Caribbean Community Climate Change Centre

A VULNERABILITY AND CAPACITY ASSESSMENT REPORT

FOR

VULNERABILITY AND CAPACITY ASSESSMENT AND NATIONAL ADAPTATION STRATEGY AND ACTION PLAN FOR ST. KITTS AND NEVIS

Final Report

December 11, 2014

Prepared for the
Caribbean Community Climate Change Centre
Belmopan, Belize

and

Ministry of Sustainable Development

Department of Physical Planning and the Environment

Basseterre, St. Kitts and Nevis

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A Vulnerability and Capacity Assessment Report
for
Vulnerability and Capacity Assessment and National Adaptation Strategy and Action Plan for St. Kitts and Nevis

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Caribbean Community Climate Change Centre, Ring Road, P.O. Box 563, Belmopan, Belize

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Technical supervision: Mr. Joseph McGann, Programme Manager, EU-GCCA Project.

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For more information visit:

- The Global Climate Change Alliance website: http://www.gcca.eu/
- The African, Caribbean and Pacific Secretariat website: http://www.acp.int/
- The Caribbean Community Climate Change Centre website: http://www.caribbeanclimate.bz
- Ministry of Sustainable Development: Department of Physical Planning and the Environment website: http://www.gov.kn/mosd

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±	plus or minus
A1B	Scenario generated by the IPCC
A2	Scenario generated by the IPCC
ADS	Agricultural Development Strategy
AMO	Atlantic Multidecadal Oscillation
AR4	Fourth Assessment Report
ARM	Agricultural Resource Management
ASO	August-September-October
B1	Scenario generated by the IPCC
BVA	Basseterre Valley Aquifer
CCCCC	Caribbean Community Climate Change Centre
CCRA	The CARIBSAVE Climate Change Risk Atlas
CMIP3	Couple Model Intercomparison Project 3
CSGM	Climate Studies Group Mona
DCPB	Development Control and Planning Board
DJF	December-January-February
DOA	Department of Agriculture
DOLS	Department of Lands and Surveys
DPPE	Department of Physical Planning and Environment
ED	Enumeration District
ENSO	El Nino - Southern Oscillation
ESL	Environmental Solutions Limited
EU	European Union
FAO	Food and Agriculture Organisation
FMA	February-March-April
GCCA	Global Climate Change Alliance
GCM	General Circulation Models
GCM	Global Climate Model
GOSKN	Government of St. Kitts and Nevis

HadCM3	Hadley Centre Coupled Model, version 3
IPCC	Intergovernmental Panel on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IWCAM	Integrated Watershed and Coastal Areas Management
JJA	June to August
m	metre
mm	millimetre
m/s	meters per second
MAM	March-April-May
mb	millibar - a unit of atmospheric pressure
MER	Multi-Electrode Electrical Resistivity
MG	Million Gallons
MGD	Millions Gallons per Day
MJJ	May-July
mm	Millimetres
MSD	Ministry of Sustainable Development
NASAP	National Adaptation Strategy and Action Plan
NBSAP	National Biodiversity Strategy and Action Plan
NDJ	November-December-January
NHC	National Housing Corporation
oC	Degrees Celsius
OECS	Organisation of Eastern Caribbean States
OET	Ocean Earth Technologies
PPE	Perturbed Physics Ensembles
PRECIS	Providing Regional Climates for Impacts Studies
PWD	Public Works Department
QUMP	Quantifying Uncertainties in Model Projections
RACC	Rallying the region to Action on Climate Change
RCM	Regional Climate Model
RCP	Representative Concentration Pathways

SEP	South East Peninsula
SIDF	Sugar Industry Diversification Foundation
SIDS	Small Island Developing States
SLR	Sea Level Rise
SON	September to November
sq.	Square
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperatures
T	Temperature
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VCA	Vulnerability and Capacity Assessment
WSD	Water Services Department

GLOSSARY

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

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

Cisterns An underground storage tank for holding water typically integrated as a structural part of a building

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

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

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

	variability) or, to variations in natural or anthropogenic external forcing (external variability).
Drought	A drought occurs when there is an extended period of deficiency in precipitation (relative to what is considered normal), which is then insufficient to meet economic, social and environmental demands.
Flood	An overflow of water from a river, lake or other body of water due to excessive precipitation or other input of water.
Groundwater	Water beneath the surface of the earth which saturates the pores and fractures of sand, gravel and rock formations
Gross Domestic Product	The market value of all the goods and services produced by labour and property located in a particular country or region.
Scenario	A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections but are often based on additional information from other sources, sometimes combined with a 'narrative storyline.'
Seawater Intrusion	Aquifers in island and coastal areas are prone to seawater intrusion. As seawater is denser than fresh water, it will invade aquifers which are hydraulically connected to the ocean. Under natural conditions, fresh water recharge forms a lens that floats on top of a base of seawater. This equilibrium condition can be disturbed by changes in recharge and/or induced conditions of pumpage and artificial recharge.
Surface water	Water collecting on the ground, in a stream, river, lake, wetland or ocean
Watershed or Basin or Catchment	A geographical area drained by a particular surface water and/or groundwater system. The basin boundaries are demarcated so that there is generally no flow from one basin into another.
Water Management Unit	A single or group of watersheds that have been grouped together for the purpose of management.
Well	A well is a borehole, adit tunnel or any other excavation constructed or used for the abstraction of water.

EXECUTIVE SUMMARY

St. Kitts and Nevis currently experience several stresses on the water sector. These include: changes in the current rainfall patterns, an increase in the demand for water, and challenges with the main water resource: the Basseterre Valley Aquifer. The demand for water is expected to increase as the economy of St. Kitts and Nevis expands, particularly in the tourism and agriculture sectors where water requirements could double in the next 10 years. Recent studies conducted in the Basseterre Valley Watershed/Aquifer show declining trends static water levels in the Basseterre well-field, early signs of salt water intrusion, the potential for degradation of groundwater quality, and threats to the watershed recharge areas from improper land usage and insufficient development planning.

Based on the challenges indicated, the Department of Physical Planning and the Environment in St. Kitts and Nevis sought funding from the Caribbean Community Climate Change Centre (CCCCCs) to execute the project: ***St Kitts and Nevis: Vulnerability and Capacity Assessment and National Adaptation*** to address these challenges. Under this project this Vulnerability and Capacity Assessment (VCA) of the Basseterre Watershed was one of the main deliverables.

Methodology

The VCA involved an assessment of the existing climate and statistical downscaling so that climate projections were made for St. Kitts and Nevis. Projections were made for rainfall, temperature, wind speed and sea level rise patterns based on the data received from St. Kitts and Nevis.

A water resource assessment was also conducted to determine existing issues with the water resources and supply from the Basseterre Watershed, which included the conduct of a water budget. The water resource analysis also included the use of projected changes for rainfall patterns and for temperature to analyse the likely impact that these would have on the current system.

A policy, institutional and legislative assessment governing the water sector for St. Kitts was also conducted and the gaps were identified.

The socioeconomic setting of the Basseterre Watershed was also assessed and the climate projections were used to analyse the likely impact on the residences and businesses in the area. Likely impacts on the agriculture and health sector were also assessed according to the term of reference.

Limitations were largely associated with the inadequacy or absence of data sets that would improve the analyses conducted.

Findings

The results of the climate analysis for St. Kitts and Nevis included projections for rainfall, temperature, wind speed and sea level rise patterns based on the data received from St. Kitts and Nevis. The following represents a summary of the main findings:

- On average, minimum, mean and maximum temperatures are projected to increase from present through the 2030s for St. Kitts and Nevis. Mean temperature increases are generally between 1 ^{o}C and 2 ^{o}C.

- Mean annual rainfall for St. Kitts and Nevis is projected to decrease by the 2030s, with the exception of the northern extent of St. Kitts, which is expected to experience an increase in mean annual rainfall. Reductions in rainfall range from approximately 3 to 7% for Nevis and 6 to 11% for southern St. Kitts.
- The projected changes in wind speed for St. Kitts and Nevis are small, with slight mean annual increases projected for the 2030s.
- IPCC projections indicate that sea levels will rise by 0.3m to 1m by the end of the 21st century. Other studies have predicted higher increases. It is therefore likely that the islands of St. Kitts and Nevis will be further impacted by rising sea levels by the 2030s.

Based on the findings presented, patterns of rainfall, temperature and sea level rise are likely to have the greatest impact on St. Kitts and Nevis, which will result in changes in the available water resources for the island. This has implications for every citizen but also for sectors that have major water users such as agriculture.

The analysis of the water resources revealed that the Basseterre Valley Aquifer and Watershed face a number of existing challenges These include: unknown hydrogeology characteristics in the upper catchment and around the island; undefined watersheds; unknown catchment response to rainfall and pumping; a lack of geo-referenced hydrological data and availability of raw data in appropriate electronic format (reservoirs, rainfall stations etc.); leakage within the distribution network and within reservoirs; aged infrastructure; lack of continuous monitoring of rainfall, streamflow and groundwater head; droughts, as well as flooding and climate change.

With the threat of reduced rainfall and increasing temperatures compounded by the existing challenges, this shows the importance of adaptation by the institutions governing the water sector to the change in climate in order to address challenges due to an already stressed water resource.

In order to adapt, St. Kitts and Nevis, although replete with examples of environmental policies and project activities it was recognized that there is a critical need for new legislation to strengthen the regulatory framework for the water sector. The absence of an updated Water Resources Legislation, an updated Public Health Act and regulations that establish water quality standards were recognized as major gaps.

St. Kitts and Nevis also lacks the financial and human resources to implement many of the policies. With increasing demands on the water sector due to growing population, and the expanding tourism and agricultural sectors, water shortages are likely to be exacerbated in the future.

St. Kitts and Nevis, like many other small island states in the Caribbean, is vulnerable to a range of large-scale global economic and environmental shocks and stresses, particularly as it relates to water. These vulnerabilities are compounded by existing socioeconomic conditions, and like the rest of the region, small size, high concentration of population and resources along the coast, susceptibility to a range of extreme weather events such as hurricanes, narrow and highly specialised economies and a limited natural resource base. The table below summaries the results of the Vulnerability and Capacity Assessment conducted for the Basseterre Watershed.

Vulnerability Assessment of the Basseterre Watershed

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
WATER SUPPLY AND MANAGEMENT					
Low annual rainfall with high inter-annual variability	Increasingly drier conditions. Heavy rainfall events decrease. Increase in annual temperatures.	More frequent drought events, increased evaporation may result in greater pathogen density in water and this could result in a lack of potable water. Population growth and expansion of tourism related activities may compound this problem.	Moderate (supply is sensitive to lower annual rainfall)	Low (Costly mitigation measures will require external funding)	Moderate
Annual exposure to hurricanes and tropical storms	Hurricane intensity expected to increase (not necessarily frequency)	Increased flooding in certain areas and exposed to risk of debris and sediment flows. Damage to water sector infrastructure- downtime can lead to loss of revenue and negatively impact water sector development plans.	High (exposure to damage and losses from storms)	Low (External funding needed purchase equipment for ghaut maintenance)	High
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise which can restrict the use of highly brackish/saline well water. Increasing population and economic growth increases water demand. Sea level rise can lead to future coastal flooding	High (sensitive to sea level rise and saline intrusion)	Moderate (Funding already identified to contract BEAD to dig new wells)	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
Meeting increased demand of water from population growth and economic activities	Reduction in annual average rainfall - more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	High (sensitive climate change impacts to lower water supply to meet demand)	Low (Costly to reduce leakages/losses within the system, external funding needed)	High
Poor watershed management	Increasing drought conditions	Increase in risk landslides and soil erosion due to change in land use, reduction of protective tree cover and reduction in infiltration.	Moderate (sensitive to extended drought periods)	Moderate (development control and community programmes can improve watershed management)	Moderate
AGRICULTURE					
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts Mean annual decrease in rainfall of between 6-11% for southern St. Kitts (which includes the Basseterre Catchment Area) by the 2030s	More frequent drought events will result in reduced crop yield. Reduction in available freshwater for crops and livestock.	High (sensitive to drought and low rainfall)	Moderate (SIDF already funding the increase in storage capacity but external funding still needed for training)	Moderate
Poor dryland farming techniques	Mean temperature increase of between 1oC and oC by 2030s create drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield. Plant stressed and wilting from increased temperature and possible introduction of new pests and	Moderate (sensitive to increased high temperatures, few soil conservation projects)	Low (external funding needed to train extension officers and farmers needed)	Moderate

Current Stresses	**Projected Stresses from Climate Change**	**Projected Impact of Changes to the Systems** *(without preparedness action)*	**VULNERABILITY ASSESSMENT**		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
		diseases			
Damage from heavy rainfall/storm events **Poor farming practices**	Hurricane intensity expected to increase (not necessarily frequency) Potential risk of sea level rise	Loss of crops, reduction in crop yield, loss of livestock Landslide and soil erosion due to heavy rains may lead result in moderate damage to crops due to debris flow and a loss of fertile top soil. The indiscriminate use of pesticides and fertilizers by some farmers in and around the Catchment Area pose the risk of contaminating groundwater resources that can in turn affect crop growth and threaten livestock. Clearing of vegetation for farming especially on slopes can lead to increased surface runoff and lower the groundwater recharge capacity of the area. May lead to moderate to high increases in salinity of low lying and coastal agricultural lands due to sea water intrusion.	Moderate (exposed to hurricanes and storms)	Low (external funding needed to train extension officers and farmers needed	Moderate
HEALTH					
Outbreak of vector borne diseases (Chikungunya, Dengue)	More periods of short duration intense rainfall, which can cause ponding Increase in temperatures	The mosquitoes which carry viruses breed in water that settles around homes, schools, churches, workplaces and playgrounds.	Moderate (sensitive to outbreak of vector borne diseases, mitigation measures	Moderate (Abate and Fogging used as vector control measures)	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
	between 1^oC and 2^oC by 2030s	Nearby wetlands are grounds for mosquito breeding. Temperature increase may also exacerbate the incidence of vector borne diseases such as malaria, dengue and chikungunya. Flash floods may also lead to loss of life.	currently being executed)		
Increase in water related illnesses (Gastroenteritis, diarrhea)	Reduction in annual average rainfall - longer dry periods Increase in frequency and severity of hurricanes and tropical storms can lead to moderate/severe damages to dams, infrastructure and landslides may also occur.	Water restrictions imposed during dry periods could increase over time increasing the risk of water related illnesses. It may also lead to a breakdown in sanitation and hygiene. Landslide and soil erosion may result in a moderate increase in turbidity and reduction in freshwater quality; increased threat of water-borne disease e.g. cholera.	Low (potentially sensitive provided that water supply reduces	Low (Currently not an issue and no local funds available to mitigate)	Moderate

1 INTRODUCTION

1.1 Purpose

Environmental Solutions Limited (ESL) has been contracted by the Caribbean Community Climate Change Centre (CCCCCs) to execute the project: ***St Kitts and Nevis: Vulnerability and Capacity Assessment and National Adaptation***. This project is a part of the overall European Union Global Climate Change Alliance (EU GCCA) Caribbean Support Project which is being executed by the CCCCCs. The EU GCCA Project aims to assist participating countries to develop the capacity to design and implement climate change adaptation policies and measures. It seeks among other things, to incorporate and mainstream climate change adaptation issues into the national development and planning processes and mechanisms in order to enhance the economic and social development of the individual participating countries in particular, and the Caribbean as a whole.

The CCCCC is working work collaboratively with the Government of St. Kitts and Nevis (GOSKN) to:

a. prepare a Vulnerability and Capacity Assessment (VCA) study in the Basseterre Valley Aquifer;

b. prepare a national sector-based Impact Assessment that will provide relevant data and information leading to the preparation of a National Adaptation Strategy (NAS) and Action Plan

The VCA report will assist St. Kitts and Nevis to identify and assess the vulnerabilities, risks and opportunities for the water resources sector within the Basseterre Valley along with identifying gaps for further investigation.

The VCA will also help to inform development of a National Adaptation Strategy (NAS) to address climate change impacts on the water resources sector in St. Kitts and Nevis. The NAS will include recommendations on the options available to the GOSKN to assist with its adaptation response in order to develop and/or increase its resilience to deal with the anticipated adverse effects of climate change on the water sector with integration of agriculture and health issues.

This document presents the findings of the VCA of the Basseterre Valley with respect to the potential impacts of climate change on the water sector

1.2 Background

St. Kitts and Nevis is a twin island country located in the Eastern Caribbean chain of islands with a total landmass of 269 square kilometers (km^2). The climate is classified as tropical marine, and rainfall is mainly orographic, increasing in amount and frequency with altitude. Rainfall on the island of St. Kitts is generally unevenly distributed between years and months, with a reliable wet period from August to November and driest months January to April. It has an average annual rainfall of about 1625mm ranging from an estimated 2000mm in the higher elevations with arid conditions in the South East Peninsula (SEP). Average annual rainfall on Nevis is about 1170mm, and therefore it has lower yielding water sources (Department of Environment, 2001).

St. Kitts and Nevis has a population of 46,398 a marginal increase of 0.16% in comparison to 46,325 in the 2001 census. Preliminary 2011 census results indicate that of this total, 34,983 persons were recorded for St Kitts while Nevis accounted for the remaining 11,415 persons St. Kitts has a population density of 206 persons per km^2 with the parish of St. George being the most populated area, 454 persons per km^2 (Statistics Department, 2012). The Basseterre Valley project area includes sections of St. George and St. Peter (Figure 1.1).

Figure 1.1: St. Kitts and Nevis Parishes (Statistics Department, 2012)

St. Kitts and Nevis, like many other small island states in the Caribbean, is vulnerable to a range of large-scale global economic and environmental shocks and stresses. These vulnerabilities are compounded by existing socioeconomic conditions: small size, high concentration of population and resources along the coast, susceptibility to a range of extreme weather events such as hurricanes, narrow and highly specialised economies and a limited natural resource base.

The Department of Physical Planning and Environment in the Ministry of Sustainable Development, as the National Focal Point, is the government Ministry responsible for the coordination and implementation of climate change policies and measures with respect to the fulfilment of the country's obligations under the convention.

St. Kitts and Nevis has taken initiatives to mainstream climate change into its national development processes and mechanisms, but not necessarily including the water sector.

1.2.1 The Water Sector

As indicated in the Terms of Reference, in St. Kitts and Nevis, it is becoming increasingly apparent that current water sector arrangements in St Kitts and Nevis threaten the continued success of the economy and the advance of its social development. Three key challenges for the sustainability of integrated water resources management have been identified: technical, institutional and financial.

Operational and Technical Sustainability

Recent studies conducted in the Basseterre Valley Watershed/Aquifer have identified the following issues *inter alia*:

- A trend of declining static water levels in the Basseterre well-field, and early signs of salt water intrusion;
- The potential for degradation of groundwater quality from domestic soak-away pits, agricultural pollution and industrial developments in the watershed;
- Threats to the watershed recharge areas from improper land usage and insufficient development planning, leading to watershed degradation and deforestation; and
- Threats to the existing freshwater aquifer from climate change induced sea-level rise.

Changing precipitation patterns and increasing frequency and intensity of extreme weather events will impact the hydrological cycle and thus water supply. St. Kitts has recently developed a comprehensive Water Conservation Plan (WCP) as a means of adapting to the projected adverse impacts of climate change.

Operational sustainability is also contingent on the pricing of water services to recover full costs and investing the capital raised in operation and maintenance to provide improved service standards. To achieve this there needs to be a better level of information, knowledge and understanding of water resources, the nature and extent of the demands on water resources, contributing conditions and the macro-economic and development context within which they are situated.

Institutional Sustainability

Institutional sustainability requires building the capacity of water services and water resource management institutions, promoting good governance and maintaining effective relationships and coordination between the relevant public authorities, the private sector and civil society. The institutional framework must take account of societal, economic and environmental conditions.

Financial Sustainability

The active management of water resources requires investment and adequate financial resources. Financial sustainability requires mobilizing sufficient capital investment to ensure the adequate provision of infrastructure to cover operation and maintenance and eventual replacement. Securing financing and investment is affected by Government's high level of indebtedness and resultant difficulties in allocating resources in the national budget.

1.3 The Consultant's Mandate

The Terms of Reference for the Consultant stipulate two specific objectives of the mandate:

a. To conduct a Vulnerability and Capacity Assessment in the Basseterre Catchment Area in St. Kitts and Nevis to determine the impacts of projected climate change on the water sector in the community; and
b. To conduct an impact assessment of climate change and climate variability on the water sector in St. Kitts and Nevis, and using the report generated to prepare a National Adaptation Strategy and Action Plan (NASAP) for the water sector.

The Results to be achieved are as follows:

- Result 1 – A technical team is established in St. Kitts and Nevis that will primarily be responsible for the conduct of the VCA and the preparation of the impact assessment, the NAS and Action Plan for the water sector on behalf of the GOSKN;
- Result 2 - The primary stakeholders, (government agencies, community groups, private sector, etc.), participate in the preparation process through adequate consultations (visioning exercises, periodic review meetings and sharing of reports);
- Result 3 - Two national workshops are utilized to support/facilitate dialogue on the VCA and NAS preparation processes and outcomes and recommendations at the national level; and
- Result 4 – Community and sector specific issues that arise or are identified during the consultancy are adequately addressed in the final report.

The geographical area to be covered in the scope of work for the VCA is the Basseterre Valley Aquifer in St Kitts, and the NAS and Action Plan will cover the entire territory of St Kitts and Nevis. The target groups to be covered include the community residents and farmers that utilize the water resources in the Basseterre Valley Aquifer location and Watershed Area in particular, and for the NAS and Action Plan the general population of St. Kitts and Nevis should be considered.

1.4 Scope and Approach for the VCA

The VCA study as indicated above refers specifically to the Basseterre Valley Watershed and Aquifer. The consultants employed an approach that drew on the methodology presented by the CCCCC supported Pulwart and Hutchinson (2008) with "Vulnerability and Capacity Assessment Methodology: A Guidance Manual for the Conduct and Mainstreaming of Climate Change Vulnerability and Capacity Assessments in the Caribbean Region" as well as the guidebook entitled "Preparing for Climate Change: A Guidebook for Local, Regional and State Governments" produced in 2007 by Center for Science in the Earth System (The Climate Impact Group).

The following tasks were undertaken in keeping with Pulwart and Hutchinson:

- Relevant stakeholders in different categories such as agriculture, water resources, physical planning, environment, health, disaster risk management were identified and contacted to obtain the various sources of data and information.
- The study area was defined and an initial list of critical issues/hotspots was compiled.
- A detailed literature review of water resources of Saint Kitts and Nevis was undertaken.
- A Review of available data and data quality was undertaken to determine the necessary temporal and spatial analysis for precipitation, groundwater resources such as consumption, demand, and availability datasets.
- The present water resource situation for population growth, industrialization and change was obtained.
- Changes in past and current supply and demand, management practices, development trends, and potential climate change impacts for scenario input were analysed.
- Data limitations and gaps were identified.
- A time based hydrological assessment of the Basseterre Valley Aquifer was conducted with the after the relevant static maps, hydro-geological information, and meteorological data were acquired.

The consultants have undertaken this assignment using the consultative and participatory approach involving all key stakeholders in combination with scientific analyses. The requirements of the TORs were met through comprehensive research and documentation review, stakeholder consultations (in various forms) and climate modelling. The consulting team used a charette-style approach to data gathering to ensure all cross-cutting issues are addressed and fully understood by the multi-disciplinary team members.

The approach for the VCA entailed three main components: a sensitivity analysis, an adaptive capacity analysis and a vulnerability analysis.

The following steps were taken in the approach to the assessment.

1.4.1 Definition of Study Area

The catchment boundary has been defined based on literature review as well as based on directions from the Department of Physical Planning and the Environment. Settlement, economic activity, surface and groundwater features within the Basseterre Valley Catchment area have been outlined to define the limits of the project area.

1.4.2 Literature Review

The Consultants had to acquire significant primary and secondary data for the country and the project area in order to complete the VCA. The following information was gathered from stakeholders and existing documentation:

1. Country specific data on for example: population, water usage, water supply, forest cover, rainfall and other weather data, stream data, groundwater data, among others.
2. Water sector and specifically Basseterre Valley Aquifer characteristics - water availability and supply in rural and urban areas, water resources and management, sanitation, finance including government spending and donor funding, government supply and capacity, sector coordination, equity, sustainability, private sector and civil society.
3. Socio-economic development trends- population growth, urbanization, rural migration, past and present supply and demand management practices.
4. Current national activities and programs relevant to the water sector (dams, drainage systems and ponds, human resources, other assets).
5. Challenges faced and priority areas for improving the Basseterre Aquifer and watershed area and water sector.

1.4.3 Characteristics of Study Area

The characteristics of the Basseterre Valley Catchment area have been outlined. The physical and socioeconomic nature of this area have been described in more detail. The physical nature of the project area has been defined and in terms of geology, hydrology and inter-linkages with the physical nature of the project are and surface and ground water supply.

The existing socioeconomic situation in St. Kitts and Nevis as it relates to population, settlement, land use, livelihoods, economic activity and vulnerability, poverty, unemployment and inequality, human development challenges, as well as generally poor governance capabilities, are of particular relevance to the water sector. This current situation has been assessed. The Water Sector is defined by The UN-Water (2008), as being – “All means and activities devoted to creating net added value from the water resources available in a given territory”. The notion of ‘net added value‘ derives from the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its contribution to its users.

Demographic census data available for 2011 and 2001 were utilised for the baseline socioeconomic assessment for the sensitivity analysis. It is important to note that some of the demographic data for the 2011 Census was not yet available and as such the 2001 Census data had to be utilized for some of the analysis. Furthermore, a best fit of the Enumeration Districts (EDs) which make up the three parishes (St. Peters, East St. George and West St. George) along with stakeholder interviews were utilized to assess the socioeconomics of the East Catchment Basin.

The TOR’s have highlighted agriculture and health as areas of key focus. Therefore, the socio economic input was mainly concerned with evaluating the impact of climate change on these user sectors.

Agricultural Sector

Agricultural users were defined as both irrigation and non-irrigation water users. Primary emphasis was placed on farmers, but main industry users such as agro processors were also considered important stakeholders. Overall, current water demand by these users was compared with supply and net water demand extrapolated using climate change scenarios and forecasts. Other pertinent issues included: the impact of sea level rise and the potential for saline intrusion into the aquifers serving agriculture. Options for reducing/redistributing abstraction from these areas, as well as combining the use of other surface water sources with adequate catchment resources, were also examined. Scenario building through community consultations in June, 2014 attempted to better understand the relationship between food security for the population, agricultural production and the water sector.

Within the limiting assumptions that attend forecasting of net water demand, recommendations have been made that can be streamed in the short to medium term.

Health

The importance of water to health is established in scientific principle, and qualitatively via several commentaries. However, the Consultants are not aware that the development and use of indices to relate the water sector to health has been done for St. Kitts and Nevis to date. In the absence of this work at the VCA level, the Consultants have examined the impact of climate change on health using two main approaches. First: Scenario building during consultations explored the relationship between sanitation and health in light of water sector issues, as well as, between climate change and health, including the outbreak of diseases. The second approach established government's direct annual expenditure on the water sector through its annual budgetary allocations and correlated this expenditure with Governments expenditure on the health sector.

However, health like the water sector is an area for which the precautionary principle in adaptation planning is highly recommended. Attention was paid to arrive at suggestions for adaptation strategies for sustainable health, given developments in the water sector arising from climate change.

The socio-economic input contributed to understanding the likely social impacts of adaptation strategies in other areas of the water sector.

1.4.4 Stakeholder Consultation

Consultations were conducted with the key stakeholders identified at the Inception Meeting. This was done in an effort to confirm the current state of the water sector. Stakeholder consultations took the form of targeted interviews, focus groups, community meetings and surveys (print and electronic).

The Consultants liaised with the Department of Physical Planning and Environment to assist in setting up stakeholder consultations. The following organisations were met with:

- Physical Planning and Environment
- Water Services Department
- Ministry of Agriculture and Fisheries
- Environmental Health Department
- Statistics Department
- National Emergency and Management Agency
- Public Works Department
- Department of Economic Affairs and Public Sector Investment Planning

- St. Kitts Farmers' Cooperative Society
- St. Kitts Meteorological Services
- Carib Brewery
- St Kitts Bottling Co Ltd
- Fisheries Division
- Saint Christopher National Trust

1.4.5 Situational Analysis of Water Sector in SKN

The water sector includes quantity and quality of ground water systems as well as the water supply and wastewater components and associated infrastructure. It also considers the role of land use and watershed management and protection, as these are considered to be key to the protection, maintenance and strengthening of the resilience of St. Kitts and Nevis' water resources to the threats posed by climate change. Water resources within the Basseterre Valley Catchment area have been defined including: water source, supply, demand and a sector analysis have been completed.

The Basseterre Valley aquifer is a significant part of the catchment area. The Basseterre Valley aquifer has been examined in terms of exposure to and experience with climate related events. Assessment of the capacity to adapt and/or cope with the effects was essential in order to ensure that investments in adaptation measures achieve desired outcomes. The results of the vulnerability assessment of key water supply systems such as this aquifer can be used to guide the decision making process in prioritizing appropriate steps that should be taken to adapt to the effects of climate change.

It is important to note that vulnerability is a multifaceted concept that is difficult to capture completely by a single measurement. This is because accurate measurements of vulnerability require an adequate reflection of processes and outcomes within systems, which are not easy to identify and characterize (Adger, 2006). Understanding the vulnerability of a system requires an assessment of its adaptive capacity, sensitivity and exposure to the forces of climate variability and change.

Currently, no standard framework exists for capturing qualitative and/or quantitative insights into conditions as well as perceptions of vulnerability (Adger, 2006).

Participatory and livelihood approaches to vulnerability assessment where indicators are informed by the primary stakeholders themselves represent a positive step towards integrating local knowledge with scientific knowledge. This VCA Report uses a combination of approaches as articulated by Pulwart and Hutchinson (2008).

Legal and Institutional framework

The legal and institutional framework was also reviewed for St. Kitts. Existing and pending policies, legislation, regulations related to the water sector were identified and reviewed. The institutions with related roles are also identified and reviewed. This assessment was supported by consultations with key agencies and document review.

1.4.6 Climate Change Analysis

Climate change and its impacts on the water sector are integrally related issues. Small Island Developing States (SIDS) have unique sustainable development challenges when compared to other countries. The challenges stem mostly from the limited availability of land as well as restrictive limitations on the fresh water resources. The SIDS of the Caribbean are constrained under the limited opportunity for water storage, hence making them vulnerable to the effects of climate variability e.g. floods and droughts. This has a real and tangible development constraint on the economy and public health, as well as on environmental quality, which for St. Kitts and Nevis also means the economy.

The Ministry of Sustainable Development reported that St. Kitts and Nevis is highly susceptible to the effects of climate change. Bueno et al. (2008) provided figures for *cost of inaction* in St. Kitts and Nevis using the 2004 GDP as the base year. By the years 2025 and 2050, costs would amount to 16 % and 35.5 % of GDP, respectively.

The climate modelling projections for St. Kitts and Nevis predict:

1. an increase in average atmospheric temperature;
2. reduced average annual rainfall;
3. increased Sea Surface Temperatures (SST); and
4. potential for an increase in the intensity of tropical storms.

(CARIBSAVE Partnership, 2012)

St. Kitts is already experiencing some of the effects of climate variability and change through damage from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns. General Circulation Models (GCM) projections indicate an overall decrease in annual rainfall of between -41 to +13 mm per month by 2080 for the higher emissions scenario. RCM projections indicate a decrease of 7-22% in total annual rainfall (CARIBSAVE, 2012). With increasing demands on the water sector due to growing population, and the expanding tourism and agricultural sectors, water shortages are likely to be exacerbated in the future.

In St. Kitts and Nevis water resources are vulnerable to sea level rise, and higher evaporation rates due to temperature increases. Given the centrality of ground water sources to the national water supply, the problem of water resources is primarily one of keeping and protecting the underground water resources. Currently the island experiences water shortages in some rural communities during the dry season (FAO, 2000). During this season natural springs experience periodic water shortages as a result of high tourism water demand, and therefore water is sourced from areas that have wells (CARIBSAVE, 2012). Because of the relatively high consumption for irrigation and the overall water scarcity situation, requests from crop farmers are rarely given consideration. This lack of water for supplementary irrigation in the dry season has been considered by the Department of Agriculture, to be the major constraint to achieving year round production of selected vegetables which is a primary goal. Climate change is expected to exacerbate these water shortages as a result of increasing temperatures, increased rainfall variability and sea level rise (FAO, 2000).

This section of the report presents an assessment of literature and results of analyses towards characterizing climate variability, trends and projections for St. Kitts and Nevis. Specifically this section reviews the current state of knowledge related to observed climate variability, trends and projections for St. Kitts and Nevis from authoritative literature, and presents results from analyses of meteorological and model data for the target region. In developing this section the following methodology was followed:

- Historical data were analyzed to produce tables and diagrams for temperature, rainfall (precipitation), wind-speed, sea levels and hurricanes that represent the current climate of St. Kitts and Nevis.
- The future possible state of the climate of St. Kitts and Nevis was gleaned from available GCM data; using tables and diagrams for the variables of temperature, rainfall, wind speed, sea level rise and hurricanes, where data is available. Specific references are made to the Basseterre Valley Watershed in particular.
- RCM data at scale for St. Kitts and Nevis were derived from PRECIS A1B Perturbed Physics Ensemble of which 6 representative members of the 17 were chosen. From this data tables for the variables of temperature, rainfall and wind speed were created. Where data is available, specific references are made to the Basseterre Valley Watershed in particular.

A review of authoritative works on climate change was done in order to examine the state of knowledge about climate change for St. Kitts and Nevis climate. These included, but were not limited to, studies by the Intergovernmental Panel on Climate Change (IPCC), Caribbean Climate Change Centre and Climate Studies Group, Mona, UWI.

1.4.7 Sensitivity Analysis

As a precursor to the sensitivity analysis the following information has been completed:

1. The geographic and biophysical boundary of the study area (spatial extent of the Basseterre Valley aquifer location) was defined.
2. The socio-economic boundary of the area (residential, fishing, farming, and industrial) was defined.
3. A country focal point or country assessment team/advisory council- Partners (government, community, private, and academic) was developed and consulted to assist in identifying potential priority vulnerabilities and potential stakeholder partnerships.
4. A climate inventory - characterized the current states of relevant knowledge of climate variability on relevant time-scales for social and environmental impacts.

The sensitivity analysis involved determining the sensitivity of the water sector to climate change. It first involved the development of climate profiles through statistical downscaling with special emphasis on rainfall. Secondary interests in health and agriculture were also noted in the TORs and therefore other parameters such as temperature, wind, and relative humidity were included. The climate profiles were compiled through examining historical trends, analyzing global and regional climate model output and using statistical downscaling (where data was available) to generate projections.

Statistical Downscaling and Analysis of scenarios for medium and long term periods were undertaken to help inform potential risk and the water sector professionals used this information to conduct analyses.

Downscaling climate models allowed the Consultants to:

- Identify climate change issues and threats through projections
- Identify vulnerability of the water sector and potential impacts
- Assess potential socio-economic impact

In the light of the results of the climate models, economic scenarios which highlight potential losses to sectors dependent on water availability were also developed.

The above data collected answered the following questions:

- How exposed is the water sector to the impacts of climate change?
- Is the water sector subject to existing stress?
- Will climate change cause the demand for water to exceed its supply?
- Does the water sector have limiting factors that may be affected by climate change?
- What is the "impact threshold" associated with the water sector?

1.4.8 Adaptive Capacity

The adaptive capacity associated with the water sector in the study area was examined. Generally, systems that have high adaptive capacity are better able to deal with climate change impacts.

