and the Grenadines.

The proposed objective for this project was to support efforts by all three countries: Dominica, Saint Lucia and Saint Vincent and the Grenadines to implement specific (integrated) pilot adaptation measures addressing the impacts of climate change on the natural resource base of the region, focused on biodiversity and land degradation along coastal and near-coastal areas (World Bank, 2006).

Project components

The project would support three activities (components) prioritised in national adaptation strategies and refined through a series of regional and national consultations.

- Component one: Design of priority adaptation measures addressing impacts of climate change on biodiversity and land degradation (total cost $1.0 million; GEF funding $0.3 million). Under this component activities will be supported by a Feasibility Analysis, Community Participation and Design of adaptation measures.

- Component two: Implementation of adaptation measures designed to address climate impacts on biodiversity and land degradation (total cost $2.15 million, GEF funding $1.7 million). This component has 6 subcomponents, subcomponent 5 of this is the integrated ecosystem approach to climate change in Bequia and Union Islands (Saint Vincent and the Grenadines) and subcomponent 6 is the climate change risk management for Spring Village (Saint Vincent and the Grenadines)

- Component Three: Strengthen national capacity to implement multiple Multi-lateral Environmental Agreements (MEA) obligations with an integrated and holistic operational framework (total cost US$2.95 million; GEF US$ 0.1 million). The subcomponents involved in this section are as follows:

    - Subcomponent 1 - Production of vulnerability atlases that identify ecosystems and development activities at risk from climate change and land degradation

    - Subcomponent 2 - Develop National Sustainable Development Strategy in at least one participating country integrating climate change, biodiversity conservation, and land degradation management within national development planning frameworks

    - Subcomponent 3 - Develop and establish, in at least one participating country, the operational frameworks (legal, institutional and management structures) for addressing multiple convention objectives in accordance with national priorities within the ―islands system management" approach

    - Subcomponent 4 - Establish a single national reporting framework for the UNFCC, CDB, and UNCCD so as to reduce the burden on limited resources available in SIDS, while pioneering a harmonized report structure that would integrate climate change, biodiversity and land degradation issues

(Source: World Bank, 2006)

5) Other Management Initiatives

Other management measures currently being designed and/or pursued by Saint Vincent and the Grenadines may be considered contributory to improving the efficiency of the water sector as part of the journey toward adaptation. It is dealing with the ―now‖ as promoted by the Global Water Partnership:

- A water quality monitoring program that is cognizant of floods, droughts and disposal of waste into water bodies.

- The national solid waste management program that prohibits open burning and the implications for water pollution.
- Vulnerability and Capacity Assessment conducted for the islands to determine the impacts of Climate Change on drinking water in the Grenadines, which pointed to acute shortage in some communities e.g. Paget farm.
- Currently, there is a project funded by GEF/World Bank to enhance the potable water supply by installing a salt water reverse osmosis (SWRO) which will be serviced by a 50kw wind turbine in an effort to enhance the water availability to residents in that community.
- A climate resilience strategy (funded by CIDA) is in progress with aims to be finished by 2011. The intention of the strategy is to identify ways and measures of improving the country‘s resilience to climate change.
- A climate change strategy was developed in 2010 with assistance from USAID and was scheduled to start implementation in latter part of 2010.

D. PRIORITISING OPTIONS FOR ST VINCENT AND THE GRENADINES

Table 15 outlines the adaption options available for strategic response to the issue, water shortage.

Table 15: Prioritising Options for Saint Vincent and the Grenadines (After ECLAC 2010 and RECCC, Water Sector 2011)

Strategic response	Adaptation Option	Ranking 1-3	Rationale for Option	Cost	Timeline	Funding Options
Increasing production/supply	Integrated watershed management and planning to increase sources and storage	1	Essential to enable sustainable yield of quality water and flood control	US$4 mil.	3 years 2012-2014	GoSVG
	Conduct studies on water needs for ecosystems hydro power and general supply potential	1	Need to build knowledge[8] base – inadequate database currently. Information system to be established through installation of equipment, monitoring and recording program, and analytical inputs.	Tbd.	2 years 2012-2013	EU, CARIWIN, GoSVG
	Diversify and combine water sources - surface, groundwater, recycling, etc.	3	Data needed to inform this action	Tbd.	3 years 2012-2014	CWSA, GoSVG
	Promote Environmental Management system for tourism sector	2	Tourism major user and sector increasingly important to economy	US$ 1 mil.	2 years 2012-2013	SVG Tourism Assoc,/CHTA
	Strengthen rainwater harvesting resources at the local level[9]	1	Build on existing local practices for obtaining water	US$1mil.	3 years 2012-2014	UNEP, Adaptation Fund
Increasing efficiency	Infrastructure Maintenance and Improvement	1	Storage facilities for surplus water, dams to harness runoff, pipeline expansion, distribution without loss due to leakage	Tbd.	5 year project 2012-2016	EU, GEF, Adaptation Fund
	Wastewater treatment	1	Reduce water contamination, encourage use of recycled water Protection of water sources	US$3mil.	3 years	GEF
	Protected areas conservation[10]	1	Sustainable water yield and flood control			
	Diversify renewable energy sources to provide options to Hydropower	2	Cost of energy and declining water resources	Tbd.	3 years 2012-2014	Adaptation Fund
	Design and implement public information program to garner political & civil support for efficiency & protection of resource	2	Citizens still have poor state of knowledge regarding water resource protection and conservation	US$2 mil.	3 years	GoSVG, EU, GEF, Adaptation Fund

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[8] Regional research to commence July 2011 on the effects of climate change on various sectors

[9] Refer to Institutional Framework below

[10] Refer to Integrated Watershed Management above

Strategic response	Adaptation Option	Ranking 1-3	Rationale for Option	Cost	Timeline	Funding Options
	Use a tariff structure in the municipal sector, to promote efficient use	3	Incentive for water conservation	n.a.	Ongoing from 2011	GoSVG
	Develop housing construction norms and green mortgage programmes for water efficiency and recycling	2	Expansion in housing construction and design, increasing water demand require efficient use	Tbd.	3 years 2012 -2014	Building Industry and Financial/ mortgage entities
	Develop water efficient program for agriculture[11]	1	Food security, agricultural productivity for export earnings	US$5mil.	3 years 2012-2014	GoSVG, Adaptation Fund
	Creation of economic and fiscal incentives for replacing water intense technologies	3	Incentivise water efficiency to encourage buy in and optimize resource.	Trade-off in Customs Revenue	2012 and Ongoing	GoSVG
	Taxes on water saving devices removed with the exception of the VAT	3	Incentive for efficient management	Trade-off in Customs Revenue, but VAT retained	2012 and Ongoing	GoSVG
Institutional Framework	Strengthen rainwater harvesting resources at the local level	1	Expansion of structured program essential to enable uninterrupted supplies. Build on existing culture – easier to gain traction [12]	US$1mil.	3 years 2012-2014	UNEP, Adaptation Fund
	Establish/enforce legal & institutional framework for efficiency, integrated water management	3	Legal and institutional framework essential for compliance. Water Resources Management Agency to be established and implement water sector policy	US$ 4mil.	2012 -2014	EU, GoSVG, UNEP
	Water Information system Data collection, Monitoring and Analysis Maintain surface and groundwater quality monitoring with respect to yield and quality based on the hydrometric system that has already been established in the National Water Resource Management Study	1	Groundwater monitoring data are also necessary to support the development and management measures needed to address the impacts from climate change. These data include: water levels, aquifer properties, abstraction rates, and natural flow rates of river and springs. Development of standards/ protocols for collecting and managing data. This would also	US$ 2.5 mil.[13]	2012 and Ongoing	EU, GoSVG, UNEP

