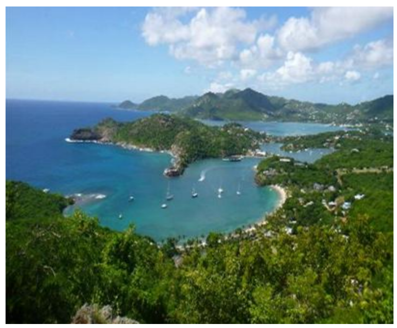
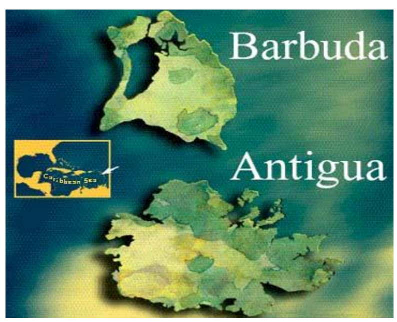
Caribbean Community
Climate Change Centre

VULNERABILITY AND CAPACITY ASSESSMENT IN THE SOUTH WEST COAST AND WATERSHED AREA OF ANTIGUA





FINAL REPORT
Submitted: December 9, 2014

Prepared for the
Caribbean Community Climate Change Centre
Belmopan, Belize
and
Environment Division
Ministry of Health and Environment
St. John's Antigua

GCCA Intra-ACP Programme

An initiative of the ACP Group of States funded by the European Union

Vulnerability and Capacity Assessment in The South West Coast and Watershed Area of Antigua

Caribbean Community Climate Change Centre
Lawrence Nicholas Building
Ring Road
Belmopan City, Belize
T: 501-822-1094

F: 501-822-1365

Published by Caribbean Community Climate Change Centre, Belmopan, Belize

Digital Edition (June 2015)
Printed Edition (June 2015)

This report was prepared for the Caribbean Community Climate Change Centre (CCCCC) and the Government of Antigua and Barbuda under the European Union Global Climate Change Alliance (EU-GCCA) Caribbean Support Project.

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

Visit our website at http://www.caribbeanclimate.bz

ISBN-13 978-976-8253-37-8 (paperback)

ISBN-13 978-976-8253-38-5 (pdf)

ACKNOWLEDGEMENTS AND DISCLAIMER

This document is an output from the EU-GCCA Caribbean Support Project, which is funded by the European Union (EU) under a Grant Contract FED/2011/267-392 for the implementation of an action entitled: Support to the Global Climate Change Alliance (GCCA) under the 10th EDF Intra-African Caribbean and Pacific financial framework in the Caribbean (EU-GCCA Project).

The report was prepared by the Environment Solutions Ltd. (ESL).

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

ESL would like to thank all the government agencies and private organisations who contributed to the preparation of this impact assessment. Firstly, the Environment Division of the Ministry of Agriculture, Health, Land and Environment, which was the focal point provided support during all the site visits and for data collection. Special thanks to Mr. Jason Paul Williams, Ms. Ediniz Norde and Ms. Nneka Nicholas of the Environment Division who were integral in data collection and setting up meetings with key stakeholders.

We would like to thank all the stakeholders (Annex 1) from the following government and private sector agencies whom we met with and who provided us with data:

- APUA
- Ministry of Agriculture, Housing, Land and Environment
- Central Board of Health
- Statistics Division
- National Office of Disaster Services
- Public Works Department
- Women Against Rape
- Professional Organization for Women in Antigua and Barbuda
- Environmental Association Group (EAG)
- Antigua and Barbuda Chamber of Commerce

We would also like to thank all the persons (residents, hoteliers, farmers and fisherfolk and other business persons) in Antigua and Barbuda who were willing to be interviewed and were very helpful in their responses.

Finally, Environmental Solutions Ltd. would like to acknowledge its team for the collaborative approach towards the development of this Final VCA. Sincere gratitude is extended to Mrs. Eleanor Jones, Managing Director of Environmental Solutions Limited, the team Project Manager, Dr. Theresa Rodriguez, Mr. George Campbell, Socio-economist, Professor Michael Taylor, Dr. Tenneisha Stephenson and Mr. Jayaka Campbell of the University of the West Indies (UWI) Climate Studies Group, Mona Campus; Ms. Michelle Watts, Hydrologist; UWI Mona, Mark Codling, GIS Specialist. We also extend our appreciation to the support team of the Climate Studies Group (Roxann Stennett-Brown, Yekini Wallen-Bryan, Anna Thomas, Christina Douglas, Theron Lumsden, Jhordanne J. P. Jones, Natalie M. McLean).

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 Health and Environment website: www.environmentdivision.htm

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AMJ	April-May-June
AMO	Atlantic Multidecadal oscillation
APUA	Antigua Public Utilities Authority
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
ASO	August-september-October
CARIFORUM	Caribbean Forum
CCCCC	Caribbean Community Climate Change Centre
CDD	Consecutive Dry Days
CWD	Consecutive Wet Days
DEM	Digital Elevation Model
DJF	December-January-February
FMA	February-March-April
GCCA	Global Climate Change Alliance
GCM	Global Climate Model
GOAB	Government of Antigua and Barbuda
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
JAS	July-August-September
JFM	January-February-March
JJA	June-July-August
MAM	March-April-May
MJJ	May-June-July
MM	Millimetres
NAH	North Atlantic High
NASAP	National Adaptation Strategy and Action Plan
NDJ	November-December-January
NGO	Non-Governmental Organization
OND	October-November-December
PPE	Perturbed Physics Experiment

PRCPTOT	Annual Precipitation
PRECIS	Providing Regional Climates for Impact Studies
R10MM	Days above 10 mm
R95P	Very Wet Days
R99P	Extremely Wet Days
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RX1DAY	Maximum 1 Day Precipitation
RX5DAY	Maximum 5 Day Precipitation
SDSM	Statististical Downscaling Model
SON	September-October-November
SRES	Special Report on Emissions Scenarios

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 under-ground storage tanks 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 persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings 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 freshwater, 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.
Sensitivity	The degree to which a built, natural or human system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature).
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 purposes of management.
Well	A well is a borehole, adit tunnel, or any other excavation constructed or used for the abstraction of water.

EXECUTIVE SUMMARY

Historically, the water sector of Antigua and Barbuda has been vulnerable to drought and climate change is expected to exacerbate this even further. Consequently, the Government has begun increasing their dependence on desalination of sea water to supply water for both domestic and commercial users. Demand for water is continually increasing with the country's growing population, changing consumption patterns and food requirements. The water shortages currently experienced are due to a number of factors – inadequate storage to hold water during rainfall events, inadequate distribution pipes, not enough treatment plants, and inefficient use of water in households, industry, and agriculture.

This study focuses on the South West Watershed Area (SWWA) of Antigua. It experiences the highest amount of rainfall in Antigua and is proned to flooding due to poor drainage, topography and poor farming practices. This study was aimed at conducting a Vulnerability and Capacity Assessment (VCA) in the South West Coast and Watershed Area of Antigua, and to determine the impacts of projected climate change on the water sector in the community. The purpose was to determine the vulnerability of the SWWA to climate related events and the extent of their capacity to adapt and/or cope in order to ensure that investments in adaptation measures achieve desired outcomes. The results of the VCA should be used to guide the decision making process in prioritizing appropriate steps that ought be taken to adapt to climate change. If the country/community is already highly vulnerable and does not have the financial, technical or human resource capacity to implement and sustain adaptation practices it is not possible to adapt to the impacts of climate change.

In order to carry out this study, climate change scenarios/ projections had to be completed first. This involved analyzing the literature and historical data and deriving RCM data at scale for Antigua and Barbuda were derived from PRECIS A1B Perturbed Physics Ensemble. To carry out the VCA the NOAA-CCCCC methodology was adapted and used in this study in combination with approaches presented in *Preparing for Climate Change: A Guidebook for Local, Regional and State Governments* (2007). This allowed for the study to be broken into three main components of analysis; sensitivity, adaptability and vulnerability. The sensitivity analysis includes a discussion on the existing water sector and natural and anthropogenic threats. The adaptive capacity analysis includes a discussion and analysis of the policy, legal and institutional framework of Antigua and Barbuda that relate to the water sector. It also includes a discussion of the SWW's capacity for social and economic resilience to climate change. The findings about sensitivity and adaptability are then combined to determine how and where the community is vulnerable to climate change.

As with any study, there were several limitations which affected the strength of the analysis. Most of these limitations related to data, both access and availability. A major suggestion of this study relates to how climate and hydrological data is collected. It is important that small islands such as Antigua and Barbuda collect all the variables necessary for climate statistical downscaling methods for more accurate projections to be made.

MAIN FINDINGS

Climate Scenarios and Future Projections

The climate projections specifically modelled in this study indicate that Antigua and Barbuda will experience the following:

1. An increase in the annual mean temperature.

2. An increase in the frequency of warm days and warm nights and decrease in cool days and cool night across GCM, RCM and SDSM as well as across scenarios for different time slices.

3. Through the 2030's median changes in rainfall projections deduced from GCM's are all negative which may suggest drier conditions. RCM ensemble mean suggest decreases in annual rainfall by approximately 5%.

4. The proportion of annual total rainfall that falls in heavy events decreases in most GCM projections, changing by -19% to +9% by the 2060's. Annual maximum 1-day rainfall totals show a tendency towards remaining constant, while the maximum 5-day rainfall is projected to decrease by up to 5 mm across the annual and seasonal timescales.

5. Consistent with the GCM projections, the PRECIS RCM suggests a decrease in the annual maximum 5-day rainfall of up to 14mm per decade towards the end of the century. The RCM however suggests that while rainfall intensity may decrease, a slight increase in rainfall duration may occur.

6. RCM ensemble means suggest an increase in wind speeds annually by up to 0.02 m/s

7. Hurricane intensity over the north tropical Atlantic is likely to increase (as indicated by stronger peak winds and more rainfall) but not necessarily hurricane frequency.

8. Caribbean Sea levels are projected to rise by up to 0.24 m by mid-century under the A1B scenario.

Given the projections, the water sector in Antigua and Barbuda is going to be further challenged. The table below highlights some of the current stresses that are affecting the water sector in the SWWA currently, what the projected stresses from climate change are likely to be, and how these stresses are likely to affect the water, health and agriculture sector in the SWWA. It then gives the vulnerability of the water sector to climate change by giving the degree of sensitivity and the adaptive capacity of the sector to deal with the issues. It highlights that there is mainly moderate vulnerability to the projected impacts of climate because despite the high degree of sensitivity, there is a moderate adaptive capacity.

Summary Vulnerability Assessment

Current Stresses	**Projected Stresses from Climate Change**	**Projected Impact of Changes to the Systems** *(without preparedness action)*	**VULNERABILITY ASSESSMENT**		
			Degree of Sensitivity	**Adaptive Capacity**	**Vulnerability**
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 (Water supply is sensitive to decrease in rainfall and increase in annual temperature)	Moderate- (Measures can be costly)	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 (Increase in hurricane intensity expected to increase flooding and damage to infrastructure)	Moderate- (Farming practices can be improved, and drainage can be improved)	Moderate
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise especially combined with increasing population growth.	High (Wells are sensitive to sea level rise and demand)	Low (nothing can be done to stop sea level rise)	High
Meeting increased demand of water from population growth and economic activities- Current yield of groundwater in	Reduction in annual average rainfall- more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	High (heavy reliance on desalination to meet demand)	Low (adaptive measures can be costly	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of Sensitivity	Adaptive Capacity	Vulnerability
SWW approximately half per capita consumption. Requirements. Contribution of ground water likely to decrease requirements.					
Poor watershed management	Increasing drought conditions	Increase in risk of forest fires which results in reduction of protective tree cover and reduction in infiltration.	Moderate (There is a tree planting program already in place)	Moderate (adaptation measures can be costly)	Moderate
Inadequate physical capital re water capture and storage infrastructure	Reduction in annual average rainfall- results in reduction in surface flows and reduced ground water recharge and ground water resources	Inadequate capture of rainfall with growing population will likely result in reduced supply or heavier dependence on desalination.	High	Moderate (adaptation measures can be costly)	Moderate
AGRICULTURE					
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts	More frequent drought events will result in reduced crop yield.	High (primarily dependent on rainwater)	Moderate (techniques can be improved but measures may be costly)	Moderate
Poor dryland farming techniques	Increase in annual temperature and drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield.	High	Moderate (techniques can be improved but measures may be costly)	Moderate
Damage from heavy rainfall/storm events	Hurricane intensity expected to increase (not necessarily frequency)	Loss of crops, reduction in crop yield	Moderate	Moderate (Improved farming practices can reduce vulnerability)	Moderate

Current Stresses	**Projected Stresses from Climate Change**	**Projected Impact of Changes to the Systems** *(without preparedness action)*	**VULNERABILITY ASSESSMENT**		
			Degree of Sensitivity	**Adaptive Capacity**	**Vulnerability**
HEALTH					
Pathogens (e.g., *E.*coli) present in cisterns & pollution of groundwater	Reduction in annual average rainfall- more droughts	Water Quality Issues	Low (chlorination is already done in the form of tablets)	High (chlorination systems will now be mandatory)	Moderate
Heavy rainfall events results in flooding and the overflow of septic systems	Hurricane intensity expected to increase (not necessarily frequency)	Water quality and health issues	Moderate	Moderate (drainage network can be improved but it can be costly)	Moderate
OTHER INTERELATED IMPACTS					
Unplanned development leading to unnecessarily expensive infrastructure development costs such as for water distribution	Reduction in annual rainfall	Will exacerbate challenges of demand management and lead to more costly downstream choices for providing adequate water supply	Moderate	Moderate	Moderate
Tourism sector-heavy users of water	Reduction in rainfall – more drought periods	Greater strains on water resources	Moderate	Moderate	Moderate

1 INTRODUCTION

1.1 Purpose

The Caribbean Community Climate Change Centre (CCCCC) received grant funding from the European Union (EU) under Grant Contract **FED/2011/267-392** for the implementation of an action entitled: *Support to the Global Climate Change Alliance (GCCA) under the 10th EDF Intra-ACP financial frame work in the Caribbean*. The EU GCCA Project is a Caribbean Forum (CARIFORUM) regional project designed to assist 16 participating countries to develop capacity to design and implement climate change adaptation policies and measures.

The overall objective of the Grant is to *support the sustainable development of the Caribbean region and preserve the progress of the countries towards the Millennium Development Goals* (MDGs). Among other things, the EU GCCA Project seeks 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 region as whole.

This component of the overall EU GCCA Project, executed by the CCCCC, entailed working collaboratively with the Government of Antigua and Barbuda (GOAB), through the Environment Division of the Ministry of Health and the Environment. The mandate was **to conduct a Vulnerability and Capacity Assessment (VCA) in the South West Coast and Watershed Area of Antigua** and to determine the impacts of projected climate change on the water sector in the community.

SWW is generally hilly terrain with the highest elevations (Mount Obama, 404m / 1,319ft) in Antigua. The area incorporates Cherry Hill, Sugar Loaf Mountain, Signal Hill, Wallings, Sage Hill and Willock Hill. This section of the island receives the highest levels of rainfall in the island. The watershed comprises 3 major watersheds (Christian Valley, Cades Bay and Claremont) with small sections of Potworks and Falmouth located on the periphery. The terrestrial area of the SWW totals 3,640 hectares and the marine area amounts to approximately 2,290 hectares, totaling approximately 5,930 hectares. The coastline of the SWWA spans a distance of 45.5 km. The SWW marine environment consists largely of coral reef habitat (Lindsay, K.C. et al., 2011) and is not the focus of this study.

The VCA focuses on the water sector and assess the effects of climate change on the agriculture and health sectors as well. The water sector includes the quantity and quality of ground water systems as well as the water supply and wastewater components, and the associated infrastructure. Sector assessment 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 Antigua and Barbuda's water resources to the threats posed by climate change. The VCA report feeds into the National Adaptation Strategy and Action Plan for the water sector in Antigua and Barbuda.

This document presents the Final VCA based on the consultation, research, review and analysis of data and information, and fulfills the three objectives of the project. It incorporates the comments made by the stakeholders at the National Workshop on October 15, 2014 (Annex 2).

1.2 Background

The twin island nation of Antigua and Barbuda is located in the Eastern Caribbean with Antigua centered at latitude 17^0 10' N and 61^0 55' N and the island of Barbuda, 28 miles north of Antigua centered at $17^0$35' N and 61^0 48' W. Antigua occupies a land area of 280 sq. km while Barbuda occupies a land area of 160 sq. km (Antigua and Barbuda Draft Action Plan, 2005). The water sector of Antigua and Barbuda as with other Small Island Developing States (SIDS)of the Caribbean is affected by the impact of climate variability which is reflected in the increase in droughts every four or five years. Population growth accompanied by decrease in daily rainfall, inadequate storage systems, lack of proper treatment facilities and the contamination of aquifers from saline intrusion are compounding the effect on water availability to the people of Antigua and Barbuda.

The water withdrawal rate per capita in Antigua and Barbuda is estimated to be 80 m^3 per year (CEHI, 2008). Water in Antigua comes from surface sources via dams and multiple small ponds; from groundwater sources; and from desalination plants. Desalination water accounts for most of the drinking water (approximately 70% during wet years and closer to 100% during very dry periods) with the remainder supplied by surface storage and wells as may be required (National Stakeholder Consultations on Water: Supporting the Post-2015 Development Agenda, 2013). Groundwater (shallow wells) is the main water source for the domestic sector in Barbuda, while the private sector depends heavily on desalinated water. The tourism sector, combined with industry, accounts for 20% of water demand in the country, with cruise ships accounting for approximately one percent (CARIBSAVE, 2012).

Based on the IPCC Fifth Assessment Report 2013, projections of temperature rise in the Caribbean basin range between 0.7°C to 2.4°C by the end of the 21st century. Similar models project changes in annual precipitation varying from –29% to +14% with a median value of -5%. Climatic changes are projected to include reduced length of rainy seasons, increased lengths of dry seasons, increased and more intense flooding events and more intense hurricanes. In small island states the impact of climate change will therefore be felt from ridge to reef.

For Antigua and Barbuda the water sector has been recognized as perhaps the most vulnerable to climate change. It has become the focus of critical assessment with respect to vulnerability, capacity and the development of national adaptation strategies and action plans. Antigua and Barbuda 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 temperature and rainfall patterns. Climate observations in Antigua and Barbuda have already shown that:

- there appears to be a decline in June precipitation;
- there has been a shift in the driest month from February to March;

- there has been a flattening of the rainfall peak in September;
- there continues to be a consistent but minor peak in rainfall in May

In the SWWA as well as in the wider Antigua and Barbudan environment, the water sector is critical not only for potable purposes but also for agriculture, food security, tourism, industrial applications and other uses. In the SWWA the primary economic activities depend heavily on the natural resources and climate conditions. The demand for water is continually increasing with the growing population, consumption patterns, and food demands. The water shortages currently experienced are due to a number of factors – inadequate storage to hold water during rainfall events, inadequate distribution pipes, not enough treatment plants, and inefficient use of water in households, industry, and agriculture (Brown, 2013). However, sections of the SWWA are also proned to flooding due to poor drainage, topography and poor farming practices.

The VCA focuses on the water sector with considerations of the attendant effects of climate change on the agriculture and health sectors. It will assist Antigua and Barbuda to identify and assess the vulnerabilities, risks and opportunities for the water resources sector within the SWWA, and will identify gaps for further investigation.

1.2.1 The Water Sector and Climate Change

The water sector has been defined above to include source and supply of water, wastewater, and associated infrastructure. Climate change is defined by IPCC (2013) as 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 persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Water is involved in all components of the climate system (atmosphere, hydrosphere, cryosphere, land surface and biosphere). Therefore, climate change can affect water through a number of mechanisms. There is abundant evidence from observational records and climate projections that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems (IPCC, 2008).

1.3 The Scope and Approach

1.3.1 Climate Change Projections/ Scenarios

This section of the report presents a review of the current state of knowledge gleaned from authoritative literature on observed climate variability, trends and projections for Antigua and Barbuda;

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 was analyzed to produce tables and diagrams for temperature, rainfall (precipitation), wind-speed, sea levels and hurricanes that represent the current climate of Antigua and Barbuda.
- The future possible state of the climate of Antigua and Barbuda was gleaned from available GCM data; this was represented using tables and diagrams and was done for the variables such as temperature, rainfall, wind speed, sea level rise and hurricanes.
- RCM data at scale for Antigua and Barbuda 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.
- A review of authoritative works on climate change was done in order to examine the state of knowledge about climate change for Antigua and Barbuda's climate. These included, but were not limited to, studies by the Intergovernmental Panel on Climate Change, Caribbean Climate Change Centre and Climate Studies Group, Mona, UWI.

1.3.2 Sensitivity, Adaptability and Vulnerability Assessment

It is first necessary to determine the degree to which the South West Coast and Watershed Area is vulnerable to climate related events and the extent of their capacity to adapt and/or cope in order to ensure that investments in adaptation measures achieve desired outcomes. The results of the VCA should be used to guide the decision making process in prioritizing appropriate steps that ought be taken to adapt to climate change. If the country/community is already highly vulnerable and does not have the financial, technical or human resource capacity to implement and sustain adaptation practices it is not possible to adapt to the impacts of climate change.

The NOAA-CCCCC methodology (*Vulnerability and Capacity Assessment Methodology,* 2008) for conducting the VCA to support adaptation to climate change was adapted and used in this study in combination with approaches presented in *Preparing for Climate Change: A Guidebook for Local, Regional and State Governments* (2007). This method was used because of its clarity and applicability. The guidebook was very useful for organizing the methodology in three main sections; sensitivity analysis, adaptive capacity analysis and vulnerability assessment.

The VCA determines the sensitivity of the water sector to climate change across different timescales, and the adaptive capacity of the water sector. The sensitivity analysis includes a discussion on the existing water sector and natural and anthropogenic threats. The adaptive capacity analysis includes a discussion and analysis of the policy, legal and institutional framework of Antigua and Barbuda that relate to the water sector. It also includes a discussion of the SWW's capacity for social and economic resilience to climate change. The findings about sensitivity and adaptability are then combined to determine how and where the community is vulnerable to climate change.

1.3.3 Water Sector Vulnerability Issues and Threats

The Water Sector was examined in terms of the core aspects of the sector:-

a. water availability/quantity (including the sources of water i.e. groundwater, surface water, rainwater harvesting and the use of sea water via desalination processes) and
b. water quality

Information and data related to the water sector was obtained from several government regulatory agencies through interviews and the sharing of relevant technical reports and databases. Information was also gained through informal interviews with community representatives, community and industry based associations; and site visits to critical watersheds, water supply systems, including reservoirs, ponds and well fields, water treatment facilities and desalination plants. The analysis of all data and information gathered led to the identification of a range of vulnerability issues and threats, which are presented and discussed using graphic, tabular and narrative formats.

Information on water availability was provided mainly by the APUA. Data includes but is not limited to pumping rates for wells and surface water systems as well as pumping rates of desalination plants, dam levels in reservoirs, pumping and static water levels in wells and sector demands.

Water quality data was provided for both groundwater (i.e. wells) and water treatment plants (which captures surface water. The physical parameters include; turbidity, colour, hardness, total dissolved solids and pH), and chemical parameters include; manganese, iron.

In light of the fact that there are no significant surface water reservoirs within the SWWA, the water quality assessment focused on the groundwater resources within the SWWA, which include the Cades Bay, Christian Valley and Claremont/Pineapple Well fields.

The specific objectives of this assessment were:-

A) To determine the influence of seawater intrusion indicated as TDS levels in groundwater, how they over time and the suitability for drinking
B) To determine the impact of anthropogenic activities (eg. soil erosion) as indicated by turbidity levels in groundwater and how they change over time
C) To determine the suitability of groundwater quality with respect to iron and manganese, for use as domestic/municipal water

As far as the data available would allow, time series plots were generated and evaluated for trends, patterns and compliance to relevant standards and guidelines.

1.4 Limitations/ Constraints

The project experienced several constraints which resulted in limitations for the outputs. They are mentioned here in relation to climate, hydrology and socio-economics.

Climate

The Meteorological Data had only one station with daily values. This constrained our ability to examine observed changes in rainfall and temperature extremes. In addition, this limited our ability to use statistical downscaling methods for projections. The absence of other variables such as relative humidity and wind also constrained the analyses. The absence of sea level data specific to Antigua and Barbuda meant that data available for the Caribbean had to be used.

Hydrology- Limitations of Water Quality Assessment

Nitrate levels in water is an important indicator of impacts from sewage and or fertilizers and *chloride* levels are important indicators of impacts from saltwater intrusion. However, data for nitrates and chlorides was not available to the consultants.

The data made available related to parameters which could be considered general/non-specific pollution indicators, such as Total Dissolved Solids and Turbidity. These parameters may clearly indicate the impact of a polluting substance, but does not point to the specific type of pollution. As such the water quality assessment could not result in a definitive determination of the influence of sea water or sewage effluent, but could suggest that sea water and sewage effluent could be impacting water quality.

The period for which data was available is limited to a seven (7) year time span, which is generally considered inadequate for a definitive evaluation of trend particularly in groundwater systems. However, annual and seasonal patterns as well as indications of possible emerging trends, may be determined by analysis of data over this period.

Socio-economics

Time and timing are expected challenges that are managed as best as possible. In this instance an important time related challenge was unavoidable given the project timelines. The field research was conducted during the height of the lead up to the 2014 General Elections, which were held within a week of the Consultants departure. While every courtesy was extended to the Consultants by host agencies, some hoped for meetings in the public and private sector did not occur. In retrospect these may or may not have deepened the anecdotal perspectives being accumulated. There was a sense of time being highly rationed for gaining the attention of some individuals and groups.

The results of the 2011 Population and Housing Census were not available when the consultants arrived but were publicly released after their departure. The uncertainty of this data becoming available and the difficulty of exploiting its full potential for insertion into the analysis belatedly was an unfortunate consequence of timing. The community based demographic and social characterizations suffered from the lack of greater depth. This was also paralleled with the water production data, in that the 2012 to 2013 data was not available to the Consultants until their analyses were well advanced.

These socio-economic limitations are not seen by the Consultants as seriously compromising either the characterization of or the findings on the sensitivity, adaptability and vulnerability of the SWW region to the likely impacts of climate change on the water sector.

2 THE SOUTHWEST WATERSHED AREA (SWWA)

The SWWA occupies approximately 18% of Antigua's total land area and incorporates Cherry Hill, Sugar Loaf Mountain, Signal Hill, Wallings, Sage Hill and Willock Hill. The coastline of the SWWA spans a distance of 45.5 km. The following subsections discuss the physical characteristics of the SWWA and its socio-economic characteristics.

2.1 Physical Characteristics

Thirteen watershed management units have been defined for the island of Antigua for the purpose of land use and water resource planning (Figure 2-1). Of these 13 watersheds, 6 of them (Body Ponds, Potworks, Fitches Creek, Parham, Bethesda and Christian Valley) have been identified as major catchments based on socio-economic and agro-ecological conditions. These 6 watersheds occupy 43% of the land area and contain 80% of the groundwater supplies and 90% of the surface water storage (Cooper and Brown, 2001). The two largest watershed units Body Ponds ($44.74km^2$) and Potworks ($38.1km^2$) drain the northern slopes of the south west volcanic region and the main parts of the Central Plain to the east and west respectively (Ministry of Public Works and Environment, 2005). The majority of the wells and ponds are found within these watersheds and others within the SW region (Figure 2-1). Their location is explained by the combined effect of the rainfall pattern of the island, accompanied by topography and soil/geology.

The terrestrial boundaries of the South West Watershed (SWW) are largely determined by the component watersheds. There are 3 major watersheds (aggregated areas for management) found within the SWW region, located on the periphery are small sections of Potworks and Falmouth. Christian Valley, Cades Bay and Claremont comprise most of the SWW area (Figure 2-1). Sugar Loaf Mountain forms the highpoint of the most extensive area of uninhabited tracts of land in Antigua. The terrestrial area of the SWW totals 3,640 hectares and the marine area amounts to approximately 2,290 hectares, totaling approximately 5,930 hectares. The SWW marine environment consists largely of coral reef habitat (Lindsay, K.C. et al., 2011) and is not the focus of this study.

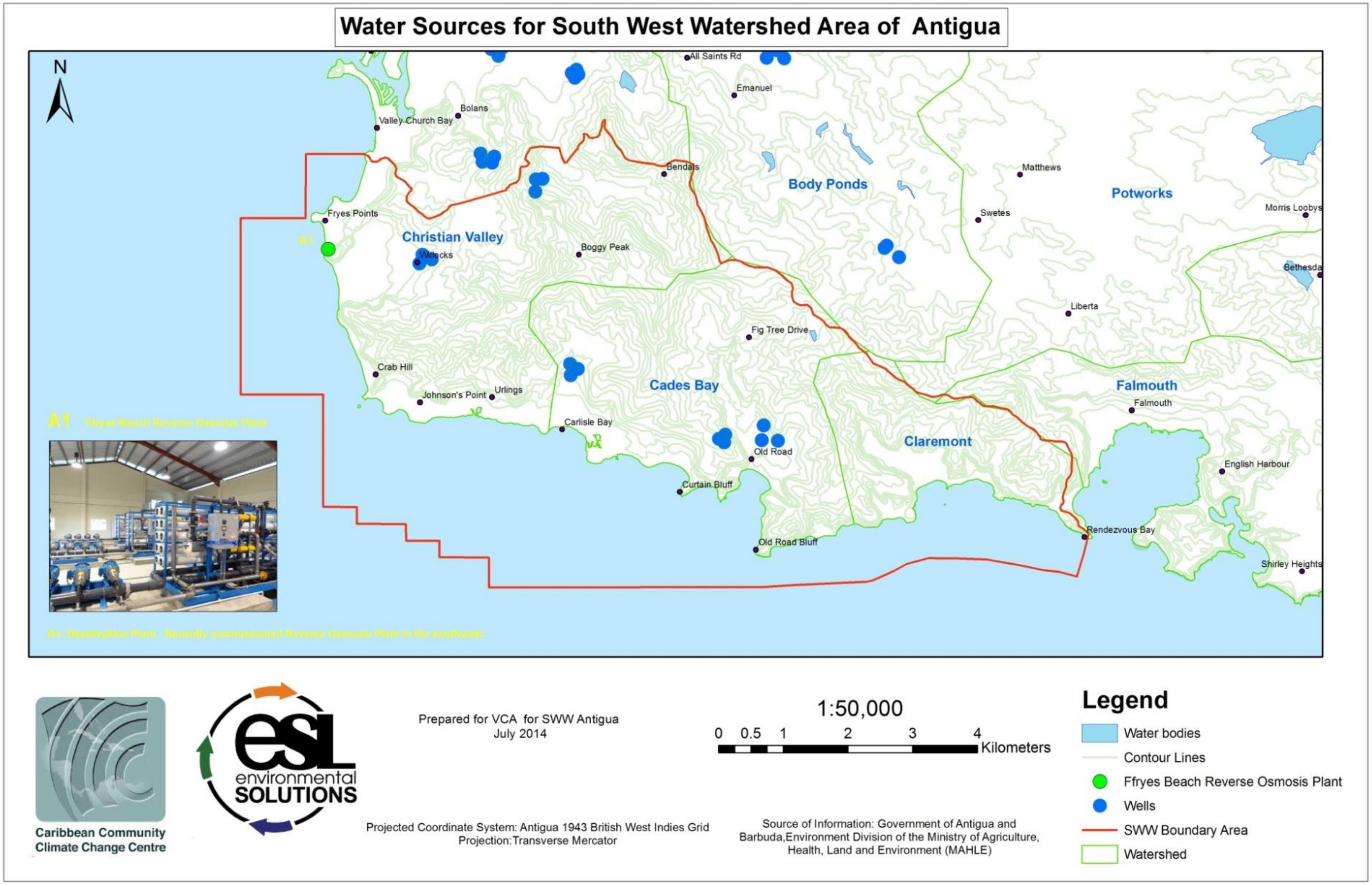


Figure 2-1: The South West Watershed Area and the water resources

2.1.1 Geology and Soil

Geologically, Antigua is divided into three regions, running roughly parallel, from the north-west to south-east (Table 2-1 and Figure 2-2).

Table 2-1: Lithology Breakdown of Antigua

Lithology	Location in Antigua	Description
Volcanic Region 1	Southwest	Consolidated pyroclastics, lava flows and hard igneous rocks in the uplands and sedimentary material in the associated valley. The slopes in this region range from $100\text{-}20^0$
Volcanic Region 2	Central Plain	Consists of a mixture of agglomerates, tuffs and conglomerates, together with some cherts and limestone. Slopes in the central plain are $<10^0$.
Limestone Region	Northeast	Geologically the most recent and is composed of a mixture of hard limestone and softer marl deposits of the Antigua formation.

The Southwest Watershed Area is situated within Volcanic Region 1, a historically volcanic region, which is underlain in the uplands by igneous rocks and consolidated pyroclastic lava flow in the (Figure 2-2). The volcanic eruptions of the past produced andesite and basalt lava flows as well as pyroclastics and ash. Slopes range from 10^o -20^0. The associated valleys consist of sedimentary material.

Soil type is important for infiltration and runoff and soil properties are closely linked with water quality. Soils of Antigua and Barbuda have been described briefly (Cooper and Brown, 2001) and have been mapped (1:25,000) and described in detail by Hill (1966). In the SWW area, the igneous rocks have weathered over time and the soils which have developed are predominantly clay loam. Over 90% of the soils in the Southwest Watershed Area are clay loam (Figure 2-3 and Figure 2-4). There is a relatively small outcrop of loam in the eastern tip of the study area, covering just 5% of the SWWA.

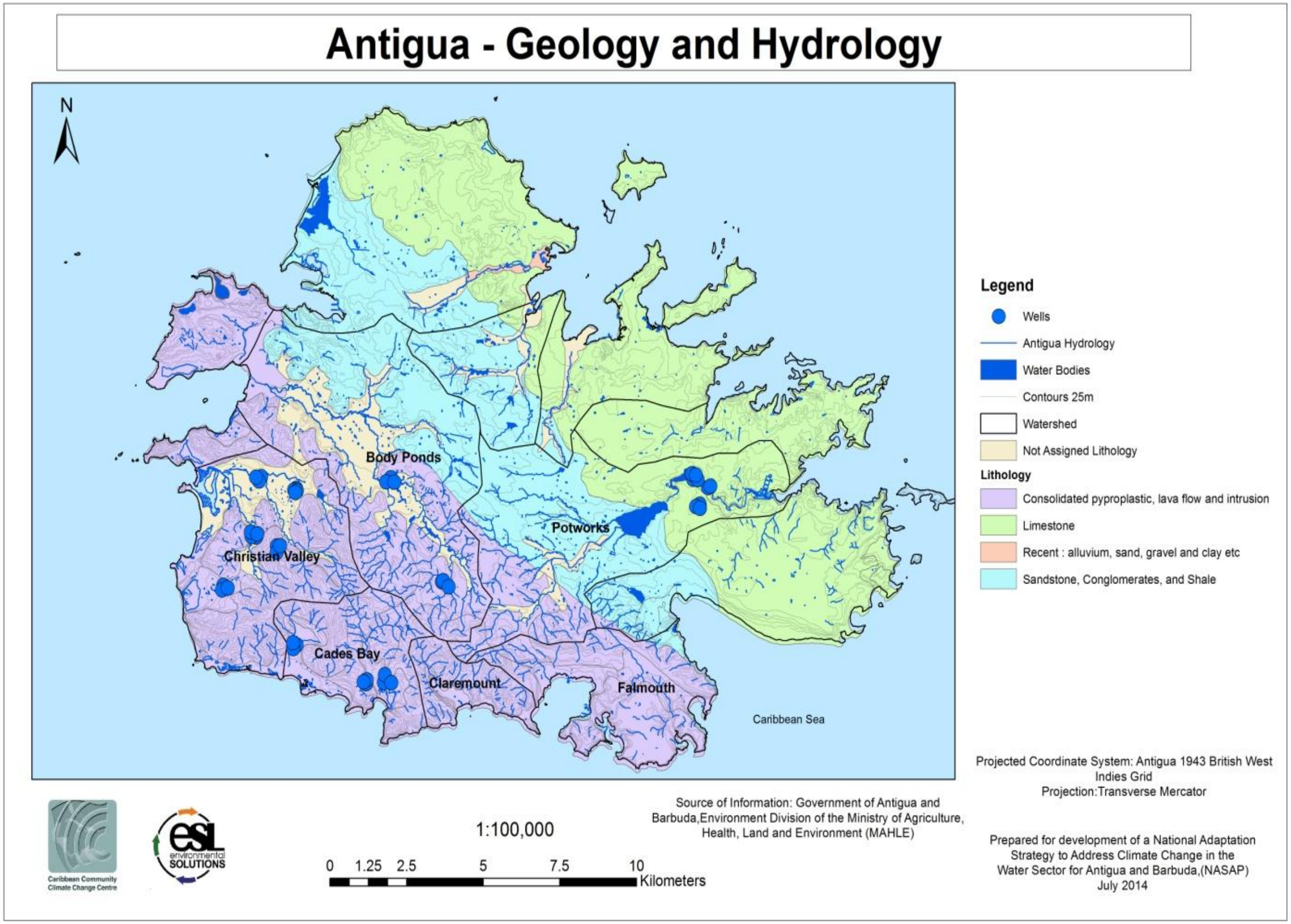


Figure 2-2: Antigua - Geology and Hydrology

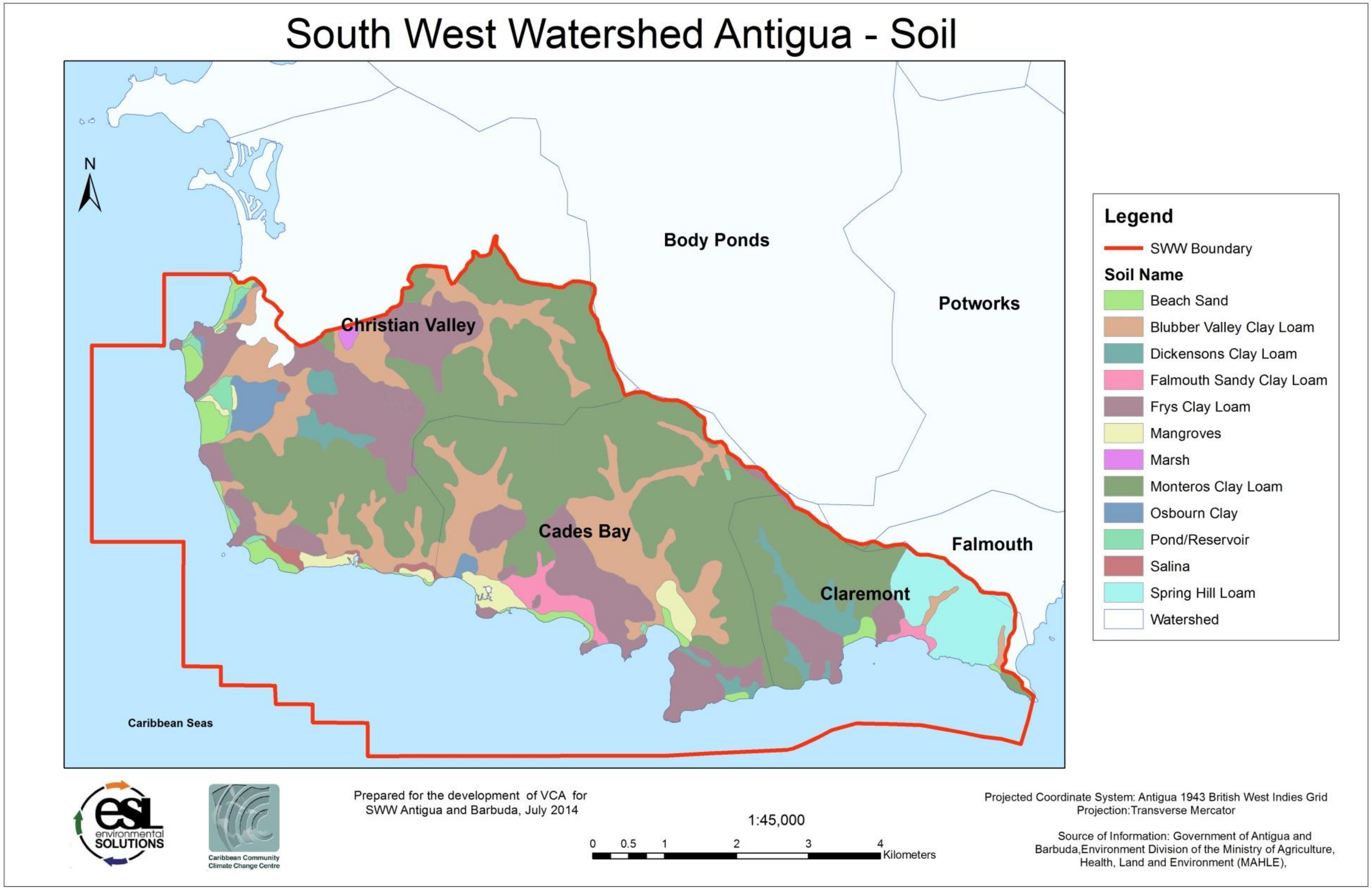


Figure 2-3: Soil Type of Southwest Watershed Area, Antigua

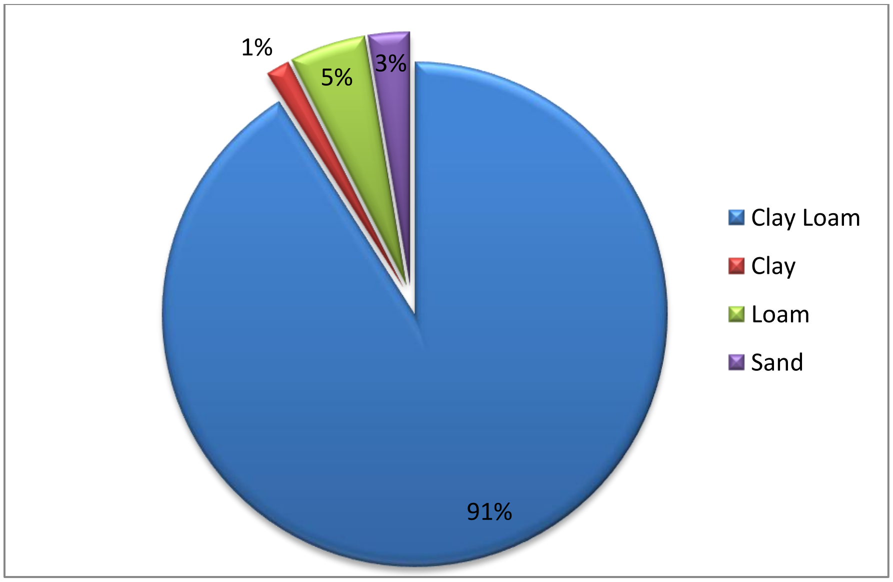


Figure 2-4: Soil Type Coverage, Southwest Watershed Area, Antigua

Soil type influences the movement of water through the soils, and in turn the extent to which aquifers are recharged. The dominant soil type, clay loam, has an average permeability of 0.8cm/hr, which is considered an intermediate level of permeability (Figure 2-5). Though not highly absorbent, if sufficiently balanced in terms of the proportion of clay to loam, clay loam would not hinder significantly the movement of water. As such, clay loam soils, generally support the recharge of aquifers and the associated well fields.

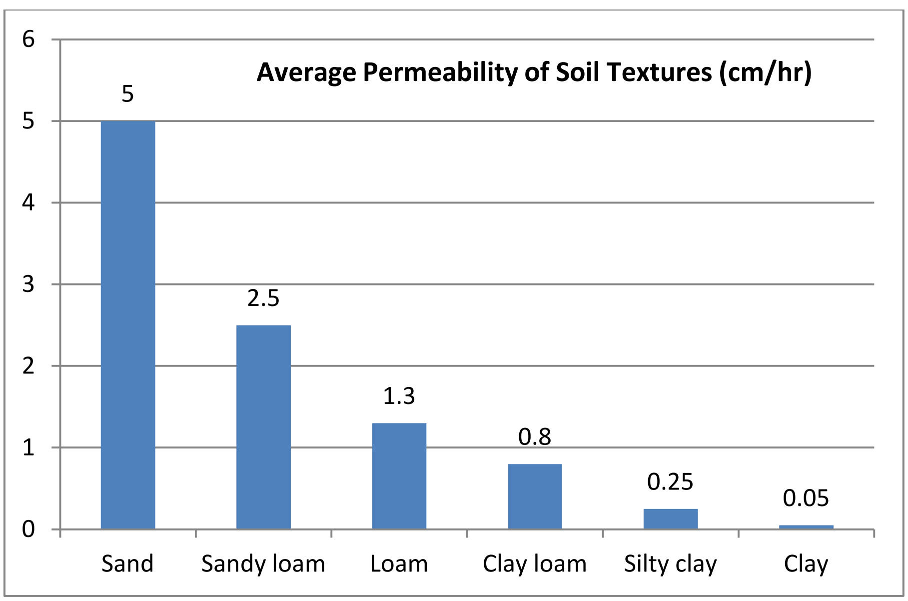


Figure 2-5: Average Permeability of Soil Textures

Source: ftp.fao.org/fi/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e09.htm

2.2 Socioeconomic Characteristics

The SWW area comprises several townships with residential and commercial populations. In addition, there are also a number of agricultural and tourism enterprises, recreational facilities and protected areas (Figure 4-2).