This analysis involved a gap and needs assessment of the institutional framework governing the water sector and was aided by stakeholder discussions. The template used summarised the review of the institutional framework of St. Kitts and key legislation governing these institutions. Recommendations for capacity building measures and other interventions were also identified.

To determine, the projected climate change impacts that will affect the water sector was considered. The question that guided this process was: "To what extent are the systems associated with the water sector able to accommodate changes in climate at minimum disruption or cost?" In conducting the adaptive capacity analysis, several things were considered:

- Are the systems associated with the water sector already able to accommodate changes in climate?
- Conversely, are there barriers to a system's ability to accommodate changes in climate?
- Are the systems associated with this planning area already stressed in ways that will limit their ability to accommodate changes in climate?

- Is the rate of projected climate change likely to be faster than the adaptability of the systems in this planning area?
- Are there efforts already underway to address impacts of climate change related to systems in this planning area?

This will provide a qualitative summary of how adaptable the systems in the water sector are to the projected regional impacts of climate change.

1.4.9 Vulnerability Assessment

The findings of the sensitivity and adaptability were used to determine how and where the community is vulnerable to climate change. The vulnerability assessment done was qualitative (high, medium, low). The vulnerability assessment is not static. Existing vulnerabilities that are identified in this assessment can change, and new vulnerabilities can emerge as a result of:

a. climate change impacts on the frequency, intensity, duration, and/or extent of specific climate events;

b. the emergence of new threats, such as the introduction of a new invasive species or disease into the community;

c. new information on how climate change may affect specific systems in planning areas within your community;

d. implementation of preparedness actions;

e. changes in the community's size, economy, preferences, or other factors that can influence a community's vulnerability to climate change.

1.5 Limitations to the Study

Inadequate climate records, limited data availability to facilitate climate modeling and water resources assessment were the main limitations as follows.

1.5.1 Climate Modeling

- Daily values for meteorological data existed for only one station.
- Changes in rainfall and temperature extremes could not be examined and the application of statistical downscaling methods for projections was hampered.
- Data was lacking for relative humidity and wind.
- No sea level data specific to St. Kitts and Nevis was available and therefore data available for the Caribbean was adopted for St. Kitts and Nevis.

1.5.2 Water Resources Assessment

1.5.2.1 Precipitation

This data is available from 1930 to 2005 for the sugar estates. Since the decline in the sugar industry, the data collection has been sporadic and it is mostly laid out in a manner which makes it very difficult to analyse time periods for individual stations. It is understood that the original data set still existed in paper format and was thus difficult to obtain. Most of the readings were collected manually during the period.

The only automatic station is located at the R.LB International airport. Data was missing for 1998 due to malfunctioning equipment as well as hurricane George's in September of that year.

All of the data provided was monthly and annual data. Based on the data collection and storage methods used was difficult and tedious to obtain decadal time spans for daily records and hence analyse catchment response to floods and droughts over any one year.

On collating the data and the analysis periods, several stations within decadal spans had missing monthly data. This affected the water budgeting approach techniques.

1.5.2.2 Basseterre Aquifer & Watershed

Ocean Energy Technologies (OET) (2009) was the consultant tasked to complete the project: *Rehabilitation and Management of the Basseterre Valley as a Protection Measure for the Underlying Aquifer.* Volume 1 of which was the development of a Water Resource Management Plan and volume 2 was the development of the National Park Management Plan.

In 1977 the Basseterre Valley Aquifer was described as a virgin aquifer. In 2009, OET delineated the watershed in order to clarify the geologic stratigraphy of the existing wellfield site. This covered 10 percent of the watershed and overall approximately 15 percent of the watershed has some data available for interpretation.

Because of the above limitation, and the vast area of approximately of 5,230 acres, it was not possible to determine the characteristics (geology and hydrogeology) of the upper portion of the aquifer. This has implications for understanding the dynamics of surface water and groundwater catchment.

Hydrogeology

Limited hydrogeological data stymied the quantification of water resources and thus figures calculated then and now should be used with some care. Values derived are primarily volumetric flow rates since the manner in which the water data is also collected makes it difficult to quantify water resources.

OET (2009) conducted a hydrogeologic model and evaluation of the Basseterre Valley Watershed. Their report indicated that there are significant limitations to the model due to the lack of hydrogeologic data in the upper watershed beyond the limits of the current well field area.

Additional hydrogeologic data collection in the upper watershed will allow for a more accurate modelling solution and water supply projections. It is necessary to define the catchment contributing water to the Basseterre Valley Aquifer, and to define the hydrogeology of the aquifer throughout the watershed.

Previous studies (e.g., Christmas, 1977; Kerr, Preistman & Associates, 1988) provided information on the general geology and hydrogeologic characteristics of the aquifer at the southern part of the watershed based on test drilling, pumping tests of test wells, and computer model simulations. Williams (1999) updated and reworked the Christmas (1977) data to determine if the safe sustained yield predicted by

Christmas (1977) still appeared valid. These early data provided a base from which Ocean Earth Technologies (OET) could ground truth the collected geophysical data and correlate geologic stratigraphy with specific lithologies. None of the early reports; however, had the opportunity to effectively define the entire watershed, aquifer thickness and distribution, aquifer hydrologic characteristics, recharge rates, fresh/salt water interface location, and fluctuations of the groundwater quality distribution throughout the Basseterre Valley Aquifer Watershed.

The existing well field, where the majority of the previous investigations have been focused, occupies less than 10 percent of the Basseterre Valley Aquifer Watershed.

Hydrology

Rainfall intensity values were unrecorded due to the nature of the equipment (i.e. manual vs automatic) the malfunctioning of equipment, and intermittent records.

Rainfall intensity influences the balance between infiltration and run-off, aquifer recharge, and erosion potential and risk. Few data are available on this aspect of the rainfall, but data by Roughton (1981) and quoted by the EP (CCA, 1991) predicted a 10 year storm intensity frequency at 125 mm/hr. Recent experiences of hurricanes in neighbouring islands would suggest that this might be an underestimate, at least during this period of enhanced tropical storm formation. Antigua has experienced rainfall amounts of over 500 mm in about 12 hours during Hurricane Lenny in 1999, and short term rainfall intensities of over 280 mm per hour during Hurricane Omar in 2008 (Cooper, 2008, unpublished data). It is very likely that in S. Kitts rainfall intensities at higher elevations and on steep slopes facing prevailing storm winds would be higher than even these amounts.

This limits the production and investigation of flood data on the catchment and production of a rainfall runoff model.

In addition Evaporation parameters have only been estimated in past reports. These range from 20 to 75 %.

1.5.2.3 Water Budget

“The Safe yield” is the primary term used in St. Kitts and Nevis to quantify water. Safe yield is defined as:

1) The aquifers capability to transmit water from areas of recharge to the points of withdrawal;
2) The amount of water available in the areas of recharge to replace the water that moves to points of withdrawal,
3) The amount of water available from storage as the water level declines.

OET (2009) reported that to establish the Water Crop or Safe Sustained Yield of an aquifer requires the following hydrogeologic information:

1. Delineation of the basin’s hydrologic boundary;
2. Definition of the underlying geology and aquifer units;
3. Determination of aquifer hydrologic parameters of Transmissivity, Storage, porosity, water level elevation, gradient and fluctuation;

4. Soils type, distribution and hydrologic characteristics;
5. Rainfall rate and distribution within the watershed;
6. Topography and geomorphology;
7. Evapotranspiration rates and distribution;
8. Surface water runoff;
9. Groundwater recharge rate;
10. Groundwater withdrawal locations, rates and periodicity.

Of these 10 Safe Sustained Yield parameters, there are five that have well documented data for the Basseterre Valley Aquifer Watershed:

1. Delineation of the watershed basin hydrologic boundary;
2. Topography and geomorphology;
3. Rainfall rate and distribution;
4. Soils type, distribution and hydrologic characteristics;
5. Groundwater withdrawal locations, rates and periodicity.

Of the above values, two variables were documented for water budget calculations: average precipitation and groundwater data. Each is collected on varying time periods or one off values making it difficult to provide correlations and trends.

Based on the data collected, the reduction of water has appeared to be monitored at two time intervals, the first in 1977 and the second in 2009. This doesn't allow for an annual water budget to be determined and therefore presents challenges for creating action strategies on a fully informed basis. It more so presents challenges in determining aquifer characteristics and hinders water management. Infrequent monitoring makes management teams more reactive in their approaches to solving water issues.

1.5.2.4 Model outputs

(OET (2009) stated that due to the fact that the quantitative hydrogeologic information that is currently available is generally located only within the well field, which encompasses approximately 10% of the entire watershed, there may be as much as a 90% error in the model calculations. However, extrapolation procedures and estimates of aquifer properties in this project are based on typical behaviour of groundwater and known geology of the region. The model results can be used as a first order approximation of the dynamics of groundwater in this area.

This means that until further hydrogeological characteristics are defined, the baseline values for water resources studies could remain in the range of -90%≤ x≥ 90 %.

1.5.2.5 Data Management

The data collection techniques and storage also hinder the management and analysis of water resources since continuous time periods are unaccounted for and trends could not be established over long periods.

Based on the previous studies, recommendations will need to be made in order to better improve data management and storage capacity prior to engaging the services of consultants.

1.5.2.6 Geographic Information System

There was no population data in ESRI or similar format to be linked to Hydrology.

There were no properly filled attribute tables within GIS for many layers which hampers the hydrology analysis.

1.5.3 Socioeconomic Assessment

The absence of certain primary and secondary data, as well as data quality issues limited the extent of the socioeconomic assessment.

A better estimate for the population figures and other demographic data specific to the project area (Basseterre Valley East Catchment Basin) would have been made if EDs and census data for were available in GIS format.

In addition, not all the 2011 census data was collated to provide demographic data such as piped water into dwelling. Only population and household numbers were available for 2011. As such, the Consultants had to utilise 2001 estimates for the remaining demographic analysis and this information is a little outdated. Further EDs used to determine the best fit scenario for the project area was a little overestimated based on the shapes of the EDs.

2 BASSETERRE CATCHMENT AREA

The Basseterre Watershed Area as delineated by the Ocean Earth Technologies Consortium (2009) is illustrated in Figure 2.1 below. The Consultants were tasked to conduct a vulnerability and capacity assessment of the Basseterre Catchment. The project area defined by the client represents the East Catchment Basin for this watershed. Figure 2.1 illustrates.

In order to conduct a hydrologically feasible analysis with particular reference to a water budget, data from both the West and East Catchment, which includes Wingfield's water system, were reviewed. (Figure 2.2). Wingfield is approximately 5.5 miles west of Basseterre along the south coast from the project area. Surface water data from Wingfield was utilized because of the interactions between surface and ground water in the two basins and also because of the limitations in available data. Rainfall data, Wingfield surface water data, and well data have been used to complete the water budget assessment.

The project area is largely residential and extends from the hills of St. Peters in the north, to the Frigate Bay Hills in the south. The northern section of the project area is characterized by hilly terrain reaching heights of 470-500m. Moving southwards gentler slopes occur and flat land in some areas. Sugar cane production was the main activity in much of the flat land in the area.

Figure 2.1: Location Map of the Basseterre Catchment Area

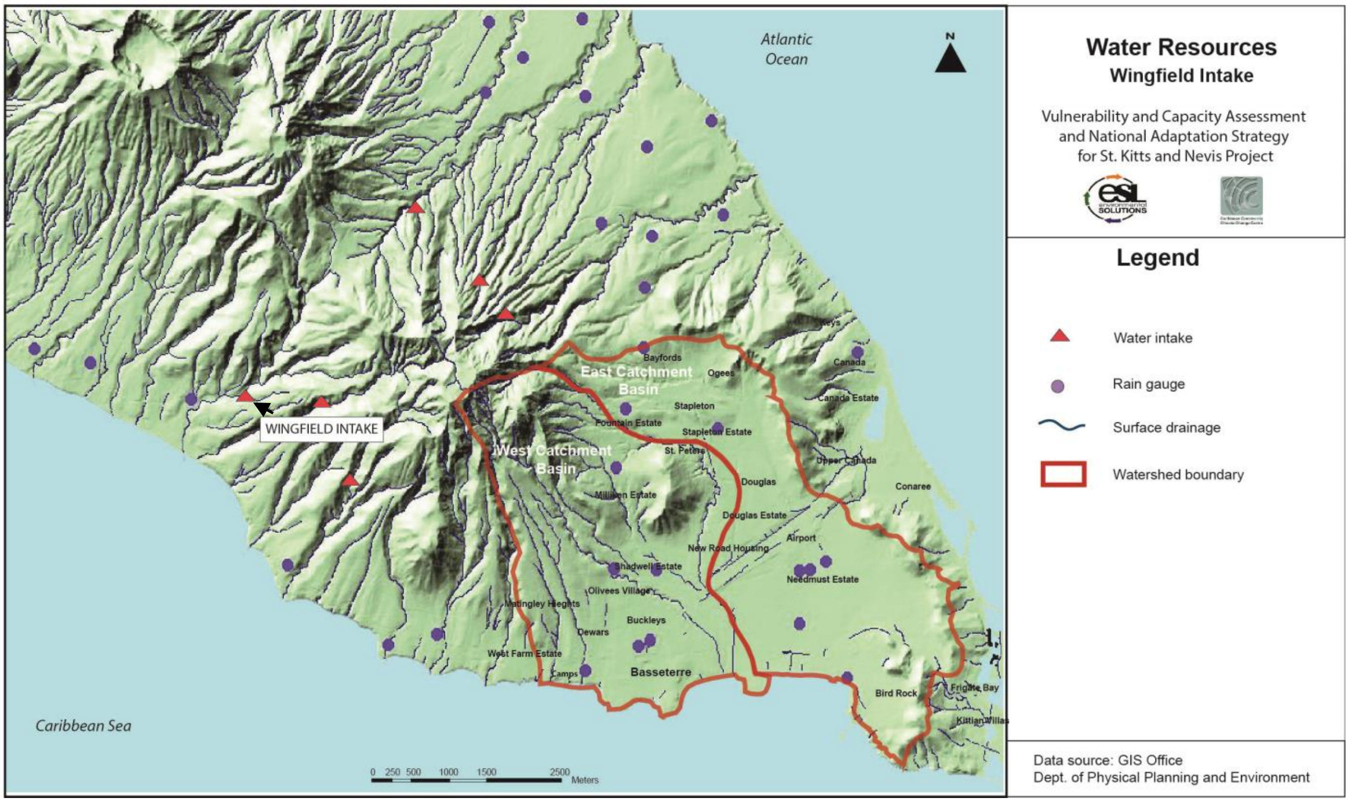

Figure 2.2: Location of Wingfield Water Intake

2.1 Physical Characteristics

The watershed covers an area of 5,230 acres (approx. 21 km^2) and the East Catchment Basin covers approximately 12 km^2. Ocean Earth Technologies (OET) (2009) indicates that the boundary of the Basseterre Valley aquifer is much larger than has been delineated in the past and that area is still unknown (OET, 2009).

The geology of Saint Kitts and its volcanic composition include intrusive igneous rocks, lava flows, and volcaniclastics with limited deposits of calcium, which resembles limestone (ibid) (Figure 2.3).

2.1.1 Geology

Figure 2.3 shows that Basseterre Watershed comprises 4 broad geological groups: recent pyroclastics, andesite dome, south east range volcanics and older volcanics. Further details on the entire watershed have not been determined; however, OET (2009) conducted detailed geological surveys of the Basseterre Valley Aquifer (BVA) delineated in Figure 2.4 below. Figure 2.4 also shows the extensive settlement areas within the project boundary and in close proximity to the aquifer. Drainage features are also evident running off hillsides and through these settlements toward the coast. Some of these drains run alongside main roads and become roadways upon entering the Basseterre capital.

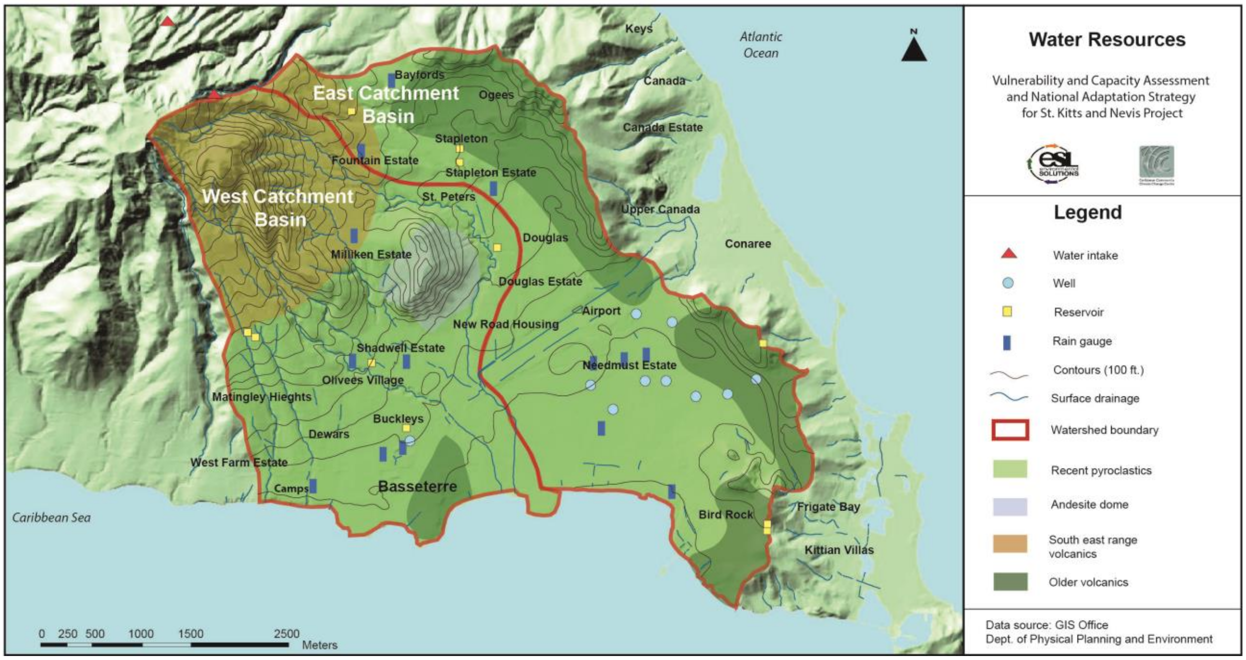

Figure 2.3: Map showing Geology and Water Resources in Basseterre Watershed

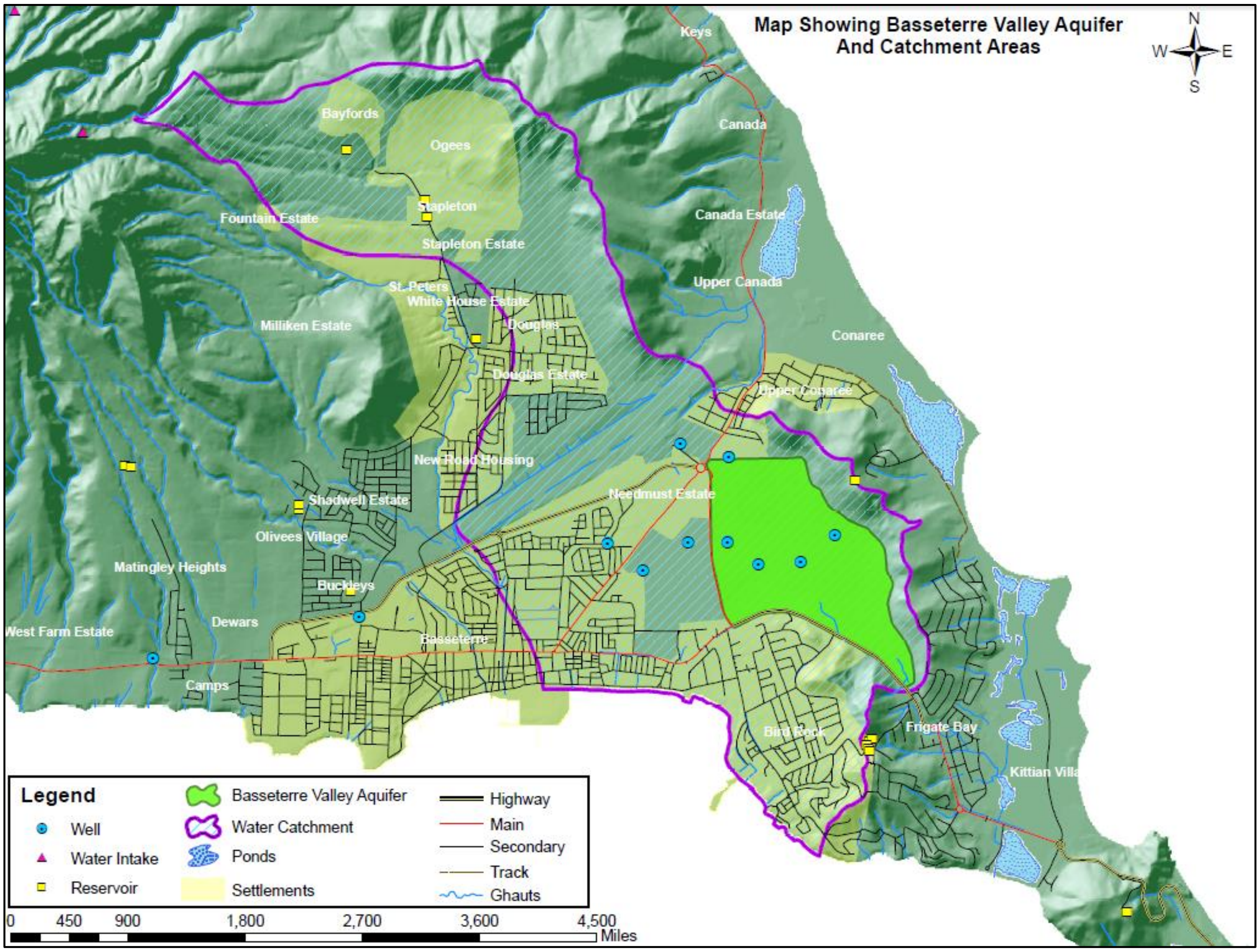

Figure 2.4: Basseterre Valley Aquifer

Of the four broad geological groups described in Figure 2.3, the Basseterre Valley aquifer is made up of two of these: recent pyroclastics and older volcanics. Christmas, 1977 in their geologic descriptions classified older volcanic into two separate units: the Basement Complex (Upper Miocene) and Older Volcanics (Late Pliocene).

The Basement Complex was identified as a pyroxene andesite lava flow. The older Volcanics are largely intrusives and volcaniclastics, including andesites (of varying mineralogy), pyroclastic breccias, mudflows, and epiclastics. All of the andesites are porphyritic.

The Younger Volcanics are a heterolithologic assemblage of rocks that occupy most of the surface geology. These rocks include lava flows, andesitic intrusions, tuffs and lapillistone (pyroclastics), mudflows, pumice, and epiclastic volcanics (Christmas, 1977).

OET (2009) demonstrated from drilling data that the aquifer comprises sand, gravel, and rocks of volcanic origin, located near and below sea level.

Williams (1999) reported that the aquifer is composed of epiclastic volcanics (coarse sands and gravels). Below 30.5 meters in elevation, sediments were reported to be very permeable; however, to the north, from 30.5 to 91.5 meters in elevation, the permeable lava unit was reported to be generally found above the water table. Here, the top of the aquifer is composed of less permeable material.

According to the Ghyben-Herzberg Principle, there is a potential for 37.8 meters (124 feet) of freshwater at this location.

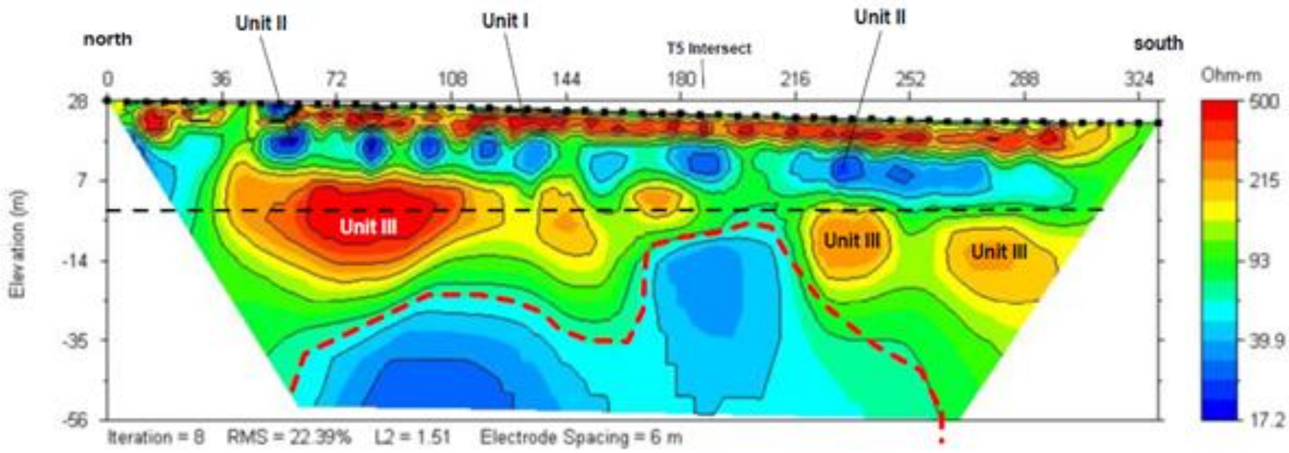

Figure 2.5: Multi-Electrode Electrical Resistivity (MER) Transect A2 Showing Geological Units (OET, 2009)

OET (2009) performed Multi-Electrode Electrical Resistivity (MER) geophysical testing. The results of this MER mapping proved to be an excellent method for delineating the upper parts of the aquifer as well as the depth and variations in the fresh/salt water interface in response to pumping. A summary of the results reported the following;

- **Unit I** is a high resistivity surficial unit of dry sands, clayey sands and volcanic rock detritus (Figure 2.5). Unit I displays an average thickness of 5.5 meters.
- **Unit II:** is an intermixed sand, clay, and rock detritus unit, exhibiting lower resistivity than Unit l. Unit II displays an average thickness of 14 meters.
- The lower resistivity signature of Unit II is due to saturation with freshwater. **Unit II** underlies **Unit I**, and is lithologically similar to **Unit I**. This unit is interpreted to represent gravels, coarse sands, and boulder rocks, and is the water storage unit for the aquifer system.
- **Unit III:** is reported to have a high resistivity strata. Unit III displays an average thickness of 41.5 meters (136 feet) thick; therefore, the entire 41.5 meters (124 feet) of fresh water should be available for mining {1 to 37 meters (3.1 to -121 feet) msl}.
- Video surveys were conducted in two of the water supply wells. These indicate that there may also be a significant quantity of shell or shale material within Unit III. The freshwater saturated portion of this unit has an average thickness of 22 meters.
- The contact of the high resistivity freshwater with the very low resistivity salt water at the base of Unit III maps the fresh/salt water interface across the mapped well-field area.

- The total depth of well 1-48 is 33.5 meters (110 feet) bls (18.4 meters {-60.4 feet} msl), and the screened production interval is from 24.4 to 30.5 meters (80 to 100 feet) bls (-9.3 to - 15.4 meters {-30.4 to -50.4 feet} msl).
- Based on the geophysics, the depth of the saltwater interface below the maximum production interval depth is approximately 14 meters (46 feet).

In summary, OET (2009) concluded that the, the Basseterre Valley Aquifer comprised primarily Unit III relative to its water supply development. Where Unit II extends below mean sea level it may also be included in the Basseterre Valley Aquifer. The majority of the Basseterre municipal wells appear to be withdrawing their water from Unit III. The Phase 1 Geophysical Mapping of the Basseterre Valley Aquifer in 2009 focused only on the acreage proposed for the Liamuiga National Park.

It was highly recommended that the further mapping and test well construction be implemented to delineate the aquifer across the remainder of the well-field area as well as across the remainder of the Basseterre Valley Aquifer Watershed.

2.1.2 Hydrology and Hydrogeology

MER data collected in 2009 indicated that the top of the reservoir unit (Unit III) reported a very good correlation between the stratigraphic interpretation made from the geophysics (i.e., Unit III is the porous reservoir unit) and the groundtruthed hydrogeologic measurement of the water bearing unit.

According to the Ghyben-Herzberg Principle, there is a potential for 37.6 meters of freshwater at this location. The elevation of the bottom of the well screen is at elevation -15.4 meters msl. Based on the geophysics, the depth of the saltwater interface is approximately -36.7 meters msl. If the water level in the aquifer at well 1-48 lowers more than 0.53 meters, there will be a loss of 21.3 meters of fresh water and the well will be pulling in saline water. Well 1-48 has exhibited an increase in TDS concentrations from 1999 to 2009 of approximately 100 mg/l. Data for 1976 was unavailable for this well. This well is showing the early signs of salt water intrusion via upconing beneath the well (OET 2009).

Water flow in an aquifer system is governed by the permeability of material, flow gradient, thickness of the aquifer and hydraulic head or artesian pressure. It is important to know the geologic lithologies and stratigraphy of the aquifer and any confining strata as the geologic character of the sediments or rock control these aquifer characteristics.

In 2009, data was collected by surface geophysics, down-hole geophysics and core drilling. Drilling Test indicated the following Hydrogeological and Hydrological Characteristics of the aquifer:

- The hydraulic parameters of the aquifer as well as the efficiency of the well being pumped were calculated by water level drawdown data.
- The aquifer parameters of Transmissivity (T) and Storage (S) are the key factors to be determined from aquifer pump test.
- Transmissivity is defined at the rate at which water of prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman, 1972).

- The Storage Coefficient is defined as the volume of water released from storage, or taken into storage, per unit of aquifer storage area per unit change in head. In an unconfined aquifer, S, is the same as the Specific Yield of the aquifer and generally ranges between 0.01 and 0.3.
- The Specific Yield of a rock or soil is defined as the ratio of one volume of water which, after being saturated, it will yield by gravity to its own volume.
- In confined aquifers the Storage is the result of compression of the aquifer and expansion of the confined water when the head (pressure) is reduced during pumping and exhibits values between 10^{-5} to 10^{-1} (dimensionless) (OET 2009).

The geological, surface water and groundwater interactions or hydrogeology linking the Basseterre Valley to the upper portion of the watershed needs to be investigated if a holistic approach to water management is to be considered along with vulnerabilities. During the 2009 study only 10 % of the aquifer's hydrogeology was defined. The well field and current water supply system is located in only 15 % of the Basseterre Valley Catchment.

Based on unknown geological and water interactions, past reports could overestimate / underestimate the water budgets because of the unknown geological characteristics of the catchment.

2.2 Socioeconomic Characteristics

The project area includes sections of the parishes of St. Peter, St. George East and St. George West. The communities: Bayfords, Ogees, Fountain and Stapleton in the northern hills which have a mixture of agricultural activities and residential settlements. Fountain and Stapleton were formerly main sugar estates in the area.

Moving southwards residential communities are prevalent. These include: Douglas Hill, Douglas Estate, New Road, John England Village, Upper Monkey Hill and Lower Monkey Hill within the East Catchment Basin project area. Figure 2.7 illustrates many of these settlements. This Basin incorporates the eastern portion of the town of Basseterre, the International Airport, Needmust Estate and the Bird Rock community.

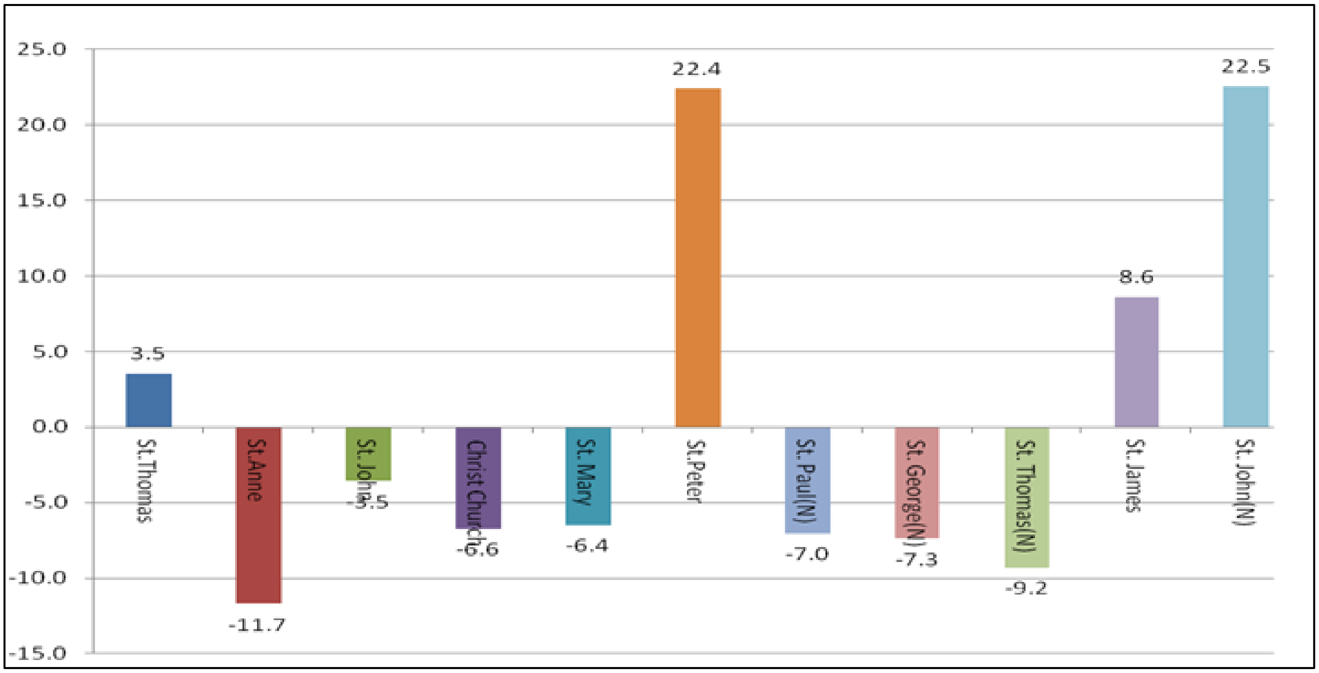

Figure 2.6: Population Growth by Parish

Population decreases were recorded for all parishes with the exception of St. Thomas and St. Peter which recorded growth of 3.5% and 22.4% respectively (Figure 2.6). The population of St. Peter moved from 3,541 in 2001 to 4,335 persons in 2011. It can therefore be said that the population in the project area is growing (Census, 2011).

