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# **Water Supply in Buea, Cameroon: Analysis and the Possibility of Rainwater Harvesting to stabilize the water demand**

*Wasserversorgung in Buea, Kamerun: Analyse und Perspektiven der  
Regenwasserbewirtschaftung zur Stabilisierung des Wasserbedarfs*

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## **DECLARATION**

I, Roy Lyonga Mbua, hereby declare that this dissertation was prepared and completed by me with the use of cited sources. This work has not been submitted in any form for the purpose of academic examination to any university. Acknowledgements have been made in the texts and a list of references in the bibliography with regards to information derived from published and unpublished works of others.

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## **DEDICATION**

This dissertation is dedicated to my parents **Prof. Fritz Ndiva Mbua** and **Mrs Martha Mbua**.



## **ABSTRACT**

Water scarcity is a global phenomenon which affects close to 2.8 billion people worldwide especially in developing countries. Buea (Cameroon) is blessed with abundant water resources but paradoxically the inhabitants of this region are facing a serious water crisis. The increase in population and rapid urbanization exert tremendous pressure on the water resources of this community. Also, the capacity of the main water supply authority CAMWATER (Cameroon Water Utilities Corporation) is insufficient to cater for the 90000 inhabitants.

This thesis explores the potential of domestic rainwater harvesting (rooftop rainwater harvesting) as the best alternative to fulfill the water demand of the population. It also promotes artificial groundwater recharge as the best way to sustainably deal with excess rainwater to decrease surface runoff and avoid flooding especially in the high altitude villages on the eastern slopes of Mount Cameroon during the rainy season. Furthermore, it examines the willingness of the community to accept this innovative alternative which will solve their water supply problems.

In an effort to combat water scarcity and decrease poverty in this region, this research analyses the possibility of domestic rainwater harvesting as a worthwhile alternative to augment the present conventional water supply systems to stabilize the water demand and create avenues for economic development. Buea has high rainfall (4000mm/year); harvesting the rainwater during the rainy season, storing it for usage in the dry season and using the excess to recharge groundwater aquifers will definitely ameliorate the status quo.

To realize these objectives, a series of double ring infiltration tests were carried out in 9 different locations. The aim of these tests was to measure infiltration rates and therefore locate areas of good artificial groundwater recharge potential. Also, 220 questionnaires were distributed in 10 villages within the municipality in an effort to characterize the water consumption pattern of the population.

The study confirms that the Buea water crisis is mainly as a result of poor water management and not due to physical or economic water scarcity. It reveals that about 86% of the population experience water shortages and CAMWATER has to double up its present capacity in order to meet up with demand. Over 80% of the population is willing to consider rainwater harvesting as a good alternative to augment their domestic water supply if government provides subventions to cover half of the installation costs. Conclusively, domestic rainwater harvesting if carried out extensively will rescue the Buea population from a disastrous water deficiency leading to detrimental environmental problems.

## **ABSTRAKT**

Wasserknappheit ist ein globales Problem, das fast 2,8 Mrd. Menschen insbesondere in den Entwicklungsländern betrifft. Die Stadt Buea (Kamerun) verfügt zwar über reichliche Wasserressourcen, aber paradoxerweise sehen sich ihre Einwohner einem ernstzunehmendem Notstand gegenüber. Das Bevölkerungswachstum und eine rasche Urbanisierung üben einen enormen Druck auf die Wasserressourcen dieser Gemeinde aus. Zudem ist die Kapazität des Hauptwasserversorgers CAMWATER (Cameroon Water Utilities Corporation) unzureichend für Versorgung der rund 90000 Einwohner.

Die vorliegende Dissertation untersucht das Potential von häuslicher Regenwassersammlung (Sammlung der Hausdachentwässerung) als bestmögliche Alternative zur Befriedigung des Wasserbedarfs. Weiterhin empfiehlt sie künstliche Grundwasseranreicherung als die beste Weise, nachhaltig mit überschüssigem Regenwasser umzugehen, weil während der Regenzeit dadurch der Oberflächenabfluss vermindert und Überflutungen insbesondere in den hochgelegenen Dörfern am Osthang des Kamerunberges (Mt. Cameroon) vermieden werden. Zudem untersucht sie die Bereitschaft der Einwohner, diese innovative Alternative zur Lösung der Wasserversorgungsprobleme anzunehmen.

Im Bestreben, die Wasserknappheit und Armut in dieser Region zu bekämpfen, wird die Möglichkeit der häuslichen Regenwassersammlung als lohnenswerte Alternative zur Unterstützung der gegenwärtigen konventionellen Wasserversorgung untersucht, um die Versorgung zu stabilisieren und Wege zur wirtschaftlichen Entwicklung zu eröffnen. Buea zeichnet sich durch hohen Jahresniederschlag (4000mm) aus. Durch Sammeln von Regenwasser in der Regenzeit, Speicherung für die Trockenzeit und Nutzung des Überschusses zur Grundwasseranreicherung lässt sich der gegenwärtige Zustand zweifellos verbessern.

Um diese Ziele zu verwirklichen, wurden Messungen mit Doppelring-Infiltrometer an neun unterschiedlichen Standorten durchgeführt. Damit sollten Infiltrationsraten bestimmt und somit Gebiete mit hohem Potential für Grundwasseranreicherung gefunden werden. Weiterhin wurden zur Charakterisierung des Wasserverbrauchsverhaltens 220 Fragebögen in zehn Dörfern im Gemeindegebiet verteilt.

Die Untersuchung bestätigt, dass die Wasserversorgungsprobleme in Buea hauptsächlich eine Folge unzureichenden Wassermanagements sind und nicht in physischer oder ökonomischer Knappheit begründet. 86% der Bevölkerung leiden unter Versorgungsengpässen. CAMWATER müsste die gegenwärtige Kapazität verdoppeln, um mit dem Bedarf Schritt zu halten. Über 80% der Bevölkerung ist bereit, Regenwassersammlung als Möglichkeit zur Erweiterung ihrer häuslichen Wasserversorgung zu erwägen, falls die Regierung / der Staat die Hälfte der Installationskosten subventionieren würde. Abschließend kann festgestellt werden, dass häusliche Regenwassersammlung, wenn sie großflächig zum Einsatz kommt, Bueas Bevölkerung vor einer desaströsen Wasserknappheit bewahren kann, die zu einem erheblichen Umweltproblem auswachsen könnte.

## LIST OF ABBREVIATIONS AND ACRONYMS

%	Percentage
€	Euro
A	Area
a.s.l.	above sea level
AES	American Electricity Supply
AGR	Artificial Groundwater Recharge
BASIX	Building Sustainability Index
CDC	Cameroon Development Corporation
CDE	Cameroonaise Des Eaux
CFA	Communate Financière Africaine
COM. WATER	Community Water
Cr	Runoff Coefficient
CVL	Cameroon Volcanic Line
d <sup>2</sup>	square diameter
DRI	Double Ring Infiltration
EC	Electrical Conductivity
EU	European Union
f	franc
GWP-Cmr	Global Water Partnership Cameroon
H	Height
IMWI	International Water Management Institute
IWRM	Integrated Water Resources Management
Kg	Kilograms
km	kilometer

Km <sup>2</sup>	square kilometer
l	liter
m.a.s.l	meters above sea level
m <sup>3</sup>	cubic meters
m <sup>3</sup> /hr	cubic meter per hour
MDG	Millennium Development Goal
mg/l	milligrams per liter
MINEE	Ministry of Energy and Water Resources
mm	millimeter
mm/a	millimeter per annum
Mt	Mount (or Mountain)
NGO	Non-Governmental Organization
NWC	National Water Council
ONEP	Office National de L'Eau Portable
R	Rainfall
RWH	Rainwater Harvesting
S	Supply
sec	seconds
SNEC	Société Nationale Des Eaux du Cameroun
SONEL	Société Nationale D'Electricité
t	time
TDS	Total Dissolved Solids
UN	United Nations
UNICEF	United Nations Children's Fund
UNWWD	United Nations World Water Development

uS/cm	microsiemens per centimeter
USA	United States of America
WHO	World Health Organization
WTD	Water Framework Directive
WWAP	World Water Assessment Programme
$\pi$	Pi
RWSSFDB	Rural Water Supply and Sanitation Fund Development Board

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## **1.0 INTRODUCTION**

### **1.1 BACKGROUND**

Water is universally one of the most influential natural resources, if not the most valuable of all. As defined in the first paragraph of the European Union (EU) Water Framework Directive (WFD) established by the European Parliament and the Council of 23<sup>rd</sup> of October 2000; “Water is not commercial product like any other but, rather, a heritage which must be protected, defended and treated as such”. Water is life; no water means no life on the planet earth. The availability of water is necessary, but the quality of available water is even more critical. In the year 2000, the United Nations established the Millennium Development Goals (MDGs) comprising 8 goals which are to be achieved by 2015. Improved water sources were accessible to over 2 billion people from 1990 to 2010, thus meeting up with the target of the MDG on drinking water (UNICEF and WHO report, 2012). The same report confirms that sub-Saharan Africa has the lowest drinking water coverage compared to all the other regions in the world. In fact, 82% of the urban population in sub-Saharan Africa has access to improved water sources compared to 95% worldwide. For the rural population, it is about 44% compared to 72% (Carles, 2009).

Unfortunately for mankind, there is an uneven distribution of both human beings and water resources globally. Therefore, areas which are occupied by human beings are not automatically areas with abundant water resources. Water scarcity can be further categorized into; physical water scarcity social and economic water scarcity. Physical water scarcity refers to a situation where; a country or region naturally has limited access to water. Furthermore physical water scarcity can be divided into two concepts which include demand-driven scarcity (water stress) and population-driven scarcity (water shortage) (Kummu *et al*, 2010). About 25% of the world’s population is located in areas of physical water scarcity. Arid and semi-arid areas are mostly characterized by physical water scarcity.

Economic water scarcity refers to a situation where by a country or region has available water resources but lacks sufficient financial means to exploit her water resources. Most parts of sub-Saharan Africa suffer from economic water scarcity. This condition continues to aggravate in

this region and will only get better if the governments of affected countries make this problem a national issue and top priority. Good governance and available financial resources are both required to combat economic water scarcity. Water scarcity issues lead to health issues as a result of the exposure to water borne diseases. In the case of water stress, people consume whatever quality of water they can lay hands on. Fig 1 shows the global water scarcity status:

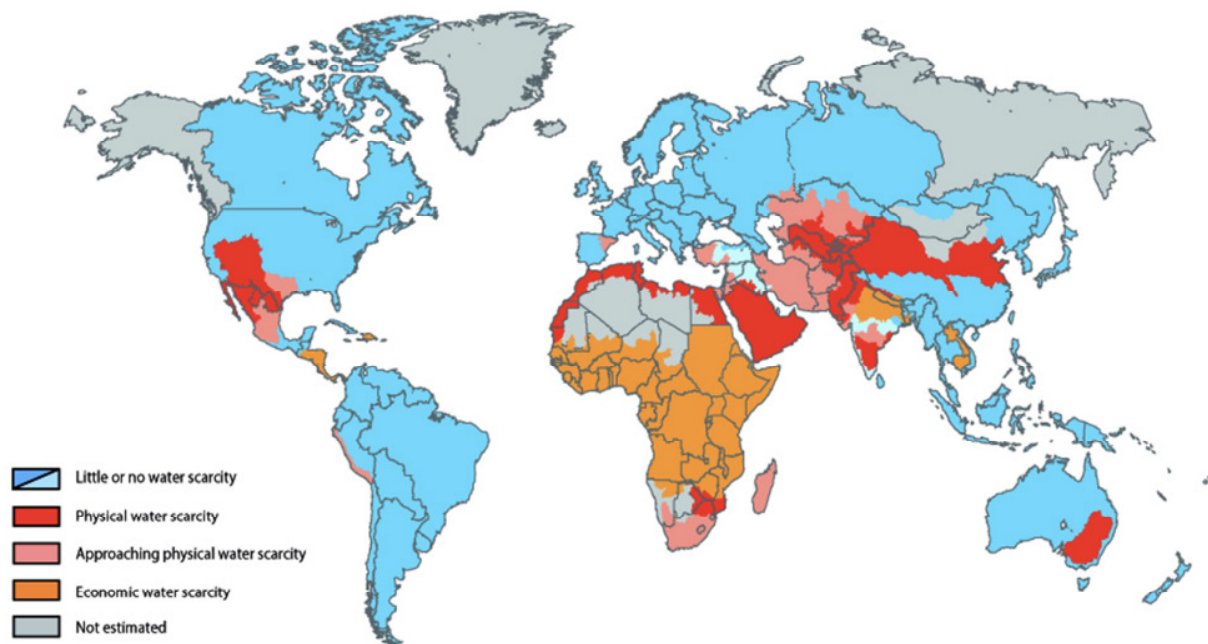


Figure 1: Physical and economical water scarcity

(Source: IMWI report, 2006)

In recent years, global scenarios have been the popular trend with regards to the prognostication of climate change as a whole and its components in particular. Alcamo *et al*, 2007 analyzed the scenario portraying the change in average annual water availability by 2050. This analyzed scenario predicts the increase in precipitation in most parts of the world resulting to an increase in water availability in those parts. Conversely, the increasing air temperatures further increases evapotranspiration in almost all parts of the world and therefore decreases water availability. Precipitation and evapotranspiration interact differently and result in either an increase or decrease in water availability in different parts of the world but evapotranspiration appears to overshadow the effect of increasing precipitation because it occurs almost everywhere (Alcamo

*et al*, 2007). This makes it quite clear that increase water availability will not be observed in all areas experiencing an increase in precipitation and evapotranspiration is the main culprit. The figure below (Figure 2.) shows the percentage change in annual water availability as prognosticated by the scenario analyzed for 2050. As for the case of Cameroon in general and Buea specifically, the scenario predicts that increasing evapotranspiration will prevail over increasing precipitation and this will most certainly lead to a decrease in water availability in this part of the country. Also, there is an increase in annual precipitation but not a corresponding increase in annual water availability. This more or less represents a worst case scenario. It is always important to consider such scenarios in an effort to attain better results in the fight against water scarcity by way of improving water policy and legislation.

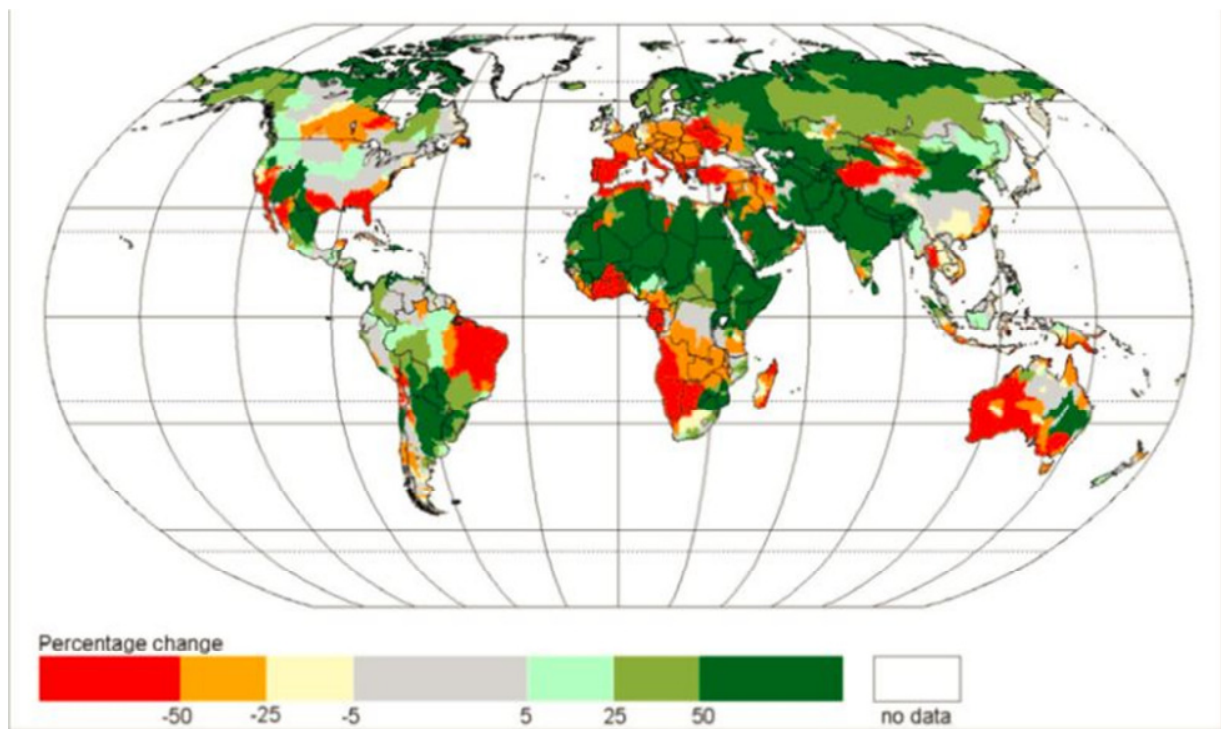


Figure 2: The percentage change in annual water availability between climate normal period (1961-1990) and the 2050's under A2 Scenario

(Source: Alcamo *et al*, 2007).

### 1.1.1 The Hydrological Cycle

The hydrological cycle is the continuous pathway through which water in its diverse physical states moves through oceans, the atmosphere and the soil. This is the source of fresh water for

our planet. The energy required to propel this process is from the sun. The sun heats up the ocean surface and as a result of this, water evaporates into the atmosphere in a process called evaporation. Ocean water is very salty and evaporation helps in its desalinization. The water vapor rises and with increasing altitude, it cools down and condenses into tiny water droplets and ice crystals forming clouds in a process known as condensation. The duration of these clouds in the atmosphere may vary depending on other physical and chemical influences but range between a couple of hours to days. When cloud particles grow large enough, they tend to fall down in the process of precipitation (rain, snow, hail etc.). Precipitation could lead to large storms which transfer heat vertically. These storms migrate and as such distribute heat from the equator and the Polar Regions. Their intensity and development is determined by surface temperatures, atmospheric moisture and wind pattern. Precipitation falling on land is absorbed into the earth in a process called infiltration, or flows on the surface as runoff which finally ends up in lakes, rivers, reservoirs, soils and aquifers.