There are no databases that inform the boundaries or contribution of the economic landscapes within the SWW. The transactional nature of economic activity permits little scope for regional mapping. While the social landscape can be somewhat inferred from official demographic data bases along with observation, very serious statistical hurdles occur, due to the challenges of time and effort in extracting the required data from available census sources or conducting surveys. As concluded by a Literature Review (Island Resources Foundation, 2011) undertaken for a Ridge to Reef Demonstration Project in another watershed location, *"major information gaps exist for social, cultural, environmental and economic data".*

To chart the quantitative social characteristics, the 2011 Census population for the SWW area from the Statistical Division was obtained. Where the characteristics of interest were available at the parish level for St. Mary and St. Paul (the only two parishes with populations represented in the SW watershed) the data of interest was extrapolated for the population of the watershed area. Where the census data was only available at the national level, the national averages were applied to the population of the SWW. The justification for this latter approach lies partly in the size, culture, social organization and generally non–diversified economic and social drivers that characterize the OECS Caribbean states. These features endow small geographic areas with a relative (but by no means static) homogeneity that is supportive of estimating in a generally data poor environment.

On this basis an implied characterization of the social status of the SWW area has been summarized in Table 2-2. It is felt by the Consultants to be sufficiently indicative to frame a useful picture of the population of the Watershed.

Table 2-2: **General Characteristics of the SWW Area**

CHARACHTERISTICS	RATIOS	NUMBERS (rounded)
POPULATION	100%	5,828 (Statistical Div.)
Male	48%	2,800
Female	52%	3,000
Population under 30 Yrs of Age	50%	2,914
Dependency Ratio	39% dependent on 61%	2,273 on 3,555
EMPLOYMENT		
Unemployed	9%	525
Self Employed	6%	350
Work Outside of Household	84%	4,900
HOUSING		
Total Dwelling Units		2,009

CHARACHTERISTICS	RATIOS	NUMBERS (rounded)
Total Households		2,009
No of Persons per Dwelling		2.9
WATER		
Public source piped into dwelling	61%	1,225 dwellings
Public source piped into yard	5%	100 dwellings
Sourced from Public Standpipe	7%	140 dwellings
Cistern	17%	342 dwellings
WASTE DISPOSAL		
Disposal by Garbage Truck	95%	1909 dwellings
POPULATION WITH DISABILITIES		
Total Population 2011 = 5,828.	With Care	Self Care
Seeing No Problems Some. Lots of. Cannot do at all.	 5303 318	 5653 62
Hearing No Problems Some. Lots of. Cannot do at all.	 5595 87	 5653 54
Walking No Problems Some. Lots of. Cannot do at all.	 5478 233	 5478 44
Remembering No Problems Some. Lots of. Cannot do at all.	 5653 245	 5595 117
Total Population with Disabilities	**883 (15%)**	**277 (5%)**

2.2.1 Summary Characterization

2.2.1.1 Population

The population in the SW Watershed has been given as 5,828, or 6.8 % of the population of Antigua and Barbuda (Statistical Division). Based on the governing assumptions the population can reasonably be characterized as follows: 52% females and 48% males; relatively young with 50% being under the age of 30; unemployment in the labour force age group is taken as 9% and self-employment at 7%. It must be noted that on census day 2011, 35% of the 15 and over population reported that they were unemployed. The total number of dwellings is 2009, the same as the number of households. This interesting statistic is an indicator of a comparatively high standard of living since it implies one household per dwelling comprising 2.9 persons on average.

1,160 persons or 20% of the population categorize themselves as having some disability whether of sight, hearing, walking or memory. Of these persons 883 or 76% have access to care, while 277 or 24% are their own care givers.

2.2.1.2 Water

61% of households or 3,553 persons receive piped water into their homes. 291 persons or 5% of households source water from pipes in their yards, 406 persons or 7% of households source water from public stand pipes and 992 persons or 17% of households have cisterns.

2.2.1.3 Sewage Treatment and Solid Waste Disposal

There is no centralized sewage system; however most of the households in the area have septic tanks. 95% of all households dispose of their garbage via garbage collection trucks.

2.2.1.4 The Economy

Tourism has been established to be a main driver in the national economy and, because it is a visibly important sector in the SWW, it can reasonably be inferred, in the absence of regional GDP data, to be equally important to the SWW economy. This is confirmed anecdotally, by both community members and tourism enterprises in the watershed (Figure 4-2).

There are eight large or important hotel properties in the area, and several guest houses and private dwellings offering some hospitality services. There are also some 5 entities that are seeking to increase their share in tourism, even if tourism is not their primary focus. An almost “stand alone” sector for its importance to food security and to the wider retail trade both locally and nationally is the fishing industry. All of these enterprises are integrally bound to the water sector to one degree or the other. They, along with all of the economic transactions that are part of the SW economy are the “conduits through which the economy transmits its contribution to climate change”.

3 SWWA CLIMATE VARIABILITY AND CHANGE

The climate of Antigua and Barbuda is typically that of small tropical islands. The combination of this nation's 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 trade winds and the passage of tropical waves, depressions, storms and hurricanes. The resulting climate regime is one characterized by a dry winter-wet summer pattern together with high and fairly uniform temperatures year-round.

Inter-annual variability in the climate of the islands is influenced strongly by the El Niño Southern Oscillation. El Niño events bring warmer and drier than average conditions during the late, wet season and La Niña events bring colder and wetter conditions at this time. Since the island of Antigua is small, it can be assumed that the projections made for the islands of Antigua and Barbuda for the Impact Assessment will not differ significantly for the SWW. The general observed climate trends and a summary of the projections are presented in the following subsections.

3.1 Rainfall

3.1.1 Climatology

A bi-modal rainfall pattern is evident for most of the stations in Antigua (see Figure 3-1 and Table 3-1). This is characterized by maxima in May and October. Rainfall observations from the V.C Bird Airport reveal that the bi-modal pattern is less well defined over 1990-2011 relative to earlier decades as a decrease in early season maximum is observed. The 1970's and 1980's have two clear peaks around the months of May and Oct/Nov. Records for the 1990's and 2000's periods suggest a shift in seasonality with two peaks occurring between August and November though still exhibiting a bi-modal distribution. The V.C Bird Airport station also records an average of 12.0 - 12.7 days per month for July-December with the least number of rain days (7.2 - 7.3 days) observed in March and April.

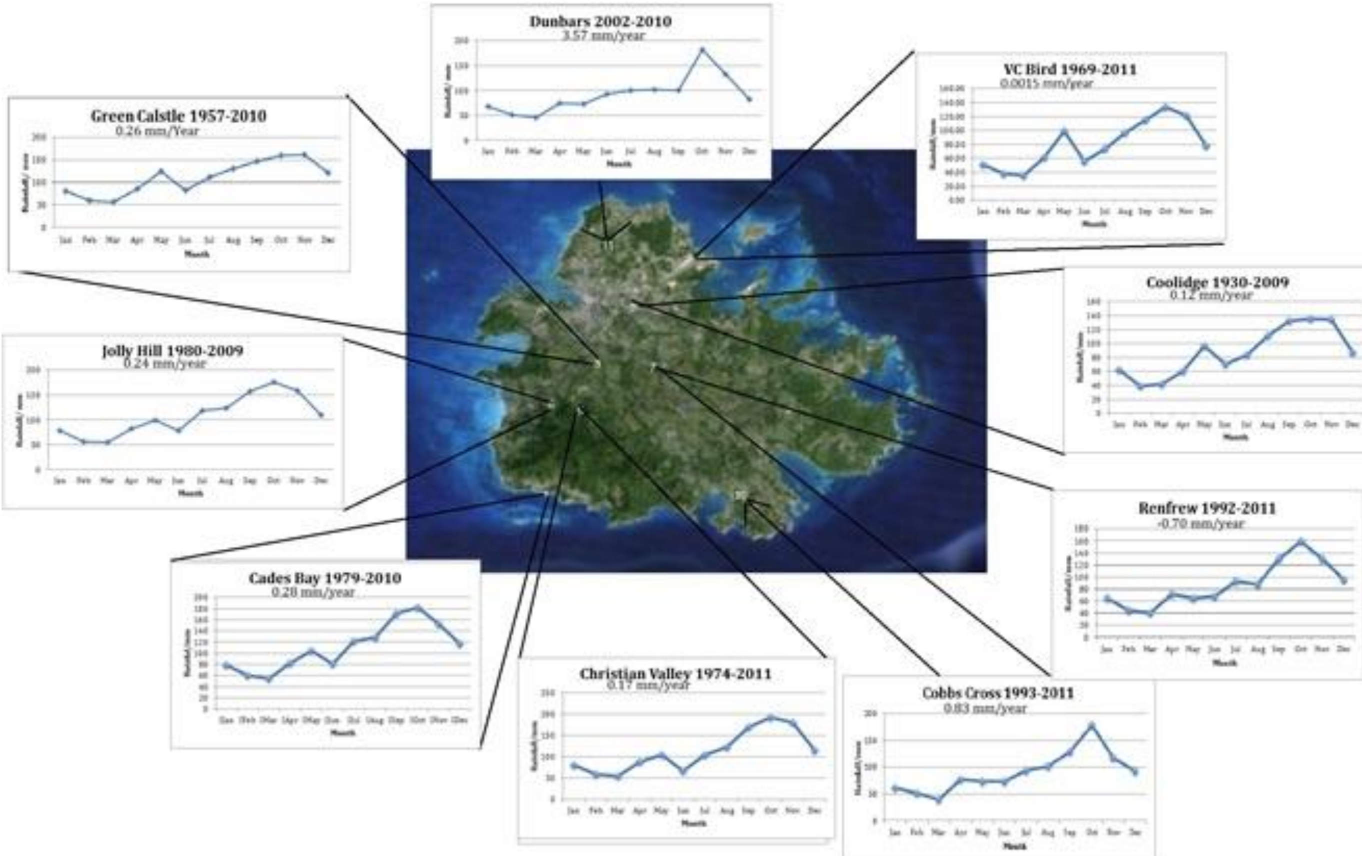


Figure 3-1: Monthly Rainfall Climatology for Stations in Antigua and Barbuda.

Table 3-1: Monthly Rainfall Climatology for Stations in Antigua and Barbuda (Values are in mm) (stations located in the SWW highlighted in pink)

MONTH	RAINFALL STATIONS									
	Cades Bay	Christian Valley	Cobbs Cross	Cochrane	Coolidge	Dunbars	Green Castle	Jolly Hill	Renfrew	V.C Bird
Jan	79.2	81.3	61.5	57.0	62.2	68.6	81.4	78.9	65.0	52.1
Feb	60.5	59.6	50.9	46.9	39.2	51.1	60.1	56.4	45.1	38.2
Mar	54.7	54.6	39.8	37.4	41.9	46.4	56.4	55.1	40.3	35.3
Apr	82.1	88.0	77.5	62.9	60.6	74.3	86.0	83.0	72.1	60.9
May	104.1	104.6	73.5	92.3	96.3	73.3	123.8	99.5	64.2	97.3
Jun	81.4	67.9	73.2	70.5	70.9	92.9	82.5	77.8	67.7	55.6
Jul	121.7	105.0	93.7	89.5	83.7	101.0	111.6	118.6	93.2	71.5
Aug	128.3	122. 8	101.9	97.2	111.6	101.7	130.5	123.5	88.6	93.1
Sep	171.4	169.6	128.5	133.5	132.4	101.2	146.6	157.2	130.7	113.7
Oct	182.0	192.3	178.8	153.6	135.2	181. 9	160.7	175.4	159.1	135.7
Nov	153.1	180.5	117.5	137.9	134.4	132.5	161.1	159.5	129.7	118.7
Dec	116.5	115.5	93.0	90.1	87.4	81.7	121.2	110.1	95.6	77.2

3.1.2 Seasonality

The percentage contribution of monthly totals to annual rainfall amounts (Table 3-2) suggests that the seasons over Antigua may be described as early dry (January-March), early wet (April-June) and late wet (July-December). Most of the stations in Antigua generally exhibit similar seasonal patterns.

The rainfall pattern over Antigua is largely conditioned by the North Atlantic High (NAH) pressure system which is a large, subtropical, semi-permanent centre of high atmospheric pressure typically found south of the Azores in the Atlantic Ocean between 30˚ N and 35˚ N. During the northern hemisphere winter the NAH is southernmost with strong easterly trade winds on the equatorial side of the system. Coupled with strong trade winds inversion, cold sea surface temperatures (SSTs) and reduced atmospheric humidity, the Caribbean generally is at its driest dring the winter. Precipitation during this period is generally due to the passage of mid-latitude cold fronts and moisture advection (weak, low level convergence). By May, the NAH moves northward, the trade winds' intensity dcreases and the

Caribbean Sea becomes warmer and the southern flank of the NAH becomes convergent (Taylor and Alfaro, 2005).

The primary source of rainfall from June to November is the passage of easterly waves which traverse the Atlantic Ocean from the west coast of Africa to the Caribbean. The waves are themselves a source of convection and can develop into depressions, storms and tropical cylcones under conducive conditions. Near July, a temporary southward movement of the NAH is associated with diminished rainfall and the occurrence of a mid summer drying. Enhanced rainfall occurs with the return of the NAH to the north and the passage of the Inter Tropical Convergence Zone (ITCZ) northward. When the NAH treks south again at the end of the year, it marks the onset of the dry season. Another atmospheric feature important to rainfall variations during the rainfall season(s) is the Tropical Upper-level Tropospheric Trough (TUTT); a trough situated in the upper level (200 hPa) tropics.

Table 3-2: Percentage Contribution of Monthly Rainfall Totals to the Annual Rainfall Totals Recorded at 11 Stations across Antigua and Barbuda (stations in the SWW highlighted in pink).

	RAINFALL STATIONS									
MONTH	**Cades Bay**	**Christian Valley**	**Cobb's Cross**	**Cochrane**	**Coolidge**	**Dunbars**	**Green Castle**	**Jolly Hill**	**Renfrew**	**V.C Bird**
Jan	6	6	5	5	6	6	6	6	6	5
Feb	5	4	5	4	4	5	5	4	4	4
Mar	4	4	4	4	4	4	4	4	4	4
Apr	6	7	7	6	6	7	7	6	7	6
May	8	8	7	9	9	7	9	8	6	10
Jun	6	5	7	7	7	8	6	6	6	6
Jul	9	8	9	8	8	9	8	9	9	8
Aug	10	9	9	9	11	9	10	10	8	10
Sept	13	13	12	13	13	9	11	12	12	12
Oct	14	14	16	14	13	16	12	14	15	14
Nov	11	13	11	13	13	12	12	12	12	13
Dec	9	9	9	8	8	7	9	9	9	8

3.1.3 Recent Trends

Most of the stations across Antigua and Barbuda have experienced increased rainfall amounts with the Cobb Cross station exhibiting a statistically significant increase. The Coolidge station is the only station indicating decreased rainfall amounts over the last couple of decades.

3.1.4 Extremes

3.1.4.1 Drought

The probability of at least one drought (severe, serious, moderate or slight) in a year is 54.5%. If there is a drought, the chance it will be severe, serious, moderate or slight is 20.9%, 22.4%, 32.8% or 23.9% respectively. The probability of at least one serious or severe drought in 5 years is 94.3%, with a probability of 99.7% for one serious or severe drought in 10 years.[1]

3.1.4.2 Extreme Indices

Increased rainfall extremes have been noted at the V.C Bird International Airport station. Though maximum 5-day rainfall has decreased by 0.23 mm per decade, the days with rainfall above 10mm has increased by 0.76 days/decade. The maximum number of consecutive wet days has increased by 0.15 days/decade and very wet days increased by 6.8 5mm/decade, suggesting increases in both intensity and duration of rainfall events.

3.2 Temperature

3.2.1 Climatology

The average monthly maximum and minimum temperature range is 5 and 4°C respectively with temperatures peaking during summer months. Maximum temperature values may reach as high as 31.5°C in these months, while minimum temperature values may drop to 22 °C in January/February. The 1990's was the hottest decade on record with the year 1998 being the very hottest and likely linked to El Nino Southern Oscillation events and the positive phase of the Atlantic Multi-decadal Oscillation (AMO).

3.2.2 Trends

The annual mean maximum temperatures between 1969 and 2011 exhibit a statistically significant trend of 0.139°C/decade while the annual mean minimum temperatures exhibit a statistically significant trend of 0.091°C/decade. The monthly mean maximum and minimum temperatures are increasing at a rate of 0.0029 °C/month and 0.0003 °C/month respectively. A step change is however evident in the maximum temperature data set in 1981 that may or may not be related to climate change.

[1] http://www.antiguamet.com/

3.2.3 Extreme Indices

Extreme temperatures at the V.C Bird International Airport have been increasing. The frequency of warm days exhibits a statistically significant increase (0.69% per decade) between 1972 and 1990. The frequency of warm nights has also increased while the frequency of cool days has decreased. The annual maximum temperatures have shown a statistically significant increase of 0.05°C per decade.

3.3 Other Variables

Relative humidity across the country tends to be generally high year round (above 70%) and predictably highest during the main rainfall period. Winds are generally from the east (E) or east-south-east (ESE), and wind speed is strongest (~6 metres per second) in the dry period from December through April. During this period the north Atlantic high is a persistent and dominant influence on the region.

Notwithstanding, strong wind gusts are also common from June to November during the passage of tropical waves, depressions, storms or hurricanes.

3.4 Hurricanes

Hurricanes tend to coincide with incidences of heavy rainfall. For example, May 1979 showed heavy rainfall and this is closely linked with Hurricane Claudette. Similarly, September 1995 had anomalously high rainfall, likely due to Hurricane Luis. November 1999 showed anomalously high rainfall and this correlates with Hurricane José. The period assessed is largely during the low phase of the Atlantic Multi-decadal Oscillation (AMO) with the exception of the late 1990's. Anomalously high rainfall events were recorded during the positive phase of the AMO.

After a near thirty year lull (1961-1989) in direct hits, the country experienced the effects of six hurricanes (direct hits or near brushes) between 1990 and 2000. In general, North Atlantic hurricane frequency is influenced by the AMO which yields active and inactive phases lasting 10 or more years (Goldenberg et al. 2001). Since 1995, the North Atlantic has swung into an active hurricane phase. 5 of the country's 6 recent hurricane experiences occurred in the current active phase of the north tropical Atlantic (1995, 1996, 1998, 1999, 2000). Since 2000 there has again been a lull in hurricane impact on the country. This is in spite of the fact that the current active hurricane phase continues in the north tropical Atlantic. There is also significant year to year modulation of hurricane frequency and track by ENSO events.

3.5 Sea Level Rise

3.5.1 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/year^{-1}) to modern rates (order mm/year^{-1}).

Tide-gauge and satellite altimeter data both reflect the rate represented in the 1993-2010 period. It is likely that rates similar to this period also occurred between 1930 and 1950. It is also likely that global mean sea level has accelerated since the early 1900's, with estimates ranging from 0.000 to 0.013 [-0.002 to 0.019] mm yr^{-2} (IPCC, 2013). Accelerations in the rate of increase over the 20th century have been detected in most regions; see for example Woodworth et al. (2009) and Church and White (2006).

3.5.2 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 sea level rise values for a number of locations in the Caribbean 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 lead 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.

3.5.3 Antigua and Barbuda

Sea level rise in the region near Antigua and Barbuda is expected to approximate to the global average (IPCC, 2007). Antigua and Barbuda already show evidence of sea level rise and based on surveys conducted, areas at greatest risk in Antigua are Dickenson Bay, Fort Bay and Runaway Bay; and in Barbuda, Cocoa Point, Low Bay and Palmetto Point, with Low Bay at greatest risk. These areas include notable resorts, ports and an airport that lies less than 6 m above sea level (Simpson et al. 2012).

3.6 Future Projections

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

Projections of rainfall and temperature characteristics for Antigua and Barbuda to mid-century are extracted for Antigua and Barbuda from the CMIP3 project (McSweeney et al. 2010). Data from 15

GCM's were analyzed and projected change averaged over Antigua and Barbuda for the 2030's and 2060's under three emissions scenarios. An inherent drawback of the GCM's however, is their coarse resolution relative to the scale of required information. The size of Antigua and Barbuda precludes it being physically represented in the GCM's and there is a need for *downscaling* techniques to provide more detailed information on a country or station level. The additional information which the downscaling techniques provide do not however devalue the information provided by the GCM's especially since (1) Antigua and Barbuda's climate is largely driven by large-scale phenomenon (2) the downscaling techniques themselves are driven by the GCM outputs and (3) at present the GCM's are the best source of future information on some phenomena, e.g. hurricanes.

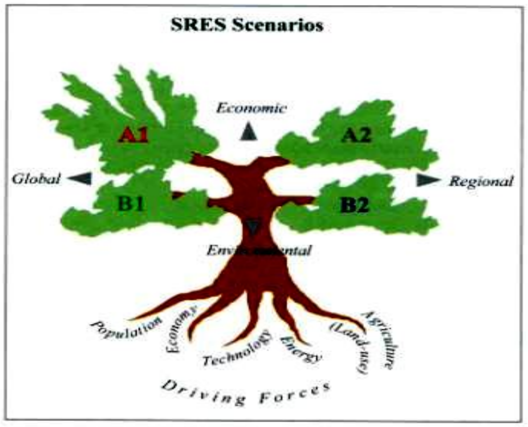
Data from two downscaling methods are applied. *Dynamical* downscaling employs a regional climate model (RCM) driven at its boundaries by the outputs of the GCM's. Like GCM's, the RCM's rely on mathematical representations of the physical processes but are restricted to a much smaller geographical domain (the Caribbean in this case). The restriction enables the production of data of much higher resolution (typically < 100 km). Available RCM data for Antigua and Barbuda were obtained from the PRECIS (Providing Regional Climates for Impact Studies) model (Taylor et al. 2007). The PRECIS model resolution is 25 km.

Statistical downscaling enables the projection of a local variable using statistical relationships developed between that variable and the large scale climate. The relationships are premised on historical data and are assumed to hold true for the future. Statistical downscaling is especially useful for generating projections at a location, once sufficient historical data are available. Statistical downscaling was undertaken for rainfall and temperature data for V.C Bird Airport station. The process was facilitated using the Statistical Downscaling Model (SDSM) (Wilby et al. 2002).

3.6.1 Emission Scenarios

The GCM's, RCM and statistical downscaling model are run using the Special Report Emission Scenarios (SRES) (Nakicenovic et al. 2000)[2]. Each SRES scenario is a plausible storyline of how a future world will look. The scenarios explore pathways of future greenhouse gas emissions, derived from self-consistent sets of assumptions about energy use, population growth, economic development and other factors. They do however, explicitly exclude any global policy to reduce emissions to avoid climate change. Scenarios are grouped into families according to the similarities in their storylines as shown in Figure 3-2.

[2] In 2000, the Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emissions Scenarios (SRES), presenting multiple scenarios of greenhouse gas and aerosol precursor emissions for the 21st century.



- **A1** storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter and rapid introduction of new and more efficient technologies.
- **A2** storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- **B1** storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies.
- **B2** storyline and scenario family: a world in which the emphasis is on local solutions to economic, social and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Figure 3-2: Special Report on Emission Scenarios (SRES) Schematic and Storyline Summary (Nakicenovic et al, 2000)

Since there is an equal probability of each storyline becoming the future, the results presented in the following section cover a range of scenarios, namely the A2, B1, B2 and A1B (see again Figure 3-2). A2 and B2 are representative of high and low emissions scenarios respectively (see Figure 3-3), and A1B is a compromise between the two. The A1B scenario is characterized by an increase in carbon dioxide emissions through mid-century followed by a decrease.

The future climate is presented as absolute or, percentage deviations from the present day climate which is in turn, represented by averaging over 30 year periods, usually 1961-1990 or 1971-2000. Results are presented for 10 year bands centred on 2030 and 2060 and for the end of the century (2100).

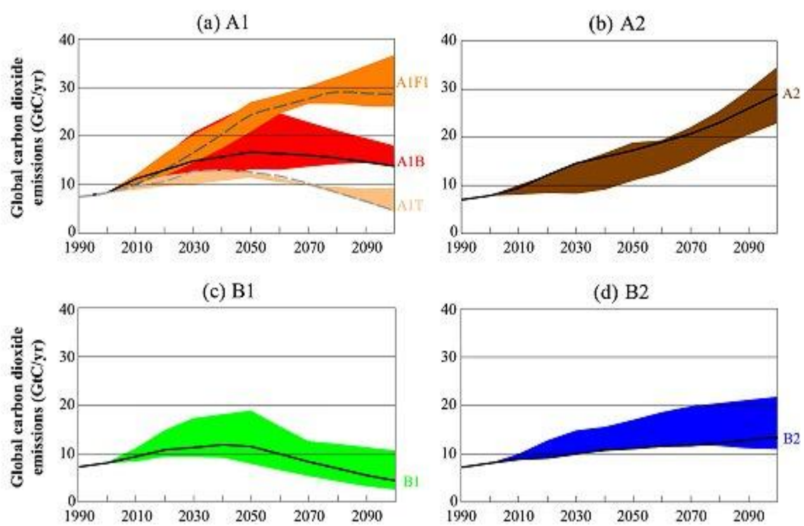


Figure 3-3: Total Global Annual CO_2 Emissions from All Sources (Energy, Industry, and Land Use Change) from 1990 to 2100 (in gigatonnes of carbon (GtC/yr) for the Families and 6 SRES Scenario Groups (Nakicenovic et al, 2000).

3.6.2 RCM Perturbed Experiments

RCM results are derived from PRECIS driven perturbed physics experiments (PPE). Created using the A1B SRES scenario, PPE's provide an alternative to using several driving GCM boundary conditions (McSweeney et al 2012). PPE's comprise a 17 member ensemble (HadCM3Q0-Q16) however, for the purposes of this study a subset of 6, representative of the overall range of key climate features were used. The 6 in question are the ensemble members Q0, Q3, Q4, Q10, Q11 and Q14.

Figure 3-4 shows how the islands of Antigua and Barbuda are represented by the PRECIS RCM. Each island is covered by two grid boxes; the larger island of Antigua is covered by grid boxes 1 and 2 whilst Barbuda is covered by the remainder. Ensuing results will seek to detail temperature (mean, maximum and minimum), precipitation and wind speed changes associated with each grid box for the 2030's. For each of these variables the average of the 6 perturbations is presented as well as the minimum and maximum associated change in the monthly, seasonal and annual time scales.

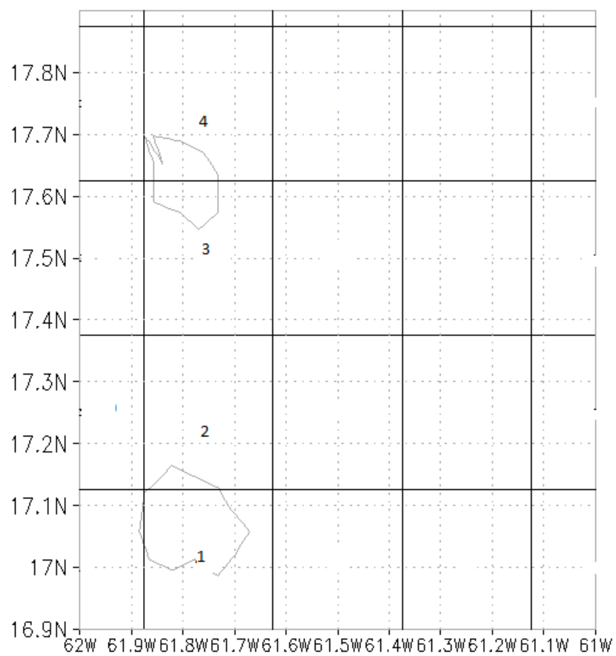


Figure 3-4: Antigua and Barbuda as represented by the PRECIS model

3.6.3 Summary of Observations and Projections

The following are some of the main points that may be noted:

Section 1

- Most of the stations across Antigua and Barbuda have experienced increased rainfall amounts with the Cobb Cross station exhibiting a statistically significant increase.
- The Coolidge station is the only station indicating decreased rainfall amounts over the last couple of decades.
- The probability of at least one drought (severe, serious, moderate or slight) over Antigua in a year is 54.5%. If there is a drought, the chance it will be severe, serious, moderate or slight is 20.9%, 22.4%, 32.8% or 23.9% respectively.
- The annual mean maximum temperatures at the V.C Bird International Airport between 1969 and 2011 exhibit a statistically significant trend of 0.139°C/decade while the annual mean minimum temperatures exhibit a statistically significant trend of 0.091°C/decade. A step change is however evident in the maximum temperature dataset in 1981 that may or may not be related to climate change.
- Extreme temperatures at the V.C Bird International Airport have been increasing. The frequency of warm days exhibits a statistically significant increase (0.69% per decade) between 1972 and 1990. The frequency of warm nights has also increased while the frequency of cool days has decreased. The annual maximum temperatures have shown a statistically significant increase of 0.05°C per decade.
- Relative humidity across the country tends to be generally high year round (above 70%) and predictably highest during the main rainfall period (see Table 1.7). Winds are generally from the east (E) or east-south-east (ESE) and wind speed is strongest (~6 metres per second) in the dry period from December through April. During this period the north Atlantic high is a persistent and dominant influence on the region.
- 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 (2.0 ± 0.2mm/year for 1971-2010).

Section 2

- The annual mean temperature of Antigua and Barbuda is projected to increase irrespective of scenario, model or methodology used.
- GCM's suggest that the mean annual temperature over Antigua and Barbuda will increase by 0.2 to 1.1°C by the 2030's and 0.4 to 2.1 °C by the 2060's relative to 1970-99.
- The PRECIS RCM suggests that the southern extent of Barbuda is projected to warm at a slightly faster rate than its northern extent by the 2030's (1.183 versus 1.083°C), whilst the reverse is true for Antigua (northern Antigua-1.195° versus southern Antigua-1.083°C).

- Annual maximum temperature at the V.C Bird International Airport is projected to increase by 0.5 - 0.6˚C by the 2020's and by 0.9-1.1˚C by 2050's. The annual minimum temperature is expected to increase by 0.5 - 0.6˚C by the 2020's and by 1.0 - 1.2 ˚C by the 2050's.
- September-October-November is a common season for which strongest warming is projected across GCM, RCM and SDSM.
- An increase in the frequency of warm days and warm nights and a decrease in cool days and cool nights is projected across GCM, RCM and SDSM and across scenarios for different time slices.
- Through the 2030's, median changes in rainfall projections deduced from GCM's are all negative which may suggest drier conditions.
- RCM ensemble means suggest decreases in annual rainfall by approximately 5%.
- The proportion of annual total rainfall that falls in heavy events decreases in most GCM projections, changing by -19% to +9% by the 2060's. Annual maximum 1-day rainfall totals show a tendency towards remaining constant while the maximum 5-day rainfall is projected to decrease by up to 5mm across the annual and seasonal timescales.
- Consistent with the GCM projections, the PRECIS RCM suggests a decrease in the annual maximum 5-day rainfall of up to 14mm per decade towards the end of the century. The RCM however, suggests that while rainfall intensity may decrease, a slight increase in rainfall duration may occur.
- RCM ensemble means suggest an increase in wind speeds annually by up to 0.02 m/s
- Hurricane intensity over the north tropical Atlantic is likely to increase (as indicated by stronger peak winds and more rainfall) but not necessarily hurricane frequency.
- Caribbean Sea levels are projected to rise by up to 0.24m by mid-century under the A1B scenario.

4 SENSITIVITIY ANALYSIS

The sensitivity analysis involves determining if the water sector is likely to be affected as a result of projected climate change. If it is likely to be affected then it can be considered ***sensitive*** to climate change. The analysis will among other things discuss: the known climate conditions resulting in stresses on the water sector; how these climate conditions affect the water sector presently; how climate change will affect supply/ demand of water; and how the impact of climate change on the water sector will in turn affect the agriculture and health sector.

4.1 Existing Water Sector Issues and Threats in SWWA

4.1.1 Hydrology and Water Resources

Limited freshwater resources have been and continue to be a major concern in Antigua. Generally, evapotranspiration rates exceed precipitation rates, and as such there are no perennial surface water sources, as the major streams are intermittent, ephemeral and yield insignificant to small quantities of fresh water for a few months after a heavy rainfall event.

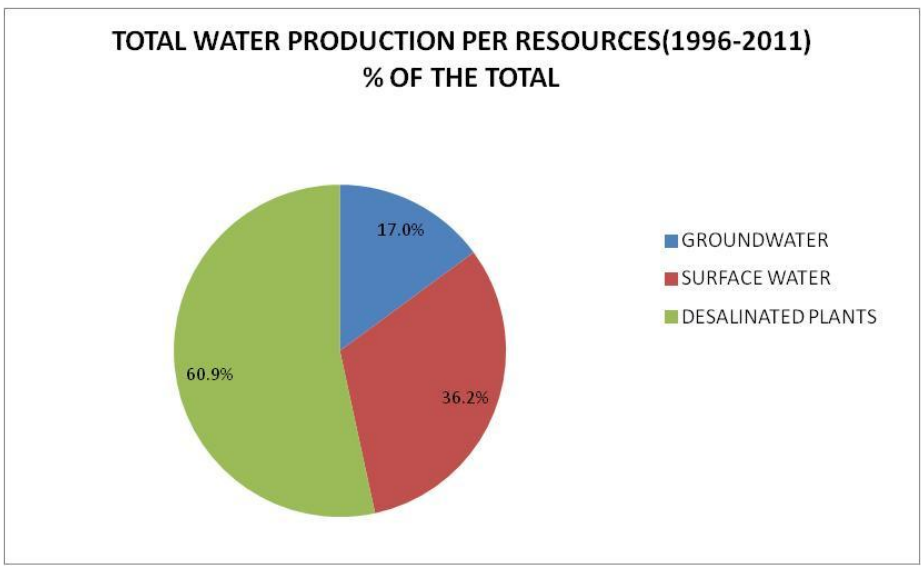


Figure 4-1: Total water production per resources (% of the total) for Antigua

Antigua's water supply needs are served by a combination of surface water, groundwater and desalination plants (Figure 4-2). The VCA area is fed by a combination of all three. However, as a result of the low annual rainfall and relatively frequent drought events, APUA is relying increasingly on desalination. Surface water in Antigua is stored in 10 medium to small reservoirs, 550 ponds and earthen dams with a total capacity of approximately 6 million cubic meters (6000 acre ft. or 1.6 billion imperial gallons) (Hodgkinson-Chin, 2001). Ground water is drawn from about 50 active wells, located in several well fields, but the major well fields are located in Bendals, Cades Bay, Diamond Hole, Jennings, Bristol, Pineapple, Fennes, Hamilton Claremont and Collins. Harvested rainwater at the household and community level is an important source of water to residential homes and some farmers. Water is stored in cisterns beneath and adjacent to homes, tanks and other containers. There are no reliable estimates of the contribution of harvested rainfall at the household level to total water demand, however, it is estimated that harvested rainfall contributes 20% of the total domestic supply (ECLAC, 2007).

Water supply from each source varies, depending upon the season (Table 4-1). The water from all three sources is often blended for quality purposes.

Table 4-1: Antigua's Seasonal Water Supply

SOURCE	DRY SEASON %	W ET SEASON %
Surface water	5	25
Ground water	20	15
Desalination	75	60

Source: Ivan Rodrigues, Antigua Public Utilities Authority -Water Resources Assessment of Dominica, Antigua and Barbuda, and St. Kitts and Nevis, 2004

The Water Division of the Antigua Public Utilities Authority (APUA) is responsible for monitoring and management of water resources, as well as the transmission and distribution of water primarily to the domestic, agriculture, government and cruise ship sectors. Under the law, APUA has exclusive rights to supply, distribute and sell water. Although, there is no clear policy to guide water allocation, in practice the tourism and domestic sectors are given priority in situations of water shortage.

In the SWW there are more surface drainage channels than in the northwestern section, due to elevation (~1300m), lithology, slopes (11-20 degrees), high rainfall and associated runoff (Figure 4-3). The channels originate in the highlands of Mt. Obama, the Shekerley Mountains and Fig Tree Hill and they exit to the coastline in a radial pattern. The pyroclastics and volcanics of Body Ponds and SWW with sedimentary rocks in the downstream end also facilitate sub-surface infiltration accounting for the sub-surface storage. There are a greater number of wells in the SWW than found elsewhere on the island (Figure 4-2).

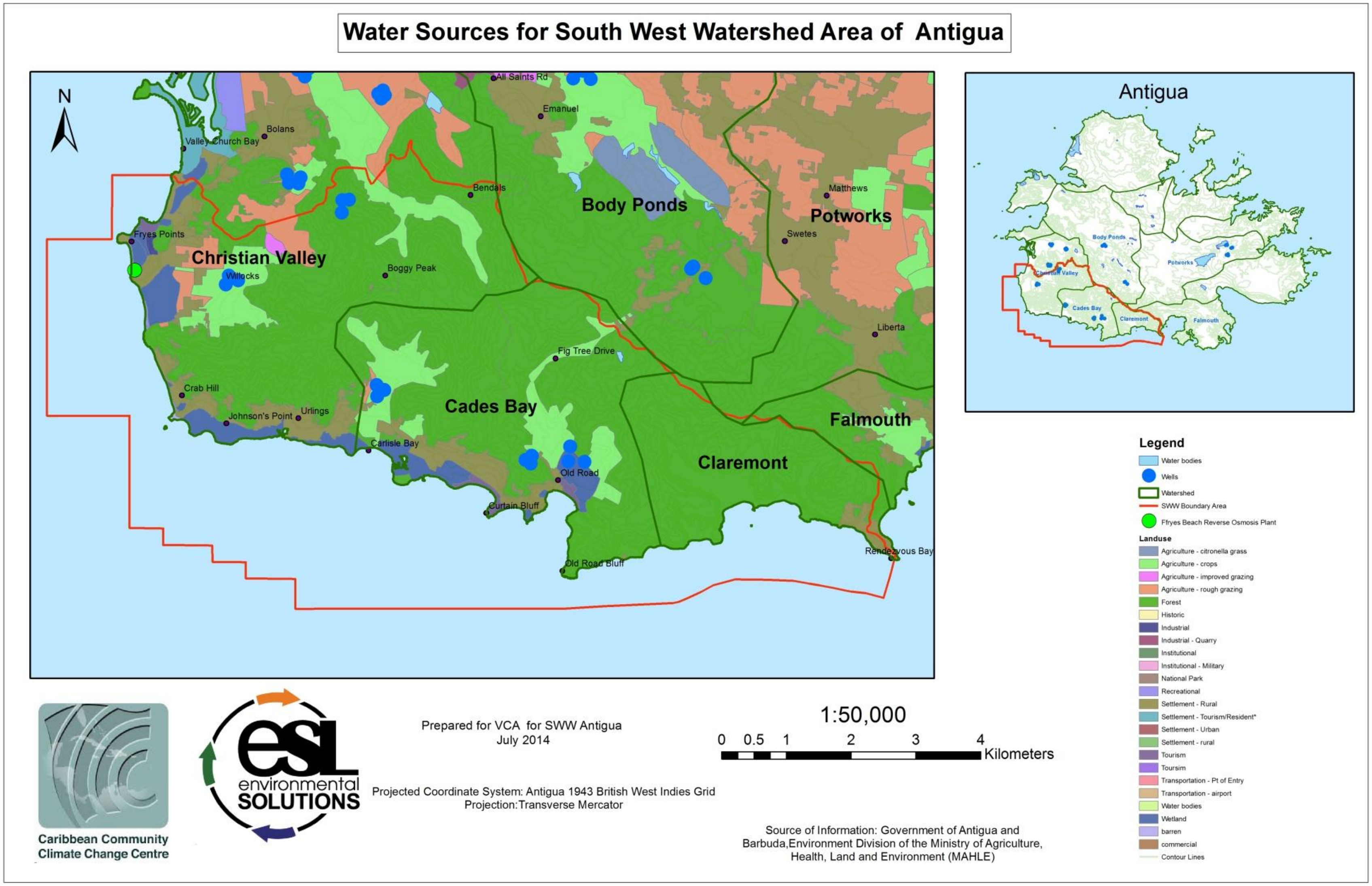


Figure 4-2: Land Use and Water Sources for the South West Watershed Area of Antigua

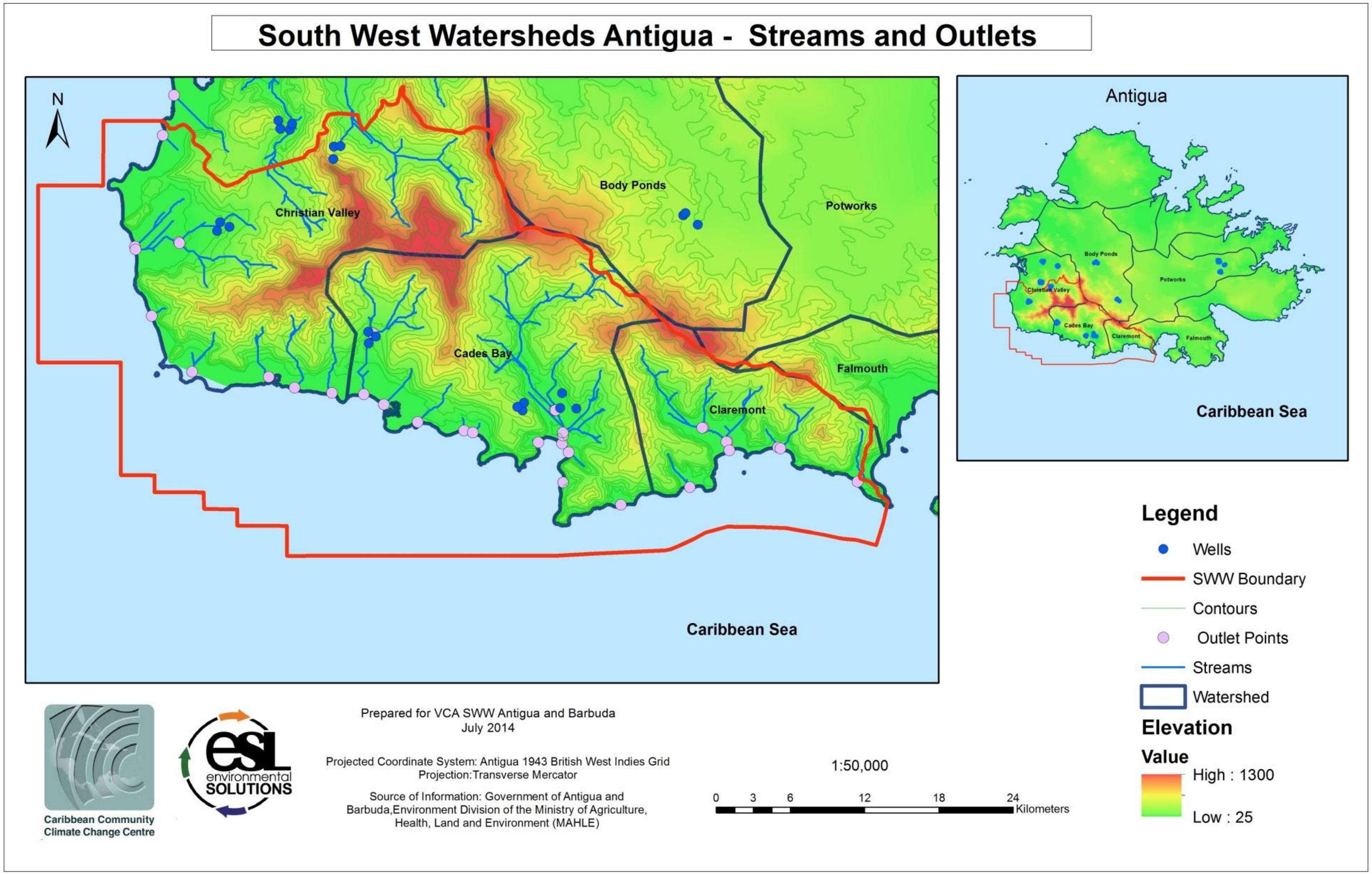


Figure 4-3: South West Watershed Area of Antigua showing drainage patterns and elevation

4.1.1.1 Precipitation

Antigua, including the Southwest Watershed area, has a bi-modal rainfall pattern with two characteristic peaks, one in the months of May-June and the second in the months of September-October. Rainfall is probably the most important and variable climatic feature and severe droughts are experienced every few years. Average annual precipitation averages about 1050 mm (40 ins.), but has ranged from 667 mm to 1708 mm since 1960 (Cooper and Brown, 2001).

Rainfall shows spatial variability across the island with the mountainous areas in the southern and southwestern section of the island showing higher values than in the eastern drier areas (SIRMZP for Antigua and Barbuda, 2011). Figure 4-4 shows that the SWW (Christian Valley, Cades Bay and Claremont) accommodates some of the areas of higher rainfall (55-50 inches) as compared to the northern section of the island (40-30 inches) (Figure 4-4).