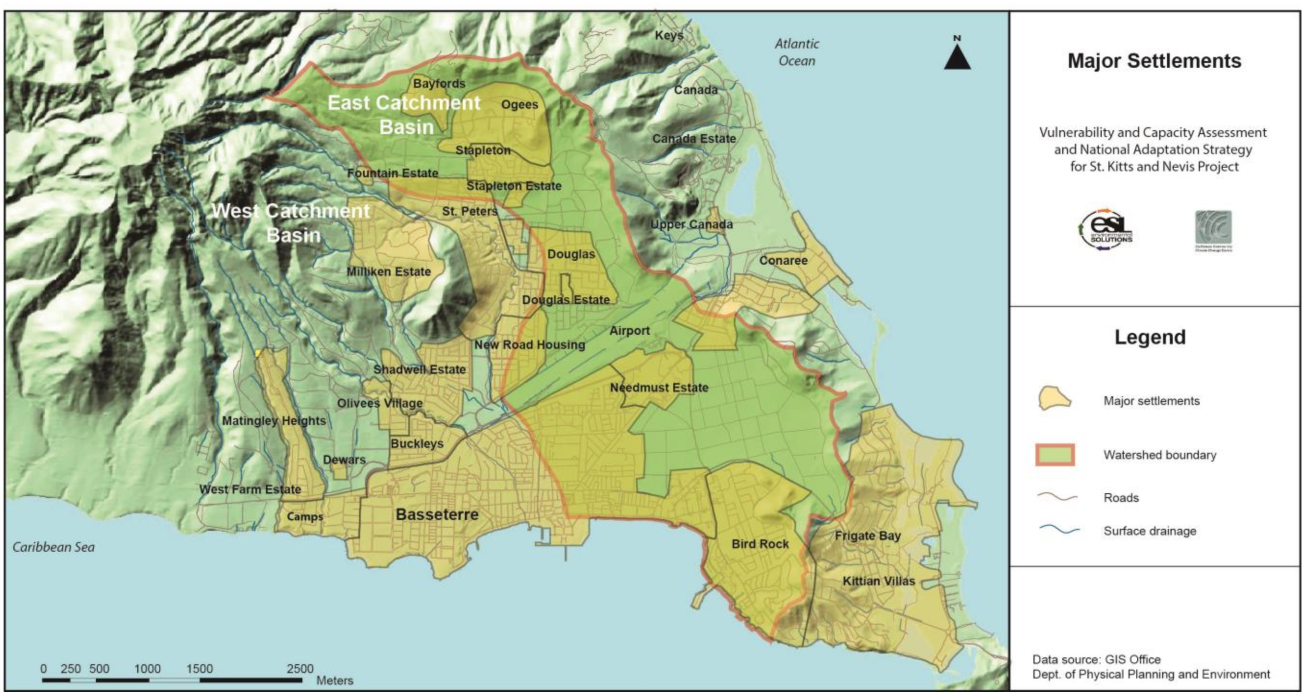

Figure 2.7: Settlements within Basseterre Catchment Area

3 BASSETERRE CLIMATE VARIABILITY AND CHANGE

3.1 Observed Climate and Trends

The climate of St. Kitts and Nevis is typically that of a small tropical island. The combination of its size, location and low-lying topography results in it being strongly influenced by features of the north tropical Atlantic. In the course of a year, the country's climate is strongly modulated by the migration of the north Atlantic subtropical high, the eastward spreading of the tropical Atlantic warm pool, the fairly steady easterly trades, and the passage of tropical waves, depressions, storms and hurricanes. The resulting climate regime is one characterized by a dry winter-wet summer pattern and high and fairly uniform temperatures year-round.

3.1.1 Rainfall

3.1.1.1 Climatology

Observed rainfall data was obtained for the period 1930 to 2006 for 8 stations in the island (see Figure 3.1). Stations were chosen based on the percentage availability of data for the referenced period.

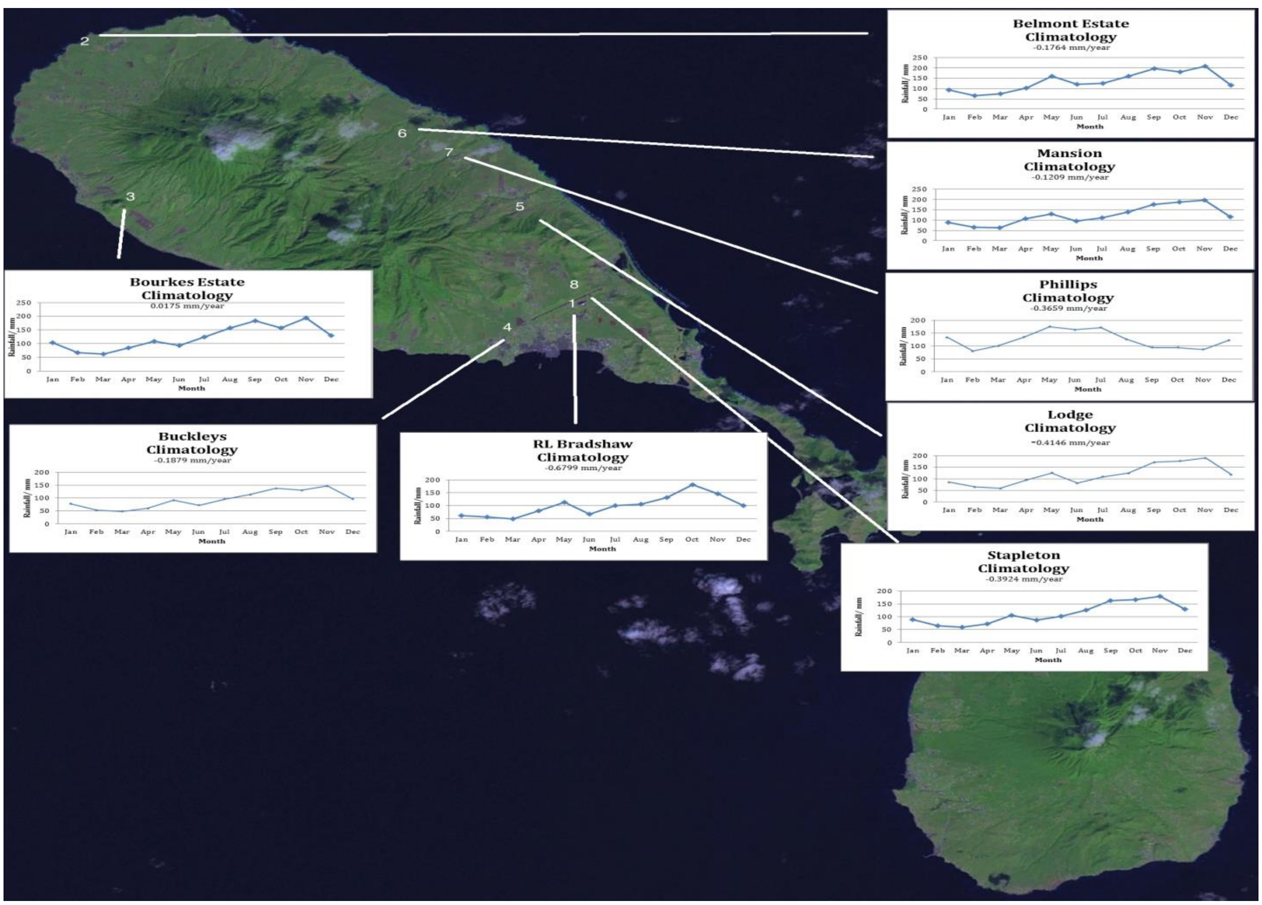

Figure 3.1: Location of stations within the island

The climatology (mean monthly variation for the year) was calculated for each station and these values are given in Table 3.1. The stations - Belmont, Phillips and Mansion - located close to the north coast of

St. Kitts, were found to receive the highest annual average rainfall amounts. The Phillips station had unusually depressed late season rainfall amounts for August – October, in comparison to the other stations. Buckleys and RL Bradshaw, located close to the southeast of the island and within the Basseterre Valley Lower Watershed, received the lowest annual average rainfall. The station at Stapleton is located in the upper Basseterre Valley Watershed and it has the third lowest average rainfall pattern of the eight stations examined.

Table 3.1: Monthly rainfall climatology for stations in St. Kitts and Nevis. Values are in mm

	Stapleton (1930-2006)	**RL Bradshaw** (1980-2014)	**Lodge** (1930-2006)	**Bourkes** (1930-2006)	**Buckleys** (1930-2006)	**Belmont** (1930-2006)	**Mansion** (1930-2006)	**Phillips** (1939-2006)	**Average**
Jan	89.86	61.57	85.51	102.88	77.27	92.22	87.35	134.00	91.33
Feb	65.21	56.90	64.66	66.16	52.92	66.43	64.36	80.37	64.63
Mar	59.90	49.30	59.18	61.43	48.54	74.87	63.42	101.02	64.71
Apr	72.46	80.35	94.06	84.18	60.12	101.96	106.76	134.33	91.78
May	105.89	113.09	124.89	109.08	91.44	160.51	128.91	174.69	126.06
Jun	87.39	67.79	81.62	92.25	72.01	120.72	96.25	163.28	97.66
Jul	102.75	99.41	108.33	124.25	95.79	125.85	110.93	170.98	117.29
Aug	125.66	105.72	124.03	157.00	113.21	160.32	139.99	126.18	131.51
Sep	163.06	131.08	171.46	182.72	137.23	196.82	174.89	94.48	156.47
Oct	166.24	181.88	176.36	157.98	129.69	181.09	187.52	94.30	159.38
Nov	178.44	145.84	188.95	192.97	146.72	208.62	195.69	87.20	168.06
Dec	129.09	100.91	117.53	129.39	96.01	116.52	116.14	122.46	116.01
Average	**112.16**	**99.49**	**116.38**	**121.69**	**93.41**	**133.83**	**122.68**	**123.61**	

(Highlighted stations located in Basseterre Valley Watershed)

Six stations under examination have the same basic rainfall profile for the period, 1930-2006. The figures depict an early season rainfall peak in May, with two minor peaks in the late season rainfall, typically occurring in September and November. It should be noted that, with the inclusion of the RL Bradshaw and Phillips stations, the two minor late season peaks are replaced by one peak in November. However, these stations were not included in the results shown in Figure 3.2, as data was not available for all the years in the referenced period (1930-2006). In general, February and March are shown to be the driest months.

The decadal breakdown, depicted in Figure 3.2 (c) and (d), spans the years 1931-2000, and reveals rainfall bimodality (1940s, 1950s) and tri-modality for all other decades. The bimodal pattern takes the form of two peaks, one in May and another in September; this corresponds to rainfall patterns observed for the Greater Antilles (see Taylor et. al., 2002).

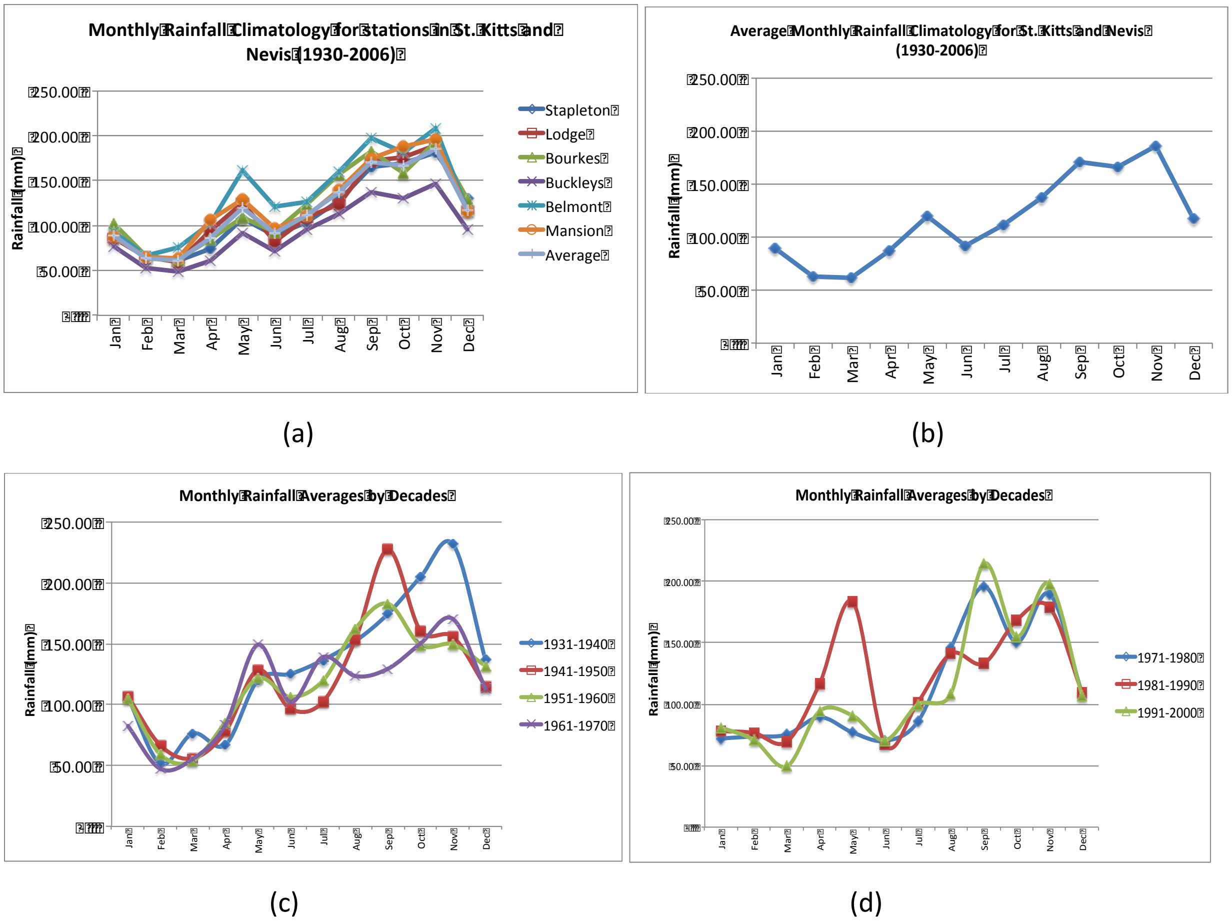

Figure 3.2: Observed Monthly rainfall means in mm (a) for six stations within the study area for the period, 1930-2006 (b) averaged across all stations for the period 1930-2006 (c) decadal averages (1931-1970) and (d) decadal averages (1971-2000)

The tri-modality observed in the decadal analysis deviates from the typical Caribbean rainfall climatological bimodal pattern, which is centred on July. This tri-modal pattern is associated with an initial peak (April-May), a secondary peak (August-September) and a third peak (November). The early season peak for the decadal breakdown tends to occur in May, except for 1971-1980 and 1991-2000. For 1931-1940, there was an additional peak in the early rainfall season as March received more than average rainfall amounts. There is greater variation in the location of the late season peaks for the tri-modal pattern.

3.1.1.2 Seasonality

The eight stations considered were found to have similar rainfall patterns: a dry season ending in March, an early wet season peaking in May and a late rainfall season typically with a maximum in November. Barring the meteorological station, Phillips, September to December accounts for approximately 45% of yearly rainfall totals. Phillips is the only station to have received 50% of its rainfall in the first 6 months and less than 30% in the traditionally more intense rainy period. The percentage contribution of monthly totals to annual rainfall amounts suggests that the seasons over St. Kitts and Nevis may be described as early dry (January-March), early wet (April-June) and late wet (July-December).

3.1.1.3 Recent Trends

Rainfall in the country displays relatively significant interannual variability. Most of the stations revealed a decreasing trend, which is reflected in the annual average.

3.1.2 Temperature

3.1.2.1 Climatology

Observed temperature data was available for only one station (RL Bradshaw) for 1981 to 2007 which is in the Basseterre Valley Watershed. The average monthly maximum and minimum temperature range is approximately 4°C and 5°C, respectively, with temperatures peaking during the summer months. Warmer than normal years may likely be linked to El Nino Southern Oscillation events and the Atlantic beginning of Multidecadal Oscillation (AMO). The 2000s were warmer than the 80s and 90s.

3.1.2.2 Recent Trends

The timeseries of maximum and minimum temperatures show a slightly increasing, but insignificant, trend for the period 1981-2007.

3.1.3 Other Variables

Climatological values for selected climate variables for the period 1980-2013 were observations recorded at the R.L. Bradshaw International Airport. Relative humidity tends to be generally high year round (above 73%) and is highest during the late rainfall season. Wind speeds were found to be highest during the dry period (Jan-Feb) and the summer months (Jun-Aug).

3.1.4 Tropical Cyclones

Tropical cyclone activity in the Caribbean and wider North Atlantic Basin has increased since 1995. Both frequency and duration of hurricanes have increased, as well as the number of intense hurricanes traversing the tropical Atlantic. However, the maximum intensity of hurricanes has remained fairly constant over the recent past. El Niño and La Niña events strongly influence the location and activity of tropical storms. Generally, fewer hurricanes track through the Caribbean during an El Niño and more during a La Niña event.

Hurricanes tend to coincide with incidences of heavy rainfall. For example, the 1990s was shown to be the decade with the highest late season rainfall amounts and the highest number of hurricanes. The period assessed is largely during the low phase of the Atlantic Multi Decadal Oscillation (AMO) with the exception of the late 1990s.

3.1.5 Sea Level Rise

3.1.5.1 Global

Using proxy and instrumental data, it is virtually certain (i.e. with 99-100 probability) that the rate of global mean sea level rise has accelerated during the last two centuries, marking the transition from relatively low rates of change during late Holocene (order tenths of mm yr^{-1}) to modern rates (order mm $year^{-1}$). It is estimated that global sea levels have risen by 0.17 ± 0.05 m over the 20th century. Satellite measurements suggest the rate of rise may have accelerated in recent years to about 3 mm/year since the early 1990s.

3.1.5.2 Caribbean

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

3.1.5.3 St. Kitts and Nevis

No extended datasets exists for mean sea levels off the coasts of St. Kitts and Nevis. However, the nearest possible sea level measurements at Lime Tree, St. Croix in the US Virgin Islands indicate an increasing trend of 2.45 mm yr^{-1} from 1978 to 2013.

3.2 Future Projections

3.2.1 PRECIS RCM Projections

3.2.1.1 Presenting the Model Data

Future climate projections at scales relevant to the small size and complex terrain of St Kitts and Nevis are derived from the PRECIS perturbed physics experiments (PPE). These experiments are at a maximum resolution of 25km and use the A1B SRES scenario as driving conditions. The PPEs, which comprise 17 members (HadCM3Q0-Q16 - otherwise referred to as QUMP ensemble), provide an alternative to using several driving GCM boundary conditions (McSweeney et. al., 2010). Only a subset of 6 - Q0, Q3, Q4, Q10, Q11 and Q14- of the 17 members were selected for the purposes of this study. Jones et. al. (2004) and McSweeney et. al. (2010) provide a full description of the Regional Climate Model (RCM), PRECIS and QUMP ensemble members.

The PRECIS RCM represents the island of St. Kitts and Nevis with 2 grid boxes each, with grid boxes 1 and 2 covering the isle of Nevis and 3 and 4, St. Kitts. These grid boxes form the basis of all the results of temperature (mean, maximum and minimum), precipitation and wind speed detailed in this section. All results cover the following decades: 2020s and 2030s.

3.2.1.2 Minimum Temperature

The mean annual minimum temperature of St Kitts is projected to increase on average by approximately 1 °C for both the 2020s and 2030s. For both the 2020s and the 2030s, the projected increases in mean annual minimum temperatures are higher (lower) for the southern (northern) reaches of St. Kitts.

There is a high degree of consensus as it concerns projected changes to minimum temperature for St. Kitts, as the minimum projected change is greater than 0.6 in all instances. The maximum projected change in minimum temperature is never less than 1°C at both the monthly and seasonal time scales.

3.2.1.3 Maximum Temperature

As was the case with annual minimum temperatures, the projected changes in annual maximum temperature for the southern regions of both islands (Grid boxes 1 and 3) is higher than the projected change associated with the northern extent (respectively Grid boxes 2 and 4). However, unlike the changes in annual minimum temperature, the highest projected changes were not associated with grid box 1 (Nevis), but rather with grid box 3 (St Kitts).

The similarities between the changes in minimum and maximum temperatures also extend to the monthly time scale for the 2020s, with largest projected changes occurring in the latter 3 months of the year; mean projected changes above 1 degree; and a max change of above 2 degrees. Similar results were gleaned for the 2030s, however, the summer months (June, July, August, September) registered the highest projected changes.

3.2.1.4 Mean Temperature

Annual mean temperatures are projected to increase by a minimum of 0.8 degrees or a maximum of approximately 1.75 degrees, over the 2020s and 2030s. The changes however projected for the 2030s are relatively greater than those associated with the 2020s. The maximum change in mean temperature is lower than the maximum changes projected for both maximum and minimum temperature. Again the greatest variations were noted in the summer months, but unlike both maximum and minimum temperature, the largest changes were not confined to just the southern extent. Nevis registered greater changes in its northern extent, whilst southern region of St. Kitts was projected to have slightly higher increases in mean temperature.

3.2.1.5 Wind Speed

The minimum projected changes in wind speed for the 2020s and 2030s are all negative. This means that at minimum, wind speeds are projected to decrease for St Kitts. A similar consensus can be seen when the maximum possible projected change associated with wind speed is examined, as a projected increase was noted for all grid boxes. The minimum changes noted in wind speed were lower for the 2030s when compared to the 2020s; the opposite was true for the changes in possible projected maximum. All the above were true irrespective of time scale (annually, monthly or seasonally).

For the 2030s, the mean wind speed is projected to increase for all areas. This consensus was missing from the 2020s as apart from the southern extent of St Kitts (Grid Box 3) only the month of December was projected to consistently have an increase for Grid Boxes 1, 2 and 4.

3.2.1.6 Rainfall

On the annual scale for both the 2020s and 2030s, the southern extent of St Kitts (Grid 3) is projected to have reductions in rainfall. Reductions range from approximately 6 to 11%for the associated region of St. Kitts. An increase of approximately 25% is evident for northern St. Kitts for both decades.

3.2.2 Results from a Statistical Downscaling Model (SDSM)

The general trend for St. Kitts is an increase in maximum temperature (Tmax) for all the time-slices (i.e. 2020s, 2050s and 2080s). For the JJA period, however, the increase from the baseline is small for all time-slices; a change of 0.3˚C by 2080s for the A2 scenario and 0.2 ˚C for B2. Annual changes include a projected overall increase of 1.6 ˚C for A2 and 1.2˚C for B2 by 2080s. For the short term (2020s), Tmax is expected to increase by 0.5˚C for A2 and 0.6˚C for B2 scenario. For the 2050s, Tmax is expected to increase by 1.0 ˚C for A2 and 0.8˚C for B2.

The overall trend was determined to be an increase in warm days and decrease in cool days for the short term (2020s) and long term (2050s and 2080s) for both A2 and B2 scenarios. This projected future warming is consistent with Campbell et. al., 2011.

Cool days are decreasing and it was most noticeable in the winter (DJF) for St. Kitts for the long term and short term. Hence the most significant warming would take place in the winter season. Cool days had no significant change in the summer (JJA).

3.2.3 SLR Projections

3.2.3.1 Projected Trends

Global and Caribbean

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

Higher projections of sea level rise are noted in the IPCC Fifth Assessment Report (AR5) in comparison to the Fourth Assessment Report (AR5). This is considered to be primarily due to the improved modeling of land-ice contributions. There is also higher confidence in the projections of sea level rise in the latter report due to improved understanding of the components of sea level, improved agreement of process-based models with observations, and the inclusion of ice-sheet dynamical changes. AR5 notes that the basis for higher projections of global mean sea level was considered but it was concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the assess *likely* rate. AR5 notes that sea level rise will not be uniform and indicates that it is *very likely* that sea level will rise in more than about 95% of the ocean area. Approximately 70% of the coastlines worldwide are projection to experience sea level change within 20 % of the global mean sea level change.

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

4 SENSITIVITY ANALYSIS

Sensitivity refers to the degree to which a built, natural or human system is directly or indirectly affected by changes in climate conditions (Center for Science in the Earth System). This section will examine the sensitivity of the Basseterre Catchment area to existing climate conditions as well as potential changes due to climate projections. Section 4.1 below examines the existing status of the water resources and socioeconomic character of the area. Existing and projected climatic factors affecting the vulnerability of the Basseterre Catchment are also discussed.

4.1 Existing Water Sector Issues and Threats in Basseterre

4.1.1 Hydrology and Water Resources

4.1.1.1 Precipitation

Isohyetal Maps were created and used to determine the average areal rainfall over the Basseterre Valley Aquifer (BVA) System (Figure 4.1).

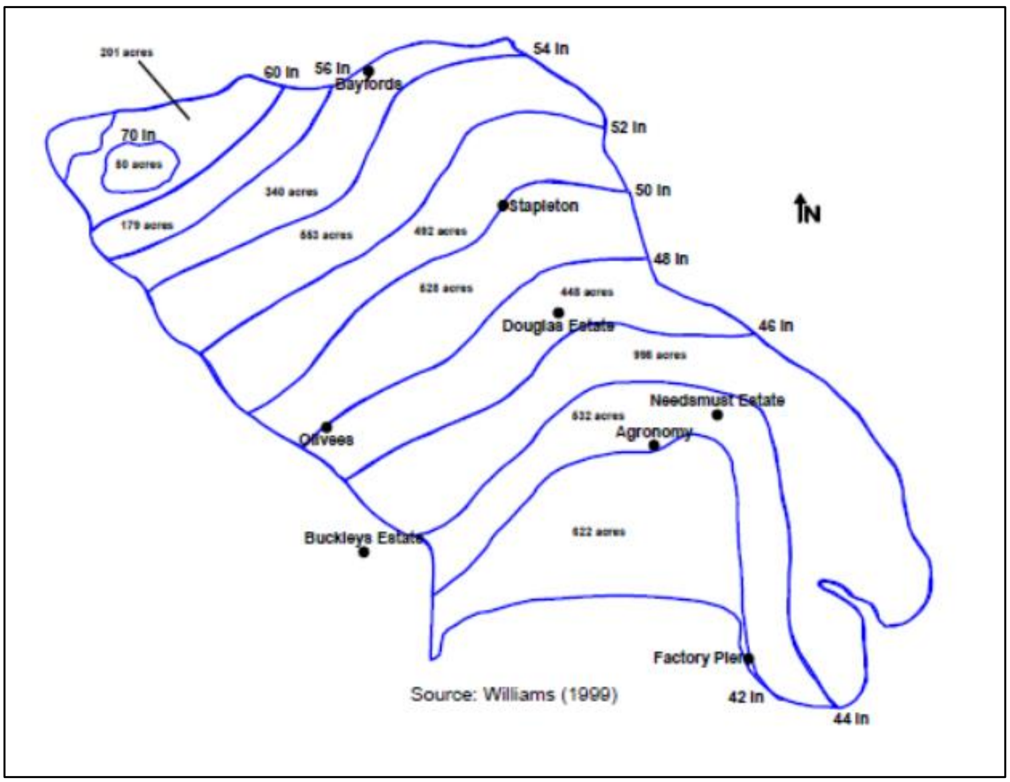

Figure 4.1: Average Annual Rainfall Distribution in the Basseterre Catchment Isohyet map 1980-1998 (Williams 1999 in OET, 2009)

During the period 1990 to 1998 and 1995 to 2005, there was an average rainfall of 52.5 inches across the catchment (Figure 4.2). The areas between the isohyets were improved from 4943 acres in 1999 to 4888 acres in 2009 using more delineation and additional mapping of the catchment.

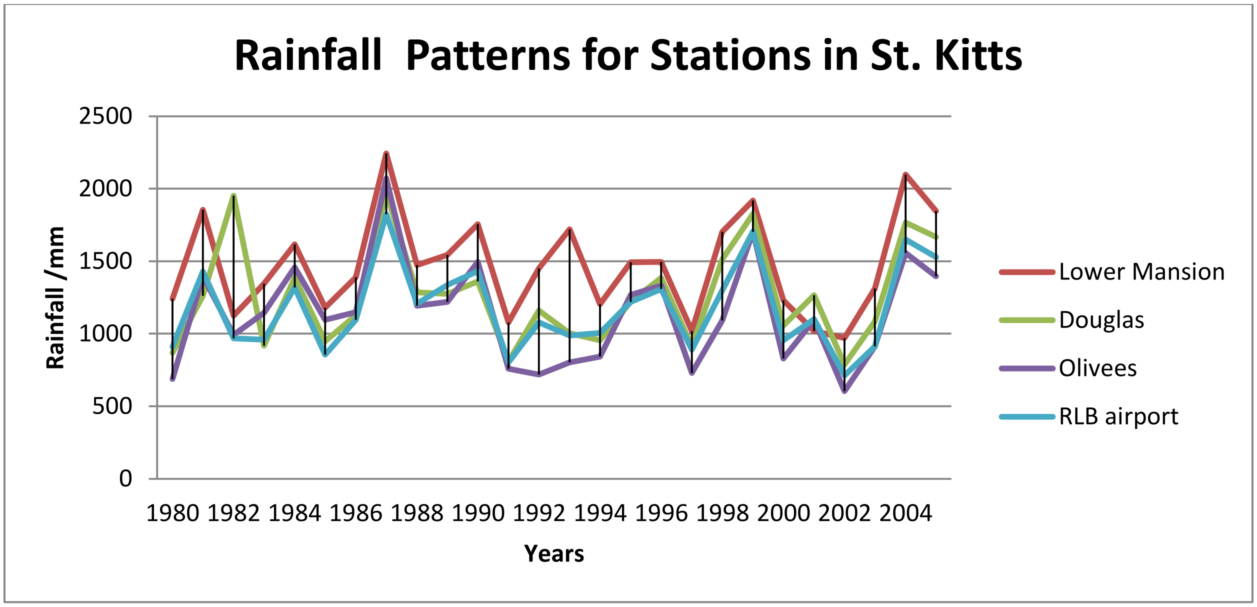

Figure 4.2: Temporal Distribution of Rainfall in Basseterre Catchment (1980-2004)

For the purposes of the water budget and study, rainfall data for the period 1980 to 2004 was obtained from rain gauges on the sugar estate and the R.L.B International Airport. Annual rainfall varies across the catchment from 41 inches in the lower Basseterre valley near the coastline to 70 inches near the mountainous region. Annual rainfall distribution between 1980 and 2004 is illustrated for 4 stations in Figure 4.2. The graph depicts the correlation of rainfall between the lower catchment near the coastline with gauges in the vicinity of the aquifer such as RLB airport, Douglas and Olivees. The Lower Mansion station was included because it was closer to elevations of the other gauges and indicated a good correlation with the North-eastern part of the island and the South-western portion of the island near Basseterre. Where rainfall values were missing at differing locations on the island, other nearby gauges could be used to estimate the values so as to create a synthetic record. It is clear from the graph that rainfall is generally higher toward the north of the Basseterre Catchment and outside of the Catchment area.

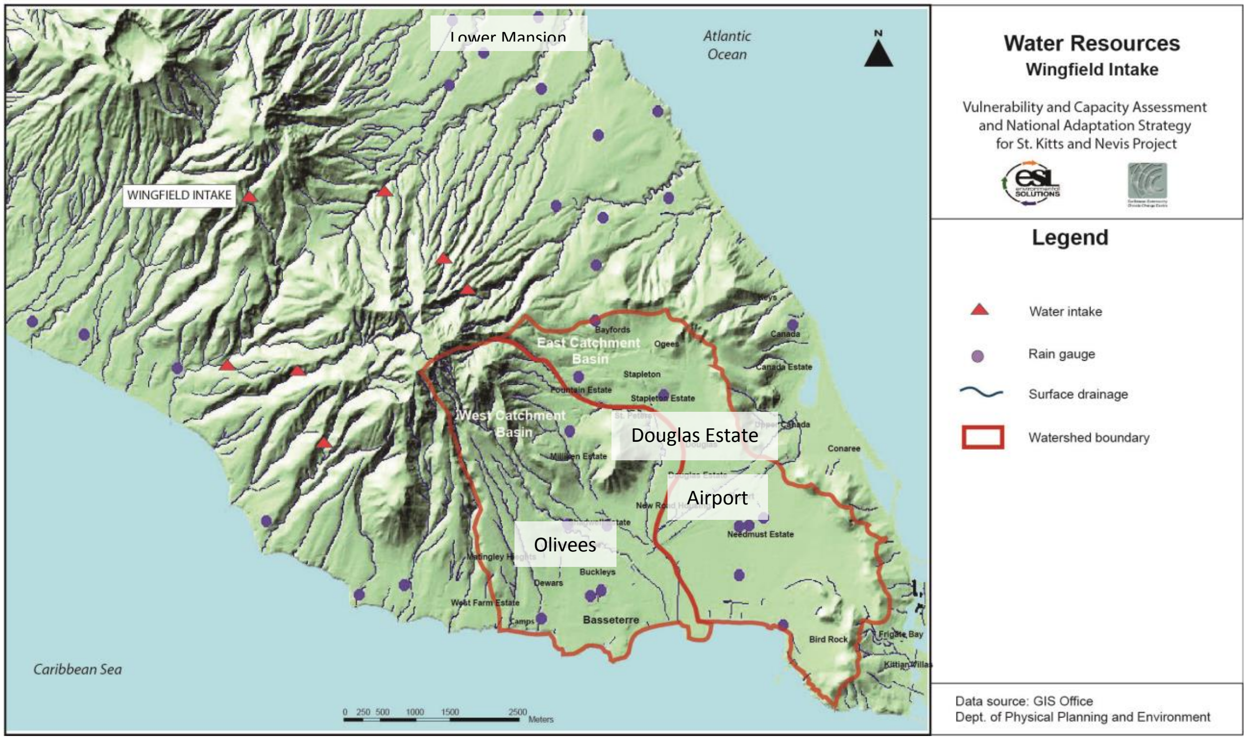

Figure 4.3: Map showing the General Location of the 4 Rain Gauges Used

4.1.1.2 Evapotranspiration and Wind Speed

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration varies regionally and seasonally; during a drought it varies according to weather and wind conditions. Because of these variabilities, water managers who are responsible for planning and adjudicating the distribution of water resources need to have a thorough understanding of the evapotranspiration process, and knowledge about the spatial and temporal rates of evapotranspiration.

Several factors other than the physical characteristics of the water, soil and plant surface also affect the evapotranspiration process. The more important factors include net solar radiation, surface area of open bodies of water, wind speed, density and type of vegetative cover, availability of soil moisture, root depth, reflective land-surface characteristics, and season of year. Assuming that moisture is available, evapotranspiration is dependent primarily on the solar energy available to vaporize the water. Because of the importance of solar energy, evapotranspiration also varies with latitude, season of year, time of day, and cloud cover (Hanson, 1989).

4.1.1.3 Groundwater/ Surface water

The surface water and groundwater catchments are interlinked. The primary recharge sites of the aquifer are located in the upper portion of the catchment within the mountain range.

The groundwater network comprises twenty-two (22) active wells, 10 of which are located within the Basseterre Valley Aquifer (BVA). An average of 62% of the entire water supply in St. Kitts is provided by these wells based on the data received from WSD.

Groundwater monitoring to determine drawdown levels from over pumping and or conditions of drought etc. is conducted by drawdown analysis of each well and limited water quality analysis.

Data available from the WSD for 2009 estimated production of 5.5 million gallons per day (mgd). Data was unavailable for the period 2010 to 2014.

The Water Services Department indicated that the current groundwater production information provided for the period 1995 to 2000 estimated an annual total of 6.6 mgd. Yet, there was an increase in the number of wells during the period 1977 to 2009. In 1988, the original BVA system comprised only 4 wells. By 2009, the number of wells increased to 10 (Table 4.1). In the pre-2004 era, the sugar cane industry influenced the demand and the consumptive patterns. As the sugar industry declined, it is expected that there would have been some decline in the consumptive patterns across the catchment. Sugar Estate records, for water usage, were unavailable during the study. In the post-2004 era, domestic and economic activity influenced the demand and the consumptive patterns.

The increase in number of wells indicates an increase in pumping and hence water usage in the BVA as illustrated in the Table 4.1. This variability in data makes it difficult to make informed decisions based on trends and correlations with catchment characteristics.

Over-pumping and salt water intrusion became characteristic of the aquifer as the number of wells increased, and water yielding capacity decreased. There is also evidence of drier areas of land on the outskirts of the aquifer's boundary. Evidence of animal migration is seen nearer to reservoirs and springs along with changes in vegetation based on the human induced movement of groundwater flow. There is a desire to double water production, but the current status of the BVA system suggests that a scientific basis for management of the resource is imperative.

It is important to note that the aquifer is designated as a national park and no agriculture is permitted within the boundaries illustrated in Figure 2.4.