Plants absorb soil water and release it into the atmosphere in a process called transpiration. These hydrological processes vary from place to place and from year to year. The global precipitation and evaporation balances out despite the variations in regions and years. Humans have access to groundwater by means of wells, bore holes and springs. Surface water access is by means of streams, lakes, rivers and reservoirs. Access to rainwater is possible whenever and wherever rain falls.

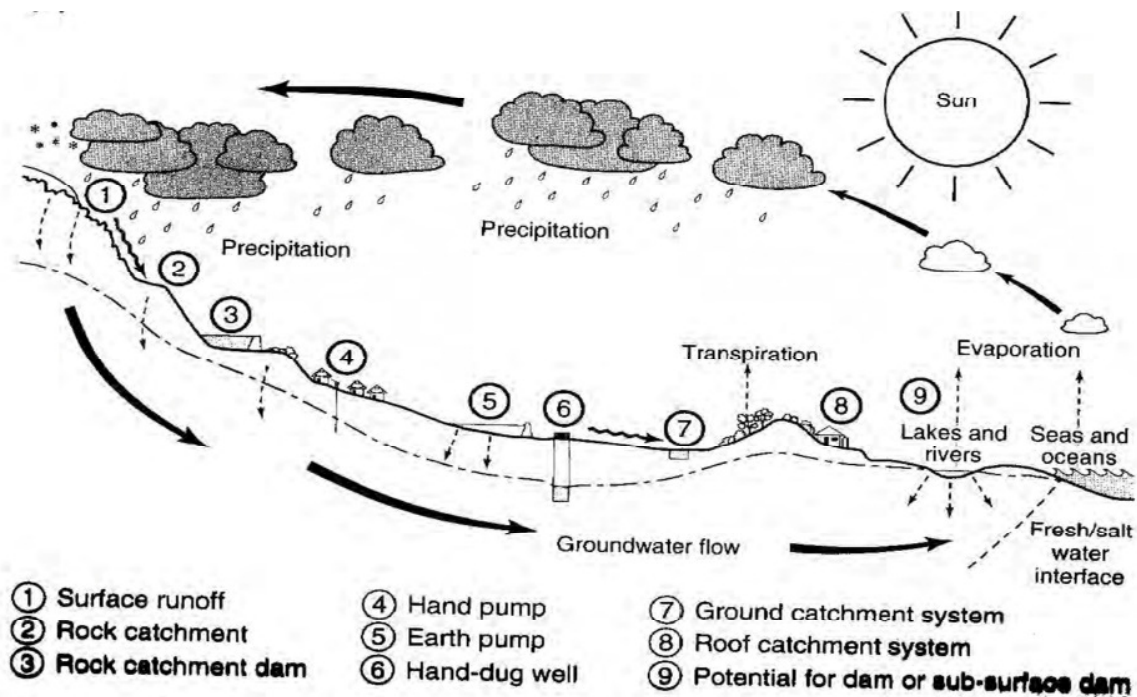


Figure 3: The Hydrological Cycle

(Source: Gould and Nissen-Petersen, 1999)

At the beginning of the new Millennium, rainwater harvesting is looked upon as a sustainable and relevant system to cater for domestic and regional water deficiency issues all around the world but more especially in South East Asia and Africa. Many countries have resurrected and ameliorated the ancient practice of collecting rainwater with the aid of modern science and technology. Fairly recently, China and India both comprising more than one third of the world's population have shown great interest in using harvested rainwater for both domestic and agricultural purposes. In Germany, the collection of rainwater from roof tops is becoming popular. This is because the cost of water has increased due to treatment as a result of contamination in certain areas. The water resources of these countries as well as other countries are finite and as such an integrated water resource management system promoting rainwater harvesting is actually a decent approach to guarantee a sustainable water supply for the future. Rainwater harvesting systems also provide a perfect opportunity for artificial groundwater recharge.



## 1.2 PROBLEM STATEMENT

The water sector in any economy is closely linked with poverty reduction, especially for developing countries that are highly dependent on rural economy. In third world countries, the increased scarcity of water by the municipal, industrial and the agricultural sectors has increased food insecurity, health problems, poverty and the lack of some basic socio-economic facilities. Therefore thoroughly addressing water deficiency issues would contribute in achieving the Millennium Development Goals (MDGs). This is true because an increase in demand threatens the sustainability of the environment in the situation of scarcity (e.g. in arid and semi-arid regions) and water availability is also crucial for the achievement of a sustainable environment and a sustainable social economic development. However, the main problem in water resource management is mostly the fragmentation by different sectors and communities. This problem has to be addressed holistically with regards to the entire water framework which should embody the concept of Integrated Water Resources Management (IWRM). The unprecedented increase in population, urbanization, and agriculture activities in recent time have resulted in the massive depletion and deterioration of the existing water resources in fast growing towns in developing countries in general and in Buea in particular. Added to these problems is the threat of climate change that is expected to increase water scarcity. It will distort the hydrological cycle in the next 100 years increasing precipitation, evapotranspiration, occurrence and frequency of storm water events and will trigger significant changes in biogeochemical processes that influence the quality of water (Pandey *et al*, 2003). Another issue of great concern is the fact that the water distribution facilities are dilapidated and need urgent reconstruction, renovation and expansion to meet the capacity of the present population. A rainwater harvesting system is not a replacement of all other water supply systems but a sustainable addition to the other water supply systems to augment water supply in a case of water scarcity like the situation in Buea, Cameroon. The local inhabitants of this region have publicly been very vocal about their grievances with respect to water crisis issues. Witnessing the number of persons at water (public) taps at peak periods of water demand, the influx of the local population into wetland areas during the dry season in order to exploit the nearby streams for subsistence agricultural purposes and also for business purposes like car wash points is an indication that there is an evident increase in water demand in this area (Lambi and Kometa, 2009).

Furthermore, there are also periodic and severe outbreaks of water borne diseases which are all indications of the poor water quality resulting from bacteriological contamination. More than 1 billion people worldwide lack access to clean drinking water and about 3 billion people around the world lack basic sanitation services (Pandey *et al*, 2003). In Buea, surface water is the main source of water for the majority of the population that has no access to pipe born water. Surface water is more prone to contamination from anthropogenic activities compared to other water sources such as groundwater and rainwater. This puts the inhabitants of this region in a very vulnerable position in terms of health issues associated with water borne diseases in contaminated surface water. Social stratification is a discrimination tool used in the allocation and distribution of treated pipe born water. In Buea, the city proper (Molyko, Bonduma, Soppo) where the richer part of the population dwell has access to treated pipe born water whereas the interior villages like Bonakanda and Bova have no access to pipe born water making them vulnerable to health problems.

Buea is an area of both subsistence and plantation agriculture. Local inhabitants are involved in small scale agriculture for domestic and commercial purposes. The Cameroon Development Corporation (CDC) which is the second to the government in terms of employment has plantations for Banana and Tea cultivation in this area. The large amounts of fertilizers (containing the likes of nitrate, phosphate and potassium) and pesticides used by CDC for crop cultivation leach through the soil and subsequently result in groundwater pollution. Fertilizers are applied in large scale and the excess nutrients not absorbed by the plants end up in surface and groundwater systems. The nitrate concentration in this area exceeds the 10 mg/l WHO nitrate limit in drinking water (Ako, 2012). Agricultural activities, septic tank leakages and other domestic mishaps disorganized dumping of waste are responsible for this. In local scale rainwater harvesting (RWH) is a good adaptation strategy against natural and anthropogenic stress facing water resources.

### **1.2.1 Integrated Water Resource Management**

Water management is faced with enormous pressure from certain socio-economic drivers. This pressure affects water management in terms of its options and needs. Populous developing

countries like China, Brazil and India are experiencing huge economic growth. This puts so much pressure on their water resources putting them in an uncomfortable position. Also, population growth plays a crucial role. Population increase is directly proportional to increasing water demand. This will further result to more wastewater and also more contamination of water sources. Trade also plays a role be it directly or indirectly. Nations having water scarcity can embark on importing water-intensive commodities in order to reduce some pressure on their water resources. Developing countries need a solid management of their water resources for them to achieve the MDG's. Implementing an Integrated Water Resource Management (IWRM) in their water management principles is the way forward. Many nations subscribe to IWRM for their water resources because of its relevance in terms of the efficient food production, irrigation agriculture, reducing water-related health risks and reducing the risk of floods and droughts (WWAP, 2009).

In 2005, the government of Cameroon, in an effort to ameliorate the state of water resource management created the Global Water Partnership Cameroon (GWP-Cmr). The main objective of the neutral platform is to bring together all stakeholders in the water sector to build up a solid IWRM plan for the nation. The neutral stakeholder platform is known as Cameroon Water Partnership (CWP). In 2007, the government of Cameroon accepted and committed itself through the inclusion of the IWRM planning process as an activity in the public investment budget for the ministry in charge of the water sector (Ngnike *et al*, 2010). The IWRM plan will serve as a road map in achieving the MDG's and at the same time combat poverty. After diagnosing the problems facing Cameroon's water sector, it is evident that an IWRM system stands a better chance to provide adequate solutions to the aforementioned problems. This IWRM concept is accepted in Cameroon as a fundamental step for a sustainable water resource management. But Cameroon is still lagging behind with regards to her IWRM work plan, thus the necessary structures for an active and effective IWRM have not yet been completed.

### **1.3 RESEARCH QUESTIONS AND HYPOTHESES**

Some research questions are raised in an attempt to address the aforementioned water scarcity problems in the study area. These questions are:

1. Is domestic rainwater harvesting a pragmatic solution to the water scarcity problems faced by the inhabitants of Buea (on the eastern slope of Mt Cameroon)? Is it feasible?
2. Does the existing water supply facility (CAMWATER) have the capacity to serve the fast growing population in Buea? What are the hurdles? How can they be overcome?
3. To what extent does the population participate in the water resource protection? Does the legal framework facilitate innovative and sustainable water management?

The research is based on the following hypothesis:

1. The water scarcity issue in Buea is a management problem and not necessarily a problem of physical water availability.
2. An IWRM incorporating domestic RWH will most definitely augment the domestic water supply. This will increase the amount of water available for household usage and therefore improve on the existing water situation.
3. RWH using excess precipitation for artificial groundwater recharge is a very effective way to manage floods in overcrowded villages with poor drainage systems in Buea.

#### **1.4 OBJECTIVES OF RESEARCH**

It is not a secret that Buea has a growing water supply problem that needs to be addressed before it gets out of hand. The overall intention of this research is to assess the status quo and make recommendations for a better water management practice that will decrease water scarcity in Buea.

The objectives are:

1. To explore the potential of RWH in the Buea municipality. Establishing the necessity to embark on RWH by households to augment their water supply.

2. To understand the domestic water consumption pattern of the population of Buea. This will facilitate a comprehensive estimation of water demand and supply in both the rainy and dry seasons. Understanding the seasonal variations is crucial in designing a sustainable RWH system for augmenting domestic water supply.
3. To determine the feasible integration of domestic RWH in terms of willingness and acceptance by the community. Examining the cost of rain water catchment system for domestic supply with regards to construction and maintenance.
4. To promote artificial groundwater recharge. Geological investigation of the soil permeability at selected locations in Buea to obtain the saturated hydraulic conductivity which is an important aspect in the recharge of groundwater.
5. To provide relevant information with respect to better water management which could be applied to other parts of the country having similar hydrogeological parameters and also integrated by government into Cameroon's water policy.

## **1.5 RATIONALE OF RESEARCH**

Developing countries are facing growing pressure on their finite water resources and are now recognizing the important role that traditional RWH technologies play in integrated water resources management (Gould and Nissen-Petersen, 1999).

Being the capital of the South West Region, Buea is a fast growing town experiencing enormous pressure on its water resources. Located on the eastern slope of Mt Cameroon, the Bakweri tribe is the main ethnic group. A wide range of other ethnic groups from in and out of Cameroon are also represented. Surface water and groundwater (and to some extent rainwater) are the major sources of water for the fast growing population. Fairly recently, there has been a rapid increase in the demand for water as a result of agricultural activities (be it subsistence or plantation) along water courses, urbanization (construction, migration due to educational, administrative activities) and also the general domestic demand. This can be justified by an observation of the crowding of public water collection points (public taps), the sale of 'sachet-water' at motor parks, increasing

car-wash points in streams, the gradual migration and relocation of small scale farmers to wetland areas (swamps) for agricultural activities in the dry season (Lambi and Kometa, 2009).

About 90% of the local inhabitants within the steeper sector of the slope (upland villages like Bova and Bonakanda) use mainly rainwater whereas about 90% of those in the lowland villages (like Bolifamba and Bomaka) rely on the use of tap water (home based or public taps) and water from streams (Ndah and Xue, 2010). So this portrays the fact that surface water is not readily available for the upland villages.

Furthermore, the capacity of the Cameroon Water Utilities Corporation (CAMWATER) which is the national water authority is not capable to cater for the population sufficiently especially in the dry season when surface water bodies are also experiencing a massive decrease in water volume. The main catchment (Called the German Spring) supplying water to the Buea population has a tremendous seasonal variation in volume of water it produces per day. The German Spring produces about 3000m<sup>3</sup> of water each day during the peak of the rainy season but produces only about 300m<sup>3</sup> in peak of the dry season. This implies a 10 fold decrease in water volume the German Spring catchment produces daily in the dry season. This makes a dry season water shortage in Buea inevitable without reaching out to other water supply alternatives. Buea with a high annual rainfall of between 3000 - 5000mm (Folifac *et al*, 2009) and with nearby Debundscha (also located on the south western slope of Mt. Cameroon), the second rainiest place in the world having an annual rainfall of about 10000mm (Molua and Lambi, 2006) RWH is the future solution to the Buea water crisis.

RWH is not a new concept; it has been in existence from time immemorial. This study explores the active integration of this concept into the water management options of the localities in Buea. A sustainable and efficient RWH system (both at domestic and agricultural levels) which encourages community participation is the way forward with regards to the immediate response towards the Buea water crisis. This research clearly indicates that water management is the main issue to tackle. RWH has to be community based and/or catchment based. The active participation of the community is essential and instrumental in protecting their water resources. Community participation helps in widening the acceptance and reducing construction cost as has been the case in some sub-Saharan African countries like Kenya. It is also important for the population to understand the importance of good water protection. The usual “top-bottom”

approach to water management in Cameroon is not the solution to water management issues. The “bottom-up” approach is preferable in the case of Buea. Individual families have to take responsibility and tackle their water problems rather than wait for the government to come to their aid. Numerous complaints to the authorities have either been ignored or have not been taken seriously.

Once more it is worth mentioning that RWH systems do not replace the other conventional water supply systems but they can act as additional water supply to complement the other systems. Overexploitation of existing water sources and water pollution problems will decrease. Most researchers have not explored the issue of artificial groundwater recharge as a perfect option to deal with any excesses from RWH catchment systems to avoid floods and their calamities. This aspect is relevant because it does not only get rid of excess rainwater but it recharges the groundwater and thus favors water resource sustainability.

## **1.6 EXPECTED CONTRIBUTION OF RESEARCH**

Both plantation agriculture and subsistence agriculture have both been at the epicenter of most research studies being carried out in this region. This is also backed up by the presence of the CDC which is the nation’s second employer after the government. This research will provide a comprehensive understanding with regards to stabilizing the water demand of the local population. This study will provide knowledge on rainwater harvesting possibilities and build the capacities of the both the local inhabitants as well as the authorities. This will provide knowledge to the community about the benefits of using free rainwater to augment their domestic water supply and the essence of community based integrated water resource management. The findings of this study will be provided to higher educational institutions, local (village) water councils and the Buea council and will assist in water management reforms. It will also be used by policy makers in the process of putting forward proper legislations in the water resource sector.

## **1.7 STRUCTURE OF THE THESIS**

This Thesis comprises of 6 chapters. The first chapter is a general introduction of certain key aspects of the study. It starts with a background exploring global water distribution and cycle, the problem statement, the research questions, the hypothesis, the objectives, the rationale of the study, the expected contribution and ends up with structure of the thesis.

Chapter 2 explores an overview of rainwater harvesting systems; their history and also the various types and traditional methods.

Chapter 3 describes the study area. It also characterizes the hydrogeology, water supply and groundwater recharge. The legal framework of Cameroon's water regime is described in this chapter.

Chapter 4 deals with the methodological framework of the research. Hydro-geological data, geological investigation data, seasonal domestic water consumption data, sampling strategy and interviews with stake holder in the Buea water sector are addressed in this chapter.

The 5<sup>th</sup> chapter focuses on analyses of results obtained in this study and the discussion of the results analyses.

Chapter 6 is the last chapter of the study and it entails conclusions drawn from the research results in chapter 5. Recommendations and prospects for the future are also part of this chapter.



## **2.0 OVERVIEW OF RAINWATER HARVESTING SYSTEMS**

### **2.1 HISTORY OF RAINWATER HARVESTING SYSTEMS**

Back in the ancient times most rainwater harvesting systems in arid and semi-arid regions had two main purposes. The first purpose was for providing water for various domestic activities especially drinking. Secondly, evaporation of the rainwater from some of the domestic impounding systems (e.g. pools, reservoirs) made available some kind of air-conditioning feeling which more or less improved on the micro-climate making it cooler and more comfortable. The origin of RWH systems is not precisely known but seems to be from early civilization of the Middle East and Asia several thousand years ago (Gould and Nissen-Petersen, 1999). Back then most water impounding structures like reservoirs, tanks and canals were predominantly for irrigation purposes but they also provided water for household activities. Sub surface water storage has been operational for centuries. People in regions of high temperatures with subsequent high evapotranspiration (arid and semi-arid regions) have exploited sub-surface water storage systems extensively. A good example is in the Thar Desert (also called the Great Indian Desert); sub-surface water storage systems have been used to store rainwater runoff. Runoff farming prevailed in many Asian countries for centuries (especially in India and Pakistan) maximizing the use of available rainwater. The locations of wells were very close to these water impounding structures and as such recharged the wells and improved on their longevity.