[11] Drip Irrigation and Greenhouse Technology

[12] As above

[13] This sum represents estimated recurrent annual costs for equipment maintenance and monitoring

Strategic response	Adaptation Option	Ranking 1-3	Rationale for Option	Cost	Timeline	Funding Options
			include improving the human and institutional capacity to collect and manage data. Determine climate change adaptation indicators for water sector and develop standards/protocols related to monitoring, evaluation and reporting of these indicators.			
Decrease Wastage	Integrated Water resource management [14]	1	Closed loop to optimize use, foster efficacy and reduce pollution	US$4 mil.	3 years 2012-2014	GoSVG
	Standards and norms for construction of infrastructure and flexibility of management	2	Sustainability of investment essential.	Tbd.	3 years 2012 -2014	Building Industry and Financial/ mortgage entities
	Infrastructure Maintenance and Improvement	1	Storage facilities for surplus water, dams to harness runoff, pipeline expansion, distribution without loss due to leakage	Tbd.	5 year project 2012-2016	EU, GEF, Adaptation Fund

[14] As above

E. SUMMARY PRIORITIES

Priority 1

1. Water Information system - Data collection, Monitoring and Analysis

The National Water Resource Management Study proposed the development of a central Water Resources Management Agency (WRMA). The Agency will establish a hydrometric network that is expected to generate the data required to inform climate related modelling and monitoring to build a resilient water sector.

The assumptions of the proposal were that:

- The core team of the Agency would be established and would reach its full staff complement by 2015
- By 2015, the hydrometric network will be fully operational, discharge weirs and measuring sections calibrated for flow and the first nation-wide recordings will be collected, entered into the national database, and initial analyses commenced.

(Egis Bceom International, 2009)

This initiative is crucial to building climate resilience in the water sector as the data required for monitoring and modelling behaviour of rainfall- runoff relationships and other parameters of water availability is not now available. The ability to plan for and manage the effects of growing variability, seasonality and intensity of hydrometeorological phenomena in St Vincent and the Grenadines requires building the database to underpin the knowledge platform.

2. Infrastructure Maintenance and Improvement

Build storage facilities for surplus water, and dams to harness runoff, and rainwater harvesting. Review placement of coastal infrastructure with respect to storm surge vulnerability and saline intrusion. Expand pipeline network to increase penetration, and effect distribution without loss due to leakage. Explore renewable energy sources to support electricity demand for pumps, desalination plants, and other operations.

3. Integrated Water resource management

This closed loop approach to water management is being promoted globally to effect optimal use of water resources and to reduce pollution. It involves protecting water sources, efficient water collection at source, treatment according to use, efficient use, wastewater collection, reuse, recycling, and reintegration into the environment

4. Integrated watershed management and planning

This initiative is essential to afford sustainable yield of quality water. The Sustainable Land Management programme already being pursued should emphasise the water management imperative for watershed protection, and the required policies and investment in slope protection, forest protection and reafforestation.

5. Strengthen rainwater harvesting resources at the local level

6. Develop water efficient program for agriculture - crop sensitivity, storage dams, soil management, drip irrigation, control of pollution from biocides

7. Promote and support Environmental Management system for tourism sector to foster ecoefficiency and waste management

Priority 2

1 Establish and enforce standards and norms for construction of water supply infrastructure.

2 Conduct studies on water needs for ecosystems, hydro power and general supply potential

3 Diversify renewable energy sources to provide options to Hydropower given the low rainfall experiences and low flows in the relevant basins.

4 Design and implement public information program to garner political and civil support for efficiency and protection of resource

5 Develop housing construction norms and green mortgage programmes for water efficiency and recycling

Priority 3

Priority 3 is no less significant but in terms of timing they are suggested for implementation following priorities 1 and 2. Implementation is a function of resource availability, but it is recommended that the Government seek the funds required to integrate the adaptation measures in current or expanded water supply programming. Programs should be approached in a holistic manner and not as —add-on” isolated initiatives.

Section 7 below examines costs of adaptation and attempts a benefit cost analysis.

VII. COST BENEFIT CONSIDERATIONS

The approach taken in this section has, to a large extent, been determined by the unavailability of capital budgeting data in relation to the adaptation strategies proposed elsewhere. On the investment side costs associated with the appropriate scaling of the technological solutions are not readily available and even more challenging would be deriving appropriate benefits streams to be applied. In short traditional cost benefit analyses were not pursued. However, as found in several other member states, there are no shortages of good ideas within the respective water authorities that remain unimplemented either because of the absence of political will, scarcity of funding or both.

The approach therefore taken involves several components, each offering different possibilities but having the same objective, looking at a canvas of options for pro-actively engaging the challenges of adaptation. The first takes each of the main adaptation strategies recommended and searches through the literature to identify where relevant adaptation projects have been selected on the basis of favorable cost benefit ratios yielded. The expectation being to offer a number of promising project types for further consideration and possible determination of their corresponding feasibilities for Saint Vincent and the Grenadines

The second takes some of the more recent detailed project identification studies undertaken within member states that can reasonably be considered to have relevance for Saint Vincent. These will no doubt require modifications and further justifications which will need to be worked out by the local water authorities.

The third recognizes that concurrently with implementing specific adaptation recommendations a useful approach might also be to suggest a percentage of GDP that be earmarked for adaptation strategies for the water sector. This requires a high level of political sensitivity to the challenges of adaptation to climate change, a sensitivity often very easily misunderstood or under rated. A major benefit however is that specific projects for funding, some of which may be the extension or expansion of current ones, would emerge through a planning process to an extent freed from the current implementation delays associated with identifying funding. This approach recognizes that the precautionary principle reflected in the ―No Regrets approach" is most likely to offer the best protection against climate change. It also finds support in the UNDP guiding principle for meeting the challenge of climate change, that adaptation must be seen as a continuous process. Each of these approaches is now presented.

A. ADAPTATION EXPERIENCES

The recommended adaptation strategies selected from those offered in Section 6 as also the matching adaptation experiences identified, meet two requirements that are important for this approach. Firstly they lend themselves to capital budgeting techniques because they present fairly determinable cost and benefit streams. Secondly they are projects that may reasonably be considered to be in potential competition with alternative water sector investments. Cost benefit analysis is essentially a tool for resource allocation; water projects that are of such a high social priority that cost benefit considerations may not be determining (restoration of damaged critical infrastructure) are not included.

Table 16 summarizes the recommended adaptation strategies and the corresponding adaptation experiences identified. These are further commented on in the text.

1) Home Collection Systems

Kuttanad is a community in the tropical monsoon belt of India at lat 10^0 N similar to Trinidad & Tobago. This well-reasoned undergrad research paper explored the cost benefits of rainwater harvesting under a variety of scenarios for households in different existing water supply conditions. The major costs included the initial construction cost of rainwater harvesting system and the maintenance costs. The major benefits include an increase in household dispensable income, time and energy saved from collecting water and reduction of epidemic outbreaks and associated medical costs. The results concluded that all households would benefit positively by investing in rain water harvesting systems with storage capacities of about 6,000 liters per household of 5, at an investment cost of about EC$900 using ferrous cement as the main building material. While there are positive differences in the social conditions obtaining in Saint Vincent and cost structures will be much higher, nevertheless the approach is worth investigating mainly to encourage water conservation among very low income households.