Table 4.1: List of wells in Basseterre Valley Aquifer System from 1988 to 2009

1988	1990	1991	1995	2000	2005	2006	2009
1- 41	1- 41	1- 41	1- 41	1- 41	1- 41	1- 41	1- 41
1- 44	1- 44	1- 47	1- 47	1- 47	1- 47	1- 47	1- 47
1- 47	1- 47	1- 48	1- 48	1- 48	1- 48	1- 48	1- 48
1- 48	1- 48	Backwash	1- 44	Ponds 1	Ponds 1	Ponds 1	Ponds 1
	Backwash	Conaree	Ponds 1	Ponds 2	Ponds 2	Ponds 2	Ponds 2
			Conaree	Backwash	Ponds 5	Ponds 5	Ponds 5
			R B L	Conaree	Conaree	Conaree	Conaree
			1- 51	R B L	R B L	R B L	R B L

1988	1990	1991	1995	2000	2005	2006	2009
			Taylors	1- 51	1-51	La Guerite (1- 51)	1 -51
				Taylors	Taylors	Taylors	Taylors

Well Construction

OET (2009) field investigations reported the following as it relates to the well constructions of the BVA;

1. The lack of detailed descriptions of the construction of these wells (total depth, cased depth, and screened interval), inconsistencies between available drilling descriptions and observations during field investigation, and the testing methodologies used in past investigations provide only a limited understanding of the true capacity of the aquifer system.
2. Additionally, partial penetration effects associated with some of the wells have not been taken into account. These can have significant effects on the aquifer parameter calculations. Video surveys of several of the production wells showed the screens to be partially plugged with sediment.
3. Additionally, the bottom half of the well screens were observed to be filled of these infiltrating sediments, effectively sealing their production capacity. The Ghyben-Herzberg principle suggests that the aquifer ranges from 30 to over 90 meters in thickness within the well-field area.
4. Water quality data do not necessarily support this range of fresh water thickness. Some of the water level measurements may not be accurate as the monitor wells may be plugged or collapsed and providing erroneous water levels.

Infrastructure (Leakage and Reservoirs)

An additional challenge within the current network is the aged infrastructure. It was reported that that portions of the infrastructure could be at least 80 years or more. Most of the network has been in operation since the 1970's, and newer residential areas are within the last 5, 10 and 15 years. Leakage was evident within the major parts of the network used for storage and distribution of the water to consumers. Figure 4.4 illustrates.

Figure 4.4: Leakage in Distribution Network and in Existing Storage within Reservoirs

For instance, currently, the Conaree reservoir is leaking and the contractors indicated that the required repairs were outside the warranty period and therefore the Water Services Department (WSD) will require substantial investments to aid in the upgrade of the network.

Other issues include the differing types of materials used to construct reservoirs. For example, challenges with fibre glass reservoirs have forced the WSD to phase out of some of the ½ million gallon tanks; this has led to reduced storage.

OET (2009) utilized formulas from AWWA Manual M-36 to estimate annual real loss of water to be in excess of 15,000,000 gallons with further losses due to leakage from excessive pressure, etc., resulting in losses of 10% of annual production or 117,000,000 gallons of water on an annual basis.

Of the amount pumped, the total percentage of usage is uncertain as metering is not consistent throughout the network.

Water Budget

Based on the limitations of the data, there are few methods which could be used. Each of the scientific methods used to estimate groundwater availability has limitations based on the assumptions of the methods and the amount of information for the aquifer. An appropriate method for conducting water balance at this location is demonstrated below based on Williams 1999 and the revised areas provided by the OET's study (See Figure 4.5, Table 4.2 and Table 4.3).

Rain (in/yr)	Average Rain*	Area (acres)	Volume (ft³)	Volume (gallons)
40-42	41	622	92599135	692641533
42-44	43	532	82972181	620631913
44-46	45	998	163044479	121957270 7
46-48	47	448	76490114	572146050
48-50	49	528	93878313	702209778
50-52	51	492	91085297	681318025
52-54	53	553	106483882	796499434
54-56	55	340	67802771	507164727
56-60	58	179	37689197	281915196
60-70	65	201	47412125	354642693
70-	70	50	12753699	95397670
Total Rainfall (M.G/Year):	**652413972 6**			
Average Rainfall (M.G./day):		**17874355**		

Figure 4.5: Water Budget for Catchment by Using Recharge 1980 to 1998 (Williams, 1999 in OET, 2009)

Table 4.2: Available Groundwater based on rainfall during 1995 and 2005

Contour Rain Value	**Average Rainfall (in/yr)**	**Area from figure 20 in acres**	**Area converted to sqft**	**Volume gallons imperial**	**Volume USA/gallons**
40-42	41	388	16901280	359546390	431796465
42-44	43	510	22215600	495653277	595253738
44-46	45	575	25047000	584816624	702334267
46-48	47	560	24393600	594874339	714413059
48-50	49	506	22041360	560384285	672992302
50-52	51	557	24262920	642043897	771061238
52-54	53	645	28096200	772635991	927895533
54-56	55	348	15158880	432594789	519523782
56-60	58	309	13460040	405066030	486463178
60-70	65	442	19253520	649344216	779828541
70	70	48	2090880	75941405	91201667
Average rainfall in/yr	52.45				
Total Area for Basseterre Valley Aquifer Revised acres		4888			
Total Rainfall MG/year				5572901244	6692763770
Total Rainfall MGD				15268223	18336339

(MG- refers to Million Gallo ns and mgd refers to millions gallons per day)

Table 4.3: Comparison of water budgets for 1980 to 1998 and 1995 to 2005

	Rainfall Period 1980 to 1998	**Rainfall Period 1995 to 2005**
Imperial MGD	5424	5573
US MGD	6524	6693

The 18 year average rainfall between 1980 and 1998 contributed 5424 MG imperial gallons or 6524 MG (US gallons) or 14.88 or 17.87 MGD (Table 4.4). The average rainfall was considered to be 1.24 or 1.48 MGD annually.

The 10 year average rainfall between 1995 and 2005 contributed 5573 MG imperial gallons or 6693 MG (US gallons) or 15.27 or 18.34 MGD (Table 4.4). The average rainfall was considered to be 1.27 or 1.53 MGD annually.

It is estimated that the average potable water supplied to Saint Kitts by the BVA during the 18 year period was 3.91 MGD. This is 17 or 14 % of the current available resource.

Table 4.4: Percentage of Water Supply Used to Available Water Resources

	Water Production Data Average over rainfall period / MGD	**Groundwater Available /US MGD**	**Groundwater Available /UK MGD**	**Percentage of Water Supply used/ US units**	**Percentage of Water Supply used/UK units**
18 year rainfall period 1980 - 1998	2.60	17.87	14.88	15%	17%
10 year rainfall 1995 - 2005	3.91	15.27	18.34	26%	21%

There was an increase in 169 MGD between the 1980 to 1998 and 1995 to 2005.

Evaporation is not accounted for in the calculation. However, evaporation is considered between 20 and 79 % in previous studies. A third method may be used to identify evaporation by utilising the airport values if the universal pan is operational at the RLB airport.

Thus the water budget’s past percentages could be amended.

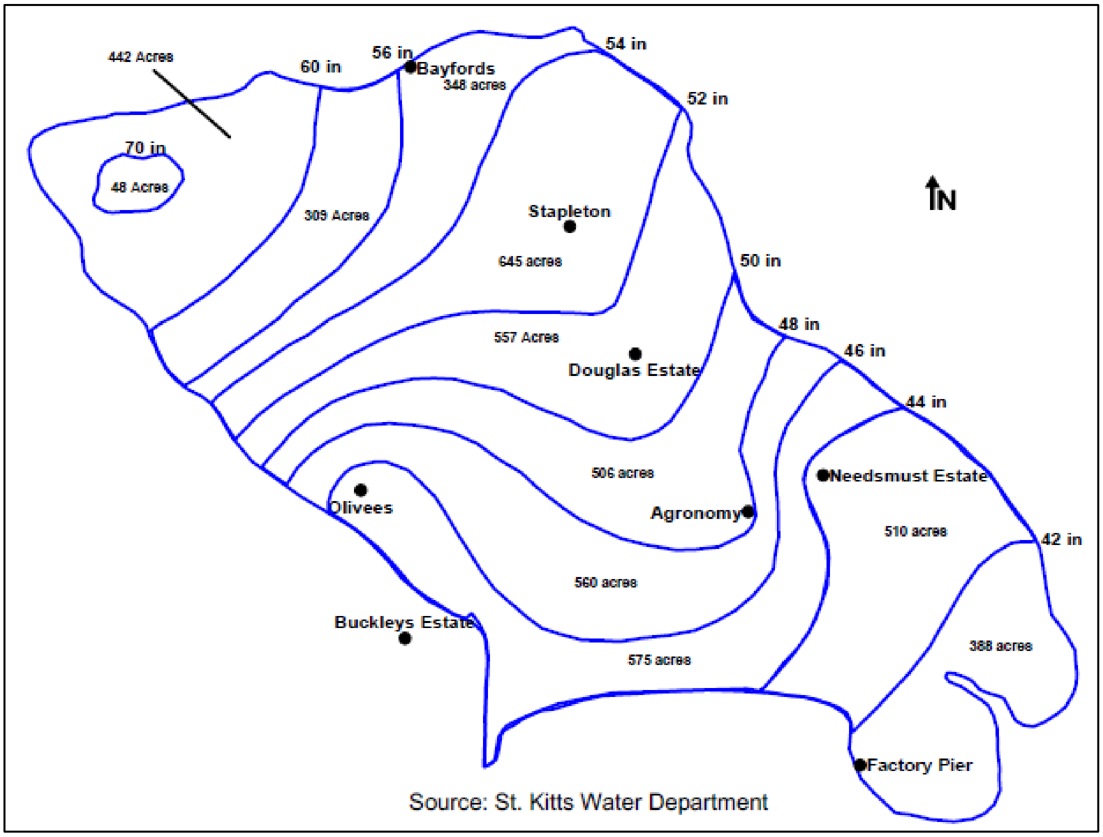

Figure 4.6: Average Annual Rainfall Distribution Basseterre Valley 1995-2005

Determination of Run off from Water Budget

The Penmad Monteith methodology was utilised to calculate evapotranspiration. Appendix III presents further details on this method.

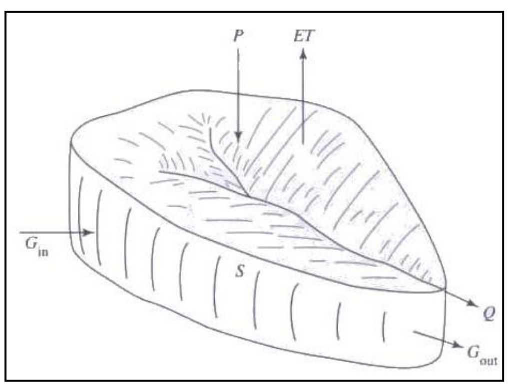

Figure 4.7: Diagram showing the location of Measured Variables within a Watershed (Dingman 2nd Edition, 2008)

Currently Groundwater monitoring is ad hoc and therefore the parameter could not be adequately accounted for during the full short term water balance/ long term balance. However, an assumption of the long term water balance over an annual period stipulates that G_{in} - G_{out} are assumed to be negligible and that:

$$I - O = \frac{\Delta S}{\Delta t}$$

Where

I – Inputs , O – outputs

$\frac{\Delta S}{\Delta t}$ - change in storage / change in time

$$\Delta S = P + G_{in} - (Q + ET + G_{out})$$

$$P = ET + Q$$

Measured variables

P – Precipitation

ET – Evapo-transpiration by utilising measured meteorological variables

G_{in} - G_{out} – unmeasured values. Assumed zero over long term budgets

$\frac{\Delta S}{\Delta t}$ – often difficult to obtain. The change in storage / change in time is assumed zero over long term budgets from lakes, groundwater and streams/rivers

n – accounts for any discrepancies in quantities

For future reference, the listed parameters above will need to be measured by the methods stated in recommendations of the National Adaptation Strategy and Action Plan so that the balance would be improved on an annual basis and on a 6 month basis instead of the 10 year / 18 year average.

From the results of the model, the meteorological variable which resembles the closest pattern to evapotranspiration is that of wind speed. In most cases, the higher the wind speed is in conjunction with other meteorological parameters, which contribute to hot /warm days, the more evapotranspiration occurs over the point of interest. The evapotranspiration is illustrated below in Figure 4.8.

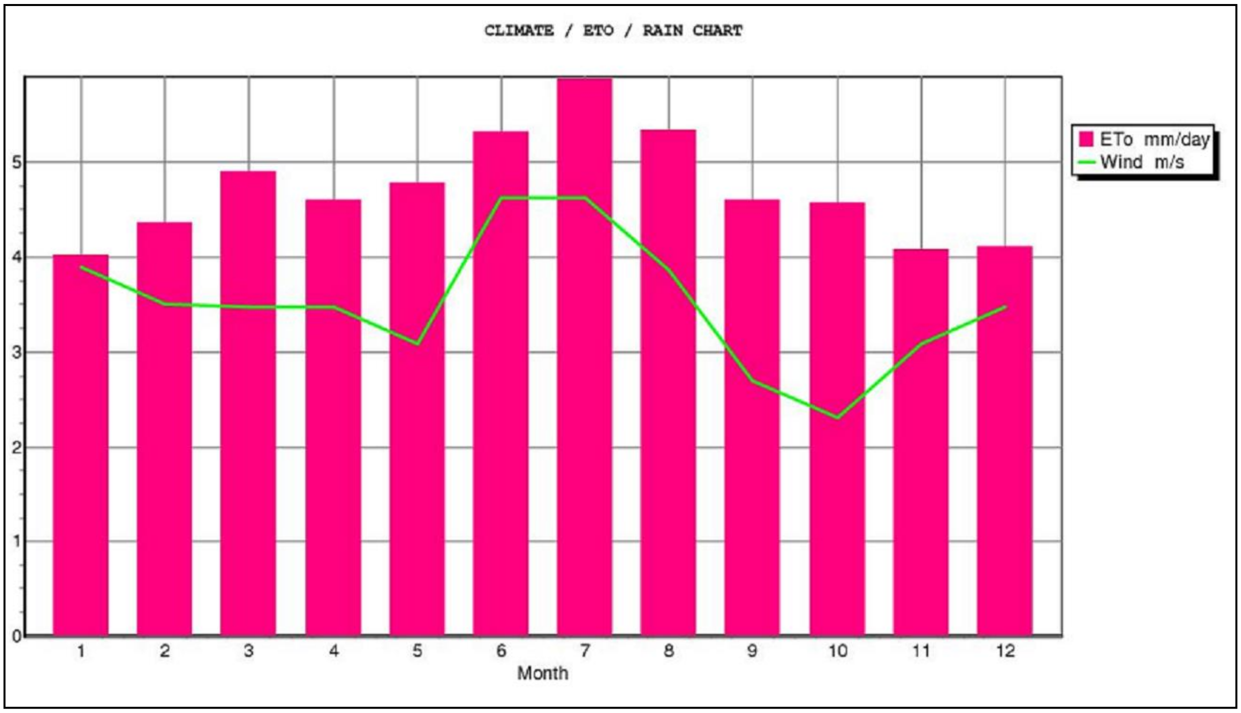

Figure 4.8: Evapo-transpiration values for the year 2000

Final Representation of Water Budget

Final representation of 10 year long term water budget

$P - ET = Q$

	Avg Precipitation P / inches	Area	Avg P/ feet	Area	Volume gallons imperial	Volume USA/gallons
Volumetric Precipitation,P	52.5	4888	4.37	4888	5.7945E+09	6.9589E+09
Volumetric Evapotranspiration, ET	5.9	2965	5.91	2965	4.7509E+09	5.7056E+09
	Volume in imperial units	**Volume in metric units**				
Avg P MGD/year	15.88	19.07				
Avg ET MGD/year	13.02	15.63				
P-E=Q	2.86	3.43				

Figure 4.9: Revised Water Bugdet based on data from 2000

Q- signifies the 10 year average runoff for the catchment, Runoff Depth in the Catchment produces 2.86 MGD from approximately an average of 240 mm annually.

Water levels and current status of the Basseterre Valley

A trend of declining static water levels was observed in the Basseterre Well field. The decline is observed from 1.5 feet to > 2 feet according to data extending back to 1970s. There is an increased decline between 1999 and 2009 as a consequence of increased groundwater abstractions (OET, 2009). The Basseterre Valley Aquifer system is not homogenous and currently the past geological investigations have only been able to determine approximately less than 10 percent of the valley. This means that hydrological, hydrogeological and geological characteristics still have many gaps and hinders the accuracy of the water balance calculations.

Groundwater Level Fluctuations

There are temporal changes in water level elevations from five water supply wells (1-48, 1-47, 1-41, Ponds 1, and Ponds 2). Measured static water levels in production wells along a west to east transect across the SE Basseterre Valley are displayed in Figure 4.7 (OET 2009).

While this is not a high-resolution record through time, there is a clear declining trend in static water levels relative to sea-level seen in each of the five wells illustrated in Figure 4.10.

The average decline in water level is on the order of 1.64 to 0.46 meters from 1980 to 1999. Since 1999 groundwater levels within the well-field have declined more than 0.6 meters for wells 1-47 and 1-41. These wells have been in production since the 1970's. Well 1-41 has declined by approximately 1 meter during this same time period. The most dramatic water level declines occur during the period 1999 to 2009. This indicates that dewatering of the aquifer has increased in response to increased well withdrawals (Figure 4.10). Note that the average annual rainfall for this same time period (Table 4.3) has shown an increase over the previous 10 years of record. The water levels also slope nearly 0.61 meters from the west side of the well-field to the east side. These declines indicate that the long term water withdrawals from the Basseterre Valley Aquifer Well-field are gradually dewatering the aquifer in this area, with the concentration of dewatering taking place in the eastern part of the well-field. The continued dewatering of the well-field will induce salt water intrusion. With these measurements, OET estimated that with the current rate of water level decline (approximately 0.6 meters over the past 10 years); the well-field, may require abandonment within 5 to 7 years.

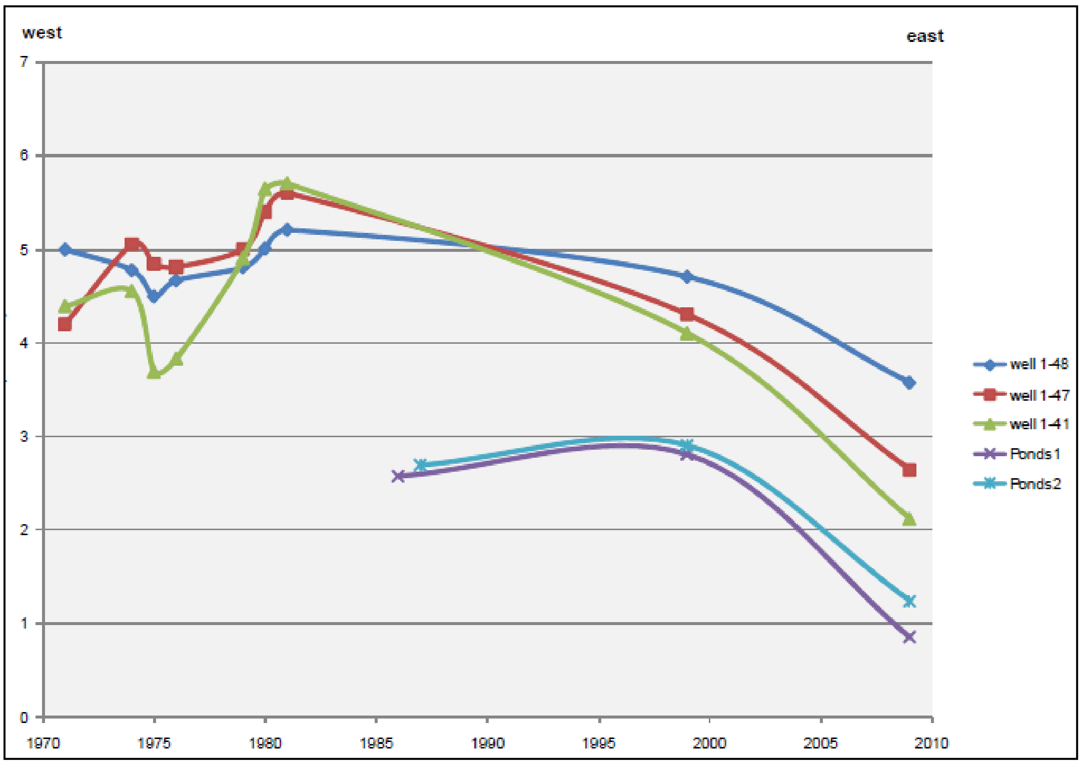

Figure 4.10: Water Table Fluctuations of Wells in Basseterre Valley (OET, 2009)

4.1.2 Water Quality

4.1.2.1 Temperature

Investigations of the water quality data revealed the lack of series information required for the study. However, it verified that testing was sporadic and continuous monitoring was required. Future studies should be commissioned in order to have a greater understanding of water quality.

The current data is collected on a monthly basis from various wells. The data set was available for one sampling event conducted in 1976 and one sampling event conducted in 1999. The well at Conaree was only sampled in 1986. These are reflected in the graph.

There is not enough detail to indicate the seasonal variations in temperature of the water. Based on this data it ranges from 28.9^{0}C to 32^{0}C. Temperature is a good indicator of the surface soil temperature and it is also important to determine the rate of chemical reactions occurring subsurface i.e. within the geo-chemistry of aquifer particularly that related to volcanic aquifers such as Saint Kitts and Nevis. Temperature is related to the dissolved-oxygen concentration in water, which is very important to all aquatic life (Barlow, 2003).

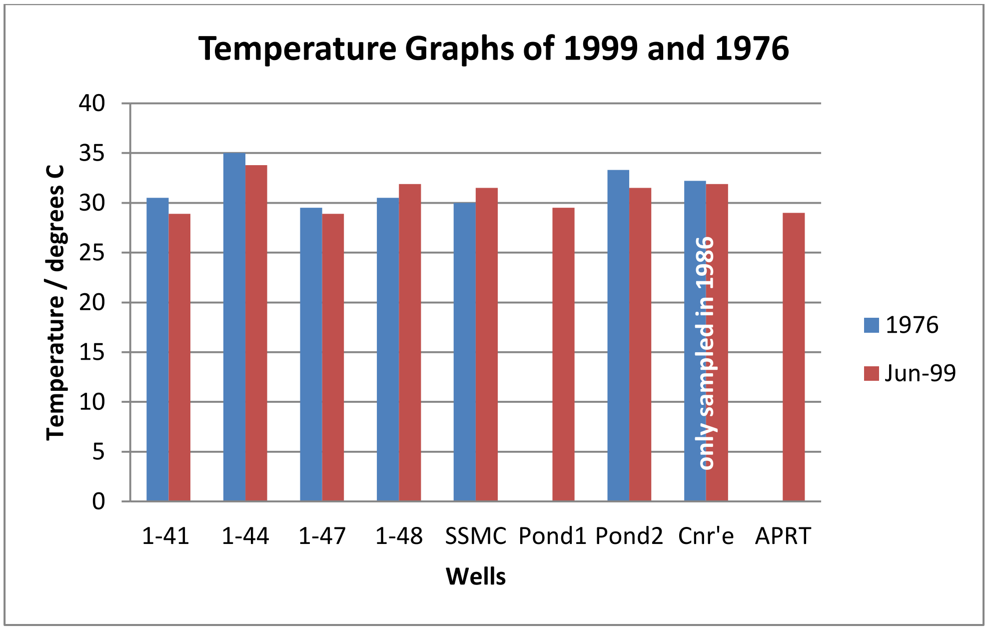

Figure 4.11: Temperature of Groundwater Trends

Changes in vegetation cover can result from changes in temperature and precipitation and as a consequent changes in management of land resources (Climate Institute, 2010). With the proposed developments to increase economic activity it is projected that the catchment will become more vulnerable to climate change impacts of increased temperature from more impermeable surfaces become apparent. In addition, increased erosion will occur with increased runoff.

The latter also has other spin offs resulting from displacement of soil water moisture and the downward movement of water to the aquifer. Should drought conditions worsen concentrations of water quality parameters will increase, additionally, because chemicals in rock are unknown, during less rainfall periods there would be need for greater treatment for potable.

Parameters in Wells

The American Groundwater trust (2003) states that "*The pH of ground water will vary depending on the composition of the rocks and sediments that surround the travel pathway of the recharge water infiltrating to the ground water. Ground water chemistry will also vary depending on how long the* *existing ground water is in contact with a particular rock*." This has greater concern for the existing construction material and future material used to maintain the well casings to pump groundwater as acidity in drinking water leads to more expensive construction of well fields. High acidity can dissolve lead or copper that may be in plumbing pipes and fixtures unless water infiltrates and replenishes the aquifer at a faster rate than pumping.

With the increased dewatering of the aquifer and high temperatures being experienced, minerals are becoming more dissolved in the water and altering its chemistry. High temperatures often increase the rate of reaction and with climate change projections this can adversely impact the aesthetics and corrosion of well casings. These disadvantages will require more expensive treatment and maintenance of physical structures which are in constant contact with water.

As mentioned, time series analysis was not possible during the study and thus annual variations were unlikely, due to the quality of data. However, the data does indicate an increased presence of ions. These include: Magnesium, Calcium, Sodium, Silicon Dioxide and bicarbonate which are dissolved in the groundwater as illustrated in Figure 4.12. Williams (1999) concluded that no significant negative effects were observed in groundwater quality from 1977 to 1999, but chloride and nitrate concentrations increased, and continual well monitoring was recommended. The data suggested that these ions are still increasing in concentration within the aquifer.

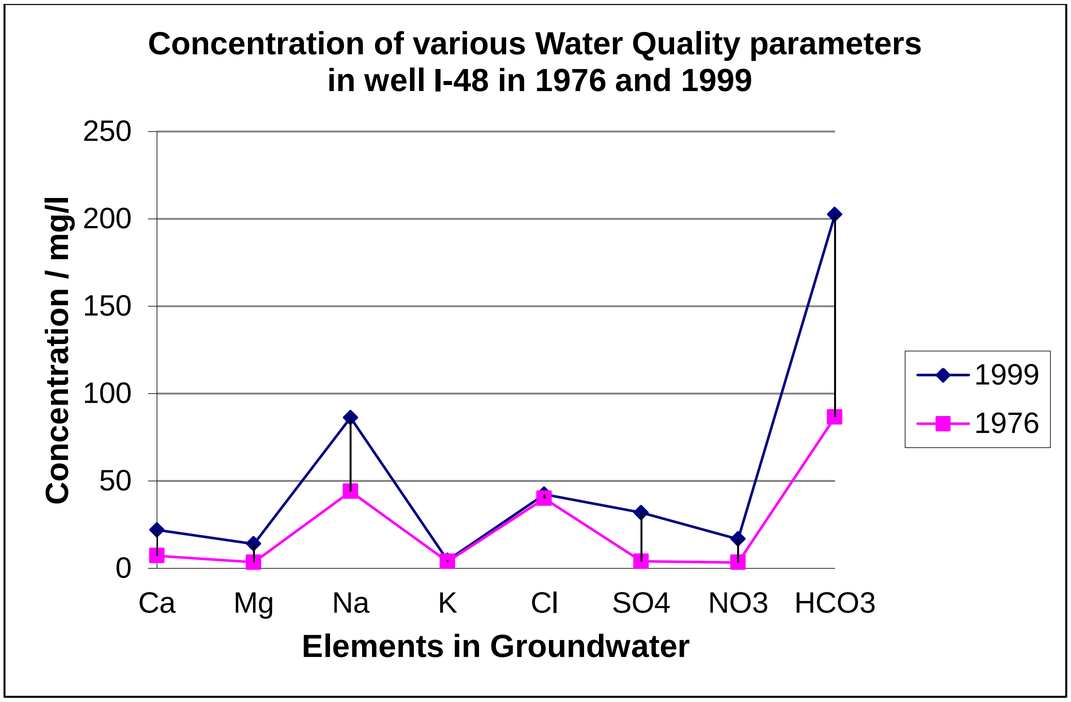

Figure 4.12: Concentration of Various Water Quality Parameters in Well I-48 in 1976 and 1999

Salt Water Intrusion

With this continued dewatering, the aquifer will lead to increased areas of salt water intrusion and declining potable water quality within the well field. Three zones of salt water were identified in 2009 and this stands to increase as the projected water demand will place further strain on the aquifer.

The close proximity of the salt water interface to the pumping level of the water supply wells within the well-field is evident.

OET (2009) reported that the early stages of saltwater intrusion have been documented in three separate locations within the Basseterre Valley Aquifer well-field, necessitating the rapid implementation of a detailed fresh/saltwater interface monitoring program, delineation of the remainder of the well-field area as well as the entire upper watershed.

A new well-field needs to be constructed to the north of the airport, and the existing well-field needs to be operated to minimize long term drawdowns in wells. The construction of the fresh/saltwater interface monitoring network will be required to manage the well-field withdrawals effectively.

4.1.3 Assessment of Existing Water Usage, Demand and Supply

Potable water supply for Saint Kitts is provided by the BVA. The water budget above provides the available water resources and the current levels of consumption are provided below in Figure 4.13.

The average water production for the period 1980 to 1998 by pumping was 2.66 mgd. The total water demand based on the data can be derived by the equation below. The regression coefficient of correlation R^2 represents a good representation of the data after completion of statistical analysis was 96%.

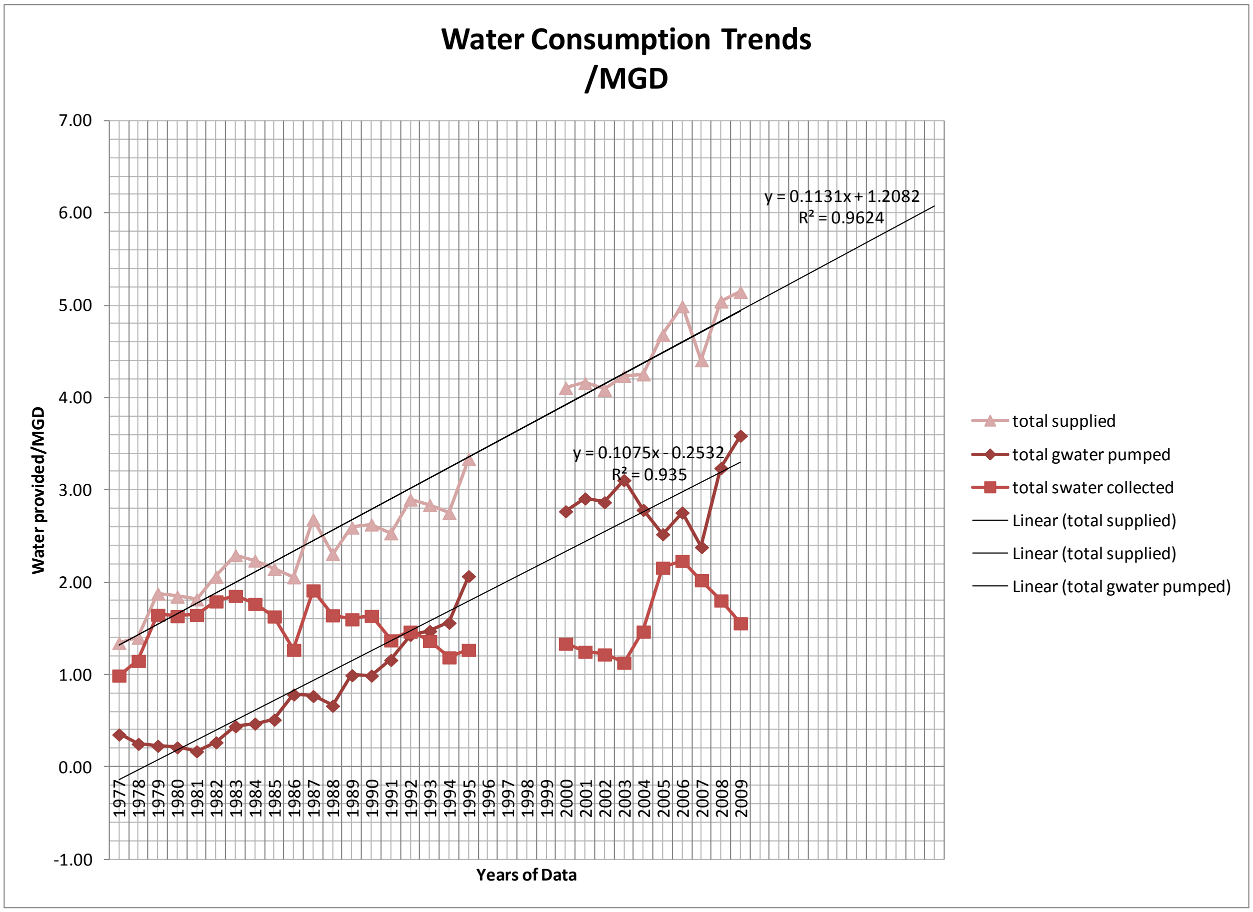

Figure 4.13: 1977 to 2009 water data from the Water Services Department (Groundwater, surface water and total pumped to public)

The data in Figure 4.13 represents the total water usage. Water consumption data is a good indicator of projecting the demand. It is essential that the data be linked to the unaccounted for water, the per person usage and industry usage in order to better understand and implement best practices for watershed management. The current data could drastically overestimate the future projections.

Total 000 gals	total pumped MGD
1977	1.34
1978	1.40
1979	1.88
1980	1.85
1981	1.82
1982	2.06
1983	2.30
1984	2.24
1985	2.14
1986	2.06
1987	2.68
1988	2.31
1989	2.60
1990	2.63
1991	2.53
1992	2.90
1993	2.84
1994	2.75
1995	3.34
1996	3.3544
1997	3.4674
1998	3.5804
1999	3.6934

Estimated by Graph 1996 to 1999

Figure 4.14: Trend in Water Consumption Related to Figure 4.10

$$y = 0.1131x + 1.2082$$
$$R^2 = 0.9624$$

Table 4.5 below demonstrates the composition of the water supply between 2000 and 2009.

Table 4.5: Composition of Water Supply

	% of Water Supply	
Year	SURFACE	GROUND
2000	33	67
2001	30	70
2002	30	70
2003	27	73
2004	35	65
2005	46	54
2006	50	50
2007	51	49
2008	42	58
2009	36	64

The questions which will need to be answered by future studies are illustrated in the conceptual model so that the resource could be better managed.

The Water Services Department (WSD) has commenced a billing system which could facilitate future sectoral analysis. However, this was introduced approximately two (2) years ago and was insufficient to be used for this study. Prior to this, the WSD shared a system with the Electricity Department and therefore historical sector consumption data was not available for water usage, demand and supply. Water production values recorded at well heads and surface water catchment points (extraction points) have been used as consumption values.

Table 4.4, Figure 4.13 and Figure 4.14 show relative groundwater and surface water supply of potable water in Saint Kitts. Water production is currently between 15 to 26 % of the current available resource. Runoff, evapo-transpiration and leakages are currently unaccounted for and these need to be taken into consideration so that better estimates can be given of the available water resource. Significant leakages were observed within the supply network, and these considerable losses can be controlled through corrective action.

Internationally, businesses such as: manufacturing drink companies and tourism utilise high volumes of water. Therefore, metering is essential so that the appropriate measures to promote water conservation and better determine usage and demand can be implemented.