Archaeologists have discovered sophisticated collection and storage systems in the Mediterranean region used at the Palace of Knossos which probably dates as far back as 1700 BC (Hasse, 1989). Also, from the 6<sup>th</sup> century onwards, the Phoenicians and Carthaginians on Sardinia were involved in the extensive collection and storage of roof runoff as their main water source (Crasta *et al*, 1982). During the reign of the Roman Empire, villas and even whole cities made use of harvested rainwater as the main source of domestic water supply especially for drinking purposes (Gould and Nissen-Petersen, 1999). The Rajiv Gandhi National Drinking Water Mission (2004) stated that Dholavira, an important site of the Indus Village in India has several reservoirs for rainwater collection (usage for drinking and irrigation) indicating RWH activities between 3000-1500 BC. In Delhi (India) structures were built to collect and confine rainwater mainly for domestic usage from the Aravalli hills in the beginning of the 11<sup>th</sup> century.

There are reports of numerous large cisterns dating about 2000 years ago which are still in use as of date with volumes ranging from 200 to 2000m<sup>3</sup> in northern Egypt (most likely the earliest RWH systems in Africa). In the Arabian peninsula where there is increasing aridity and consequent decline in groundwater levels for the past 4500 years, early water impounding structures have been documented (Pandey *et al*, 2003). It is worth mentioning that the largest cistern in the world is the Yerebatan Sarayi located in Istanbul (Turkey). It has a capacity of 80000m<sup>3</sup> with a length of 140m and a width of 70m (Hasse, 1989). Rainwater harvesting systems in Japan have made it possible for people to live for centuries in many small off shore volcanic islands such as the Miyake-jime Mikura-Jima in the Pacific and also many islands in Japan Inland Sea which lack alternative sources of water supply (Gould and Nissen-Petersen, 1999).

Sub-Saharan Africa should not be left out with regards to the history of RWH. For centuries, rainwater has been collected from roof catchments in its simplest manner in rural and to a certain extent in urban areas in sub-Saharan Africa. Many centuries ago, the original inhabitants of the Kalahari Desert area practiced RWH in combination with hunting and gathering to survive the harsh living conditions in the area. According to Gould and Nissen-Petersen (1999), the Kalahari Bushmen traditionally collected and stored rainwater in Ostrich eggs keeping them for long periods with the intention of usage in times of extreme drought and water scarcity.

In the whole of Africa, Kenya leads the way in terms of RWH technology and practice. Over the last few decades Kenya has moved from having only a few thousands of the population actively using rainwater to a little above a million. The reality is that, this is still on the rise because of the lack of assessable surface and groundwater resources in most parts of the country. Also, the conventional water distribution is not sufficient enough to cater for the populations water demand. Kenyan are also very independent, motivated and very organized with regards to this technology, making use of home based available personnel (skills and labor) and materials.

In Ghana, portable water shortages and high rate of water borne diseases due to unsafe drinking water have all resulted in the pursuit of alternative water supply systems. RWH is presently growing in Ghana especially in rural areas where traditional methods of RWH have been in use for decades. In urban Ghana, the use of modern rainwater collection techniques is on the rise. In the northern part of Ghana 3 main Non-Governmental Organizations (NGO's) namely; World

Vision, The Presbyterian Church and New Energy support and promote RWH (Barnes, 2009). Early RWH practices in Ghana include the collection of rainwater from trees using Banana leaves as gutters; collecting about 300 liters of water after a single heavy rainfall (Barnes, 2009).

Other countries in sub-Saharan Africa with less remote history of RWH documented but are making efforts to integrate RWH as part of their water resource management system include Burkina Faso, Zimbabwe, Cameroon just to name a few.

## **2.2 DRIVERS FOR RWH SYSTEMS**

There are certain a number of factors that trigger the necessity of integrating RWH into the management of water resources all over the world especially as conventional water supply is finite and also not readily available for the inhabitants in areas of physical and economic water scarcity. Some drivers for RWH systems include:

### **➤ Water Scarcity**

This is basically the main reason why RWH is gradually gaining popularity in arid and semi-arid areas in the world. Water scarcity could be in terms of lack of sufficient surface and ground water resources, contaminated surface and groundwater resources, poor governance and water policy; inadequate funds allocated for water exploitation and distribution projects.

### **➤ Water Prices**

Throughout the world, water is a very expensive commodity. It is a natural phenomenon that people will most probably drift away from higher prices in the quest for substitutes with lower prices. As the price of water increases, people tend to save water and consider other water supply options. There is a direct relationship between the rise of modern RWH systems with increasing water prices in both developed and developing countries. For instance, 35%

of new buildings in Germany have a RWH system installed. Those willing to install such a system on their buildings are awarded grants to assist the project (Green and Anton, 2012)

➤ Cutting Cost

Aiming at reducing pumping costs and energy use with respect the supply of water to elevated areas, new RWH approaches are considered and incorporated into regulations for the construction of new buildings. In India, Bangalore was the first city to implement a RWH policy (Bulusu, 2013). It will be a step forward for many developing countries to make a similar move.

➤ Legislature

Some countries (e.g. Belgium) have gone as far as promulgate laws that reduce the demand for mains water supply and use rainwater for other domestic uses apart from drinking. Austria has introduced legislation to increase the number of RWH systems. This legislation brought about the Building Sustainability Index (BASIX) which aims at reducing the amount of portable water by homes and their greenhouse gases emissions as well (BASIX, 2013).

## **2.3 BENEFITS OF RWH**

RWH be it for domestic and/or other purposes have many advantages as well as disadvantages. With regards to the case study which will be discussed in the later chapters, the advantages of RWH greatly outweigh the disadvantages. The disadvantages are mainly associated to construction costs and the water quality if the area an industrial area prone to air pollution which will subsequently contaminate the rainwater before it is collected. The issue of cost is basically with regards to how sophisticated the RWH system is constructed. Also, there is no 100% precision on the amount and frequency of rainfall. Climate change impacts make weather much more unpredictable and this might be favorable for tropical areas (more intense rainfall) whereas

arid regions will experience a decrease in the little rainfall they already have. For the success of a RWH system detailed analyses of rainfall data, catchment properties, storage facilities and maintenance, water consumption patterns, per capita income of population have to be taken into consideration. The usage of local materials and the involvement of the local community in collaboration with the local authorities and NGO's (which could support financially) helps neutralize some disadvantages.

The benefits of RWH are as follows:

➤ Free for all

Anyone anywhere at any time can collect and store rainwater as long as rain falls without paying a price. This makes rainwater a better alternative to augment other conventional water supplies which are costly and unreliable.

➤ In-situ Usage

Rain water collected domestically from the catchment (roof or ground catchment) is used on site for household activities. This saves time and money for water transportation from public taps, streams or wells. For example the inhabitants of Bova village in Buea spend an average of 3 Euros/ week (2000 f CFA/ week) for the transportation of water from Muea village.

➤ Environmental Friendliness

As a renewable resource, rainwater is an environmentally friendly water alternative which perfectly fits in any sustainable water management system.

➤ Recharges Groundwater

RWH systems are very important in mitigating flood and this is by means of artificial groundwater recharge of depleted groundwater aquifers.

➤ Less Contamination

The level of rainwater contamination is far less than that of surface and groundwater. Proper catchment and storage management of RWH systems make them require less treatment compared to other water supply options. This system contributes in solving the problem of endemic water borne diseases occurring in developing countries with water management issues.

➤ Simple Setup and Maintenance

RWH systems range from traditional methods (practiced thousands of years ago) to modern methods (with improved technology) practiced today. They also range from impounding water in a 20 liter (l) plastic bucket to a sophisticated domestic RWH system. Individuals make decisions on the construction and maintenance of their systems.

➤ Employment

Integrating RWH systems in water resource management provides employment opportunities for the local inhabitants.

➤ Conflict Free

Unlike surface and groundwater resources, rainwater is conflict free. No individual can claim ownership of rainwater. Inter-tribal conflicts as a result of surface water ownership or water misuse by upstream villages are not associated with RWH.

➤ Community Development and Women Empowerment

In most developing countries, women play an important role in household and community water management. Sidelining women from water management issues is not sustainable for community development. In sub-Saharan Africa, women manage household activities such as cooking, washing of clothes, bathing children, catering for drinking water etc. Giving them the opportunity to incorporate their knowledge and experience is crucial.

➤ Negligible Running Cost

After setting up a functioning RWH system, future expenditures are negligible. Maintaining the system is not an expensive task.

## 2.4 TRADITIONAL RAINWATER HARVESTING METHODS

As previously mentioned, RWH practices have been in existence for centuries and is still being practiced today. There have been a wide range of techniques in different parts of the world to harvest rainwater. These are convenient cost-benefit techniques that are suitable and effective in the regions in which they are used. Rural areas are still practice traditional RWH methods till date. Some selected methods of traditional water and rainwater-harvesting include:

**2.4.1 Khattara;** found in the arid and semi-arid regions in Morocco. It has been in use for several hundred years now and is the main water harvesting system used. The Khattara system is community based involving a few hundred water users (some kind of traditional organization) who share the maintenance and financial burden proportionate to their individual water rights (UNWWD Report 3, 2009).

**2.4.2 Qanats are Khattaras;** found in Syria and Yemen which have been renovated and are reused today to supply water for drinking and irrigated agricultural activities. Qanat system is an underground tunnel that's taps groundwater and delivers it to settlements and arable lands using gravity flow conditions (UNWWD Report 3, 2009).

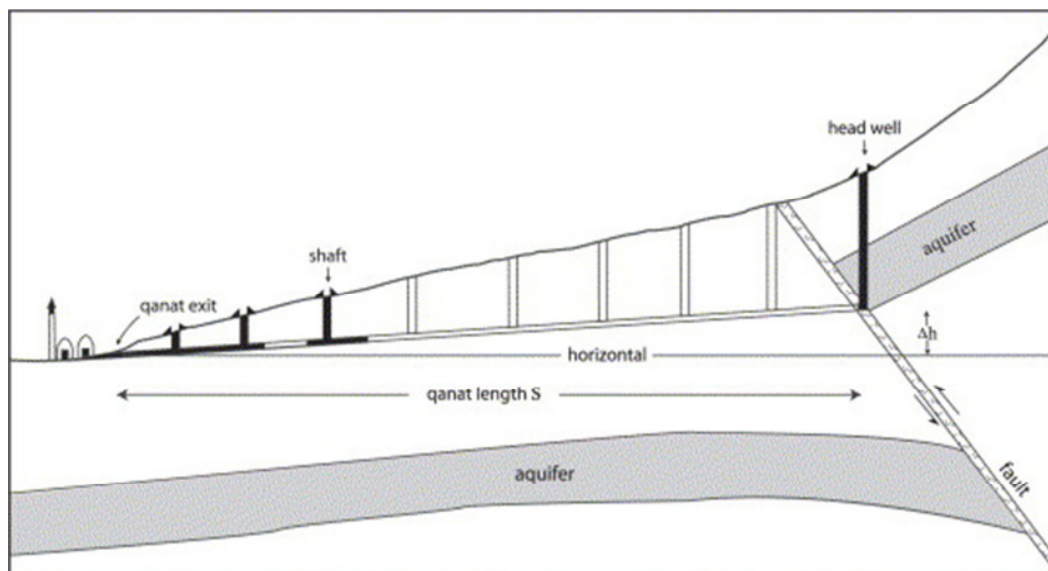


Figure 4: A typical Qanat System

(Source: Stiros S C, 2006)



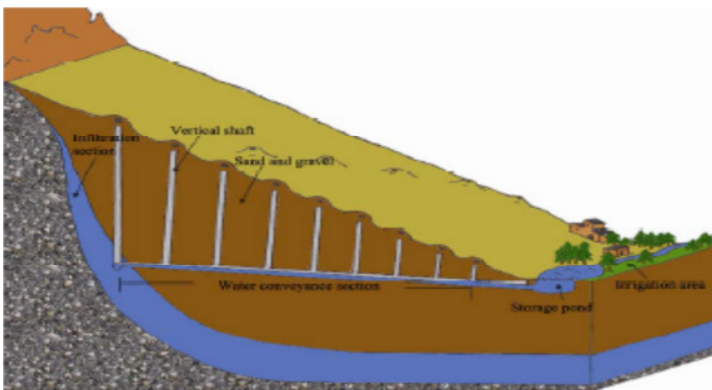


Figure 5: Qanats in China and Iran

(Source : Hu *et al*, 2012)

**2.4.3 Terraces** are the oldest water harvesting method in the Wadi Oum Zessar region in Tunisia and the west bank region. These are small retaining walls made of rocks to decelerate water flow from steep slopes controlling erosion (UNWWD Report 3, 2009).



Figure 6: Terraces in Arizona

(Source: Donkin, 1979)

**2.4.4 Birkats** are excavations in to the ground mostly found in Oman and Ethiopia. They have been instrumental for in proving water supply for small settlement. Their main function is to impound rain water and subsequent runoff.



Figure 7: Birkats in Yemen

(Source: Hovden, 2006)

**2.4.5 Tankas** refer to underground tanks located in houses or within the courtyard. This is mainly used in the Rajasthan region in India. Their main purpose is to supply water for the household during periods of water scarcity in this arid environment. It is a cylindrical cistern that receives water from a roof or courtyard catchment. It stores water for months and save the household time and inconvenience fetching water during drought periods. Its tank could have a capacity up to 25,000 liters (Kapadia, 2011). Centralization of water supply and technological development promoting pipe born water made Tankas less popular in the 20<sup>th</sup> century. Population growth resulting in inadequate supply of water, surface and groundwater contamination issues and the costs of water extraction and purification are good reasons to revive this traditional RWH method.

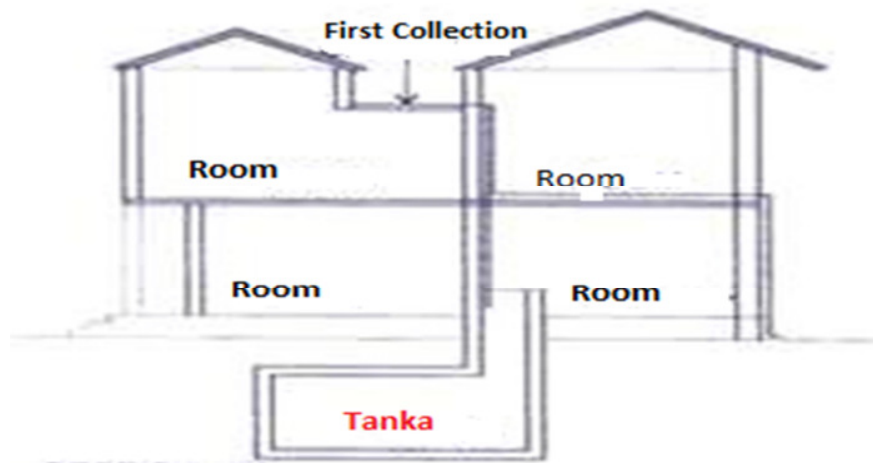


Figure 8: Tanka for Rainwater Storage

(Source: Kapadia, 2011)

**2.4.6 Khadin** also known as Dhora is an embankment built across a slope to trap rainwater runoff. It collects and stores the rainwater mainly for agriculture and cattle all year round. It harvests water on farmland and this area is thereafter used for agriculture. Khadins are up to 3m high and may be 100m to more than 10km in length serving as reservoirs where water can be directly extracted for various uses (Gould and Nissen-Petersen, 1999).

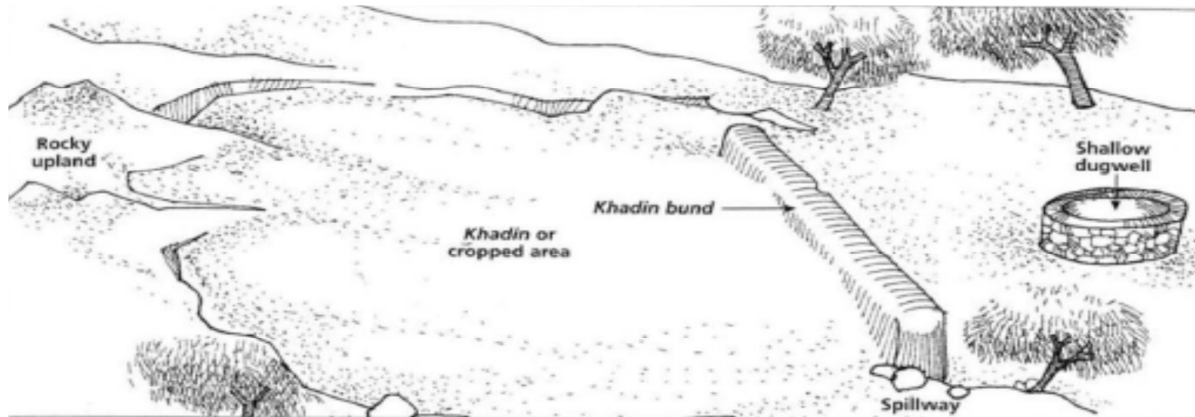


Figure 9: A typical Khadin System

(Source: Kolarkar, 1997)

**2.4.7 Zings** are small tanks in which melted glaciers waters collect. Water is brought to the tank by channels. Early during the day, the glaciers melt and drip into the channels and fill them up resulting to flowing water in the later part of the day.



Figure 10: A Zing System

(Source: CGWB, 2011)

**2.4.8 Shuijiao** is a tank found underground having a volume of up to 30m<sup>3</sup>. It has been in existence for centuries and many households in the Gansu and Shanxi province use this system to cater their domestic water needs (Gould and Nissen-Petersen, 1999).