Spatial variability of the rainfall pattern correlates with the variation in the number of wells in the SWW area. This is as a result of the higher rate of subsurface infiltration in the downstream end of the highlands comprising of sedimentary rocks. The SWW has low to moderate risk from drought as compared to the northern and eastern regions.

Three (3) weather stations are located within the Southwest Watershed Area; two (2) in Christian Valley Watershed and one (1) in the Cades Bay Watershed (Figure 4-4). Rainfall analyses of these stations are presented in the subsection below.

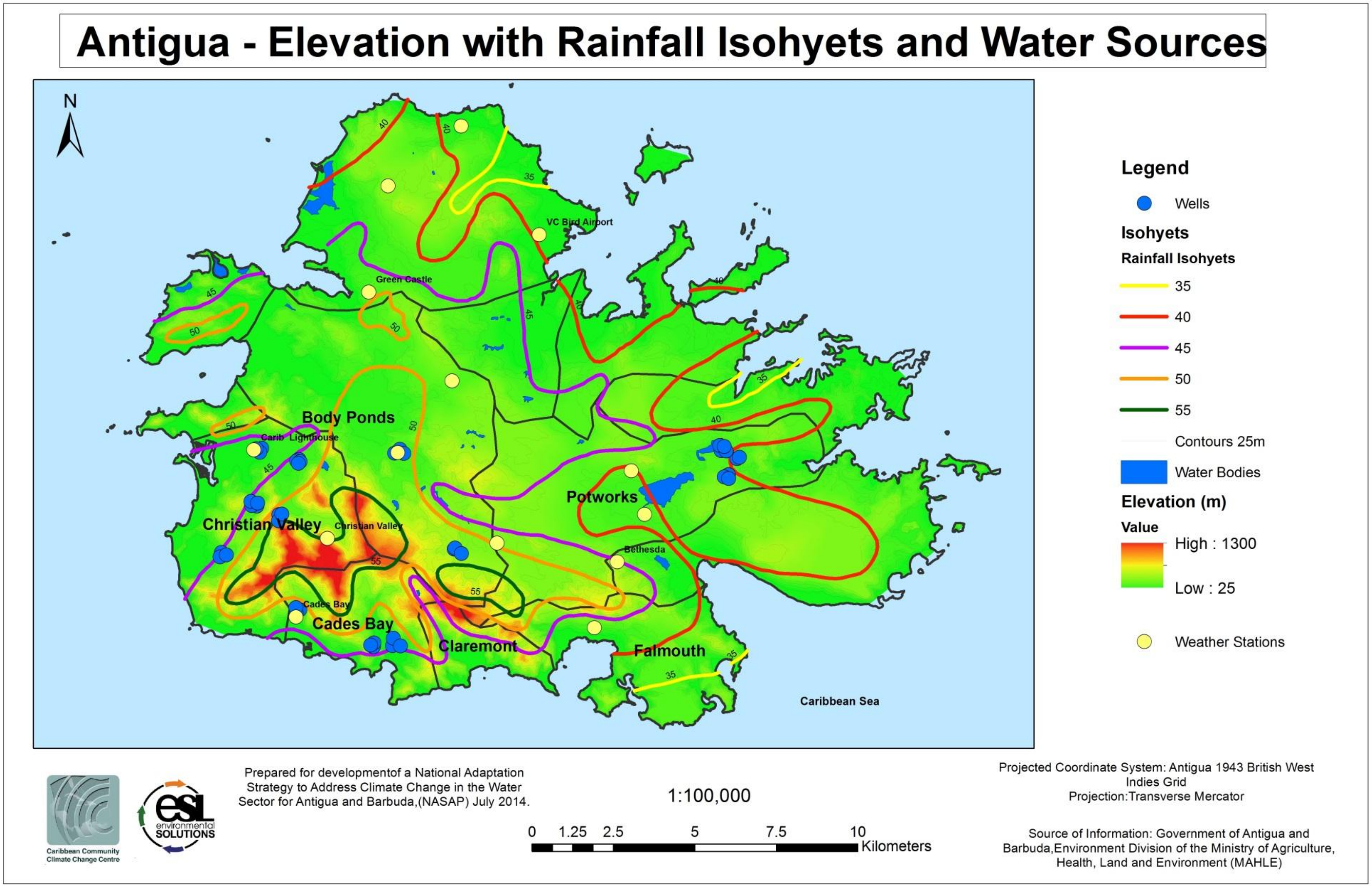
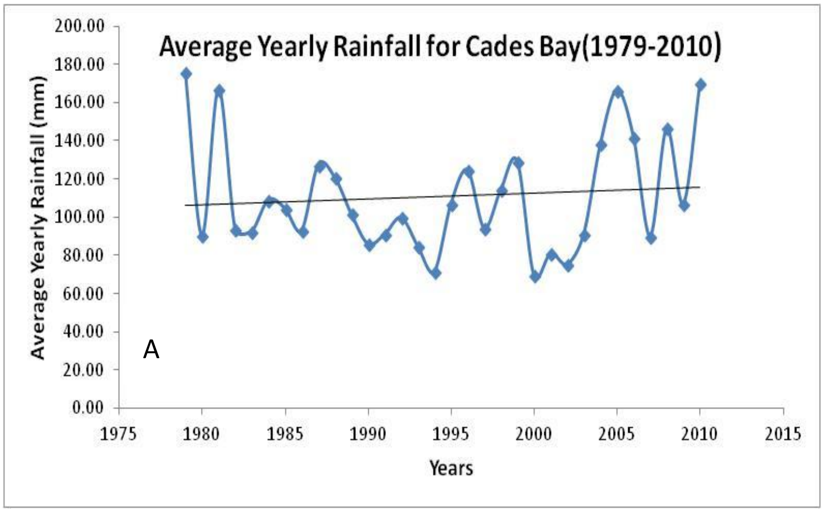


Figure 4-4: Elevation Map of Antigua with the Rainfall Isohyets, Well and Weather Station Locations

A. Rainfall Analysis

The average annual rainfall pattern for the stations, Christian Valley and Cades Bay are shown in Figure 4-5a-b.



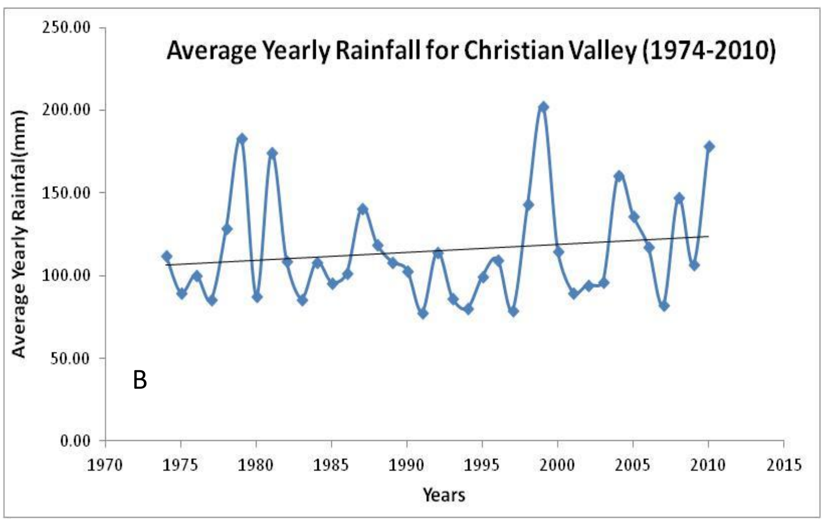


Figure 4-5: Average Yearly Rainfall for Cades Bay and Christian Valley

Of the four (4) rainfall stations assessed, Christian Valley shows the maximum average annual rainfall of 202mm. Although daily rainfall data was obtained for the VC Bird station (1970-2013), only monthly means were obtained for the other stations as mentioned above, and as such the analysis of the stations in the SWW was limited to the use of monthly means.

Therefore, based on the analysis of monthly data, the Cades Bay station does not show a strong bimodality post 1990 with a lower early maxima as compared to the period from 1979-1989.Christian

Valley shows stronger modality in the earlier decades with progressive shift in seasonality and lower rainfall in the early season for the later decades (post 1990). These stations also show an overall bimodal rainfall distribution pattern with two maxima, one in May and the second between September-October. The analysis points to the fact that there is a significant decrease in the rains for the months of May from 1990 onwards with the second maxima shifting from September to August –October.

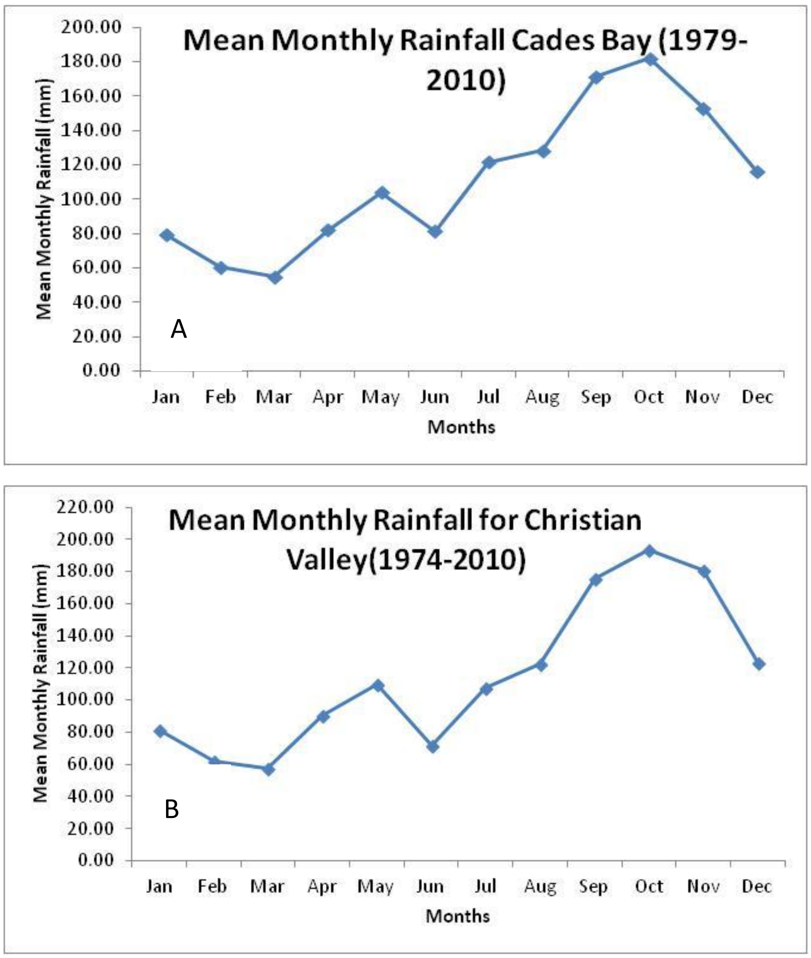


Figure 4-6: Mean Monthly Rainfall for Cades Bay (A) and Christian Valley (B).

4.1.1.2 Groundwater

Approximately fifty (50) wells throughout Antigua supply groundwater from several well fields and most wells are drilled to depths of between 24 -30 meters (80-100ft). The most suitable groundwater in Antigua is said to be located in Southwest Watershed Area within the sandy deposits beneath the valleys of this volcanic region (See Figure 4-4). The well fields in the SWW are located with the Bendals, Claremont, Christian Valley and Cades Bay areas. Together, these well field provide fifty five percent (55%), more than half the total groundwater production of Antigua (Figure 4-7).

Table 4-2: Wells and Well Fields in the SWWA

WELL FIELDS	WELLS
Christian Valley	Christian Valley Nos. 2,3,5,7,9,10,11,12,13 &14
Cades Bay	Cades Bay Nos. 1,9,10,11,12,13,14,15 &16
Claremont	Claremont Nos. 3,8,9,10,11,12 &13 Pineapple Nos. 1,2 & 3
Bendals	Bendals Nos. 3,6,7,11,12,13,15,16,17,18,19,20,21,22,23

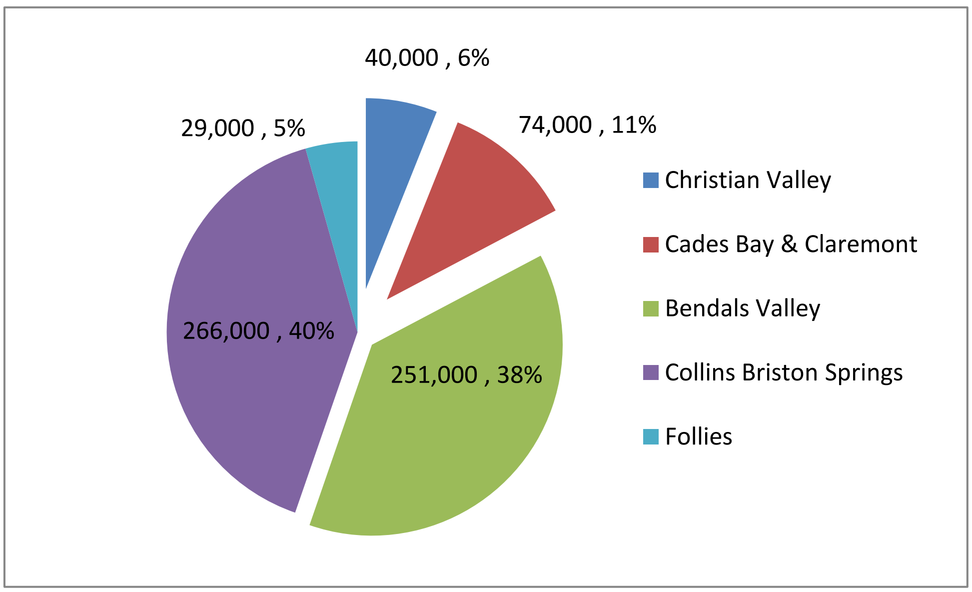


Figure 4-7: Annual Groundwater Production by Well Field (CM/ Yr) (Source: Yearwood, 2000)

During periods of severe drought, when surface sources are depleted or are near depletion, there is added pressure on groundwater resources. Wells are often over pumped to unsustainable levels, even while desalination plants are operating at maximum rates.

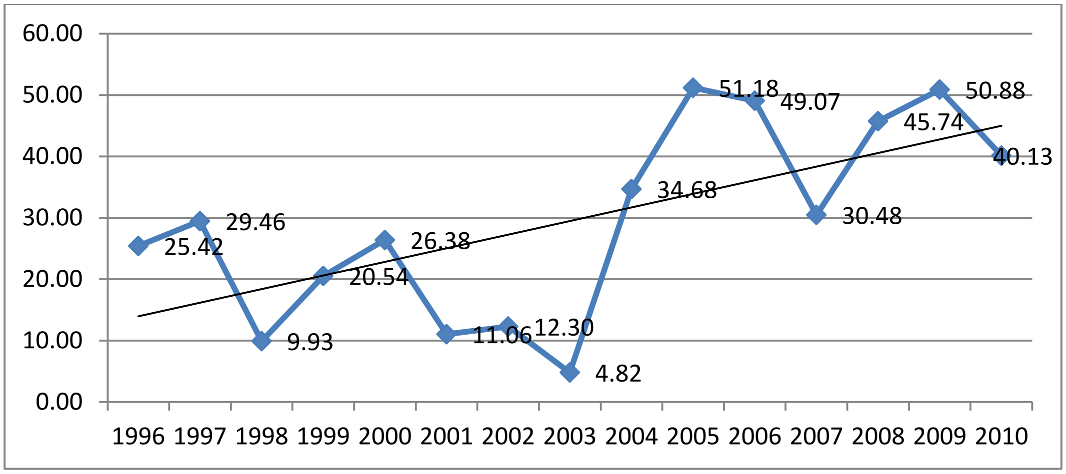


Figure 4-8: Average Annual Groundwater Production/ Abstraction (Mgals)- Antigua

The average annual groundwater production in Antigua, over the period 1996 through to 2010, indicates an increasing reliance on groundwater over that period, particularly since 2004. (Figure 4-8). Over the first eight years, 1996 to 2003, the average annual groundwater production was 17.4MGals/yr, with a high of 29.46 in 1997. Between the years 2003 to 2005, the average annual groundwater production doubled to 37.7MGals/yr and is sustained at this higher production level for most of the subsequent years leading up to 2010.

It is significant to note, however, that groundwater production within the SWWA over the eleven year period 2003 to 2013 does not show a similar trend. Instead, a steady net decrease in production over these years (Figure 4-9) is indicated. Although wells in the Bendals well field also show a declining trend in production over the years, they also show significant increases in production, with clear peaks in 2006 and 2009.

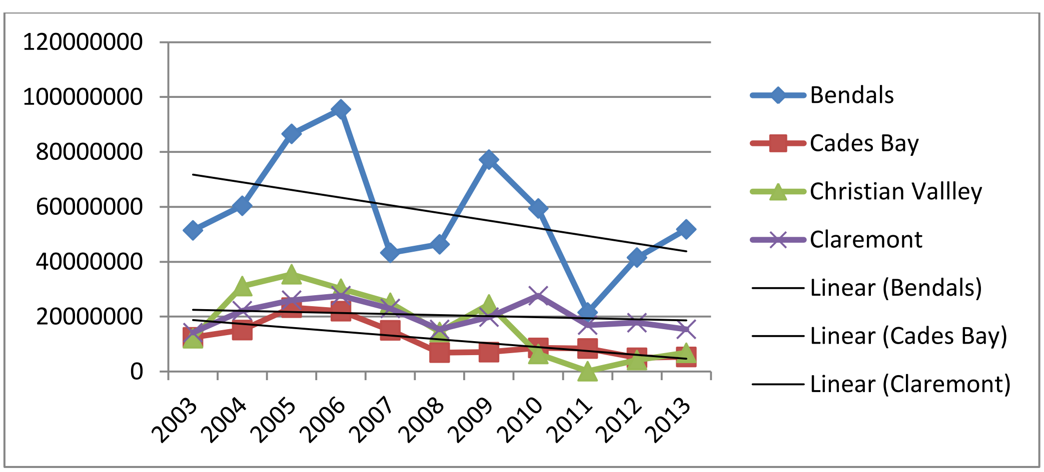


Figure 4-9: Annual Groundwater Production by Well Fields in SWW area (Imperial Gallons)

Pumping water levels in wells indicate the extent to which the groundwater around the wells is being replenished/replaced as the groundwater is extracted/abstracted. The greater the fall in water levels during pumping, the greater the stress on the aquifer in terms of the ability of the aquifer to support and sustain the rates of pumping. Extensive drawdown levels also places greater pressure on pumps to deliver the same production rates.

The pumping water levels of a few wells within the Christian Valley, Cades Bay and Claremont well fields of the SWWA were plotted and the extent of drawdown (ie. difference between the static and pumping water levels) examined. The wells within the Cades Bay well field, (namely, Cades Bay No. 9 and No. 12) and Christian Valley (No. 7) show the largest drawdowns over the period 2003 to 2014, with a Cades Bay well showing a drawdown of 55.8ft in 2010 and a well at Christian Valley showing a drawdown of 70.6ft in 2003. In light of the fact that the depths of these wells range between 80ft and 100ft, these drawdown levels are considered very significant in terms of the added pressure on electrical pumps and the aquifer's capacity to support and sustain the pumping rates. The decline in the well production observed at wells in the Cades Bay and Christian Valley wellfields, (Figure 4-10) , is consistent with aquifers overpumped and stressed in terms of the significantly high drawdown.

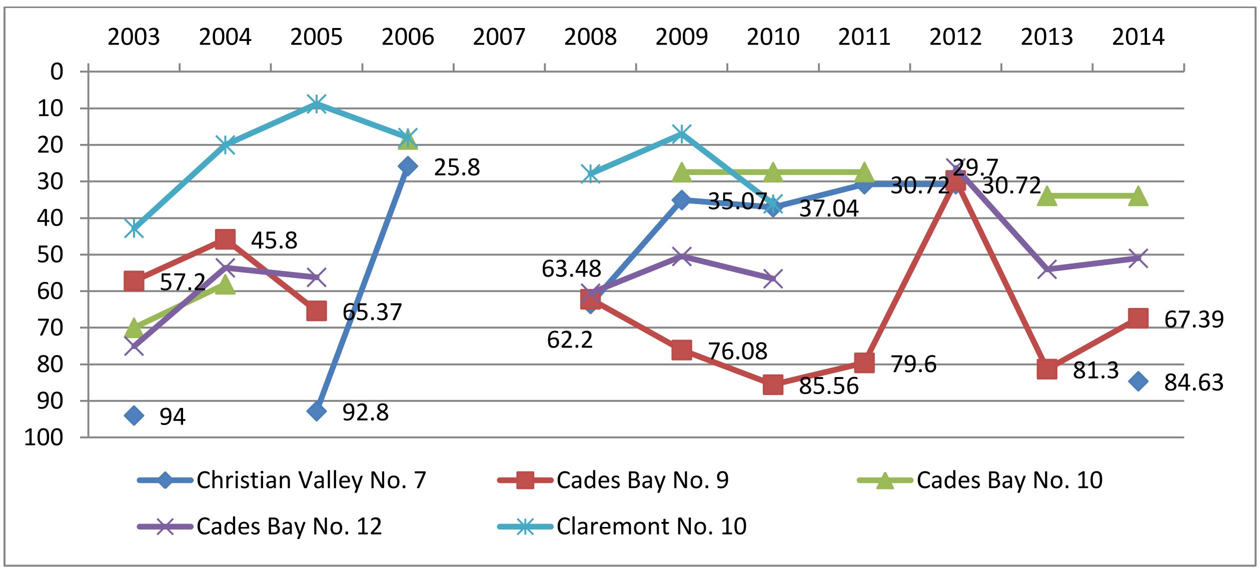


Figure 4-10: Well Pumping Levels (Ft. below groundsurface)

Static Water Level (SWL)

Cades Bay No.- 12-27.9ft, Cades Bay No. 10- 18.5ft, Claremont No. 10 – 5.7ft, Cades Bay No. 9 -29.7ft, Christian Valley- 23.4ft.

Generally, static water levels in wells reflect the natural level of the water table within the particular regional aquifer system, in the absence of pumping of the well. The static water level within wells is not expected to fluctuate significantly from one month to the next, if the aquifer is recovering adequately after periods of pumping. As such, fluctuating static water levels from one month to the next could be pointing to a condition where an aquifer is being overpumped. A review of static water levels for wells in Claremont, Cades Bay and Bendals throughout 2011, indicate that wells within the Bendals wellfield have relatively stable static water levels, while the wells within Cades Bay and Claremont, show greater variability. The static water level in Cades Bay wells rises from 11.6m below ground surface in May 2011 to 7.4m in October of the same year- a rise in static water level of 4.2m. On the other hand, the static water levels at Claremont wells fall from 4m in May 2011 to 8m in September of the same year- a fall in static water level of 4m.

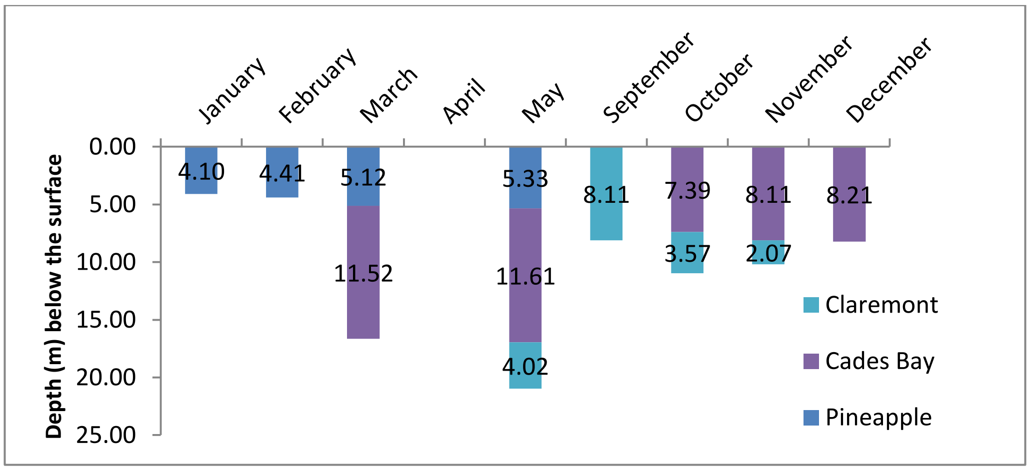


Figure 4-11: Static Water Level (M) in wells of Cades Bay and Claremont area, SWWA (2011)

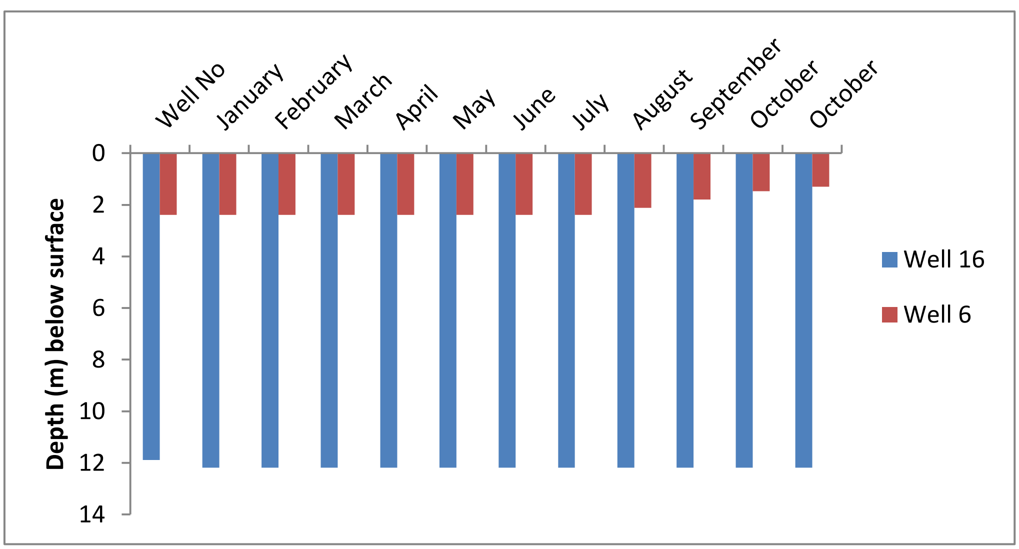


Figure 4-12: Static Water Level (M) in wells of Bendals Area (2011)

Pumping Water Levels and Their Proximity to Sea Level

In order to reduce the risk of saline intrusion in wells, it is generally recommended that pumping water levels for wells near coastal areas, be maintained above sea level. A review of the pumping water levels of the well fields in the SWW area indicates that pumping water levels in some wells are relatively close to sea level, and as such this increases the risk of saline intrusion.

In some years, primarily the drier years (such as 2003 and 2010), wells in the Cades Bay and Christian Valley well fields have recorded pumping water levels close to and below sea level. Some examples are shown in the table below.

Table 4-3: Pumping water levels for wells in the SWW area

Well Name / Year	Well Elevation (m)	Pumping Water Level (m)	Above Sea Level (m)
Cades Bay No. 9 (2010)	27.7	26.07	**1.63**
Cades Bay No. 11 (2003)	28.34	27.8	**0.54**
Christian Valley 7 (2003)	31.4*	28.6	**2.8**
Christian Valley 7 (2009)	31.4*	32.6	**- 1.2 (Below Sea level)**
Claremont 10 (2003)	21.6	13.04	**8.56**

(* Average elevation of Christian Valley (CV) Wells No. 2 & 3: Elevation of CV 7 was not provided)

4.1.1.3 Surface water

Despite the fact that the SWWA experiences some of the highest rainfall in the island of Antigua, there are no significant surface reservoirs or ponds within the SWWA to store the rainfall runoff. Bendals water treatment plant, located within the SWWA, receives surfacewater from the Hamilton Dam, a municipal reservoir, with a drainage area of 175ha and a storage volume of 104,120m^3. Hamilton Dam is next to Bendals and is located in St. John, Antigua and Barbuda, but outside of the study area.

Over the years, inadequate catchment management, indicated by changes in land use, has resulted in increased siltation, organic, chemical and bacteriological contamination, which has direct implications for both the quality and quantity of water stored in reservoirs and ponds. Generally, surface storage of water is a less reliable water supply and the current and projected climate change is likely to further affect land use, vegetative cover, erosion and fire frequency.

Surface water storage, however, has its benefits, as it adds to the total available freshwater and if catchment /watershed management initiatives continue, are intensified and sustained, then the issues of contamination could be better controlled. Further the operating costs of distributing water supplied from surface sources is generally less, since energy costs associated with lifting water from depths beneath the ground, as in the case of pumping wells, are eliminated.

4.1.1.4 Desalination

Water demand in Antigua and Barbuda exceeds the natural freshwater carrying capacity of the country. Hence, the heavy reliance on desalination, which is more expensive than surface and groundwater supply and highly subsidized by the earnings of tourism.

Currently, there are three (3) desalination plants being operated in Antigua, two government-owned and one privately owned. The largest desalination plant is privately owned by SembCorp/Eneserve and provides approximately 3.1 MIG/Dp (60-75% of Antigua's drinking water), while the other two government operated reverse osmosis desalination plants, APUAs Camp Blizzard and Ffryes Beach, each produce 600,000 Imp Gallons per day. The Ffryes Beach Reverse Osmosis Plant is located within the SWW area (Figure 4-13).

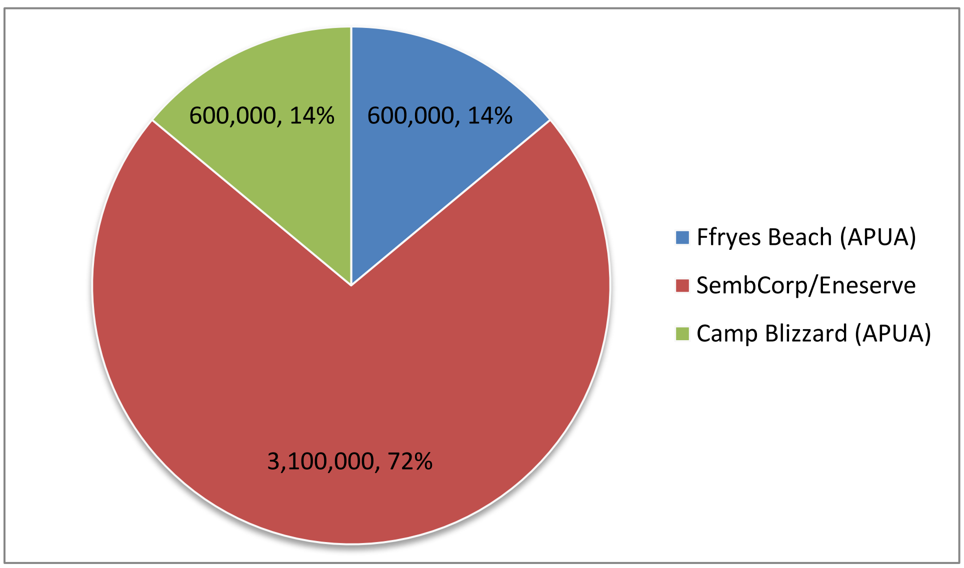


Figure 4-13: Water Supplied by Desalination Plants, Antigua (Imp. Gallons)

APUA indicated that the two government operated reverse osmosis/desalination plants are costly to operate and relied upon only as the need arises. They try to rely on surface and groundwater as much as possible, however, due to the recurring drought conditions, this is often difficult. The cost of producing water by desalination is significantly more expensive than that for groundwater and surface water (Figure 4-14).

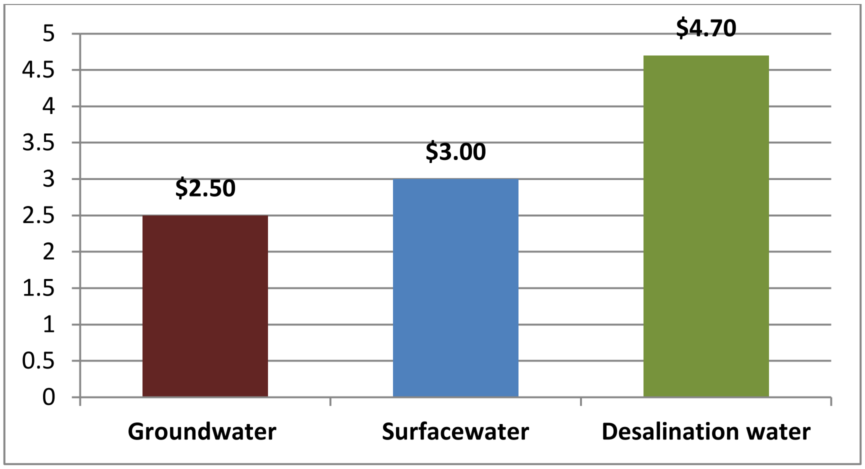


Figure 4-14: Cost of Water Production (US$ per m^3) Source: Fernandez, 1991

Some private coastal hotels and manufacturing plants have invested in their own desalination plants to ensure a dependable water supply. During droughts, desalination plants provide up to 83 percent of potable water.

The desalination water supply option presents certain environmental challenges, particularly those associated with the impact of discharging brine to the sea. Both flash-distillation and reverse osmosis desalination technologies require the disposal of super saline wastewater (brine). Other chemicals such as sulphuric acid, chlorine and copper sulphate are injected into the pipelines to remove scaling and to inhibit the attachment of bivalves to the pipelines (UNDP). Eventually, these chemicals discharged to the coastal marine environment, often at elevated temperatures, may alter and disrupt the natural marine habitats and coastal environment in general.

The dependence on desalinated water over the eleven (11) year period, 2001-2011 indicated in Figure 4-15, shows a distinct decline during the years 2004-2005, reaching the lowest levels of production in 2005. This reduced dependence on desalinated water coincides with a period of sustained elevated rainfall, as reflected at the Christian Valley and Cades Bay weather stations (Figure 4-16). Elevated rainfall during the years 2004 and 2005, would have replenished and sustained the water available in reservoirs and aquifers, allowing the APUA to reduce production of the more expensive option of desalination and increase reliance on surface reservoirs and wells. This period of reduced dependence on desalinated water in 2005, was short lived, as by 2006 through to 2011, the production of desalinated water reverted to over 1000 million gallons per year.

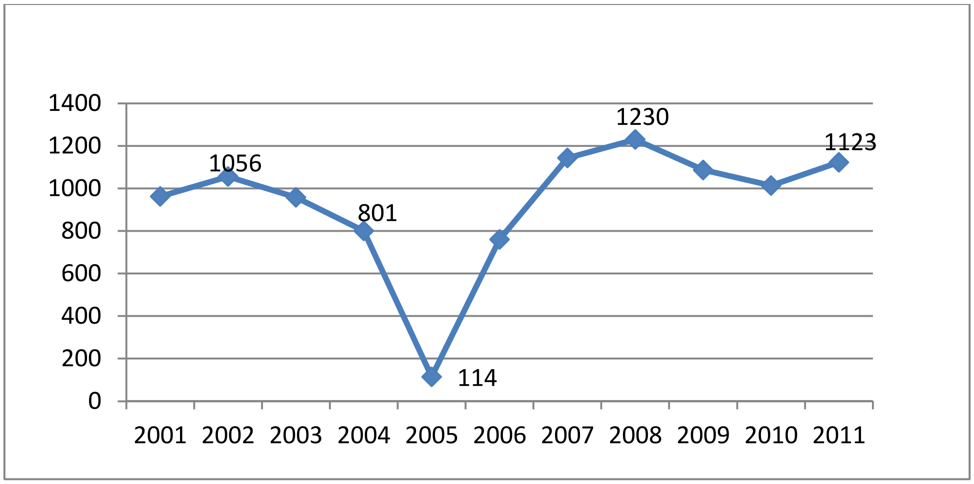


Figure 4-15: Desalination Production (MG)

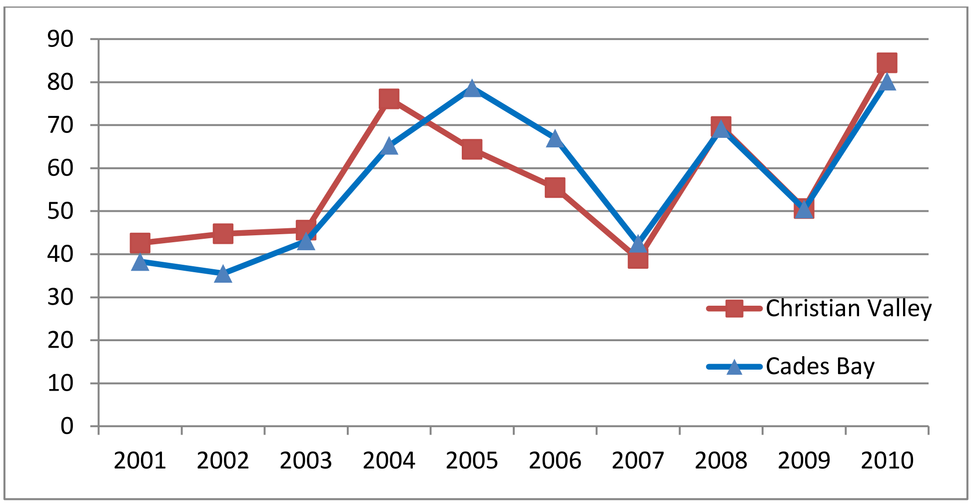


Figure 4-16: Annual Rainfall in the SWWA (inches)

Managed Aquifer Recharge (MAR)

If or when tourism declines, the cost of the desalination option may become prohibitive. As such it is strategically critical, that feasible and sustainable options to augment existing freshwater supplies, be explored and implemented.

Aquifers are replenished naturally by the infiltration of rain through the soil and rocks as well as from the infiltration of rivers and streams. Land use changes over the years, however, have resulted in significantly high rates of runoff of freshwater to the sea and reduced infiltration to the aquifers.

In Antigua and Barbuda, where there is inadequate freshwater resources in storage to supply the demand throughout the drought periods, Managed Aquifer Recharge (MAR) could provide an opportunity to replenish aquifers, restore groundwater levels, reverse saline intrusion, improve water quality through dilution and natural filtration and augment water supply. In addition, MAR will reduce loss of water to evaporation and runoff to the sea and in general, would improve preparedness and capacity of the country to adapt to the current and expected future climate variation which affect water supply. Some other benefits associated with the MAR are improved coastal water quality, mitigate floods and freshens saline/ brackish aquifer.

The available techniques for MAR are generally straightforward, cost effective and sustainable. Many can be adopted by communities at a small scale with locally available materials and manpower. The source of water is usually harvested rainfall and harnessed surface water runoff. (Source: MAR- Practical Techniques for the Caribbean, 2010, GWP Consultants).

The methods of MAR which are considered most appropriate for technical consideration are:-

- Well Injection
- Infiltration Ponds
- Rainwater Harvesting for Aquifer Recharge
- Recharge Weirs or Check Dams

4.1.2 Water Quality

As the agency responsible for the monitoring, treatment and distribution of water to the public, APUA has responsibility for and is required by the Ministry of Health, to routinely test the quality of well water (groundwater), reservoirs/ponds (surface water) and water supplied from desalination plants. The monitoring of harvested rainwater collected in cisterns and other storage facilities at the household level, is the responsibility of the Central Health Board in the Ministry of Health and the overall regulatory monitoring of all domestic water supplies is the responsibility of the Ministry of Health.

The WHO Guidelines for Drinking Water Quality have been adopted and are used by APUA to assess the suitability of water supplied for drinking. In general, the parameters tested include:- pH, turbidity, colour, total dissolved solids, alkalinity, calcium hardness, manganese, iron, phosphate, nitrates, chlorine residual, total and faecal coliform. However, data for all parameters from APUA was not made available for this assessment. The data provided and used by the Consultants in this assessment included physical (turbidity, colour, hardness, total dissolved solids and pH) and chemical parameters (iron and manganese):

In light of the fact that there are no significant surface water reservoirs within the SWW area, this water quality assessment focuses on the groundwater resources, which include the Cades Bay, Christian Valley and Claremont/Pineapple Well fields.

The specific objectives of this assessment were:-

a) To determine the influence of seawater intrusion indicated as TDS levels in groundwater, how they over time and the suitability for drinking
b) To determine the impact of anthropogenic activities (eg. soil erosion) as indicated by turbidity levels in groundwater and how they change over time
c) To determine the suitability of groundwater quality with respect to iron and manganese, for use as domestic/municipal water

4.1.2.1 Approach

A well field refers to a group of wells in relatively close proximity to each other which tap the same aquifer system. There are several wells within each well field and since these wells tap the same aquifer system, the average value for wells within each well field was used in the assessment of the quality of each aquifer. As such the graphs presented in this section reflect monthly averages of each of the indicator parameters, i.e. Turbidity, Total Dissolved Solids, Manganese and Iron. The individual wells within each well field which show significant variations from the average, are also highlighted in the discussion.

a) *Determining the influence of seawater intrusion, indicated as TDS levels in groundwater, how they change over time and suitability for drinking.*

The influence of seawater intrusion is usually indicated by the relative concentration of sodium and chloride. However, in the absence of data for the parameters sodium and chloride, the indirect indicator Total Dissolved Solids (TDS) was used. There is generally strong correlation between TDS levels and salinity, associated with seawater intrusion, as such elevated TDS values are taken as an indication of the influence of seawater intrusion or seawater upcoming due to overpumping. TDS levels may also indicate impacts from anthropogenic activities such as agricultural runoff, urban runoff, industrial wastewater and sewage. In general, the SWW area could be expected to have a relatively low impact in terms of urban and agricultural runoff as well as industrial. Sewage may be an aspect of concern since there is no sewerage network and no central sewage treatment facilities to serve the general public.

Total Dissolved Solids (TDS) are the compounds in the water that cannot be removed by a traditional filter. TDS can give water a murky appearance and detract from the taste quality. Gastrointestinal irritation in some individuals can be caused by high TDS levels. TDS can also interfere with treatment devices and is an important consideration when choosing a treatment system.

b) *Determining the impact of anthropogenic activities (resulting in soil erosion) as indicated by turbidity levels in groundwater and how they change over time*

Turbidity in groundwater resources is a measure of the amount of suspended materials such as clays, silt and or finely divided organic and or inorganic material. Water quality of wells which tap aquifers with high water tables may be highly influenced by surface water which contains clay, silt and other sediments. Increased turbidity could be associated with soil erosion on the slopes within the watersheds which recharge these aquifers in the SWW area.

Turbidities in excess of 5 units are easily detectable in a glass of water and are usually objectionable for aesthetic reasons. Clay or other inert suspended particles in drinking water may not adversely affect health, but water containing such particles may require treatment to make it suitable for its intended use.

c) *Determining the suitability of the groundwater quality, with respect to iron and manganese, for use as domestic/municipal water supply*

The APUA is guided by the health based World Health Organization Drinking Water Quality Guidelines and the data is assessed by comparing the values with the following standard limits.

Parameter	Standard Limit
Total Dissolved Solids (TDS), mg/L	<1000
Colour (Colour Units, CUs)	< 15
Turbidity (NTU)	< 5
Iron (Fe), mg/L	< 0.3
Manganese (Mn), mg/L	< 0.5

Significance of Water Quality Parameters

Turbidity

- The presence of suspended material such as clay, silt, finely divided organic material, plankton and other inorganic material in water is known as turbidity.
- Turbidities in excess of 5 units are easily detectable in a glass of water and are usually objectionable for aesthetic reasons. Clay or other inert suspended particles in drinking water may not adversely affect health, but water containing such particles may require treatment to make it suitable for its intended use.

Colour

- Dissolved organic material from decaying vegetation and certain inorganic matter cause colour in water. Occasionally, excessive blooms of algae or the growth of aquatic microorganisms may also impart colour.
- While colour itself is not usually objectionable from the standpoint of health, its presence is aesthetically objectionable and is very often a reliable indicator of pollution.

Total Dissolved Solids

- Total Dissolved Solids (TDS) are the compounds in the water that cannot be removed by a traditional filter. TDS can give water a murky appearance and detract from the taste quality.
- Gastrointestinal irritation in some individuals can be caused by high TDS levels.
- TDS can also interfere with treatment devices and is an important consideration when choosing a treatment system.

pH

- pH is a measure of how acidic or alkaline a solution is. Consuming excessively acidic or alkaline water is harmful to human health.
- Drinking water must have a pH value of 6.5-8.5 to fall within WHO Drinkingwater Guideline

Manganese & Iron

- Manganese (Mn) and Iron (Fe) exist in well water as a naturally occurring groundwater minerals, but may also be present due to underground pollution sources.
- Elevated levels in water may cause the growth of Fe and Mn bacteria.
- It produces objectionable stains , it deposits in pipelines and tap water may contain black sediments and turbidity due to precipitated Mn.

4.1.2.2 Groundwater Quality

In Antigua, groundwater resources are limited and threatened by excessive use, saltwater intrusion and pollution from sewage. The influence of sea water on groundwater quality is greater the closer the wells are to the coastline. Saline intrusion into wells is further exacerbated during periods of extended drought, when wells are overpumped and the fresh groundwater-seawater interphase shifts causing seawater to migrate further inland. Some wells have been abandoned (ie. capped /closed) or temporarily out of service due to saltwater intrusion. Below is a summary discussion and the details are in Annex 3.