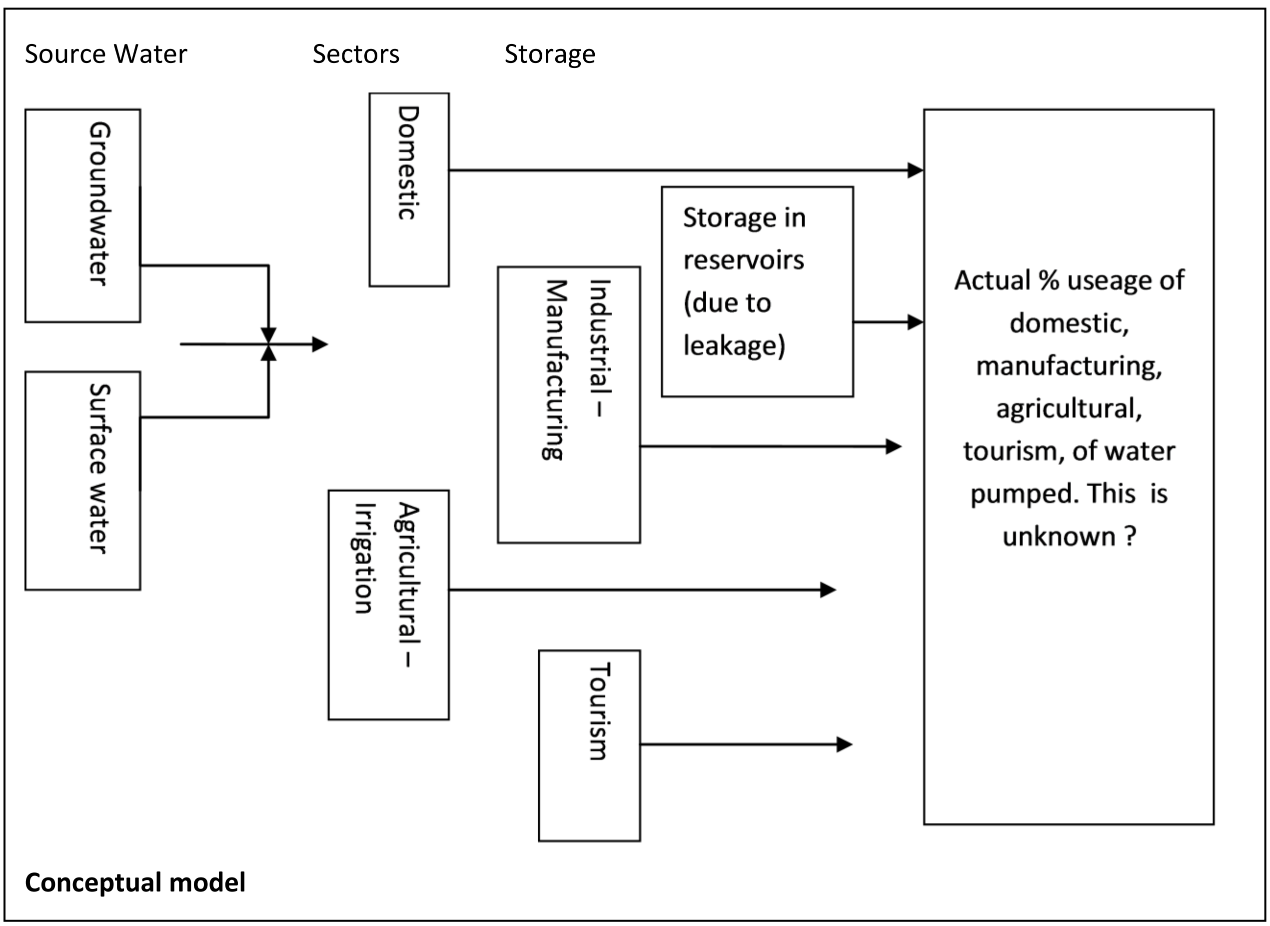

Figure 4.15: Conceptual Model

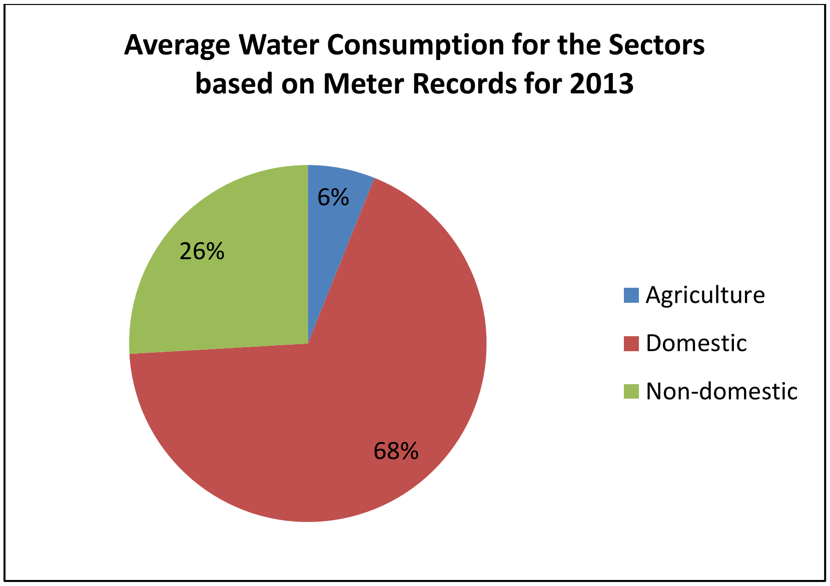

Figure 4.16: 2013 Average Water Consumption for the Sectors based on WSD Meter Records

The St. Kitts Water Services Department (WSD) commenced metering by sector in 2013. Disaggregated historical consumption data was not readily available for analysis. The 2013 consumption data indicated that domestic consumers have the greatest demand (Figure 4.16). Agriculture is rainfed and as shown in Figure 4.16 only 6% of consumption is taken for the agriculture sector.

4.1.4 Existing Climatic Threats

4.1.4.1 Drought

The Basseterre aquifer is the main aquifer in St. Kitts. It is largely coastal and as noted above is being pumped without continuous monitoring of the hydrological parameters. As a result of this predisposing factor, drought conditions will reduce freshwater interface lens and allow further saltwater intrusion.

In addition, prolonged drought conditions can lead to further reductions in water quality within the aquifer because there will be higher concentrations of salt/ deposition of other ions. The removal of these ions will result in higher drinking water treatment costs. However, once salt water intrudes coastal aquifers it primarily destroys mechanical equipment, such as, pumps leading to the abandonment of the investment. Salt water intrusion will also affect the other parts of the aquifer as the up-coning rises. Alternative sources such as desalination may have to be considered. Desalination is associated with high energy cost and therefore models that use renewable energy need to be explored and replicated.

4.1.4.2 Flooding

The Inland Flood Hazard Assessment and Mapping for St. Kitts and Nevis (2001) stated that soils in St. Kitts are shallow and therefore only limited amounts of rainfall can be stored. Shallow soils also contribute to high levels of runoff. The upper watershed is largely forested, with urbanization and agriculture occurring on the foothills. It is significant to note that because agriculture and food production occurs mainly at the foothills, destruction of crop is possible due to erosion. Destruction of crops, seeds, and stored food stocks during inundation is limited as agriculture occurs on the foothills and not on floodplains.

Public infrastructure and private property may be damaged with inundation and deposition of significant quantities of silt. The persons living along Lower College Street ghaut are exposed to the danger of swift moving water when it flows in full. Figure 4.17 shows evidence of the erosion that takes place in the College Street Ghaut during rainfall events. For Basseterre and Lower Bath Ghaut, ground floors of buildings and residences are sensitive to rising flood waters and buildings and loose property can be swept away. An additional danger arises from boulders transported by the swift currents and floating debris such as cars and logs that can increase damage as they impact structures downstream. Properties on riverbanks may be in danger if riverbanks erode and trigger bank failure. Damage to road infrastructure triggers social and economic dislocation.

Figure 4.17: Scouring of the College Street Ghaut

Past floods have resulted in numerous physical injuries as well as disease transmission. Diseases commonly are associated with disruption of fresh water supply; contact with floodwaters contaminated by septic tank and wastewater treatment plant overflows; the creation of appropriate habitat conditions for certain rodents, insects and organisms that transmit diseases.

The propensity to high runoff is exacerbated by the frequent occurrence of high intensity rainfall. The capacity of the drainage facilities and the presence of lands with very little gradient adjacent to those drains with limited carrying capacity influences flood risk.

There are constraints with the data for examining the temporal and spatial distributions of rainfall over each of the islands. "As much as daily rainfall data actually recorded on the island were available, these records are not immediately useful for determining peak flows from watersheds with times of concentration considerably less than 24 hours. All of the watersheds on the island have small times of concentration. It is therefore necessary to know how the daily rainfall is distributed over the 24 hours and perhaps divide this daily rainfall into smaller storms having durations that match the estimated times of concentration" (OAS, 2001b).

4.1.5 Anthropogenic Issues

4.1.5.1 Maintenance within the sector

Currently, watershed management falls within the purview of the Department of Physical Planning and Environment (DPPE) but there is no single agency with a clear mandate to manage water resources and watershed areas. As a result, there is no Watershed Management Plan for the Basseterre Valley Catchment Area.

There have been a few initiatives within the project area with a focus on aspects of watershed management. These include:

- The restriction of developments above the 1000 feet contour which has generally been adhered to.
- The Basseterre aquifer has recently been designated as the Basseterre Valley National Park. A Management Plan for the National Park and a Water Resource Management Plan for the aquifer have been developed in order to better regulate development activities in Basseterre.
- Consultations with the St. Christopher's National Trust indicated that some years ago berms were constructed in the College Street Ghaut, which proved very helpful to control water flow and hence flooding (Figure 4.18). When these catchments were filled in with silt and sand, this was mined and sold to construction companies. This no longer happens and so ghauts are filled with dirt and vegetation and scouring of the banks and flooding is now a challenge when it rains.

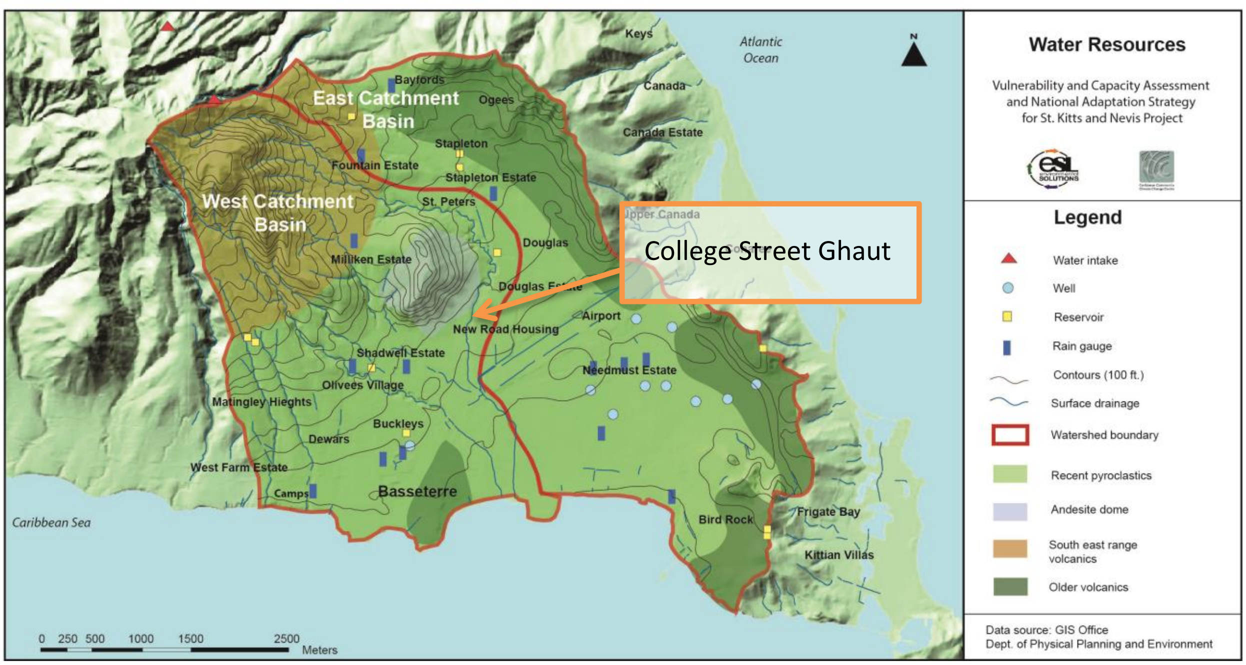

Figure 4.18: Map Showing the location of College Street Ghaut

Despite these initiatives a comprehensive watershed management plan is needed for consistent and coherent oversight of the entire watershed to ensure that it is protected from degradation. With a growing population and a growth in development investors, preventative and mitigation measures need to be put in place to combat issues related to flooding, ground water pollution, deforestation, burning, erosion, poor farming practices, and inappropriate siting for housing and other development.

There is a significant challenge faced by the Government of St. Kitts and Nevis (GOSKN) with water leakages and wastage within the water storage and distribution system overall. The St. Kitts and Nevis Environmental Profile published in 1991 outlined that the Basseterre Valley aquifer supplies most of the water on St. Kitts and that significant leakages existed within the systems estimating losses of 61% based on the difference between the amount pumped and that consumed (GOSKN, 1991).

The water resource assessment reported in Section 4.1.1.2 of this document highlights that this challenge from 1991 still remains and that the Water Department is still in dire need of a leak detection and repair system. Accessing external funding to support this has been a challenge over the years but the matter is critical as the aquifer is being pumped at almost maximum capacity and the sustainability of its supply to a growing population and a developing economy is compromised. Although stakeholder consultations revealed that there are plans and funding available to drill wells at higher altitudes, inefficiencies within the system will continue there would be to losses and wastage of water from the new well sources.

As indicated above, water monitoring at various points within the system is recommended as a first step in addressing leakages. Monitoring equipment should be installed strategically at several locations along the distribution network: into and out of each reservoir; at extraction points; and at end points. This will allow for leakages to be detected at specific points so that they can be quantified and prioritised based on the extent of loss in a particular area.

4.1.5.2 Economic development patterns

Agriculture

The main agricultural commodity over the past century for St. Kitts and Nevis was sugar cane. Like many English speaking Caribbean countries, this commodity and it's by products are either on the decline or cultivation has ceased. This commodity was not only an invaluable foreign exchange earner but the investment in the monitoring regime for natural resources was extensive. The agricultural industry has been diversifying since the end of the sugar industry in 2005 and has been faced with challenges in crop production.

The Ministry of Agriculture and Fisheries in St. Kitts has indicated that there is a major water challenge for the agriculture sector in St. Kitts. It is not the priority of the Water Services Department in St. Kitts to provide water for farming purposes. The water usage per farm is not readily available as many are not attached to a metering system. This industry has both monitored and unmonitored farm lands. However, crude estimates can be drawn from the limited documented information available.

In the Basseterre Valley Catchment area some agriculture takes place in the upper slopes of St. Peters in Ogees and Stapleton (Figure 4.19). Site visits showed that crops such as: corn, bananas, red and white sorrel, sweet potatoes, melons, pumpkin, tomatoes are all planted in the area.

Figure 4.19: Farming in the Project Area (Stapleton)

Small farmers are particularly vulnerable to variable climatic extremes as their livelihoods are most weather dependent for crop growth and livestock rearing.

Evidence strongly suggests that increased droughts and floods may be exacerbating poverty levels, leaving many rural farmers trapped in a cycle of poverty and vulnerability to diminishing resources (Phiri et al. 2005).

Smallholder farmers must develop water conservation and water harvesting systems in order to maximize rainfall use efficiency on their own farms. Beside lower investment costs and higher rates of returns, smallholder irrigation development is easier to manage and operate than large-scale centrally managed irrigation schemes. However, despite the low development cost and high rate of returns, there have been inadequate investments, mainly due to misplaced government priorities, declining external support, poor marketing infrastructure, and non-conducive policy and institutional frameworks.

It is imperative to consider decentralization of water for irrigation for small farmers as an appropriate climate adaptation strategy.

While some farmer groups have grown more active in operating these projects, government agencies have largely been responsible for maintenance and operation, often with little cost recovery (Peacock et al. 2007) and poor performance.

This is seen in both islands where centralization of water source has caused decision makers to reduce the provision of water to small farmers and allocate water to major economic activities. Activities include those related to the hotel industry because of the high injection of monetary proceeds for the acquisition of land and other resources. There is low investment in agriculture and rates of return over longer periods of time which generate steady employment and strengthen food security islandwide.

The Government of St. Kitts and Nevis has been encouraging greenhouse farming and funding has been provided to construct greenhouses, water catchment ponds, and purchase drip lines to combat the water shortage issues being faced across the island. Greenhouse farming was also evident in the project area (Figure 4.19, Figure 4.20). Discussions with extension officer at the Department of Agriculture revealed that there are two greenhouses, 30 x 100 feet long, in the project area growing tomatoes, cucumbers, ginger, and peppers. They have indicated that some training has been done in harvesting, storing, and pulling down greenhouse in preparation for hurricanes to protect from potential. However, no training has been done to teach farmers how to put back the plastic after the event passes.

Figure 4.20: Water Catchment Pond (left) and Greenhouse Farming in Stapleton (right)

The Ministry has reported a series of failures related to the rain water harvesting techniques, which were adopted to assist farmers in capturing rainfall for crop production. Many of these in the southern and western sections of the island failed because of limited rainfall which led to empty ponds in several cases. Based on the research on rainfall in Section 3.1.1, it is important to note that agricultural activities are concentrated on the western side of the island whereas higher rainfall is focused on the east. Because of the lack of trained personnel, and underutilised data within the Ministries, it has been believed that more rainfall occurs on the western side of the country near the capital.

Future investments in infrastructure to capture rainfall and or surface water will fail if orographic patterns and hydrological information is not utilized correctly to ensure that decisions on multimillion dollar investments are strategically built and located to ensure successful irrigation schemes for the agricultural sector.

The Department of Agriculture has indicated that public education is still needed for drought control measures to be implemented and utilised by local farmers. There needs to be more awareness on disease threats and prevention measures as well as how to deal with invasive species. Seeds are generally imported and sold to farmers for planted many different types of crops, but there have been complaints on many occasions that a number of the seeds do not grow.

Fisheries

No current water supply issues were reported by stakeholder in the fisheries sector. Water is only used for cleaning at the Basseterre Fishing Complex which is run by the Fisheries Division. Currently, fisherfolk do not pay for water at the complex and there is no metre to monitor water use at the complex. The Fisheries Division has recently requested that the Water Services Department install a metre at the Fishing complex as there are plans to do more processing in the future. In the last year approximately 7,500 lbs. of smoked fish was provided through the complex.

There are five main fishing sites around the island of St. Kitts: East Basseterre, West Basseterre, Old Road, Dieppe Bay, and Sandy Point. The South Bank of Nevis and North of St. Kitts are fish variety areas. Stakeholder consultations indicated that since 2005 nearshore species as well as conch are on the decline. Issues that have been raised include:

- Increased sediment management and nitrates from run off is seen as a threat to the fishing sites and hence the catch. A low biomass of herbivores, including surgeonfishes, parrotfishes and Diadema urchins were noted in nearshore reefs (Bruckner and Williams, 2012) Stakeholder consultations with the Fisheries Division indicated that this has been attributed to the increase in number of small crop farmers and use in chemicals since 2005.
- Reef degradation is evident and it was reported that corals are breaking off (Bruckner and Williams, 2012). A high cover of macroalgae and cyanobacteria were evident, which was greatest near the coastline especially off populated areas which include Basseterre. Despite these issues, the reefs showed a moderate level of resilience but measures are required to protect the reefs from further degradation.
- The have indicated that waters are getting warmer in recent years the dry periods have been longer which negatively impact fish catch. There has, however, been no analysis for temperature and rainfall to properly determine these changes but the Fisheries Division has reported that prior to 2001 there were well over 1000 fishermen but many person have come out of fishing because they have indicated that catches are getting smaller and smaller. 756 fishers were counted in 2013.
- Over fishing of fish including reef fish

Some measures have been put in place by the Fisheries Division to combat some of these issues such as to discourage the use of fish pots coupled with a greater incentive to catch pelagic fish to reduce overfishing of reef fish. Currently, the government has demarcated the 2 mile radius, right around the island of St. Kitts to declare it a Marine Management Area. Existing incentives to catch pelagic fish include the placing of 8 fads about 10 miles out. So far it helps fish landing and fisherfolk have reported that it has been successful when they go to the specific locations and drop line.

Another measure is to supplement the fish catch in St. Kitts is for the Fisheries Division to utilise unsuitable designated agriculture land for the construction of aquaculture ponds. This may include some areas the in Basseterre Valley East Catchment area which was formerly used to grow sugar-cane. They are seeking the use of brackish wells in Cayon, Pason Ground and Half Way Tree to supply water for aquaculture ponds which may require 1,800,000 to 3,300,000 gallons/day to sustain the industry. The Fisheries Division has developed a draft Aquaculture Strategy 2013-2014 as aquaculture is seen as a means to address recent reductions in fish landing for various varieties of fish including dolphin and tuna fishes. Currently, Tilapia is grown via aquaculture in 100% seawater, but in order to commercialise, St.

Kitts will need to grow Tilapia in fresh water because they mature faster. This will increase the demand for fresh water to be supplied to aquaculture.

Tourism

The Citizenship by investment program established in St. Kitts is one of the oldest in the Caribbean. Established in 1984, there is currently an acceleration of development in the island due to the decline of the sugar industry. As a result of this decline, land has become available. There are approximately 40 developments planned for the island.

The pace of economic development in terms of tourism related activity is worth about $1.2 billion US. The Water Services Department is not in a position to provide for new developments. They have indicated that developments will have to be responsible for their own water supply by way of desalination plants.

The 648 room Marriott hotel, the flag ship hotel of St Kitts was opened in 2002, and a desalination plant was installed to support their operation.

Four approved developments are in the pipeline for the country. These include:

- Kittitian Hill, sustainable luxury living
- Park Hyatt
- Koi Resort residences
- Christophe Harbour

Koi Resort Development is proposed to be constructed on the south eastern fringes of the project boundary and extends to Half Moon Bay. The other developments are outside and are not close to the project area. A decision to allocate 3 groundwater wells to Kittitian Hill development in the north of the island could prove difficult in the future for assessment of the resource as the monitoring will mainly be conducted by the developers who have contracted international consultants to advise on quantity and quality. Results are to be shared with the Water Services Department through the necessary arrangements. With the exception of Kittitian Hill, It is also very likely that the other developments may consider the construction of a desalination plant for their water supply since there are no well options or government supply options for these operations.

The current situation of the aquifer requires attention and measures need to be incorporated into water resource management. The two hotels in the Basseterre Project area, Bird Rock Hotel and the Timothy Beach Hotel rely on water from WSD. The Marriott Hotel which was constructed about 10 years ago is located just outside the south eastern boundary of the project site and relies completely on the desalination water for their operations. With the existing challenges faced by the aquifer, along with the climate change threats of decreased rainfall in the southern part of St. Kitts, as rightly indicated in stakeholder consultations, the aquifer cannot sustain the local water supply along with new hotel developments within the southern sections of the island.

Commerce and Industry

Not many manufacturing industries operate in St. Kitts. A few bottling and beverage companies dominate the sector. The St Kitts Bottling Co Ltd. is one prominent bottling company that bottles water under the Aquavita brand; they also manufacture Coca Cola, Fanta, Sprite, Sparkle and other beverages for the local and export markets. Bottling companies abstract a considerable amount monthly and annually for their operations.

Sugar cane by-products such as rum and molasses, often utilise several gallons of water to wash the cane in order to obtain the necessary by products through the process of fermentation, distillation and stilling.

Demerara Distillers (St Kitts - Nevis) Ltd was started in 1670. Demerara Distillers Ltd has the capacity to produce in excess of 26 M litres of pure alcohol annually and is the largest supplier of bulk rums. Demerara Distillers Ltd has “a unique position in the world of rum in continuing to operate the original production stills used on three of the great sugar estates of the 18th and 19th centuries” (Demerara Distillers Limited n.d.).

A third bottling industry includes the manufacturing of the Brinley Gold Rum, the family business began on the island of St. Kitts in 1986.

Other commercial enterprises include automobile services such as Automotive Arts, Hyundai and Suzuki car dealers, and supermarkets such as Horsford’s.

This water usage monthly / annually provided by these facilities was inputed as a part of the assessment of water usage per sector.

4.1.5.3 Social Characteristics and Issues

Demographic Trends

The 2011 preliminary census estimates reveal that there are 34,983 persons living in St. Kitts and 13,212 households. Of the total population of St. Kitts, 17,236 are male and 17,747 are female, which represents an almost equal male to female ratio. Data from 1990 and 2011 revealed that the population of St. Kitts is growing. Fertility and mortality have been relatively low in the intervening decades, showing a steeper decrease in the last decade and a half.

The population of the project area, Basseterre Valley East Catchment basin, has been estimated based on the fact that the project area covers sections of the parish of St. Peters, St. Georges East and St. Georges West. As indicated above in Section 1.5, most of the demographic data for the 2011 Census was not yet available and as such the 2001 Census data had to be utilized for the analysis. A best fit of the Enumeration Districts (EDs) which make up the three parishes (St. Peters, East St. George and West St. George) along with stakeholder interviews were utilized to assess the socioeconomics of the East Catchment Basin.

The 2001 Population for the project area has been estimated at 6,786. Of this, there are 3,271 males and 3,515 females which is an almost equal share of both genders. Additionally, an estimated 2,371 households are present within the project area with a mean household size for 2.9 for each household.

Most of the households within the project area are either owned by the head of the household or privately rented (Figure 4.21). Little unplanned development takes place within the project area.

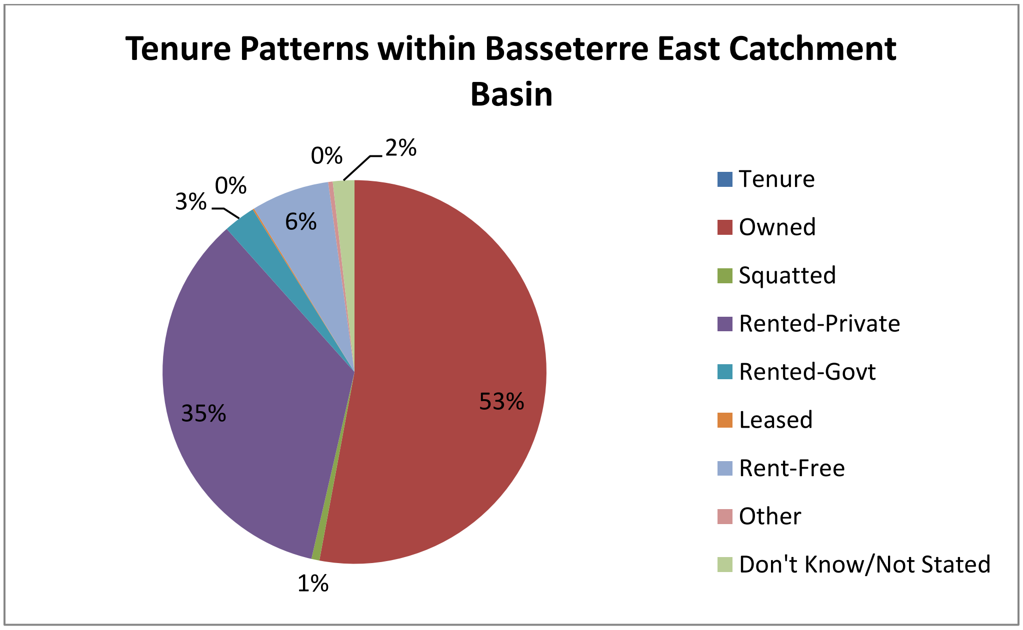

Figure 4.21: Household Tenure Patterns within the Basseterre Valley East Catchment Basin

85 % residents within the project area are supplied by the public water supply, piped into their dwelling, 9% piped into yard and a few relying of a public stand pipe (Figure 4.22). Community consultations also concur that resident relay on public water supply but they have also indicated that they have no issues with water lock offs or with the quality of water supplied to them by the WSD. To date the public supply system has been reliable in both respects. Community consultations reveal that residents do not have alternative sources of water, nor do they practice to store water as part of their culture because it is always in supply.

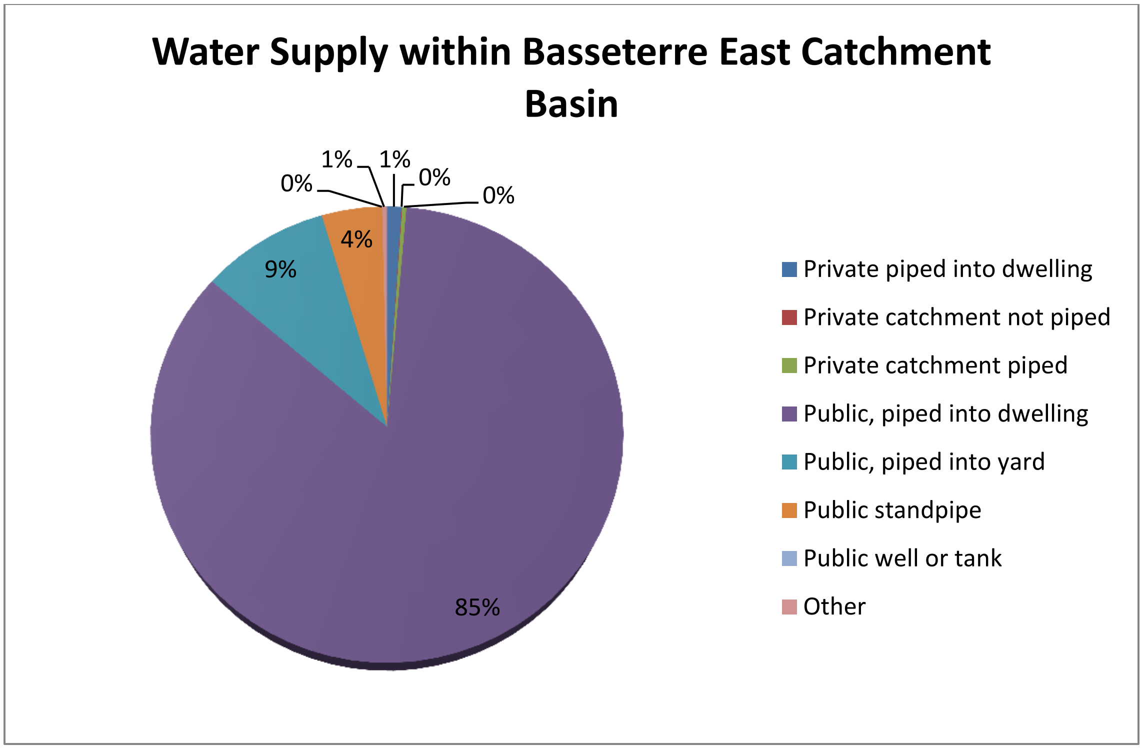

Figure 4.22: Water Supply within the Project Area

Most residents within the area utilise flush toilet facilities. Most of these residents have their facilities linked to a septic/ soakaway system. St. Kitts reports 78 % of the total utilises flush toilets connected to a septic/soakaway system. The minority is connected to a sewer system. Although in the minority, there are still some pit latrine within the project area. The use of soakaways are very prevalent in the project area and it exposes the Basseterre Valley Aquifer to possible contamination.

<u>Vulnerable Population</u>

There are approximately 9% of residents that are elderly within the project area, these persons are aged 65 years and over. In addition, approximately 15% of residents within the project area have been reported to have some kind of disability. Disabilities include:

- Sight impaired
- Hearing impaired
- Speech impaired
- Challenges with upper limbs
- Challenges with lower limbs
- Neck and/spine disability
- Slow
- Mental

It is evident that there are many residents within the community that are already predisposed to health challenges which makes them vulnerable.

Almost half the community has at least a high school education. In addition, a significant 18% of the community has attained up to a primary school education (Figure 4.23). This represents a project area that is literate. Despite this there still remains a fair portion of the population that are likely to need assistance in reading and writing representing a fair portion of the population who is predisposed to a vulnerability factor.

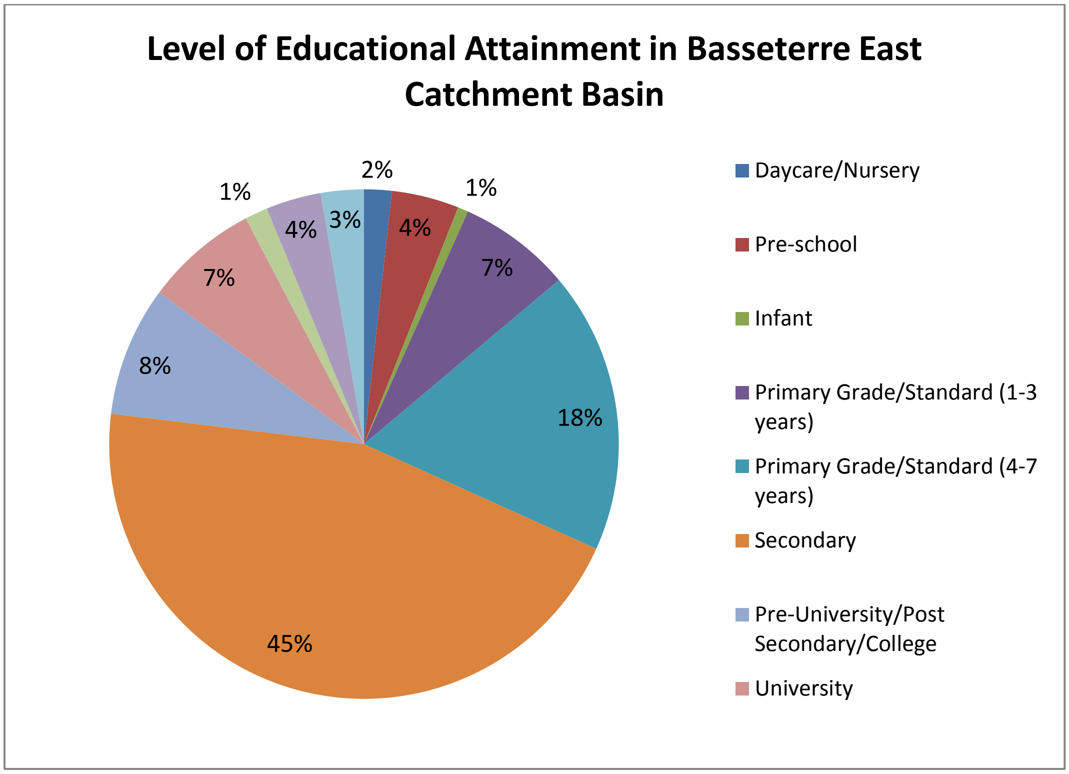

Figure 4.23: Level of Educational Attainment

Health

Health and disease information was not available at the ED level to determine the case of the Basseterre East Catchment Basin. Of the 35, 217 persons in St. Kitts in 2001, persons with chronic illnesses within St. Kitts and Nevis represents 21% of the total population. Type of illnesses are illustrated in Figure 4.25. This shows that a fair portion of the population within the project are already vulnerable because of their health status.