Figure 11: A Shuijiao Underground Tank

(Source: Qiang and Yuanhong, 2003)

**2.4.9 Jars, Buckets and Pots** are mostly used in rural areas in sub-Saharan Africa to collect rainwater from roof catchment gutters and store them for domestic use. These jars and pots are locally made and fulfill the purpose of rainwater collection. This collection is in a small scale (due to small volume of jars, buckets and pots) and cannot serve the household for long periods of water scarcity, except very large jars as shown on Figure 12 which could go for months.



Figure 12: Traditional Jars for RWH.

(Source: RWSSFDB, 2006)

## **2.5 TYPES OF RWH SYSTEMS**

There are a number of criteria that are considered in classifying RWH systems. They are either with respect to the size and type of catchment surface, the purpose for the collected water, the type of tank used for water storage as well as the type of material used for the construction of the storage tank (Gould and Nissen-Peterson, 1999). RWH by roof catchments for domestic purpose is the type of RWH discussed in this study.

## **2.6 COMPONENTS OF A RWH SYSTEM**

A typical RWH system consists of 4 main components which are further divided into a series of smaller components. These include; the catchment system, the conveyance system, the storage system and the recharge system.

### **➤ The Catchment Surface**

This is the surface that traps rainwater directly as the rain falls and collects rainwater runoff. There are different types of catchment systems which include; roof catchments, ground catchments and rock catchments. Roof catchments may be constructed using thatched grass, cement, corrugated galvanized iron sheets, wood shingle and tiles. Corrugated galvanized iron sheets (which provide good catchment surfaces) are the most common roof catchment material found in Buea. More than 90% of residential and commercial buildings are equipped with corrugated galvanized iron sheet roofs. This provides a good platform for implementing RWH system in Buea.

The main problems with corrugated galvanized iron sheets are cost and durability. These sheets are expensive to the average local inhabitant. Bootleg cheaper sheets imported from neighboring Nigeria and also China does not stand the test of time and quickly undergo corrosion in the humid tropical climatic condition. The roofs of some newly constructed buildings around Molyko (University area) are painted. Painted sheets may contaminate the rainwater that collects at the catchment (roof). Domestic RWH systems using rainwater for drinking purposes should not use painted sheets and corrosive materials because of concerns about the quality of water.

Nevertheless, water from roof catchments with painted and corrosive sheets can still be used for other domestic purposes. Figure 13 below shows the roofs of a building in Buea covered with corrugated iron sheets.



Figure 13: Corrugated iron sheets on a building in Buea.

(Source: Manyi, 2005)

#### ➤ Conveyance System

The transport system which is actually the system through which rainwater collected from the roof catchment flows to the storage tank. This system includes; gutters, pipes, first-flush diverters and filters. Gutters are constructed all around the roof catchment to direct the impounded rainwater from the roof catchment through conduits (down pipes) and filters to the storage device. In Buea most people use metal drums of varying sizes as storage device but there have been a gradual influx of large plastic (100 liters) containers in the last few years. Some of these plastic containers are used to store groundwater extracted from boreholes. These gutters made of metal and plastic materials are visible in some houses practicing traditional rainwater



harvesting. A cheaper alternative will be the use of bamboos (very available in the Buea area) as gutters but it is not as effective as plastic and metal gutters. Plastic materials are the most common used in the construction of buildings in Buea and most parts of Africa. Plastic pipes are the best for a domestic RWH system in this area. They are not the cheapest means but they are the most cost effective for this purpose. Also a wire mesh is placed at the roof catchment outlet to trap leaves and other solid materials from entering and eventually blocking the pipe system.

A first flush device is necessary to flush out the first few liters of rainwater that may contain dust, bird droppings and carcass of small animals (for example wall geckoes and lizards) that could potentially decrease the quality of rainwater collected.

Furthermore, rainwater collected goes through a process of water purification. The type of purification method depends on the final use of the rainwater harvested. If the intention is to use the water for drinking, a purification method targeting chemical and biological contamination is required. But generally, sand filtration is mostly common in this part of the country and even entire region as the basic method of water purification. Sand, gravel and cloth in that order are used by local inhabitants to purify surface and groundwater as well as rainwater.

#### ➤ Storage System

It is of utmost importance to properly store the rainwater collected in order to be able to use it when need arises. Rainwater is stored in above ground or underground in tanks, and also in reservoirs. For domestic RWH, above ground and underground storages are most predominant. The storage tanks are constructed using steel, plastic, concrete, compressed soil, Ferro-cement and wood. In Buea, plastic and steel tanks above ground are mostly used by hotels and other institutions to store pumped water from wells. For underground storage tanks, the use of concrete and Ferro-cement are predominant. Prudent consideration has to be taken with respect to the construction of the storage tank. It is the most expensive component of a RWH system and as such enough understanding of the dynamics of such a system is necessary. It is important to make sure that the tank material is affordable, waterproof, does not contaminate the water and should be able to resist the environmental conditions of the area.

The tanks should be sealed to avoid the breeding of mosquitoes and other insects which pose a significant threat to human health. The shape and size of tanks vary and are a function of the weather conditions of the area. Areas with long periods of drought imply longer periods of water scarcity and therefore require larger storage devices to store enough water to cater for the long periods of drought. Also the water demand of the household should also be considered in determining the size of the rainwater storage tank required. Underground tanks have to be cylindrical in shape so as to overcome pressure differences between the pressure exerted by the water in the tank and that exerted by soil water and soil pressure on the tank.

➤ Recharge System

This system makes use of excess rainwater which cannot be stored in the storage device because it has exceeded its storage capacity. Artificial Groundwater Recharge (AGR) is aimed at artificially connecting excess rainwater (runoff) to either existing wells or well which are specially designed for this purpose. There are many techniques to artificially recharge rainwater either directly on the surface or sub surface. These include recharge wells, recharge pits, borehole flooding, filling natural openings in the soil, dug well recharge, basin or percolation tanks, and over irrigation. It is important for rainwater to be filtered before it goes into recharge structures. Figure 14 below shows the main components of a domestic RWH system.

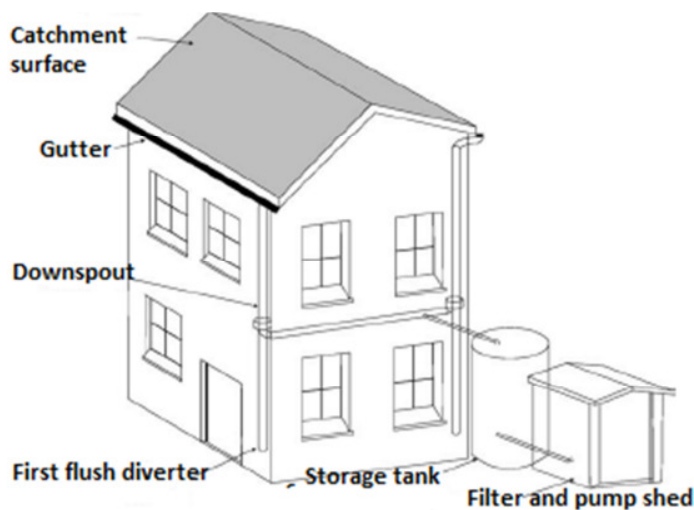


Figure 14: Typical components of a domestic RWH system

(Source: Li *et al*, 2010)

### **3.0 DESCRIPTION OF STUDY AREA**

#### **3.1 LOCATION AND DESCRIPTION**

Cameroon is located in west central Africa with a surface area of 455,000 km<sup>2</sup>. It borders Nigeria, Chad, Central African Republic, Congo, Gabon, Equatorial Guinea and the Atlantic Ocean. The Cameroonian population is estimated at about 20, 5 million. The nation is said to be “Africa in Miniature”. This means that all what is found in Africa can be found in Cameroon. It is divided into 10 Regions which were called Provinces till the presidential decree in 2008 change them Regions. Yaoundé is the national capital and Douala is the economic capital. The South West Region is one of the two Anglophone regions in the country. Buea is the Regional capital of the South West Region and the former capital of Southern Cameroons (1949-1961).

The German Explorer Gustav Nachtigal arrived and annexed Cameroon in July 1884. From that date, Cameroon became a German colony. Buea was the capital of Cameroon during the German colonial rule. The Germans were defeated in 1916 by a coalition of French and British soldiers in Cameroon and took over territorial rule of the country. The British took control of two regions in the west of the country (presently known as the North West and South West regions) and the French took control of the rest of the country. The most conspicuous physical feature of Buea is Mount (Mt) Cameroon (also called Cameroon Mountain or Mt Fako). This is the highest mountain in west and central Africa with a height of about 4095m above sea level (a.s.l.). It is an active volcano with its last eruption on the 2<sup>nd</sup> of February 2012. It is part of the Cameroon Volcanic Line (CVL) which stretches from the Gulf of Guinea through the western High Plateau, Lake Nyos, and the Oku Massif right up to the Ngoundere Plateau. The memorable eruption of the south flank of the mountain on the 28<sup>th</sup> of March 1999 produced so much lava which almost reached the Atlantic Ocean and stopped a few hundred meters at Bakingili in Limbe.

Buea lies on the eastern slope of Mt Cameroon and has a population of about 90,088 inhabitants (according to the 2005 population census by National Institute of Statistics, Cameroon). It is a town characterized with administrative activities, plantation agriculture, educational activities (Buea has the first Anglo-Saxon University in Cameroon) and small businesses. The Bakweri tribe is the indigenous inhabitants but there are also a large number of inhabitants from other

parts of the country as well as abroad. The presence of the Nigerian Consulate in Buea is an indication of the significant presence of the Nigerian population in this region. The Buea municipal council runs the daily affairs of the town and is headed by the mayor. Buea municipality comprises of Mile 14 (Dibanda), Mile 15 (Ekande), Mile 16 (Bolifamba), Mile 17, Mile 18 (Bomaka), Muea, Molyko, Bonduma, Great Soppo, Clerks Quarters, Small Soppo, Bokwaongo, Likoko-Membia, Federal Quarters, Buea Town, Bova 1 and 2, Bonakanda, Bokwai and Bokova. The topography is hilly and characterized by numerous springs and streams. Below are figures 15 and 16 which show the map of Cameroon and the map of Buea respectively (showing Mt Cameroon the main villages and surface water bodies):



Figure 15: Map of the Republic of Cameroon

(Source: Page, 2003)

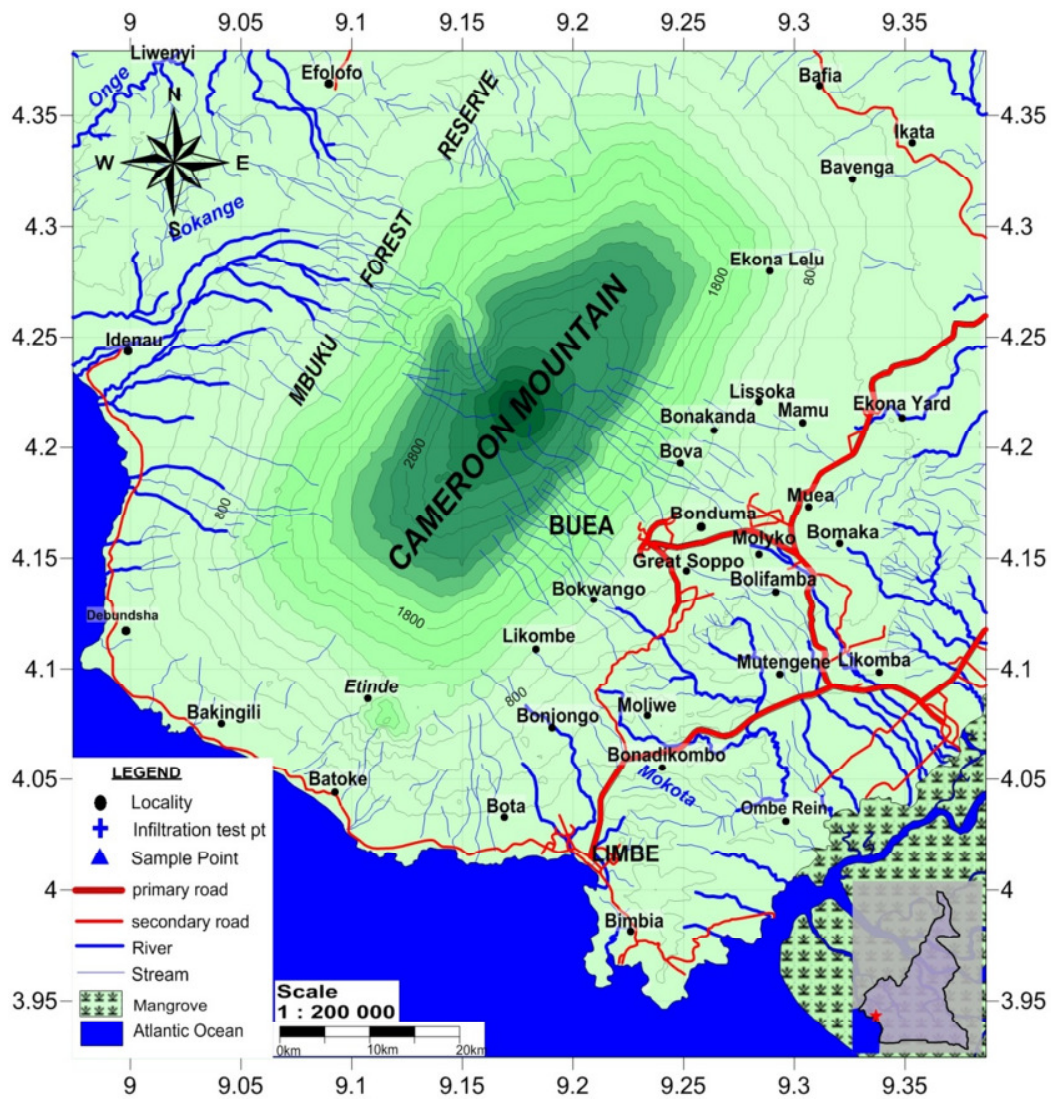


Figure 16: Map of Buea on the eastern slope of Mt Cameroon

(Source: Base Map from National Institute of Cartography, Cameroon, 2013)

### 3.2 GENERAL GEOLOGY

Mt Cameroon (4095 m.a.s.l.) lies along the Cameroon Volcanic Line (CVL) which stretches from the Atlantic Ocean right up towards Lake Chad. The CVL is a tectonic structure comprising a chain of volcanoes extending for about 1600 km. It covers both oceanic and continental crust including the oceanic volcanic islands Bioko, Sao Tome, Principe and Pagalu of the Gulf of Guinea. Mt Cameroon is about 50 km in length and about 35 km wide. A smaller mountain emerges on the southern flank of Mt Cameroon and it is known as Mt Etinde or Little Mt Cameroon with its peak at 1713 m a.s.l. Buea is located on the eastern slope of Mt Cameroon and its geology is a result of the presence and influence of the active volcanic activities of the mountain. Mt Cameroon is one of the most predominant touristic attractions in Cameroon. The annual Mt Cameroon race attracts national and international participants and audience. The eastern slope of Mt Cameroon is considered a hot-spot for biodiversity because it harbors some endemic flora and fauna species.



Figure 17: A picture of Mt Cameroon from Upper Farms, Buea

(Source: Author, 2013)



The Mt Cameroon area is characterized by basaltic rock types. Basalts are igneous rocks that are mainly made up of plagioclase and pyroxene minerals. They are dark in color, fine grained, rich in iron and magnesium and are mostly extrusive resulting from lava flow from a volcanic eruption. Basalts are the most abundant rocks on the earth surface. Most ocean floors are underlain by basalts and some part of continental crust are covered by basalts brought about by lava flows due to volcanic activity. Figure 18 below shows the geology of the whole Mt Cameroon region especially Buea on its eastern slope.

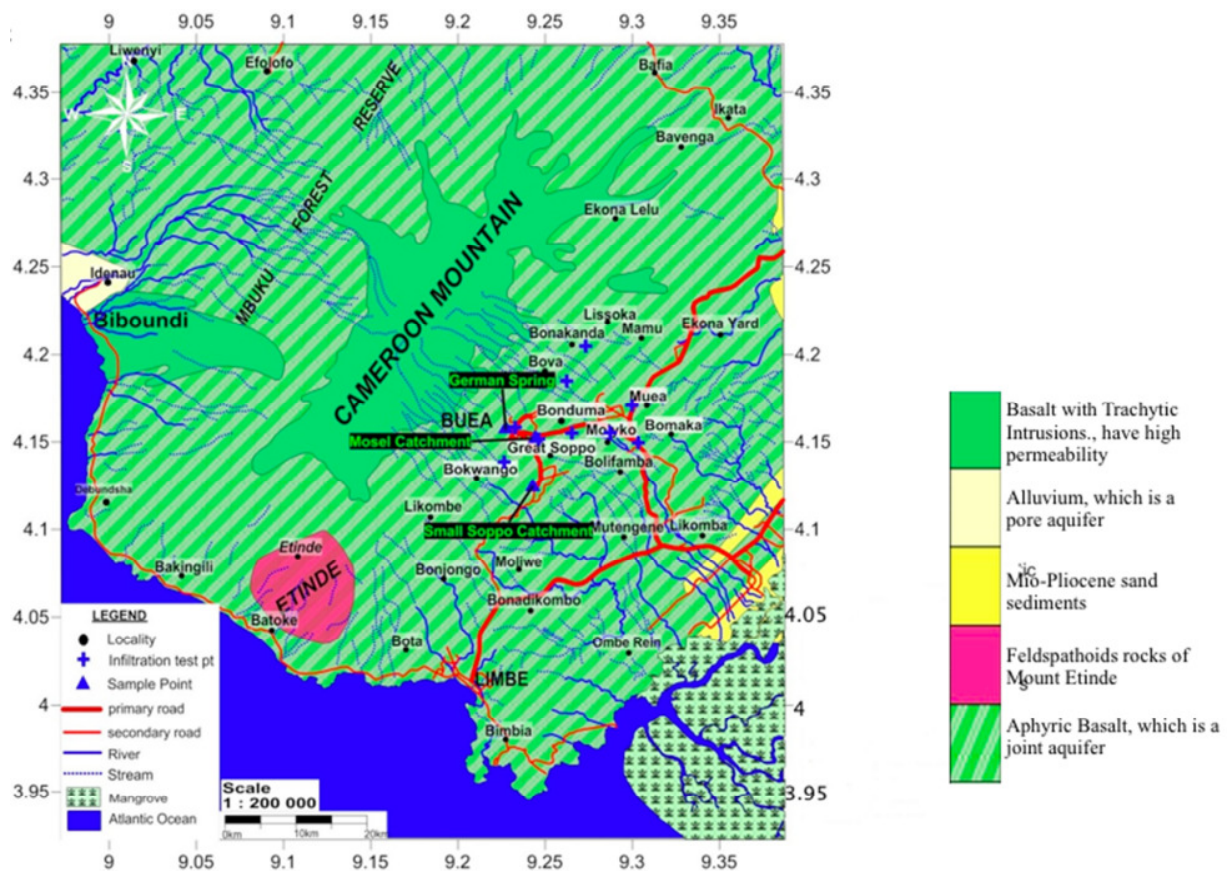


Figure 18: Geological Map of Buea including Mt Cameroon (Base Map from National Institute of Cartography, Cameroon, 2013)

The volcanic activity of Mt Cameroon dated back during the Late Miocene Epoch (11 million years ago) lead to the deposition of basaltic lava flowing down the mountain. Mt Cameroon is mainly composed of alkali basalts with trachytic intrusions and at the lower elevations below 1800 m the rocks are mainly aphyric basalts. Aphyric basalts are formed by rapid crystallization in the absence of large and well-formed crystals (phenocrysts). Sediments from the Cretaceous

to Quaternary epoch are beneath the basaltic rocks which are underlain by a basement of Precambrian metamorphic rocks. There are more than 100 scoria cones (steep conical hill) on the flanks and around the lowlands of the volcano. Sedimentary rocks are predominant around the Tiko plain extending right up to Douala. Alluvial deposits and clays as a result of weathering of igneous rocks are mostly found around the creeks in Tiko plain (Ako, 2011).