A) The influence of seawater intrusion on groundwater over time and suitability for drinking

Although TDS is considered an indirect indicator of the influence of seawater, it is accepted that the influence of seawater on groundwater quality would be clearly and directly reflected in the levels of TDS readings observed. The "Glossary of Salt Water" published by the Water Quality Association classifies water as follows:

Fresh: <1,000 ppm TDS
Brackish: 1,000-5,000 ppm TDS
Highly Brackish: 5,000-15,000 ppm TDS
Saline: 15,000-30,000 ppm TDS
Sea Water: 30,000-40,000 ppm TDS
Brine: 40,000-300,000+ ppm TDS

Based on the above definition of fresh water, the TDS data analyzed for the period under review, indicates that groundwater at Christian Valley and Cades Bay well fields is consistently fresh. On the other hand, the TDS levels at Claremont/Pineapple well field indicate that the groundwater shifts over to brackish quality on some occasions. Generally, TDS levels at Claremont/Pineapple well field are consistently higher than the levels at the other two well fields assessed. This suggests that the Claremont/Pineapple well field is most affected by processes that promote salinity and if no corrective action is taken, the Claremont/Pineapple well field is likely to be the first well field to become unacceptable as a water source due to elevated salinity levels.

With regard to the suitability of the groundwater for human consumption as it relates to TDS, it should be noted that TDS is generally considered an aesthetic parameter, with no direct health related impacts. As such the standard limit adopted by Antigua is the WHO’s recommended guideline of <1000mg/L. However, an aesthetic objective of ≤ 500 mg/L has been established for total dissolved solids (TDS) in drinking water by WHO, which is based on taste, as higher levels are considered unpalatable. In addition to the taste consideration, higher levels above 500mg/L result in mineral deposition and corrosion. In a study by the World Health Organization, the following conclusions about the preferred level of TDS in water were arrived at:

Table 4-4: Taste of Water with Different TDS Concentrations

LEVEL OF TDS (MILLIGRAMS PER LITRE)	RATING
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

When groundwater of the SWW area is assessed against the findings of this WHO taste preference study, most of the data across the three well fields would indicate a rating of Fair to Poor (Table 4-5). Claremont/Pineapple well field has the most instances of TDS occurring in the 'Poor' rating. However, there is no clear sustained trend in TDS levels over the period under review.

Table 4-5: Groundwater Quality in the SWWA Based On Salinity and Taste Ratings

GROUNDWATER by Well Field	Salinity Rating	Taste Rating (WHO)	
Christian Valley	Fresh	Good to Fair	
Cades Bay	Fresh	Good to Fair	
Claremont/Pineapple	Fresh to Brackish	Good – Fair – Poor	**BRACKISH/POOR WQ:** **Claremont Well No. 9** **Claremont Well No. 10** **Claremont Well No. 8** **Pineapple Well No. 1** **Pineapple Well No. 2**
Bendals	Fresh	Good to Fair (NB. Predominantly GOOD)	

B) Determining anthropogenic impacts/soil erosion, indicated by turbidity levels in groundwater and how they change over time

Typically, it is not expected that groundwater should be significantly affected by turbidity, except in those sedimentary rock units with high conduit flow features such as karstic formations or where there are anthropogenic influences related to soil erosion and siltation of aquifer recharge waters which originate from surface sources.

Turbidity (suspended material such as clay and other inert particles) is another parameter which is considered for aesthetic reasons and as such the standard adopted by APUA/Antigua is based on the fact that turbidity in excess of 5 units is easily detectable in a glass of water and is usually considered objectionable for aesthetic reasons.

Most of the turbidity readings for the three well fields assessed meet the turbidity standard of <5mg/L. There are however, instances where the standard is exceeded in all three well fields, with the Claremont/Pineapple well field showing the highest frequency of exceedence as well as the highest deviation above the standard (a factor x10). Cades Bay, on the other hand shows the lowest incidents of exceedence with marginal deviations above the standard (a factor x2). The incidents of exceedence are generally short lived, manifested as spikes on the graphs, as the levels revert to compliance levels within the one month sampling interval.

The significantly high spikes in turbidity observed at the Claremont/Pineapple well field suggest that there may be anthropogenic influences associated with land use practices which result in soil erosion in the recharge areas of this aquifer.

There are no observable trends in turbidity over the period under review.

C) The suitability of groundwater quality with respect to iron and manganese for use as domestic/municipal water supply

The APUA/Antigua has adopted the WHO guideline of <0.3mg/L and <0.5mg/L for iron and manganese respectively and most readings for all three well fields fall within the requisite standard. However, for each well field there are instantaneous spikes which exceed the standards. With respect to Manganese, generally, the wells in the Claremont/Pineapple well field have the highest peaks ie. greatest deviation above the standard limit and the highest frequency of exceedence: while wells in the Cades Bay well field have the lowest peaks, ie. smallest deviation above the standard limit, and the lowest frequency of exceedence. With respect to Iron, again the Claremont/Pineapple well field shows the highest peaks ie. greatest deviation above the standard limit, but is equal to the Cades Bay well field in the frequency of exceedence.

Colour is a reliable indicator of pollution, since high quality groundwater is generally colourless. The data indicates that whenever, manganese and iron are significantly elevated, the colour readings are at their maximum, which indicates that the elevated manganese and iron are associated with a source of pollution which discolours the groundwater. There is no observable trend in iron or manganese levels in the well fields over the period under review, however it is useful to note, that the timing of the peaks in both iron and manganese, being in the years 2007 and 2009 coincides with relatively lower levels of rainfall in the SWWA.

4.1.2.3 Surface water Quality

There are no perennial surface water flows in Antigua. The surface water that exists occurs as dammed sections of dry river courses and ponds. The quality of these surface water sources is influenced by land use and the extent of vegetative cover over the lands which drain to these ponds and dammed river segments. Generally, extensive grazing and poor soil conservation practices on slopes associated with agricultural activities on the hillsides, contributes to increased soil erosion and in turn elevated turbidity levels.

Bendals reservoir is a water source for agriculture and has a relatively small storage capacity of 23,000m^3. No water quality data was provided for this reservoir.

The quality of water delivered to surface reservoirs used for municipal and agricultural water supply, is strongly influenced by the land use and general management of these lands in the SWWA.

The water quality database available to the consultants indicates that Bendals Water Treatment Plant receives surface water from Hamilton Dam, a municipal reservoir, with a drainage area of 175ha and a storage volume of 104,120m^3. Very few data points for this treatment plant were included in the database. The database included data for four months; July and August 2004 and February and March 2006 and is presented in Table 4-6. This limited dataset does not allow the analysis of trend or meaningful assessment of incidents of exceedence of the relevant standards over an extended period.

Table 4-6: Water Quality Data for Bendals Water Treatment Plant (Quality after Treatment)

Standard		21-Jul-04	27-Jul-04	19-Aug-04	13-Feb-06	28-Mar-06
pH	**>6.5 <8.5**	7.1	6.9	7.2	6.8	6.7
Turbidity	**<5NTU**	2.85	2.65	2.9	1.92	0.24
Colour	**<15CU**	14	9	**82**	10	5
Iron	**<0.3mg/L**	0.083	0.076	0.11	0.115	0.004
Manganese	**<0.5mg/L**	**0.6**	0.2	0.8	**0.6**	0.2
T. D.S	**<1000mg/L**	212	135	420	324	403

Based on the limited dataset, pH, Turbidity, Iron and TDS readings were in compliance with the relevant standards during these four months. Colour and Manganese were out of compliance, with colour reaching 82CU in August 2004 and manganese reaching 0.6mg/L in July 2004 and again in February 2006.

The data available for the raw water coming into this treatment plant indicates that turbidity, colour and iron are usually out of compliance in the raw water, however, the treatment process is able to bring these parameters into compliance.

4.1.3 Existing Assessment of Sectors in SWW area

As previously discussed, most of the land within the SWW remain uninhabited and predominantly under forest cover, with stretches of wetlands associated with coastal lowlands and inland river courses. Most of the development in the area is concentrated along a narrow southern central coastal fringe of the Cades Bay Water Watershed, where tourism is dominant, and along the northeastern section of the Christian Valley Watershed where there is both tourist and residential settlement (Figure 4-2). There is some agriculture within the area but it is not significant.

The tourist sector in the area depends on a combination of reverse osmosis and water from APUA. However, the larger and more luxurious hotels tend to have their own reverse osmosis plant and rarely use water from APUA, whereas the smaller hotels depend on APUA. In some instances hotels barge in their own private water from Dominica. The farming sector relies primarily on rainfall and the domestic sector depends on a combination of all three sources.

The data from APUA on demand cannot be broken down for the SWW. However, for Antigua, the sectoral analysis of the water demand shows that the domestic sector contributes to 64% of the total water demand for the years ranging from 2001-2011 followed by the commercial sector (23%) and the agriculture sector (1.7%) (Figure 4-17).

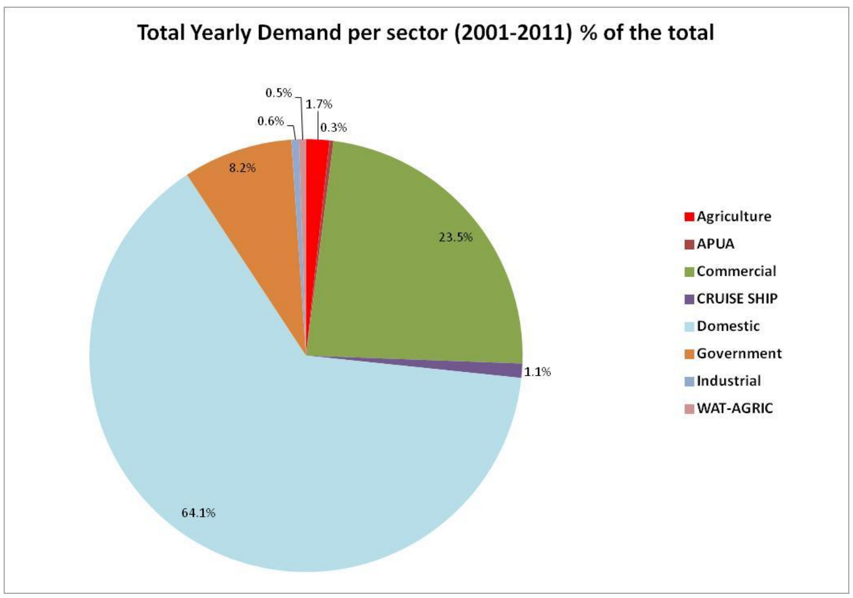


Figure 4-17: Total Yearly Demand per Sector Expressed as Percentage of the Total (APUA database)

The trends for total annual demand (2001-2011) shows that although the production indicates an increasing trend, the demand is showing a decrease post 2009 (Figure 4-18). This could be as a result of new developments creating their own source of water through privately owned reverse osmosis plants.

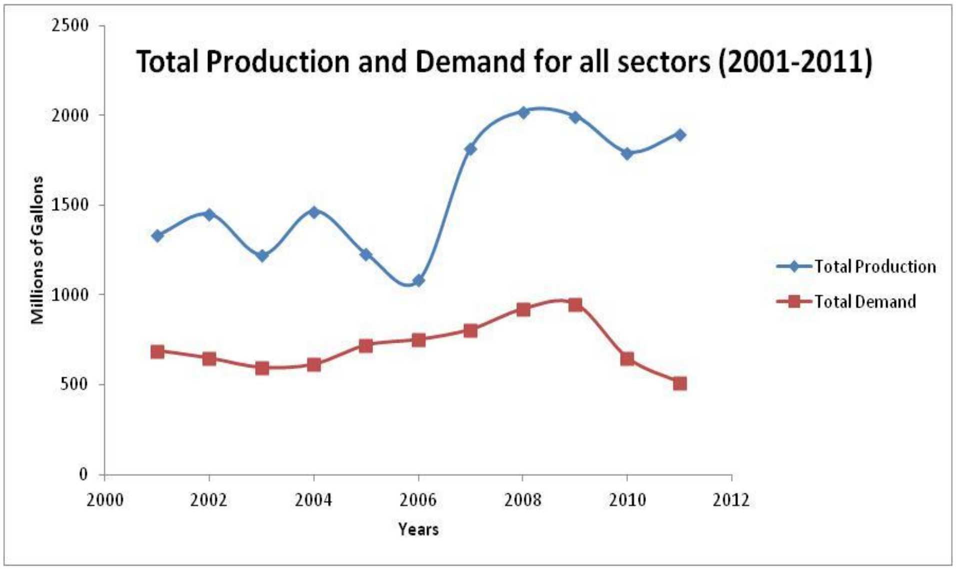


Figure 4-18: Total Demand and Production of Water from 2001-2011

Sectoral analyses of the demand and the number of customers in each sector from 2011-2011 shows that the domestic sector comprises the highest number of customers (94%) of the total as opposed to the other sectors (Figure 4-19).

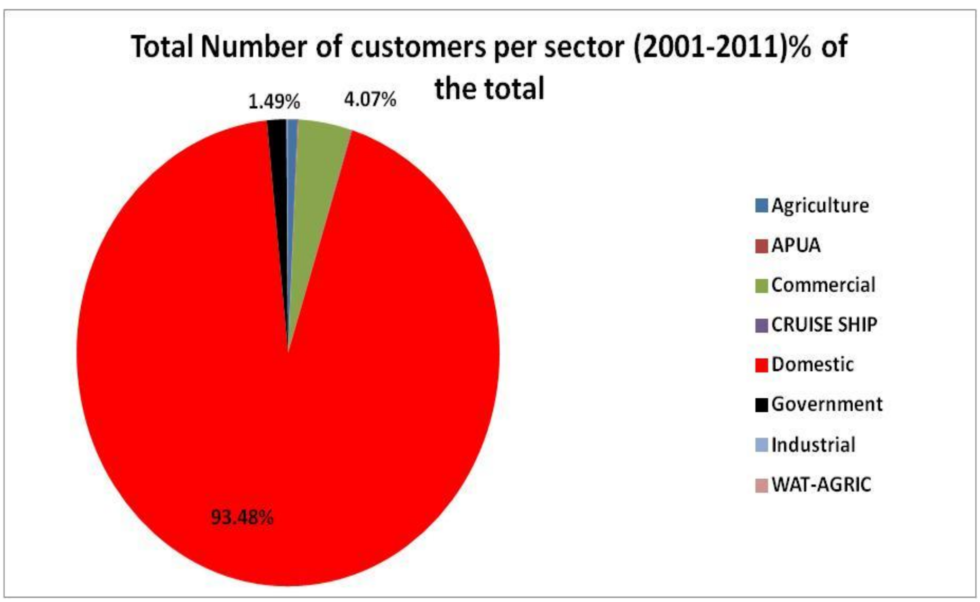


Figure 4-19: Total Number of Customers Expressed as a Percentage of the Total for Antigua (APUA database

The available data from APUA shows an increasing trend in the demand for water in the three main sectors of domestic, commercial and government post 2004 and, with a significant linear trend coinciding with the number of customers. There is no direct data available for the production of the water for each sector and hence, the sectoral production and demand analysis is limited.

4.1.3.1 Agriculture

Agriculture is not a widespread and intense activity within the Southwest Watershed Area as most (approximately 64%- Agricultural Census 2007) of the watershed remains under forest/woodlands, and fallow/resting lands. The dominant agriculture is in the form of rough and improved grazing occuring in the northeastern section of the SWWA within the Christian Valley Watershed area. However, interviews with farmers indicated that there are significant pineapple plantations in Claremont and Urlings, with one of the largest located in Claremont. Mangoes, citrus, coconut, cassava and potatoes are also grown. Associated with livestock rearing is use of lands for grazing.

Figure 4-20: Map of Agricultural Divisions, Antigua and Barbuda (*Source: Antigua and Barbuda Presentation to Workshop for Caribbean on FAO/UNFPA Guidelines, June 2013)*

The Antigua and Barbuda Agricultural Census Report 2007, identifies five (5) agricultural divisions, one of which is referred to as the Southwest District (Figure 4-20). This district extends beyond the SWW but includes all of it. However, for the purpose of presenting a general agricultural profile of the SWWA, some of the information generated for the Southwest Agricultural District is considered a reasonable reflection of the SWW area.

The Agricultural Census Report 2007, defines an agricultural holding (or farm) as an economic unit of agricultural production under single management comprising all livestock kept and land used wholly or partly for agricultural production purposes, without regard to title, legal form or size. In 2007, of all 1,226 agricultural holdings/farms throughout Antigua, 19% (234) were located within the southwest agricultural division (Figure 4-21). The acreage under agriculture decreased by approximately 60% between 1984 and 2007, from 1149.8 acres to 463.59 acres.

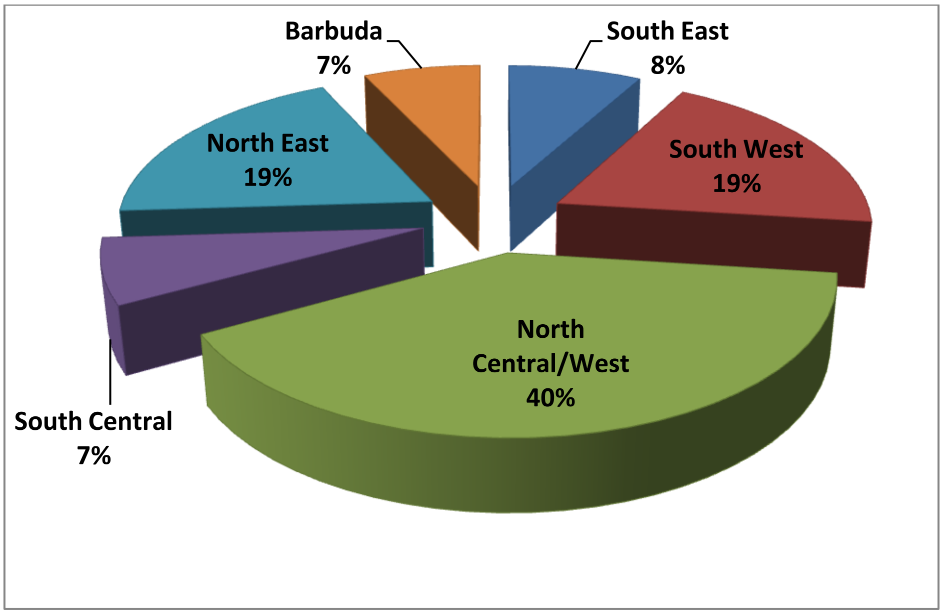


Figure 4-21: Percentage of Agricultural Holdings by Agricultural Division
Source: Agricultural Census Report, 2007

The Agricultural Census Report 2007, indicates that of the total land under agriculture, (which includes forests and woodlands and fallow land) permanent crops utilized 19% and pasture occupied 11% (Figure 4-22).

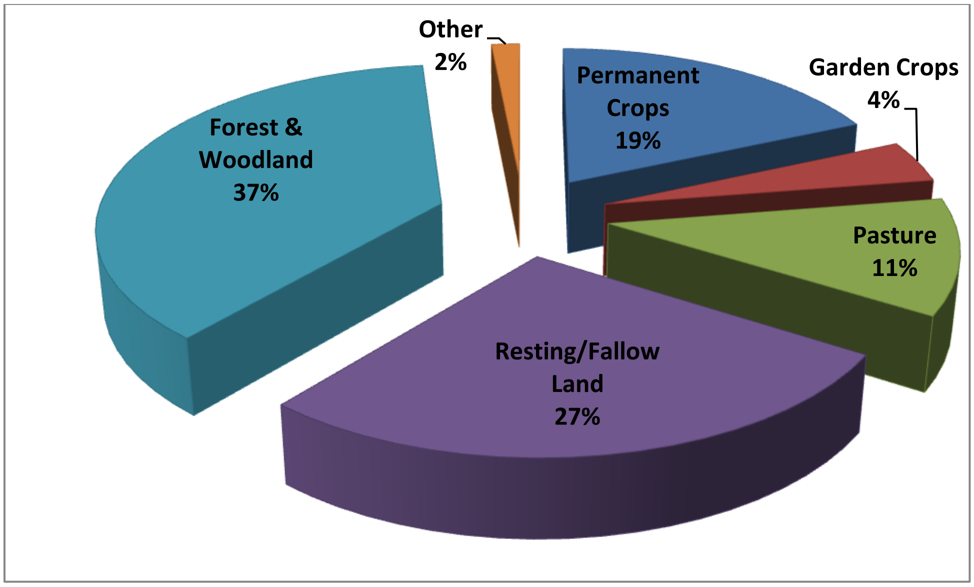


Figure 4-22: Acreage by Type of Land Agricultural Land Use within Southwest Agricultural District, 2007

In general, annual average evapotranspiration is significantly higher than the annual average rainfall, as such agricultural sector cannot rely on rainfall to sustain production yields at even moderate levels. Irrigation is therefore essential to the agricultural sector and many of these farmers rely on APUA for water, which is predominantly well water. Irrigation water is sold to farmers at $25EC per 1000 gallons which to many, is too expensive, others rely on rainfall. Few farmers practice dryland farming techniques such as mulching. The agricultural sector in general, represents less than 1% of the total water demand.

In recent years, there have been no major water supply developments for agriculture. The Ministry of Agriculture, through its Soil and Water Conservation Division has encouraged farmers to invest in irrigation, through provision of assistance with the construction of mini-dams and larger ponds in strategic areas. Drip irrigation as a water conservation technology is also promoted and some farmers have adopted these technologies to varying extents. Water conservation practices such as mulching and drip-irrigation is used at Claremont Farms to conserve moisture in the growing of pineapples. Most farmers are not inclined to adopt these conservation methods due to the cost associated with mulching and the water saving devices. With the climatic forecasts indicating less rainfall and increased droughts, irrigation is and will continue to be essential to the sector.

With added pressures on the agricultural sector of increasing competition in the world market, due to reduction and removal of protective tariffs, together with the national efforts by the Ministry of Agriculture to have local farmers meet local market demands of the tourist sector for vegetables and fruit, a reliable and affordable water supply to agriculture becomes even more critical.

The repeated occurrences of hurricanes accompanied by intense rainfall, presents a real threat to the investments in larger and more efficient irrigation systems, as the hydraulic structures such as dams, pipelines and pumps are damaged and destroyed. In the absence of a well-articulated policy for water allocation by sector, during periods of drought, water which would normally be supplied to farms is diverted to supplement domestic/municipal water supplies. This highlights the need for the agricultural sector to move toward greater water supply independence, thereby reducing the dependence on municipal sources of water for irrigation.

As a consequence of drought, widespread crop failure was reported. Even for farms with access to potable water, rationing of supplies meant that priority for scarce water was given to hotels and households.

Drought affects the health, weight (hence marketability) and productivity of livestock. Hot weather causes heat stress, which is said to reduce fertility through sperm damage. Hot weather also affects libido in male animals, decreases milk production in cows and kills chickens (Cadogan, 2000). In some cases, livestock farmers killed their animals to avoid death from the effects of the drought. In other cases, animals that died from drought effects were butchered and sold without the knowledge of consumers, causing great alarm when this was discovered (Jackson, 2001).

An assessment of the natural resources of Antigua and Barbuda identified reclamation and recycling of treated sewage water as a potential source of agricultural water supply. The report estimated that up to 4 550 m^3/day could be collected from some 600 ha of urban area if adequate sewage system existed. Villages, hotels and the airport were also identified as potential sources of reclaimable waste suitable for tree crops and pasture irrigation (FAO, 2000). This only becomes a feasible option when and if the more densely populated urban areas are sewered and sewage is treated centrally.

4.1.3.2 Tourism

Antigua's main foreign exchange earner is tourism. It is centered around hotels primarily in the coastal areas, as well as the cruise and yachting sub-sector, which contributes significantly to the overall tourism earnings and employment. The main tourism zones are Antigua's north coast, Five Islands' peninsula (including Deep Bay and Hawksbill Bay, Jolly Beach/Jolly Harbour), Long Bay Coastline and Falmouth Harbour/English Harbour. In the SWW area, the main tourist areas are along the coast of the Cades Bay Watershed. These include; Ffryes Point/ Bay, Darkwood Beach, Turners Beach, Curtain Bluff and Carlisle Bay (Figure 4-2).

Antigua's tourism is based mainly on the quality of its beaches, climate and sea. Both drought and hurricanes/storms affect the quality of beaches and the availability of water to the tourism sector. Although some of the larger hotels have invested in private water supplies in the form of desalination plants and private wells, not all hotels are able to. Several properties do not have reserve or alternative water stored, and often those that do, are still challenged during extended periods of drought. Others rely on the public supply (APUA, personal communication, 2014).

The hotels that do not have alternative sources of water, other than public supply, are affected negatively by water shortages during periods of drought. There is a low tolerance of tourists to inadequate water supply, therefore the economic implications of dissatisfied tourists are significant. Hoteliers have indicated in discussion that tourists often shorten their vacations, cancel the plans to visit and consider very carefully whether they will return for vacations.

On the other hand, excessive rainfall associated with hurricanes and storms, threatens some coastal hotels and vacation properties, as storm surge may remove or deposit beach sand and reduce the quality of bathing waters, eg. Beaches at Ffryes Point/Bay. Rivers also discharge high turbidity and otherwise contaminated water to the coastal environment, rendering the beaches unsuitable for recreation after the storm event. Storms also result in damage to hotel infrastructure and landscapes, which often results in temporary closure, reduced operation and loss of revenue. Often, staff is temporarily or permanently laid off during this period.

4.1.3.3 Health

The link between water and health is understood when conditions associated with inadequate potable water and excess water/flooding, are examined. Inadequate potable water creates hygiene challenges at several levels; the household level, institutions such as schools and workplaces and commercial establishments including those responsible for food handling and preparation e.g. restaurants, hotels and supermarkets. At all these levels the challenge is similar, that of maintaining the basic health support requirements such as routine and thorough hand-washing, the maintenance of clean surfaces and spaces, as well as the management of sewage associated with flush toilets. If this challenge is either not met or not met consistently, the likelihood of bacteriological contamination and the spread of disease increases. Both water borne and food borne illnesses associated with poor hygiene can create significant negative impacts on a society's health and productivity. In an attempt to cope with the condition of inadequate potable water, decisions are made to close schools for certain periods, government offices and other businesses shorten work hours and as a result the general productivity of the society is significantly reduced.

Excess water in the form of flooding incidents, on the other hand, presents unhygienic conditions where sewage may be washed out from pits and septic tanks and these contaminated flood waters that do not run off quickly, are left as standing water bodies around homes, communities and areas where the public must traverse. Not only are standing bodies of contaminated water a breeding site for pathogens (disease causing organisms), but these water bodies become breeding grounds for a range of mosquitoes which are vectors of other diseases, such as malaria, chikungunya, dengue fever and others.

4.1.3.4 Municipal Water

Calculations based on certain assumptions made by the consultants (See Section 5.5), indicate the following for the SWWA (Figure 4-23):-

- Total Domestic Water Demand is 66.6MG/Yr
- Groundwater to Domestic Supply – 30.1MG/Yr (45%)
- Surfacewater to Domestic Supply – 10MG/Yr (15%)
- Desalination /Other Transfer to Domestic Supply – 26.5MG/Yr (40%)

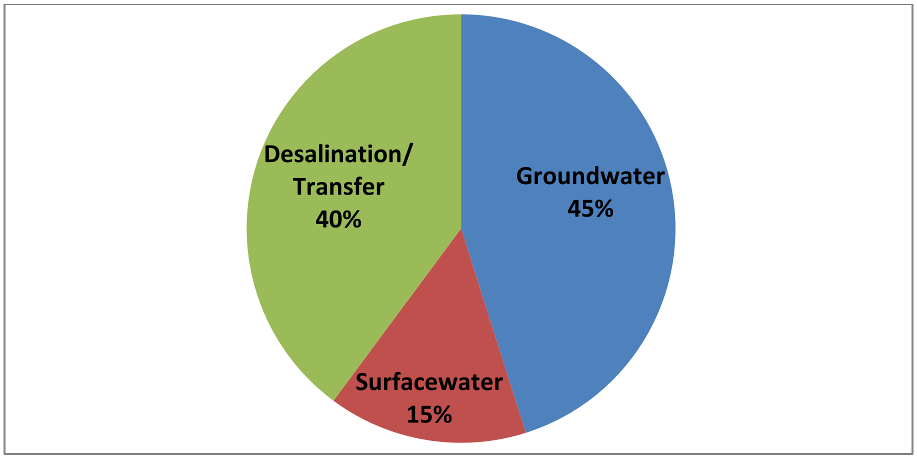


Figure 4-23: Source of Domestic Water in SWWA

The population growth rate of Antigua and Barbuda has been relatively stable over the last fifty three (53) years (1960-2013), ranging between -1.75% to 2.79% and over the last ten years (2003-2013), the growth rate has been remained between 1% and 1.12% (Figure 4-24). In 2013 the annual growth rate was 2013.

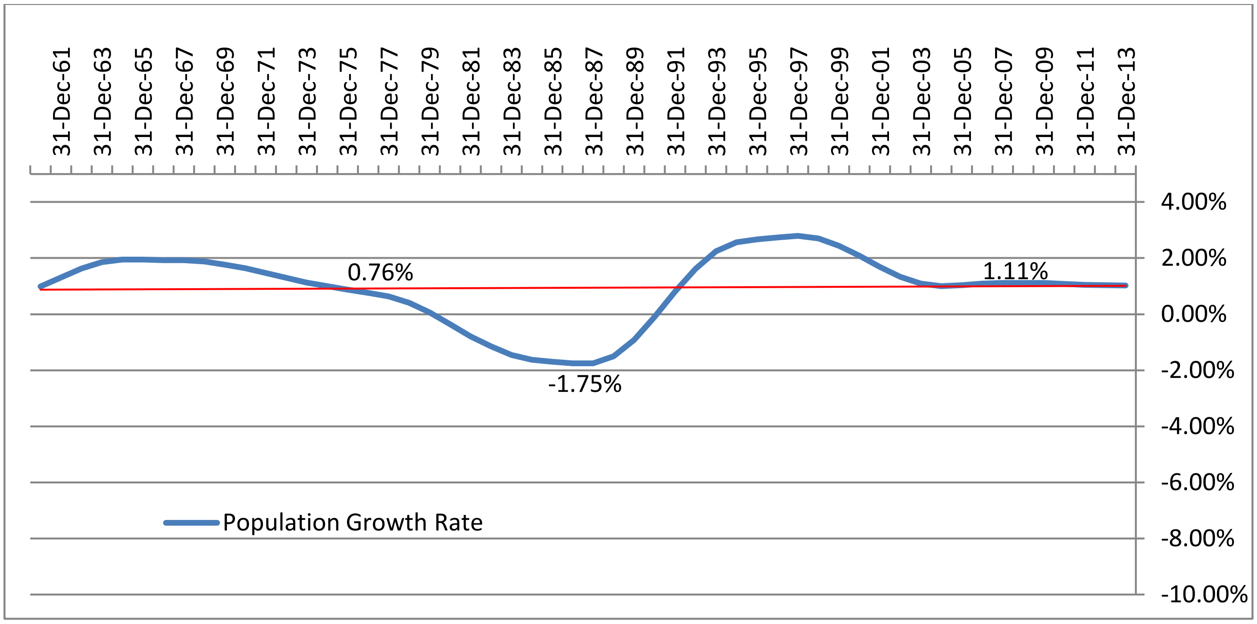


Figure 4-24: Antigua & Barbuda's Population Growth Rate 1960-2013

In an attempt to estimate future domestic water demand for the SWW area, we assumed that population growth rates in SWW area are similar to the national growth rates, which may be a slight over estimation of growth rates for the SWW area since, as a predominantly rural and mountainous area, the population density is relatively low. In the absence of growth rates specific to the SWW area we have made this assumption and presented two scenarios based on 1) a population growth rate based on the ten (10) year average annual growth rate and 2) a population growth rate based on the minimum annual growth rate over the last ten (10) years. The projections are twenty (20) and fifty (50) years into the future ie. the years 2034 and 2064 (Figure 4-25).

Scenario A:
Future Water Demand using **Average** annual population growth rate for years 2004-2013 - (Growth Rate 1.06%)

Scenario B:
Future Water Demand using **Lowest** annual population growth rate for years 2004-2013- (Growth Rate 1.0%)

Applying the 10 year minimum annual population growth rate of 1%, it is estimated that by the year 2034 (20 years into the future) the population of the SWW area would increase from 5,828 to 7,182 and the domestic water demand would increase by 22%. Fifty years into the future (ie. by 2064), the population would be 9,680 and the domestic water demand would increase by 64.4% (Table 4-7).

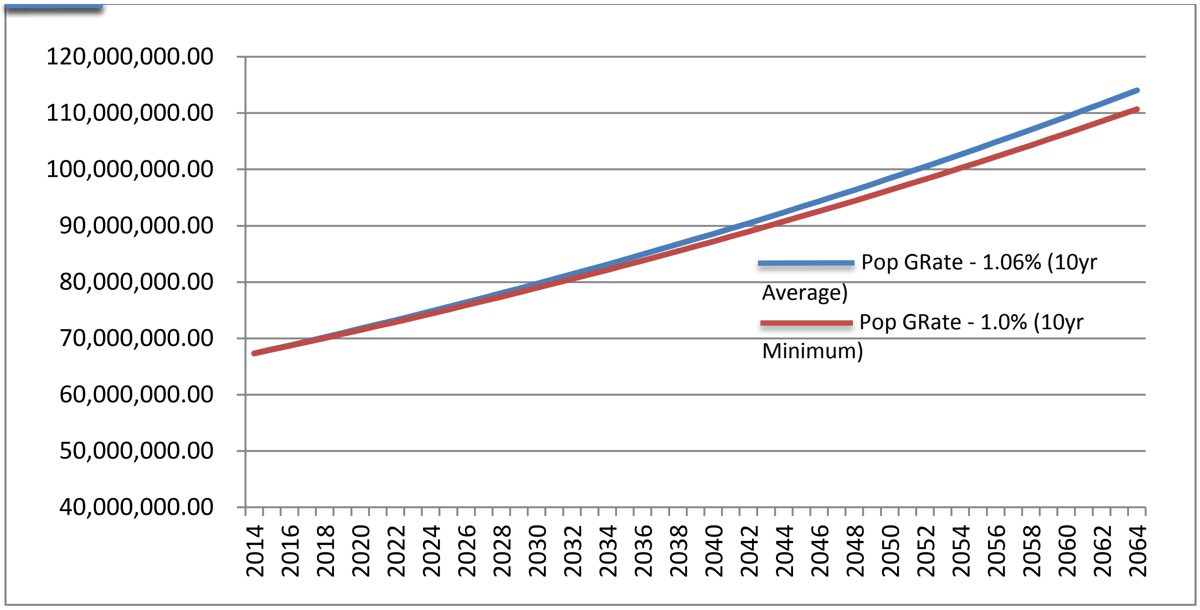


Figure 4-25: Estimated Future Domestic Water Demand in the SWW area (MG/Yr)

Table 4-7: Estimated Future Domestic Water Demand for the SWW area

Future Year	DOMESTIC WATER DEMAND SCENARIOS	
	Scenario A: AVERAGE	**Scenario B: LOW**
2034 **(Next 20 yrs)**	23 % Increase Water Demand - 83.13MG	22% Increase Water Demand - 82.15MG
2064 **(Next 50yrs)**	69.4 % Increase Water Demand 114.1MG	64.4% Increase Water Demand -110.7MG

4.1.4 Climatic Threats

This section discusses the exposure of the SWW and the impacts of past climate related events drought, hurricanes, flooding and sea level rise on the area.

4.1.4.1 Hurricanes

Some of the major hurricanes which have affected the island and caused major damage from flooding are: Hurricane Lenny (November, 1999), Hurricane Omar (October, 2008) and Hurricane Earl (August, 2010).

Based on the historical and current experience of predominantly dry climatic conditions, the response of communities in the Southwest Watershed Area, to extreme rainfall events including hurricanes, is not one of fear or apprehension. Communities generally, accept hurricanes as an act of God and welcome the rains as they anticipate having their cisterns, tanks, aquifers/wells and reservoirs/ponds filled, as well as the quenching of normally parched farm lands and livestock. Communities consider the threat of hurricanes as secondary when compared to the more real and present dangers associated with drought.

However, those communities within the SWW area, such as Bendals, Bolans, Crabb Hill and Jennings, which have suffered periodically from flooding and storm surge, associated with hurricanes and other instances of intense and or prolonged rainfall events, are more sensitive to and aware of the negative impacts (Figure 4-26). These communities in collaboration with the National Office of Disaster Services have established and implemented evacuation plans, which involve timely warnings and movement to designated shelters.

Ffryes Beach has experienced storm surge associated with a hurricane, which led to significant quantities of sand being washed ashore and onto the roadways. Interviews with hotel workers in the Ffryes Beach area did not reveal any targeted or strategic efforts or mitigation strategies to alleviate future incidents of storm surge.

Flooding conditions often have an impact on the quality of surface sources of water including ponds and reservoirs. Water quality is negatively impacted by elevated turbidity levels, due to increase soil erosion from slopes which drain to the ponds/reservoirs. Depending on the levels of contamination (i.e. high turbidity) the public water supply agency, APUA, has established as system of mixing different sources of water to reduce contaminants to acceptable levels before distribution to the public.

4.1.4.2 Flooding

The agency with responsibility for providing assistance to communities affected by flood disasters is the National Office of Disaster Services (NODS). The main cause of flooding in Antigua and Barbuda is short duration, high intensity rainfall associated primarily tropical depressions and storms. According to U.S. Army Corps of Engineers (2004) and stakeholders, the main causes of flooding are as a result of:

- Soils that have generally low permeability or/and shallow depths
- Dense drainage networks (mainly Antigua) that permit rapid flow within the channel banks and rapid concentration of runoff onto the floodplains.
- Expanding urbanization, which replaces pervious areas with impervious surfaces such as roofs and roadways
- Widespread grazing by goats and cattle (mainly on Antigua) that compacts soils and removes vegetative cover, leaving the soil surface exposed to the full impact of the rainfall and vulnerable to soil erosion.

- Poor/ lack of maintenance of dry river systems
- Poor maintenance of drainage systems

Figure 4-26 shows the areas in Antigua which have experienced flooding/inundation and the areas deemed to be subject to low to very high risk of flooding. The SWWA is generally not prone to flooding. However, three (3) areas are indicated as flood prone areas; Bendals, Jennings and Bolans. Bolans is also classified as a high flood risk area.

In August 2010, rainfall associated with Hurricane Earl led to flooding in several areas across Antigua including the West Palm Beach area of Bolans. It was reported that eight (8) persons had to be rescued in West Palm Beach, Bolans after being trapped by flooding (Antigua Observer Newspaper, Aug 30, 2010).

In 1999 Hurricane Lenny produced severe flooding. As much as 635 millimeters (mm) (25 inches) of rain fell on Antigua and Barbuda during this hurricane. In the southern part of Antigua, wells and critical components of water treatment plants were submerged during flooding. Flooding of wells result in the loss of power and contamination of the well water (U.S. Army Corps of Engineers, 2004).

Interviews with representatives of communities within the Southwest Watershed Area indicate that the population has over the years developed a certain capacity, within limits, to adapt or adjust to the impacts of these climatic conditions. The adaptation strategies alleviate the stresses and impact to varying degrees.

It is generally accepted that reduced vegetative cover, particularly within important watersheds, exacerbates flooding associated with average as well as extreme rainfall events. Landcover change analysis, involves the overlay of satellite images which reflect the status of vegetative cover at different points in time. These images highlight the change in vegetative cover within the SWW area. Between the years 1990 and 2000, these satellite images indicate that vegetative cover decreased in some areas and decreased in others, while between 2000 and 2010, these images indicate no significant areas of decrease in vegetation (Figure 4-27).

Some new areas of increased vegetation are evident in 2010 which were not evident prior to 2000 and areas which were previously indicating decreased vegetation show a reversed situation of increasing vegetation. This could be interpreted as a positive development since the SWWA is considered an important catchment area and extensive vegetative cover is important to supporting the recharge of major ground and surface water resources.

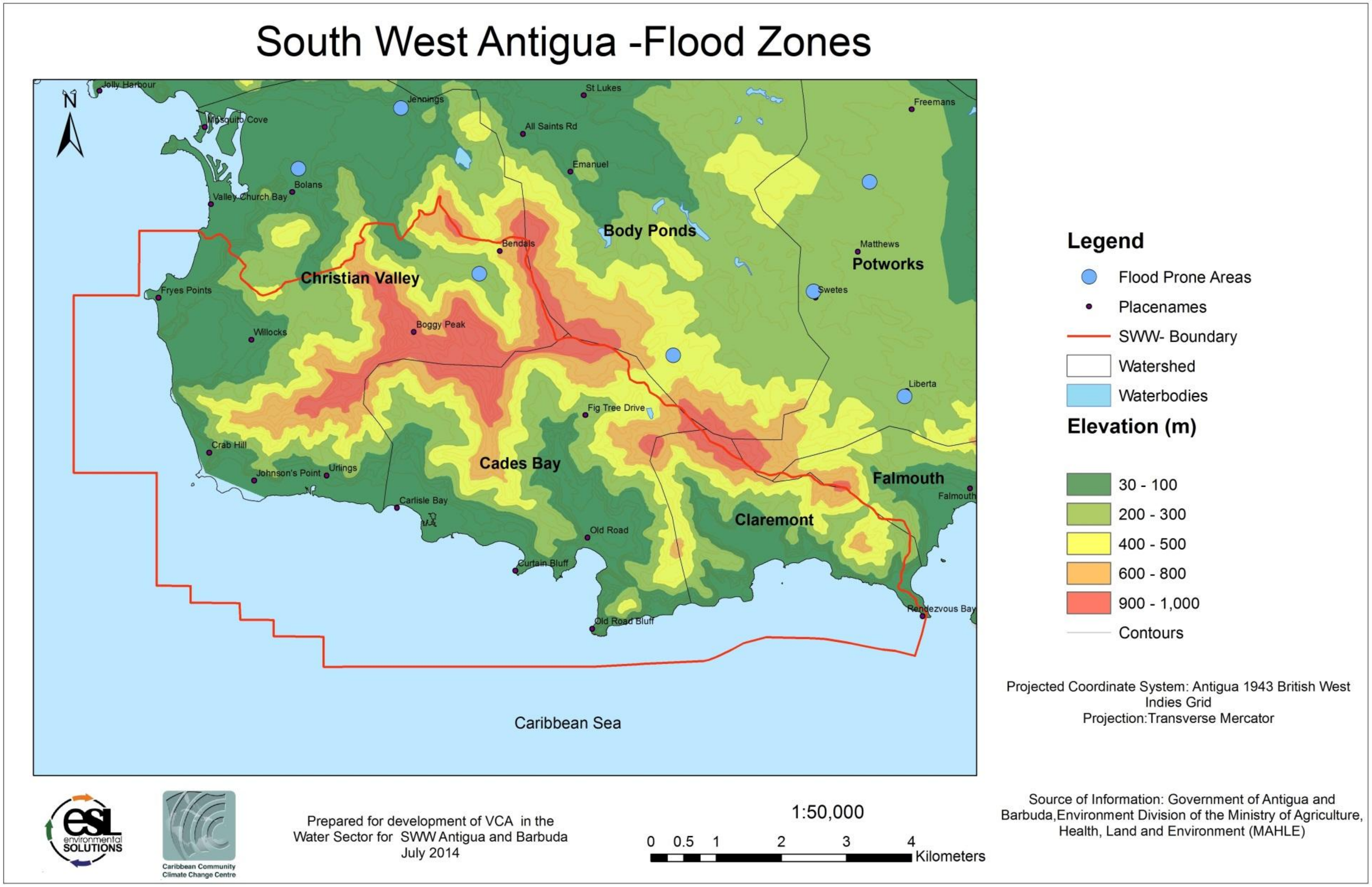


Figure 4-26: Flood Zones within the SWW

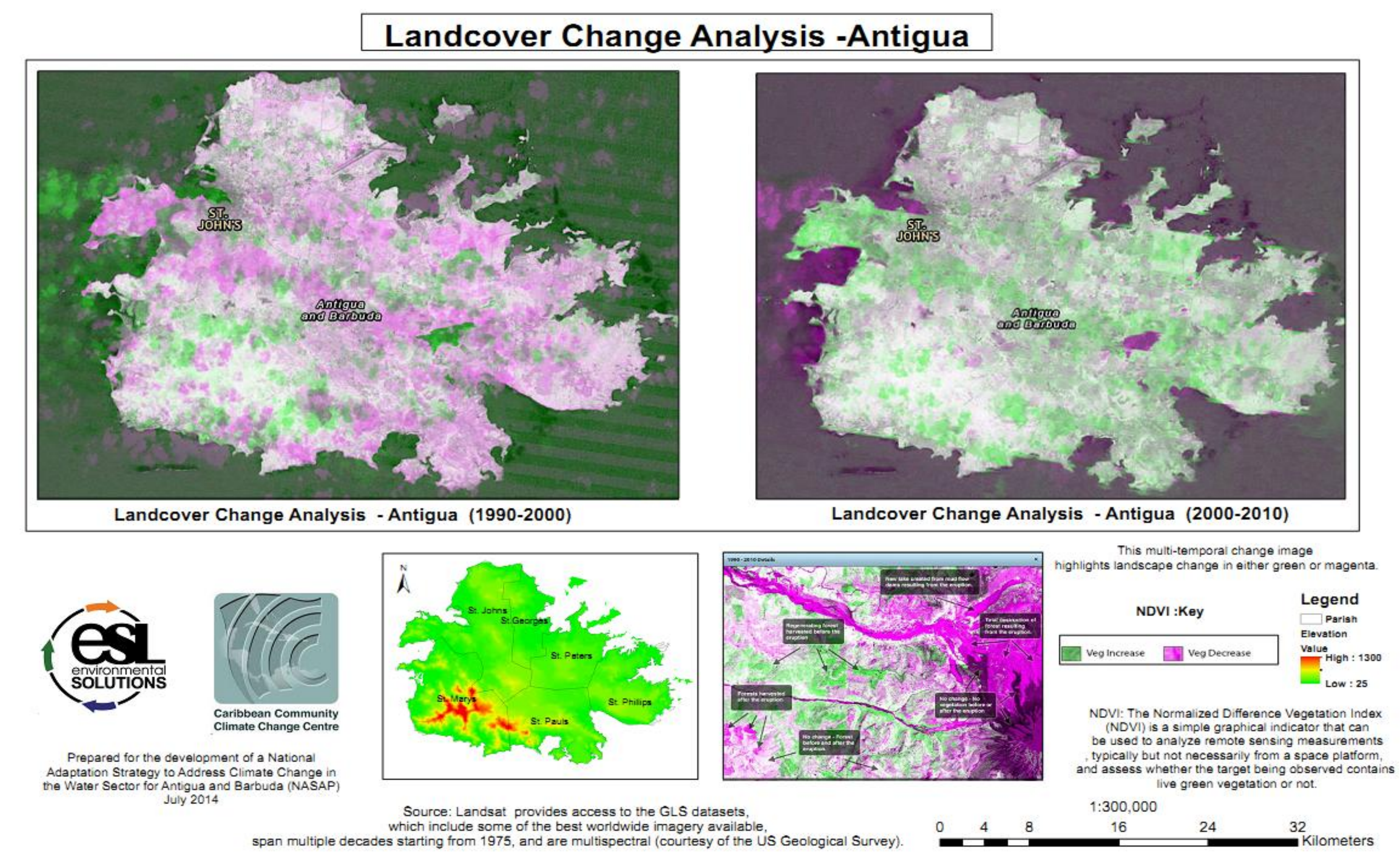


Figure 4-27: Landcover Change in Antigua

4.1.4.3 Hydrologic Analysis and Flooding

Hydrologic Analysis is intended to estimate the runoff associated with rainfall events within watersheds. The purpose of this hydrologic analysis is:

a) to estimate peak discharges which are expected based on current climatic/rainfall conditions
b) to estimate the peak discharges within the same watersheds, associated with projected rainfall, based on climate change modeling projections and
c) to compare the estimated peak discharges generated in a) and b) as an indication of the potential impact of climate change on flooding.