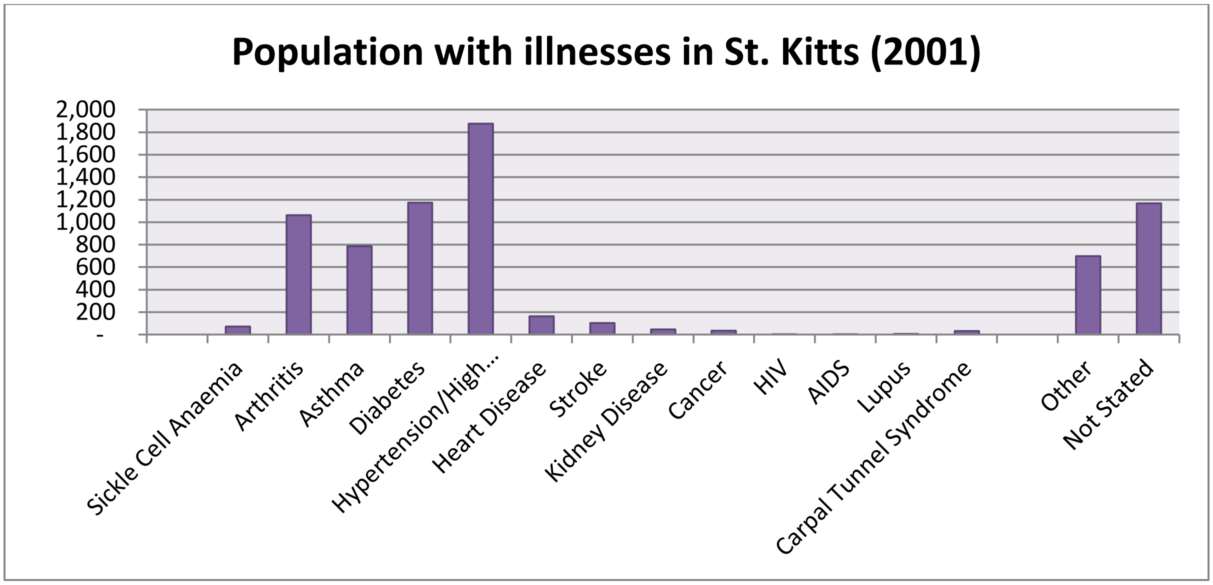

Figure 4.24: Population with illnesses in St. Kitts based on 2001 Census

Poverty Trends

Based on the desk study conducted, poverty reduction seems to be a crucial development issue for the Federation. In 2007 the poverty rate in St. Kitts stood at 23.7%. When considering the distribution of poor by parish in St. Kitts, most of the poor are located in St. John (20.9%) followed by St. George-Basseterre W. (18.0%) and St. Mary (17.1%). Trinity has the smallest proportion of the poor (0.0%) followed by Christ Church (4.1%). The Basseterre Valley East Catchment area falls within the parishes of St. Peters and Basseterre East and West. Utilising the three parishes as a best fit for the project area, it is estimated that this area holds 34.82% of the poor within the entire St. Kitts. This is significant.

Table 4.6: Geographic Location of the Poor by Parish 2007-2008

Parishes in St Kitts[1]	**Socio Economic Status**	
	Poor %	**Percentage of Parish Population Poor**
Basseterre East	12.52	14
Basseterre West	18.0	23.7
St. Pauls	7.5	26.9
St. Anne	9.1	24.1
St. Thomas	6.5	28.5
Trinity	0.0	0
Christ Church	4.1	15.1
St. John	20.9	42.9
St. Mary	17.1	36.9
St. Peter	4.3	16.4
All St. Kitts		**23.7**

Source: CPA St. Kitts and Nevis 2007-08

[1]Italics: Parishes in the CFRNP

In terms of gender, females account for a slightly larger percentage (52.5%) of the poor population on St. Kitts compared to their male counterparts (47.8%). While this suggests some degree of disparity between the genders, it may also be a function of the sheer size of the female population in St. Kitts as females also accounted for a larger percentage of the non-poor population on the island.

Table 4.7: Poor Population by Sex, St. Kitts

St. Kitts	Socio Economic Status		
	Poor	**Non Poor**	**Total**
	No.		
Male	47.8	46.5	46.8
Female	52.2	53.5	53.2
Total	100.0	100.0	100.0
Total (N)	9,075	29,230	38,305

Source: CPA St. Kitts and Nevis 2007/08

Employment and livelihoods

The 2007/08 Country Poverty Assessment of St. Kitts and Nevis indicates that 6.3% of the population of St. Kitts is currently unemployed. However, the report notes the phenomenon of "working poor" in St. Kitts, whereby persons who are employed are still below the poverty line. The majority (81.6%) of the poorest population in St. Kitts are actually employed. Thus even with a relatively small unemployment rate of 6.3%, a high level of poverty still remains a troubling problem on the island of St. Kitts.

Table 4.8: Employment Status of Population by Socioeconomic Groupings, St. Kitts

Employment Status by Socio-Economic Grouping			Per Capita Consumption Quintiles					
			Poorest	II	III	IV	V	Total
			%					
Male	Employment Status	Employed	77.2	94.4	96.9	97.8	97.5	94.0
		Unemployed	22.8	5.6	3.1	2.2	2.5	6.0
		Total (N)	1,304	1,725	2,004	2,241	2,043	9,317
Female	Employment Status	Employed	84.7	94.2	94.4	95.7	96.2	93.4
		Unemployed	15.3	5.8	5.6	4.3	3.8	6.6
		Total (N)	1,848	1,949	2,042	2,419	2,467	10,725
Both Sexes	Employment Status	Employed	81.6	94.3	95.6	96.7	96.8	93.7
		Unemployed	18.4	5.7	4.4	3.3	3.2	6.3
		Total (N)	3,152	3,674	4,046	4,660	4,510	20,042

Source: CPA St. Kitts and Nevis 2007/08

Several factors affect poverty in St. Kitts and Nevis and by extension the project area. As previously mentioned, the closure of the sugar industry had a particularly hard blow to some of the most vulnerable socioeconomic groups of people in society through losses in income and social safety nets. The small open economy makes the islands particularly vulnerable to external economic shocks, and places the country at a disadvantage in terms of international trade. These external factors are often beyond the control of the nation state and thus the island's economy is for the most part dictated by a range of larger-scale global economic processes such as trade liberalization and food/fuel price spikes.

4.1.5.4 Settlement

Anthropogenic factors can exacerbate the effects of climate change and as such it is important to examine the settlement patterns within the project area. Some issues were already raised above (Sections 4.1.5.1 to 4.1.5.3) with respect to:

- water supply and the significant vulnerable population that exist within the East Catchment Basin
- degradation of the environment and economic pressure to develop the area
- inefficiencies in physical infrastructure
- limited financial resources available for catchment maintenance

Because settlements in particular, transmit anthropogenic impacts mainly via the following community based actions, they will be examined more closely in the subsections below.

4.1.5.4.1 Waste Management and Pollution

99% of households within the project area rely on trucks to dispose of their garbage. Few persons indicate that they dump or burn their garbage. Stakeholder consultations with the residents highlighted that garbage trucks frequently traverse the area to collect waste but there are some persons who still dispose of their garbage inappropriately in pile along or inside a drainage pathway (Figure 4.25). A part from these practices the streets in the area were generally clean and not littered. It was indicated that there are few roadways on slopes that are too narrow for the garbage trucks and many of these persons still burn their garbage.

Figure 4.25: Some dumping recognised along ghaut in Upper Monkey Hill

Projected population increases may result in the greater environmental pollution as more and more persons live higher up on slopes where the traverse of garbage collection is a challenge. In addition, increasing urbanization and urban sprawl takes place around the Basseterre capital which includes much of the project area. As indicated above census results showed significant growth in the St. Peters area as more and more residential communities are constructed to provide homes for the growing population. Changing lifestyles and increased living standards may also result in more solid waste generation and higher consumption of water, even if at a declining rate.

There is no sewage treatment system in the project area as well as within the wider St. Kitts and soakaway systems are the norm. This also places Basseterre groundwater system at risk from contamination which can increase the cost of water treatment overtime. Lower lying settlements could be at risk from the wash out of septic systems during heavy rainfall. Although this is not currently a challenge, there is great potential for this to occur over time should no plans be put in place to have a central waste water treatment and sewage systems in place. With new developments coming on stream and the need to protect coastal waters from pollution and high nutrient loading, considerations should be made to improve sewage and trade effluent treatment requirements.

Land Use

Land use within the study area is a mix of residential, agricultural and commercial (Figure 4.26).The southern portions of the project area is a large portion of the Basseterre City Centre which is largely commercial. North of this airport is the airport and much of the northern boundaries of the project site is agricultural. Residential settlements occur in the eastern and central sections of the project area which largely falls within St. Peters which is the fastest growing parish in St. Kitts and Nevis. There is a practice for community residents to plant agricultural process along the banks of drainage paths (Figure 4.27).

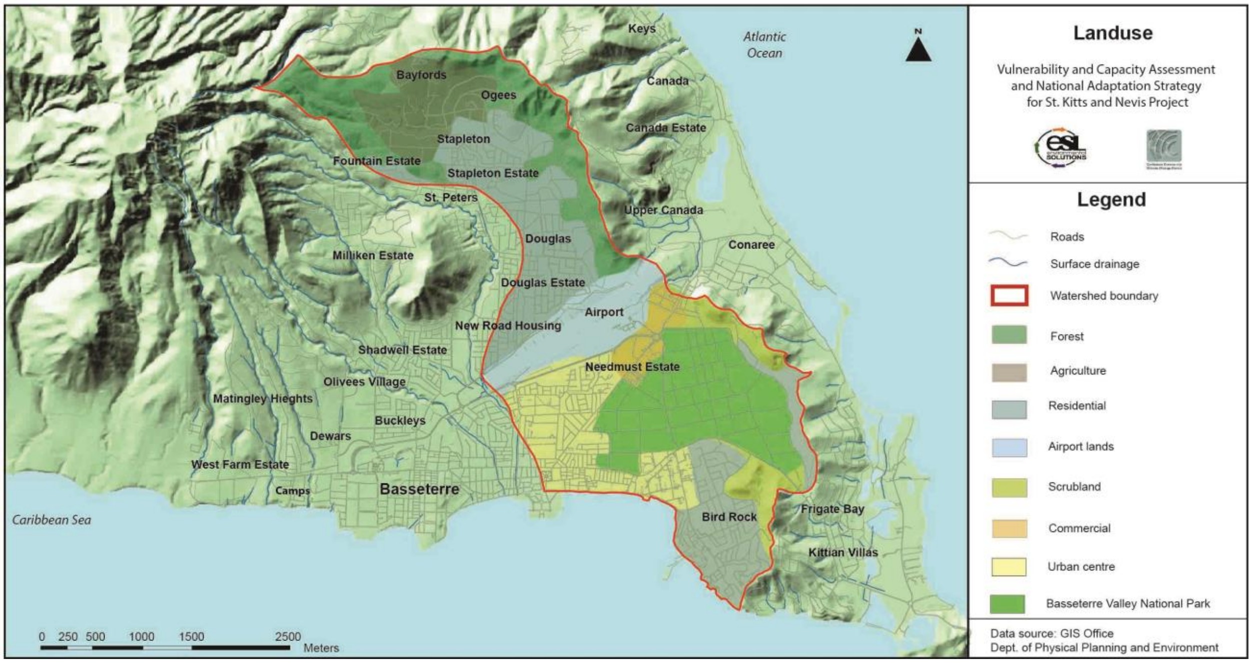

Figure 4.26: Land Use within the Project Area

Figure 4.27: Bananas Planted in the College Street Ghaut

Deforestation is also a potential challenge as there are increasing development investments and a growing population the demand for land competes with forest conservation. In addition, stakeholder consultations already reveal that there is a major runoff problem with old sugar lands on the hillsides that are being developed for housing. 94% of the households in the project area utilise LPG gas for cooking. Very few rely on wood/coal for cooking which does not indicate an issue with deforestation for fuel. However, without a vibrant watershed protection plan and programme for the Basseterre Catchment area, it is not a certainty that areas will remain under forest vegetation to facilitate infiltration to replenish groundwater resources, the sustainability of the Basseterre aquifer is put at risk.

The initiative by the DPPE to declare Basseterre Aquifer a National Park was a positive move and this should also be considered for the upper slopes of the watershed areas.

Increasing growth in population, housing construction, development construction, and the increasing risk of poor waste management, and deforestation due to competition for land and a lack of a comprehensive watershed management plan these are anthropogenic factors that can exacerbate the effect of climate change. Further without an integrated land use plan for St. Kitts to rationalize and direct competing land use requirements in the Basseterre Catchment area is a major hindrance to bringing control and potential sustainability to the watershed. The project area is therefore predisposed to the negative effects of climate change.

4.2 Summary Sensitivity Analysis

Table 4.9 below summarises the sensitivity analysis for the Basseterre Catchment area with respect to the supply of water, the management of water as a resource, agriculture and health within the area.

Table 4.9: Summary Sensitivity Analysis

Current Stresses	Projected Stresses from Climate Change	Likely Impacts	Projected change in stresses to systems *(without preparedness action)*	Degree of sensitivity
WATER SUPPLY AND MANAGEMENT				
Low annual rainfall with high inter-annual variability	Increasingly drier conditions. Heavy rainfall events decrease. Increase in annual temperatures	More frequent drought events. More evaporation that may lead to greater pathogen density in water and this could result in a lack of potable water	Could get worse (can no longer supply water to new tourism developments)	Moderate
Annual exposure to hurricanes and tropical storms	Hurricane intensity expected to increase (not necessarily frequency)	Residential and commercial areas may be prone to flooding and exposed to risk of debris and sediment flows based on location of ghauts. Heavy rains may contaminate watersheds through transport of wastes into surface drainage systems. Damage to water sector	Likely to get worse	High

Current Stresses	Projected Stresses from Climate Change	Likely Impacts	Projected change in stresses to systems *(without preparedness action)*	Degree of sensitivity
		infrastructure and equipment on account of more intense hurricanes, flooding and land slippage events. Damages, associated repair costs and downtime can lead to loss of revenue and negatively impact water sector development plans.		
Over extraction of wells resulting in saline intrusion	Increase in sea levels	Combined with increasing extraction to meet population growth, groundwater quality may be adversely affected by the proximity of some underground sources to the coast due to sea water intrusion. Increased incidence of coastal flooding in relation to storm surge	Likely to get worse	High
Meeting increased demand from population growth and economic activities	Reduction in annual average rainfall- more droughts	Climate change impacts on water supply likely to be compounded by increasing demand due to population growth and increasing economic activities.	Likely to get worse	High
Poor watershed management	Increasing drought conditions	Reduction in infiltration due to deforestation to accommodate housing and economic developments	Could get worse (Currently legislation restricts development above the 1000ft. contour line.)	Moderate
AGRICULTURE				
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts Mean annual decrease in	More frequent drought events will result in reduced crop yield. Reduction in available freshwater for crops and livestock.	Likely to get worse (Currently funding available for water storage ponds but these are still rain-fed)	High

Current Stresses	Projected Stresses from Climate Change	Likely Impacts	Projected change in stresses to systems *(without preparedness action)*	Degree of sensitivity
	rainfall of between 6-11% for southern St. Kitts (which includes the Basseterre Catchment Area) by the 2030s			
Poor dryland farming techniques	Mean temperature increase of between 1^{o}C and ^{o}C by 2030s create drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield. Plant stressed and wilting from increased temperature and possible introduction of new pests and diseases	Likely to get worse (Existing projects are looking at soil conservation techniques)	Moderate
Damage from heavy rainfall/storm events **Poor farming practices**	Hurricane intensity expected to increase (not necessarily frequency) Potential risk of sea level rise	Loss of crops, reduction in crop yield, loss of livestock Landslide and soil erosion due to heavy rains may lead result in moderate damage to crops due to debris flow and a loss of fertile top soil. The indiscriminate use of pesticides and fertilizers by some farmers in and around the Catchment Area pose the risk of contaminating groundwater resources that can in turn affect crop growth and threaten livestock. Clearing of vegetation for farming especially on slopes can lead to increased surface runoff and lower the groundwater recharge	Could get worse but uncertainties in frequency of high intensity storms	Moderate

Current Stresses	Projected Stresses from Climate Change	Likely Impacts	Projected change in stresses to systems *(without preparedness action)*	Degree of sensitivity
		capacity of the area. May lead to moderate to high increases in salinity of low lying and coastal agricultural lands due to sea water intrusion.		
		HEALTH		
Outbreak of vector borne diseases (Chikungunya, Dengue)	More periods of short duration intense rainfall, which can cause ponding Increase in temperatures between 1°C and 2°C by 2030s	The mosquitoes which carry viruses breed in water that settles around homes, schools, churches, workplaces and playgrounds. Nearby wetlands are grounds for mosquito breeding. Temperature increase may also exacerbate the incidence of vector borne diseases such as malaria, dengue and chikungunya. Flash floods may also lead to loss of life.	Could get worse (Abate being used to control mosquitoes at larval stage, fogging machine recently being used to control adult mosquitoes)	Moderate
Increase in water related illnesses (Gastroenteritis, diarrhea)	Reduction in annual average rainfall - longer dry periods Increase in frequency and severity of hurricanes and tropical storms can lead to moderate/severe damages to dams, infrastructure and landslides may also occur.	Water restrictions imposed during dry periods could increase over time increasing the risk of water related illnesses. It may also lead to a breakdown in sanitation and hygiene. Landslide and soil erosion may result in a moderate increase in turbidity and reduction in freshwater quality; increased threat of water-borne disease e.g. cholera.	Could get worse	Low

5 ADAPTIVE CAPACITY ANALYSIS

"*The adaptive capacity describes the ability of the built, natural and human systems associated with the water sector to accommodate changes in climate with minimum disruption or minimum additional cost.*" (Climate Impacts Group, King County, Washington, and ICLEI-Local Governments for Sustainability, 2007). Climate variability and change brings about unpredictable changes in long term weather patterns which exposes life to potentially negative impacts. It is important for any society to adapt to these changes to reduce their vulnerability to any negative impacts. Gupta et al. (2010) indicated that adaptive capacity of a society is embedded in institutions. Institutions are traditionally conservative and reactive and the climate modelling, water resource and socioeconomic assessments done under this project aim to pre-empt likely changes in these weather patterns so that plans can be put in place to proactively respond to environmental change (ibid).

This section assesses the existing institutional, policy and legislative framework governing St. Kitts, examines initiatives already undertake to address water related issues, and assesses the ability of the community and economic sectors to adapt to projected climate change.

5.1 Institutional, Policy and Legislative Analysis

5.1.1 Institutional Mapping and Linkages between Policies Legislation and implementation

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

A wide range of institutions are involved in water resources management for St. Kitts and Nevis and by extension the Basseterre Catchment area. Figure 5.1 below illustrates the Institutional arrangement governing the water sector in St. Kitts. Although this report focuses on the Basseterre Catchment area, it was important to examine the government structure of St. Kitts and the existing roles and initiatives that are already in place to inform the adaptability of the people of Basseterre to potential climate change impacts.

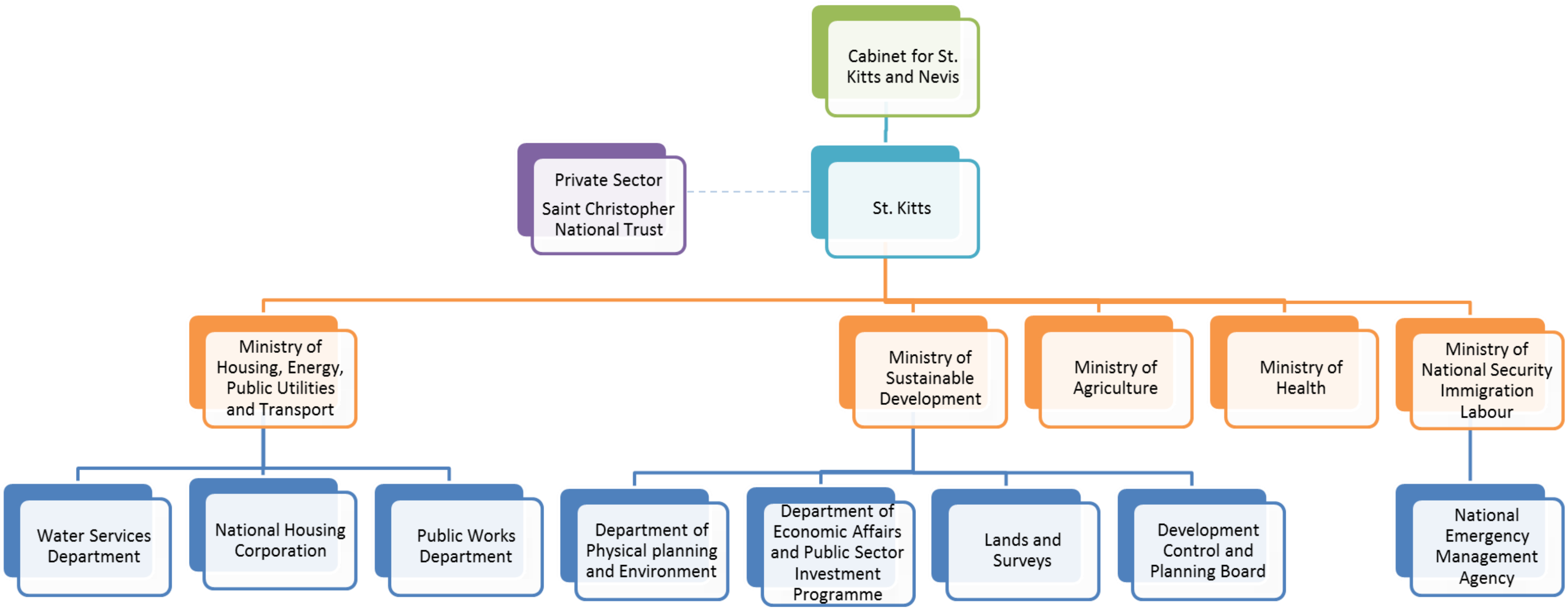

Figure 5.1: Institutional Map

Table 5.1 which follows outlines the key institutions relevant to the water sector, their mandate, the policies and legislation that mandate their activities and their current roles.

Table 5.1: Government Mandate, Legislation and Policies

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
ST. KITTS				
Water Services Department	The Water Services Department (WSD) is responsible for the identification, upkeep and protection of water supply sources on St. Kitts.	Water Courses and Waterworks Ordinance (Cap 185 of 1956)	None	It is not a watershed management institution although the Act makes provision for the declaration of watersheds to protect waterworks and water sources. WSD working in close collaboration with the DPPE, has spearheaded the implementation of the first phase of the IWCAM project which seeks to rehabilitate the lower coastal section of the Basseterre.
Public Works Department (PWD)	The Public Works Department oversees the design of new and maintenance of existing public infrastructure, including roads, drainage, bridges, and culverts.	None	None	Responsible for overseeing the design, construction and repair of public buildings. As a member of the DCPB, the PWD provides technical support to the land development and building application review processes.
Ministry of Sustainable Development	In 2005 the Ministry of Development and Planning was transformed into a Ministry with responsibility for Sustainable Development. The new Ministry of Sustainable Development (MSD) assumed the land and survey	None	None	The Ministry of Sustainable Development is the lead government agency with overall responsibility for the development and coordination of policies and programmes to protect St. Kitts - Nevis's natural environment,

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
	portfolios of the Ministry of Agriculture and Housing and the environment management portfolio from the Ministry of Health. As a result, the departmental components of the Ministry of Sustainable Development now include: a. Administration b. Economic Affairs and PSIP c. Physical Planning and Environment d. Lands and Surveys e. Statistics			including the management of all matters pertaining to Multilateral Environmental Agreements (MEAs).
Department of Physical Planning and the Environment (St. Kitts) (DPPE)	Enable the implementation of the NCEPA. Spearhead the design and implementation of the countries, development agenda and to better equip St. Kitts Nevis to meet its international obligations to various bi-lateral and multilateral economic and environmental agreements.	National Conservation and Environmental Protection Act, No. 5 1987 South-East Peninsula Land Development and Conservation Act, 1986 Frigate Bay Development Corporation Act. No. 13 of 1972 Beach Control	National Environmental Management Strategy (2005) National Environmental Action Plan National Biodiversity Strategy and Action Plan (NBSAP) National Adaptation	The Ministry of Sustainable Development the Department of the Environment was merged with the Physical Planning Division to create the Department of Physical Planning and the Environment (DPPE). The DPPE functions as the lead agency for physical planning, development control and environmental management. As lead agency for environment, the DPPE functions as the focal point in St. Kitts-Nevis for the UNFCCC, UNCBD and the UNCCD. Plays a pivotal role in the administration

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
		Ordinance St. Kitts-Nevis Building Regulations, Code and Guidelines (No. 7 of 2000) Whitegate Development Corporation Act, No. 15 of 1999	Strategy (NAS) (2006-2013)	of sustainable development in St. Kitts-Nevis. Currently the focus of the DPPE's main work is oversight a number of climate change projects and meeting the international agreements, local development applications.
Department of Lands and Surveys (DOLS)	DOLS is responsible for the design, survey and implementation of residential land subdivision schemes.	Development Control and Planning Act, No. 14 of 2000	None	Strategic objective is to establish a fixed boundary coordinated cadastral system after a systematic resurvey, cadastral plans, topographical maps, and the complete development of a Land Information System that would fully support the survey, registration, valuation and management of land. With representation on the Development Control and Planning Board, the Department of Lands and Surveys works closely with key public sector institutions to rationalize land use and land development decisions.
Development Control and Planning Board	Responsible for the review and determination of all building and development planning	Development Control and Planning Act (No.	None	• Agriculture and rural development, • Environmental protection,

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
(DCPB)	applications on St. Kitts. Responsible for zoning, review of environmental impact assessments and the design and implementation of development plans and broader national policy instruments such as the NPDP.	14 of 2000)		• Water resource management, • Land use planning, • Climate change adaptation, and • Biological diversity conservation
Department of Economic Affairs and Public Sector Investment Programme	Lead coordinating unit for local, regional, and international projects. Operates as the country contact for lending and donor agencies Facilitates the coordination of requests for technical assistance, grant funding and loans between various government ministries and non-governmental institutions and external donor agencies.	None	None	Manages the Government's Public Sector Investment Programme (PSIP) through close collaboration with line ministries and statutory corporations. The PSIP directs the preparation of the capital budget and assists in ensuring a holistic approach to inter-ministerial and inter-departmental programming, to avoid duplicity.
Department of Agriculture	The Department of Agriculture's (DOA) main focus is on agricultural extension services, focusing primarily on methods of cultivation and overall crop production. Agricultural development policies and programmes in St. Kitts-Nevis are developed and managed by the Department of Agriculture on St. Kitts	Agricultural Development Act 1973 Water Courses and Waterworks Ordinance (Cap 185 of 1956) Forestry Ordinance No. 10, 1903	St. Kitts Agricultural Development Strategy (ADS) 2013-2016	Generally, the Department of Agriculture is responsible for a range of services related to agriculture and rural development in both St. Kitts and Nevis.

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
	and on Nevis.			
Ministry of Health	The Public Health Department is responsible for monitoring and testing water quality. In response to pollution issues Environmental Health Unit currently monitors the state of pollution in St. Kitts-Nevis.	Public Health Act No. 22 of 1969	None	Monitoring and testing water quality Respond to pollution issues Environmental Health Unit currently monitors the state of pollution in St. Kitts-Nevis.
National Housing Corporation (NHC)	Responsible for the supply of affordable shelter accommodation and related infrastructure.	National Housing Corporation Act	None	The NHC is vested lands by the Government of St. Kitts-Nevis. NHC is responsible for development of the lands in accordance with guidelines established by Department of Physical Planning, Natural Resources and the Environment.
National Emergency Management Agency (NEMA)	Responsible for the coordination of pre and post disaster management activities at the community and national levels, in order to minimize vulnerability and mitigate against the impact of disaster on life, property and the well-being of residents of St. Kitts and Nevis.	National Disaster Management Act	National Hazard Mitigation Policy	NEMA is guided by the National Disaster Plan. NEMA operates as the Secretariat for the St. Kitts-Nevis National Disaster Mitigation Council which was established in 1999. The Council provides general oversight and related policy guidance. NEMA is responsible for emergency shelters. NEMA works with Meteorological Office and the Seismic Research Unit (SRU) to be able to provide early warning bulletins. NEMA organizes training for volunteers,

Government Agency/ Ministry	Mandate	Legislation	Policy/Plan	Current Roles
				and other personnel, in such areas as Shelter Management, Damage Assessment and Needs Analysis, Hazardous Materials, Mass Casualty Management and Land Search and Rescue. NEMA also operates a public awareness program via radio, television, print and exhibitions.
St. Kitts Meteorological Services	The Met Services provides information to for Civil Aviation Authority. Their role have been expanded to providing weather information the public and providing Advisories to various sectors	None	None	Collects and provides weather information and advisories to • Civil Aviation • The public • Various sectors

5.1.2 Institutional Initiatives and Capacity Issues

In determining the adaptability of St. Kitts to projected changes in the Basseterre Catchment, the existing initiatives need to be examined as well as the ability of the existing institutions to address climate variability and change issues. Existing initiatives are discussed below by institution and capacity issues follow in Table 5.2.

5.1.2.1 Department of Physical Planning and the Environment

The Department of Physical Planning and Environment (DPPE) has executed a number of project initiatives to deal with development control and environment and natural resource management. DPPE has recently completed the project: *Rehabilitation and Management of the Basseterre Valley as a Protection Measure for the Underlying Aquifer* in 2009. This project was carried out by the Ocean Earth Technology Consultancy group and it focused on conducting the following assessments:

- Hydrogeologic evaluation of the Basseterre Valley Aquifer
- Geophysical mapping of the Liamuiga National Park for water supply
- Survey of natural resources (Watershed Status)
- Review of current Policy and Legislative framework for water resources management

These assessments informed the delineation and development of the Basseterre Valley National Park Management Plan and the Water Resource Management Plan for Basseterre Valley Aquifer in order to better regulate development activities in Basseterre. The Water Services Department (WSD) of the Ministry of Public Works, Utilities, Transport and Post supported the DPPE on this initiative.

The development of the Management Plan for the Wingfield Area was also a key initiative of DPPE.

5.1.2.2 Water Services Department

The Water Services Department (WSD) has spearheaded the implementation of the first phase of the IWCAM project which seeks to rehabilitate the lower coastal section of Basseterre.

WSD has also undertaken the project: *Rallying the Region to Action on Climate Change (RACC)* which is being executed within the Organisation of Easter Caribbean States (OECS). This project is funded by USAID, and DPPE has given WSD significant support on this project. The project has four main aims:

1. To improve the enabling environment to build understanding and support for policies and laws that reduce vulnerability to climate stresses
2. To launch interventions in freshwater and coastal management to build resilience and demonstrate results
3. To build institutional capacity and address information gaps through support for key practitioners in government and related sectors affected by climate change as well as support for institutions in the region such as training facilities, government department and entities charged with development data
4. To build awareness of the public on water wastage issues and the risk of future water shortages as a result of climate change, and improve capacities for climate change adaptation.

Phase 1 of this project has been completed and it involved the completion of a series of water audits that reported high levels of leakage. The project involved training water auditors and included public and private sector: medium sized hotels, agriculture, schools, and abattoirs. Water use was audited and issues found were rectified.

The project has a public education component where persons are asked to sign up and commit to one activity that will conserve water. The launch was held on Thursday May 8, 2014 and it was entitled: *Water Wise Campaign*. Water consumption for the individuals who signed pledge cards will be monitored and these persons will receive a plaque at the end of the programme.

Phase 2 of the project involves installation of water saving devices, retrofitting, and a second audit to be completed.

WSD currently supplies water largely to domestic users and commercial entities. Little water is supplied to the agriculture sector and new tourism developments are being asked to supply their own water by way of desalination plants. The Department of Agriculture has taken on this issue to ensure that water is supplied to their farmers. This is discussed in Section 5.1.2.3 below.

A decision to allocate 3 groundwater wells to the new Kittitian Hill development could prove difficult in the future for assessment of the resource as the monitoring will mainly be conducted by the developers who have contracted international consultants to advise on quantity and quality. Results are to be shared with the water department through the necessary arrangements.

With the increase in developments, more solutions are needed for water supply. To date, the Water Services Department has plans to contract BEAD LLC to excavate some additional wells in the northern part of the island to drill for an additional 1 million gallons of water per day.

There are plans for a number of projects to come on stream led out by the Water Services Department. These include:

- Inventory of persistent organic pollutants – Water management project
- Upgrade Water regulations
- Assessment of leaks into aquifer from Oil Plant near the aquifer
- Comprehensive Water Master Plan for the whole island of St. Kitts

The Mexico Infrastructure Fund for Mesoamerica and the Caribbean is being accessed for the following projects to be conducted:

- Engineering Study
- Institutional Reform for the Water Services Department
- Tariff Study
- Assessment of the current treatment and distribution of water
- Water Demand
- Climate Change Scenarios
- Reduced accumulated water

- System improvements over 20 years
- Produce Management Plan
- Capacity of Water Department

Enhancing Conservation and Energy Efficiency in Water Supply and Distribution is another anticipated project which will examine: the water system; water loss and the purchase of automated shut offs; procure zone metering devices which can have zones and metering of water in and out of each zone; conduct water audits and leak detection including equipment; tap into water resources in the mountains; conduct energy audit for water; use of energy efficient devices; water treatment; and educational awareness about water conservation practices and training.

Funding from the Caribbean Development Bank has been sought to develop a Water Master Plan.

Government revenue is being used for a Water Disinfection / Chlorination project. Materials have been purchased and the project is anticipated to be 5 years long. Government revenue is also being used to secure fencing and upgrade pump houses.

5.1.2.3 Department of Agriculture

The Department of Agriculture has indicated that the Sugar Industry Diversification Foundation (SIDF) is funding a project currently called the Agricultural Resource Management (ARM) Project. The project has been involved in constructing water catchment dams in key areas starting with O'Gees (St. Peters), Upper Mansion, Estridge and Farms (Sandy Point) (Figure 5.2). The project also assists farmers around the island in soil conservation and land management techniques to improve the quality and yield of their produce (St. Kitts & Nevis Sugar Industry Diversification Foundation, 2014). Water catchment facilities were constructed in particular areas based on a number of factors, some of which include:

- ease of accessibility to farms that have need for irrigation water
- topography in respect to minimizing the cost of excavation
- low risk of erosion due to altering the landscape to construct the dam
- where a spillway could be easily constructed to take any potential overflow away from the site without causing soil erosion or damage to any nearby properties, farms, roads or ghauts

Figure 5.2: Water Catchment Dam being constructed to supply small farmers on Stapleton Estate, St. Peters

- where possible, a site is chosen that could have access to water from the public water supply system for possible sourcing of additional water for irrigation (e.g. at Ogees and Upper Mansion)
- where possible dams are constructed on sites that may be close to water catchments in nearby ghauts (e.g. Whites where we pipe water from the Cayon River to the dam)

The Department has also received funding to construct water wells for their farmers, but to date, the necessary arrangements have not been made with the Water Services Department to start these wells.

The Department of Agriculture has been encouraging farmers to use protected agriculture as a protection from pests, monkeys, and praedial larceny. Protected agriculture is also encouraged because it utilises less space and can accommodate a water catchment facility to deal with the dry conditions. Farmers were able to receive funding for a green house, drip irrigation lines and a 1 million gallon tank through the Sugar Industry Diversity Fund.

Two members of staff have recently been sent to the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados to be trained in managing an automatic weather station. It is the aim of the Department of Agriculture to have their own stations to collect meteorological data that they can use.

In March 2011, researchers from the University of the West Indies in Trinidad and Tobago and McGill University in Canada began the Food Security Project funded by the Canadian International Food Security Research Fund through CARICOM. The aim was to improve the nutrition and health of CARICOM populations through sustainable agricultural technologies that increase food availability and diversity of food choices. Using a 'farm to fork' approach, project researchers working in St Kitts were able to boost the production and consumption of a more diverse range of nutritious and safe food. The project included the introduction of drought resistant measures such as the use of: plastic mulch, drip irrigation, banking, inter-cropping with larger crops. The use of vetiver grass, sluices and ditches to protect against soil erosion was also encouraged.

5.1.2.4 National Emergency and Management Agency

The National Emergency Management Agency (NEMA) is in negotiation with CDEMA to undertake a Mainstreaming Disaster and climate Change Project. The project will involve a community workshop to be held for 3 days. The workshop will build awareness within the communities on climate change and the threats that this may have on water supply. This project intends to build community awareness construct a water storage tank on one of the shelters. This is a pilot project on water storage and harnessing and it should demonstrate climate smart disaster risk management.

CDEMA is working with NEMA to implement an evacuation policy; the workshop for this project was held on August 21, 2014.