According to Lambi and Kometa (2009), the jointed and fractured nature of the basalts coupled with the unwelded nature of the pyroclastic rock deposits gives the underlying substratum a high porosity and permeability portraying the underlying lithology as spongy material with good drainage. Also the scoriaceous materials resulting from the volcanic eruptions of Mt Cameroon have cavities and gas vesicles which account for the high degree of porosity and permeability. This will be further discussed in the forthcoming chapters.

### **3.3 HYDROGEOLOGY**

Air masses (warm moisture laden winds mainly the Monsoon of western Sub-Saharan Africa) carrying rain forming clouds blowing in from the coast are blocked by the mountain forcing the air to rise, then cools down and condenses resulting to precipitation. This occurs in from late June till early October and accounts for the rainy season. The dry season from late October till early June is brought about by North-East Trade Winds. The Mt Cameroon region has the highest precipitation in the entire nation. Debundscha (with about 10000 mm/a) which is amongst the five rainiest places in the world is located on the southwestern slope of the mountain. Buea on the eastern slopes also has high annual precipitation of between 3000 to 5000 mm. This high precipitation recharges the aquifers and guarantees a sustainable groundwater resource for the region. The precipitation percolates through the porous scoriaceous materials into the perched water table recharging the aquifer. Also the jointed nature of some of the basaltic rocks and the porous nature of the scoriaceous materials makes this area rich hydrological reservoir (Lambi and Kometa, 2009). Volcanic activities resulting in faults, cracks and fissures further facilitate the percolation of water through the impermeable layers of basalt into the deeper aquifers. Water that does not infiltrate as a result an impermeable barrier of



basaltic rocks form perched aquifers. Most streams at 1800 m and below arise as springs (Lambi and Kometa, 2009). Some of the springs of Mt Cameroon flow continuously all year round and some (particularly in Mile 29, Mautu between Ekona and Muyuka) have been commercially exploited on the eastern slope of Mt Cameroon by SUPERMONT (a commercial natural mineral drinking water and sweet drinks company). SUPERMONT is not part of the Buea municipality. Below is the map of the eastern slope of Mt Cameroon showing the drainage of Buea and all 3 catchments including points of all the infiltration tests carried out on the field;

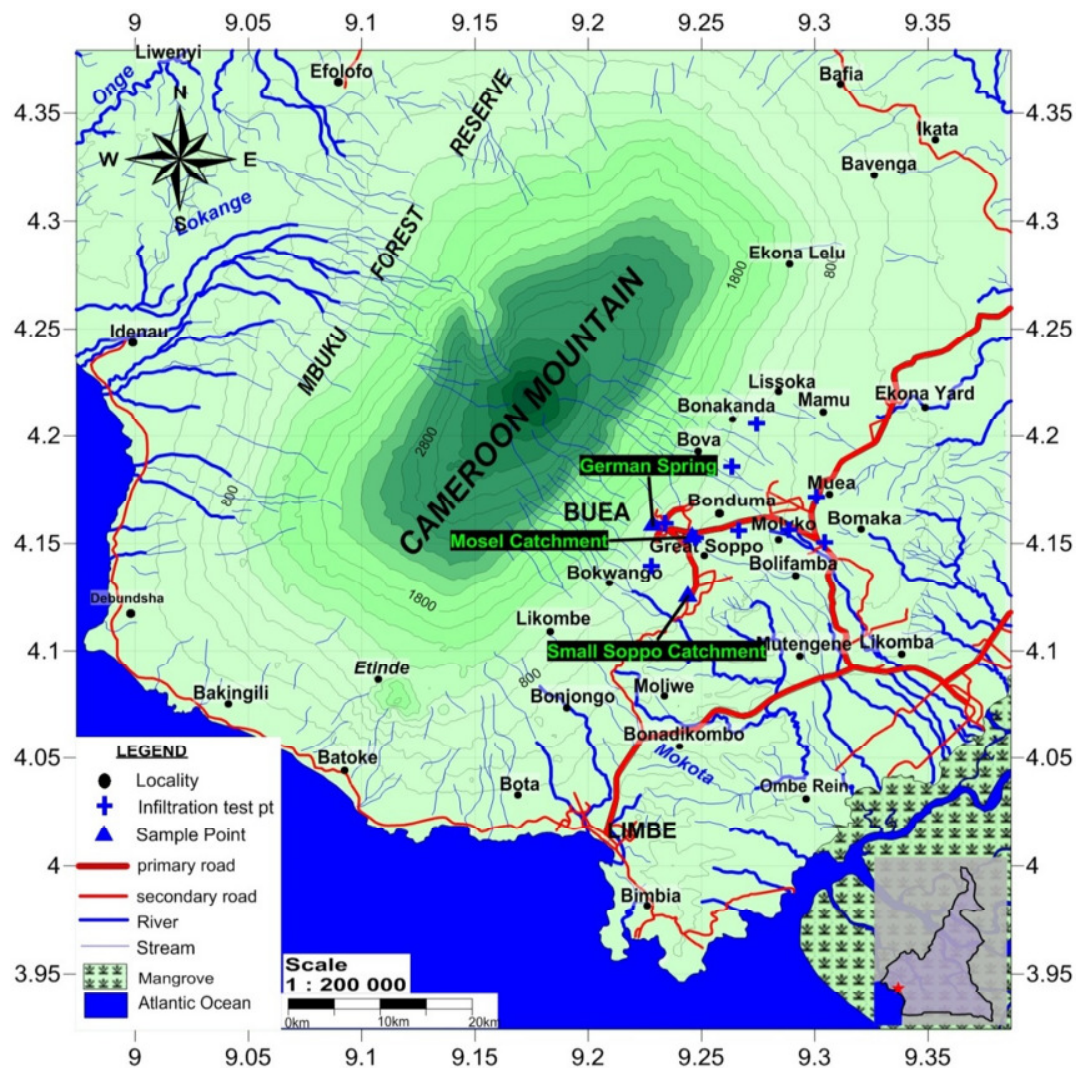


Figure 19: Hydrogeological Map of Buea with all 3 catchments and locations of infiltration tests (Source: Base Map from National Institute of Cartography, Cameroon, 2013).

### 3.4 WATER SUPPLY

Cameroon is obliged to double its effort to attain the MDG target for drinking water in rural areas. The government is taking some steps which have a better outlook for the future. Portable water supply in Cameroon was initially in the hands of Société National des Eaux du Cameroun popularly known in its French acronym SNEC. SNEC was dissolved in 2009 and was immediately replaced by Cameroon Water Utilities Corporation (CAMWATER). CAMWATER is an asset holding public company created in 2009 which is mainly responsible for portable water supply throughout the country by way of overseeing national water policy, investment and projects. CAMWATER has delegated Camerounaise Des Eaux (CDE), a private operator under a lease contract to manage water catchments, treatment, distribution and maintenance. CDE is managed by a board led by the Moroccan based Office National de l'Eau Portable (ONEP). CAMWATER and CDE have a major task which is to ameliorate the acute water shortage problem faced by the residents of the Buea Municipality by commercially providing portable water to the Buea inhabitants.

CDE is directly involved in the supply of portable water to the inhabitants of Buea. According to information from the CDE Buea branch and the regional headquarters in Limbe, there are 3 catchments in the Buea Municipality. The 3 catchments include:

➤ The German Spring

This is the first catchment in the Buea Municipality and it was developed back then when Buea was the capital of German colonial rule in Cameroon. This catchment involves a spring flowing down from the lower part of the mountain a few hundred meters from the Buea Central Prison yard at Upper farms.

The influx of water into this catchment has decreased immensely over the last few years. Up to 2 years ago, this catchment received about 1000m<sup>3</sup> of water per day and this has dropped to about 300m<sup>3</sup> per day presently. This catchment closes its supply tanks for about 17 hours per day and opens them just for 7 hours a day. The only forms of water purification are mechanically by way of sand filtration and chemically by chlorination. Since the German Spring is located on the



slope of the mountain, the water flows down by gravity for distribution. Figures 20 and 21 below, show the German Spring Catchment and its storage facility.



Figure 20: The German Spring catchment at the foot of Mt Cameroon, Buea

(Source: Author)



Figure 21: The German Spring Storage Facility Upper Farms, Buea

(Source: Author)

➤ The Small Soppo Catchment

The Small Soppo Catchment went operational early this year (2013) and provides an additional 4800m<sup>3</sup> of water to what was initially present. It actually has a capacity of 7000m<sup>3</sup>. It pumps water to Mosel Spring (the 3<sup>rd</sup> catchment) at the rate of 200m<sup>3</sup>/hr where it is treated. It has a pumping capacity of 250m<sup>3</sup>/hr but operates on 200m<sup>3</sup>/hr. Hence it pumps 50m<sup>3</sup> less than capacity.

The water influx to this catchment has also decreased within the last few months after its establishment. Electricity is required in order to pump water from this catchment to the Mosel Spring and this therefore means that in the absence of electricity, there will be no water. This is



catastrophic considering the frequent power (electricity) cuts in Buea. The American based corporation American Electricity Supply (AES) acquired 56% of Société Nationale d'Electricité du Cameroun (SONEL) in 2001 and merged to form AES-SONEL. AES-SONEL is in charge of electricity supply throughout the nation. Their unreliability in power supply is heavily felt in Buea. The Small Soppo Catchment can be seen on figure 22 below.



Figure 22: The Small Soppo Catchment in Buea (Source: Author)

➤ The Mosel Catchment

This is the third catchment in the Buea Municipality. Water is not filtered at this facility but the water is analyzed with respect to its chemical and biological purity. The water is then pumped at the rate of 450m<sup>3</sup>/hr. This catchment pumps water into a 250m<sup>3</sup> tank located around the Police Credit Union which further supplies Federal Quarters, Clerks Quarters, Lower Farms and Long Street depending on how much water is available and also whether electricity is available or not. The water is distributed through underground pipe systems to the consumers of the municipality. There are prospects of constructing a fourth catchment at Biaka Street (towards Molyko). This is a 24 months project designed to satisfy the water demand of the Buea population. About 11000m<sup>3</sup> of water is required per day by the Buea residents but CAMWATER and CDE are still lagging behind their target value. Figure 23 shows the storage facility at the Mosel Catchment.



Figure 23: Storage Tanks at Mosel catchment in Buea (Source: Author)

As earlier mentioned, the main methods of purification include Sand Filtration and Chlorination. The potential hydrogen and quantity of chlorine in the water is checked. The quantity of chlorine

should be about 4 mg/l. Also, bacteriological analysis is carried out twice a month at the regional laboratory in Limbe and the central laboratory in Douala.

Table 1: Distribution of Catchments in Buea and the volume of water produced

CATCHMENTS		CAPACITY	VOLUME OF WATER PUMPED OUT/DAY	OBSERVATIONS
✓ GERMAN SPRING	PRESENT TANK	5000m <sup>3</sup>	1000 m <sup>3</sup>	+2000m <sup>3</sup> (DURING PEAK OF RAINY SEASON -WASH PERIOD)  Only 300m <sup>3</sup> DURING DRY SEASON. THIS IS ABOUT 10 TIMES LOWER
	GERMAN TANK	300 m <sup>3</sup>		
✓ SMALL SOPPO CATCHMENT		7000 m <sup>3</sup>	4800 m <sup>3</sup>	MAY PUMP LESS DUE TO POWER FAILURE
✓ MOSEL TREATMENT STATION		7000 m <sup>3</sup>	3600 m <sup>3</sup>	MAY PUMP LESS DUE TO POWER FAILURE
			DRY SEASON	RAINY SEASON
			TOTAL VOLUME PRODUCED/DAY	9400 m <sup>3</sup>
			CURRENT DEMAND FOR AREAS COVERED BY CDE	11000 m <sup>3</sup>
			DEFICIT (-) AND EXCESS (+)	-1600 m <sup>3</sup> +400 m <sup>3</sup>



It is not a secret that the capacity of CAMWATER and CDE is too small to cater for the water demand of its direct subscribers and those relying on public water points (taps). The water transport (pipes) and storage facilities (tanks) are old and there is heavy water loss as a result of leakages. The current water supply capacity is actually sufficient for about half of the population. Buea currently has a population of about 90,000 inhabitants and the population is still on the rise. Furthermore, some individuals cannot afford the service of the Water Utility Corporations because they simply don't have the financial means to subscribe for the commercial water supply at their homes.

Since CAMWATER and CDE cannot cater for each and everyone in the vicinity of Buea and its environs, some villages have taken upon themselves and embarked on their own community water schemes. A good example is the Community Water Project of the Muea Catchment. This community initiative was founded in Bokwai village as far back as 1963. Sand filtration and chlorination are the major water purification methods used. Over the years water levels have decreased immensely especially during the dry season. As a result, the volume of water pumped out has decreased and cannot satisfy the people of Muea. The water management committee has neither records of the volume of water produced nor the size of the water tanks.

Such community based water supply schemes have certain constraints that inhibit their smooth functioning. Financial deficiency and lack of continuous financial support from local government or NGO's makes it very difficult to maintain existing structures and personnel for the water supply scheme. The same tank built about 50 years ago is still in use without any form of renovation, considering that the population of Muea has increased tremendously. The only form of maintenance has been pipes which were changed from asbestos through metallic to plastics. Another major setback is that the local inhabitants do not cooperate with the community water management board.

There are also reported and well publicized cases of deadly clashes between villagers and the workers of the Water Utilities Corporations. In 1991, clashes between inhabitants of Kumbo in the North West Region ended up with the loss of 6 lives. The Kumbo inhabitants fought successfully to regain full control of their water supply which was handed over to SNEC by a



presidential decree transferring their community water supply ownership to state ownership (Page, 2002). There are also other cases of the Water Utility Corporation being chased out of villages who have struggled to put up their own water supply schemes that seem to function. The perfect solution to all these issues is making use of the abundant precipitation in Buea by way of domestic RWH.

### **3.5 GROUNDWATER QUALITY**

There have been some interesting studies on the hydrogeology of the groundwater resources of the Mt Cameroon region but the detailed hydrogeology of this region is still unknown to a greater degree. Lambi and Kometa (2009), Endeley et al (2001), Ako *et al*, (2012) and a host of others have carried out resourceful research to this effect.

The groundwater quality is very crucial in this region where the population is on the rise and the surface water resources are polluted or prone to pollution by both natural and anthropogenic activities. In Buea, groundwater is preferably of better quality for both domestic and agricultural activities. Dumping of domestic waste, poor sewage disposal, surface water misuse (e.g. for car wash and defecation) have all rendered surface water unreliable for domestic purposes especially for drinking.

Buea, as a result of the presence of Mt Cameroon has a large water storage capacity and harbors many springs which arise either from the lahars or from the plane of contact of pyroclastic materials and basalts (Lambi and Kometa, 2009). Lahars are volcanic mud or debris flow which could be fluid when flowing and solid when stationary. Buea and the entire eastern slope of Mt Cameroon are rich in Andosols (or Andisols) which are fertile soils good for agriculture. The fertile soils coupled with both high precipitation and rich groundwater resources have attracted the influx of people from other parts of the country as well as large-scale plantation agriculture (at the lower slopes of the mountain below 1500m). The extensive plantations owned by the CDC include; the banana plantation from Molyko right up to Bokova, palms and rubber plantations in Tiko, Moliwe and Ombe, the tea plantation in Tole and other chunks of private small scale subsistence agricultural activities scattered all over the Buea municipality. The

groundwater quality in terms of its chemical composition is determined by certain factors which are both natural and anthropogenic. The natural factors include; the mineralogy of the rocks at the watershed and the aquifer, the climate and the composition of precipitation. Anthropogenic factors that determine groundwater quality include; agriculture, industrial activities and urban activities (Ako *et al*, 2012).

Generally, concerns with regards to drinking water always include contamination by chemical substances like heavy metals, high levels of nitrogen and other micronutrients, bacteria and other pathogens. Bacteriological contamination and contamination by other microbes are of top priority because their effects are usually instantaneous. Health hazards as a result of the effects of chemical contamination are mostly associated with long-term exposure and as such it is viewed as less of a threat compared to health hazards caused by bacteria and other microbes. Ako *et al*, (2012) concluded that spring water from the Mt Cameroon area has Total Dissolved Solids (TDS) of less than 600 mg/L and Electrical Conductivity (EC) within the desirable limits of 750  $\mu$ S/cm. TDS expresses the total amount of mobile charged ions and EC expresses the ability of water to conduct an electric current. They are both within the limits of good quality drinking water as per the drinking water standards of the World Health Organization (WHO).