The Soil Conservation Service (SCS) now Natural Resource Conservation Service (NRCS) TR-55 runoff curve number (CN) methodology was used in the estimation of the runoffs. The CN is dependent on the type of soil and land cover within the watershed.

For southwestern Antigua, land cover consisted mainly of high density urban areas and wetland along the coast, with the forested and farming areas inland. The soil map of the same area showed the soil type to be predominantly clay loam. This classified as soil type ‘D’ in the hydrologic soils groups (HSG) classification. This classification when applied with the land cover and assuming a wet or saturated soils conditions, which is typical during storm events, a CN of 85 was applied to hydrologic calculations for southwestern Antigua.

Rainfall data was very limited. The only available daily rainfall data was obtained from the V.C. Bird International Airport in northern Antigua. The rainfall analysis included an analysis of the 24-hour rainfall depths for the 5, 10, 25, 50 and 100 year return period storms. These rainfall depths were used to calculate the peak discharges for the watersheds within southwestern Antigua. Runoff from the watersheds were also analysed for climate change impact using the worst case scenario from climate change analyses that were conducted for Antigua and Barbuda. The worst case scenario indicated that rainfall could increase by up to 9%. Five (5) major watersheds were identified. The peak runoffs from the hydrologic calculations are presented in Table 4-8 with ‘PC’ = Present Conditions and ‘CC’ = Climate Change.

The hydraulic analysis which would assess the risk of flooding for communities within the low-lying areas and floodplains based on the calculated peak flows from the hydrologic analysis was not possible due to lack of data. Data required included channel cross-sections along the streams and general description of the stream channels, floodplain elevation (centimeter accuracy), the types of hydraulic structures along the rivers including their hydraulic openings, elevation etc. and historic flood data (if available). It is recommended that this analysis be carried out when these data are obtained.

Table 4-8: Peak Discharges for Major Watersheds under Present Rainfall Conditions (PC) and Projected/Future Rainfall (CC).

MAJOR WATERSHEDS	AREA	PEAK DISCHARGES FOR MAJOR WATERSHEDS (M^3/S)									
		5yr		10yr		25yr		50yr		100yr	
	(ha)	PC	CC	PC	CC	PC	CC	PC	CC	PC	CC
A	1578.4	477.1	529.5	642.1	717.6	855.1	943.2	1025.2	1136.4	1184.8	1308.0
D	783.9	270.5	300.1	363.5	406.1	483.6	533.2	579.4	642.2	669.4	738.8
B	373.5	138.0	153.3	185.4	207.2	246.8	272.4	295.4	327.6	341.3	376.8
C	336.7	141.2	156.6	189.3	211.5	251.4	277.4	301.0	333.7	347.6	383.6
E	321.2	131.1	145.6	176.0	196.7	233.7	257.8	279.8	310.4	323.2	357.0

The results indicate that peak discharges for the major watersheds will increase by between 10% to 12%. Those areas within the southwest watershed area which currently experience flooding associated with rainfall, are likely to experience greater flooding impacts with the projected 9% increase in rainfall. Greater flooding impacts could involve larger areas of inundated land, as wells as greater depths of flood waters, both of which could represent exponential increases in damage to land, property and infrastructure as well as negative impacts on public health and safety.

It is therefore recommended that hydraulic analyses be conducted particularly of the areas which historically experience flooding. This would allow for an assessment of the extent and nature of this likely greater impact and inform the types of interventions, such as flood control structures and building restrictions, needed to mitigate the negative impacts.

4.1.4.4 Drought

Drought generally implies less than 826 mm (32.5 inches) of precipitation annually (U.S. Army Corps of Engineers*,* 2004*).* Antigua is prone to droughts and has an average annual rainfall ranging from 890 to 1,400 mm (35 to 55 inches). The average annual rainfall for Antigua is about 1,040 mm (41 inches).

Antigua has had three recent droughts (1983/84, 1993 to 1994, and 2001 to 2002). Annual rainfall for VC Bird indicates that the years 1997, 2000, 2001, 2003 and 2009 experienced rainfall below the drought limit of 826mm (Figure 4-36), while for the two rainfall stations within the SWW, though they showed a corresponding pattern of declining rainfall during these years, the extent of decline was less and there was no instance between 1997 and 2010 where annual rainfall at the SWW stations fell to or below the drought limit of 826mm. The lowest annual rainfall was 833.3mm at the Cades Bay station in 2000 (Figure 4-28).

In 1983, annual rainfall was 566 mm (22 inches). This was the lowest rainfall since 1874. The 1983 drought left all the ponds and most reservoirs empty. Also, a large number of livestock, including cattle and pigs, died or were stressed due to water shortage. Water rationing was introduced, and the neighboring islands barged potable water to the island.

During the 1993 to 1994 drought, the V.C. Bird International Airport recorded an average rainfall of 1,016 mm (40 inches) for 1993. This was a problem because approximately 33 percent of the rainfall for the year fell in May, so much of the precipitation was lost as runoff. This was followed in 1994 by an average precipitation of 775 mm (32 inches). The availability of desalinated water as a potable water source made up for the lack of recharge to surface and ground water supplies from precipitation for the islands' residents and tourists (U.S. Army Corps of Engineers, 2004).

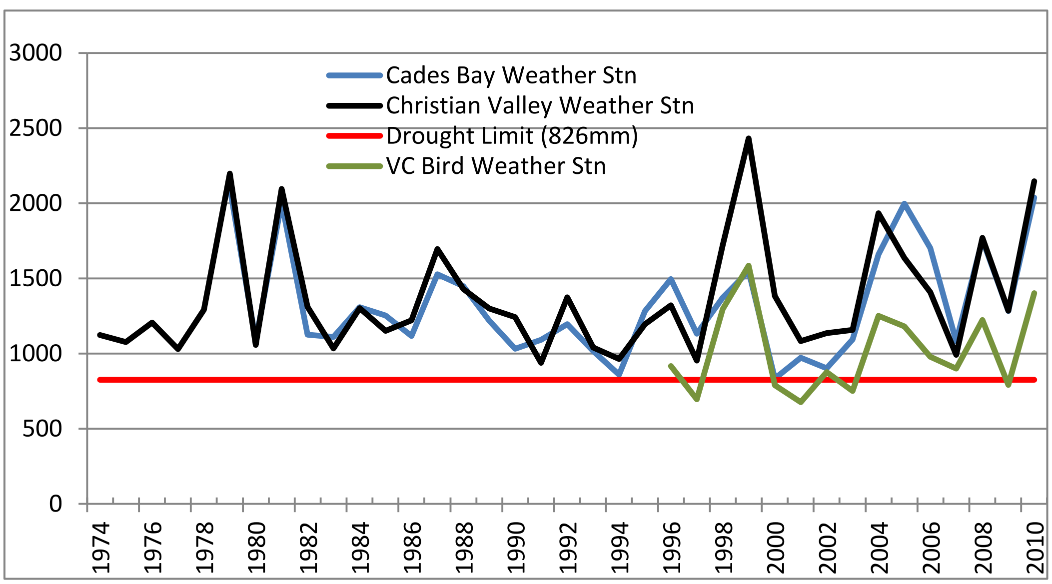


Figure 4-28: Annual Rainfall at SWW Weather Stations and VC Bird Station (mm)

The very high risk areas for drought are the northern and southern regions of Antigua. The southwestern and eastern areas are assessed as having moderate risk of drought (Figure 4-29).

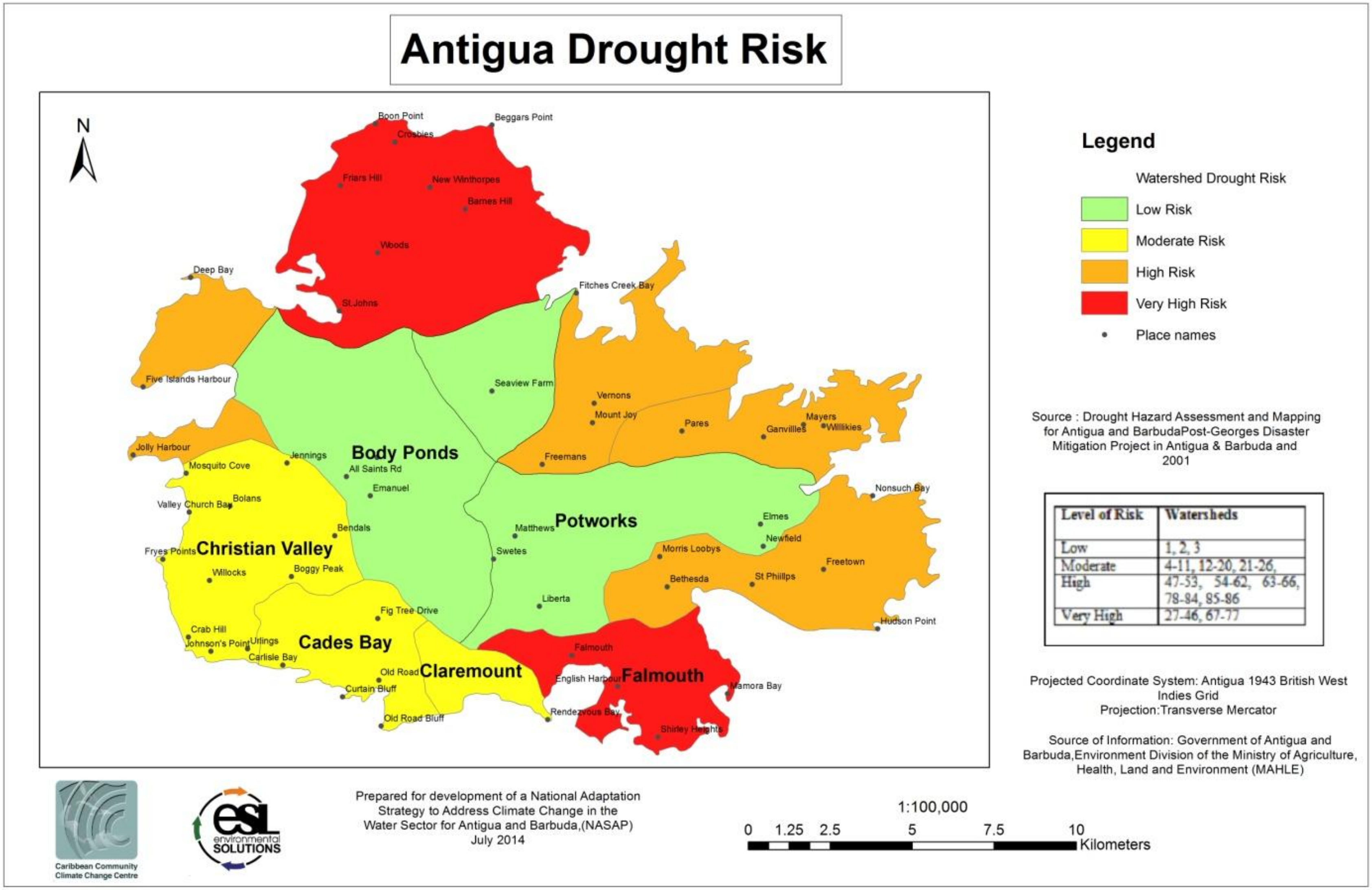


Figure 4-29: Drought Risk of Antigua

4.1.4.1 Sea level Rise

Several wells within the Claremont/Pineapple wellfield, one of the major well fields in the SWWA, have been and are currently producing brackish water, indicating that there is already some influence of seawater on groundwater quality. In the SWW area there are well fields less than 1 km inland from the coastline and therefore very likely to be influenced by changes in sea level.

A rise in sea level is likely to exacerbate salinity problems in those wells now pumping brackish water and create salinity problems in other well fields. In an effort to reduce the risk of saline intrusion into wells, operators will eventually be forced to reduce pumping rates, i.e. pump less groundwater, resulting in a net reduction in the total available groundwater from these wells: a situation where deteriorating water quality translates directly to reduced quantity available.

It is expected that water demand will increase in the future, and therefore the SWW area, which now relies on groundwater to supply 45% of the demand, will be forced to reduce its dependence on groundwater. The area will have to fill the gap with alternate sources, either desalination, which is more costly and or surface sources of water, which are outside the SWW area, also presenting additional costs associated with water transfer over longer distances.

4.1.5 Anthropogenic Issues

As used in this report, the term anthropogenic is defined to mean those actions of, relating to, or resulting from the influence of human beings on climate change. Nothing in the definition of anthropogenic actions limits them to being direct actions or negative ones. In this section several examples of human centered actions or conditions having an indirect impact on climate change are included. For example, in considering the resilience of a community to climate change, low levels of education, or no understanding of climate change, will create and perpetuate the very anthropogenic actions that require mitigation or adaptation strategies to counter. Conversely, a funded program of climate change awareness at the community level, also has a causative indirect impact on climate change, for the positive.

An assessment of the strengths and weaknesses of communities to the impact of climate change (or their resilience) should not overlook these interplays once they are the causes of human impacts on climate change. They are part of the overall balance sheet. As a general proposition, it would be useful if anthropogenic issues came to be analyzed for their cumulative and non-cumulative anthropogenic impacts on climate change.

The following sections describe the impacts arising from the main economic and social activities of human beings in the project area. In Sections 5 and 6 which follow, the adaptive capacity of both the natural environment, and the human environment, along with the current sensitivity analysis, will inform the vulnerability of the SWW.

4.1.5.1 Catchment maintenance

As previously mentioned, there are no major surface water storage systems in the SWW area. The communities of the SWW are dependent well water from within the area, and also catchments that are mainly outside of the area.

Water storage systems are essential infrastructure in the water sources chain. A major challenge for APUA, mainly for financial reasons, has been their basic functional maintenance. These works have been performing well below their potential holding capacity for long periods, and infrequently cleaning for sedimentation and vegetation simply keeps poorly functioning systems in operation.

Low and zero water supply are characteristics of some of the water storage systems during drought periods. This defeats their design function and as happened earlier in 2014, rationing had to be resorted to. In addition sourcing more water from the SembCorp desalination plant was necessary to meet the estimated 5 to 6 million gallons daily requirement.

During that period renewed efforts were made to seek emergency assistance to clean dams and ponds across the island. It was estimated by APUA that US$500,000 would cover the reconstruction and cleaning of Body Pond, Hamilton and Fisher dams.

There is an effort by APUA to rotate the cleaning of ponds and dams annually, as had been done for 2012 and 2013, but funding has for some while been the determining factor.

4.1.5.2 Economic development patterns

The SWW area is predominantly forested with rural settlement and tourism taking place mainly within the coastal zone. Relatively little agricultural activity takes place although the selling of fresh produce and other retailing are important occupations in the coastal zone.

4.1.5.3 Economic Enterprises in the SWW

The anthropogenic issues derive in important measure from features of economic development that reflect the issues of unplanned development and the absence of a resource management zoning plan. With no proper zoning, land utilization is ad hoc and may eventually prove inimical to the interests of the environment and economic growth. As one example, the more fertile flat agricultural lands have steadily retreated in the face of advancing settlement and tourism expansion. There is a cost in terms of food security and the relatively quicker degradation of the coastal ecology by the built environment. Marine ecosystems are under threat but also the watershed forest lands by housing and other developments. These developments are not only expanding along the coastline but also inland. The absence of rational planning has created an imbalance between the populating of the SW coastal areas and civic amenities, supporting infrastructure, green space and parks, and diverse employment opportunities. Other than tourism, commerce, and agriculture (mainly fisheries) there are no significant sources of employment. This requires some residents to travel outside of the watershed for employment and livelihoods. These issues also exacerbate the challenges of water management particularly the provision of adequate supply and the attendant requirements of distribution.

Since tourism, commerce, agriculture and construction are likely to continue as the future drivers of the SWW economy, a comment follows on their relationship with the water sector and its interface with climate change.

Tourism

The tourism economy of the SWW area is represented mainly by international properties such as Carlisle Bay Beach. There are a number of other hospitality properties and tourist targeted attractions. Table 4-9 indicates the main ones. Nelson's Dockyard which is not officially within the project area also brings visitor traffic along the SW Coastline.

Table 4-9: Economic Enterprises in the SWW

HOTELS & TOURISM	OTHERS & ATTRACTIONS
Antigua Rainforest Canopy Tour – Wallings	Claremont Farms at Claremont – Claremont
Blue Heron Hotel – Johnsons Point	Orange Valley Agricultural Station – Orange Valley
Carlisle Bay Hotel – Old Road	Cades Bay Pineapple Station – Cades Bay
Curtain Bluff Hotel – Old Road	South Coast Horizons – Old Road/Cades Bay
Jolly Beach Resort – Jolly Beach	Christian Valley Agricultural Station – Christian Valley
Coco Beach Hotel – Valley Church	Urlings Fisheries Complex - Urlings
Jolly Harbour Marina – Jolly Hill	
South Coast Horizons – Old Road/Cades Bay	
UNDERWAY OR PENDING	
	Development and enhancement of Ffryes Bay/ Beach
	Development of Rendezvous Bay
	Orange Valley
	Development of Valley Church
	Development of Darkwood Area

Tourism presents interesting contrary tensions in relation to the water sector. The sector is not water efficient in terms of its per capita consumption relative to domestic consumption. Using indicative figures derived for Antigua and Barbuda, overnight visitors account for 5 times the volume of water demanded as do local residents (Campbell, 2006). This is partly because the service industry hotels must do extensive landscape watering, daily cleaning of rooms, filling of swimming pools, and kitchen and laundry services. On the other hand, tourism foreign exchange earnings pay for the energy costs of local water production, and desalinated water is a significant source of potable water supply.

Where tourism is year round, it can concentrate visitor flows in relatively small and distinct geographical areas, creating the supply and distribution challenges of catering to select enclaves of development. This is only partly true for the SWW coast as most large/ upscale hotels have their own desalination systems.

For the future, tourism's contribution to water use is likely to increase as a function of numbers and quality of the tourism product. A comparison with other economic sectors, for example agriculture, is instructive. The national consumption of agricultural water is less than 1% of total water consumption, whereas the consumption of the commercial sector (significantly tourism driven) is 28%. A concern, in the literature, is whether tourism-related water abstractions are sustainable, and whether these interfere with other users, for example of domestic water. The tourist industry in the SWW can place considerable pressure on available fresh water resources.

4.1.5.4 Agriculture

The agriculture economy of the SWW comprises mainly small farming plots some with livestock. Pineapple plantations and mangoes also come mainly from this area (Figure 4-30). The largest pineapple farm is Claremont, but there is also one in Urlings. Mango is a popular tree crop because it requires relatively little water. Farmers complain that Government is pulling more water from the SW Coast of the island and so the supply is not enough for further expansion of crops such as pineapples.

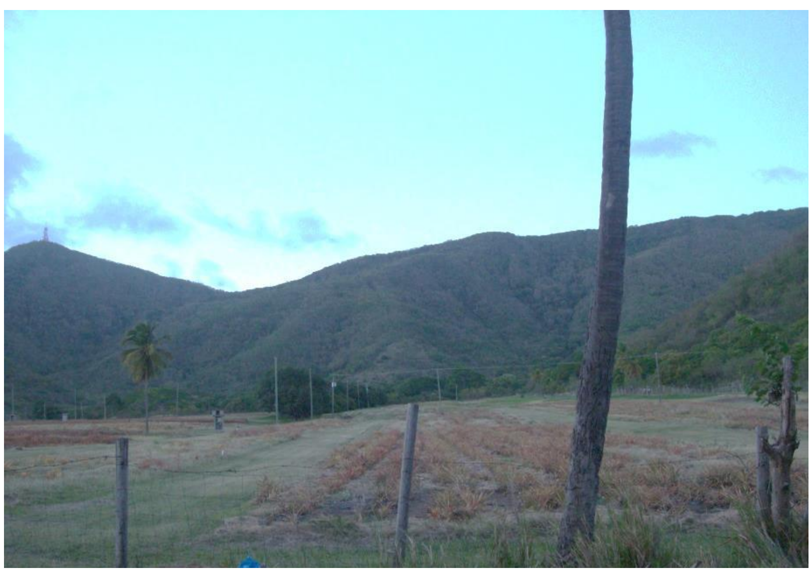


Figure 4-30: Pineapple cultivation in the SWW

The challenges presented for the water sector by farming communities relate to the following:

- Potential eutrophication of the aquifer and damage to the coastal waters, by the use of fertilizers;
- Land clearing in the watershed;
- Poor farming practices both with crop cultivation and animal husbandry. Traditional cultivation practices can waste water resources and efficient drip irrigation is not practiced by many farmers. Poor husbandry practices result in overgrazing as animals are often left to forage.

According to Antigua and Barbuda's Second National Report to the UNCCD, the results of land degradation have left marks and barriers to the development of the island which include;

- The degradation of vegetation into scrub caused by large scale monoculture;
- The immense damage to the flora caused by free roaming and unmanaged livestock;
- Poorly managed agricultural plots which have increased the land's susceptibility to erosion.

It is interesting to note that one group of farmers indicated challenges to their supply of water from saline intrusion as the shoreline recedes. However they were careful to indicate that their production was influenced more by market demand/preference than by water.

4.1.5.5 Fisheries Sub-Sector

The Fisheries sub-sector accounts for the greatest contribution by the agricultural natural resource sector to GDP. In 2011 it accounted for 51.5% or EC$26.3 million dollars. One of the largest and best equipped fishing beaches in Antigua is the beach at Urlings in the SWW area operated by the St. John's Fisherman's Cooperative (Figure 4-31).

Figure 4-31: Urlings Fishing Complex

According to the members, climate change has already impacted them. They cite the following in support of this claim:

- Lionfish is prevalent but it is not a desired fish.
- Whereas, 50 years ago they were diving 85- 90 ft. to sparefish, recently they have to be diving to 100ft to get the same fish.
- The better quality fish are being found further out to sea.
- They have noticed sea level rise, beaches are being eroded and the sea is coming further inland.

4.1.5.6 Construction

Construction as represented by low investment home improvements and home construction as well as hotel property expansion has played some role in the post 2008 economic recovery in the SWW. However, very few larger construction projects have taken place in the past 2 years. One exception being on the SWW's western border with the building of a high end apartment complex near Darkwood Beach. Limited public sector construction has taken place.

It is difficult to predict the impact that the short to medium term construction developments will have on the water sector of the SWW. However the absence of a spatial plan, or the coming into being of the planned Sustainable Island Resource Management Zoning Plan, has led over the years to an important challenge for the water sector. Low density developments have been taking place in an unplanned way and essentially at the developers' discretion re siting. This creates major challenges for efficient and lower cost infrastructure planning since there are inefficiencies associated with low density developments. This holds true for roads, power, drainage works and water distribution. It also makes social amenities planning more difficult and less efficient. Also, in the absence of more effective monitoring and the imposition of deterrents, the problem of squatting accompanies some developments. This is the practice of simply extending the boundaries of the development by backfilling, a practice usually involving government land. Its implications are felt when open green space is infringed or natural water ways are blocked and flooding results. A focus group at Pares cited examples of this type of occurrence the in the Bendals area.

4.1.6 Socioeconomic Issues

4.1.6.1 Employment and Livelihoods

Employment and livelihoods in the SWW are tied to tourism occupations, retailing, fishing and some agriculture. Construction has also been an important activity. These sectors have been recovering from a protracted period of economic downturn and recovery since 2008. This depression was mainly tied to the world economy although local climatic events were also important. The contribution to employment of the various economic sectors is not known.

At the national level in 2012, the total contribution of travel and tourism to direct and indirect employment was 19,000 jobs or 69% of total employment (Travel & Tourism's Economic Impact 2011, World Travel and Tourism Council and The Caribbean Hotel & Tourism Association).

It is likely that the tourism employment contribution to the SWW economy is significant. The national employment contribution of agriculture including fisheries is approximately 8%. These two subsectors may therefore contribute in the order of 77% to total direct and indirect employment of the SWW. The anthropogenic impact of these sectors on climate change will greatly depend on the education and participation of those employed in them.

4.1.6.2 Poverty

Poverty at the national level, as measured by an indigence index was estimated to include 3.7% of the population for 2005/2006 (Kairi Consultants Ltd, 2007). No update of this baseline index was available. Prorating for the 5,828 population of the SWW gives an estimate of 216 persons or about 74 households being indigent. Table 4-10 and 4-11 are taken as representative of the SWW population comprising St. Mary and St. Paul's. A measure of reliability in making this extrapolation is that the standard deviation between the percentages of indigent persons across all parishes including Barbuda is 4.86% (Kairi Consultants Ltd, 2007). Inspection indicates that the values derived by Kairi are reasonably clustered and that the standard deviation expressing the average degree of variability in that data would be acceptable for purposes of an approximate extrapolation.

Table 4-10: Estimated Indicators of Vulnerability in the SWW

INDICATOR OF VULNERABILITY	HOUSEHOLDS %	INDIVIDUALS %
Indigent	3.1	3.7
Low Educational attainment (Not passing any school examination)	Na	52.3
No Employment (No adult employed in household)	21	13.4
Insufficient employment (less than one in two adults employed in the household	26.7	23.9
Poor Access to Drinking Water (If no piped water)	6.0	5.5
Poor quality of housing (toilet is a pit latrine or worse)	22.7	20.4

Source: Consultants Estimates based on Kairi, 2007

Table 4-10 reflects that besides the indigent population, the social and household implications for climate change are associated with unemployment and insufficient employment affecting 42% of households. With poor health prospects due to poor access to drinking water and poor quality of housing affecting 28.7% of households.

From Table 4-11 it can be inferred that within the population of the SWW, 2.83 persons in 10 are vulnerable to varying degrees or 28. 3%.

Table 4-11: Socio Economic Vulnerability for the SWW Population (Persons)

	POPULATION	%
Non Vulnerable	4,178	71.7
Vulnerable	583	10.0
Poor But Not Indigent	851	14.6
Indigent	216	3.7
Total	**5,828**	**100**

An important implication for the adaptation of the water sector to climate change arising from poverty, is that this percentage of the population is least able to be participatory in either the planning or implementation process required for meeting this challenges. It is that section of the population most requiring the allocation of resources by the state to provide minimum levels of welfare and livelihood protection in the face of climate change impacts on the water sector.

4.1.6.3 Health and Disablement

The Central Board of Health (CBH) for Antigua and Barbuda, has offered the Consultants the following perspectives on health issues for Antigua and Barbuda:

- In the rainy season (late November to April) there is always an increase in Diarrhea cases. In the dry seasons Scabies (a water wash disease) sometimes increases. These are water related rather than water borne diseases.
- Antigua and Barbuda does not have water borne diseases. Rather water related diseases.
- There are serious drainage problems with heavy rain.
- Most drains are not paved, are not properly sized nor cleaned regularly.
- Most rainfall events are torrential. There are well known flooding areas.
- Soak-away and septic tanks become inundated with floods.
- Contamination of cisterns and the presence of *E.coli* in tested cisterns are high.
- The health system in relation to monitoring and prevention is epidemiologically focused.

The CBH anticipates that some of the health impacts of climate change will see an increase in vectors such as mosquitoes, and similarly with leptospirosis, particularly in the wet season.

The Consultants accept that the above characterization applies equally to the SWW. The reality is that most of the concerns expressed originate from humans interventions. Community voices listened to by the Consultants, whether individual or via focus groups, confirmed the accuracy of the CBH's assessment.

Table 4-12: Estimated Population with Disabilities in the SWW

TOTAL POPULATION 2011 = 5,828.	WITH CARE	SELF CARE
Seeing		
No Problems	5303	5653
Some/ Lots of/Cannot do at all	318	62
Hearing		
No Problems	5595	5653
Some/ Lots of/Cannot do at all	87	54
Walking		
No Problems	5478	5478
Some/ Lots of/Cannot do at all	233	44
Remembering		
No Problems	5653	5595
Some/ Lots of/Cannot do at all	245	117
Total Population with Disabilities	**883 (15%)**	**277 (5%)**

Generally, disabilities tend to be randomly distributed among populations that are not disproportionately engaged in very hazardous occupations. Therefore projecting national disability rates onto sub sets of the population, can be assumed to offer reliable indicators. Table 4-12 shows these projections for the SWW area, derived using the 2011 Census.

Of the population of the SWW, 1,160 persons or 20% can be described as having some disability whether of sight, hearing, walking or memory. Of this number 883 or 15% have access to care, while 277 or 5% are their own care givers.

Similar in some respects to poverty, but presenting different qualitative challenges, the implication of disability for the water sector and climate change is that the dependency of the disabled must be transferred to other community members or the State. When added to, or weighted for, the age dependency ratio (47% of the population dependent on 53% in 2013) then participation in vulnerability strategies places greater reliance on fewer individuals. The cost of direct societal support coupled with the likely loss of productivity and revenues becomes another source of drain on the mitigation and adaptation planning resources for climate change.

4.1.6.4 Settlement

Settlements bring particular challenges to the anthropogenic impact on climate change. Some of this has already been discussed for the SWW area. For example 1) degradation of the environment once unplanned development takes place; 2) Stress on physical infrastructure; 3) Increasing cost of supplying potable and other water needs; 4) Less overall resources to finance improvements in the water sector to help reduce the impacts of climate change.

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

4.1.6.5 Waste Management and pollution

87% of households in the parishes of St. Mary and St. Paul reported using garbage trucks as a means of solid waste disposal (Figure 4-32). It can reasonably be assumed that the percentage in the SW Watershed is comparable. The National Solid Waste Authority has the responsibility for the storage, collection, transportation and disposal of all waste. Selected urban areas are serviced twice weekly, suburban and rural areas are serviced once weekly. Unfortunately solid waste disposal remains a challenge due to the limited collection services from often over-flowing metal skips that are favoured for communities.

Although not transported to the coast via rivers, solid waste they can be transported via flood created water ways. Drainage systems on the coast are sometimes rendered non operative for periods, by the accumulation of garbage. The SWW enjoys the benefit of a generally accepted well organized and efficient waste management system. The National Waste Management Authority has its own leachates prevention plan and has the cooperation of both NGO's and community members in keeping litter under control. Tourism sector interests also play an active role.

Figure 4-32: Utilising the sanitary landfill

The environment will be faced with increasing strain because of projected population increase. This in turn will potentially result in increasing urbanization, changing lifestyles and increased living standards. The results will be more solid waste generation, higher consumption of water, even if at a declining rate.

This will also be reflected in a growing tourist industry which in addition, will increase effluent treatment requirements.

The National Waste Management Authority is likely to confront the continuing challenge of maintaining a good service in the face of increasing volumes of waste generation and limited financial resources.

4.1.6.6 Land Use

The likely increases in population, land use diversity and growth in densities along the SW coastal area, will reinforce the degree of human impacts on coral reefs and other marine ecosystems such as mangroves and sea grasses. Sand mining is also a contributor to coastal erosion, which in turn will compound the effect of sea level rise. Agricultural practices still include some slash and burn in land clearing as reported earlier. Cultivation and husbandry practices are not conservation oriented even though water is a major constraint.

Fishers along the SW Coast feel that the marine environment is deteriorating continuously based on changes noticed in their fishing grounds. They attribute this to climatic factors but land based pollutants, mangrove degradation and some overfishing are also factors.

4.1.6.7 Deforestation

The total forest area in Antigua and Barbuda is 9000 ha representing 20.5% forest cover (Convention on Biodiversity, 2012). This would imply the production of millions of metric tons of living forest biomass. Deforestation is generally put at less than 1% by stakeholders. The SWW area is one of the densest woodlands in Antigua. The relatively limited size but hilly nature of the SWW make soil and water conservation a priority. The smallness of the overall area means that although there may be high species endemism the total population of any individual species makes them vulnerable. Anthropogenic threats arise from the concentration of population densities along the lower slopes of the watersheds and the coastal zone. This increases pressure on the watershed due to land use modification both along the coast and upwards into the lower regions of the watershed. Due to the relatively small geographical area of the woodlands, they are not attractive for forestry exploitation due to economies of scale and so commercial replanting is marginal. These economies mainly relate to small markets and few export opportunities. Nevertheless coal burning and tree cutting continue to operate without effective regulation and contribute to the environmental threats of storm floods, food security and sometimes fire.

There are outstanding issues of both policy and administration which limit the Antigua Forestry Department from accelerating the implementation of a national forestry protection plan and the updating of the Forestry Act, Cap. 99 of 1941. As well as updating legislation such as the National Parks Act (1984) to protect and develop ecological resources.

There is a need to finalize area development plans to rationalize and direct competing land use requirements in the SW Watershed area. This is an important hindrance to bringing control and potential sustainability to the watershed.

4.1.6.8 Individual and Collective Social Behaviour

Social and individual factors also play an important part in limiting the correction to anthropogenic impacts. Two characteristics stood out clearly in the several community engagements between the Consultants and community members:

1. The predisposition to blame the government for most environmental challenges
2. The preference to look to government for their solutions and the corollary attitude that the government has the responsibility to provide these solutions.

This is partly an educational challenge but it is made difficult by the belief system among rural populations that land use and water access and allocation, favour economic interests and big business.

Notwithstanding these realities, there are active citizens associations and community groups that are protesting land use abuses.

4.2 Summary Sensitivity Analysis

The water sector challenges are associated with inadequate available resources due to low rainfall and extreme drought conditions, as well as other factors which further compound the difficulties of meeting the water demands. These include the following:-

Limited Quantities and Deteriorating Quality of Groundwater

The groundwater production data provided indicates that there is a steady decline in groundwater production from the four main well fields within the SWW area; Christian Valley, Cades Bay, Claremont/Pineapple and Bendals. We can safely assume that water demand in the SWW area in general has not declined over this period of assessment, and as such this reduction is most likely a response to water quality challenges (such as elevated salinity and turbidity levels as well as other pollution indicators such as manganese and iron) as well as aquifer yield limitations indicated by significant drawn down levels in several of the wells. With the forecasted climatic conditions of less rainfall and longer drought periods, the available groundwater in the SWW area is likely to decrease and the pressure to over-abstract from wells to meet the increasing demands will further exacerbate the impact of sea water intrusion on groundwater quality. Over time groundwater with increasing salinity levels also has the negative effect of corroding pumps, pipelines and other physical infrastructure, thereby reducing the life of the water supply infrastructure and increasing the operating cost of water supply. It is expected that the forecasted rise in sea level, may create new salinity issues in some wells fields and exacerbate the existing ones, further reducing the total available groundwater.

Costly Treatment of Desalination Option

Desalination of sea water to meet approximately 45% of the SWWA's water demand is accepted as necessary given the fact that there are no significant surface sources of water within the region. Desalination is a costly alternative and the capacity of the country to pay the cost of this water source now and in the future is in question. It is anticipated that, with declining available groundwater, based on the abovementioned factors, together with the absence of significant surface storage within the SWW area, dependence on the desalination option is likely to increase in the future. The cost constraints of this alternative may require serious consideration of development of surface storage capacity within the SWW area to take advantage of the higher than average rainfall in the area.

Use of Expensive Potable Water for Agriculture

All water provided by the APUA is treated to the standard of drinking water. As such, the water supplied to agriculture by APUA is expensive potable water. A benefit associated with this arrangement, is that water which would normally be supplied to the agricultural sector can easily be diverted to serve the domestic sector, as is often the case, particularly during periods of extended drought. On the other hand, water for agriculture does not require the costly and advanced level of treatment currently effected and as such, well needed financial resources are unnecessarily expended.

With the current practice of diverting agricultural water to meet domestic demand during periods of water shortage, the agricultural sector, is faced with a challenge now and even greater challenge in the future. Those farmers who have implemented water conservation farming techniques, are better able to withstand the dry periods, reducing the extent of losses, while those who continue to rely on rainfall and water supplied by APUA are likely to suffer greater losses.

Anthropogenic Issues

Anthropogenic actions that limit or make more difficult the ability of the water sector to meet water demand in the SWW under conditions of climate change can be summarized as follows:

The lack of financing to enable APUA to keep pace with the upkeep and maintenance of catchments that serves the SWW area reinforces the challenge already posed by inadequate storage capacity. The solution to some extent depends on the priorities that government assigns to water and the funding APUA allocates to maintenance. Currently the dependency on grant assistance or soft lending is not a sustainable solution. Tariff adjustments combined with reducing the losses associated with unaccounted for water, as well as applying alternative energy solutions to containing water production costs should be considered part of the short to medium term solution. Conservation education, while concurrently expanding the exploitation of known water resources, requires further programmed action.

The type and scope of economic activity also poses challenges for the water sector. With respect to the type of economic activity the two most important economic drivers in the SWW are tourism and agriculture including fisheries. Tourism is a major consumer of water resources, but is also a significant contributor to the revenues supporting the water sector. The reality however is that tourism absorbs a significant proportion of generated water production, and is satisfying that demand to the disadvantage of other sectors. An inescapable trend is the requirement for large properties to secure their own water through desalination thereby reducing the demand on climatic water. With respect to smaller properties they continue to rely on public water supply. What portion of their demand is also being supplied by privately installed desalinated water, is uncertain. The tourism sector has traditionally led in terms of making itself into a green product, and to this extent is supportive of strategies to improve the water sector's ability to cope with climate change.

Crop and livestock production on balance probably have a deleterious impact on the water sector. However because neither crop nor livestock production is that important an activity in the SWW area with the correct watershed protection interventions, the challenges that poor farming practices create for the water sector, can be ameliorated. Fisheries, while a very important economic driver, is a comparatively benign type of economic activity in relation to the water sector.

It is the local physical planning function, or absence of it, that represents a significant contribution to the vulnerability of the water sector. Unplanned development and the absence of a resource management zoning plan has resulted in land utilization being ad hoc and sometimes capricious. This has been inimical to the efficient management of water resources.

The demographic and social landscape in the SWW is contributory to the challenge that the water sector confronts in climate change.

Tourism and Agriculture may contribute in the order of 77% to total direct and indirect employment of the SWW. The anthropogenic impact of these sectors on climate change will greatly depend on the education and participation of those employed in them.

Poverty is contributory to the issues of the water sector as well. It is estimated that 216 persons or about 74 households are indigent in the SWW. Poverty brings to the challenges of the water sector these issues: low educational attainment; no, low or insufficient employment; poor access to drinking water and poor housing quality. Poverty contributes to the problem through issues of lifestyle, health, absorption of scarce resources, inability to participate effectively in mitigation of adaptation measures. Indigents become an important part of the problem of managing water resources, while contributing nothing or very little by way of revenue resources.

Indigence presents its own unique issues. Some 1,160 persons or 20% in the SWW population are estimated to have some disability whether of sight, hearing, walking or memory. Of this number 5% are their own care givers. The implication of disability for the water sector is the dependency that must be transferred to other community members or the State. When added to, or weighted for, the age dependency ratio (47% of the population dependent on 53% in 2013) then participation in vulnerability strategies places greater reliance on fewer individuals. The cost of the social security net for indigents coupled with their likely loss of productivity and revenue contribution negatively impacts mitigation and adaptation planning resources for climate change.

There are also a number of more readily identified and better studied community contributors to the health of the water sector. They include the environmental degradation associated with unplanned development and stress on physical and social infrastructure and the increasing cost of water supply as a consequence. Issues of waste management and pollution contribute to leaching and compromise the quality of ground water with its spin off effects on coastal and marine resources.

The projected steady increase in population growth though at a declining rate, in turn will result in increased urbanization, improved lifestyles and living standards. The results will be more solid waste generation and higher water demand. Urbanization will change land use patterns and see the growth in densities along the SW coastal area reinforcing the degree of human impacts on coral reefs and other marine ecosystems. Deforestation brings several challenges to the water sector, including its inhibition of the natural replenishment of the aquifers. Coal burning and tree cutting continue to operate without effective regulation and contribute to the threat of flood damage to the watersheds but also to the built water infrastructure such a wells and reservoirs.

The challenges to the water sector summarized above are also contributed to by administrative tardiness in preparing and or implementing policy and legislation supportive of adaptation measures re climate change. Although finalized the active application and enforcement of the SIRM Zoning Plan, in effect an integrated land use plan, is a major requirement for bringing control and potential sustainability to the watershed.

Finally, social and individual factors also play an important part in limiting the correction of anthropogenic impacts. The tendency to await government interventions for promoting sustainable development and the negative social perception that land use and water access and allocation favours economic interests and big business.

Table 4-13 below tabulates these and other projected stressors and likely impacts and attempts to categorize the degree of sensitivity to climate change they represent.

Table 4-13: Summary of 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 (they rely heavily (70%) on desalination)	Moderate
Annual exposure to hurricanes and tropical storms	Hurricane intensity expected to increase (not necessarily frequency)	Some water catchment areas may be prone to flooding and exposed to risk of debris and sediment flows. Heavy rains may contaminate watersheds through transport of wastes into surface drainage systems. Damage to water sector 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.	Likely to get worse	High
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. Damage to pumps and pipelines associated with corrosive effect of high salinity water.	Likely to get worse	High
Meeting increased demand from	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	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
population growth and economic activities		activities.		
Poor watershed management	Increasing drought conditions	Increase in risk of forest fires which results in reduction of protective tree cover. Increased reduction in infiltration	Could get worse (currently there is a tree planting program)	Moderate
Inadequate physical capital re water capture and storage infrastructure	Reduction in annual average rainfall- results in reduction in surface flows and reduced ground water recharge and ground water resources	Increased reliance on groundwater and desalination because of reduced capture and contribution of surface water to supply challenge	Likely to get worse if water capture and storage do not increase.	High
AGRICULTURE				
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts	More frequent drought events will result in reduced crop yield.	Likely to get worse	High
Poor dryland farming techniques	Increase in annual temperature and drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield.	Likely to get worse	High
Damage from heavy rainfall/storm events	Hurricane intensity expected to increase (not necessarily frequency)	Loss of crops, reduction in crop yield	Could get worse but uncertainties in frequency of high intensity storms	Moderate
Brackish groundwater	Increased salinity in groundwater/aquifers	Damage to soil structure and reduced crop yield	Likely to get worse	High
HEALTH				
Pathogens (e.g., *E.*coli) present in cisterns &	Reduction in annual average rainfall- more droughts	Increased reliance on the use of cisterns at the household level- could be increase in water related illnesses such as gastroenteritis	Could get worse (mandatory chlorination already	Low

Current Stresses	Projected Stresses from Climate Change	Likely Impacts	Projected change in stresses to systems *(without preparedness action)*	Degree of sensitivity
pollution of groundwater			underway)	
Heavy rainfall events results in flooding and the overflow of septic systems	Hurricane intensity expected to increase (not necessarily frequency)	Increased water related illnesses	Could get worse but uncertainties in frequency of high intensity storms	Moderate
OTHER INTERELATED IMPACTS				
Unplanned development leading to unnecessarily expensive infrastructure development costs .	Reduction in annual rainfall	Will exacerbate challenges of demand management and lead to more costly downstream choices for providing adequate water supply	Likely to get worse- Development increasingly out of step with sustainability and more intractable and expensive to rectify.	Moderate
Tourism sector- heavy users of water	Reduction in rainfall – more drought periods	Greater strains on water resources	Likely to get worse with a growing tourism sector- desalination is a costly option	Moderate

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). The adaptive capacity analysis is the second step in the VCA. Generally, systems that have a high adaptive capacity are better able to deal with climate change impacts. This section outlines the institutions involved in water resources management and their capacity, the policies, legislation, plans and international conventions that relate to the water sector. It highlights the gaps and makes recommendations for going forward. It also discusses the existing coping and adaptation strategies for the local community and economic sector to deal with projected impacts on the water sector.