5.1.2.5 Institutional Capacity Issues

Local institutions (both formal and informal) play an important role in building resilience and reducing vulnerability to climate change. They perform a range of essential functions, including provision of physical infrastructure and services, disaster response planning, regulation of property rights, information dissemination, coordination with decision-makers at other levels, and organizing social action. They are also the principal vehicle through which external support for adaptation (e.g., training and capacity building, etc.) is and will increasingly be delivered.

Increasingly, local institutions are challenged to respond to increased exposure to risk and vulnerability as a result of climate change. For there to be effective local adaptation local institutions need to be responsive, flexible and able to adapt to the uncertainties associated with climate change. However, local governance that is responsive to climate adaptation is constrained by weak technical and managerial capacity, poor funding, poor linkages with other institutions at different levels, weak systems for gathering and disseminating information, and unclear mandates and conflicting priorities between levels and agencies of government. This is often the case in many of the SIDS in the Caribbean. Table 5.2 below discusses the capacity issues of the local institutions directly/ indirectly involved in the water sector in St. Kitts.

Table 5.2: Challenges with Institutional Capacity

Government Agency	Capacity Issues
Department of Physical Planning and the Environment (DPPE)	The DPPE indicated that there has been no budget to do work locally for the past 18 years and the department continues to seek project funding to do many activities. The government budget only covers administrative costs, overheads, salaries etc. Therefore they cannot properly fulfil their mandate. Staffing is limited and so that each person has to take on more than one role. Much of the staff hired has a wide range of background degrees and they are trained on the job training and to do the work required. Areas of training needed include: coastal resources, coastal zone management, and the monitoring of reefs and protection. The Fisheries Department do not monitor reefs but are instead more concerned with fishing restrictions and the increase in fish stock. Since the rain gauges for the sugar estates are non-functional, the DPPE is seeking funding to set up automatic weather stations to collect the requisite data. There is no single authority which has watershed management as its mandate, and many institutions have some responsibilities for coastal zone management. As such, the focus that is needed for this area is not fully achieved.
Water Services Department	The Watercourses and Waterworks Ordinance (1956) makes provision for the declaration of watersheds to protect waterworks and water sources. Watershed management is critical to maintaining both surface and groundwater sources. However, the Water Service Department does not regard itself as a watershed management institution although they do work closely with DPPE. Limited staffing and lack of training in Water Resources aspects of monitoring by using automatic groundwater water equipment, setting up hydro-meteorological networks for multipurpose including water quality watershed management, flooding and droughts along with hydrogeology data management along with internal analysis hinder the department.

Government Agency	Capacity Issues
	The Water Service Department now lacks a hydrologist/driller; most of our potable water is derived from wells (70%) thus this position is critical for operations. A mechanical engineer is also needed to manage aspects of the operations and maintenance divisions. Various locations have limited equipment for metering so these are urgently required to address significant leakages within the systems. WSD also needs to replace its aged driller rig, crane truck and standby generator sets. Lack of knowledge of Hydro-geological characteristics, hydrological and hydro-geological testing within each watershed/ major watersheds along with lack of internal analysis of the information are also inadequate to perform effective water management strategies. Training is needed in the area of water quality monitoring and testing, and information technology particularly as it relates to management and operation of our billing system. The island is experiencing phenomenal expansion in the tourism sector, significant capital inflows are needed to expand the physical infrastructure to meet the associated increased water demand.
Department of Agriculture	The Department of Agriculture is adequately staffed although there is need for more training in water management, irrigation, and in general dryland farming techniques. Two members of staff have recently been training to use the rain gauge equipment; however, there is limited funding from the GOSKN to provide the rain gauges needed to monitor rainfall patterns in major farming areas. The reassignment of persons after training is also foreseen as problematic after prerequisite training is undertaken. Currently, additional in-house training to pass on the hydrological technology /instrumentation has not occurred to share the knowledge with other departments who may have staff to assist in the rain gauge monitoring network. Data storage and calibration of equipment is required so that the instrumentation can provide both agriculture and water studies with adequate information for droughts, floods and catchment management in both disciplines.
Environmental Health Department	The Public Health Act 1969 is out-dated but the process to update this plan has already started. The revised Act should address areas not currently considered such as general guidelines for vector control. Staffing is limited and as a result there are some gaps in management. Ideally it would be best to have a member of staff focussed on a port

Government Agency	Capacity Issues
	heath to deal with issues related cruise and aeroplanes passengers, import and export goods etc. Currently, staff members juggle their time for food inspections, water quality, port health etc. to deal with matters as they arise. In addition, limited staffing also hinders the analysis of potable more frequently than once a month, which would be more ideal. Basic training of officers is lacking and there are many persons with on the job experience who need formal training in areas such as: vector control management and port health. The Health Department is also in need of lab equipment such as: a spectrophotometer, pH Metre, BOD of tests required on their potable water supply. E. coli and Enterococci are not tested for due to the lack in reagents needed although faecal coliform is done. These tests would be useful on a case by case basis because of the health risks which they pose. There are also other basic needs such as adequate computers and back up storage for the Departments data: there is currently one computer to eight officers. The Department had recently received two new machines for fogging due to the rise in Chikungunya. As a result of staff, training, budgeting and equipment limitations, the Department is reactive, and not proactive.
Public Works Department	The budget for PWD has been cut and so there is no monitoring of activities although the Department still tries to maintain low levels of silt in the ghauts in addition to managing the quarry. PWD used to rent heavy equipment to clear ghauts but over time this was not sustainable. Garbage and domestic waste in ghauts is sometimes a challenge. There are a few bridges which cross ghauts and are prone to scouring but there is no legal framework to oversee this type of road construction. There is no Act or Policy which governs the work of the Public Works Department. PWD is made up of mostly engineers and there is need for some training to be done in management to build capacity. There is no Land Management Unit and so PWD would benefit from training in river catchment given the gap.
National Emergency Management Agency (NEMA)	NEMA is not appropriately staffed. Currently there are two major gaps: the absence of a Deputy NDC and a Planning Officer. Limited government funding has hindered the filling of these positions as required. For continuity of NEMA there is need for training of younger staff member in the area of management and disaster management at the degree level. This will allow the agency to be more proactive instead of reactive in its activities.

Government Agency	Capacity Issues
	There is limited funding for the cadre of volunteers at the community level. The local budget funds are only enough to support salaries and other administrative expenses. Consistent training is needed for the community volunteers and staff as first responders and community emergency response. There are eight (8) local districts in St. Kitts and five (5) on Nevis which all have volunteers, however, not all the volunteers are trained. St. Kitts has identified training offered by USAID and CDEMA but there is no funding to tap into this training. Communication equipment are limited and there is need for other basic equipment like hard hats, boot rain coats, etc. for volunteers to respond appropriately. NEMA would like to have equipment stored within the community so that in the event of road blocks emergency cases can be addressed.
St. Kitts Meteorological Services	There is no known Act governing the Meteorological Services. It is their intent to develop a Policy document that can be used to guide the drafting of an Act. There are standards set by the World Meteorology Office and the International Civil Aviation Office that demands local Meteorological Services to meet their standards. SKN is currently not able to meet these because of the lack in the appropriate legal framework. They require that policies are created internally to govern how the office operates and to monitor the progress of service being provided but these services operate separately as the St. Christopher Air & Sea Ports Authority (SCASPA) and Nevis Air & Sea Ports Authority NASPA in two different Ministries. It is a requirement of these external organisations to have the Metrological Service for each country to be under one Authority even though different offices can fall under this Authority but currently this does not exist. They also lack monitoring equipment. It is the desire of the St. Kitts Met Services to increase spatial coverage; they are currently a part of the project: Strengthening Hydro-meteorological Operations and Services (SHOCS). This project and funding from the CCCCCs has led to the installation within 2013/2014 three new weather stations in: Brimstone Hill, in Cayon and on the South East Peninsula that reads data every 10 minutes. Staffing is limited for data management and data analysis. There is need for dedicated staff and properly trained in this area. There is no government funding to do any of these and Met Service is dependent on external funding sources.
Lands and Surveys	The Ministry of Sustainable Development lacks a basic land policy for SKN

Government Agency	Capacity Issues
Department	which would achieve certain objectives relating to the govern land use, land use management, security and distribution of individual and collective land rights. Sustainable Land Management regulations also need to be adopted to strengthen the overall sustainable development policies, interventions and overall national physical development in SKN.

5.2 Adaptability of the Socioeconomic Sector

Adaptation can be broadly defined as the process of change by which a social or ecological system becomes better suited to its environment. When applied to social systems, the ability to implement suitable adaptation measures is rooted in a society's adaptive capacities, which are in turn determined by a range of development related issues (Adger et al., 2005; Brooks et al., 2005). In the context of climate change, adaptive capacity has been defined by the IPCC (2007) as "the ability or potential of a system to respond successfully to climate variability and change". A country's adaptive capacity can therefore be determined by a wide range of factors, including *inter alia*:

- access to an adequate range of viable technological options for reducing vulnerability;
- range of viable policy instruments with which the country might affect the adoption of these options;
- availability and distribution of resources required to underwrite the adoption of adaptation policies;
- stock of human capital, including education and personal security;
- stock of social capital, including the definition of property rights;
- access to risk-spreading processes (e.g., insurance, options and futures markets);
- the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of decision-makers themselves.
- the availability of resources and their distribution across the population

In the context of developing countries, many of which possess limited institutional capacity and access to resources, adaptive capacity could be shaped by an even broader set of determinants that operate at various scales simultaneously. At the community level, there are also a wide range of factors that must be taken into consideration when determining local-scale adaptive capacities. The ability of local communities to adapt depends on a mix of social, bio-physical and technological constraints. For instance, the ability of communities to form networks through collective action that insulates them against the impacts of climate change can be seriously compromised in societies where the policy environment is not fully developed or where institutional capacity and access to resources are limited.

5.2.1 Community (Existing Coping/Adaptation Strategies)

Identified in this section of the report are the location- and climate-specific factors currently driving vulnerability for the Basseterre Catchment Area and the accompanying coping and adaptation strategies (if any) that are being employed by local communities.

Floods

The fieldwork data indicate that flooding is not a major issue for the area at present. The ghauts usually flow straight to the sea unless they are blocked. However, both terrestrial and coastal floods may become more of an issue in the future with a changing climate. Additionally, increased tarmac surfaces associated with the growth of residential settlements in recent years will lead to increased surface runoff, thus heightening the susceptibility of the area to flooding.

Hurricanes

The area is definitely susceptible to hurricane impacts. The destructive potential of a hurricane is significant due to its high wind speeds and torrential rains that produce flooding and occasional storm surges reaching heights of several feet above normal sea level. Hurricane Georges was the last major hurricane to have directly impacted the island in 1998. In all, Hurricane Georges caused 5 fatalities, left 3,000 homeless, and resulted in $445 million (1998 USD) in damage on the island. Since 1998, there have been a total of seven (7) hurricanes that have passed within 150 km of the island, a few of which have caused significant coastal damage. In 1999 Hurricane Lenny, moving in an atypical west to east pattern, passed 39 km offshore from Saint Kitts causing significant beach erosion and coastal flooding along the island's western coast. In 2008, Hurricane Omar passed some 150 km east of the islands as a Category 4 storm, causing significant damage to coastal infrastructure from wind and storm surge.

The community consultations revealed that a number of households in the study area were severely impacted from the passage of Hurricane Georges. Several of the persons consulted indicated that their homes were completely destroyed from the hurricane while other residents stated that they suffered extensive damages to the exterior and/or interior of their houses. Other impacts included loss of electricity and water during and immediately after the storm. Also a few persons indicated that the hurricane prevented many individuals from attending work and some schools had to be kept closed for several days.

In terms of response, most of the persons that suffered property damage by the hurricane have since made changes to their properties. A number of the community residents interviewed indicated that they have changed their building material from wood to concrete. A few others have either replaced their roofing material (mostly from zinc to concrete slab or shingle) or have reinforced their roofs.

It is important to note though, that the majority of residents have not done anything in preparation for future hurricane impacts. One major constraining factor to adaptation is finance. The cost of renovation was cited by a few residents as a major hindrance to adaptation. Even persons who have since made changes to their homes pointed out that it was very expensive to maintain their housing infrastructure. This is significant given recent climate change projections for the Caribbean that suggest hurricanes will increase in both frequency and severity.

Drought

Drought does not seem to be a major problem for the area at present. Residents also stated that they usually do not experience water lock-offs, and when they do, it is usually linked to repair or maintenance activities and immediately after a heavy rainfall event primarily due to siltation.

While this suggest a low exposure for the area to drought impacts, further analysis suggest that households have very limited adaptive capacity. Even though the area is not affected by drought currently, if these events are to become more frequent in the future, most households are not prepared for it. Most of the households surveyed do not normally practice storing water. Most of these households rely almost entirely on tap water. Only a limited number of households were seen practicing rainwater harvesting.

5.2.2 Economic Sector

Agriculture

The nature of the agriculture sector in St. Kitts also makes it highly sensitive to variations in climate. The majority of farmers in the study area were observed practicing open field cultivation and relied on rainfall as a primary source of freshwater. Despite this, hardly any rainwater harvesting was seen being practiced in the study area. Farming is being done on a small scale with limited to no application of technology. The sector is therefore susceptible to a range of climate related hazards including hurricanes, droughts, heat stress, flooding as well as infestation from pests and plant diseases.

There are a number of programmes currently underway that are aimed at addressing the water situation for the agriculture sector. The Ministry of Agriculture has recently embarked on a rainwater harvesting project with McGill University. The project involved the construction of several dams that would be used to store water for crops and livestock. There are also a number of projects promoting protected agriculture among local farmers, especially to safeguard farmers from pest infestation, invasion from monkeys and praedial larceny. There is also an Agriculture Adaptation Strategy (2012-2017) that is geared towards diversifying the sector.

While these initiatives offer tremendous potential for transforming the island's agriculture sector, they have been constrained by a number of intervening factors. The most obvious being funding. Access to a sufficient and sustained pool of funding is definitely needed if the Department of Agriculture is to maintain and scale up these projects. It was reported that there are a number of important capacity building project ideas that have not yet materialized due to a lack of funding. Also, many local farmers (the majority of which operate on a small scale) find it very difficult to access credit for their farms. A lot of these farmers do not own the land they farm on, which prevent them from using it as collateral to access loans. There is also a general lack of equipment and trained personnel for collecting and storing vital agro-ecological information for the sector. Finally, as the tourism sector continues to expand in Saint Kitts, accessing water for agricultural use might become more difficult. The continued development of desalinization plants especially by large flagship hotels that could sufficiently meet tourists' water demands offers one promising solution to this problem however.

Tourism

Since the closure of the sugar industry in St. Kitts in 2005, the Government of Saint Kitts and Nevis has been encouraging investors into the island to build on the tourism industry. Stakeholder consultations indicated that in the next 5 years, St. Kitts will have 5 new hotels and 1000 more new homes and with continued growth in agriculture and golf courses which will lead to a significant increase in water demand. Currently, The Marriott Hotel has the only desalination plant in St. Kitts and Nevis. However, this is likely to increase since the Water Services Department has indicated to all new hotel developers that they will not be able to provide them with water.

Commerce and Industry

St. Kitts does not have a large manufacturing sector except for a few bottling companies. These were identified as significant water users and consultations revealed that 100% of their water is supplied by the Water Services Department.

The Carib Brewery which is a part of the ANSA McAL Group of Companies group out of Trinidad is one such entity which has indicated that they government supply has always been consistent, affordable and of good quality. They have a good relationship with the WSD and are a priority customer so they are always provided with water. They have an annual usage of approximately 607,000 hectalitres spending approximately EC$200,000 for water annually.

During the interviews with the Coca Cola Company, they concur a similar scenario as the Carib Brewery. Coca Cola has an estimated usage of 4,131,070 litres annually. Bother operations have water storage to last about two days should their supply be disconnected although there is no documented business continuity plan.

Water is valued in but the commerce and industries as it is critical to their operations but many admit that they have no plans in place should the public supply fail.

One organisation has indicated that they have a waste water plant and would like to reuse that water if treated to irrigate the playfield and use in road construction but the Government has been slow to buy-in so right now their waste water is treated and disposed.

5.2.3 Health Sector

The combined population of St. Kitts and Nevis is estimated at just over 50,000 with approximately 35,000 persons living in St. Kitts. The country's population has grown steadily from a total of 46,000 persons in 2001 to approximately 52,000 persons in 2010. Between 1990 and 2010, the population increased by approximately 19.8%. There has also been a demographic shift towards older ages over the period, with relative similarity among age groups younger than 55 years. Fertility and mortality have been relatively low in the intervening decades, showing a steeper decrease in the last decade and a half.

Ministry of Health unpublished documents indicated that in 2006–2010, the average number of live births per year was 693, a decline of 5.7% from 736 in 2001–2005. There was minimal change in the number of live births between 2006 (662) and 2010 (656). However, the crude birth rate increased during the period, rising from 13.2 per 1,000 of the population in 2006 to 14.4 in 2009, with a low of 12.6 in 2010. The crude death rate was 7.5 per 1,000 population in 2006 and 7.0 in both 2007 and 2008. In 2009, the rate declined to 6.8, but in 2010 it returned to the 2006 level of 7.5 (Table 5.3). Life expectancy was 74.4 years in 2010 (males, 72; females, 76.8). That figure compares favorably with the 2006 figure of 73 years. The total fertility rate declined from 2.3 children per woman in 2009 to 1.85 in 2010.

Table 5.3: Selected Demographic Indicators

Indicators	*2006*	*2007*	*2008*	*2009*	*2010*
Total births	*662*	*690*	*709*	*749*	*656*
Crude birth rate	*13.2*	*..*	*..*	*14.4*	*12.6*
Total deaths	*373*	*353*	*359*	*353*	*373*
Crude death rate (per 1,000 pop)	*7.5*	*7.0*	*7.0*	*6.8*	*7.5*
Infant deaths	*9*	*14*	*8*	*15*	*12*
Infant mortality rate (per 1,000 live births)	*13.6*	*20.3*	*11.3*	*17.4*	*13.6*
Neonatal deaths	*9*	*14*	*8*	*13*	*9*
Neonatal mortality rate (per 1,000 live births)	*13.6*	*20.3*	*11.3*	*17.4*	*13.6*

Sources: Heath Information Unit, Ministry of Health GoSKN; PAHO

While the demographic indicators seem positive, climate change will undoubtedly present new challenges to the health sector. Studies have already shown for instance that human health on islands can be seriously compromised by lack of access to adequate and safe freshwater resources (see for example Nurse et al. 2001; Mimura et al. 2007). There is certainly a growing concern in the Caribbean that freshwater scarcity and more intense droughts could lead to deterioration in sanitation and hygiene (Cashman et al. 2010). Interviews with representatives from the Environmental Health Department and the Physical Planning and Environment Department, confirmed that residents in the Basseterre Catchment Area usually experience water quality problems when there is a heavy downpour. This usually worsens when there is an extended dry period. However, it was also reported that catchment samples generally show high levels of turbidity and bacterial contamination during the wet season.

While our study did not establish any direct link between climate variability and human health in Saint Kitts, there is growing evidence from other parts of the world that indicate that the incidence of certain communicable diseases have been increasing and will continue to increase as a consequence of climate change. The outbreak of Dengue in Trinidad and Tobago for example, has been linked to changes in rainfall (Chadee et al. 2007). Studies conducted in the Pacific islands have also established a direct link between malaria, dengue and climate variability (Russell, 2009). These and other health risks, including cholera, are projected to increase with future climate change. The recent spread of the chikungunya arbovirus within the Caribbean is indicative of how susceptible the region is to mosquito-borne diseases, all of which will be influenced by changes in local climatic conditions.

5.2.4 Visioning

The Consultants consulted with the community of St. Peters as key stakeholders because the area spans the upper watershed of the Basseterre East Catchment Basin. From the consultation, the residents outlined the hazards that they have been affected by in the past. Hazards include soil erosion, flooding as illustrated in Figure 5.3 below. Much of the hazards are associated with the College Street Ghaut in the project area.

Figure 5.3: Community Perspective on Vulnerability Issues in the Basseterre Watershed Area

A visioning exercise was also conducted as part of the stakeholder consultation. The residents were asked to think about and list what they envisioned the community 5 to 10 years into the future. The results are as follows:

1. Stabilised ghaut/channels
2. Planting of fruit trees
3. Pedestrian friendly road design - side walk
4. More community facilities – parks, centres, etc.
5. Better control of illegal dumping in ghauts
6. Regular cleaning and maintenance of ghauts
7. Job creation within the community
8. More adequate street lights in Cedar Path
9. Paved road in Cedar Path, Stapleton and other areas up the slope
10. Guard rails along roads in the steep hillsides

11. Regularised public transport system
12. Roundabout by Anglican Church
13. Access to garbage collection points

5.3 Adaptability of Water Sector in Basseterre

Adaptive capacity "describes the ability of built, natural and human systems associated with a given planning area to accommodate changes in climate with minimum disruption or minimum additional cost." (Pulwarty and Hutchinson, 2008). The existing exposure of the systems to stress, the projected stresses, the projected impacts, the existing initiatives at both the community and institutional level, their ability to accommodate change, and needs have been used to evaluate the adaptive capacity of the water sector.

Table 5.4 outlines the adaptive capacity of St. Kitts to deal with the climatic projected stresses and likely impacts on the water sector in Basseterre.

Table 5.4: Summary Adaptive Capacity Assessment

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	**Adaptive Capacity**
WATER SUPPLY AND MANAGEMENT				
Low annual rainfall with high inter-annual variability	Increasingly drier conditions. Heavy rainfall events decrease. Increase in annual temperatures.	More frequent drought events, increased evaporation may result in greater pathogen density in water and this could result in a lack of potable water. Population growth and expansion of tourism related activities may compound this problem.	Capacity and storage can be improved by better maintenance and monitoring of the catchment systems already in place. (Leakages in distribution network and storage areas to be addressed. This is a costly venture and will require external funding)	Low
Annual exposure to hurricanes and tropical storms	Hurricane intensity expected to increase (not necessarily frequency)	Increased flooding in certain areas and exposed to risk of debris and sediment flows. Damage to water sector infrastructure- downtime can lead to loss of revenue and negatively impact water sector development plans.	Improve farming practices to reduce erosion and sediment flows. Regular maintenance of ghauts (e.g. College Street and Westbourne) along the roadways within the St. Peters area is needed. (External funding needed by the PWD to purchase equipment for sustainable ghaut maintenance)	Low
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise which can restrict the use of highly brackish/saline well water.	No physical infrastructure will reduce sea level rise, but lobbying for greater financing to explore other viable efficient sources & treatment may be possible.	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	**Adaptive Capacity**
		Increasing population and economic growth increases water demand. Sea level rise can lead to future coastal flooding	Can reduce & rotate abstraction from the wells with the use of scientific data to inform decisions during wet and dry seasons. (Plans are being made for BEAD to dig wells in other locations through external funding)	
Meeting increased demand of water from population growth and economic activities	Reduction in annual average rainfall - more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	The WSD indicated that they do not have enough water to supply new tourism developments. Abstraction from the Basseterre aquifer is near maximum capacity. Reduction in water loss by improving monitoring at more points along the distribution network to reduce leakages. (Costly operation and external funding likely necessary) Capacity and storage can be improved through greater development control of watershed area to prevent deforestation. (External funding needed to increase storage)	Low
Poor watershed management	Increasing drought conditions	Increase in risk landslides and soil erosion due to change in land	Can undertake tree planting programme in critical areas (community involvement	

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	Adaptive Capacity
		use, reduction of protective tree cover and reduction in infiltration.	need to support Ministry of Sustainable Development). Development control needed. Mitigation measures to be put in permit conditions and monitored to ensure new housing and tourism development do not lead to landslides etc.	Moderate
AGRICULTURE				
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts Mean annual decrease in rainfall of between 6-11% for southern St. Kitts (which includes the Basseterre Catchment Area) by the 2030s	More frequent drought events will result in reduced crop yield. Reduction in available freshwater for crops and livestock.	Increase the use of dryland farming techniques and introduce the use of more drought resistance crops. (External funding needed to train needed for both extension officers and farmers) Increase the storage capacity of water specifically for farmers to be used by farmer groups. (SIDF already funding increase in storage)	Moderate
Poor dryland farming techniques	Mean temperature increase of between 1oC and oC by 2030s create drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield and even greater demand for water.	Increase the use of dryland farming techniques such as mulching and introduce the use of more drought resistance crops. (External funding needed to train needed for both extension officers and farmers)	Low

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	**Adaptive Capacity**
		Plant stressed and wilting from increased temperature and possible introduction of new pests and diseases	Increase the use of fruit trees on farms. Will also be useful in watershed management.	
Damage from heavy rainfall/storm events **Poor farming practices**	Hurricane intensity expected to increase (not necessarily frequency) Potential risk for sea level rise (SLR)	Loss of crops, reduction in crop yield Landslide and soil erosion due to heavy rains may lead result in moderate damage to crops due to debris flow and a loss of fertile top soil. The indiscriminate use of pesticides and fertilizers by some farmers in and around the Catchment Area pose the risk of contaminating groundwater resources that can in turn affect crop growth and threaten livestock. Clearing of vegetation for farming especially on slopes can lead to increased surface runoff and lower the groundwater recharge capacity of the area.	Improve farming practices to reduce run-off. Increase use of wind barriers. (External funding needed to train needed for both extension officers and farmers) Consider wind resistant varieties of bananas (bigger trunks). (External funding needed to launch such a project.)	Low

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	**Adaptive Capacity**
		SLR may lead to moderate to high increases in salinity of low lying and coastal agricultural lands due to sea water intrusion.		
HEALTH				
Outbreak of vector borne diseases (Chikungunya, Dengue)	More periods of short duration intense rainfall, which can cause ponding Increase in temperatures between 1oC and 2oC by 2030s	The mosquitoes which carry viruses breed in water that settles around homes, schools, churches, workplaces and playgrounds. Nearby wetlands are grounds for mosquito breeding. Temperature increase may also exacerbate the incidence of vector borne diseases such as malaria, dengue and chikungunya. Flash floods may also lead to loss of life.	Need policy to govern fogging and larvicide treatment activities. (Recently received two fogging machines to control adult mosquitoes)	Moderate
Increase in water related illnesses (Gastroenteritis, diarrhea)	Reduction in annual average rainfall - longer dry periods	Water restrictions imposed during dry periods could increase over time increasing the risk of water related illnesses.	Mandatory chlorination systems persons who are forced to have water storage facilities, in particular cisterns. (Currently not a critical issue but no local funds	Low

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	ADAPTIVE CAPACITY ANALYSIS	
			Ability of the Systems to Accommodate Projected Impacts with Minimum Disruption or Costs	**Adaptive Capacity**
	Increase in frequency and severity of hurricanes and tropical storms can lead to moderate/severe damages to dams, infrastructure and landslides may also occur.	It may also lead to a breakdown in sanitation and hygiene. Landslide and soil erosion may result in a moderate increase in turbidity and reduction in freshwater quality; increased threat of water-borne disease e.g. cholera.	available to mitigate)	

6 VULNERABILITY ASSESSMENT

6.1 Socioeconomic Vulnerability

St. Kitts and Nevis, like many other small island states in the Caribbean, is vulnerable to a range of external shocks and natural disasters. Climate change arguably poses one of the biggest threats to the natural resource base of the country. These threats could also have significant social and economic consequences. Medium and longer term changes in temperature, precipitation, and sea level driven by climate change can add to existing stresses on natural resources caused by other influences such as population growth, land-use changes, and environmental degradation. The country can also be exposed to increases in the frequency of extreme weather events, particularly droughts, floods and hurricanes. These events can be costly, particularly with respect to damages to key infrastructure and the loss of life. Changes in precipitation and increased evaporation from higher temperatures can affect water supplies and water quality, posing threats to irrigation, fisheries and drinking water.

These and other non-climatic threats are mediated, and even compounded at times, by existing socioeconomic conditions, alongside regional characteristics including the small areal size of most Caribbean states, high concentration of populations and resources along the coast, susceptibility to a range of extreme weather events such as hurricanes, narrow and highly specialised economies and a limited natural resource base. For example, the fact that over 60 percent of the population in St. Kitts and Nevis lives in coastal areas, places the population at high risk from sea level rise and other climate change related impacts. Past and recent impacts from hurricanes and tropical storms are indicative of the Federation's heightened vulnerability to damage from extreme weather events. Since 1950, 16 named storms have passed within 100 km of the islands[1].

As aforementioned, this vulnerability is the result of a number of interrelated stress factors and conditions that have come together. When taken together, these conditions represent a serious threat to human development and wellbeing in St. Kitts and Nevis, to the safety and integrity of public infrastructure and personal property, and to the quality of the country's natural resources to name a few. In the case of freshwater, social challenges such as poverty and unemployment may affect people's ability to access this very important resource. For St. Kitts and Nevis, these challenges can be made worst by climate change. Given the country's heavy reliance on rainfall as a source for freshwater, and the close proximity of its underground water resources to the coast, the potential impact of climate change on both the quality and the quantity of these resources is likely to be significant.

6.1.1 Results from Socioeconomic Review

This section reports on the findings of the desk review and field study that were conducted for the socio-economic component of the VCA. The TOR singled out agriculture and health as areas of key focus. Therefore, most of the sectorial analysis conducted has been concerned with evaluating the potential

[1] See World Bank (2010) Disaster Risk Management in Latin America and the Caribbean Region: GFDRR County Notes – St. Kitts & Nevis

threats climate change pose to these two sectors, especially as it relates to their reliance and use of freshwater resources.

6.1.1.1 Vulnerability Assessment of the Agriculture Sector

Susceptibility to Economic Shocks

Since the demise of the sugar industry, most of these former sugarcane lands lie idle. At present, the medium to longer term challenge for the government is to provide significant opportunities to reconfigure the economy to become more productive and competitive. While this has seen significant investment in the service sector, there has also been a drive to diversify the agriculture sector. One key area of focus is to improve and increase local farmers' access to fertile agricultural land to grow non-sugar crops that could supply the expanding tourism industry. There is also tremendous potential to supply nearby sub-regional markets with vegetables and fruits.

Despite these potential areas for growth, the agriculture sector in St. Kitts and Nevis is susceptible to a wide range of externally generated shocks. These shocks are both environmental and economic in nature and range from hurricane impacts, landslides and flooding to the removal of long-held preferential market access and high price competition from food imports. In terms of direct effects, the collapse of the sugar industry has had a deleterious impact on the economy of St. Kitts and Nevis. In the 2007 St. Kitts and Nevis National Budget Address, the Government estimated that taking into account the direct economic contributions of sugar cane and sugar manufacturing sub-sectors, the collapse of the sugar industry directly reduced GDP by 1.9% (SKN CPA 2007/2008). Indirectly though, the end of sugar in SKN has had an even greater impact on peoples' livelihoods in particular due to the industry's tremendous multiplier effects.

The situation has been made worse as the economy of St. Kitts and Nevis transitions from an agriculture-based economy to a service-based economy led by tourism. This transition towards a service-based economy was set in motion following the end of the commercial production of sugar on the island of St. Kitts in 2005. The economy of St. Kitts and Nevis has suffered significant losses since the ending of sugar production and government efforts to diversify into other economic activities have been met with mixed results. Although the sugar industry had been in decline for several years prior to its closure, the industry still played an essential role in the economic and social development of St. Kitts and Nevis (Ministry of Sustainable Development, GoSKN 2006). Likewise the number of persons involved in the sugar industry was on the decline leading towards its closure in 2005, but there are still many former sugar workers who are going through a difficult period adapting to a post-sugar economy (see Clarke 2013).

While the tourism industry offers tremendous economic benefits for St. Kitts and Nevis, the sector's performance to date has been mixed. The tourism and hospitality sector is particularly susceptible to global economic processes and events, as seen in the case of the global turndown in travel immediately following the 9/11 terrorist attacks in the United States in 2001 and after the global financial meltdown and recession that began in 2008 (Figure 6.1). Additionally, the industry tends to be seasonal and is particularly strong in the peak winter season (December to April) but weaker during the off-peak summer season (May to November). The United States is the leading market for visitors, with the United Kingdom, Canada and the Caribbean also being important markets. In 2004, total visitor arrivals (stay-over and cruise) to St. Kitts and Nevis totaled over 380,000, and visitor expenditure amounted to over US $96 million. In that same year the contribution of hotels and restaurants to GDP was 8.5%.

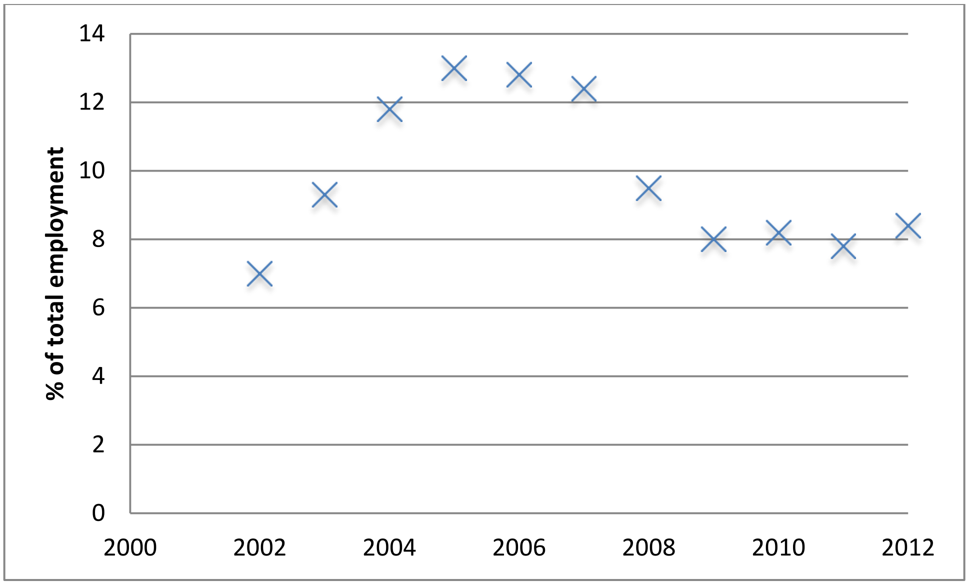

Figure 6.1: Direct Contribution of Travel & Tourism to Employment

Table 6.1: Selected Tourism Statistics 1998-2004

Item	2000	2001	2002	2003	2004
Stay-over arrivals	76,350	74,227	72,852	94,617	124,158
Cruise passenger arrivals	170,887	259,134	171,814	156,284	260,566
Number of calls	343	358	263	270	373
Estimated visitor expenditure (USD mn)	58.5	61.9	56.3	75.6	96.7
Tourist accommodation (rooms)	1,602	1,489	1,862	1,859	1,895
Contribution of hotels and restaurants to current GDP (%)	5.6	5.7	5.4	6.9	8.5

Source: Ministry of Sustainable Development, GoSKN 2006

The sector is also vulnerable to competition from food imports. Like many of its regional counterparts, Saint Kitts import the majority of food consumed in the island. This not only poses a significant threat to the economic livelihoods of local farmers, but also renders the country vulnerable to global food price shocks that could have an adverse negative impact on national food security.

Susceptibility to Future Climatic Changes

This subsection outlines some of the key climate-induced risk factors identified for the agriculture sector in the Basseterre Catchment Area based on a detailed desk review of global/regional climate change science literature and the future climate projections generated by the Climate Studies Group.

Possible risk factors for the agriculture and water sectors in the Basseterre Valley Catchment area are listed below:

- Increase in frequency and severity of hurricanes and tropical storms may lead to a moderate to high damage to crops and loss of livestock from a combination of wind and flooding damage
- Landslide and soil erosion may lead result in moderate damage to crops due to debris flow and a loss of fertile top soil.
- Sea level rise may lead to moderate to high increases in salinity of low lying and coastal agricultural lands due to sea water intrusion
- Increased frequency in drought events may cause moderate to high levels of increase in the wilting of crops; increase in evapotranspiration leading to a reduction in available plant moisture; reduction in crop yield and quality
- Mean temperature increase of between 1 ^{o}C and 2 ^{o}C by 2030s may lead to a low to moderate risk of plant stress from increased temperature and possible introduction of new pests and diseases.
- Mean annual decrease in rainfall of between 6-11% for southern St. Kitts (which includes the Basseterre Catchment Area) by the 2030s will likely result in a moderate to high reduction in available freshwater for crops and livestock.