2) Community Tree Planting

This study‘s abstract justifies the program in these terms ―trees provide us with many ecosystem services, including air quality improvement, energy conservation, Storm water interception, and atmospheric carbon dioxide reduction. These benefits must be weighed against the costs of maintaining trees, including planting, pruning, irrigation, administration, pest control, liability, cleanup, and removal. The study examines both rural and urban community forestry in both private and public spaces and concludes that, ignoring such intangibles as impacts on psychological health, crime, and violence but factoring ecosystem services and carbon sequestering very acceptable cost benefit ratios are obtained. The project envisioned the planting of 500 small, 500 medium and 500 large trees for a total investment cost of US$458,000 over a 40 year project cycle with a cost benefit ratio of 11.0 to 57.0 in year 20, depending on tree size planted.

Table 16: Summary of recommended adaptation strategies and corresponding adaptation experiences

	Adaptation Strategies	Adaptation Experiences	References
1	Home collection systems	A research paper to ascertain the net benefits or costs of rainwater harvesting in a rural poor community in tropical monsoon India. This has not been implemented.	Water Quality Study and Cost-Benefit Analysis of Rainwater Harvesting in Kuttanad, India. 2009.
2	Tree planting	A USA Forestry Dep't sponsored community tree planting study To establish the cost benefit of such programs in relation to planting small medium and large ―yard trees" in Hawaii. Ecosystem benefits and CO_2 sequestering were compared with establishment and maintenance costs.	Tropical Community Tree Guide: Benefits, Costs, and Strategic Planting (2008). Kelaine E. Vargas, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Shelley L. Gardner, and Qingfu Xiao USDA.
3	Irrigation systems	An impact assessment of irrigation Projects in 5 States in India. The systems examined included canal irrigation, tube wells, river lift and flood protection. Generally The net benefits realized by the user community from the investments in irrigation have been found fairly high.	Investments in Irrigation Projects — An Impact Analysis S.L. Kumbhare and Madhurima Sen*. Department of Economic Analysis and Research, National Bank for Agriculture and Rural Development (NABARD) In Section 7.2 below an example of establishment costs and associated yields of greenhouse technology, proposed for Jamaica is offered.
4	Desalination (SWRO)	No satisfactory cost benefit project specific reports identified.	However the findings of the Egis Bceom International Report of 2009 are summarized Section 7.2 that follows.
5	Integrated Water Resource management	Studies examined were mainly ground water, watershed or river basin focused. Surface water management projects were identified but not with cost benefit or economic analysis undertaken	The costing for catchment systems proposed for neighbouring Grenada is presented in Section 7. 2 that follows

4) Irrigation Systems

The abstract of this study states ―Physical infrastructure development is a powerful means of promoting economic growth as (i) it creates production facilities, ―crowds in" private investment and thereby stimulates economic activities, (ii) reduces transaction and marketing costs, improving competitiveness, and (iii) provides employment opportunities to the poor. Rural Infrastructure Development Fund (RIDF) supported irrigation projects help provides the necessary impetus for infrastructure development, thereby aiding in capital formation. Evaluation of irrigation investments under RIDF in the states of Uttar Pradesh, Haryana, Orissa, Maharashtra and Assam has revealed that the investments are economically viable. The net benefits realized by the user community from the investments in irrigation have been found fairly high, except in Orissa and Uttar Pradesh.

The projects investigated ranged from small to medium sized projects with capital costs per Ha ranging from $12,000 EC, to $670 EC with average costs per hectare of irrigation potential ranging from $1,700 EC to $670 EC. Economic Rates of return ranged from 5% to > 50% depending on the specific project. The relevance for Saint Vincent would be that crop yield performance under irrigation ranged from 23% to 79% for projects in crops such as sugarcane, onions, vegetables and fodder.

5) Desalination

A CEHI evaluation (The Evaluation of the use of desalination plants in the Caribbean – Preliminary Report 2005) made the observation that desalination plants are found in many Caribbean islands, including Antigua and Barbuda, the Bahamas, the Cayman Islands, the Turks and Caicos Islands, Barbados, The British Virgin Islands and Trinidad and Tobago.

Subsequent to that report a plant has also been established in Saint Vincent and Grenadines. The preferred desalination option is overwhelmingly the Reverse Osmosis process. This process has become less complicated, and has the advantage of being able to be quickly commissioned into use (less than a year) is more economical on space than other desalination processes. The downside is their dependency on electrical energy which is more expensive than conventional extraction from ground water or surface water sources. In most islands private operators sell water to the public water utilities. No relevant cost benefit studies have been identified.

B. PROJECT IDENTIFICATION STUDIES UNDERTAKEN, OR PROPOSED, OF RELEVANCE TO SAINT VINCENT & THE GRENADINES.

Despite the imperfections in scenario forecasting, the challenge of successfully adapting to climate change is less about solutions than about resolve. Water Authorities throughout the region have a well-grounded appreciation of the opportunities and threats to ensuring future water availability. In many instances important adaptation initiatives are proposed but not implemented. In this section we briefly summarize some of the projects that have either been completed or at different stages of the project cycle and also include one or two that are proposed for further consideration.

1) Desalination

Currently there is a project funded by GEF/World Bank to utilize a wind driven SWRO to enhance water availability to communities in the Grenadines. The location of the project is on the Grenadine Island of Bequia. Paget Farm, on the south-eastern side of Bequia, was identified as being a vulnerable community to the impacts of decreasing rainfall as a result of climate change. The project involved installation of a salt water reverse osmosis (SWRO) plant to provide to the residents of Paget Farm an adequate supply of potable water. The final capital cost and current running expenses for the plant is not immediately available. However at the time of the feasibility the capital costs were set at $3.4m.

This project is considered a pilot project. If its feasibility is established then a SWRO should be considered for Canouan and Union Island. In the absence or more recent capital cost estimates those developed by Bceom are indicative (table 17).

Table 17: Capital cost estimates – initial investment 2010 (US$m 2008 constant prices)

Component	Canouan	Union Island	Total
Desalination and Piped Distribution			
Rainfall.			
With no contribution	1.7	2.8	4.5
With contribution	1.7	2.8	4.5
Desalination + Tanker distribution.			
With Rainfall Contribution	1.6	2.1	3.7

(Source: Egis Bceom International, 2009)

The Bequia plant experience will be useful in determining the potential average incremental cost per gallon for desalinated water.

2) Rainwater Harvesting

A project entitled the National Rainwater Harvesting Program has been undertaken in Grenada by the Caribbean Environmental Health Institute (CEHI) with funding by UNEP. The program had several activities including the development of 8 technical studies. These activities were at the commencement of the project in 2006 estimated at:

Awareness Raising	*US$49.700*
Capacity Building	*US$43,600*

Legislation and Policy Formulation	*US$47,200*
Program Administration, Monitoring and Evaluation	*US$179,500*
Total	*US$320,000*

The type of project lends itself to possible modification and replication in Saint Vincent and the Grenadines. This would be a good example of the desired objective of encouraging regionally developed and tested projects in support of adaptation throughout member states.