5.1 Institutional Review

The institutional map takes into account all agencies (public and private) which relate to the several functions and resources considered to form a part of the water sector (Figure 5-1 and Table 5-1).There is no single authority which has watershed management as its mandate and many institutions have a degree of responsibility for coastal zone management. State lands for agriculture are allocated by the Extension Division of the Ministry of Agriculture, Lands Fisheries and Barbuda Affairs and, parcels of more than 2 hectares are handled by the Lands Division in the same Ministry. Record keeping is outdated and frequent disputes arise as to who has been allocated which land.

A large number of institutions are involved in activities associated with watersheds, water harvesting and treatment and with the marine and coastal zone. These institutions include government ministries, statutory bodies, NGO's and community groups, the most important of which are described below. There are no designated watershed reserves and currently no legislation dealing specifically with watershed management. New draft legislation will provide some improved legal status for watersheds. **The national public utility company (APUA) has legal rights over all water resources but has no legal obligations regarding watershed protection or maintenance.**

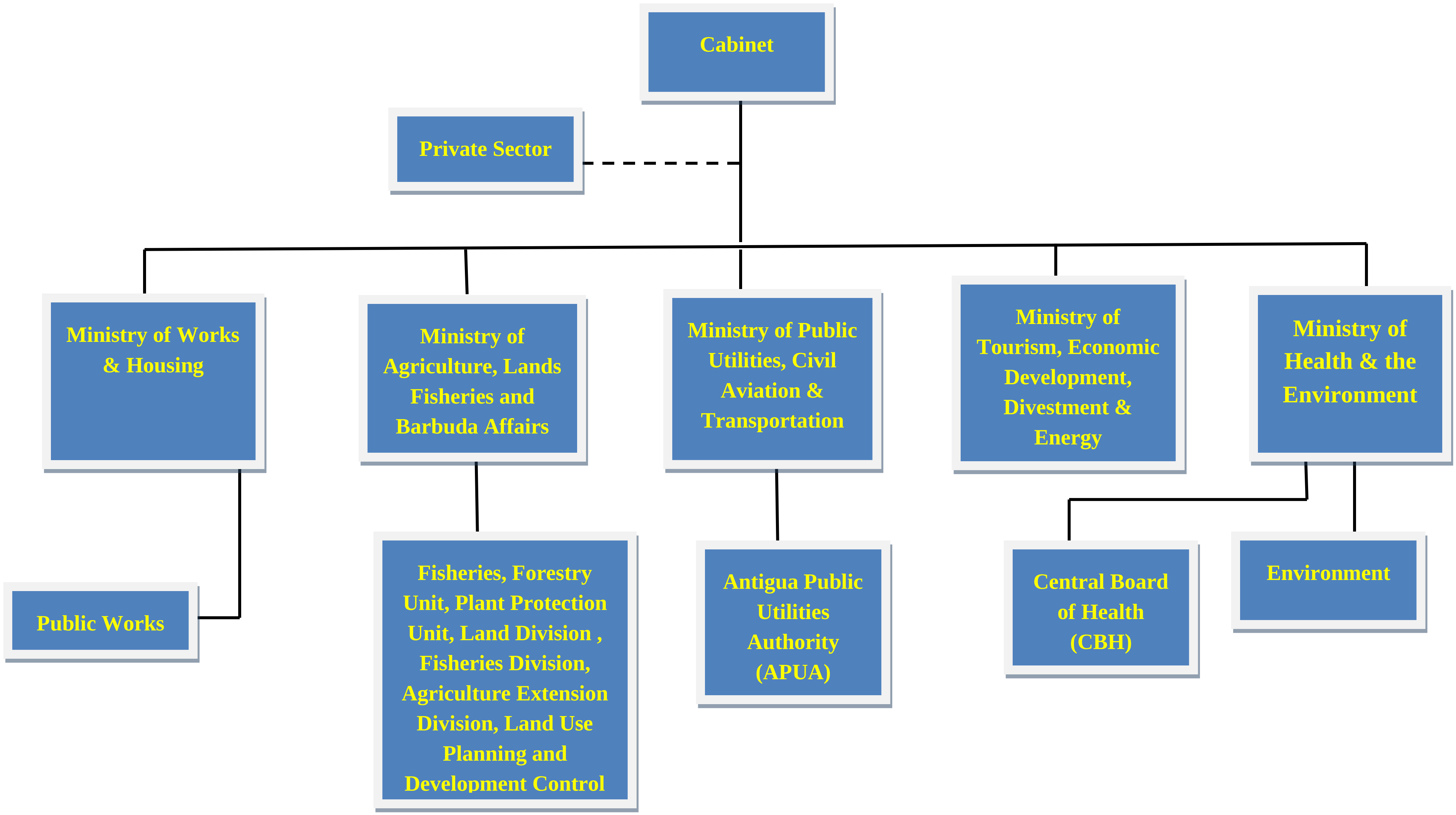


Figure 5-1: Institutional Map

Table 5-1: Agencies with responsibility within the Water Sector

GOVERNMENT AGENCY/ MINISTRY	MANDATE	LEGISLATION	POLICY/PLAN	CURRENT ROLES
Ministry of Health and Environment	Responsible for the implementation of the government's policy and strategy in the use and allocation of land.	• Watercourses and Waterworks Act, Chapter 194 • Fisheries Act, 1984		• It formulates and implements the Government's policies and strategies and monitors and coordinates the work of various agencies and bodies that support the sector. • It executes its responsibilities through various Departments and Divisions and collaborates with a range of national organizations in the public and private sectors, as well as regional and international agencies.
The Environment Division	Main mandate is to coordinate the national environmental program. It has expanded in response to environmental issues related to the Development Control Authority (DCA) and the processing of Environmental Impact Assessment (EIAs).	Environmental Protection and Management Bill, 2013 (Pending)	• Environmental Management Strategy and Action Plan • Policy Framework for Integrated (Adaptation) Planning and Management (draft)	• The Environmental Division is responsible for the implementation of Environmental Protection Orders, development and implementation of National and International projects, and any other duties assigned by the Ministry or the Cabinet of Antigua and Barbuda
Forestry Unit	It is responsible for wildlife and for **the conservation and management of the nation's terrestrial biological diversity**	• The Forestry Act • The Bush Fires Act, Cap. 62. • Forestry and Wildlife Bill		• It has responsibility for managing the country's forest and woodland areas and theoretically for reforestation • Biodiversity conservation and eco-tourism development

GOVERNMENT AGENCY/ MINISTRY	MANDATE	LEGISLATION	POLICY/PLAN	CURRENT ROLES
The Land Division	Responsible for the management and control of Government lands, including land reclamation, land use and the sub-division of land.	• The Barbuda Land Act, 2007 • Crown Lands (Regulations) Act, Cap.120 • Physical Planning Act, 2003		• Reallocation of subdivision of government lands to residential, agricultural and industrial uses and consequently has a major role to play in the conversion of land to non-agricultural uses.
The Agricultural Extension Division	Responsible for farmers and also for the allocation of state lands to farmers for agricultural purposes (based on rentals)			• Farmer training and assistance and is also involved with allocation of the state lands to farmers for agricultural purposes
Land Use Planning and Development Control	To regulate built development through the Physical Planning Act	• Physical Planning Act • Crown Lands (Regulations) Act, Cap. 120 • Forestry Ordinance (Cap 99, 1941)		• Granting or refusing of permission to develop land
Ministry of Public Utilities	The Water Division in APUA has legal control over all water resources in the country and is mandated to provide supplies of water to meet the municipal needs of the country.	• Public Utilities Act, 1973	• National Integrated Water Resource Management Policy (2011)	• Management of water sources such as ponds, dams, reservoirs, wells and the ocean. We also manage the distribution infrastructure which includes constructing and expanding water mains as well as repairing broken pipes. • Responsible for water quality testing
Ministry of Public Works and Communications	Responsible for roads and drainage structures throughout the country. They are responsible for roads and drainage structures throughout the	• National Solid Waste Management Authority Act, 1995		

GOVERNMENT AGENCY/ MINISTRY	MANDATE	LEGISLATION	POLICY/PLAN	CURRENT ROLES
	country	amended by the National Solid Waste Management Authority Act.		
Central Board of Health	Responsible for regulating all matters concerning public health in Antigua and Barbuda.	• Public Health Act, 1957 • Litter Act		• Among other things, it has responsibility for enforcement of the environmental sanitation regulations, preventing the spread of infectious diseases, operating a mosquito control programme and for the handling of liquid and solid waste.
NODS	It seeks at all times to save lives, protect property in Antigua and Barbuda and aid in sustainable development by protecting the environment.	• Disaster Management Act		• It has responsibility to reduce the vulnerability of natural and technological hazards in the twin island state, through multi-sector and integrated hazard risk reduction management. NODS through its operations seeks at all times to save life and protect property in Antigua and Barbuda. NODS also provides administrative and emergency support base on request from the Caribbean Disaster Emergency Management Agency (CDEMA) to assist any of the CDEMA member states.

5.2 Policy and Legislative Review

There are a number of statutes that have some bearing on water. However the key statutory provisions are contained in the Watercourses and Waterworks Act, the Public Utilities Act and the Forest Act. Nevertheless as water sector concerns span over a wide range of topics this section will review all relevant legislation relating to water.

While there is a wide range of statutes dealing with water and other natural resource management issue most of these statutes are outdated and need for substantial reform. In addition most of the Statutes lack regulations for their effective implementation.

The following Acts relate to the water sector and have been reviewed in greater detail in the Impact Assessment and NASAP for Antigua and Barbuda:

- Watercourses and Waterworks Act, Chapter 194
- The Forestry Act, Cap. 178
- Public Utilities Act, Cap. 359
- The Bush Fires Act, Cap. 62.
- Crown Lands (Regulations) Act, Cap. 120
- St. John's Development Corporation Act
- Barbuda Land Act, 2007 (Act 23 of 2007)
- Physical Planning Act
- Fisheries Act
- The Beach Control Act, Cap. 45
- The Beach Protection Act, Cap. 46
- Botanical Gardens Act, Cap. 56
- Public Health Act
- Litter Act
- National Solid Waste Management Authority Act, 1995 amended by the National Solid Waste Management Authority Act.
- The Pesticide Control Act, Cap. 375
- National Parks Act, Cap. 290 and National Parks (Amendment) Act, 1995 2000, 2004
- Marine Areas (Preservation and Enhancement) Act, Cap. 259
- Port Authority Act
- Disaster Management Act
- Pending Legislation
    - Environmental Protection and Management Bill, 2013
    - Forestry and Wildlife Bill

The following policy documents relate to the water sector have been reviewed in greater detail in the

Impact Assessment and NASAP for Antigua and Barbuda:

- National Integrated Water Resource Management Policy (2011)
- Environmental Management Strategy and Action Plan
- Policy Framework for Integrated (Adaptation) Planning and Management (draft)

International Conventions

International law is much different from domestic law. Domestic law describes the rights and obligations of persons and their relationship to each other and the government. Domestic legal systems almost always include general methods for enforcing laws and adjudicating disputes.

International laws set out the powers and obligations of nations. Usually only nations, not individuals, may seek enforcement of the laws. Though there is an International Court of Justice, unlike a domestic court, it has no authority to force parties to appear before it or to abide by its decisions. Often international law is established through mutual agreements or treaties, and individual treaties may spell out specific means of enforcement or resolution of disputes. These dispute resolution mechanisms may be open only to Nations party to the agreement and not to their citizens in their own right.

Sometimes international accords are not intended to be directly enforceable. Nations will sometimes sign non-binding statements of policy or principle. These may serve as a step towards future treaties, as policy guides for international organizations, or as persuasive references in policy debates involving the signing governments. Violations of the principles, however, have no defined consequences.

Nevertheless, both binding and non-binding international law may make itself felt in domestic situations. A nation may pass domestic laws to implement a treaty or international standard of behaviour. Or, a nation may simply conform its actions to the course of international law without specific new domestic laws. For example, a country might render promised technical assistance to another without needing a change of domestic law to comply. Accords may occasionally make themselves felt through non-governmental action. For example, non-governmental organizations (NGOs) around the world have embraced the Forest Principles signed at the 1992 Rio "Earth Summit". Even industry groups have adopted codes of practice reflecting the Forest Principles.

The following international conventions relate to climate change and water have been reviewed in detail in the Impact Assessment and NASAP for Antigua and Barbuda:

- United Nations Framework Convention on Climate Change (UNFCCC)
- Kyoto Protocol
- The Convention on Biological Diversity
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, 1971 (Ramsar Convention)

- Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean (SPAW Protocol)
- United Nations Convention to Combat Desertification in those Countries experiencing Serious Drought and/or Desertification, Particularly in Africa, Paris (1994)
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their disposal
- Vienna Convention for the Protection of the Ozone Layer
- Montreal Protocol on Substances that Deplete the Ozone Layer
- Ramsar Convention on Wetlands
- Kyoto Protocol to the United Nations Framework Convention on Climate Change (Not yet in force)
- The United Nations Convention to Combat Desertification and Drought (UNCCD)
- United Nations Conference on the Sustainable Development of Small Island Developing States, Bridgetown, (1994)

5.3 Analysis of Policy, Legal and Institutional Framework

5.3.1 Weaknesses in Policy Framework

There is an absence or weakness of policies to guide development and management of land use, water resources or the coastal zone. It is difficult to manage a resource effectively in the absence of clearly defined policies, especially where the resource is used by a large number of different stakeholders, whose needs must be taken into account. For example, there is no established policy relating to land use. In addition there is also need for a comprehensive policy framework for environmental management.

5.3.2 Existing Legal Instruments

A large number of national legislation apply to water resources. Similarly there are disparate institutions responsible for water resources. The legal framework process of distilling this wide array of legislative instruments into a coherent framework still has to be done. Comprehensive legislation relating to water would facilitate a more coherent regulatory framework for the water sector.

There are also major gaps in the legislative framework. For example there is no Meteorological Act and the legislation in relation to public health needs substantial revision. There is also a clear and pressing need to enact comprehensive environmental legislation (i.e. enacting the Environmental Protection and Management Bill) and also addressing watershed management issues.

5.3.3 Fragmented Legal Support

Legislation governing sustainable land management has developed piecemeal and is scattered through a wide range of legislation. Even if laws were consolidated a considerable degree of amendment would be needed to make the legislation comprehensive.

The legal framework in relation to land use is very comprehensive but needs some updating. For example whilst the Registered Land Act is comprehensive it would be preferable if under this Act the subdivision, pooling or re-parcelling of land should not be obtained without the approval of the Development Control Authority (DCA).

5.3.4 Inadequate Enforcement

Most of the existing Acts and Regulations are not adequately enforced which, in part, is due to lack of staff.

5.3.5 Overlapping Institutional Framework

With respect to pollution, a range of statutes deal with this matter. The Public Health Act prohibits the pollution of watercourses. The Public Utilities Act deals with the prevention of the pollution of sources of public water supplies and the Act empowers the making of comprehensive water pollution control regulations. The National Parks Act, the Marine Areas (Preservation and Enforcement) Act and the Fisheries Act all seek to protect wetlands from pollution. The existing water pollution control legislations are manifestly inadequate. New legislation for water pollution should reflect concern for the quality of fresh water resources. Comprehensive regulations should also be put in place to establish water quality standards.

The main laws that provide for land use planning and development are the Slum Clearance and Housing Act, Cap. 404 and the Physical Planning Act which establish CHAPA and the DCA respectively as administrative bodies with authority to address land use issues. In practice, allocation of land for development is carried out in the case of government land, by two separate agencies. The Land Division of the Ministry of Agriculture and CHAPA. None of the legislation mentioned provides any mechanism for consultation or coordination between these different agencies.

The DCA under its Act, is given responsibility for the development of land in rural and urban areas. The DCA also has responsibility "to prepare development plans for the State of Antigua and Barbuda". At the same time, CHAPA has under its Act, a mandate "to prepare, adopt and revoke or modify schemes for the development of the entire country of Antigua and Barbuda or any part".

The DCA also has power to grant permission to develop lands with or without conditions or to refuse permission and CHAPA has the power to "grant permission in writing to develop land, construct, demolish, alter, extend, repair or review a particular building in the area to which a scheme relates".

Adding to these factors, is the situation that the St. John's Development Corporation Act which Act establishes the SJDC as an agency empowered to lay out, construct and maintain roads, construct and maintain buildings and carry out other building and engineering operations necessary or desirable within a designated area. The area that has been designated by the Act is limited to specified areas in the city of St. John's. The SJDC also has authority to prepare a development plan for the designated area which sets out the manner in which land in the designated area is to be used and laid out, including provisions relating to the number and type of buildings to be constructed and proposals for establishing water supply, drainage and a sewage disposal system.

In addition, under the National Parks Act, the National Parks Authority is mandated to prepare plans for development and management of all designated national parks and, within the designated park the powers of DCA, CHAPA and the Port Authority are subordinate to that of the NPA as they relate to development control and planning functions.

5.3.6 Land Use Practices and Procedures

The Physical Planning Act provides for a National Development Plan for Antigua and Barbuda. Section 10 (4) (a) provides that a development plan may "define the sites of proposed roads, public and other buildings and works, or the allocation of land for agricultural residential industrial or other purposes of any class....." Pursuant to this provision in the Act, a Draft Land Use Plan was formulated for Antigua and Barbuda in 1999, as Volume 3 of the Draft National Development Plan. This Draft Land Use Plan in relation to the agricultural sector "seeks to allocate quality agricultural land and water resources, so as to minimise loss of agricultural land to build development and to facilitate sustainable and productive agricultural development and, to protect and promote the sustainable use of the country's forest reserves."

The proposed policy on built development on agricultural land is articulated by proposing that residential development should only be permitted on agricultural parcels to provide accommodation for farm owners and/or their workers. It stipulates that the maximum permitted density in areas of prime quality agricultural lands should not exceed two dwelling units per acre. The plan also proposes that residential development in rural areas should be contained so as to control its encroachment onto agricultural lands.

A key goal of the plan is to conserve and allocate good quality agricultural land and water resources to facilitate sustainable and productive agricultural development. The plan recommends that the decline in the agricultural sector be halted by supporting crop production by ongoing policy measures including the grant by Government, of long term leases for 25 years with an option for renewal.

5.3.7 Watershed Protection

The Forestry Act is out of date and needs substantial overall reform and revision. A Forestry and Wildlife Act has been proposed but this Act needs revision to bring it in compliance with the current needs and requirements of forestry.

A major failing of the Forestry Act is that it does not address the issue of watershed protection. Another factor is that the Forestry Act does not address the issue of intersectoral cooperation. This is a major failing as any forestry legislation dealing with current conditions in Antigua and Barbuda should address the issue of intersectoral cooperation.

There are a number of options in addressing the issue of watershed protection. First, the revised Forestry and Wildlife Act should specifically deal with the issue of watershed protection. In addition the Forestry and Wildlife Protection Act could establish a Watershed Management Council.

5.3.8 Inter-Agency Co-operation

Given the large number of institutions involved in some way or another in land use issues, collaboration among these organizations and institutions is necessary and important, if conflict and competition is to be minimized. At the moment there are very few formal attempts to provide this collaboration, most of which takes place either informally at a personal level or ad hoc through special meetings or workshops dealing with specific problems. More recently activities associated with the various environment-related conventions, such as biodiversity and climate change have provided opportunity and resources for inter-ministerial and inter-agency meetings and discussions surrounding their proposals for plans of action and the government has set up a coordinating committee of these conventions which meets every few months.

With respect to the management of watersheds, a properly constituted Watershed Management Committee could provide a considerable degree of coordination among agencies such as APUA, Forestry Divisions, as well as other stakeholders. The Fisheries Advisory Committee, established under the Fisheries Act, was intended to provide coordination and a broader input into the programme of the Fisheries Division, but it is not presently functioning and Fisheries staffs are equivocal about its ability to function effectively. They prefer to see these aspects of collaboration and coordination tackled on an issue or problem basis, as this seems to provide a better chance for effective discussion and decision making to take place. At the moment, both Forestry and Fisheries Divisions seem to have a relatively good record of working with other government agencies, NGOs and community groups.

Nevertheless, weaknesses are apparent with respect to inter-ministerial collaboration. The involvement of the various Ministries and agencies in discussions about water and coastal zone resources management issues has, in general, not been very consistent or effective.

5.3.9 Institutional Capacity

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 of the local population 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 discusses the capacity issues of the local institutions directly/ indirectly involved in the water sector in Antigua and Barbuda.

Table 5-2: Institutional capacity of the main institutions within the water sector

INSTITUTION	CAPACITY
Ministry of Health and the Environment	Staffed with well qualified professionals in many areas, but frequently lacks the basic equipment and supplies to do an effective job. Professional staff is often not adequately provided with support staff having adequate training.
Environment Division	Present staff is adequately trained. However there are not enough technicians to effectively carry out the mandate of the office. There is a need for at least 4 additional staff trained at master’s degree levels or above for effective implementation of the draft EMPB. There have been budget cuts consistently over the past few years. It was cut by 60% between 2011 and 2012 and there have been additional cuts in the years since then. Currently, there is no funding for the implementation of programs, the budget only covers staff payments. The Environment Division relies mostly on funding from international donors to implement projects/activities at the national level. The Division design project strategically so that synergies are created and programs can be implemented and sustained. The funding for staff is from the National Treasury.
Forestry Unit	Seriously understaffed and under budgeted, which makes it impractical to attempt any significant forestry development activities.
APUA- The Water Business Unit	The Water Business Unit which is the water section of APUA is heavily subsidized by the other units (electricity and telecom). Water rates

INSTITUTION	CAPACITY
	have remained the same since 1991. In order to address the water storage issues there would need to be a tariff review and they would need to collect all of the money owed to them by the Government who is the largest consumer of water.
Central Board of Health	Funds in the environmental health budget have traditionally been adequate, with some support from the Medical Benefits Scheme, to provide free and accessible primary care for the entire population. Antigua and Barbuda has a sufficient number of health facilities (both public and private), distributed evenly across the country. There is adequate availability and access to primary health care, and most types of specialized health services are available in-country at Mount St. John's Medical Centre, as well as at a number of modern private clinics. However, there are gaps in terms of the efficiency of service delivery and quality assurance. The Ministry of Health is in urgent need of detailed health services cost data to make informed funding decisions in the short term as well as to develop a long-term plan for funding Mount St. John's Medical Centre while preserving primary health services. Improved cost data will enable the Ministry of Health to prioritize health expenditures within the envelope of available funding. The Ministry of Health is challenged by a scarcity of resources, including financial and human resources.
The National Office of Disaster Services (NODS)	Present staff is adequately trained. However there are not enough technicians to effectively carry out the mandate of the office. There needs to be more 'buy-in' by government officials to ensure implementation of the Act so as to allow resources, when received during emergencies, are properly dispersed.

5.3.10 Summary

In summary, there are a number of statutes that have some bearing on water. However, there is an absence or weakness of policies to guide development and management of land use, water resources or the coastal zone. There are a large number of national legislation apply to water resources. Similarly there are disparate institutions responsible for water resources. The legislation governing sustainable land management has been developed piecemeal and is scattered through a wide range of legislation. Most of the existing Acts and Regulations are not adequately enforced, in part is due to lack of staff.

A number of developments have taken place in Antigua and Barbuda to address the water sector issue. These include the preparation of a draft National Integrated Water Resources Management (NIWRM). Policy – Antigua and Barbuda (June 2011) but this was never finally approved by the Government. In addition there was the National Stakeholder Consultations on Water (April 2013), but again this did not result in any formal governmental approval.

Whilst there has been considerable work done in various areas of water sector no final water sector policy has been developed and submitted to Government to establish an overarching framework for the management of all aspects of the water sector.

There are several local institutions directly and indirectly related to the water sector, but their ability to fulfill their mandates is sometimes significantly limited by staffing and budgeting issues. This therefore means that their adaptive capacity is limited.

5.4 Recommendations for Policies and Legislation

5.4.1 Policy Recommendations

Several recommendations have been made for upgrading the relevant policy, these include:

- That a climate change policy be developed by the Government – that the Policy be presented to Cabinet for approval.
- An outline of the possible scope of a climate change policy is set out below.
- There needs to be a link between the climate change policy and the water policy.
- Revise the Watershed Policy and the Water Policy to take into account climate change considerations.
- A National Land Use Plan should be developed and finalized at an early date. The National Land Use Plan should address a range of concerns including: (a) the alienation of aqua-cultural land for the built environment especially in rural areas.

5.4.2 Recommendations for upgrading of Legislation

Several recommendations have been made for upgrading the relevant legislation. , these include:

- The enactment of a Water Resources Act.
- Revised the Public Health Act to provide for comprehensive framework for pollution and promulgate regulation and promulgate regulations to deal with water quality standards.

- The enactment of the Environmental Management Act is of critical importance for establishing a framework for environmental management. The Act however, needs a number of significant revisions. The draft Bill also needs to be reviewed in order to avoid overlaps with the Physical Planning Act and other legislation.
- That the proposals for the enactment of a Meteorological Act be implemented.
- The Physical Planning Act should be amended to make it a mandatory requirement for the DCA to consult with the Agricultural Department where a proposal for built development is adjacent to or in the environs of agricultural land, to determine the impact which built development will have on agricultural production on surrounding land.
- Establish an agency with a clear mandate to manage all water resources for Antigua and Barbuda including a mandate to develop and manage in particular all watershed areas. It is best if the management responsibilities for water rest within one or two organizations.
- A watershed management plan should be created.

5.5 SOCIOECONOMIC ANALYSIS

There is currently no information available to the Consultants on the water balance with respect to the SWW area. Although ground water yield is estimated to be 30,115,614 gallons per annum, surface water contribution has not been established. There are however two national estimates of surface water contribution, that provide a tentative basis for examining surface water use in the SWW area. One estimate puts total surface water production for Antigua and Barbuda at between 5% (dry season) to 25% (wet season) of total water production. A second estimate suggests that harvested rainfall contributes 20% of total domestic supply. Indicative data can be derived from these estimates for arriving at a tentative surface water contribution to the SWW area. Since, the countries average per capita consumption of water in 2011 was 11,438 gals/annum then an estimate of total annual demand for APUA water (which is not however the only source of water) in the SWW comprising a population of 5,828 could be of the order of 66.6m.gals. This suggests that only about 45% of the per capita based demand for APUA water in the SWW area is covered by ground water resources generated in the catchment area.

There are no significant reservoirs or ponds in the SWW and although there are numerous ponds on the west coast, all of these ponds are brackish to saline (US Army Corps of Engineers, 2004). In the absence of contributing reservoirs and ponds, rainwater harvesting should be an important source of supply. Further the SWW area enjoys the highest rainfall rates, and has a moderate drought risk. Assuming that rainfall harvesting accounts for 20% of total domestic water supply in the SWW then Table 5-3 provides an indicative picture of the ability of the SWW watershed to meet the water needs of the communities.

If 20% of domestic water demand is contributed by surface water in the SWW area then based on the ground water yields from the wells in the SWW area, the shortfall to climatic water demand to be met by desalinated water is 2.9 million gallons per annum. An important qualification being the inherent uncertainty of the 20% assumption re rainfall harvesting. This highlights the critically important and likely increasing role of desalination in meeting the growing social and economic water requirements of the SWW area. Despite being the wettest watershed, as a result of the low annual rainfall and relatively frequent drought events, APUA is relying increasingly on desalination to make up shortfalls in demand.

Table 5-3 is to be interpreted with care. It does not derive the total volume of water available in the SWW, this figure remains unknown. It only estimates, by deduction, the volume of water generated in the watershed that is available to meet water demand for APUA water , as presently extracted. It will be shown by reference to the domestic demand for water, that the current yield of climatic water from the SWW is at best marginal in terms of supplying the needs of the household sector alone.

Table 5-3: Coverage of Domestic Water Demand in the SWW vs Water Supply Resources (Gals M)

DEMAND AND SUPPLY IN THE SWW	VOLUMES	Shortfall to be met from transfers from other watersheds or desalination or both.
Demand calculated from per capita domestic demand	41.3	2.9 m
Coverage of Supply based on :		
Ground water Resources (given)	30.1	
Surface water contribution (assumed at 20% of domestic demand: *A&B Per capita domestic demand x 20% / Pop SWW).*	8.3	
Indicative climate water resources in support of water demand	38.4	

Data compiled by the Consultants.

This estimate of shortfall has shortcomings because of the underlying assumptions. Firstly that surface water contribution to domestic water supply in the SWW is proportionate to the estimated national contribution (5 to 25%) and closer to the value used. The second is on the demand side, that the national per capita domestic consumption is a good proxy for the SWW area. Also the use of domestic per capita demand, ignores the importance of the demand for water in the economic sectors. If the average national per capita demand for water is substituted for domestic demand in Table 5-3 and implied surface water supply taken at the upper estimate for Antigua and Barbuda of 25%, of total production, the requirement for desalinated water increases significantly in the SWW. Finally is the reality that the need for water by communities is also served by precipitation. The extent to which is not a known.

However, the findings do support a tentative conclusion, that as presently exploited, the climatic water resources of the SWW are insufficient to support both domestic water consumption and the economic requirements of the watershed, without augmentation by climatic water transfers or desalination. This is not a comforting scenario when it is considered that the watershed is the wettest in the Island, contains the most woodland and is not the most densely populated. The SWW area also contains the most diversified and rich terrestrial eco-systems in Antigua and Barbuda The unknown but likely significant demands for environmental water further strengthens the conclusion that in relation to exploitable climatic water within the parishes of St. Mary and St. Paul, the SWW can probably be characterized as water starved. The section that follows assesses the SWW communities coping and adaptation strategies and those of the economic sectors against this background.

5.5.1 The SWW's Capacity for Social and Economic Resilience to Climate Change

The capacity to deal with, and resilience to the impacts of climate change on the water sector can be presented as a statement of assets that strengthens the social and economic fabric of the communities to cope. Once the threats are established and the degree of resilience identified, then the vulnerability of the community can be better assessed. The approach taken in this section departs from that straight conceptual path only to the extent that in identifying the capacities, note is also taken of issues that compromise or undercut them.

Sometimes resilience at the community livelihood level may be different and at odds with the resilience in the supporting economy and visa verse, both in terms of drivers and perspectives. In Table 5-4 below this dichotomy is more easily spotted. This balance sheet approach will also help to contextualize the vulnerability assessment that follows in Section 6.

In addressing the issue of resilience and capacity to cope, the Consultants have relied on observation but also a series of focus groups and interviews conducted with groups and individuals including government agencies and private sector associations within and outside of the SWW area.

Table 5-4: Resilience Indicators

	LOCAL COMMUNITIES	ECONOMY
Physical Capital Infrastructure for Rainfall and Irrigation Systems.	Approximately • 17% of dwellings have Cisterns/tanks. • 61% have piped water into dwelling. • About 95% have access to potable water.	• Large pineapple estates have irrigation systems (Claremont and Urlings). • Large hotels have desalination plants that employ reverse osmosis technology, combined with water catchment systems • Most small farmers have no effective rainfall irrigation systems except the use of catchment containers. • Most small farms have some form of rudimentary drip irrigation system using APUA water. • Great uncertainty as to which agency has responsibility for flooding and drains.
Social Capital Community attitudes Community Associations and initiatives	• Social capital in most communities appears to involve varying degrees of fellowship goodwill and social intercourse. • No obvious evidence of high levels of social capital in water conservation. Social capital defined here specifically as actual community sponsored investments in water conservation and climate change. • Generally community members have a basic awareness of climate change but do not take climate change seriously. • Some exceptions stand out. St. Johns Fisherman's Cooperative, Bolans Community Group. The Environmental Action Group. • No Water management associations or networks.	• Active Antigua and Barbuda Hoteliers Association. • Active Environmental Division as well as other environment related agencies, though greatly limited by human resources and finance. • Active APUA water agency , though critically underfunded. • National NGO network but severely under- funded. Often key person led. • Women Against Rape (WAR) and POWA (Professional Organization for Women in Antigua and Barbuda)POWA are sensitized ,re water related gender issues and implications for climate change. • Donor Agency and Bi-laterals concern/support for Climate Change in most community focused funded projects. See also below • An informed opinion offers low flatness, low rain and high solar intensity as reasons why Barbudians are considered to be sensitive to impacts of climate change. • Some hotels Green Certified others practice without going for certification • Hotels complain that water costs are very high.

	LOCAL COMMUNITIES	ECONOMY
	• However good potential exists for extending visioning exercises as a means of community sensitization and motivation. All communities have leadership skills that can be harnessed.	
Natural Capital Land and Water Availability	• Communities complain they need more and better community catchment systems. • Communities complain that quality of APUA supplied water cannot be trusted. • Communities note that water is not that expensive at the household level .	• The SWW area covers 8,995 acres • Enjoys a low population density of • 0.64 persons per acre. Compared with the density of the Parish of St John Rural 1.7 persons and of St. John's Capital of 18 per acre. • Resource rich in biodiversity. • The Watershed includes the coastal zone and therefore the interface of this biodiversity with settlement is critical. • Natural capital in land therefore high. • SWW served by a total of 29 wells of varying productivity. • Amount of water available in the watershed not known. • Groundwater yields about 30.1m gals per annum. • Per capita water consumption is estimated at 66m gals or twice ground water yield. • No major surface water catchments. • Desalination expensive option. • Natural capital re exploitable water resources therefore uncertain. • SWW has excellent beach lands. • Combines coastline with aesthetic landscape. • Increasing importance as economic growth node for tourism and upscale residential development. • Good beach nourishment practices by main hotels. • Incomplete road development along coastal area. • Some wetlands. • Poor coastal inshore marine resources but good offshore fishing

	LOCAL COMMUNITIES	ECONOMY
		resources. • There is no government watershed policy but there is a Water Resources Policy.
Financial Capital Cash, Credit, Savings, Animals	• The Antigua and Barbuda Development bank funds mortgages, students loans and small business initiatives. • Risk Insurance is available by insurance providers with branches in the SSW.	• The Antigua and Barbuda Development bank provides developmental funding. Its lending practices emphasis environmental sustainable development. • The Antigua and Barbuda Investment Authority (ABIA) offers accessible financing facilities for business start up and working capital lending. Will consider investments in the water sector. • There are 25 general and life insurance companies in Antigua and Barbuda. • Hotel Managers operating in the SWW report good financial services and access to disaster risk coverage. • The IMF has found the Antigua and Barbuda international banking sector fully or largely compliant with most Basle Core Principles.
International Capital (Technical Assistance) Though often national in scope these bilateral financial programs are important sources of direct and indirect resilience support to communities, including the SWW.	• No information was captured in relation to specific technical assistance programs in the SWW • The instant project by Environmental Solutions Ltd is funded by Caribbean Community Climate Change Centre and the Global Climate Change Alliance and is centered on the water sector and climate change in the SSW.	• **BILATERAL RELATIONS AND SOCIAL AND ECONOMIC COOPERATION (2013)** **Japan** - The Japan Grass-roots Human Security Programme –NGO's & Local Government. - Antigua and Barbuda Waste Recycling Co-operation to recycle waste materials, - Gilbert Agricultural Rural Development (GARD) Centre vulnerable youth vocational and entrepreneurial training programme. - Technical support fisheries for development and resource management. - Short term training in the areas of tourism, coastal fishing, and solid waste management

	LOCAL COMMUNITIES	ECONOMY
		Republic of Cuba - Studying at the tertiary level in Cuba in a wide range of subject areas. Medical teams in support of health care system and technical support for infrastructure development projects. - Technical support from visiting hydraulic, quarry and road engineers. - **The Republic of Korea** - **The Bolivarian Republic of Venezuela – PetroCaribe Agreement** - Approximately 40 percent of fuel debt to be repaid in the form of concessional loans over a 25-year period at an interest rate of 2 percent per annum. **Government Social Programmes:** - The Peoples Benefit Programme (PBP) To date, over 2,500 persons have received special debit cards to purchase food and selected personal items from designated outlets. - The Senior Citizens Utility Subsidy Programme (SCUSP) started in 2008 and provides pensioners in Antigua and Barbuda a grant towards their utility services. • The SWW area has in recent years benefited from several water related studies that have examined in detail aspects of the water challenges facing Antigua and Barbuda.
Human Capital Labour, knowledge (through education, experience	• Community discussions indicated awareness of the term Climate Change, but almost no appreciation of what it meant in forecast climate terms. • Most persons do not take climate change seriously.	• Large hotels conduct climate change awareness sessions for their staff. • Public sector workers spoken to had good awareness of climate change implications for communities and economy. • Institutional strengthening components attach to most donor funded projects

	LOCAL COMMUNITIES	ECONOMY
	As mentioned earlier criteria for vulnerability include education and income. • 22% of the adult 15 yrs and over population (the greater part of the labour force age) in St Mary & St Paul have attained post Secondary education (2011) • 38% of the adult 15 yrs and over population in St. Mary and St. Paul were either unemployed or inactive (2011). • The above ratios are likely to be the same among the population of the SWW and suggest that these criteria for vulnerability are present.	• Climate change considerations attach to most donor funded projects. • Architectural and engineering skills reside in both the public and private sector to guide most engineering solutions to housing and infrastructural challenges by climate change. • Public agencies not always headed by technically qualified persons but rather administratively qualified persons.

NGO's With Outreach Mandates That Include SWW Communities.

A & B ASSOCIATION OF PERSONS WITH DISABILITIES: Disability awareness and support group focussing on changing the attitude of society towards children and adults with disabilities and to improve the services available to persons with disabilities in Antigua.

ANTIGUA & BARBUDA MARINE ASSOCIATION: to develop, promote & protect the marine industry & environment.

ANTIGUA CONSERVATION SOCIETY : Newly formed organisation that advocates for the protection of Antigua & Barbuda's fragile coastal and marine ecosystems for current and future generations

ENVIRONMENTAL AWARENESS GROUP (EAG): A not-for-profit non- governmental organization focused on raising public awareness for the values of, and threats to, natural resources in Antigua and promote their sustainable management.

SPORTS, TRADE, INDUSTRY AND COMMERCE & CULTURE has the vision to become the premier catalyst for the reformation of the sporting, recreational and community-based governance systems in Antigua and Barbuda.

A & B COALITION OF SERVICE INDUSTRIES is an organization that facilitates the growth and sustainable development of Antigua and Barbuda's Service Sector to become internationally competitive.

In summary it can be seen that the community and the economy bring a dynamic interchange of assets and liabilities to the capacity equation. The value or weight to be placed on each requires its own detailed cost benefit study, assuming that that could be done. For it depends on many imponderables, as for instance the weight to be given to energy in contributing to climate change, as opposed to the weight to be given to human capital – education and knowledge and therefore technological progress over millennia. These are very difficult questions to assess, and perhaps the proof will rest in hindsight.

In Section 6, the Consultants will derive a working position on the vulnerability of the water sector to climate change in the SWW, and the vulnerability of the populations who reside in it and partially depend on it for their own sustainability.

5.5.2 *"The Old Road Community Dream"* - A Community Visioning Exercise

A Community Visioning Exercise was conducted in the Old Road Community with 8 persons in attendance. The exercise was very participatory with the main direction of the meeting being determined by the group. The community arranged the venue, and invited participants. The two consultants on hand, once having explained the purpose and processes, simply acted as facilitators.

The processes involved the following steps:

1. Participants were first asked to identify the vulnerability of their community to different climate related hazards (Figure 5-2).
2. Participants were then asked to each vision what their community would be like over a period of time agreed as 15 years.
3. Persons broke up into small groups to brainstorm the question from as many angles as they wished consistent with the general objective of achieving sustainable development against their knowledge of Climate Change.
4. The larger group was reconstituted and each participant was called upon to contribute the most important points they wanted to communicate to the group.
5. A community member with very good drawing skills had earlier sketched an outline of the community. This now became the planning map and ideas were sketched and allocated to their approximate spatial points.
6. At the completion of a robust discussion a common vision statement was created.
7. The final step was to Name the Plan with the name ***"****The Old Road Community Dream"* being adopted. The meeting ended by participants pledging to work together to continue the planning.

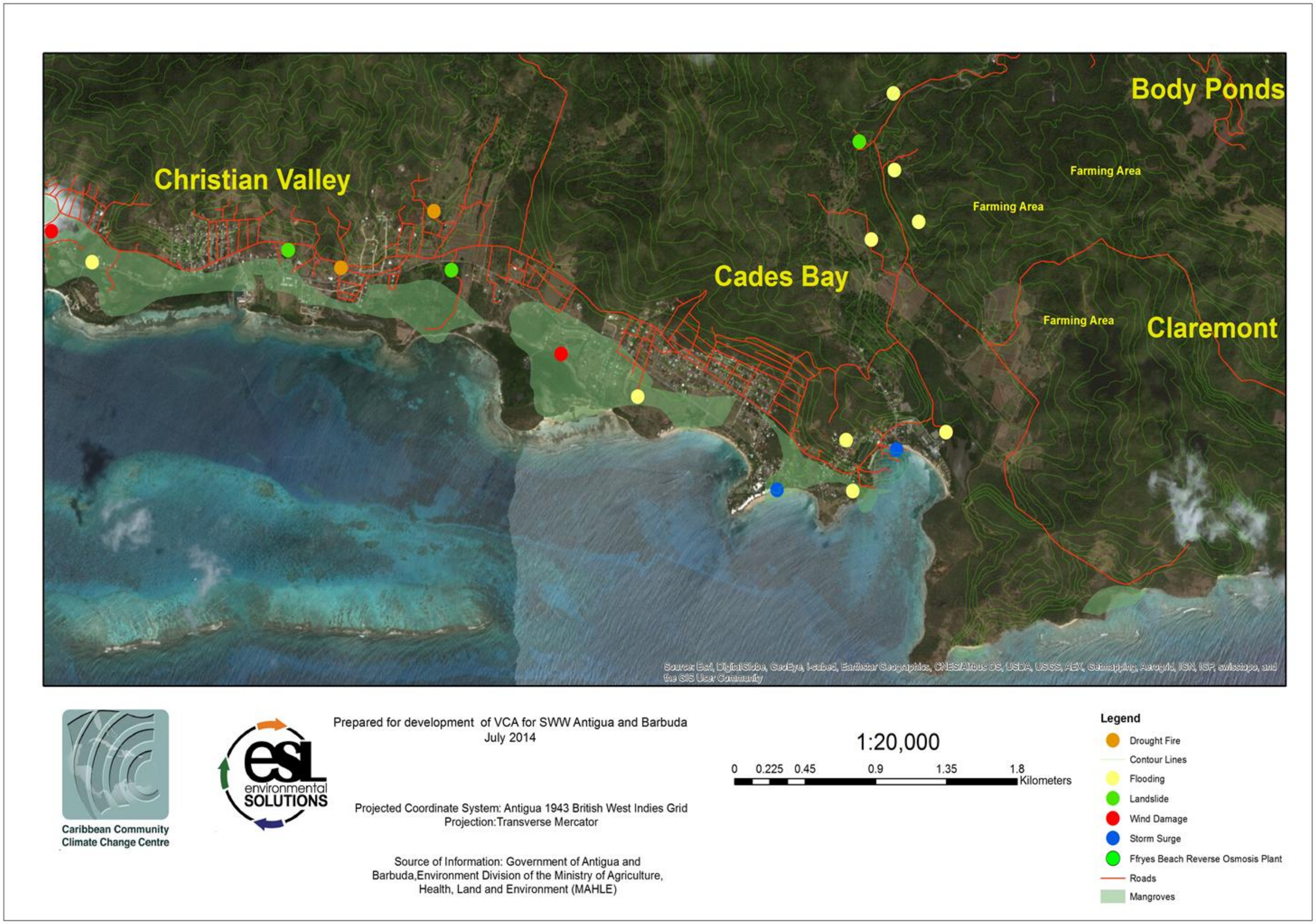


Figure 5-2: Perceived Vulnerabilities by Community Members in the SWW area

The Issues needing to be addressed in the Future

- Fig Tree Drive floods because of the large volume of water from too much rain. The slopes are very steep. Even if the drains were expanded it would not help much
- Major watershed to the north of the area and major dams as well- when these fill up because of a lot of rain they flow down into Fig Tree Drive area
- This community is close to the sea and the water will find its way to the sea affecting the community in the process
- The wall at Curtain Bluff and Carlisle Bay affects the movement of water off of the road into the sea causing flooding and making it worse in these areas
- People shelter in schools and churches but not all shelters have toilets etc. The shelters are adequate to stand up to storms but not to deal with hygienic issues and sleeping issues during and after the storm. Toilets might be in a different building.
- Carlisle Bay is the roughest beach on the island
- The area of Old Road is known as fruitful vale
- Everywhere in the SW suffers the same from drought
- Fires in the Urlings area in the hills due to the drought
- Fig Tree area- well known area for underground water and feeds the rest of the island

Proposed Solutions for Preparing the Future

Landslides

- Landslides that occur in the area occur because of steep sloped. There needs to be contour farming. They need to do contouring with grass
- Not enough vegetation on the slopes to hold the soils
- They need to do more tree planting
- There needs to be better farming practices, they need to stop slash and burn farming
- Maybe some walls can be put up along the edge of drains (gabion baskets)
- Drains need to be cleaned regularly and culverts need to be bigger

Storm Surge

- Nothing really can be done about storm surge because it is nature
- Protect the seas grass

Visioning *"The Old Road Community Dream"* in the next 15 years

- Agro-processing plant (for fruit)
- Landscaping along the highways
- Revive the farm areas
- Trails and Agro tourism (Historical sites)

- Wind Generator and Wind pumps
- Refurbish the Grace Bay school
- Refurbish the Sugar Mills for tourism
- Proper access and water main to the farms
- Renovate the Claremont Bluff
- Real Time Plantation Tourism
- Senior Citizen Centre
- Beach facilities installed
- Tourism for Wallings

5.6 Adaptability of the Water Sector in the SWW Area- Summary

It has been suggested that, as presently exploited, the climatic water resources of the SWW are insufficient to support both domestic water consumption and the economic requirements of the watershed, without augmentation by climatic water transfers or desalination. Considering the wetness of this area it suggests an urgent need to evaluate the feasibility of constructing more catchment areas.