In addition to these external threats, there are a number of internal stress factors that further renders the agriculture sector vulnerable to climate change impacts. These include;

- High reliance on rainfall. Most of the farmers in Saint Kitts (and in extension the Basseterre Catchment Area) practice rain-fed agriculture. The small size and fragmented nature of most of these farm holdings make it very difficult to set up on-farm irrigation facilities.
- Poor farming practices. The indiscriminate use of pesticides and fertilizers by some farmers in and around the Catchment Area pose the risk of contaminating groundwater resources that can in turn affect crop growth and threaten livestock. Also the clearing of vegetation for farming on can lead to increased surface runoff and lower the groundwater recharge capacity of the area.

6.1.1.2 Vulnerability Assessment of the Health Sector

According to the recent IPCC AR5 report, the effects of climate change on human health globally, will be both direct and indirect, and are expected to exacerbate existing health risks particularly in the most vulnerable communities where the burden of disease is already high (Nurse et al. 2014). As aforementioned, many small island states around the world are already suffering from either climate sensitive or induced health problems including the loss of life from extreme weather events such as hurricanes and flash floods and a range of vector- and water-borne diseases such as malaria, dengue, schistosomiasis and leptospirosis. Extreme weather events such as hurricanes, droughts and floods can have both short-term and long-term effects on human health, including drowning, disablement, and even lead to mental health problems associated with property damage, loss of economic livelihoods and death of loved ones.

Studies have also shown that climate change will have adverse effects on freshwater resources, particularly for island communities in the Caribbean and the Pacific and Indian oceans (Cashman et al. 2010; McMichael and Lindgren 2011). Having adequate and reliable access to clean potable water and good sanitation are extremely crucial to human health and wellbeing. Achieving this is however contingent on a number of factors including a country's level of economic development, the state and quality of existing water and sanitary infrastructure, the nature and distribution of water resources, population growth trends and settlement distribution to name some. Climate change may also affect a country's water resources through sea level rise which could have adverse effects on human health. Changes in average temperature may introduce new disease carrying vectors that could also have a direct negative impact on a country's health sector.

A key focus of the socio-economic component of the VCA is to better understand the likely social impacts that could arise from developments in the study area's water sector arising from climate change and demographic trends. The following table outlines some of the key climate-induced risk factors identified for the health and water sector in the Basseterre Catchment Area based on a review of global/regional climate change literature and the future climate projections for Saint Kitts generated by the Climate Studies Group.

Possible risk factors for the health and water sectors in the Basseterre Valley Catchment area are listed below:

- Increase in frequency and severity of hurricanes and tropical storms can lead to moderate/severe damages to dams and other water infrastructure, increased turbidity and reduction in freshwater quality; heightened threat of water-borne diseases; loss of life due to flash floods etc.. Ponding may also lead to increase threat of vector-borne diseases like dengue and malaria.
- Landslide and soil erosion may result in a moderate increase in turbidity and reduction in freshwater quality; increased threat of water-borne disease e.g. cholera.
- Sea level rise may result in moderate to high increases in salinity of groundwater aquifers due to sea water intrusion, will lead to reduced freshwater availability and increased risk of water insecurity.
- Mean temperature increase of between 1 ^{o}C and 2 ^{o}C by 2030s can moderately exacerbate the incidence of vector borne diseases such as malaria, dengue and chikungunya.
- Mean annual decrease in rainfall by 2030s with high inter-annual variability may result in a moderate to high reduction in availability of freshwater and might also lead to increase water lock offs for households and a breakdown in sanitation and hygiene.

6.1.2 Commerce and Industry

The businesses within this sector are completely dependent on water from the Water Resource Department. Although they have reported to have no issues with the quality and consistency of the water supplied to their operations. This is a positive historical trend.

It is evident from the water resource assessment that the public water supply system is already stressed from high extraction rates and inability to drill more wells, threats of reduced infiltration due to land demands for development and others already discussed. With the onset of climate change and climate change impacts such as lower annual rainfall and risk of sea level rise, this places added pressure on an already stressed supply which means that business operators are vulnerable, should public supply be disconnected for days due to uncontrolled circumstances. Some operators have water storage that can support their operations, but this supply cannot last beyond two days.

Development control measures at the government level should consider requirements for developers to consider drainage plans that facilitate infiltration in large spaces such as parking lots and vegetation landscapes that enhance infiltration. In addition, Commercial and industrial entities should consider alternative water sources as a back-up so that they will be able to adapt to future risks.

Potential increases increase in frequency and severity of hurricanes and tropical storms can also lead to damages to buildings, data, and equipment critical to business operations. The lack of disaster risk management plans and/business continuity plans within many businesses on a large scale also increases vulnerability because it means that many operations have not considered the measures that the business would take before during and after an event.

6.2 Basseterre Catchment Vulnerability

The "annual rainfall, for stations in St. Kitts, depicts relatively significant interannual variability, with a slight decreasing trend in rainfall for the period 1930 to 2006. Stations close to the north coast (northwest and north-central sections) of the island generally received more annual average rainfall than the other stations." Section 3.1.1 indicated:

- The month of May is the typical peak for the early rainfall season, receiving largest rainfall amounts for the first six months of the year. For the late rainfall season, highest rainfall totals are generally obtained in November. Several of the stations within St. Kitts exhibit a tri-modal pattern, with two peaks within the late rainfall season.
- Maximum and minimum temperatures within the island show a slight increasing trend for the period 1981-2007, with July-August generally as the warmest months of the year.
- On average, minimum, mean and maximum temperatures are projected to increase from present through the 2030s for St. Kitts and Nevis. Mean temperature increases are generally between 1 ^{o}C and 2 ^{o}C.
- Mean annual rainfall for St. Kitts and Nevis is projected to decrease by the 2030s, with the exception of the northern extent of St. Kitts, which is expected to experience an increase in

mean annual rainfall. Reductions in rainfall range from approximately 3 to 7% for Nevis and 6 to 11% for southern St. Kitts."

Based on the total water resource between the years 1998 to 2005 for the BVA, the 2030s projections of climate outlined above will have a negative impact on water resources for the Basseterre Valley aquifer and by extension the island. The correlation between atmospheric temperature and also surface temperature of water will cause problems for not just the general environment due to increasing evaporation rates but the changes in water quality which will increase bio-geochemical reactions underground especially those related to volcanic rocks.

	Rainfall Period 1980 to 1998	Rainfall Period 1995 to 2005	Reduction by 6 %	Reduction by11 %
Imperial MGD	5424	5573	5238	4904
US MGD	6524	6693	6291	5890

With the northern portion of the island projected to increase in mean annual rainfall, the planning of investment for groundwater exploration will need to be rethought and strategically placed to capture rainfall which will infiltrate the underlying bedrock.

With decreases in rainfall projected over the BVA, the continual dewatering of the aquifer and projected demand for water will place further stresses on the aquifer as saline intrusion will become a prominent feature of it as demand increases. This is demonstrated in the Figure 6.2 below.

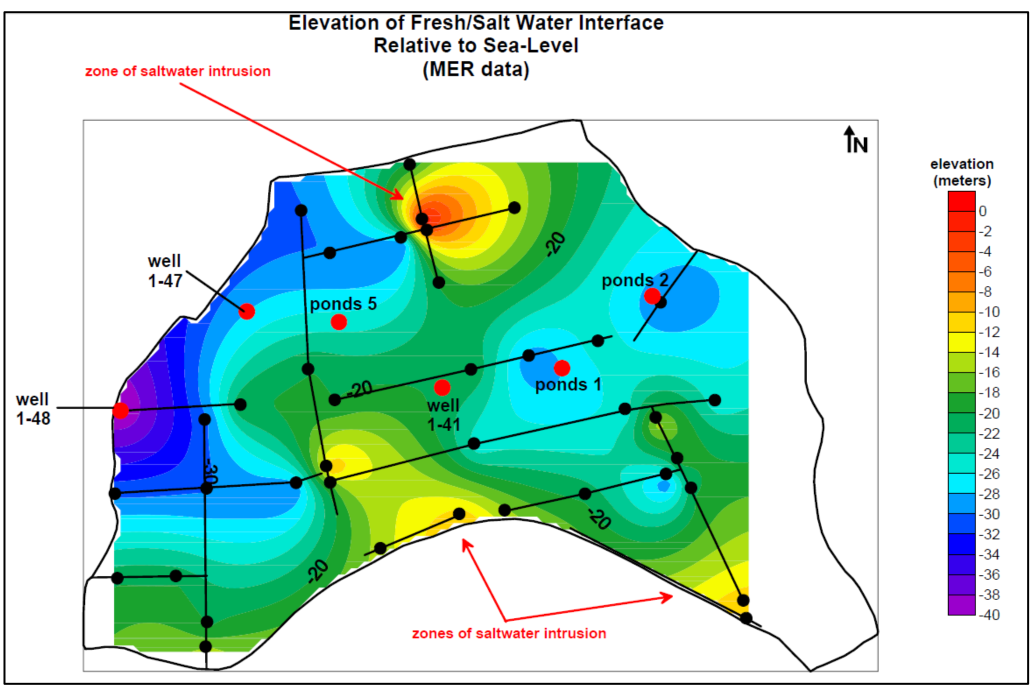

Figure 6.2: Salt Water Intrusion Compliments (OET 2009)

During summer months of July and August, temperatures in tropical zones, are often seen as increasing in the climate change projections and this increases the vulnerability of utility companies in handling the effects of droughts and mitigating other climatic stresses. Sources of uncertainty in handling climate changes especially those related to hydrological changes in the Caribbean will require better data management and flexibility in the operations of the utility managing the resource as it impacts the delivery of water and by extension economic activity.

The augmentation of groundwater resources by using energy efficient technologies will eliminate drastic increases in operational cost which are currently increasing as illustrated in Figure 6.3 below.

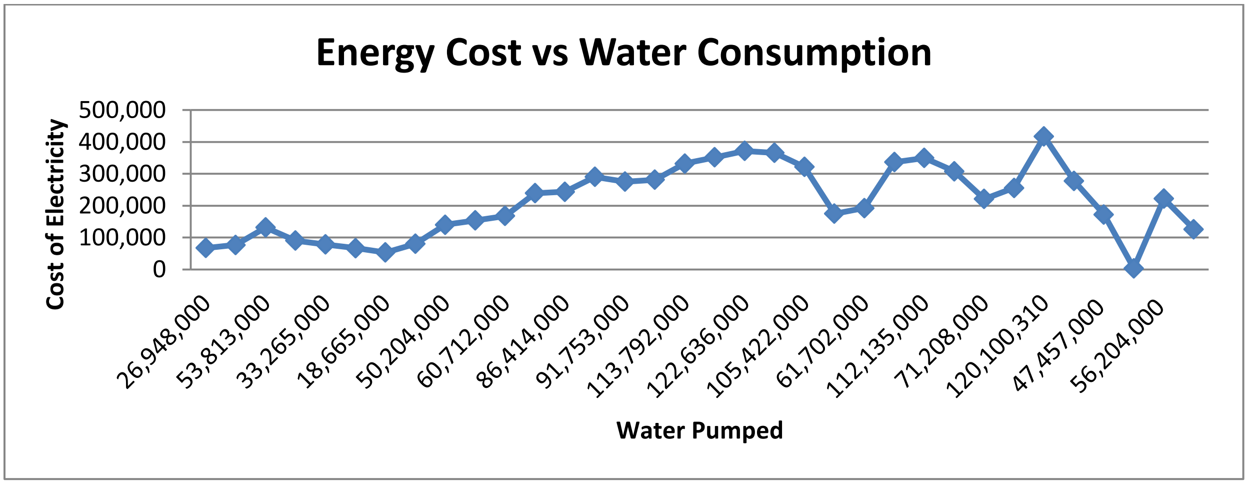

Figure 6.3: Energy cost vs consumption

There is a combination of factors that reduce the island's capacity to provide water for domestic consumption, agricultural, manufacturing and tourism related activities. These include the:

- Current projected climatic stresses on the aquifer
- Current mismanagement of the resource due to lack of scientific data used in decision making process
- Links between water and sanitation, which are intrinsically linked to health and poverty. Immediate increase in water demand being created by industries, such as, tourism and other economic related activities.
- Projected increase in population which will therefore increase usage over time.
- Based on the evidence in Sections 4.1.1 and 4.1.3, the current over pumping of the resource and inadequate infrastructure has led to:
    - Further deteriorating conditions of groundwater wells
    - Further deteriorating distribution and storage facilities
    - Lack of metering and infrequent monitoring of water quality
    - Lack of recording surface and groundwater parameters
    - Lack of hydro geological and hydrology practice within the department and internal data analysis

- Non-existent integrative legislative support for water, sanitation, health and the environment

At its current rate, if the appropriate recommendations are not adopted and implemented within the next five years the country will have detrimental effects on the ability to distribute water of the appropriate quality for hygienic practices and general social care programs.

6.3 Summary Vulnerability Analysis

Table 6.2: Summary Vulnerability Analysis

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	Adaptive Capacity of the water sector	Vulnerability of systems in the water sector
WATER SUPPLY AND MANAGEMENT					
Low annual rainfall with high inter-annual variability	Increasingly drier conditions. Heavy rainfall events decrease. Increase in annual temperatures.	More frequent drought events, increased evaporation may result in greater pathogen density in water and this could result in a lack of potable water. Population growth and expansion of tourism related activities may compound this problem.	Moderate (supply is sensitive to lower annual rainfall)	Low (Costly mitigation measures will require external funding)	Moderate
Annual exposure to hurricanes and tropical storms	Hurricane intensity expected to increase (not necessarily frequency)	Increased flooding in certain areas and exposed to risk of debris and sediment flows. Damage to water sector infrastructure- downtime can lead to loss of revenue and negatively impact water sector development plans.	High (exposure to damage and losses from storms)	Low (External funding needed purchase equipment for ghaut maintenance)	High
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise which can restrict the use of highly brackish/saline well water. Increasing population and	High (sensitive to sea level rise and saline intrusion)	Moderate (Funding already identified to contract BEAD to dig new wells)	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
		economic growth increases water demand. Sea level rise can lead to future coastal flooding			
Meeting increased demand of water from population growth and economic activities	Reduction in annual average rainfall - more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	High (sensitive climate change impacts to lower water supply to meet demand)	Low (Costly to reduce leakages/losses within the system, external funding needed)	High
Poor watershed management	Increasing drought conditions	Increase in risk landslides and soil erosion due to change in land use, reduction of protective tree cover and reduction in infiltration.	Moderate (sensitive to extended drought periods)	Moderate (development control and community programmes can improve watershed management)	Moderate
AGRICULTURE					
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts Mean annual decrease in rainfall of between	More frequent drought events will result in reduced crop yield. Reduction in available freshwater for crops and livestock.	High (sensitive to drought and low rainfall)	Moderate (SIDF already funding the increase in storage capacity but external funding still needed	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
	6-11% for southern St. Kitts (which includes the Basseterre Catchment Area) by the 2030s			for training)	
Poor dryland farming techniques	Mean temperature increase of between 1oC and oC by 2030s create drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield. Plant stressed and wilting from increased temperature and possible introduction of new pests and diseases	Moderate (sensitive to increased high temperatures, few soil conservation projects)	Low (external funding needed to train extension officers and farmers needed)	Moderate
Damage from heavy rainfall/storm events **Poor farming practices**	Hurricane intensity expected to increase (not necessarily frequency) Potential risk of sea level rise	Loss of crops, reduction in crop yield, loss of livestock Landslide and soil erosion due to heavy rains may lead result in moderate damage to crops due to debris flow and a loss of fertile top soil. The indiscriminate use of pesticides and fertilizers by some farmers in and around the Catchment Area pose the risk of	Moderate (exposed to hurricanes and storms)	Low (external funding needed to train extension officers and farmers needed	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
		contaminating groundwater resources that can in turn affect crop growth and threaten livestock. Clearing of vegetation for farming especially on slopes can lead to increased surface runoff and lower the groundwater recharge capacity of the area. May lead to moderate to high increases in salinity of low lying and coastal agricultural lands due to sea water intrusion.			
HEALTH					
Outbreak of vector borne diseases (Chikungunya, Dengue)	More periods of short duration intense rainfall, which can cause ponding Increase in temperatures between $1^{o}C$ and $2^{o}C$ by 2030s	The mosquitoes which carry viruses breed in water that settles around homes, schools, churches, workplaces and playgrounds. Nearby wetlands are grounds for mosquito breeding. Temperature increase may also exacerbate the incidence of vector borne diseases such as malaria,	Moderate (sensitive to outbreak of vector borne diseases, mitigation measures currently being executed)	Moderate (Abate and Fogging used as vector control measures)	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of sensitivity of the water sector	**Adaptive Capacity of the water sector**	**Vulnerability of systems in the water sector**
		dengue and chikungunya. Flash floods may also lead to loss of life.			
Increase in water related illnesses (Gastroenteritis, diarrhea)	Reduction in annual average rainfall - longer dry periods Increase in frequency and severity of hurricanes and tropical storms can lead to moderate/severe damages to dams, infrastructure and landslides may also occur.	Water restrictions imposed during dry periods could increase over time increasing the risk of water related illnesses. It may also lead to a breakdown in sanitation and hygiene. Landslide and soil erosion may result in a moderate increase in turbidity and reduction in freshwater quality; increased threat of water-borne disease e.g. cholera.	Low (potentially sensitive provided that water supply reduces	Low (Currently not an issue and no local funds available to mitigate)	Moderate

7 SUMMARY AND RECOMMENDATIONS

7.1 Climate

Annual rainfall for stations in St. Kitts depicts relatively significant inter-annual variability, with a slight decreasing trend in rainfall for the period 1930 to 2006. Stations close to the north coast (northwest and north-central sections) of the island generally received more annual average rainfall than the other stations.

The month of May is the typical peak for the early rainfall season, receiving largest rainfall amounts for the first six months of the year. For the late rainfall season, highest rainfall totals are generally obtained in November. Several of the stations within St. Kitts exhibit a tri-modal pattern, with two peaks within the late rainfall season.

Maximum and minimum temperatures within the island show a slight increasing trend for the period 1981-2007, with July-August generally as the warmest months of the year. On average, minimum, mean and maximum temperatures are projected to increase from present through the 2030s for St. Kitts and Nevis. Mean temperature increases are generally between 1 oC and 2 oC.

Mean annual rainfall for St. Kitts and Nevis is projected to decrease by the 2030s, with the exception of the northern extent of St. Kitts, which is expected to experience an increase in mean annual rainfall. Reductions in rainfall range from approximately 3 to 7% for Nevis and 6 to 11% for southern St. Kitts.

The projected changes in wind speed for St. Kitts and Nevis are small, with slight mean annual increases projected for the 2030s.

IPCC projections indicate that sea level will rise by 0.3m to 1m by the end of the 21st century. Other studies have predicted higher increases. It is therefore likely that the islands of St. Kitts and Nevis will be further impacted by rising sea levels by the 2030s.

7.2 Water Resources

Human existence depends on water. The geosphere, the atmosphere and the biosphere are all linked to water. Water interacts with solar energy to determine climate and it transforms and transports the physical and chemical substances necessary for all life on earth.

With the use of scientific data, a more sustainable approach could be achieved by managing the resource for all stakeholders involved.

Effective water resource management is critical to achieving reasonable success in mitigating the impacts of drought, flooding and climate change. Additional stresses on the system currently include: the aged physical infrastructure network, several collapsing wells, lack of methodologies to account for water usage such as appropriate water budgeting techniques and a lack of methods to document streamflow and runoff in the event of failure / non-existent equipment. As a result, there is limited annual/seasonal analysis of both rainfall and groundwater resources undertaken internally.

The losses experienced by the WSD are unaccounted for across the distribution system and can appear as though the economic activity and domestic demands are substantially influencing water use. This is one of the problems of the existing system, which attribute to major consumptive patterns.

Often, mismanagement of water resources is due to lack of trained individuals and lack of understanding of geological and hydrogeological characteristics, which lead to misinformed decisions and results in alternating wells for production or opting to pump more water than is required for specific periods. Currently, the design of the well-field places stress on the groundwater network and strains on mechanical equipment because it is constantly over worked and water pumped is lost from the underground water reserves across the network. Therefore it is advisable to incorporate a water management plan for the groundwater basin and in each watershed across the island to alleviate future problems.

7.2.1 Basseterre Valley Aquifer

7.2.1.1 Water Budget Annually – Scientific

The reconstruction and alignment of new wells should be drilled based on scientific data. OET (2009) reported that additional water supplies need to be developed now. Construction of new wells should be placed to the north of the airport and in the higher elevations of East Sub-Catchment of the Basseterre Watershed. Sufficient well pumping capacity should be installed to double the average day demand for the water system. This will permit the operation of the well-field in a manner necessary to minimize groundwater mining, prevent insufficient pumping capacity in the event of a well pump loss, provide adequate distribution of the wells to prevent water level drawdown interference between wells, and minimize impacts on the fresh/saltwater interface. The distribution and locations of new wells should be determined on completion of the MER mapping, monitored well construction, and validation of storativity, and transmissivity coefficients by aquifer performance testing. The depth of volume of each unit should also be ascertained by future studies for Unit 1, 2 & 3.

7.2.1.2 Storage

Studies should be undertaken to evaluate the potential of constructing reservoirs in the upper parts of the Basseterre Watershed. These could be used to collect runoff for recharging the aquifer and for use within irrigation schemes or be used directly for potable water supply. Principle unknowns are the permeability of the soils (e.g., whether lined ponds are required in the upper parts of the watershed) within the stream beds in the upper watershed, and actual runoff quantities at various points along the major stream channels.

The OET hydrological study completed in 2009 has some recommendations about well construction techniques that are still applicable. The following is a list of specifications for proper screen and gravel pack wells that would maximize well efficiency:

- An outer well casing 20 to 30 cm greater in diameter than the inner casing and set to the same depth as the inner casing.

- An inner casing attached via screw coupling or weld to the well screen. The well screen should be fully penetrating the producing part of the aquifer and the same diameter as the inner casing.
- Screen slots should be wire wrapped or machine cut with No. 80 to 100 slot.
- Screens should be gravel packed with 0.25 X 0.50 mm rounded silica gravel from the bottom of the screen up to land surface. The total gravel to be used on the gravel packing is commonly 2 to 4 times the theoretical.
- The well should be developed with a very large air compressor until the well stops taking gravel and the discharge water is free and clear of sediment.
- A gravel supply port should be installed through the outer casing.

7.2.1.3 Water Supply

Agricultural projects should be developed based on sound scientific evidence to avoid future failures and with some degree of flexibility because of the uncertainty that the future holds.

The Water Services Department has about five options for ensuring steady water supply; this include the following:

1) Reduce the significant losses that are not accounted for in the water supply system.
2) Improved data collection of flow, well and aquifer data followed by the hydrological assessments of water resources within the north and south can guide useful management strategies that will lead to more efficient use of extracted water.
3) Explore groundwater aquifers in the upper mountains.
4) Trap surface water for augmentation purposes and expand storage in the northern portion of the island which will be closest to the source of increase trends of rainfall as opposed to investing only in the existing storage.
5) Use of desalination water. This would also require a supporting policy to guide the installation and sector/industry use of desalination water.

7.2.1.4 Water Quality

The Environmental Protection Department of the USA stated that Water Quality Monitoring programs should be conducted for many purposes. Five major purposes are to:

- characterize waters and identify changes or trends in water quality over time;
- identify specific existing or emerging water quality problems;
- gather information to design specific pollution prevention or remediation programs;
- determine whether program goals -- such as compliance with pollution regulations or implementation of effective pollution control actions -- are being met; and
- Respond to emergencies, such as spills and floods.

The water program should be developed in conjunction between the Ministry governing the water department and Health. This data should then be shared and reviewed at periodic intervals to ensure the goals are being met.

7.3 Policy and Legislation

Based on the policy and legislative review conducted, new legislation is needed to strengthen the regulatory framework for the water sector. These would include a new Water Resources Legislation, a new Public Health Act and new Regulations to establish water quality standards. A critical area for new legislation is in respect of pollution. The early enactment of the National Conservation and Environmental Management Act will strengthen watershed management, establish a regulatory framework for pollution and provide a comprehensive legal framework for environmental management.

While St. Kitts-Nevis is policy rich it lacks the financial resources to implement many of the policies. As articulated by interviewees and the various national reports, various components of the current framework must be strengthened in terms of an increase in the staff complement of various institutions; provision of requisite training for staff; provision of relevant regulatory and enforcement capabilities of institutions; maintenance of a baseline of programmatic activities such as data collection and monitoring; the ability to use information from various sources for decision making; and the development of fiscal policies to stimulate corporate environmental stewardship, and to incentivize new business models that focus on the sustainable utilization of natural capital to attract foreign exchange.

There is a need for a comprehensive Water Policy to provide a comprehensive framework for the management of water and watersheds.

There is also a need for a Climate Change Policy which would establish an overarching framework for all climate change issues.

7.4 Institutional Framework

The findings of the institutional capacity assessment revealed that limited staffing and budgeting resources are preventing a number of institutions from effectively executing their mandates.

Training was a need in all the institutions, but was constrained by budgeting issues. All the government institutions are dependent on external funding sources to fulfil their mandate. This indicates that their ability to adapt to climatic changes over time is not high and very dependent on the availability of funds from external sources and the willingness of external donors. Staffing is also an issue and the government is strapped for financial resources to take on the required staffing so Institutions are forced to make do with the existing staff; this causes a set-back in the completion of some activities.

DPPE is working in association with WSD to receive funding for the purchase of some Automatic Weather Stations. The Department of Agriculture has also expressed the need for some weather stations; however, the traditional manual rain gauges are preferred in their case due to their durability. Past failures with more high tech equipment was as a result little knowledge transfer upon returning from training programmes. A good coordinated effort is recommended among these government institutions in the purchase, monitoring of data, and the maintenance of these equipment.

It is recommended that a series of durable non-expensive automatic hydro-metric stations be placed in the north, south, east, and west of the island. It was recognised in the rainfall analyses that several of the stations not far in distance apart had values that were highly correlated. It is therefore not necessary to purchase as many gauges similar to those which existed when the sugar industry was operational. It may then be useful to utilise the manual gauges in the farming locations required by the Department of Agriculture to supplement the data from the four (4) automatic stations.

It is important to note the type of automatic gauges that are desirable to be set up. There are different types of automatic weather stations:

- those that the readings can be automatically transferred while in office,
- those which are predominantly used for meteorological offices
- those which are necessary for hydro-meteorological analysis
- those that require a site visit to physically download data
- others which can transfer the data to a computer via telecommunication options.

The location of these devices, durability should be considered to ensure sustainability and longevity for the local environment in which it will be stationed.

It is critical that the stations are configured to collect minutely/hourly data and calibrated so that data can reflect extreme events and comprehensive hydrological and climatic analysis can be conducted. This will inform more accurate water budget analyses and rainfall-runoff models. Maintenance of equipment must be considered. DPPE can choose to maintain a company/individual to service the equipment, and - provide technical needs which can be provided remotely.

It is important that persons are properly trained to use the devices; persons with a background or interest in information technology or electronics and competent with a variety of software packages/programming skills and knowledge of hydrology are essential to maintain on staff after the completion of any training programme.

7.5 Socioeconomic Aspect

The communities within the project area are growing and there are predisposing factors that make the area vulnerable to potential reductions in rainfall as a climate change impact. Further a significant portion of the population is already vulnerable based on various disabilities.

It was recognised that agriculture is an important aspect of the project area and it is vulnerable to drought conditions as well as damage that can be caused by hurricanes. Water storage within the project area and the harvesting of crops prior to events are means to reduce loss respectively. With respect to water storage, due to limited rainfall in the Basseterre Valley Catchment area to infill ponds during the dry season alternative measures need to be considered. These may include:

1. Stricter water conservation methods
2. Exploring dry farming practices
3. Use of more crops resistant to water shortage areas

4. Diversification of livelihoods into economic activities that are less sensitive to climatic impacts and that provide opportunities and linkages with other sectors like manufacturing and tourism.

It is important to note that with competing uses for land due to the close of the sugar industry. A watershed management plan for the area would be necessary to ensure that as development occurs the critical water resource that supplies the most of St. Kitts is protected from degradation.

In consideration that this sector is solely dependent on a vulnerable public water supply it is recommended that business consider the implementation of a business continuity plan to prevent future losses due to potential climate change impacts. It is excellent that many large operators have a storage water supply. This is a good preparedness strategy that is recommended for all business operators small and large.

There needs to be government buy-in on the implementation of a range of mitigation measures that can conserve and reuse water in ways as discussed under Section 7.2 above.

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Annex I – List of Stakeholders Interviewed

STAKEHOLDER GROUP	POINT PERSONS
St. Kitts	

STAKEHOLDER GROUP	POINT PERSONS
Department of Physical Planning and Environment	Ms. June Hughes, Senior Environmental Officer Ms. Cheryl Jeffers, Environmental Officer Graeme Brown, GIS Specialist
Water Services Department	Mr. Denison Paul, Acting Manager
Ministry of Agriculture and Fisheries	Mr. Thomas Jackson, Director of Agriculture Mrs. Racquel Williams-Ezquea, Agriculture Officer Mr. Paul Benjamin, Extension Officer
Environmental Health Department	Mr. Oren Martin, Environmental Health Officer
Statistics Department	Mr. Carlton Phipps, Director
National Emergency and Management Agency	Mr. Carl Herbert, National Disaster Coordinator
Public Works Department	Mr. Cromwell Williams, Director
Department of Economic Affairs and Public Sector Investment Planning	Mr. Auren Manners, Project Analyst
St. Kitts Farmers' Cooperative Society	Mrs. Anabella Nisbett, President Mr. Nisbett
St Kitts Meteorological Services	Mr. Elmo Burke, Meteorological Officer
Carib Brewery	Mr. WIlkin, Manager
St Kitts Bottling Co Ltd	Mr. Tony Sutton, Production Engineer
Fisheries Division	Mr. Marc Williams, Director
Saint Christopher National Trust	Mr. Manchester, Executive Director
Nevis	
Ministry of Communication, Works, Public Utilities, Posts, Physical planning, Natural Resources and Environment	Mr. Ernie Stapleton, Permanent Secretary
Physical Planning, Natural Resources and Environment	Mrs. Angela Walters-Delpeche, Director Ms. Renee Walters, Project Manager
Water Services Department	Mr. Roger Hanley, Manager
Environmental Health Department	Mr. Anthony Webb, Public Health Inspector
Ministry of Agriculture	Mr. Keith Amory – Director Mr. Floyd Lyberd, Agroforestry Officer Mr. Walcutt James, Chief Extension Officer Mr. Randy Elliott, Agriculture Supervisor
Fisheries Division	Ms. Laurel Appleton, Director

Annex II – Water Quality Standards

The Public Health Department of St. Kitts has indicated that they utilise the World Health Organisation (WHO) guidelines for drinking water quality. OET (2009) reports that of the 12 parameters outlined by

WHO, St. Kitts test for and provide values for 5 of these parameters to monitor their potable water supply. The Table below shows the water quality report conducted by OET (2009).

	Parameter	WHO[8]	Comment
1	Free chlorine	>0.5 mg/l after 30 min at pH <8.0	
2	Nitrate	50 mg/l	
3	Manganese	0.4 mg/l	
4	Fluoride	1.5 mg/l	
5	Faecal and total coliform	Should be absent after disinfection	The WHO DW Guidelines specify that E Coli (which is the dominant bacterium in faecal coliforms) should not be detectable in 100 ml of sample.
6	pH		pH within a range of 6.5 – 9.5 is recommended.
7	Total Suspended Solids (TSS)		The WHO DW Guidelines specify that if the water is turbid it should be clarified before disinfection (filtration, settling and decanting). Filtration pore size rating of <1 m (absolute is recommended to ensure removal of *Cryptosporidium* oocysts.
8	Total Dissolved Salts (TDS)	*No health based criteria given*	Mainly inorganic salts: calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates
9	Phosphate		
10	Total Hardness		Caused by calcium and magnesium in water. This is not expected to be high in volcanic environments.
11	Conductivity		
12	Chloride		

Annex III - Methodology for Calculating Evapotranspiration

Advantage of using Penman Monteith for calculation of Evapotranspiration

The Food and Agriculture Administration (FAO) stated the follow:

- The Penman methods require local calibration of the wind function to achieve satisfactory results.
- The radiation methods show good results in humid climates where the aerodynamic term is relatively small, but performance in arid conditions is erratic and tends to underestimate evapotranspiration.
- Temperature methods remain empirical and require local calibration in order to achieve satisfactory results. A possible exception is the 1985 Hargreaves' method which has shown reasonable ET_o results with a global validity.
- Pan-Evapotranspiration methods clearly reflect the shortcomings of predicting crop evapotranspiration from open water evaporation. The methods are susceptible to the microclimatic conditions under which the pans are operating and the rigour of station maintenance. Their performance proves erratic.
- The relatively accurate and consistent performance of the Penman-Monteith approach in both arid and humid climates has been indicated in both the ASCE and European studies.
- The analysis of the performance of the various calculation methods reveals the need for formulating a standard method for the computation of ET_o. The FAO Penman-Monteith method is recommended as the sole standard method
- The FAO Penman-Monteith method is maintained as the sole standard method for the computation of ET_o from meteorological data.

Recommendation

1. The program shows promising results for calculation of this parameter for Saint Kitts and Nevis. Unfortunately, there were a few variables missing from the meteorological data of Nevis and this could not be performed. However, Saint Kitts is one of the closest islands to Nevis and shares similar climatic characteristics.
2. This is the first time meteorological data has been used to perform this task instead of the estimated percentages listed in past reports and it is recommended that the evaporation values for Saint Kitts be used for Nevis until the data gaps are filled. Both islands require Class A Pan for comparison of future values and constant collection of current meteorological values from the airport stations.

Trial Run using CROPWAT for calculation of Evapotranspiration from meteorological Data

Evapotranspiration

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	22.5	27.5	76	3.9	8.1	17.5	4.03
February	22.2	27.6	73	3.5	7.7	18.6	4.38
March	21.4	26.2	68	3.5	8.5	21.5	4.91
April	24	26.7	79	3.5	8.3	22.2	4.61
May	23.8	29.2	77	3.1	7.6	21.3	4.8
June	25.5	29.1	73	4.6	7.2	20.5	5.33
July	26	30.9	73	4.6	8.9	23	5.9
August	25.5	30.2	78	3.9	9.1	23.3	5.35
September	23.8	30.7	79	2.7	7.6	20.4	4.62
October	23.7	30.5	76	2.3	9	20.8	4.58
November	24.8	28.4	76	3.1	8.1	17.8	4.09
December	24.4	27.9	74	3.5	8.5	17.4	4.12
Average	24	28.7	75	3.5	8.2	20.4	4.73

Figure 4 RLB International Airport Meterological Data , 2000

Contact Us:

CARIBBEAN COMMUNITY
CLIMATE CHANGE CENTRE
2nd Floor, Lawrence Nicholas Building
Ring Road, P.O. Box 563
Belmopan, Belize.

Tel: +(501)822-1094/ 822-1104
Fax: +(501)822-1365
Email: oed@caribbeanclimate.bz
Website: www.caribbeanclimate.bz

We Are Social...
@CARICOMClimate

or

Ministry of Sustainable Development
Department of Physical Planning and the Environment
P.O. Box 597 Bladen Commercial Development,
Wellington Road
Basseterre, St. Kitts and Nevis