3) Water Resources Conservation and Management

A regional project entitled the Integrated Watershed and Coastal Area Management Project (GEF-IWCAM) was completed in 2010. This project was supported by the Global Environment Facility and undertaken by the Caribbean Environmental Health Institute CEHI. The overall objective of this project was to strengthen the commitment and capacity of the participating countries to implement an integrated approach to the management of watersheds and coastal areas. The long-term goal is to enhance the capacity of the countries to plan and manage their aquatic resources and ecosystems on a sustainable basis. In all 9 demonstration projects were developed in 8 countries. Of the four main themes targeted, that of Water Resources Conservation and Management can be considered of relevance to Saint Vincent and the Grenadines. Saint Lucia and Saint Kitts developed demonstration projects addressing these themes. The Saint Lucia project involved protecting and valuing of watershed services and the developing of management incentives in the Fond Dor' Watershed area. The Saint Kitts and Nevis project was the rehabilitation and management of the Basseterre valley as a protective measure for the underlying aquifer. It is recommended that the experience and findings of these projects could be examined for their relevance to Saint Vincent and the Grenadines. The experience gained could be used to assist in the development and implementation of more specifically tailored demonstration projects.

4) Fiscal Incentives in Support of Adaptation

The administration can be more supportive of water conservation practices through tax incentives on simple household devices that reduce water consumption. One example of where this applies is in water saving devices such as high efficiency showerheads, water-saving aerators, flapperless toilets and simple leak detectors. Supported by a public education campaign, the potential target beneficiaries are the metered customers both household and commercial. Currently, import duties on such devices comprise a base tariff of 5% a customs service charge of 4% and Vat at 15% or a cumulative tax of 25.5 %. Domestic consumption of water is estimated at about 5.5 million m^3. It is estimated that water saving devices can save up to 25-50% of household use. At the lower figure this would represent a potential 1.4 million m^3 per annum for domestic consumption. The appropriate revenue loss versus the likely responsiveness of consumers to such an incentive is an area that should be further explored. However it is likely to prove an unattractive proposition to Government without also including the water savings by the hotel sector, other commercial accounts including the public sector (see table 18).

Table 18: Priority Investments with Indicative Costs

Ranking	**Strategic Response**	**Adaptation Option**	**Indicative Cost US$**
First order of Priority	Increasing production/supply	Integrated Water Management to increase planning and storage over 3 yr period 2012-2014	4,000,000
		Strengthen rainwater harvesting resources at the local level. Over 3 year period 2012-2014	1,000,000
	Sub Total		5,000,000
	Increasing efficiency	Waste Water Treatment 3 year period 2012-2014	3,000,000
	Sub Total		3,000,000
	Institutional Framework	Strengthen rainwater harvesting resources at the local level 3 yr program 2011-2014	1,000,000
		Water Information System 2012 ongoing	2,500,000
	Sub Total		3, 500,000
	Decrease Wastage	Integrated water resource Management 5 year period 2011-2015	4,000,000
	Sub Total		4,000,000
	TOTAL		**15,500,000**
Second Order of Priority	Promote Environmental Management system for tourism sector. A two year project 2012-2013.		1,000,000
	Design and implement Information Program . A two year program 2011-2014.		2,000,000
	Sub Total		3,000,000
	TOTAL		3,000,000
Third Order of Priority	None of these projects have as yet had an indicative cost derived.		Nil
SUM			**$18,500,000**

5) Irrigation

Greenhouse technology confers many benefits to cost effective productivity. Several systems are available and some are in use in Saint Vincent. The application of this technology to the production of produce into the tourism sector should be explored and costed. Using an example derived from Jamaica a greenhouse covering approximately 3,000 square feet fully erected costs about US$17,000 before duties. In addition to producing the equivalent of approximately one acre of produce it confers several additional advantages. The main ones being pest and disease management, significantly reduced labour costs, a reduced water cost function because water is bought to the plant on an as needs basis.

C. BUDGETARY APPROACH TO MEETING WATER DEMAND

Saint Vincent‘s economy is small open and very dependent on its transactions with the rest of the world. This relationship drives its tourism, influences its manufacture and commences, impacts employment and largely determines domestic prices and availability of capital. These complicate the relationship between water and the economy. A broader perspective must therefore be adopted when considering what adaptation strategies to pursue. These strategies will need to address satisfying the average annual water demand as the end objective of policy while at the same time accepting that resource constraints dictate that selective and manageable solutions be identified and consistently applied as the best defense towards meeting the climate change challenge.

The objective of this section is focused on arriving at some indicative estimate of the resource needs to satisfying the average annual water demand forecast. The model presented in section 4 provides this future water demand assessment. Average annual water supply will be sufficient to meet demand under each of the climate change scenarios. The average annual water demand will be approximately 55* 10^6m^3 under the BAU scenario, 68 *10^6m^3 and under the A2 scenario 66 10^6m^3.

1) The current cost of water production

The base year for the construction of table 19 was 2010. The cost of water production in that year was derived by relating the data derived for Grenada on a pro-rated cost of production basis to Saint Vincent based on relative water production. The average cost of water production in 2010 was derived from an actual cost reported for the year for the year 1998 for Grenada. This cost was adjusted for inflation to 2010. This is not an ideal approach but the water supply characteristics of both Islands are not too dissimilar and a better estimate was not available.

Table 19: Cost of Water Production

Climate Change Scenario	Average water production/ annum 2010 - m^3	Average Cost Per Annum in constant prices 2010	GDP 2010	Cost of Water as Percentage of GDP in 2010
A2	66,000	US$2,295,000	US$583,000,000	0.39
B2	60,000	US$2,086,363	US$583,000,000	0.35

In the absence of costing specific adaptations the next best approach might be to suggest and justify a percentage of GDP that be earmarked for adaptation strategies for the Water Sector arising from Climate Change. This suggestion recognizes that the *precautionary principle* reflected in the *'No Regrets 'approach* is most likely to offer the best protection against Climate Change.

From table 19 the following efficiency ratios can be derived based on the B2 Scenario

GDP   &   *Water Production*

Water Production   *Cost of Water production*

US$583,000,000   *60,000 /$10^6$ m^3*

60,000 10^6 m^3   *US$2,086,363*

US$ 9,716/ $10^6 m^3$ *0.029 /10^6 m^3*

The ratios express that the value of every 10^6 m^3 of water production accounts for the equivalent of US$9,716 of GDP. Similarly, every $10^6 m^3$ of water production costs US$35 to produce. Therefore every dollar invested in water supply has greater efficiency in relation to GDP than to cost of production. These ratios can be used to offer an indicative target of GDP expenditure on the water sector.

Bueno and others (2008) in their study cost of inaction have determined that the climate change impact would affect Saint Vincent significantly if the BAU approach is adopted. This impact would amount to 11.8% of GPD in 2025 ($68.8M in 2010 dollar terms) and increase to 47.2% by 2100. Since it can be shown that every $1 investment in the water sector will contribute more to GDP than the cost to producing that water, then a considerable offset to the impact implied by Bueno and others (2008) can be realized by increasing investment in water production. However it must be emphasized that these efficiency ratios are only indicative since the impact on GDP is not necessarily direct. A recommendation would be that Government set as a target steadily increasing its investment in the water sector consistent with moving its percentage of GDP to 0.75% or doubling the current allocation to water production within 5 years to US$4.4M. This could be used to financing adaptation strategies such as investment in new or improved water capacity and related adaptation strategies.