### **3.6 WATER ASSOCIATED HEALTH ISSUES**

Water shortage in Buea has led to many people consuming water of doubtful quality. Water is necessary for life on earth and as such in the absence of clean portable water; people are forced to consume water which is not suitable for drinking. This predicament has propelled the occurrences of water borne infections in the municipality. These water-borne diseases are of different types and ranges which include; protozoa infections, parasitic infections, bacterial infections and viral infections. These infections mostly occur as a result of the ingestion of contaminated water, consumption of food prepared with the use of contaminated water and poor hygiene. The occurrences of these water borne diseases have been rampant and have also been the cause of the death of many inhabitants of the municipality. There have been outbreaks of some epidemic diseases like the outbreak of cholera in Buea, claiming 46 lives between 2010

and 2011. It is worth mentioning that female Anopheles mosquitoes transmit malaria. They breed in poorly stored or disposed water, ponds or lakes and transmit the biggest killer disease in Africa. Table 2 below shows some frequent water borne diseases experienced in Buea.

Table 2: Some frequent Water Borne Diseases in Buea

Diseases	Culprit	Mode of Infection	Main Symptoms	Preventive & Curative Means
Cholera	Vibrio cholerae (bacteria)	Contaminated drinking water	Diarrhea, nausea, nosebleed, cramps, vomiting, low blood pressure and could be rapidly fatal	Vaccine is available although not so efficient. Consume boiled and chemically disinfected water (water treatment)
Hepatitis A	Hepatitis A virus	Water or food contaminated with feces	Fever, fatigue, jaundice, diarrhea, weight loss, abdominal pain	Vaccine is available Water treatment
Typhoid Fever	Salmonella typhi (bacteria)	Contaminated water with feces of infected person	High fever up to 40°C, diarrhea, could be fatal if untreated	Vaccine and drugs are available Water treatment
E. coli Infection	Escherichia coli (some strains of E. coli bacteria)	Water contaminated by E. coli bacteria	Diarrhea, high dehydration	Water treatment
Poliomyelitis	Poliovirus	Water contaminated by feces of infected person	Fever, headache, seizures, spastic paralysis, could be fatal	Vaccine is available Water treatment
Salmonellosis	Salmonella (bacteria)	Contaminated water and mostly food	Diarrhea, abdominal cramps, fever, vomiting	Drugs Consume cooked food and use treated water
Dysentery	Shigella dysenteriae (bacteria)	Water contaminated with the bacteria	Vomiting blood, passing out feces with blood	Drugs Water treatment

Source: Adapted from Ndah and Xue (2010)

### **3.7 LEGAL FRAMEWORK OF CAMEROON'S WATER REGIME**

The right to water is a fundamental right to human beings being that water is the most indispensable resource. This right is most effective when nations subscribe to the international human rights law and incorporate these laws into their domestic policies and legal frameworks. The state or nation then has the obligation to enforce the right to water by way of the judicial system if there is any form of violation by anyone who so ever. The Johannesburg Declaration and Plan of Action after the World Summit on Sustainable Development in Johannesburg in 2002 stated that the right of access to water is a serious crisis on the rise and all nations should address this issue by putting in place measures that will ensure the right of access to water to all (Tamasang, 2007). There have been cases around the world where individuals have used the right to water as a legal weapon to augment the livelihood of the poor.

The Bon Vista Mansions Case in South Africa in 2001 is a good example of how individuals can obtain their right to water by way of the judicial system (courts) if their rights are violated. The residents of the Bon Vista Mansions in South Africa sued the local council in charge of water supply because their water supply was unjustly disconnected (because of unpaid water bills) therefore rendering them unable to exercise their right to water. The residents were granted *locus standi* (the right to bring action to court or to be heard in court) and were eligible to proceed with the case. The courts found that the local council's decision constituted *prima facie* a breach of the water rights of the residents and made a decision based on the constitution which guarantees everyone the right to water. The water supply of Bon Vista Mansion's residents was reinstated (Kothari, 2006).

The rights of access to water are recognized under the Cameroonian law but the Cameroon constitution does not provide for the rights to water explicitly. It is stipulated that "everyone has the right to a healthy environment, the protection of the environment shall be the duty of every Cameroonian, and the state shall ensure the protection and improvement of the environment" (Tamasang, 2007). So the right to water is embodied in provisions of socio-economic and

environmental rights. From the Cameroonian perspective, the right to water is not viewed as a basic human right but as sovereign right of the state. It is rather unfortunate that Cameroon lacks a formal and coherent water policy document. There are some general and incoherent documents and speeches containing aspects of water policy but they are not as robust as they should be. Also, the progress of the water sector of Cameroon is hindered by the absence of comprehensive legal status of laws and some regulatory texts (for example no legal status of river basin) which play a key role of a solid legislative and regulatory framework. Another point of weakness is the fact that the main stake holder of the water sector which is the Ministry of Energy and Water Resources (MINEE) has never been able to convene a meeting of the National Water Committee (NWC) since its creation in 1998 despite its duty to convene NWC meetings as stipulated in the national water law (Ngnike et al, 2010).

The Cameroon National Assembly, in a third Ordinary Session on March 1998 in Yaoundé deliberated and adopted Bill N° 634/PJL/AN which was promulgated in to Law N° 98-005 on April 14<sup>th</sup> 1998 on water systems. Some Articles of the law states:

- Article 1: This law lays the principles of water management, environmental protection and public health, and the general legal framework of the water regime.
- Article 2, a: Water is a common heritage of the nation in which the state provides protection, management and easy access to all.
  - b: However, the state may transfer all or part of its powers to regional and local authorities.
  - c: The water management may also be subject to concession or leasing on terms laid down by decree of application of this act.
- Article 3: The following are under this Act and its implementing regulations:
  - a: Surface water; runoff, rivers and backwaters (water held by a dam)
  - b: Groundwater; seepage and groundwater

c: water source waters available on the market with reported therapeutic (curative) qualities

d: Mineral water; groundwater containing minerals dissolved with a therapeutic action

The laws governing water resources in Cameroon does not have any provisions with regards to rainwater. Surface water, groundwater, portable water by commercial water suppliers, mineral water are all covered by the law mentioned afore. The harvesting of precipitation is still free and has no restrictions at the moment. For example in the state of Colorado (USA) regulations prohibit property owners from collecting rain falling on their property. Regulations state that the rain falling on their property belongs to the state and it is illegal to collect the rainwater without permission. Fortunately, this is not the case in Cameroon where everyone can collect rainwater whenever, wherever and however. This advantage favors the peaceful exploitation of rainwater harvesting systems in Buea.

### **3.8 RWH SYSTEM COST IN BUEA**

The cost of a domestic RWH system varies with regards to location, physical characteristics of the area, economic viability of the population, cost of labor, cost of materials and also how sophisticated the system should be. This makes it difficult to generalize or predict the cost of such systems especially in sub-Saharan Africa.

It is worth mentioning that it is cheaper to incorporate a RWH system during the construction of a building than to construct it on an already existing building. The most expensive part of a RWH system is the storage facility (tank). In order to approach the installation of such a system in a cost effective manner, prior findings have to be made with regards to the potential amount of rainwater to be collected and the household water consumption pattern. These findings are necessary to design the tank in the most cost effective way. The cost of typical moderate and affordable rainwater harvesting for an average household in the Buea municipality will be further discussed amongst the other research results in chapter 5.

## **4.0 METHODOLOGICAL FRAMEWORK OF RESEARCH**

### **4.1 INTRODUCTION**

The main focus of this research study is to provide a roadmap through which the water scarcity problems faced by the inhabitants of the Buea municipality can be ameliorated in an effort to attain the MDG's (put forward by the UN in the year 2000) which have to be attained by the year 2015. This research promotes IWRM as a necessity to holistically combat water scarcity and its associated problems. In order to achieve the goals of this research, physical, economic, and socio-cultural data had to be obtained and analyzed.

### **4.2 HYDROLOGICAL DATA**

It is inevitable to pursue RWH technology without considering one of its major components, which is precipitation. Rainfall has to be available for such a system to function. It is of great importance to acquire and assess rainfall data for at least the last 10 years to have a solid impression of the rainfall pattern in a particular region before considering RWH as a potential source of domestic and or agricultural water supply supplement. Rainfall data should be long term to avoid making decisions which might be based on sudden spikes in the rainfall data which are not habitual and might not occur again in a long time. So long term data minimizes such aspects by providing a wide range of data whereby spikes can be identified and comprehended.

Rainfall data for the Buea municipality was obtained from the data set of Fraser et al 1998. They obtained this data from the CDC through their extensive network of some selected meteorological stations in their plantations around the Mt Cameroon region. The data obtained was recorded by a 127 mm diameter rain gauge. With regards to rainfall in the Buea municipality, rainfall data for Molyko is representative for the Buea municipality. The sample size for this data is 10 years. Below is the annual monthly rainfall totals for Molyko, Buea. Also the current average monthly precipitation for Buea, the current average days with precipitation per month and the current average monthly temperatures from the Douala observatory weather station (about 57 km from Buea) are presented on the Table (3) and figures (24, 25 & 26) below.

Table 3: Annual Monthly Rainfall Totals of Molyko, Buea (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984							172,9	117,8	222,9	226,2	93,2	
1985	33,6		151,8	114,7	236,1	170,6	207,3	312,4	294,9	213,7	113,5	
1986	4,6	63	163,6	147,5	173,9	183,2	302,6	146,5	434,2	367,6	22,5	
1987		11,6	76,5	127,8	118,9	161,2	127,2	253,2	185,8	128,9	17,8	
1988			56,3	91,5	181,8	106,8	277	230,9	259,5	327,5	34,7	6,8
1989			26,1	113	129	107,9	184,5	314,6	214,4	115,1	38,9	
1990		8,8	90,2	113,8	117,4	170,1	218,3	260	223,4	84,8	53,9	
1991		96,6	91,5	167,3	149,4	277,7	238,7	329	49,7	115,7		38,4
1992	2,9		27,8	94,2	172		133,8	374,2	295,7	227,2	87,6	
1993	18,1	8,9	186,8	165		157,2	58,7	244,9		153,8	143,2	41,3

(Source: adapted from Fraser *et al*, 1989)

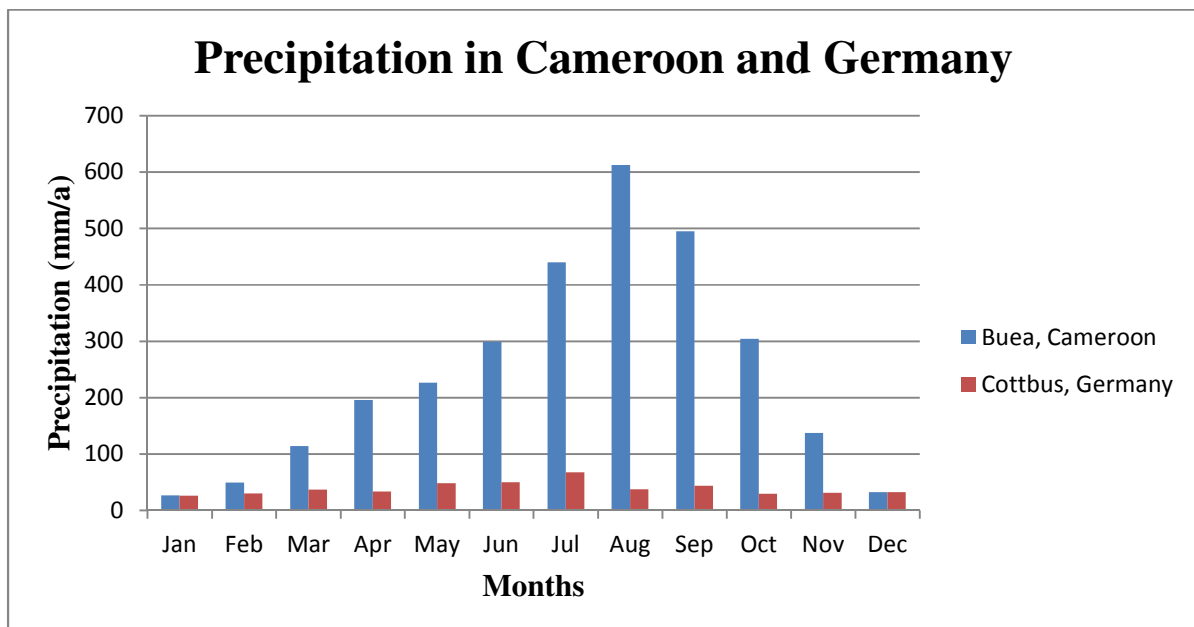


Figure 24: Comparison of the Average Monthly Precipitation for Buea and Cottbus

(Sources: [http://www.yr.no/place/Cameroon/South\\_West/Buea/statistics.html](http://www.yr.no/place/Cameroon/South_West/Buea/statistics.html),  
<http://www.worldweatheronline.com/Buea-weather-averages/Sud-Ouest/CM.aspx>)



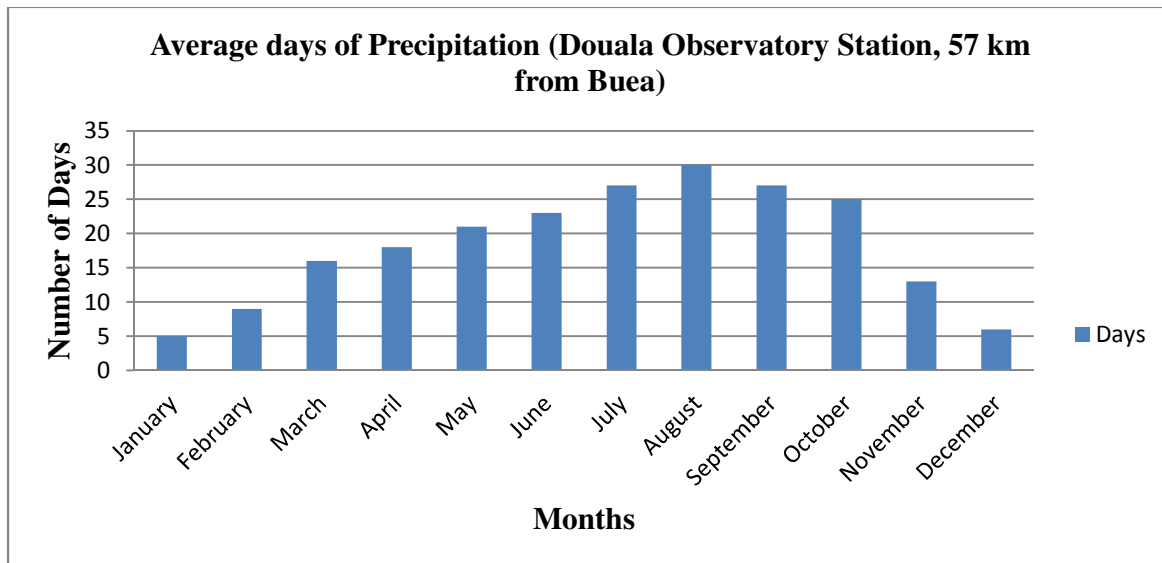


Figure 25: Average Days of Precipitation per Month  
 (Source: [http://www.yr.no/place/Cameroon/South\\_West/Buea/statistics.html](http://www.yr.no/place/Cameroon/South_West/Buea/statistics.html))

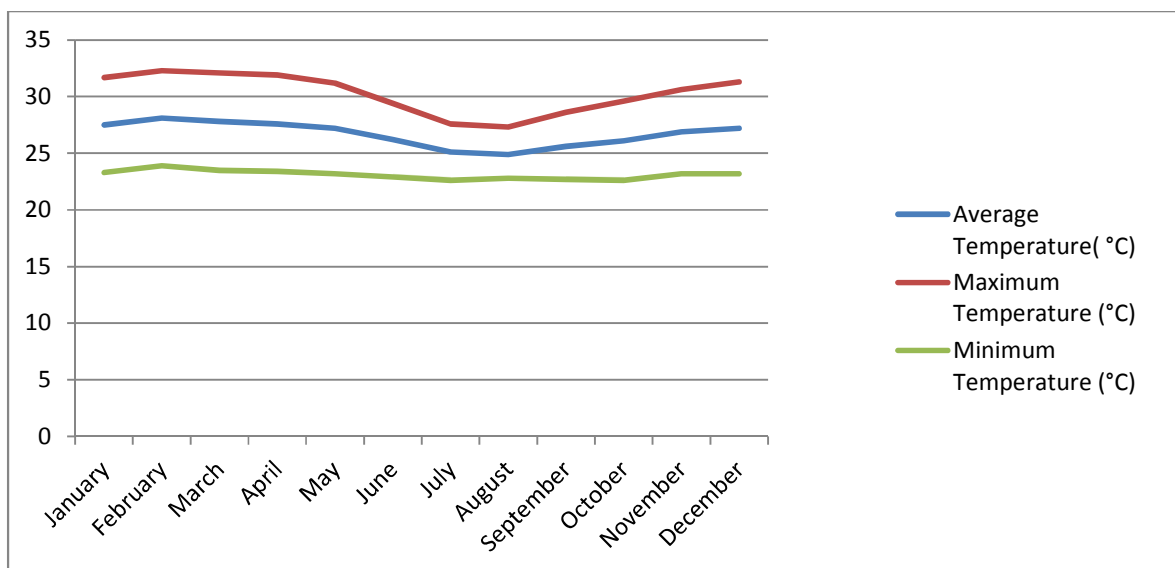


Figure 26: Average Monthly Temperatures for Buea  
 (Source: Adapted from Fraser *et al*, 1989)

## 4.3 GEOLOGICAL INVESTIGATION DATA

Buea has a high annual precipitation (3000 to 5000 mm) and as such it is very important to ensure that the excess rainwater which is not harvested goes into the aquifers and contributes sustainably to groundwater recharge. In this study, infiltration tests were carried out in 9 villages of the municipality. The aim of these infiltration tests is to determine the steady state infiltration rate (and saturated hydraulic conductivity) at each of the 9 locations in order to identify areas good for artificial recharge. The test is known as the double ring infiltration (DRI) test performed on the soil surface. This is a measure of permeability and gives information of how conductive a soil is at saturation.