The capacity of the communities and economy of the SWW area to deal with, and their resilience to, the impacts of climate change on the water sector is presented as a statement of assets that strengthens the social and economic fabric of the community and economy to cope.

In summary these assets are characterized as:

Physical Capital: This assessment based on physical infrastructure for rainfall harvesting and irrigation indicates that at the community level, irrigation assets are very poor and rainwater harvesting assets only fair. However, access to potable water is very good. Within the wider economy, the main economic drivers, the larger hotels, have in place desalination plants and rainwater catchment systems. Smaller hotels also rely on rainfall catchment systems as well. Large farms use catchment systems for irrigation while most small farmers use rudimentary rainfall harvesting to supplement limited irrigation.

Social Capital: As in community attitudes, associations and initiatives, are assessed as poor. Little real concern for, or understanding of, climate change is detected, and no community based funding initiatives were identified. However NGO's do exist that focus on community issues. Operating in the wider economy are active associations and agencies and in particular donor agencies in support of capacity building institutional strengthening and adaptation strategies.

Natural Capital: The communities view themselves as at a disadvantage re natural capital complaining that there needs to be more and improved constructed catchment areas in the SWW to offset the absence of natural ones. They also distrust the quality of APUA's supplied water but they accept that water rates are fair. More objectively, the SWW area covers just under 9,000 acres and enjoys a low population density of about 0.64 persons per acre as compared with 18 persons per acre in the capital city of St. John's. Also, the watershed is rich in biodiversity and offers a coastal zone that generates both employment and economic growth and income through tourism. In contrast there are no major surface water catchments. The consultants are of the opinion that relative to demand coverage the extracted output of climatic water is insufficient to meet this demand, and the alternative, desalinated water, is an expensive option. The natural capital re available and exploitable water resources remains unclear.

Financial and International Capital: Although development capital is critically short in relation to water sector and other pressing needs, Antigua and Barbuda is well supplied by banking and insurance companies that operate throughout the country. Collateral based as these institutions are creates a barrier to many community based financing needs. The case is therefore made for more effective micro lending schemes at that end of the funding market. At the opposite end venture capital lending is not easily arranged or available, except perhaps to the tourism sector. Government resources cannot meet the public sector needs yet alone, be supportive of private credit needs. Donor financing in the water sector appears to be mainly via studies and institutional strengthening reforms, though technical assistance to APUA has been noted.

Human Capital: There is a degree of resilience that resides in individuals that enables them to adapt to change and rise to challenges. It is underpinned by their degree of knowledge and understanding of the circumstances requiring resilience. Indicators of human capital are therefore education and financial capability as measures of empowerment. In this respect the population of the SWW presented the following profile (2011 Census). 88% of the parish populations had not progressed beyond a secondary education. On census day 38% of persons reported being unemployed. These conditions can be assumed to mitigate against empowerment although no actual measures can be ascribed. The economic sectors, particularly the main drivers tourism, commerce and agriculture are empowering of their workers and also have supporting associations and networks that strengthen their resilience. To this extent resilience at the community level and within the wider economy is likely to be considerably different. On balance the SWW area can best be characterized as having moderate to good resilience to the challenges of climate change.

Legislation, policy and the role of local institutions are very important in increasing the resilience of the community to climate change. There are a number of statutes that have some bearing on water, however, there is an absence or weakness of policies to guide development and management of land use, water resources or the coastal zone. There is a body of national legislation that applies to water resources but it has been developed piecemeal and is scattered through a wide range of legislation. Similarly there are various institutions that impact importantly on aspects of water resources. However, their ability to fulfill their mandates is sometimes significantly limited by staffing and budgeting issues. This means that their adaptive capacity is limited. With upgraded policy and legislation directed at managing water resources in light of climate change, the adaptive capacity of the area will likely increase significantly. This is because local institutions (both formal and informal) will then play an important role in building resilience and reducing vulnerability to climate change. These agencies are also the principal vehicle through which external support for adaptation (e.g., training and capacity building, etc.) is and will increasingly be delivered.

Table 5-5 presents a qualitative assessment of the adaptive capacity of the SWW area grouped under water supply management, agriculture, health and other interrelated impacts. In Section 6, the Consultants examine the issue of vulnerability, and derive a working position on the vulnerability of the water sector to climate change in the SWW. In particular on the vulnerability of the populations who reside in it and partially depend on it for their own sustainability.

Table 5-5: Summary of Adaptive Capacity

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 of the catchment systems already in place. However, this can be costly.	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.	Improve farming practices to reduce erosion and sediment flows. Can widen and do regular maintenance of the drains along the roadways.	Moderate
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise especially combined with increasing population growth. Damage to pumps and pipelines associated with corrosive effect of high salinity water.	Cannot do anything to stop sea level rise. Can reduce extraction from the wells but it would mean heavier reliance on desalination, which would then need to be expanded (a costly option).	Low
Meeting increased demand of water from population growth and economic	Reduction in annual average rainfall- more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	The water sector is already highly dependent on desalination because of already limited supply from	

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**
activities **Contribution of ground water likely to decrease relative to desalination.**			surface and groundwater. Capacity and storage can be improved by better maintenance of the catchment systems already in place (eg., Wallings Dam). However, this can be costly. Increased numbers of desalination plants can be an option but this is more costly.	Low
Poor watershed management	Increasing drought conditions	Increase in risk of forest fires which results in reduction of protective tree cover and reduction in infiltration.	Can extend the tree planting programme already in existence (costly for the Forestry Department alone). Can start a sensitization programme for farmers about burning and the importance of preserving the watersheds.	Moderate
Inadequate physical capital re water capture and storage infrastructure	Reduction in annual average rainfall- results in reduction in surface flows and reduced ground water recharge and ground water resources	Reduced capture and contribution of surface water to supply challenge and greater reliance on both ground water and desalination	Integrated water management system to reduce wastage and rationalize resources towards meeting demand, but in the medium to long run, physical capacity can be upgraded. This will be an expensive endeavor.	Moderate
AGRICULTURE				
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts	More frequent drought events will result in reduced crop yield.	Increase the use of dryland farming techniques and introduce the use of more drought resistance crops.	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**
			Increase the storage capacity of water specifically for farmers to be used by farmer groups.	
Poor dryland farming techniques	Increase in annual temperature and drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield.	Increase the use of dryland farming techniques such as mulching and introduce the use of more drought resistance crops. Increase the use of fruit trees on farms. Will also be useful in watershed management.	Moderate
Damage from heavy rainfall/storm events	Hurricane intensity expected to increase (not necessarily frequency)	Loss of crops, reduction in crop yield	Improve farming practices to reduce run-off. Consider wind resistant varieties of bananas (bigger trunks). Increase wind barriers.	Moderate
Brackish groundwater	Increased salinity in groundwater/aquifers	Reduced crop yield. Salinity in brackish well water will increase and wells with freshwater likely to become saline.	There would have to be reduction in the reliance on groundwater sources and heavier dependence on desalinated water which would be more expensive.	Moderate
HEALTH				
Pathogens (e.g., *E.*coli) present in cisterns & pollution of groundwater	Reduction in annual average rainfall- more droughts	Water Quality Issues	Develop & implement specific design criteria and operation and maintenance requirements for roof catchment systems. Develop mandatory	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**
			chlorination systems for cisterns. Increase testing of private cisterns. Establish routine testing of nitrates, chlorides and sodium (i.e. indicators of sewage and seawater impacts) in ground and surfacewater sources. Each of these measures will be costly.	
Heavy rainfall events results in flooding and the overflow of septic systems	Hurricane intensity expected to increase (not necessarily frequency)	Water quality and health issues	Improve drainage network. Develop specific design criteria for all new onsite/household sewage systems to protect groundwater and reduce the chance of washout during flood events. Develop and enforce sewage effluent standards for central/package sewage treatment plants. Develop Trade (Industrial) Effluent Standards. Each of these measures may take time and will be costly	Low
OTHER INTERELATED IMPACTS				
Unplanned development leading to unnecessarily expensive	Reduction in annual rainfall	Will exacerbate challenges of demand management and lead to more costly downstream choices for providing adequate water supply	Expensive to put in new infrastructure. May have to rely more heavily on desalination which is equally	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**
infrastructure development costs such as for water distribution			costly.	
Tourism sector- heavy users of water	Reduction in rainfall – more drought periods	Greater strains on water resources	Individual hoteliers will have to depend more heavily on privately sourced water - RO	Moderate

6 VULNERABILITY ASSESSMENT

The conceptual framework for climate vulnerability focuses on how different climate hazards affect agents and systems, and has three constituent elements: exposure, sensitivity, and adaptive capacity. Vulnerability to climate change is a function of biophysical outcomes related to variations and changes in climate variables, as well as of the socio-political and institutional factors that can vary significantly at a relatively fine scale (Adger, 2006).

6.1 South West Watershed Vulnerability

The climate modeling projections done for this study, indicate that Antigua is projected to experience a decrease in the total annual rainfall and generally drier conditions leading up to 2030. The projections also indicate an increase in the frequency of warm days and warm nights, and rainfall intensity may decrease accompanied by a slight increase in rainfall duration. The intensity of hurricanes over the north tropical Atlantic are likely to increase, however, the frequency of hurricanes may not necessarily increase. Additionally, sea level rise is expected by up to 0.24m by the mid-century. More specifically:-

- An increase in annual mean temperature, by 0.2 – 1.1 degree Celcius by 2030 and 0.4 – 2.1 degrees Celcius by 2060
- The southern region of Antigua (which includes the SWWA) will warm at a slightly slower rate than the northern region, so that by 2030 the north would warm by 1.195 degrees Celcius, while the south would warm by 1.083 degrees Celcius.
- September, October and November are expected to experience the strongest warming
- An increase in the frequency of warm days and warm nights
- A decrease in the frequency of cool days and cool nights
- A decrease in annual rainfall by approximately five percent, 5%
- A general decrease in rainfall intensity but slight increase in rainfall duration
- An increase in hurricane intensities
- An increase in annual wind speeds by up to 0.02m/s
- A rise in sea level by up to 0.24m by the mid century

The following table discusses the vulnerability of the main sectors of the economy.

Table 6-1: Vulnerability of the Sectors in the South West Watershed Area

VULNERABILITY	SECTOR	DESCRIPTION
High Vulnerability	**Agriculture**	The vulnerability assessment indicates that the Agricultural sector is highly vulnerable to more frequent droughts (which are likely) and longer droughts (which are almost certain). More frequent droughts are expected to result in less and lower quality crops & livestock production, decreased pasture growth and increased erosion of topsoil. Profitability and growth in the agriculture sector is also vulnerable to frequent and longer droughts. The level of threat is considered high to extreme and demands the attention at the most senior leadership levels of industry and government in collaboration with community groups and stakeholders, to make the necessary effective interventions, which are not currently part of routine activities. The impact can potentially be addressed through the implementation of a range of appropriate water conservation techniques and irrigation systems at sufficiently large scales or coverage, including drip irrigation mulching, water storage via rainwater harvesting and increased onsite water storage systems.
	Public Health & Public Safety	Public Health and Public Safety is highly vulnerable to increased intensity hurricanes, which are associated with flash floods, higher peak wind speeds. High wind speeds often results in falling trees, detached and air borne roofs and debris, which presents a very real risk of physical injury to the population. More intense hurricanes are expected to flood homes, hotels and access roads, restricting movement and endangering lives. Flooding of homes is often associated with flooding of onsite sewage facilities, which contaminates flood waters with disease causing organisms which increases the risk of disease contraction, particularly among young children and the elderly. The level of threat is high, indicating the need for the attention at senior levels of industry executives, agency management and policy development. More senior industry and government representatives need briefing and effective responses are usually transformational and not generally incremental routine action. The risk can be addressed by the implementation of improved building codes, developing a legal framework and regulations for the treatment and disposal of sewage at all levels, both the rural and urban context.
	Tourism	The profitability and growth of tourism in the SWWA is moderately vulnerable to more frequent and longer droughts. With the low tolerance for water shortage inconveniences by tourists and the economic importance of this sector, hotel operators and the government have made some adaptive responses which have alleviated

VULNERABILITY	SECTOR	DESCRIPTION
Moderate Vulnerability		some of the negative impacts of droughts on the tourist. The level of threat is considered high to extreme, as the assessment examines profitability, growth and the impact on the tourist market. This indicates that attention is needed at senior levels of the tourism industry (private and government) and in the area of policy development. The risk can be addressed by the hotel owners investing in private water supplies, APUA establishing arrangements to truck water to hotels strategically and at this time this sector benefits from the diversion of irrigation water to meet the water demands of the tourism sector. The diversion of irrigation water to the tourism sector is not considered an ideal or sustainable adaptive response, when considering the need to meet growth and development targets of the agricultural sector. Other adaptive responses must be explored to address the water supply shortfall of the tourism sector.
	Natural Resource Sustainability and the Environment	Watershed integrity in terms of forest cover, water quantity and water quality are moderately vulnerable to increased bush and wild fires. Wild fires remove vegetative cover and increases soil erosion by both wind and water. Soil erosion increases turbidity and siltation in surface reservoirs and ponds, thereby reducing water quality and water quantity through reduced storage capacity. The level of threat is considered high, as the consequences are considered major, ie. semi-permanent loss of environmental amenity and danger of continuing environmental damage. The risk can be addressed by the strategic planting of appropriate trees and grasses, which have fire retarding properties. More effective engagement of communities in the effort to reduce the instances of fires should also be pursued

.

6.1.1 Community

While the proceeding sensitivity and adaptability analyses indicate that both sexes will be impacted by the influence of climate change on the water sector, it is generally accepted, and a focus of concern, that women are at a particular disadvantage. Therefore, although several social related vulnerabilities are covered in this section, the vulnerability of females to climate change and water is given some focus.

The female population in the SWW is estimated to be 52% of total population, based on 2011 parish census data, it has grown by 3.7% in the inter-censual period. With respect to water scarcity women generally carry the burden of ensuring adequate household water for cooking bathing and cleaning. They arrange for its collection storage and allocation. In some drought conditions this amounts to assuming responsibility for rationing. Because they are the household's principal care givers, they are the principal health monitors and carry the burden of ensuring that adequate levels of sanitation are maintained. As many females are also heads of households they also carry the burden of being chief breadwinners. This role is particularly onerous because national dependency ratios indicate that just under half of any community's population is likely to be dependent on the rest.

With respect to more intense flooding and storm events, women are arguably the most affected by natural disasters, and the gender requiring the most support in the recovery period. Their lack of disaster management appreciation and coping skills combined with their lack of experience in the public spheres limit their ability to engage with relief and emergency response mechanisms that oftentimes ignore these realities. Women's main employment occupation in rural agricultural communities is often farming or farming dependent, and other (often hustling) occupations in the informal sectors. These sectors are often the worst hit by disasters resulting in the post disaster rate of unemployment among them being disproportionately high. More pernicious is their vulnerability to exploitation, physical, sexual and economic, because of male control over economic resources. Similarly, in Antigua and Barbuda social and cultural norms (Blacks/Whites/Chinese/Muslims/Hindu/Rasta) define acceptable 'womanly' activities in ways that are often inhibiting of their acquiring basic survival skills such as escaping, climbing, or swimming in facing flooding or storm surge risk.

Although the issues confronting Gender define their vulnerability to climate change, the women of Antigua and Barbuda are much better positioned than several of their regional counterparts and more so if the ALM countries are considered. For 2012, Antigua and Barbuda with a HDI of 0.760 placed 67 out of 187 countries and territories on the International Human Development Index (UNDP Human Development Report 2013) and is ranked equal with Trinidad and Tobago as one of the highest in the Anglophone Caribbean. However because of the lack of relevant data a Gender Inequality Index (GII) was not determined. The per capital GNI was $12,900 in 2013 (World Bank). On Census Day 2011, of the age group 15years and over, of those who reported being employed, females accounted for 51.5% . and males 48.5%. *(2011 Population and Housing Census. The Statistics Division.)* Similarly there are no laws that discriminate against females, and where a few older laws may still exist, judicial practice has long since surmounted them. Further, re the water sector, females (as also males) have always lived with water supply challenges. Culturally as community humour is quick to point out, community members have been *'living a lifetime of adaptation'*.

In assessing their sensitivity and adaptability in relation to their vulnerability, a balanced opinion would be that the women of the SWW are vulnerable on two main counts. Firstly, the risk shared by the general population to the discontinuities of climate change, such as flooding and hurricanes. Recommended adaptation strategies must therefore be: more adequate shelter provision; a more adequate security net as in affordable insurance and credit availability for recovery financing. Also, temporary unemployment compensation. Concurrently infrastructure to improve flood control and mitigate storm surge hazard must be put in place. Similarly programs of education that provide women with a better understanding of disaster and disaster management so as to build their coping strategies.

Secondly females in the SWW must be released from the metaphorical role of 'bearers of water' and the weight of that role in the household (most severe under conditions of drought). The state has a critical responsibility in this regard. APUA must establish a better accounting of its water resources and be accountable for optimizing its management of these resources. Unaccounted for water must be accounted for. Resort to desalination as the ultimate back up, must be evaluated not only in terms of foreign exchange expenditure but as an increased financial burden on community members of which females will carry a disproportionate share.

An inescapable reality is that relative to the current period, the future will see significant population numbers inhabiting a relatively fixed spatial area. In the broadest interpretation of social and economic carrying capacities, this challenges an immediate planning response to ensure the future wellbeing of the SWW communities and the area's economy, in which, the particular challenges and vulnerabilities faced by women must factor strongly.

Overall the prospects for women under conditions of climate change into the mid future, do not currently present themselves as being dire. But rather one of likely diminishing concern provided the business as usual option does not hold sway over programmed change.

The 2011 Census indicates that 48% of the population in the SWW parishes, is under 30yrs of age, of which approximately half are below the labour force age of 15yrs. Unless the population tree changes significantly, the expected trend is towards a younger population, given numbers and fertility rates. However much will depend on economic growth and its incentive to young person's not to migrate internally or externally. The significance of this is that young labour force populations have often not built up either the social networking or financial capital to have an adequate security net in the event of setbacks. A reasonable conclusion would be that close to half of the population in the SWW area comprise persons with a very limited and inadequate social security net. This should be qualified by noting that approximately 50% of the national population have some form of insurance.

6.1.2 Water Access

The relationship of the population of the SSW is estimated to be that 61% of households or 3,553 persons receive piped water into their homes. 291 persons or 5% of households source water from pipes in their yards, 406 persons or 7% of households source water from public stand pipes and 992 persons or 17% of households have cisterns (Section – 2.2.1.2).

By first world or more developed states standards we can establish these targets to challenge water management planning in the SWW (Table 6-2).

Table 6-2: Indicative Targets for Household Water Access

Percent of Household with piped water	100%
Percent of households sourcing water from pipes in their yard	0%
Percent of households sourcing water from public standpipes	0%
Percent of households with cisterns	100% in water poor environments

It is recognized that piped water into households may not necessarily mean potable water delivered from a treatment plant. However in relation to a basic targeted level of improvement, tap water available inside all dwellings is a minimum achievable goal as also all households having cisterns and utilizing rainwater harvesting strategies.

Two important questions follow. What are the conditions that describe vulnerability with respect to water access among the vulnerable population and given the impact of climate change on the water sector what are the future prospects for reducing this vulnerability?

The main issues relate to health and convenience. Other issues relate to interpersonal and communal tensions and security. With respect to health, open standing or stored water is a health hazard for washing cleaning and drinking in particular. The household practice is to transfer water from all the external sources eventually into open of even closed storage containers within the household. Perhaps in the worst case scenario, transporting water to kitchen and bathroom in the same container. Where cisterns exist, water may be stored there first. Although Antigua and Barbuda does not have water borne diseases, it is not immune to them. They do have water related diseases, such as dysentery, gastroenteritis and other non-potable water related illnesses. Further in poorer households water may be recycled for different purposes. Bath or sink water will be used for washing floors or crop watering.

Households without piped water require that water collection becomes a household routine. This often involves children as main lifters and bearers starting from a young age, with several attendant vulnerabilities.

As in other Caribbean countries where an important water source comes from community standpipes, a standpipe culture emerges in which women are often the disadvantaged. Pecking orders are established, most commonly where children are made to give way to adults, tensions arise which sometimes leads to violence, and a pervasive sense of dehumanization and being disadvantaged becomes normative . Personal security is also a consideration that women must additionally worry about.

In Antigua and Barbuda the percentage of the population with relatively easy access to water is much better than in countries generally characterized as water starved. Nevertheless the objective reality of water bearers is one of being vulnerable. Under conditions of climate change, where water resources will come under greater stress, then, unless much greater focus is put on water management and the improvement and expansion of existing water distribution systems, the described vulnerabilities will persist.

Of the population, it is estimated that in the SWW, 1,160 persons or 20% of the population categorize themselves as having some disability whether of sight, hearing, walking or memory. Of this number 883 or 15% are likely to have access to care, while 277 or 5% are likely to be their own care givers (Section 4.1.6.3)

The water related challenges of households are considerably exacerbated where some members have disabilities. More so where the disabled are their own care givers. In all instances, but more so in the case of the latter, piped water into such households is arguably a moral imperative for the Government.

It requires little elaboration that under conditions of climate change, where water resources will come under greater stress, then the described vulnerabilities assume even greater importance.

As a percent of the population (20%) persons having some disability, constitute a significant sub set, which typically but not necessarily, goes hand in hand with ageing, another vulnerable subset. As the population grows, in accordance with SRES projections for Antigua and Barbuda, the number of persons with disabilities will increase. The appropriate mitigation strategies must include a combination of improved household livelihoods, better community health services particularly in-home care services, and improved and expanded water distribution systems that enhance rather than diminish the water security of this challenged population.

6.1.3 The Economy and Vulnerability

*Tourism has been established to be a main driver in the national economy and, because it is a visibly important sector in the SWW, it can be reasonably inferred, in the absence of regional GDP data, to be equally important to the economy of the watershed (*Section 2.2.1.4).

Therefore in assessing the vulnerability of the SWW economy to the impact of climate change on the water sector, tourism must be a focus. An appropriate economic simile would be that tourism is an exogenously dependent export with the SWW being one plant through which it is processed. A gauge of the importance of tourism to the SWW is that the area comprises close to 20 main entities either fully partially or intending to be engaged in tourism. There are 7 main hotels. National average employment in tourism both directly and indirectly is estimated at about 68% of the labour force (Caribbean Hotel and Tourism Association (CHTA). The report, titled "Travel & Tourism Impact 2011") which can be shown to equate to about 1 person in 4.5 of the population. By comparison Jamaica's tourism impact on employment is about 24% of the labour force. In the absence of better data, it can further be inferred that tourism related employment in the SWW engages some 1,295 persons.

That established, the important questions remain; what are the conditions that describe vulnerability with respect to the impact of climate change on the water sector and given these conditions, what are the future prospects for reducing this vulnerability?

The direct impact of tourism on water resources is negative. The average tourist consumes about 5 times the amount of water per capita than nationals. Therefore in a scenario where the water sector is threatened by climate change conditions, tourism puts a disproportionate strain on the demand for water resources. Further water is a costly expense to hotels dependent as they are on desalinated water. For properties that cannot afford their own desalination plants, their operational challenges, including level of services offered and operating expenses, are intrinsically tied to water availability. In discussions with hoteliers operating in the SWW, it was emphasized that holidaying tourists generally have a low tolerance threshold for poor water services and while showing understanding of conditions will not readily return to the property. Visitor arrivals are less sensitive to hurricane events, since the high travel periods tend to begin after the end of the traditional hurricane season. Hotel infrastructure, particularly beach areas are at high risk from hurricane events and storm surge. Although experience has enabled some planning, and reasonably effective recovery strategies, predicted climate change storm events make low lying coastal properties vulnerable. To date, most coastal hotels have had to deal with beach erosion and loss due to sea level rise. It is recognized as an ongoing and increasing challenge in the sector.

The future prospects of reducing the vulnerability of the tourism sector to climate change, lie mainly in the following directions; ensuring structural integrity of buildings to wind events; with respect to the water sector, design retrofitting where necessary to accommodate storm surge and desalination, with increasing attention to water and energy conservation.

Currently about 25% of all capital investment in Antigua and Barbuda is in tourism. Investors are concerned about protecting their investment against conditions of climate change and are increasingly resorting to best building practices, shoreline modification strategies and water conservation methods, to ensure this. A complimentary adaptation movement is the international tourism market towards green tourism. Several hotel properties in Antigua have been going for partial and complete green certification.

Overall the longer term prospects for Tourism in Antigua and Barbuda continue to be good even in the face of current climate change scenarios. It is a premier tourism destination in the Eastern Caribbean and the Caribbean region has continued to be a favorite travel destination in major economies. This will rebound to tourism in the SSW. The appropriate adaptation strategies must be implemented and must be complimented by adaptation strategies that ensure the strengthening of other critical areas of the economy such as energy industry and commerce.

6.1.4 Agriculture

"The agriculture economy of the SWW comprises mainly small farming plots some with livestock (Section 4.1.5.5).

The vulnerability of the farming community to climate change is directly related to the availability of water for cultivation and husbandry, and storm water in relation to damage to crop and livestock. All other impacts are relatively less important. By these criteria, farmers in the SWW must be considered highly vulnerable. This is because surface water is almost non existent in the SWW, well water is highly controlled by APUA and water supplied by APUA although supplied well below its economic cost, is in the context of irrigation and profitability, very expensive. Also under climate change conditions drought will become more intense. Similarly wind and flood events mainly occasioned by passing storm systems, have been traditionally, very destructive to agricultural production.

What are the strategies that can be employed to reduce this vulnerability to these different agents?

With respect to the availability of water, it is important that every effort be made to examine the hydrological possibilities of constructing more reservoir areas. It is also important that distribution inefficiencies resulting in inadequate water pressure and burst mains be identified and rectified. Similarly programs of watershed protection and development must be fast-tracked.

Likewise due to saltwater intrusion into the aquifers, particularly on farms bordering the coastal zone, it is necessary that further research be undertaken to determine appropriate strategies for reduction/ redistribution of abstraction points, and aquifer recharge as a buffer to saline intrusion. It might also be desirable to assess the feasibility of groundwater desalination and whether the risk of exacerbating saline intrusion.

In relation to cultivation and animal husbandry. Increased and improved irrigation practices and farm water are very dependent on improved water supply which is mainly an APUA challenge to address. However with the appropriate technical assistance farmers must be encouraged to:

- Investigate important pests and plant diseases including weeds to the impact of climate change. These have important consequences for crop yield.
- Investigate genetic diversity within crop types that might be better suited and utilized to compensate for climatic variability.

- Engage local and international expertise in areas such as: plant breeding; agrochemicals and fertilizers; irrigation and agricultural equipment and farm supplies on the implications of climate change.

- Investigate the use of alternative water sources such as grey water and treated sewage effluence.

- Investigate improved water harvesting systems.

6.1.5 Poverty

It has been established that poverty equates to vulnerability. The Consultants estimate that the indigent population of the SWW is about 4%. At its core, indigence means existing at the minimal means of existence. The pertinent questions however are:

What are the conditions that make indigent persons vulnerable to the impact of climate change on the water sector and given that impact what are the future prospects for reducing this vulnerability?

Table 6-3 addresses the first question with respect to the relationship between indigent persons and the water sector

Table 6-3: The relationship between indigent persons and the water sector

INDICATORS OF INDIGENCY	PERCENT OF HOUSEHOLDS	VULNERABLITY
No Adult Employed in Household	21	• Indigents likely to be recipients of social water or dependent on contributed water (shared by others) or stolen water. In conditions of reduced supply, the indigent are most likely to experience critically reduced access to water • Hygiene considerations are secondary to food water shelter. Potable water may be available for drinking but contaminated water is likely to be used in all other circumstances. • Most likely to have no sanitary facilities and use pit latrines contributing to eutrophication issues. • Source of water stand pipe and or insanitary rain harvesting efforts. • Waste disposal practices poor and environmental issues assume no or very low priority. • Humane vectors for communicable diseases.
Insufficient Employment	26	
Poor access to drinking water	6	
Poor Quality of Housing	23	• Roofing material improvised or makeshift or tarpaulin. • No source of light • Habitats for water dependent vectors

		• No or low resilience to heavy rainfall or more serious disasters, such as flooding and storm events. • Disproportionate requirement for recovery assistance • Improper land tenure or squatting • Complicates efficient land use planning and resource planning.

What therefore are the future prospects for reducing this vulnerability?

The vulnerability of Indigents to the impacts of climate change on the water sector, cannot be sustainably mitigated short of the eradication of poverty. This makes the condition of poverty one of the most intractable and challenging social and economic problems to overcome in the environment.

According to the *United Nations Sustainable Knowledge Platform* no uniform solution for poverty exists. However there are certain targeted policy actions that have to be implemented if it is to be eradicated. Priority actions on poverty eradication include:

1. improving access to sustainable livelihoods, entrepreneurial opportunities and productive resources;
2. providing universal access to basic social services;
3. progressively developing social protection systems to support those who cannot support themselves;
4. empowering people living in poverty and their organizations;
5. addressing the disproportionate impact of poverty on women;
6. working with interested donors and recipients to allocate increased shares of ODA to poverty eradication; and
7. intensifying international cooperation for poverty eradication

The relationship between several of these priority actions, and the protection of water resources and adaptation strategies to climate change, reflect an interesting congruency. This is because in relation to changing and preparing the human condition to confront climate change, the operative mechanism must be social reengineering. Social engineering is not poverty alleviation, neither is it adaptation to climate change. It is essentially changing behavior towards achieving the required harmonization of human development with the environment as a condition of influencing and reversing climate change.

Several of the action strategies enumerated above and in earlier sections, can be read as key components of this desired objective. As social reengineering relates specifically to the water sector in Antigua and Barbuda and by extension in the SWW, an important challenge will be the implementation of an integrated total water management program that achieves a high level of buy-in from the communities it will benefit.

In the Table 6-4 that concludes this section of the report, a summary of the main vulnerabilities of the SWW area to the impact of climate change on the water sector will consolidate the findings of the other main sections.

Table 6-4: Vulnerability Assessment- Summary

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of Sensitivity	Adaptive Capacity	Vulnerability
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 (Water supply is sensitive to decrease in rainfall and increase in annual temperature)	Moderate- (Measures can be costly)	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 (Increase in hurricane intensity expected to increase flooding and damage to infrastructure)	Moderate- (Farming practices can be improved, and drainage can be improved)	Moderate
Over extraction of wells resulting in saline intrusion	Increase in sea level	Water quality problems may arise especially combined with increasing population growth.	High (Wells are sensitive to sea level rise and demand)	Low (nothing can be done to stop sea level rise)	High
Meeting increased demand of water from population growth and economic activities- Current yield of groundwater in SWW	Reduction in annual average rainfall- more droughts	Reduction of water supply from rain fed sources (groundwater and surface water storage areas)	High (heavy reliance on desalination to meet demand)	Low (adaptive measures can be costly	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of Sensitivity	Adaptive Capacity	Vulnerability
approximately half per capita consumption. Requirements. Contribution of ground water likely to decrease requirements.					
Poor watershed management	Increasing drought conditions	Increase in risk of forest fires which results in reduction of protective tree cover and reduction in infiltration.	Moderate (There is a tree planting program already in place)	Moderate (adaptation measures can be costly)	Moderate
Inadequate physical capital re water capture and storage infrastructure	Reduction in annual average rainfall- results in reduction in surface flows and reduced ground water recharge and ground water resources	Inadequate capture of rainfall with growing population will likely result in reduced supply or heavier dependence on desalination.	High	Moderate (adaptation measures can be costly)	Moderate
AGRICULTURE					
Heavy dependence on rainwater	Reduction in annual average rainfall- more droughts	More frequent drought events will result in reduced crop yield.	High (primarily dependent on rainwater)	Moderate (techniques can be improved but measures may be costly)	Moderate
Poor dryland farming techniques	Increase in annual temperature and drier conditions	Increased evaporation combined with drier conditions and poor farming practices will result in reduced yield.	High	Moderate (techniques can be improved but measures may be costly)	Moderate
Damage from heavy rainfall/storm events	Hurricane intensity expected to increase (not necessarily frequency)	Loss of crops, reduction in crop yield	Moderate	Moderate (Improved farming practices can reduce vulnerability)	Moderate

Current Stresses	Projected Stresses from Climate Change	Projected Impact of Changes to the Systems *(without preparedness action)*	VULNERABILITY ASSESSMENT		
			Degree of Sensitivity	Adaptive Capacity	Vulnerability
HEALTH					
Pathogens (e.g., *E.*coli) present in cisterns & pollution of groundwater	Reduction in annual average rainfall- more droughts	Water Quality Issues	Low (chlorination is already done in the form of tablets)	High (chlorination systems will now be mandatory)	Moderate
Heavy rainfall events results in flooding and the overflow of septic systems	Hurricane intensity expected to increase (not necessarily frequency)	Water quality and health issues	Moderate	Moderate (drainage network can be improved but it can be costly)	Moderate
OTHER INTERELATED IMPACTS					
Unplanned development leading to unnecessarily expensive infrastructure development costs such as for water distribution	Reduction in annual rainfall	Will exacerbate challenges of demand management and lead to more costly downstream choices for providing adequate water supply	Moderate	Moderate	Moderate
Tourism sector-heavy users of water	Reduction in rainfall – more drought periods	Greater strains on water resources	Moderate	Moderate	Moderate

7 RECOMMENDATIONS

The recommendations in this section are generally, but not in all instances, sequenced in accordance with the main sections of this report, Sensitivity, Adaptability and Vulnerability. The recommendations are grouped according to Water Resources and Management, Socio-Economics and Institution and Legislation.

The recommendations arising directly from this Vulnerability and Capacity Assessment are presented in Table 7.1 However, it is to be noted that this south west watershed study is a companion document to the National Adaptation Strategy and Action Plan for Antigua and Barbuda (NASAP) which has studied the impact of Climate Change on the Water Sector of Antigua and Barbuda. The NASAP therefore contains several recommendations that will have an important bearing on the water sector in the south west watersheds. In Table 7.2 the Consultants have highlighted the main supporting recommendations in the NASAP report in an attempt to keep both sets of recommendations in their appropriate context. It is hoped that this approach will accommodate the desirability of differentiating stand-alone recommendations for the VCA based on assessing the watersheds study area, from recommendations arising from studying the water sector at the national level which will nevertheless importantly impact the water sector in the watersheds. To prevent unnecessary repetition some recommendations that are obviously generic to both have been excluded from Table 7.1. Table 7.1 did not include costs because this was not a requirement of the study.

7-1: Table of Recommendations from the VCA

WATER SECTOR ISSUES	RECOMMENDATIONS	RECOMMENDED TIMELINE
Water Resources and Management	• Cleaning badly silted reservoirs and ponds that form part of the water supply system to the SWW. *This recommendation concurs with the National Stakeholder Consultations on Water: Supporting the Post-2015 Development Agenda.* • APUA must establish a better accounting of its water resources and be accountable for optimizing its management of these resources; unaccounted for water must be accounted for. • Through its responsible ministries the Government should create an education campaign focused on training farmers, improved farming practices to include water conservation measures such as mulching, etc.	Short to Medium term
Socio Economic	• The Consultants support the early creation of an appropriate funding mechanism for supporting the environment to include the water sector, solid waste management and health. Note should be taken of innovative taxation measures in other member states. For example, special issue taxes like the Green Fund Levy in Trinidad and Tobago or consumptive taxes channeled through enabling agencies. For example The Institute of Sports (INSPORTS) Jamaica. • The requirements for granting incentives to the Tourism sector, under the Tourism & Business Special Incentives Act (2013) should emphasize water and energy conservation. This could be done using the Act's requirement for an Environmental Impact Assessment to accompany applications, and ensuring that these two issues are elevated a high technical design and monitoring priority in such assessments. • At the community level, the indigent population is estimated at 3.7 % and other vulnerable persons including the disabled at 24. 6%, representing 2.8 persons in every 10 with special vulnerabilities. It is recommended that the Government undertake a case by case review of these persons so as to better document their vulnerabilities and putting in place an adequate system of welfare and livelihood protection. This should commence immediately so as to improve their capacity to cope with climate change and its anticipated impact on the water sector. • Through its responsible ministries the Government should create community targeted programs to support resilience building to climate change. One important objective of these programs should be to improve physical infrastructure for rainfall catchment and irrigation systems within each	Short Term Short Term Short Term Short Term

WATER SECTOR ISSUES	RECOMMENDATIONS	RECOMMENDED TIMELINE
	community, particularly with the objective of encouraging the increase of acceptable rain harvesting facilities in dwellings. • Encouragement of community mobilization programs to tap into and build the social capital resources available. Since direct government intervention in and any attempt at the control of social capital is the antithesis of the autonomy linkages and trust that build social capital, local administrations will need to shift their emphasis from regulator and provider to new roles as facilitator (Crocker et al., 1998). Support for 'Better Village' type programs, sports programs and infrastructure, classroom interventions and the building and maintenance of functional community centers are interventions that support communities developing internal and external networks. • The capacity of women to perform their role as care givers must be given more direct support. This means for example: more adequate shelter provisions against unfavorable climatic events. A more adequate security net as in affordable insurance and credit availability for recovery of loss financing. Temporary unemployment compensation. • Infrastructure to improve flood control and mitigate storm surge hazard must be put in place. • Programs of education that provide women with a better understanding of disaster and disaster management so as to build their coping strategies	Short to Medium Term Short to Medium Short to Medium Short to Medium
Legislation and Institution	• The capacity of local institutions is very important because they play an important role in building resilience and reducing vulnerability to climate change. Where possible, external funding can be sought to allow for the institutions to carry out their mandate as best as possible. • A climate change policy should be developed by the Government. There needs to be a link between the climate change policy and the water policy. • The Watershed Policy and the Water Policy should be revised to take into account climate change considerations. • The Physical Planning Act should be amended to make it a mandatory requirement for the DCA to consult with the Agricultural Department where a proposal for built development is adjacent to, or in the environs of agricultural land so as to determine the impact which built development will have on agricultural production on surrounding land. • The Water Resources Act needs to be enacted.	Short Term Short Term Short Term Short Term

WATER SECTOR ISSUES	RECOMMENDATIONS	RECOMMENDED TIMELINE
	• Revise the Public Health Act to provide for comprehensive framework for pollution and promulgate regulation and promulgate regulations to deal with water quality standards. • The enactment of the Environmental Management Act is of critical importance for establishing a framework for environmental management. The Act however, needs a number of significant revisions. The draft Bill also needs to be reviewed in order to avoid overlaps with the Physical Planning Act and other legislation. • The proposals for the enactment of a Meteorological Act need to be implemented. • A new Forestry and Wildlife Act should be enacted which would address watershed management issues. • The Physical Planning Act should be amended to make it a mandatory requirement for the DCA to consult with the Agricultural Department where a proposal for built development is adjacent to or in the environs of agricultural land, to determine the impact which built development will have on agricultural production on surrounding land. • Carry out a feasibility study to establish an agency with a clear mandate to manage all water resources for Antigua and Barbuda including a mandate to develop and manage in particular all watershed areas.	Short to Medium Term Short Term Immediate Short Term Immediate Short Term Short to Medium Term

Table 7-2: Main Supporting Recommendations of the NASAP Study

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
To develop a Watershed Master Plan	Detailed mapping of the different soil types of the watersheds, spatial variability and depth range of different soil types. Analyse satellite data for change in soil pattern and ground truth with field data. Improve the landuse classification system as per the standards used in the Caribbean and update the landuse map for each watershed. Note the change in the landuse pattern for the last 10 years from satellite images as well as from aerial photographs Prepare draft Watershed Plan Consultations	Short- Medium Term	$195,000	GWP-Caribbean	Lead Agency : Environment Division Partner Agency: APUA, Ministry of Agriculture, Lands Fisheries and Barbuda Affairs.
To develop a Water Resource Master Plan	Review and update the existing water resources master plan/report.	Short- Medium Term	$50,000	GWP-Caribbean	Lead Agency: Environment Division Partner Agency: APUA

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	New water resource report or master plan should take into account the impact of climate variability, land use change and impact of increase in urbanisation and population on the available water resources. Prepare draft Watershed Plan Consultations Implement the new water resource master plan.				
To amend the Physical Planning Act	Engage consultant to identify the gaps Prepare amendments to Physical Planning Act to include among other things, ponds that should be protected Consultations Approval by Attorney General's office	Short term	$30,000	IDB/ CDB	Lead Agency: Physical Planning Partner Agency: Attorney General's office

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	Cabinet approval Submission to Parliament Parliamentary approval				
To prepare and finalize Local Area Plans to prevent development in areas that compromise water resources such as building in recharge areas, slopes and water ways and squatting.	Conduct local land use assessments for the major zones as defined from the Sustainable Island Resource Management Zoning Plan for Antigua and Barbuda to prevent development in areas that compromise water resources. Map local land use areas and develop local area plans.	Short term	$75,000	GEF/ UNDP/ CDB	Lead Agency: Environment Division Partner Agency: Development Control Authority
To conduct a feasibility study to create a water resources agency for Antigua and Barbuda with a mandate to manage all water resources and watershed areas	Engage Consultant Carry out feasibility study to create a new water resource agency- to include costs and potential source of funding for the new agency.	Medium Term	$75,000	CDB	Lead Agency: Office of the Prime Minister, Ministry of Health and Environment Partner Agency: Attorney General, Environment Division

OBJECTIVE	**ACTIVITIES**	**TIMELINE**	**FUNDING**		**RESPONSIBLE AGENCIES**
			Indicative Costs (US$)	**Potential Source of Funding**	
To develop water-budgets for each major watershed.	Calculation of water-budgets for each basin for each month and then final yearly water budget. Continuous analysis of the water budget using the rainfall, evaporation and storage data for effective management of water availability and projection into short, medium and long term time periods	Short Term- to be continuous assessment	- (If additional technical assistance is required that would have to be costed for separately)	Technical Skills in house (APUA)	Lead Agency: APUA
To build capacity for the National Disaster Management Agency in several aspects of disaster management	Liaise with USAID and CDEMA to conduct training workshop to improve several aspects of disaster management including: damage mitigation, community disaster management and flood preparedness. Include the volunteers and staff to be trained as community emergency first responders. Seek out scholarship programmes from institutions such as: Commonwealth Scholarship Caribbean, and International	Short term Short term	$80,000 TBD (Depending	European Community Humanitarian Office (ECHO)/ Canadian Caribbean Disaster Risk Management Fund / CDB/ IDB	Lead Agency: National Office of Disaster Services (NODS) Partner Agency: Environment Division

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	Universities that offer Degrees in Disaster Management, Continuity Management and other areas arising Source and purchase key equipment needed for NODS Identify various storage locations for emergency equipment and renovate facilities as required	 Short term Short term	on Program and University) TBD (Depending on price of equipment needed) 20,000		
Additional and upgraded water storage catchment systems	Consultancy to carry out the following tasks: 1. An assessment of all surface water storage systems. 2. Determine if there is a need for additional storage or if upgrading the existing storage systems would be adequate. 3. Determine the needs to upgrade and improve the existing storage catchment systems. 4. Conduct a cost-benefit analysis on the options Prepare tender documents for the feasible options should be	Short Term Medium Term	$100,000	CDB/ GWP-Caribbean/ IDB	Lead Agency: Environment Division Partner Agency: APUA, Ministry of Agriculture, Lands Fisheries and Barbuda Affairs, Public Works.