2) Applying Net Present Values (NPV)

In table 19 it is estimated that in year 2010 it would have cost US$2,086,363 to produce the annual average water requirements of 60,000 $10^6 m^3$ corresponding to the demand for water under the B2 scenario . This scenario was chosen because it was considered the most appropriate ‗story' for Saint Vincent. If the limiting assumption is made that the average annual dollar value invested in water production remains constant from 2011 through 2050 or over a 40 year investment horizon, then three corresponding net present values can be derived applying assumed discount rates of 4%, 2% and 1% (table 20).

The NPV enables the projected 40 year annual investment expenditure in water production to be expressed in terms of reducing all annual payments to the equivalent of one payment made at the outset (2011). In this instance the NPV is US$41m on a total investment of $88m over the 40 year period. The NPV being a positive value confirms that it is an acceptable investment decision since the equivalent of US$41m invested in 2011 would be comparable to investing a total of $88m in smaller annual increments. As reflected in table 20 lower discount rates improve the NPV.

Nevertheless the limiting assumption applied, that the annual value of investment in water production remains constant, leads to a static and not particularly satisfactory investment strategy. The purpose in calculating the NPV is to benchmark this ‗worse case' Government spending decision on water production so as to compare it with the NPV arising from the recommendation to link investment to a percentage of GDP (table 20).

Table 20: NPV of Investment Scenarios in Water Production 2011-2050(US$m).

Investment Scenarios	Investment in water production 2011. (Constant prices).	Projected Total Investment Expenditure to 2050	NPV @ 4%	NPV @ 2%	NPV @ 1%
1. Annual investment in water production remains fixed at 2011 level.	US$2,100,000	US$84,000,000	US$41	US$61	US$78
2. Annual Investment in Water Production if set at 0.75% GDP annually.	US$4,400,000	US$176,000,000	US$56	US$68	US75

A worse case investment scenario would be that in which investment in water production is maintained at close to current levels in constant prices. This possibility is not to be dismissed. Full recovery from the physical damage inflicted by Hurricane Ivan is still in progress and severe budgetary constraints suggests that financing the water sector at the percent of GDP recommended, may pose challenges. Further the net water demand forecast shows that under both the B2 and A2 scenarios, net water demand is respectively, flat and only gradually increasing over the same period and in both instances, is adequately covered by projected water supply. Given these realities, increased allocations to water production including the financing of adaptation strategies may well become secondary to other economic and political priorities.

The recommendation made that Government sets as a target, steadily increasing its annual investment in water production to 0.75% of GDP over the next 5 years, can be used to derive further NPV‘s by assuming that this percent of GDP is maintained each year from 2011 through 2050. The resulting total investment in water production of US$176M can be shown to yield a NPV of US$86m (2011) using the same 4% discount rate. The NPV decision rule is to accept all positive NPV projects where other constraints do not exist. Or, if expenditure decisions are assumed mutually exclusive, accept the one with the highest NPV. Both these general rules would be consistent with the adoption of the recommendation.

D. AN ESTIMATE OF THE COST OF CLIMATE CHANGE.

In addressing the issue of the cost of climate change on the water sector in Saint Vincent and the Grenadines and given the paucity of adequate forecasting data and the difficulty of assessing risk over time, the best available estimate can be derived by using Bueno and others as a starting point. Accepting their 2050 projection that the cost of climate change will equate to about 24% of GDP, and projecting Saint Vincent and the Grenadines estimated current GDP (in current Prices) of US$600m to 2050, by using an estimated annual average growth rate of 5% permits the following results.

In 2050 GDP would be US$4b. Two adjustments must be used to arrive at the cost of climate change in Saint Vincent and the Grenadines. Firstly by applying 24% of GDP derived from Bueno and others the impact on GDP in 2050 is approximated at $960m. Secondly an adjusting percentage is required to attribute the contribution of the water sector in GDP in 2050. The only available proxy figure for this contribution is the total cost of water production as a percent of GDP from table 21 for the B2 scenario. By applying this percentage (0.75%) to the 2050 GDP or US$4.0b then the following comparisons can be constructed.

Table 21: Cost of Climate Change under BAU and Cost Benefit Ratio of Investment under B2. (US$)

GDP 2050 at Current Prices (US$)	Loss to GDP in 2050 under BAU Scenario (following Bueno and others)	Water Production Investment in 2050 under B2 scenario. (0.75% of $4,000,000	Cost/Benefit ratio of climate change loss to GDP vs. expenditure in adaptation. (960,000,000/30,000,000)
4,000,000,000	960,000,000	30,000,000	32:1

Although annual adaptation investments of US$4.4m cannot be assumed sufficient to offset the full costs of climate change, it should be noted that the estimate of Bueno and others (2008) of 24% applied only to the impact of recurring storm events. The effect of annual and seasonal deficits to key sectors is expected to have a significant impact that would further exacerbate the projections of Bueno and others (2008). A reasonable conclusion to be drawn is that there is likely to be a significant benefit to adaptation if the level of average annual investment identified in the prioritized projects costed are continued into the future. In addition, adoption of the recommended GDP approach would further strengthen coping strategy for the water sector in the light of climate change. Ongoing refinements to climate change forecasting and improved data collection in the water sector, will allow a much more accurate picture to emerge.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Bueno and others (2008) in their study on the *Costs of Inaction* for the Caribbean in the face of climate change listed St Vincent and the Grenadines among the countries which would experience significant impacts on GDP between now and 2100 without adaptation interventions. Given the structure of the economy with its heavy dependence on tourism, and the projected effects of climate change parameters the progression in the percentage impact on GDP would be as follows:

Table 21: SVG - Climate Change impact and % GDP 2025 to 2100

2025	**2050**	**2075**	**2100**
11.8	23.6	35.4	47.2

The projected estimates of Bueno and others (2008) were based only on hurricane damage, extrapolated from average annual hurricane damages in the recent past; Tourism losses, assumed to be proportional to the current share of tourism in each economy; and infrastructure damages, due to sea-level rise (exclusive of hurricane damage), which are projected as a constant cost per affected household.

The costs of inaction are high, and thus it is more important to start acting on adaptation and mitigation even when there is limited information on which to base the policies, than to ignore the problems climate change already poses. (de Bruin and others, 2009).

It has been clearly shown that whereas Saint Vincent and the Grenadines experiences high rainfall totals overall there is a wide disparity in totals between mainland St Vincent and the Grenadines. Further the total rainfall received masks the accentuated seasonality, variability, and growing incidence of extreme events. Each of these factors has considerable implications for water demand and supply as demonstrated above, notwithstanding the projected positive balance under each of the BAU, A2 and B2 scenarios modeled for 2011 to 2050.

The Grenadines which are the centre of the tourism industry has already had desalination introduced as an option for augmenting supply deficits. Desalination is an option that should be explored for adaptation to the current challenges, but the issue of energy efficiency and options should be included in the feasibility analyses going forward. The use of wind power should be evaluated for replication.