### 4.3.1 Double Ring Infiltrometer Test

McKenzie *et al.*, 2002 stated that the saturated hydraulic conductivity can be calculated from measurements of steady-state infiltration through the DRI test on the surface of the soil. It is the preferred method to measure saturated hydraulic conductivity in the field. This test is rapid and could take less than 20 minutes if conditions are favorable. It is also not expensive to carry out and the equipment can be constructed with the use of readily available materials. The DRI test requires a lot of water and it is advisable to be carried out not too far from a water source or to have large quantities of water on-site. The experiment is as follows:

➤ Equipments;

These include; a ring of 60 cm in diameter (height of 25 cm), a ring of 30 cm in diameter (height of 25 cm), a burette, a bucket, a stopwatch and water.

➤ Procedure;

The procedure was carried out according to the method described by McKenzie *et al.*, 2002. Firstly, the experiment site has to be situated and the ground cover (grass and other litter) are carefully removed without disturbing the top surface of the soil. Thereafter, both rings are placed on the soil surface and knocked down about 10 cm deep into the soil so that they can be fixed to the ground firmly though out the whole process. A burette was then inserted in the inner ring. Water was carried in a bucket and poured into the outer ring first so that the soil profile around the inner ring would be wet and when the inner ring is later filled with water, only vertical flow

will occur. The burette readings were then taken with time as the water level in the infiltrometer dropped. The values obtained were then used to plot a graph of height (H) against time (t) for each location signifying infiltration of water over time. The gradient gave the infiltration rate of each location. Tests were carried out in 9 locations (villages) in the Buea municipality.

The steady-state infiltration rate is reached when the soil becomes saturated and this is seen where the data points show linearity on the graph. When the linear section on the graph is identified, a best fit line is fitted to the applicable data. The steady-state infiltration rate is given by the gradient of this fitted line which can be multiplied by 1.45 to get the saturated hydraulic conductivity (refers to how conductive the soil is at saturation) of that particular location.



Figure 27: Double ring infiltration set-up during field test in Muea

(Source: Author)

➤ Calculations:

Infiltration = Total volume of water added / Area of the inner ring (cm)

$$\text{Area of the inner ring} = \frac{\pi d^2}{4} \quad (\text{cm}^2)$$

Steady state infiltration rate = Infiltration / Time taken (mm/hr)

This DRI test is a good method to obtain the saturated hydraulic conductivity of a particular soil type but some errors could arise if the procedure is not properly followed.

#### **4.4 SEASONAL DOMESTIC WATER CONSUMPTION DATA**

When it comes to assessing water consumption patterns in hydrogeology, it is way more accurate when the consumption of both the dry and rainy seasons are taken into consideration rather than a general annual consumption pattern. That is, both seasons should be accounted for separately because their consumption patterns vary. The consumption patterns also vary from continent to continent, with about 5 liters per day or less in most African countries. Decades ago the UN declared that the minimum of 20 liters per day the target for water supply per person per day in rural communities in third world countries. The amount of rainfall in Buea is sufficient to surpass such values and rescue inhabitants facing water scarcity. The next issue is the size of roof catchment and the capacity of the storage tank. If these two factors are taken care of, households will experience abundant supply of water for domestic purposes.

In this study, the approach adopted for seasonal water demand takes a series of factors into consideration. Normally, the simple estimation will be; the water use (in liters) multiplied by the number of persons in the house and then multiplied by the number of days in a year. But the approach used in this study takes into consideration the following; water use per person, seasonal water use (considers dry and rainy season), the number of people living in the house (considers permanent residents and long-term guests, persons studying out of town etc.). The data for all the 10 study areas are then used to obtain an average daily water demand value per capita (per person), from which the daily demand for about 90,000 residents of Buea is calculated.

The results obtained are estimates of domestic water consumption. It is very difficult to acquire perfect water consumption values. Shortcomings include the fact that consumption is mostly taken into consideration instead of demand. In a case where water is not readily available to a household and they have to fetch water miles away, such a household may consume less water than it normally needs because of the aspect of cost and time. Conversely, if this household is next to a public water point (tap) its consumption might increase as a result of their proximity to water. The results of water consumption analysis will be shown in chapter 5.

## **4.5 SAMPLING STRATEGY**

There are two major sampling strategies when it comes to scientific research. Probability and non-probability sampling methods are the two major strategies which are further divided into many sub categories. Probability sampling involves random selection whereas non-probability sampling does not. Non-probability sampling is further divided into accidental sampling and purposive sampling.

This study makes use of the purposive sampling (also known as judgmental sampling) method. This method is applied in situations where there is a premeditated purpose (target) for the sampling. This is also characterized by focusing on a particular target group. With purposive sampling, information is most likely obtained from the target population but care should be taken because there is a great likelihood that sub groups in the population that are more readily accessible could be given too much weight or consideration. This method is further divided into snowball sampling and expert sampling methods.

### **4.5.1 Expert Sampling**

This type of purposive sampling method is applied in circumstances where information is obtained from individuals that have extensive knowledge on the topic of research. Such individuals provide resourceful information that are relevant and might have been very difficult for the researcher to obtain within scheduled time. For the purpose of this study, two cases of expert sampling were carried out by way of interviews.

The first interview was carried out with the Regional Delegate for Energy and Water Resources of the Southwest region in Limbe. This interview resulted in the acquisition of valuable information on the Buea water crisis and the measure being put in place by the government.

The second interview was performed with an official of the CDE. This interview provided information on the water distribution capacity of the CDE, the villages supplied with pipe-born water, the genesis of the water for the municipality and the problems faced by the CDE in their effort to increase the volume of water supplied to the entire municipality.

#### **4.5.2 Questionnaires**

Questionnaires for this study were tailored to achieve resourceful information with regards to the objectives of the study. These are formal standardized questionnaires which seek for quantitative information about the water consumption pattern of a typical household. The data obtained by this questionnaire was further analyzed with the aid of Microsoft Excel. The questionnaires comprised of semi-structured closed-ended and open ended questions which were administered by the researcher and two assistants. The closed-ended questions enabled respondents to make an answer choice from a list of answers. Open ended questions required respondents to express their opinion independent of any influence from the part of the researcher.

A total of 220 questionnaires were administered in 10 villages in the Buea municipality, which include Bomaka, Bova 1, Buea Town, Bonduma, Bokwango, Great Soppo, Bonakanda, Molyko, Muea and Bokwai. All questionnaires distributed were obtained giving a total response rate of 100%. This high response rate is justifiable because the questionnaires were administered and collected at the residences of the respondents exercising a lot of patience for each respondent to comfortably go through all the questions at their own pace. There were a few instances where respondents were not literate enough to understand the questions. In such cases the questions were communicated to the respondents in the local dialect and also in Pidgin English successfully.

It was a four section question questionnaire. Section A targeted general information of respondents. This was aimed at assessing their demographics and level of literacy. Section B focused on the domestic water supply status quo. The goal of section C was to assess

respondent's knowledge on RWH and its practice. Section D which is the last section of the questionnaire concentrated on detail information of the domestic water demand and consumption pattern of respondents.

#### **4.5.3 Data Analysis**

Both primary and secondary data are used in this study. Primary data was obtained through experiments and surveys and were analyzed scrupulously by the researcher. The hydrological and geological maps of Buea were constructed using "Surfer 9" which is a very good contouring, gridding and 3D software used by Scientists and Engineers to construct maps. Data from field experiments (the double ring infiltration test) and the questionnaire survey were analyzed by way of Microsoft Excel. Secondary data (data not collected by the researcher) from literature review were also used in the study.

The data obtained were represented in the forms of tables, figures, graphs, bar charts and text. Results of data analysis are presented sequentially accompanied by discussion to facilitate coherency and understanding. Chapter 5 concentrates on the presentation of results and discussion.

## 5.0 RESULTS AND DISCUSSION

### 5.1 ESTIMATION OF POTENTIAL RAINWATER HARVESTED AND COST OF THE SYSTEM

The potential rainwater harvested by a domestic RWH system can be estimated by way of calculation. This depends on the amount of precipitation, the catchment (roof) surface area and the catchment runoff coefficient. There are different runoff coefficients for different roofing materials. The runoff coefficient used in this study is 0.8 for roof catchments made of corrugated iron sheets (typical of the study area). Gould and Nissen-Petersen (1999) formula for mean annual runoff from a roof catchment **S** is given as follows:

$$\mathbf{S} = \mathbf{R} \times \mathbf{A} \times \mathbf{Cr}$$

Where, **S** stands for Mean Rainfall *Supply* in m<sup>3</sup>

**R** stands for Mean Annual *Rainfall* in mm/a

**A** stands for Catchment Surface *Area* in m<sup>2</sup>

**Cr** stands for Runoff *Coefficient*

For a single household (12m by 12m bungalow) in Bonakanda village, Buea:

$$\begin{aligned} \mathbf{S} &= \mathbf{4000 \text{ mm/a}} \times \mathbf{144 \text{ m}^2} \times \mathbf{0.8} \\ \mathbf{S} &= \mathbf{4 \text{ m/a}} \times \mathbf{144 \text{ m}^2} \times \mathbf{0.8} \\ \mathbf{S} &= \mathbf{460.8 \text{ m}^3/\text{annum}} = \mathbf{460800 \text{ l/annum}} \\ &= \mathbf{1.26 \text{ m}^3/\text{day}} = \mathbf{1260 \text{ l/day}} \end{aligned}$$

The results of the calculation above shows that, there is abundant supply of rainwater to meet the needs of the residents and the excess used for sustainable aquifer recharge by way of infiltration. The average daily water demand per capita in Buea is 23.775 liters and if a household with 6 persons collect 1260 liters of rainwater each day, it is comfortable to confirm that their water



needs will be met satisfactorily. The main issue of concern is storing the water for future use in times of severe water crises in the dry season. The water supply has to exceed the demand for water to be stored for future use.

Furthermore, the storage capacity of the system has to be large enough to accommodate surplus water during the rainy season to stabilize demand in the dry season. The storage component is the most expensive component of a RWH system and its volume actually depends on the duration of water scarcity and the water consumption per capita during the period of water scarcity. Below is an estimated cost of a moderate domestic RWH system taking into consideration the present water consumption pattern and the rainwater harvesting potential in Buea and prices of materials in Buea and its environs.

Table 4: Estimate of domestic RWH System Cost in Buea

<b>Materials</b>	<b>Quantity or Type</b>	<b>Price in FCFA</b>	<b>Price in EURO</b>
PVC Pipes	5 m	10,000	16
PVC Gutters		45,000	69
Iron loops and clips		15,000	23
Mesh net (as filter)	2 x 1 m	45,000	69
Glue	1 Kg	10,000	16
Cement	10 bags	48,000	74
Sand	22 tons	65,000	99
Gravel	3.25 cm <sup>3</sup>	95,000	145
Clay bricks	4.5 x 9 x 2.5 inches	150,000	229
Transport		50,000	77
Labor		40,000	61
<b>Total</b>		<b>573,000</b>	<b>878</b>

The estimate above is for a storage tank made of concrete and ferro-cement. Plastic tanks (Polyethylene) are cheaper (cost about 200 €/ 1000 liters tank) than concrete tanks but concrete tanks are more durable and employs the services of the local inhabitants (provides employment). Since the storage tank is the most expensive component, people have to basically get what they can pay for. Below is a storage tank which is built of clay bricks and concrete. The tank can stand the test of time and it is a good example of the type of rainwater storage tanks suitable for Buea. Buea experiences earth tremors during volcanic eruptions of Mt Cameroon and these earth

tremors could destroy such a tank. Plastic tanks as a result of their elasticity will acquire less damage. Figure 28 below, shows an underground ferro-cement RWH storage tank:



Figure 28: An underground ferro-cement rainwater storage tank.

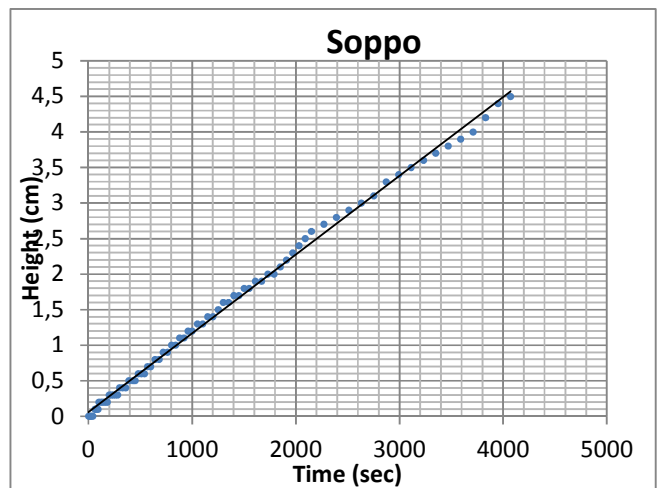
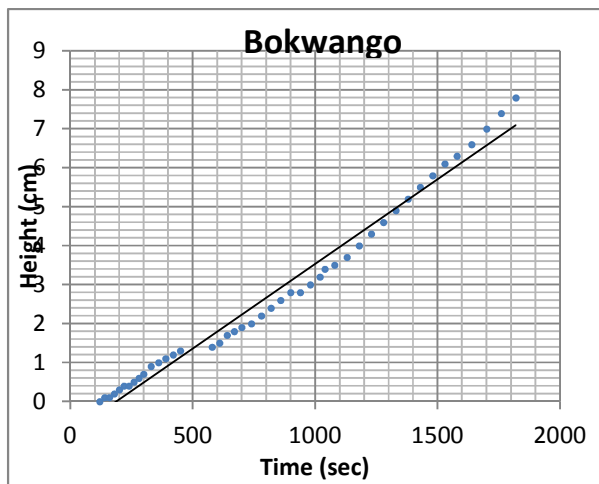
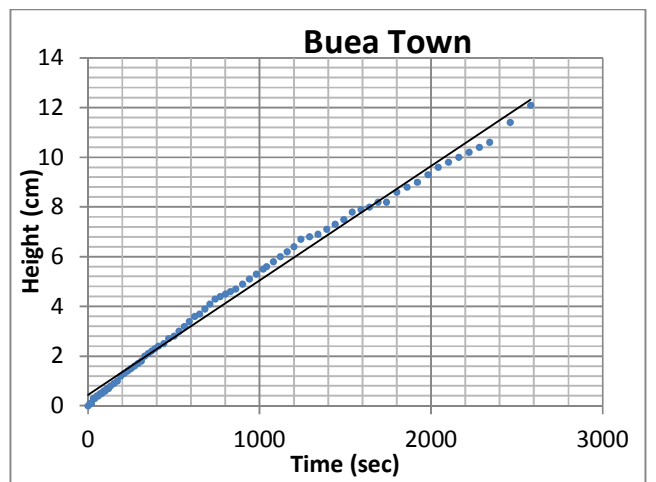
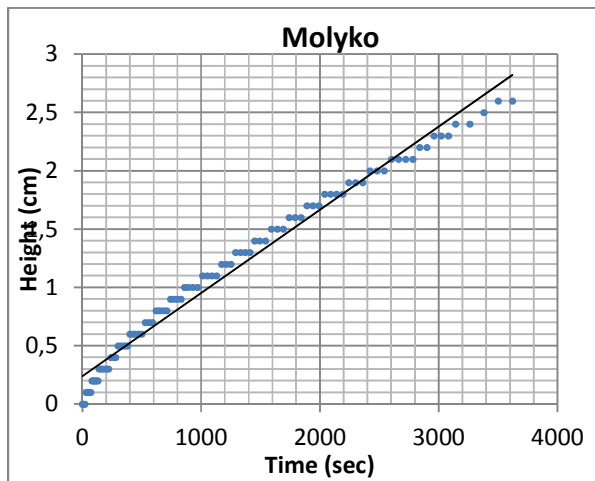
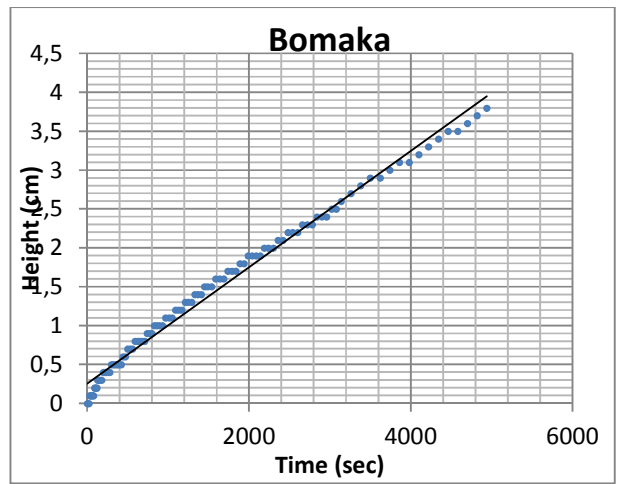
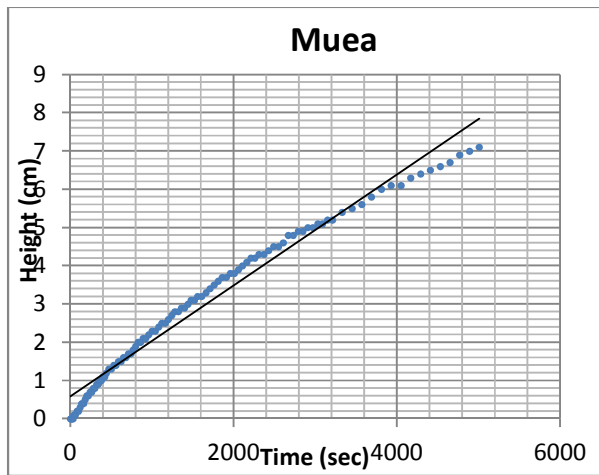
(source: Helmreich, 2009)