OBJECTIVE	ACTIVITIES	TIMELINE	FUNDING		RESPONSIBLE AGENCIES
			Indicative Costs (US$)	Potential Source of Funding	
	prepared Engage consultants to carry out either de-silting exercise or improvement of drainage ways etc. Consultancy to do an assessment of the watershed areas for the water storage catchments that are being upgraded- focusing on geology, slope stability, farming practices etc.	Medium Term Medium Term	To be determined based on the options chosen $150,000		

Note: On-going Immediate Short term= 1-3 yrs Medium= 3-5 yrs Long term= > 5 yrs

REFERENCES

Adger, W.N. 1999. *Social Vulnerability to Climate Change and Extremes in Coastal Vietnam*. World Development 27(2), 249-269.

Adger, W. N., Paavola J., Huq S., and Mace M.J. (Ed). 2006. *Fairness in Adaptation to Climate Change,* The MIT Press, pp1-19.

Brown, D. 2013. *Climate Change Threatens Water and Food Security in Antigua.* Inter Press Service News Agency.

Cadogan, P. 2001. *'Drought Hazard Assessment and Mapping for Nevis: Post Georges Disaster Mitigation Project in Antigua and Barbuda and St Kitts and Nevis'*, (OAS and USAID): Quoted from article 'Extreme Weather Distresses Regional Farmers, Caribbean Edition, Executive Time, Pg 13.

CARIBSAVE. 2012. *CARIBSAVE Climate Change Risk Profile for Antigua and Barbuda, Summary Document*.

Campbell, D. 2006. *Tourism in the Caribbean: An Environmental Concern.* http://jrscience.wcp.muohio.edu/fieldcourses06/PapersMarineEcologyArticles/TourismintheCaribbean.AnE.html.

CEHI. 2011. *A National Integrated Water Resource Management (IWRM) Policy for Antigua and Barbuda.*

CEHI. 2008. *Proceedings National Symposium on Integrated Water Resources Management and Rainwater Harvesting Antigua and Barbuda*, Caribbean Environmental Health Institute (CEHI), the Antigua Public Utilities Authority (APUA), The Global Environment Facility-funded Integrating Watershed and Coastal Areas Management (GEF-IWCAM) Project and the United Nations Environment Program (UNEP), St. John's, Antigua.

Convention on Biodiversity. Country Profile: Antigua and Barbuda. 2012. (http://mail.cbd.int/countries/profile/?country=ag)

ECLAC. 2007. *Overview of the Water Profile and the Capacity of National Institutions to Implement IWRM*, ECLAC Report

Emanuel et al., Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations. *Bull. Amer. Meteor. Soc.,* **89,** 347–367; DOI:10.1175/BAMS-89-3-347.

FAO, 2000. *Irrigation in Latin America and the Caribbean in Figures*. Water Report 20. http://www.fao.org/nr/water/aquastat/countries_regions/atg/index.stm

Feenstra, J. & Burton, I. (1998) *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies.*

Government of Antigua and Barbuda. 2001. *Natural Hazard Mitigation Policy and Plan.* Washington D.C.: USAID and the Organization of American States (OAS).

Halcrow, Sir William and Partners. 1977. *An engineering study of the water resources of Antigua.* Volume 1 - 4, Min. of Overseas Development, London, UK.

Hodgkinson-Chin, E. 2001. *Drought Hazard Assessment and Mapping for Antigua and Barbuda :Post-Georges Disaster Mitigation Project in Antigua & Barbuda and St. Kitts & Nevis*. Organization of American States, Unit for Sustainable Development and Environment for USAID-Jamaica/Caribbean Regional Program.

Hill, I. 1966. *Soil and Land Use Surveys No. 19A & 19B: Antigua and Barbuda*, Regional Research Centre, UWI, St. Augustine, Trinidad.

IPCC, 2013: Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Island Resources Foundation (IRF). 1991. *Antigua and Barbuda Environmental Profile*

Jackson,I. 2001. *'Drought Hazard Assessment and Mapping for Nevis: Post Georges Disaster Mitigation Project in Antigua and Barbuda and St Kitts and Nevis'*, (OAS and USAID)

Kairi Consultants Ltd. 2007.L*iving Conditions in Antigua and Barbuda: Poverty in a Services Economy in Transition*. Volume I- Main Report. The Caribbean Development Bank

Lindsay, K & Baldwin, K. 2011. *Marine Biodiversity and Natural Resources Assessment for the Assessment and Mapping of the Southwest Region of Antigua, Island Resource Foundation*

Rodrigues, Ivan. 2004. *Antigua Public Utilities Authority: Water Resources Assessment of Dominica, Antigua and Barbuda*, *St Kitts & Nevis.*

Simpson, M. C., Clarke, J. F., Scott, D. J., New, M., Karmalkar, A., Day, O. J., Taylor, M., Gossling, S., Wilson, M., Chadee, D., Stager, H., Waithe, R., Stewart, A., Georges, J., Hutchinson, N., Fields, N., Sim, R., Rutty, M., Matthews, L., and Charles, S. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - Antigua and Barbuda. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

Taylor, M. A., Centella, A., Charlery, J., Borrajero, I., Bezanilla, A., Campbell, J., Rivero, R., Stephenson, T. S., Whyte, F., Watson, R. 2007. *Glimpses of the Future: A Briefing from the PRECIS Caribbean Climate Change Project*, Caribbean Community Climate Change Centre, Belmopan, Belize. 24 pp.

Taylor, M. A., D. B. Enfield, and A. A. Chen, 2002: *The Influence of the tropical Atlantic vs. the tropical Pacific on Caribbean Rainfall*. Journal of Geophysical Research, 107(C9) 3127, doi:10.1029/2001JC001097

Taylor, M. A. and E. J. Alfaro (2005). *Climate of Central America and the Caribbean*. Encyclopedia of World Climatology. J. E. Oliver. New York, Springer-Verlag: 183-189.

UNCCD Draft National Action Plan for Antigua and Barbuda by Technical Committee, 2005

UNDP Project Document, *Demonstrating the Development and Implementation of a Sustainable Island Resource Management Mechanism in a Small Island Developing State.* PIMS 1899 ATLAS Project ID: 00053747)

US Army Corps of Engineers, 2004. *Water Resources Assessment of Dominica, Antigua and Barbuda, St Kitts & Nevis*

ANNEXES

ANNEX 1: LIST OF STAKEHOLDERS

STAKEHOLDER GROUP	POINT PERSONS
Environment Division	Jason Williams, Devon Burke, Nneka Nicholas, Mr. Christian, Dr. Helena Brown, Delamine Andrew
APUA	Ivan Rodrigues
Ministry of Agriculture, Housing, Land and Environment	Representatives from Lands Division, Forestry, Agriculture Extension Division and Ministry of Agriculture
Central Board of Health	Lionel Michael
Statistics Division	Juan Gardner
National Office of Disaster Services	Philmore Mulling
Farmer Group	Derrick Jackson – Orange Valley- Livestock Lenry Josiah- Claremont- Livestock and crops Byron Francis- Cades Bay-Livestock Dian Gones- Vet and Livestock Division
Women's Group- Women Against Rape (WAR) and Professional Organization for Women in Antigua and Barbuda	Alexandrina Wong- Women Against Rape (WAR) Giselle Isaac- POWA (Professional Organization for Women in Antigua and Barbuda)
Urlings Fishing Group	8+ fisherfolk
Individual Community Members	From Ffryes, Crabb Hill, Urlings, Old Road, Pares Village, John Hughes Community, Willikies,
Old Road Community	8 persons
Bolans Community Group	
Public Works Department	Mr. Pile
Hoteliers	Tamarind Hill – Rufus Gobat Curtain Bluff
Extension Officer	Ikah Fergus
Environmental Association Group	Dr. Cooper

ANNEX 2: NATIONAL WORKSHOP STAKEHOLDERS

October 15, 2014- NODS Conference Room

NAME	ORGANIZATION	EMAIL	TELEPHONE
Winston McCalla	ESL	Vin5002001@yahoo.com	876-999-9639
Eleanor Jones	ESL	ejones@eslcaribbean.com	978-9519
George Campbell	ESL	oeg@hotmail.com	978-9519
Theresa Rodriguez	ESL	trodriguez@eslcaribbean.com	978-9519
Joseph McGann	CCCCC	jomac31@yahoo.com	501-8222-1094
Karel Forde	Ministry of Finance	karelforde@gmail.com	462-2469
Ruth Spencer	GEF/SGP	rvspence@hotmail.com	783-7286/ 461-0325
Krishma Primus Ormond	Plant Protection Unit	kishmaprimus@yahoo.com	764-7378/ 562-2776
Lia Nicholson	Environment Division	nicholsonlia@gmail.com	728-9009
Nneka Nicholas	Environment Division	nneka.nicholas@gmail.com	724-9957
Dwight Laviscount	Environment Division	dwightlaviscount@yahoo.com	720-7157
Ediniz Norde	Environment Division	fostinas@gmail.com	724-6422
Jacqueline Yearwood	Antigua and Barbuda Investment Authority	jyearwood@antigua.gov.com	481-1015
Atiya Fabian	Ministry of Agriculture	atiyalfabian@gmail.com	726-3510
Prince Harris	APUA	prince.harris@outlook.com	783-3070
Simon Toulon	APUA	kamaltoulon@gmail.com	720-2406
Kasi Cochrane	Development Control Authority	cochraneagel@yahoo.com	779-6265
Marlon Jeffers	ABS Tv	marlonjeffers@hotmail.com	779-5775
Juan Gardner	Statistics Division	juan.c.gardner@gmail.com	771-0479
Tesfa Francis	APUA	tfrancis@apua.ag	727-0174
Brian Cooper	National Parks	brian.cooper@nationalparksantigua.com	788-7586
Alphaeus Tonge	Statistics Division	alphaeus.tonge@gmail.com	788-9125
Vashti Ramsey	Ministry of Tourism	vashtirmasey@yahoo.com	770-6719
Alvan Guishard	NODS	alvanguishard@gmail.com	464-2024
Lucia Mings	ETC	lucia_mings@yahoo.com	764-0304
Gregory Bailey	Ministry of Agriculture	agroject@yahoo.com	764-1262

NAME	ORGANIZATION	EMAIL	TELEPHONE
Amiah Nicholas	Ministry of Tourism	Amiah.nicholas@gmail.com	464-3887
Janice O'Keiffe	Public Works	-	728-6263
Ansha Jacobs	Ministry of Health and Environment	ayjacobs@icland.com	464-3400
A. Louise Henry	Directorate of Gender Affairs	Alh_loveable@hotmail.com	723-7489
Siobhain Harris	Development Control Authority	Siobhainharris160@hotmail.com	784-0519
Tricia Lovell	Fisheries Division	trlov@hotmil.com	720-5910
Owalbi Elabays	Extension Division	Owo_lab_1@yahoo.com	764-1268
Ato Lewis	Environment Division	-	-

ANNEX 3- GROUND WATER QUALITY ASSESSMENT

1. <u>Christian Valley Well Field</u>

The groundwater quality data available for wells in the Christian Valley Well Field spans a period of six years, 2005-2010. Ten (10) wells are listed as part of the Christian Valley Well Field though data is not provided for all ten wells. The data set reflects monthly sampling. The data indicates that for the six year period under review, pH and Total Dissolved Solids met the requisite standard/guideline. However, there were several instances of exceedance of the standard for Turbidity, Colour, Manganese and Iron.

a) Total Dissolved Solids & pH

The monthly average TDS values ranged from 408 – 756mg/L and there were no individual wells within the well field that exceeded the standard of 1000mg/L (Figure 1). There is no clear overall trend across the time period under review (2005-2010), however, TDS readings begin to show a distinct sustained increase beginning July 2009 at 539mg/L and reaching a high of 752mg/L in March 2010, a net increase of 213mg/L. The period after March 2010 shows a steady marked decline in TDS falling from 752 to 587mg/L in July 2011, a decline of 165mg/L.

It is worth noting that the other well fields; Cades Bay and Claremont also show a steady increase in TDS over this period; July 2009 – March 2010, as well as the subsequent steady marked decline through to 2011.

All pH values fell within the standard range of > 6.5 and < 8.5.

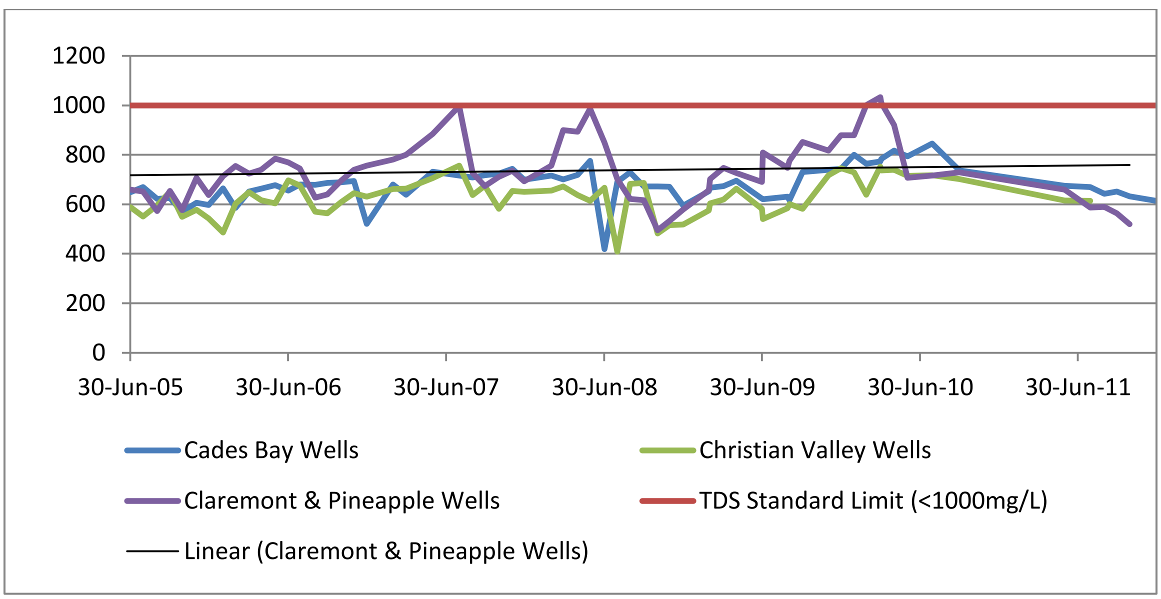


Figure 1: Total Dissolved Solids in SWW Wells (mg/L)

b) Turbidity

The monthly average turbidity values ranged from 0.14 to 20.35NTU. Of a total of sixty (60) monthly sampling sessions, there were five (5) instances where average turbidity levels exceeded the standard (<5NTU). The values that exceeded the standard ranged from 5.39 to 20.35 NTU. Christian Valley Well # 2 showed the highest actual turbidity readings of 46.2 and 54.4 NTU in February and October 2007 respectively. Christian Valley Nos. 7 and 9 also showed several instances of turbidity levels above the standard limit.

No overall trend in turbidity levels was observed for the period under review. It is worth noting that the year 2007, which recorded the highest turbidity levels, was also the year with the lowest recorded rainfall (over the ten year period, 2001-2010) at the Christian Valley weather station.

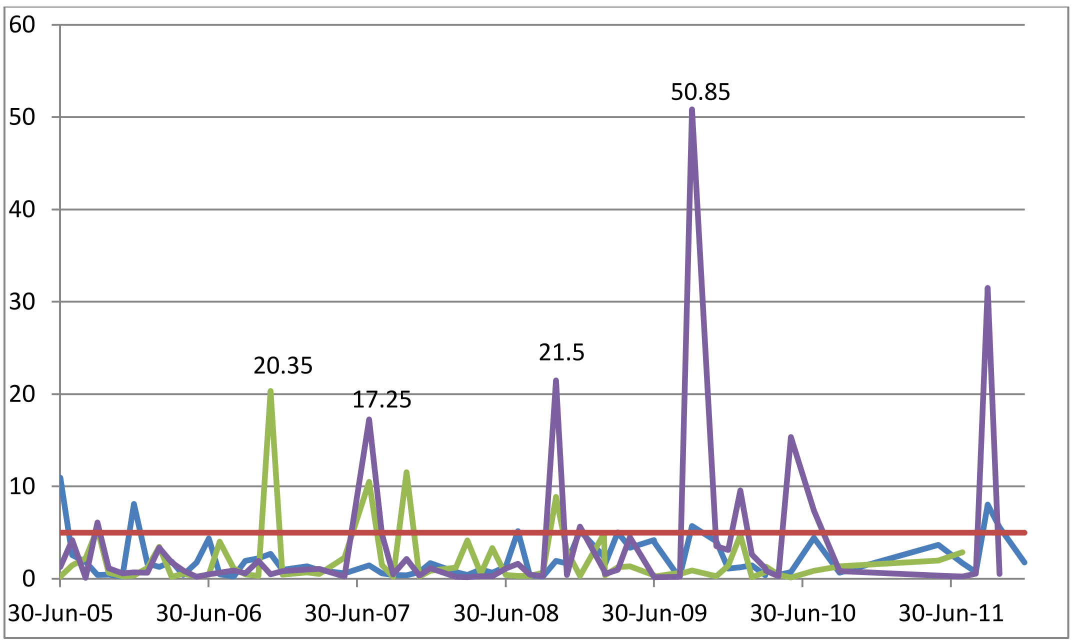


Figure 2: Turbidity Levels in SWWA Wells (NTU, mg/L)

c) Colour

Of the sixty (60) monthly sampling sessions, there were twenty five (25) instances where colour levels exceeded the standard (<15 Colour Units (CU)). Colour levels that exceeded the standard ranged from 20 to 100 CU, with Christian Valley Well #2 showing the highest colour reading of 100CUs in February 2007. Christian Valley Wells Nos 5, 7 and 9 showed highs of 40, 60 and 50 CUs respectively. No overall trend in colour values was observed.

d) Manganese

Average monthly Mn levels ranged from 0 to 0.88mg/L. Of the sixty (60) monthly sampling sessions, there were two (2) instances where average monthly manganese levels exceeded the standard (<0.5mg/L). Manganese levels exceeded the standard in November 2006 (0.8mg/L) and October 2007 (0.88mg/L) respectively. Christian Valley Well No. 2 showed the highest actual Mn reading of 3.9mg/L in October 2007. There was no observed trend in manganese levels over the period under review.

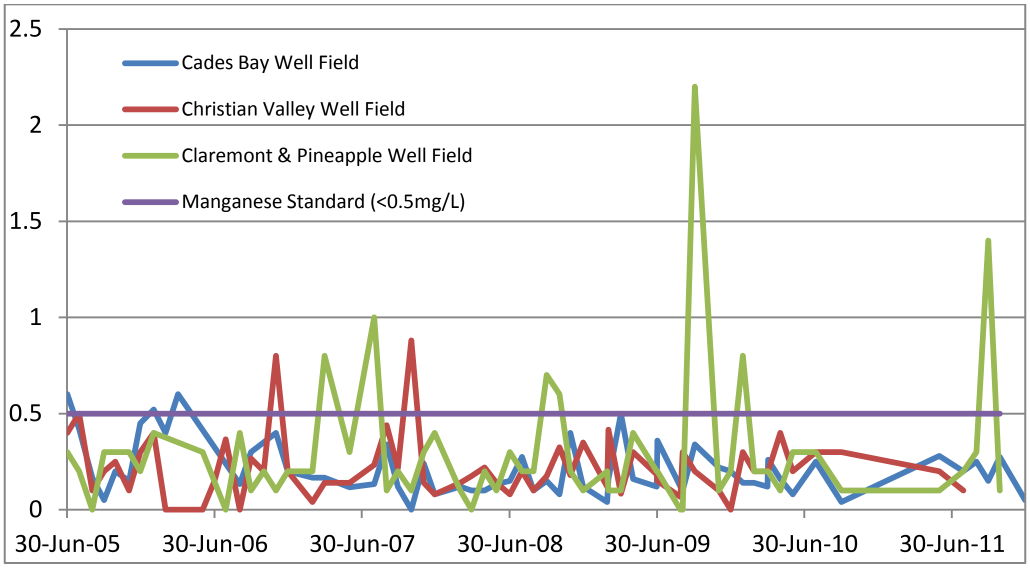


Figure 3: Manganese Levels in SWWA Wells (mg/L)

e) Iron

The average monthly iron levels ranged from 0.005 to 1.31mg/L over the period under review, 2005 - 2010. There were nine (9) instances where average monthly values exceeded the standard limit (<0.3mg/L).

The individual well with the highest iron reading was Christian Valley Well No. 2 at 3.106mg/L in February 2007. The other wells which exceeded the standard include Christian Valley Wells No. 5, 7 and 9. There is no observable trend in the levels of iron over the period under review.

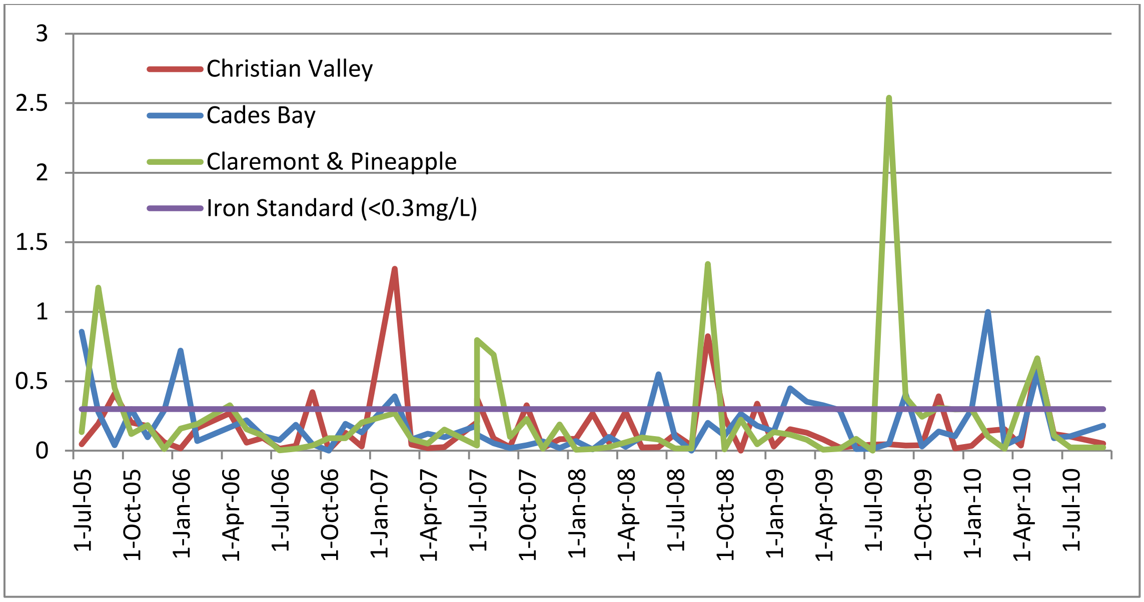


Figure 4: Iron Levels in SWWA Wells (mg/L

2. <u>Cades Bay Well Field</u>

The groundwater quality data available for wells in the Cades Bay Well Field spans a period of seven (7) years, 2005-2011. Nine (9) wells are listed as part of the Cades Bay Well Field though data is not provided for all nine wells. The data set reflects monthly sampling . The data indicates that for the seven year period under review, pH and Total Dissolved Solids at Cades Bay Well field met the requisite standard/guideline. However, there were several instances of exceedance of the standard for Turbidity, Colour, Manganese and Iron.

a) Total Dissolved Solids & pH:

The monthly average TDS values ranged from 419 – 845.5mg/L and there were no individual wells within the well field that exceeded the limit of 1000mg/L. Cades Bay Well No. 9 showed the highest actual TDS reading of 880mg/L in July 2010. There was no observable trend in TDS levels over the period under review 2005-2011, however, TDS readings begin to show a distinct sustained increase beginning August 2009 at 631.2mg/L and reaching a high of 845.5mg/L in July 2010, a net increase of 214mg/L. The period after July 2010 shows a steady marked decline in TDS falling from 845.5 to 613.5mg/L in Dec 2011, a decline of 232mg/L.

It is worth noting that the other well fields; Christian Valley and Claremont also show a steady increase in TDS over this period; 2009 – 2010, followed by a steady decline through to 2011.

All pH values fell within the standard range of > 6.5 and < 8.5.

b) Turbidity

The monthly average turbidity values ranged from 0.22 to 10.94NTU. Of a total of sixty (60) monthly sampling sessions, there were eight (8) instances where average turbidity levels exceeded the standard (<5NTU). In September 2011, Cades Bay Well No. 10 showed the highest actual turbidity reading of 31.1NTU. While Cades Bay No 12, showed a turbidity reading of 30.9NTU in June 2005. No overall trend in turbidity levels was observed for the period under review.

c) Colour

The Colour standard is <15 Colour Units (CU). Of the sixty (60) monthly sampling sessions, there were twenty four (24) instances where colour levels exceeded the standard. Colour levels that exceeded the standard ranged from 20 to 100 CU, with Cades Bay Nos 9 and 10 showing the highest colour reading of 100CUs in February 2007. No overall trend in colour values was observed.

d) Manganese

The Manganese standard is <0.5mg/L. Average monthly Mn levels ranged from 0.04 to 0.6mg/L. Of the sixty (60) monthly sampling sessions, there were three (3) instances where average monthly manganese levels exceeded the standard. Both Cades Bay Well No 1 and 10 showed actual readings of 1mg/L in March 2006. There was no observed trend in manganese levels over the period under review.

e) Iron

The Iron standard is <0.3mg/L. The average monthly iron levels ranged from 0.0105 to 1mg/L over the period under review, 2005 -2011. There were twelve (12) instances where average monthly values exceeded the standard limit.

The individual well with the highest iron reading was Cades Bay Well No 10 measuring 2.55mg/L in September 2011. The other wells which exceeded the standard include Cades Bay Wells No. 1, 9 and 12. There was no observable trend in the levels of iron over the period under review.

3. <u>Claremont & Pineapple Well Field</u>

The groundwater quality data available for wells in the Claremont & Pineapple Well Field spans a period of seven (7) years, 2005-2011. A total of ten (10) wells are listed as part of the Claremont and Pineapple Well Field, though data is not provided for all ten wells. The data set reflects monthly sampling. The data indicates that for the seven year period under review, pH values at Claremont & Pineapple Well field met the requisite standard/guideline. However, there were several instances of exceedance of the standard for Turbidity, Colour, Manganese, Iron and Total Dissolved Solids.

a) Total Dissolved Solids & pH

The TDS standard is <1000mg/L. The monthly average TDS values ranged from 495 – 1033mg/L. Of the sixty (60) monthly sampling sessions, there were three instances where average TDS values exceeded the standard. However, there were eleven (11) instances where individual wells exceeded the standard limit. Pineapple Well No 1 showed the highest actual reading of 1780mg/L in October 2007. The other wells which exceeded the standard limit include Claremont Well Nos 8, 9 and 10, and Pineapple Well Nos 2 (Table 1).

There was no observable trend in TDS levels over the period under review 2005-2011, however, average monthly TDS readings begin to show a distinct sustained increase beginning October 2008 at 495mg/L and reaching a high of 1033mg/L in March 2010, a net increase of 538mg/L. The period after March 2010 shows a marked decline in TDS falling from to 519mg/L in October 2011, a decline of 514mg/L.

It is worth noting that the other well fields; Christian Valley and Cades Bay also show a steady increase in average TDS over this general period, followed by a marked decline. Also, generally, the wells in the Claremont/Pineapple well field show the highest TDS levels when compared with the wells of the Cades Bay and Christian Valley Well Fields.

All pH values fell within the standard range of > 6.5 and < 8.5.

Table 1: Individual Wells of the Claremont/Pineapple Well Field which Exceeded the Standard Limit for Total Dissolved Solids

Individual Wells	Date	TDS (mg/L)
Claremont Well No. 9	April 2010	1074
	May 2010	1132
	June 2010	1068
	July 2010	1006
Claremont Well No. 10	May 2010	1087
Claremont Well No. 8	March 2010	1040
	June 2010	1125
Pineapple Well No. 1	October 2007	1780
Pineapple Well No. 2	Oct 2007	1060
	May 2008	1000
	July 1, 2008	1100
	July 30, 2008	1260

b) Turbidity

The Turbidity standard is <5 NTU. The monthly average turbidity values ranged from 0.1 to 50.85 NTU. Of a total of sixty (60) monthly sampling sessions, there were nine (9) instances where average turbidity levels exceeded the standard. December 2009, showed the highest average monthly turbidity reading of

50.85 NTU, and the individual well with the highest turbidity reading was Claremont Well No. 8 with a reading of 99.9 NTU in December 2009. There were a total of seventeen (17) instances where five individual wells exceeded the standard limit. These wells which exceeded the limit include Pineapple Wells No 1 & 2 and Claremont Wells No. 8,9, and 10. No overall trend in turbidity levels was observed for the period under review.

c) Colour

The Colour standard is <15 Colour Units (CU). Over the period under review, the standard limit for colour was exceeded in nineteen (19) instances. The maximum colour reading of 100CU was reached in three separate instances, at three different wells; Claremont Well No. 9 on Nov 2011, Claremont Well No. 10 on September 2005 and Pineapple Well No 1 on October 2007. Claremont Well No 10 exceeded the standard limit in twelve (12) instances, Claremont Well No 9 in three instances, Pineapple Well No. 2 on two occasions and both Claremont Well No. 11 and Pineapple Well No. 1 exceeded the colour limit on one occasion.

It is noteworthy, that on the three instances when colour readings were at their maximum of 100CU, the levels of iron (Fe) and manganese (Mn) at these wells were at their highest levels, with Iron (Fe) at 3.3 mg/L (Fe standard limit <0.3mg/L) and Manganese (Mn) ranging from 2.4 to 4.7mg/L (Mn standard limit <0.5mg/L). There was no observable trend in colour values over the period under review.

d) Manganese

The Manganese standard is <0.5mg/L. Over the period under review, the standard limit for Manganese was exceeded in eight (8) instances. The maximum manganese reading was 4.7mg/L at Pineapple Well No. 1 on October 2007. The standard limit for Manganese was exceeded at four wells, namely Claremont Wells No 9, 10 and 11, as well as Pineapple Well No. 1.

Claremont Well No. 10 exceeded the standard limit in four instances (ranging from 0.5-0.9mg/L), Claremont Well No. 9 in two instances (0.6 and 2.4mg/L) , and both Claremont Well No. 11 and Pineapple Well No 1 exceeded the standard limit once, with readings of 2mg/L and 4.7mg/L respectively.

It is noteworthy, that on the three instances when Manganese was highest, these wells also showed the highest colour values of 80CU and 100CU (Standard Limit for Colour <15CU).

e) Iron

The Iron standard is <0.3mg/L. The average monthly iron levels ranged from 0.003 to 2.54mg/L over the period under review, 2005 -2010. There were twelve (12) instances where average monthly values exceeded the standard limit.

Four (4) individuals wells show the highest iron reading of 3.3mg/L, namely Pineapple Well No 1, Claremont Wells No 8 (in December 2009), 9 (in November 2011) and 10 (in September 2005). The other wells which exceeded the standard include Pineapple Well No 2 and Claremont Well No. 11. There was no observable trend in the levels of iron over the period under review.

4. Bendals Well Field

The groundwater quality data available for wells in the Bendals Well Field spans a period of seven (7) years, 2005-2011. A total of sixteen (16) wells are listed as part of the Bendals Well Field, though data is not provided for all sixteen wells. The data set reflects monthly sampling. The data indicates that for the seven year period under review, pH values at Bendals Well field met the requisite standard/guideline. However, there were several instances of exceedance of the standard for Turbidity, Colour, Manganese and Iron.

a) Total Dissolved Solids & pH

The TDS standard is <1000mg/L. The monthly average TDS values ranged from 364 – 674mg/L. Of the sixty (60) monthly sampling sessions, there were no instances where average TDS values exceeded the standard, neither were there any individual readings which exceeded the TDS standard limit, as the readings were consistently well below the standard limit (Figure 5).

There was no statistically observable trend in TDS levels over the period under review 2005-2011.

All pH values fell within the standard range of > 6.5 and < 8.5.

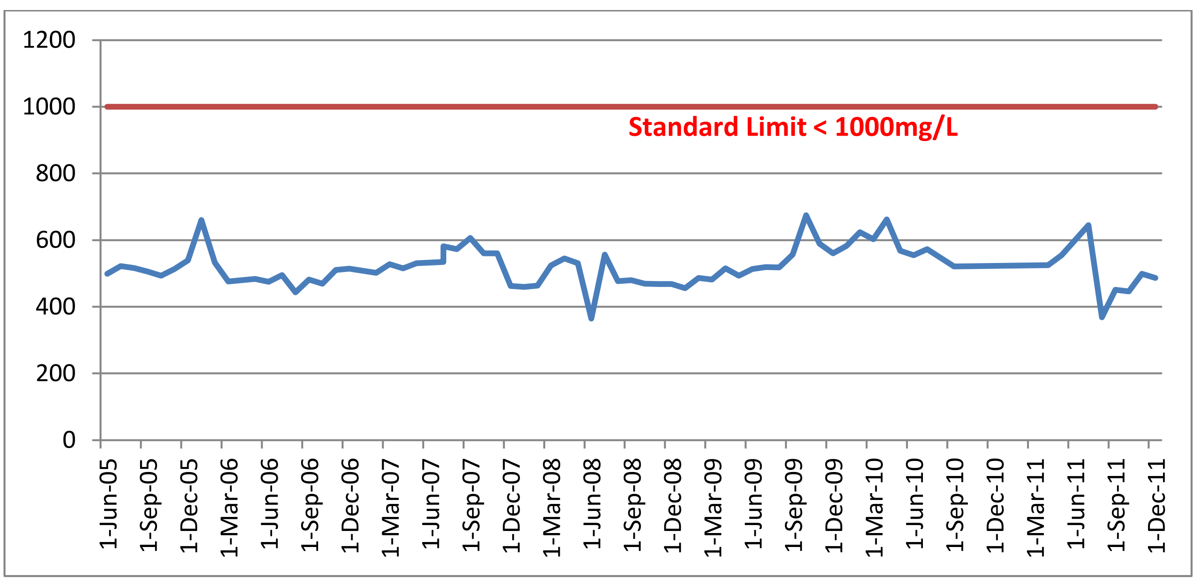


Figure 5: Total Dissolved Solids at Bendals Well Field (mg/L)

b) Turbidity

The Turbidity standard is <5 NTU. The monthly average turbidity values ranged from 0.13 to 11.19 NTU. Of a total of sixty (60) monthly sampling sessions, there were four (4) instances where average turbidity levels exceeded the standard (Figure 6). All four instances were during the year 2007; July, October, November and December 2007, with the highest average turbidity being 11.19 NTU in October 2007. The two wells with the highest actual turbidity readings were Bendals Well No. 12 at 66.8 NTU in July 2007 followed by Bendals Well No. 11 at 59 NTU in October 2007. Other wells with elevated turbidity levels include Bendals Well No. 3 at 36.6 NTU in March 2008, Wells No. 6, 16 and 17 at 18NTU, 17.7 NTU and 17.7 NTU respectively. The year 2007, which showed the highest turbidity levels was also a year with relatively low annual rainfall at the Christian Valley and Cades Bay weather stations. No overall trend in turbidity levels was observed for the period under review.

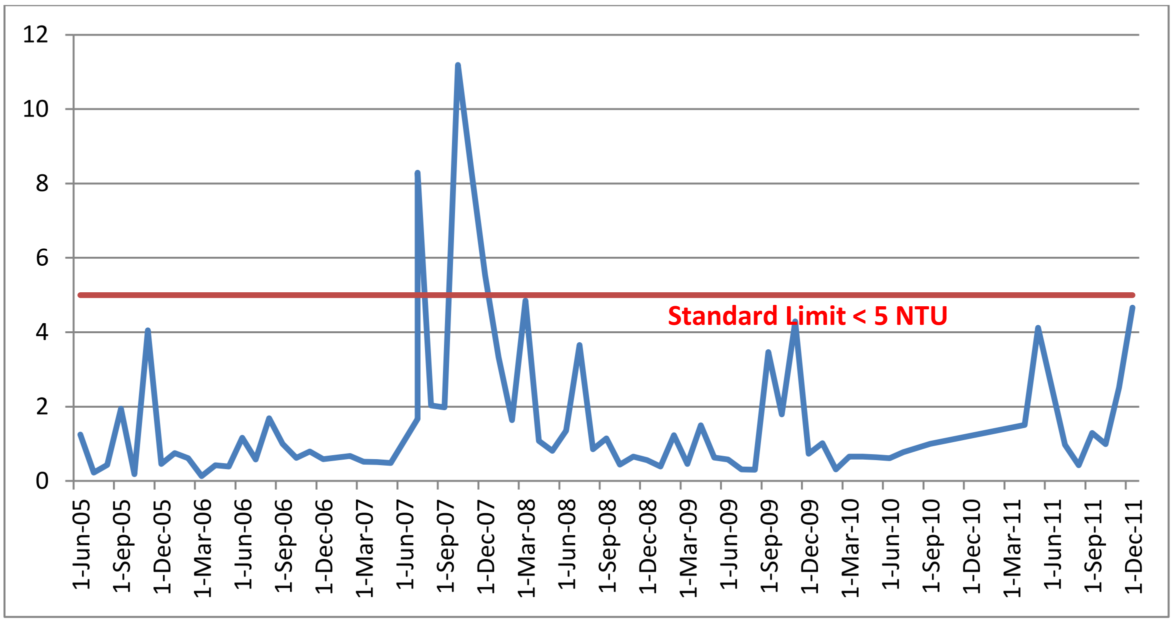


Figure 6: Turbidity (NTU) at Bendals Well Field

c) Colour

The Colour standard is <15 Colour Units (CU). Over the period under review, the average readings exceeded the standard limit in five (5) instances. The maximum average colour reading was 30CU in October 2007. The individual wells with the highest color reading were Bendals Wells No. 11, 12 and 16, all at 100CU. Other individual wells which exceeded the standard limit on one or more occasions are Bendals Wells No. 3 (50CU in October 2009), 17 (30CU in July 2007), 18 (30CU in October 2007), 19 (30CU in July 2007) and 21(40CU in August 2006). At the three times when colour readings registered the highest readings of 100CU, the levels of iron (Fe) and manganese (Mn) at these wells were also elevated as high as 3.3mg/L - Fe and 2.3mg/l – Mn. There was no observable trend in colour values over the period under review.

d) Manganese

The Manganese standard is <0.5mg/L. Over the period under review, the average readings exceeded the standard limit for Manganese twice, once in August 2005 and once in December 2007 (Figure 7). However, individual wells in the Bendals well field exceeded the standard limit with the highest reading recorded at Bendals Well No. 11 – 2.3mg/L Mn in October 2007, followed by Bendals Well No. 21 at 1.7mg/l Mn in August 2007 and Bendals Well No. 15 at 1mg/L Mn in July 2008. There was no observable trend in the levels of manganese over the period under review.

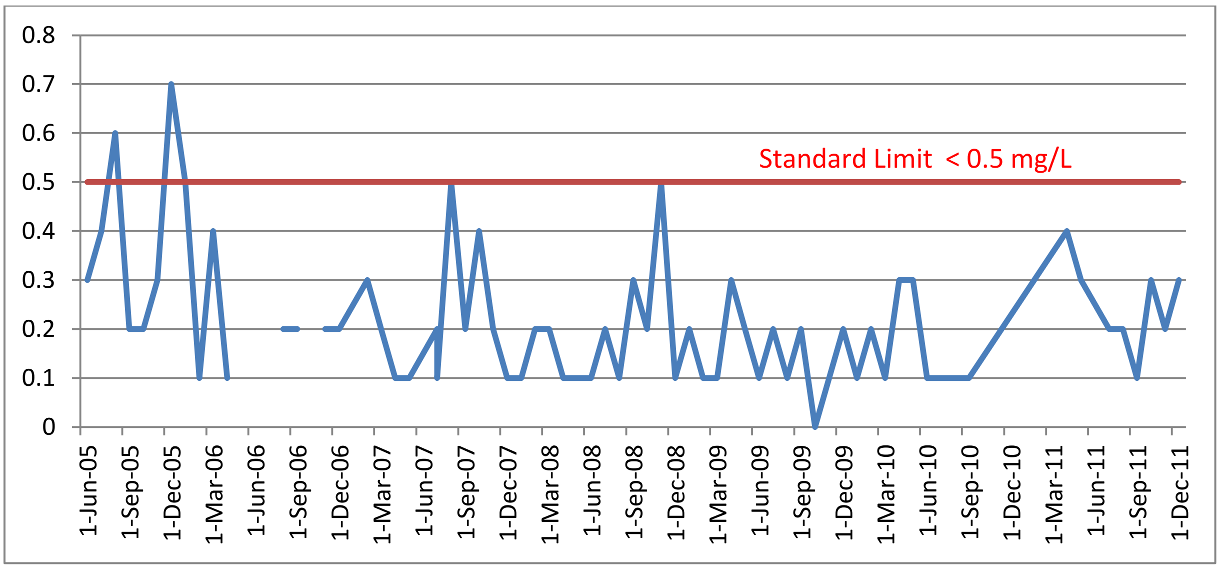


Figure 7: Manganese Levels at Bendals Well Field (mg/L)

e) Iron

The Iron standard is <0.3mg/L. The average monthly iron levels ranged from 0 to 1mg/L over the period under review, 2005 -2011. There were twelve (12) instances where average monthly values exceeded the standard limit (Figure 8).

Two (2) individuals wells show the highest iron reading of 3.3mg/L, namely Bendals Well Nos. 11 and 12 all occurring in 2007. Other wells which exceeded the standard include Bendals Well No. 3 at 2.3mg/L in March 2008 and Bendals Well No. 18 at 1.2mg/L in April 2009. There was no observable trend in the levels of iron over the period under review.

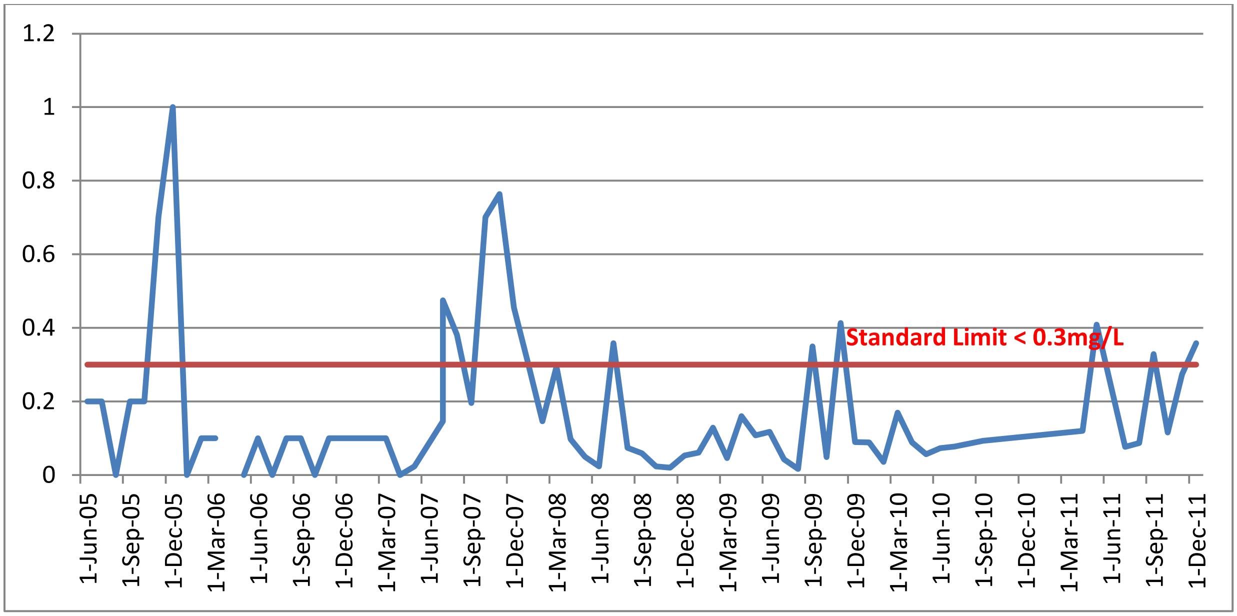


Figure 8: Iron Levels at Bendals Well Field (mg/L)

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

or

The Environment Division
Ministry of Health and Environment
Factory Road
St. John’s, Antigua

Tel: + (268)242-4625 or 562-2568
Fax: + (268)462-4625
Email: sirmmab@gmail.com
Website: www.environmentdivision.htm