REFERENCES

Alcubilla, R.G., Lund, J.R., (2006), ―Derived willingness-to-pay for household water use with price and probabilistic supply”. *Journal of Water Resources Planning and Management.* **Vol 132** (6), 424–433

Alexander, L., Zhang, X., Peterson, T. , Caesar, J., Gleason, B., Klein Tank, A., Haylock, M., Collins, D., Trewin, B., Rahimzadeh, F., Tagipour, A., Rupa Kumar, K., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D., Burn, J., Aguilar, E., Brunet, M., Taylor, M., New, M., Zhai, P. Rusticucci, M., Vazquez-Aguirr, J. (2006), ―Global observed changes in daily climate extremes of temperature and precipitation”. *Journal of Geophysical. Research*, **Vol 111** D05109, doi:10.1029/2005JD006290.

Arnell, N. W. (2004), ―Climate change and global water resources: SRES emissions and socio-economic scenarios”. *Global Environmental Change.* **Vol 14**, 31-52.

Arbués, F., Garc´ıa-Valiñas, M., Mart´ınez-Espiñeira, R. (2003), ―Estimation of residential water demand: a state-of-the-art review”. *Journal of Socio-Economic* **Vol 32** 81-102. Elsevier Science Inc.

Asian Development Bank. (2010), *Economic Valuation of Regional Climate Change Impacts in the Water Sector*. [online] < http://www.adb.org/Documents/events/2010/Economics-Climate-Change-PRC/CRodgers-eco-valuation.pdf>[Retrieved 18 January 2011]

Bakker, M., and Schaik, H. (2010), *Perspectives on water and climate change adaptation: Climate change adaptation in the water sector – Financial issues*. [online]< http://worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Climate_Change/PersPap_11._Financial_Issues.pdf>[Retrieved 11 January 2011]

Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (Eds.). (2008), *Climate change and water* (Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat). Geneva, Switzerland: IPCC.

Bceom and Stewart Engineering Limited. (2006), *Windward Water Supply Project: Socioeconomic Feasibility Study - Water Demand in the Grenadines*. St. Vincent and the Grenadines Central Water Sewerage Authority.

Bell, D., and R.C. Griffin. (2005) ―Determinants of Demand for Water Used in Texas Communities.” *Annual Meeting of the Western Agricultural Economics Association*. San Francisco, California.

Billingy, H. K. (2007), *Development of an Erosion Risk Map for the Montreal Subwatershed, St. Vincent, using the RUSLE, Remote Sensing and Geographic Information Systems*. Centre for Resource Management and Environmental Studies, The University of the West Indies.

Boruff, B. J. (2006), *Historic Hazards Events for St. Vincent and the Grenadines*.

Bynoe, M. Undated. *The methodological approach to the review of the Economics of climate change study in the Caribbean (draft*). Caribbean Community Climate Change Centre.

Caribbean Environmental Health Institute. (2007a), *Background information*. Castries, St. Lucia: Author. Taylor, M. A., Centella, A., Charlery, J., Borrajero, I., Bezanilla, A., Campbell, J., and others (2007). *Glimpses of the future: A Briefing from PRECIS Caribbean climate change project*. Belmopan, Belize: Caribbean Community Climate Change Center.

Caribbean Environmental Health Institute. (2007b), *Road map towards integrated water resources management planning for Grenada*. Castries, St. Lucia: Author.

Caribbean Environmental Health Institute. (2007c), *Road map towards integrated water resources management planning for Union Island*. St. Vincent and the Grenadines. Castries, St. Lucia: Author.

Caribbean Environmental Health Institute. (2002), *Water and climate change in the Caribbean*. Castries, St. Lucia: Author.

Caribbean Environmental Health Institute. (2001), *St Vincent National Report Integrating Management of Watersheds & Coastal Areas in SIDS of the Caribbean, The Vincentian Perspective*. [online] http://www.cehi.org.lc/water_resources/projects/iwcam/national_reports/st_vincent/stvincent_national_report.pdf>[Retrieved 18 January 2011]

Cashman, A., L. Nurse and C. John. (2010), Climate Change in the Caribbean: The Water Management Implications. *The Journal of Environment Development* 2010 19:42 [originally published online 19 November 2009]

Cashman, A., L. Nurse and C. John. (2009), Climate Change in the Caribbean: The Water Management Implications. *The Journal of Environment Development* 2010 19:42 originally published online 19 November 2009

Chakanda, R., Kafuwa, D., Bah, K. (2008), *The effect of climate change on agricultural systems and crops production – analysis of three countries*.

Chandler, J. A. (2004), ―An analysis of the economic impact of hurricanes Dennis, Floyd, and Irene on North Carolina's lodging industry". *CHRIE Journal of Hospitality and Tourism Research,* **Vol 28**(3), 313–325.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, (2007), Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis.*

Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Culzac-Wilson. L. (2003), *St. Vincent and the Grenadines Report to the Regional Consultation on SIDS Specific Issues*.
[online]<http://www.pnuma.org/sids_ing/documents/National%20Reports/St.%20Vincent%20National%20Report.pdf > [Retrieved 7 September 2010]

Central Intelligence Agency and Food and Agriculture Organization (Content source); World Wildlife Fund (Content Partner); Juan Pablo Arce (Topic Editor). (2009), "Saint Vincent and the Grenadines." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [online] [First published in the Encyclopedia of Earth 7 May 2009; Last revised 21 May 2009]
<http://www.eoearth.org/article/Saint_Vincent_and_the_Grenadines>[Retrieved 7 September 2010]

Caribbean Disaster Emergency Response Agency (CDERA). (2003), *Status of hazard maps Vulnerability Assessments and digital maps - St. Vincent and the Grenadines Country report*.

Dalhuisen, Jasper M., Raymond J. G. M. Florax, Henri L. F. M. de Groot, and Peter Nijkamp (2003), ―Price and income elasticities of residential water demand: Why empirical estimates differ", *Land Economics* **Vol 79** 292-308

Diaz, H. and Morehouse, B. (2003), ―Climate and Water in Transboundary Contexts: An Introduction." *Climate and Water: Transboundary Challenges in the Americas*, eds. Henry F. Diaz and Barbara J. Morehouse.pp3-24. Dordrecht: Kluwer Academia Publishers.

Duchin, F. (1992), *Industrial input-output analysis: implications for industrial ecology, Proceedings of the National Academy of Sciences*, Vol. 89: 851-855.

Durrant, S. (2007), *Monitoring the effect of below average precipitation on water resources in Paget Farm, Bequia, Grenadines*. MSc Research report, CERMES, UWI.

ECLAC, 2011. *The economic impacts of climate change on the tourism sector in Montserrat and Saint Lucia*. Unpublished.

Economic Commission of Latin America and the Caribbean (ECLAC). (2010), *Economics of Climate Change in Central America*.

Egis Bceom International. (2009), *National Water Resource Management Study*. Government of St. Vincent and the Grenadines.

Economic Commission of Latin America and the Caribbean (ECLAC). (2011), *Review of the economics of climate change in the Caribbean Phase II - the water sector LC/CAR/L.260*

Environmental Solutions Limited (ESL). (2008), Coastal vulnerability assessment, St. Vincent and the Grenadines. Prepared by Environmental Solutions Ltd, Kingston, Jamaica under consultancy to Chemonics International for the USAID- COTS program.

Farrell, D., Moseley, L., and Nurse, L. (2007), *Managing water resources in the face of climate change: A Caribbean perspective.* Proceedings of the 8th Annual Sir Arthur Lewis Institute of Social and Economic Studies (SALISES) Conference, UWI, St. Augustine, Trinidad, March 26-28, 2007.

Giannini, A., Cane, M., Kushnir, Y. (2001), ―Interdecadal Changes in the ENSO Teleconnection to the Caribbean Region and the North Atlantic Oscillation". *Journal of Climate*. **Vol 14** 2867-2878

Gleick, P., Singh, A., Shi, H. (2001), *Threats to the World's Freshwater Resources*. A Report of the Pacific Institute for Studies in Development, Environment, and Security, Oakland, California, in cooperation with the United Nations Environment Programme.

Gleick, P.H. and others (2000), *Water: The Potential Consequences of Climate Variability and Change*. A Report of the National Water Assessment Group, U.S. Global Change Research Program, U.S. Geological Survey, U.S. Department of the Interior and the Pacific Institute for Studies in Development, Environment, and Security. Oakland, California.

Global Water Pertnership. (2005), *Global Water Partnership Policy on Partners*. [online] < http://gwp-cacena.org/en/pdf/gwp_policy.pdf> [Retrieved 2 March 2011]

Government of St. Vincent and the Grenadines (GoGVG). (2001), *Population and Housing Census Data Report*.

Griffin, R. C., and J. W. Mjelde (2000), *Valuing water supply reliability*, Am. J. Agric. Econ., 82, 414 – 426

Harou, J., Pulido-Velazquez, M., , D., Medellín-Azuara, J., Lund, J., Howitt, R. (2009), ―Hydro-economic models: Concepts, design, applications, and future prospects". *Journal of Hydrology*. [online] **Vol 375** pp.627-643 <http://cee.engr.ucdavis.edu/faculty/lund/papers/JulienHydroEcon2009.pdf>[Retrieved 18 January 2011]

Hansen, Lars G. (1996), ―Water and energy price impacts on residential water demand in Copenhagen", *Journal of Land Economics* **Vol 72** 66-79

Hentschel, J., and Lanjouw P. (1997), *Household Welfare Measurement and the Pricing of Basic Services*. [online] <

http://elibrary.worldbank.org/docserver/download/2006.pdf?expires=1308928057&id=id&accname=guest&checksum=AA0ED04DFFB6C2577963B534AB6067EA>[Retrieved 18 January 2011]

Höglund, Lena (1999), ―Household demand for water in Sweden with implications of a potential tax on water use", *Water Resources Research* **Vol 35** 3853-3863.

Hoffmann, M., Worthington, A., Higgs, H., (2005), *Modelling residential water demand with fixed volumetric charging in a large urban municipality: The case of Brisbane, Australia*. Discussion Papers in Economics, Finance and International Competitiveness, School of Economics and Finance, Queensland University of Technology

Homer, F and D. Shim. (2004), *St. Vincent and the Grenadines environmental management and action plan 2004-2006*. Canadian International Development Agency.

Intergovernmental Panel on Climate Change. (2007a), Climate Change *The physical science basis — summary for policy makers*. Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007b), Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change. (2000), *IPCC Special Report Emissions Scenarios – Summary for Policymakers*. Intergovernmental Panel on Climate Change, United Nations Environment Programme, and Wold Meteorological Organisation.

Nauges, C., and A. Thomas. 2000. ―Privately-operated Water Utilities, Municipal Price Negotiation, and Estimation of Residential Water Demand: The Case of France." *Land Economics* **Vol 76** (1) 68–85

John, N. 2009.*Assessment of the Climate Change Impact on Streamflow of the Montreal Watershed, St. Vincent*.National Central University. International Environmental Sustainable Development Program

Jorgensen, D., Wilcoxen, P., (1993), ―Reducing US carbon dioxide emissions: an econometric general equilibrium assessment". *Resource Energy Economics.* **Vol 15** 7–2.

Joyette, Antonio and Joslyn, Ottis. 2011. *Climate Change Consultants*. Kingstown, St. Vincent and the Grenadines

Kamat, R., Rose, A,, Abler D. (1999), ―The impact of a carbon tax on the Susquehanna river basin economy". *Energy Economics* **Vol 21** 363–38

Knights R. (n.d.), *Climate Change and Biodiversity in St. Vincent and the Grenadines*. [online]<http://www.climatechangeandbiodiversity.ca/Final_Panama_Presentations/Plenary_3_Session_1/2_Ruth_knights.pdf>. [Retrieved 7 April 2011]

Leontaritis, I.J. and S.A. Billings. (1985), *Input-Output Parametric Models for Non-Linear Systems*. Part I and Part 11. Int. J. Control, 41(2), pp. 304-344.

Manton, M. J., Della-Marta, P. M., Haylock, M. R., Hennessy, K. J., Nicholls, N., Chambers, L. E., and others (2001), Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific, 1961-1998. *International Journal of Climatology, 21*, 269-284.

Martínez-Espiñeira, R. (2007), *An Estimation Of Residential Water Demand Using Co-Integration And Error Correction Techniques*. Journal of Applied Economics. **Vol X**, No. 1: 161-184

Martínez-Espiñeira, R. (2002), *Residential water demand in the Northwest of Spain.* Environmental and Resource Economics **Vol 21** pp. 161-187

Mavromatis T, Jones PD. (1998), —Comparison of climate change scenario construction methodologies for impact assessment studies". *Agricultural and Forest Meteorology* **Vol 91** 51-67

McSweeney*, C.,* M. New and G. Lizcano. *UNDP Climate Change Country Profiles St Vincent and the Grenadines*. [online]<http://country-profiles.geog.ox.ac.uk/index.html?country=St_Vincent_and_the_Grenadines&d1=Reports>[Retrieved 7 September 2010]

Miller, R. E. and P. D. Blair: 2009, *Input-Output Analysis: Foundations and Extensions*. Cambridge University Press, 2 edition. forthcoming.

Mirza, M. M. Q., & Ahmad, Q. K. (Eds.). (2005), *Climate change and water resources in South Asia*. Leiden, Netherlands: A. A. Balkema Publishers.

Moore, W., Harewood, L., Grosvenor, T. (2010), *The Supply Side Effects of Climate Change on Tourism*. Unpublished.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Yong Jung, T., Kram, T., Lebre La Rovere, E., Michaelis, L., Mori, S., Morita, T., Pepper, W. Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N., Dadi Z., (2000), *Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, U.K., 599 pp. Available online at: http://www.grida.no/climate/ipcc/emission/index.htm

Overmars, M., and S. Gottlieb. (2009), *Perspectives on water and climate change adaptation: Adapting to climate change in water resources and water services in Caribbean and Pacific small island countries*. [online]< http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Climate_Change/PersPap_03._Small_Island_Countries.pdf> [Retrieved 2 March 2011]

Pangare, G., Pangare, V., Binayak, D. (2006), *Springs of life, India's water resources*, Academic foundation, New Delhi.

Peterson, T., Taylor, M. Demeritte, R., Duncombe, D. Burton, S., Thompson, F., Porter, A., Mercedes, M., Villegas, E., Semexant Fils, R., Klein Tank, A., Martis, A., Warner, R., Joyette, A., Mills, W., Alexander, L., Gleason, B. (2002), ―Recent changes in climate extremes in the Caribbean region. *Journal Geophysical Research*, **Vol 107**, 4601, doi:10.1029/2002JD002251.

Ringler, C. 2008. ―The Millennium Ecosystem Assessment: Tradeoffs between Food Security and the Environment." *Turkish Journal of Agriculture and Forestry*. **Vol 32,** 3: 147-157

Rodgers, C. (2010a), *Economic Valuation of Regional Climate Change impacts in the Water Sector*. [online]< http://www.adb.org/Documents/events/2010/Economics-Climate-Change-PRC/CRodgers-eco-valuation.pdf> [Retrieved 8 September 2010]

Rodger, C. (2010b), *Economic Impacts of Climate Change on the Water Sector: Methodological Approachesr*. [online]< http://www.adb.org/Documents/events/2010/CPST-Brainstorming-Meeting/presentation-cpst-rodgers.pdf> [Retrieved 8 September 2010]

Rose, A., Cao, Y., Oladosu, G. (2000), *Simulating the economic impacts of climate change in the Mid-Atlantic Region.* **Vol 14:** p. 175–183 Department of Energy, Environmental, and Mineral Economics and Centre for Integrated Assessment. [Published 2 May 2000

Rose A, Carmichael J, Oladosu G, Abler D (1999) *Modeling the economics of natural hazard impacts and policy responses using computable general equilibrium analysis*. The Pennsylvania State University, University Park The Pennsylvania State University, University Park, Pennsylvania 16802, USA

Rosenberg, D.E., Tarawneh, T., Abdel-Khaleq, R., Lund, J.R., (2007), ―Modeling integrated water user decisions in intermittent supply systems". *Water Resources Research*, **Vol 43**

Shahateet, M. I. T. (2008) ―An Econometric Model for Water Sector in Jordan", *Journal of Social Sciences*, **Vol. 4** No. 4, pp. 264-271.

Smith Warner International Limited. 2006. *Coastal Zone Management Report for an Integrated Coastal Zone Management Study*.

St. Vincent and the Grenadines: The Yachting Sector. (2002), Prepared as part of the Dutch-funded project NET/00/79 –*Development of a Regional Marine-based Tourism Strategy*".

Taylor, M.A., Centella, A., Charlery, J., Borrajero, I., Bezanilla, A., Campbell, J., Rivero, R., Stephenson, T. S., Whyte, F., Watson, R. (2007), *Glimpses of the Future: A Briefing from the PRECIS Caribbean Climate Change Project.* Caribbean Community Climate Change, Belmopan: Belize

Terry, J. P. (2007), *Tropical cyclones and impacts in the South Pacific*. New York: Springer.

Turner, K., Stavros, G., Clark, R., Brouwer, R., and J. Burke (2004), *Economic valuation of water resources in agriculture*, FAO, Rome
The Poverty Reduction Task Force (PRTF) of the National Economic and Social Development Council (NESDC). (2003), *St. Vincent and the Grenadines Interim Poverty Reduction Strategy Paper*.

United Nations. (2006), *World population prospects: The 2006 revision population database*. [online]< http://www.esa.un.org/unpp/[Retrieved 19 June 2007]

United Nations Development Programme (UNDP). (2010), *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change*: *Modelling the transformational impacts and costs of sea level rise in the Caribbean.* Prepared by The CARIBSAVE Partnership for UNDP Barbados and the OECS for CARICOM Member States.

United Nations Economic Commission for Latin America (UNECLAC). (2010), *The Economic Impacts of Climate Change in Latin America and the Caribbean*. United Nations, Santiago, Chile.

United Nations Environment Program (UNEP). (2004), *UNEP's assistance in the implementation of the Barbados programme of action for the sustainable development of small island developing states*. The Hague, Netherlands: Author.

United Nations Environment Program (UNEP). (2003), *GEO Latin America and the Caribbean*: Environmental Outlook 2003. Mexico: United Nations

United Nations Framework Convention on Climate Change (UNFCCC). (2010), *Initial Communication on Climate Change for St. Vincent and the Grenadines*

United Nations Framework Convention on Climate Change (UNFCCC). (2008), *Feeling the heat future effects: A question of degree*. [online] <http://unfccc.int/essential_back-ground/feeling_the_heat/items/2905.php.> [Retrieved 21 May 2008]

VINLEC. (2010), *Drought affects VINLEC production*. [online] http://www.svgtoday.com/?p=1171> [Retrieved 12 October 2010]

World Bank. (2006), *CARIB-GEF-Implementation of Pilot Adaptation Investments in Dominica, St. Lucia and St. Vincent & the Grenadines: Project Information Document*. [online]< http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187283&siteName=WDS&entityID=000090341_20060206130343 . > [Retrieved 8 April 2011]

World Bank. (2006), World Development *Indicators*. EM-DAT

World Bank. (2000),*Cities, seas and storms: Managing change in Pacific Island economies: Vol. 4: adapting to climate change*. Washington, DC: Author.

Yano, T., Aydın, M., Haraguchi, T., (2007), ―Impact of climate change on irrigation demand and crop growth in a Mediterranean environment of Turkey", *Sensors*, **Vol 7,** 2297-2315.

Zhou, Y. and R.S.J. Tol, (2005), Evaluating the costs of desalination and water transport. *Water Resource. Res.*, 41, 1–10.

APPENDIX I

Specifically activities will include:

Literature Review

i. Examine the relevant literature on the water sector to obtain information and data that would inform the report. This would include the following:
   a. Assessment reports of the water sector in the country with particular reference to the contribution of the sector to GDP;
   b. Review of climate data namely temperature, precipitation and sea level rise;
   c. Examination of projections of climate scenarios;

ii. Review the findings of previous studies and data on the economic models[23]• that are available and that may be useful in selection/development of an appropriate model to conduct the analysis;

Data Collection and Analysis

i. Estimate the water balance including water availability and use, potentials, consumption by uses, and unmet demand;
ii. Create a baseline and Various Water demand scenarios;
iii. Estimate of runoff and future water availability related to the different climatic and socioeconomic scenarios;
iv. ldentify the main risk factors and factors (climatic and non-climatic) that increase the sector's vulnerability;
v. Assessment of policies to conserve water, reduce water use and enhance supply, including technologies like desalination;
vi. Assessment of water pollution and sanitation;
vii. Conduct an economic assessment on the water sector with and without Climate Change related impacts and extreme events;
viii. Assessment of adaptation actions and future adaptation options. Estimation of costs and benefits of adaptation; and
ix. ldentification of investment opportunities in water harvesting and efficient water management.

Characteristics of the data:

a. Official annual, quarterly and monthly series with the widest possible scope as published by Central Banks, Statistical Institutes and government;
b. Series at constant prices with base year as recent as possible;
c. Not all the series should have the same frequency that is not all should be annual but quarterly and monthly. There should be consistency among the series;
d. These requests are the minimum. This list is not exhaustive, in the case that more information is available; all the/options may not be pursued if there is not available information;
e. There must be consistency between series;
f. The series must be submitted in EXCEL in the requested order with the commentaries in Word;
g. Each series must include the reference to its source.

Series:

a. National water availability and national water availability (cubic meters per person).
b. Rains, evaporation-transpiration and filtering.
c. Regional distribution of water availability including Rains, Evaporation-transpiration and filtering. The data should allow for running of some econometric estimation.
d. Water demand:
    i. National water demand;
    ii. Water demand by sectors: For example: domestic, agricultural, industrial;
    iii. Water demand by regions. Series should be consistent with income and price variables, The data should allow for running of some econometric estimation;
e. National water prices:
    i. Water fees.
    ii. Water costs.
f. Series by regions of rains, evaporation and temperature. Similar classification for information on income and prices by regions.
g. These data would be used to build a vulnerability index for water consumption.