## 5.2 ANALYSIS OF THE HYDROGEOLOGY OF BUEA

The double disc infiltration test was performed in 9 villages in the Buea municipality and the results are as follows:

Table 5: Double Disc Infiltration Test Results

Location	H1 (cm)	H2 (cm)	H2-H1 (cm)	t1 (sec)	t2 (sec)	t2-t1 (sec)	Infiltration rate (cm/sec)	Infiltration rate (m/day)
MUEA	2	6.2	4.2	1000	4000	3000	0.0014	1.2
BOMAKA	0.5	3.25	2.75	400	4000	3600	0.0008	0.7
MOLYKO	0.5	2.35	1.85	400	3000	2600	0.0007	0.6
BUEA TOWN	2	12	10	350	2500	2150	0.0047	4.0
BOKWANGO	1	5.7	4.7	420	1500	1080	0.0044	3.8
SOPPO	0.5	4.5	4	400	4000	3600	0.0011	1.0
BUNDUMA	5.5	23	17.5	800	4000	3200	0.0055	4.7
BONAKANDA	0.5	2	1.5	600	3000	2400	0.0006	0.5
BOVA II	5	31.5	26.5	200	3000	2800	0.0095	8.2



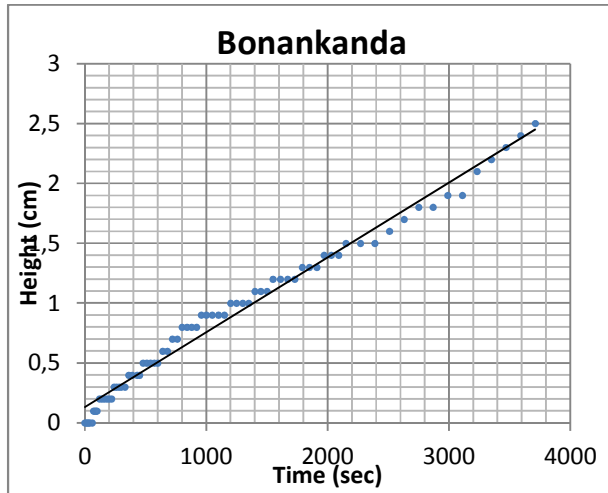
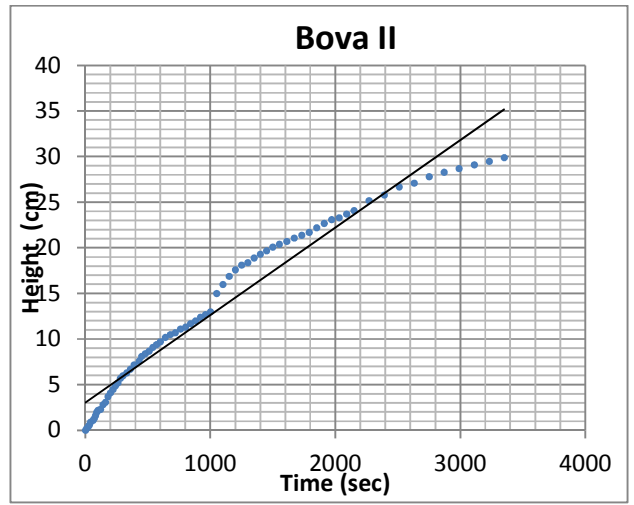
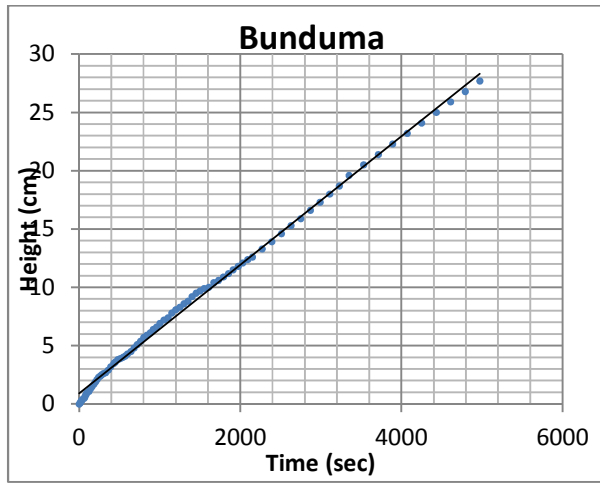


Figure 29: Infiltration rate graphs for all study areas

### 5.2.10 Map of Infiltration Rates

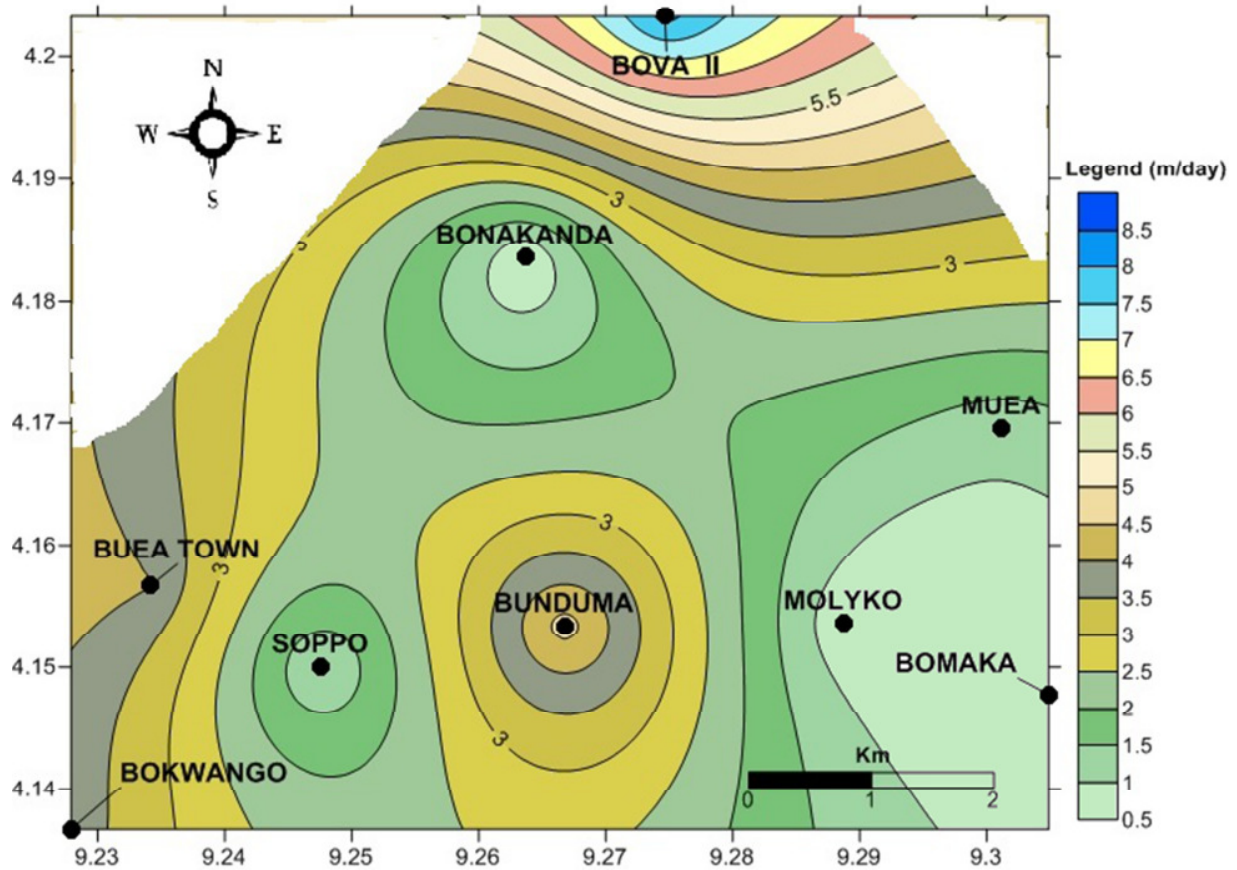


Figure 30: Map of infiltration rates in Buea

### 5.2.11 Discussion of Infiltration Test Results

Infiltration is the best method to minimize storm water runoff and hence prevent the event of floods. It also provides great opportunity for the soil to filter water therefore getting rid of some contaminants. Information with regards to the infiltration rates of areas in Buea will enhance the location of favorable areas of artificial GWR and the most suitable techniques which could be applied to successfully to enrich groundwater. That is, it will provide some guidance in making decisions on the type of GW recharge systems to be practiced in specific areas. Economical and sustainable GWR depends so much on maintaining a high rate of infiltration.

The infiltration rate of a given soil is the rate at which that particular soil absorbs water available to its surface as a result of precipitation or irrigation. At the beginning, the infiltration rate is high and then declines and finally culminates towards near constant values. This rate decreases as interconnected pores and void spaces are gradually filled with water. In the case where the rate of precipitation is more than infiltration, runoff sets in. The soil attains a state of saturation when all the pore and void spaces are totally filled with water. The ability of the soil at this state to transmit water under a given hydraulic gradient is known as its saturated hydraulic conductivity. This actually refers to the ease with which soil pores that are filled with water still allow water movement through the soil mass. The saturated hydraulic conductivity is dependent on temperature, fluid viscosity, gradient and structure.

When the soil is over saturated, infiltration will decrease and surface runoff will begin and increasingly take over infiltration. The rate at which water infiltrates the soil is higher in wet soils (due to higher hydraulic conductivity) and decreases as the soil becomes dryer. Displacing air from pores in dry soils decreases infiltration rate. Pore sizes and the manner in which pores are interconnected influence infiltration rate significantly. Clay soils which are characterized by smaller pores, pose more resistance to the force of gravity and this effect decreases infiltration rates. Conversely, sandy soils have larger pores which results in water moving through faster than in clay soils. Furthermore, temperature influences infiltration rates a great deal. Temperature and infiltration rates have a direct proportional relationship. Lower temperatures are associated with a decrease in infiltration rates. Also, vegetation enhances infiltration by way of their root systems. The roots create more pores in the soil for water percolation. Clogging of soil aggregates are also prevented by the presence and growth of plant roots.

Buea has a high annual rainfall and domestic RWH systems cannot entirely impound, store and use the rainwater to its last drop. The rain falls on rooftops and open landscape. The excess storm water falling on the land surface (which is not collected) has to be destined for GWR. Natural GWR processes cannot solely cater for the large amount of available water. Also, the geology does not facilitate natural GWR processes to handle the storm water entirely. Evaporation is relatively high in this area and it accounts for a great decrease in the amount of water available

for artificial recharge. Since natural recharge is not as efficient as desired in this region, artificial GWR is an awesome process to sustainably cater for excess storm water.

Bokwango, Upper-farms, Bonakanda are all settlements between 840 to 950m above sea level. These villages are closest to the mountain and have experienced serious cases of floods as a result of large amounts of surface run-off flowing from heavy rainfall events and streams flowing down the mountain. In Bonalyonga (a village closest to Buea Town), run-off from the mountain with a lot of debris flows right down to the Buea Town market flooding the market and other private properties. This particular event does not happen yearly but happens during the peak of the rainy season in years of very heavy rainfall. These floods have not yet been reported to have claimed lives but have caused considerable damage to homes and farms of the residents of these areas. Many associate these flood events to lack of good drainage systems in Buea, poor garbage disposal, lack of proper construction technics and nonchalance with respect to town planning and housing guidelines. The municipal council deserves some credit for the construction of gutters along the roadsides from Mile 17 right up to Buea Town. This has been labeled by some people as a political strategy to flex political power. Artificial GWR will solve this problem of flooding in the villages mentioned above. Flowing streams from the mountain could also be diverted into infiltration wells or used for other purposes. This will act as a flood protection measure to protect property damage, damage to farms, and the potential loss of life. It could even generate income or reduce expenditure for the residents of these villages.

The infiltration rate results obtained show that Bonakanda, Molyko, Bomaka, Soppo and Muea have medium infiltration rates with respect to the Tidemann classification scheme. The Tidemann classification puts infiltration rates into three groups which include; Low infiltration rates (values less than 0.36m/day), medium infiltration rates (values between 0.36m/day to 1.2m/day) and high infiltration rates (values greater than 1.2m/day). According to the Tidemann's classification, Bokwango, Buea Town, Bonduma and Bova II have high infiltration rates. These results show that these settlement areas are all suitable for the practice of infiltration techniques to recharge groundwater. The table below shows the correlation between infiltration rates, soil group and soil texture.

Table 6: Correlation of Soil Texture, Infiltration Rate and Hydrological Soil Grouping:

<b>Soil Texture Class</b>	<b>Minimum Infiltration Rate (m/day)</b>	<b>Hydrological Soil Group</b>
<b>Sand</b>	<b>5,04</b>	<b>A</b>
<b>Loamy Sand</b>	<b>1,50</b>	<b>A</b>
<b>Sandy Loam</b>	<b>0,62</b>	<b>A</b>
<b>Loam</b>	<b>0,32</b>	<b>B</b>

(Source: Rawls *et al*, 1982)

With the aid of the above classification scheme, the infiltration rate results were used to classify the study areas in terms of soil texture and hydrological soil groups.

Table 7: Classification of study areas results into Soil groups and soil texture classes:

<b>Location</b>	<b>Infiltration Rate (m/day)</b>	<b>Hydrological Soil Group</b>	<b>Soil Texture Class</b>
<b>MUEA</b>	<b>1,20</b>	<b>A</b>	<b>Loamy Sand</b>
<b>BOMAKA</b>	<b>0,7</b>	<b>A</b>	<b>Loamy Sand</b>
<b>MOLYKO</b>	<b>0,6</b>	<b>B</b>	<b>Loam</b>
<b>BUEA TOWN</b>	<b>4</b>	<b>A</b>	<b>Loamy Sand</b>
<b>BOKWANGO</b>	<b>3,8</b>	<b>A</b>	<b>Loamy Sand</b>
<b>SOPPO</b>	<b>1</b>	<b>A</b>	<b>Sandy Loam</b>
<b>BONDUMA</b>	<b>4,7</b>	<b>A</b>	<b>Loamy Sand</b>
<b>BONAKANDA</b>	<b>0,5</b>	<b>B</b>	<b>Loam</b>
<b>BOVA II</b>	<b>8,2</b>	<b>A</b>	<b>Sand</b>

The results in Table 6 (above) show that all study areas are favorable for infiltration methods with the aim of recharging the groundwater aquifers. Flooding and ponding of water has been a great concern in villages close to the mountain due to high precipitation and the sloping landscape of Buea (eastern slope of Mt Cameroon), it is difficult for runoff to thoroughly



infiltrate. Much of the runoff is lost to the atmosphere as a result of evaporation caused by the high temperatures. Therefore artificial groundwater recharge is absolutely necessary.

### 5.3 VARIATIONS IN DOMESTIC WATER CONSUMPTION

There are two main seasons in Buea, the dry season and the wet or rainy season. Water scarcity is mostly experienced during the dry season. During the rainy season, rainwater is in abundance and if properly stored, it will cater for the water needs of the dry season. The results of the questionnaire survey provided resourceful information about the water supply status quo of the Buea municipality.

#### 5.3.1 Households experiencing significant water shortage

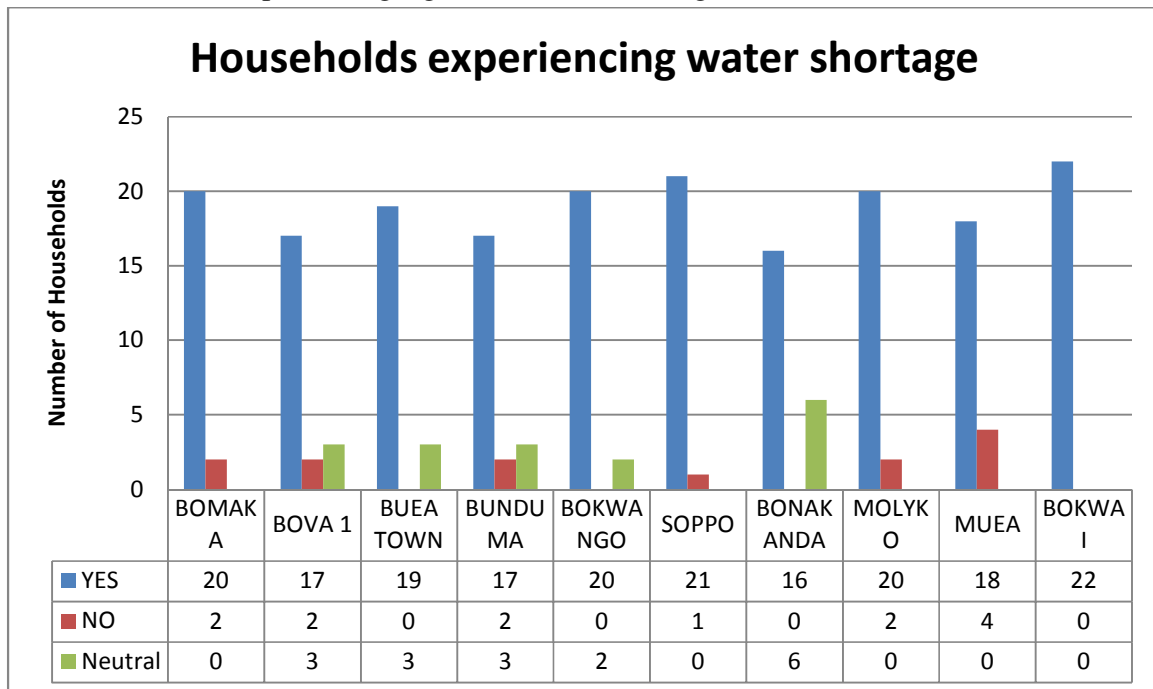


Figure 31: Households facing significant water shortage in all 10 study areas in Buea

### 5.3.2 Households with Pipe-borne water access

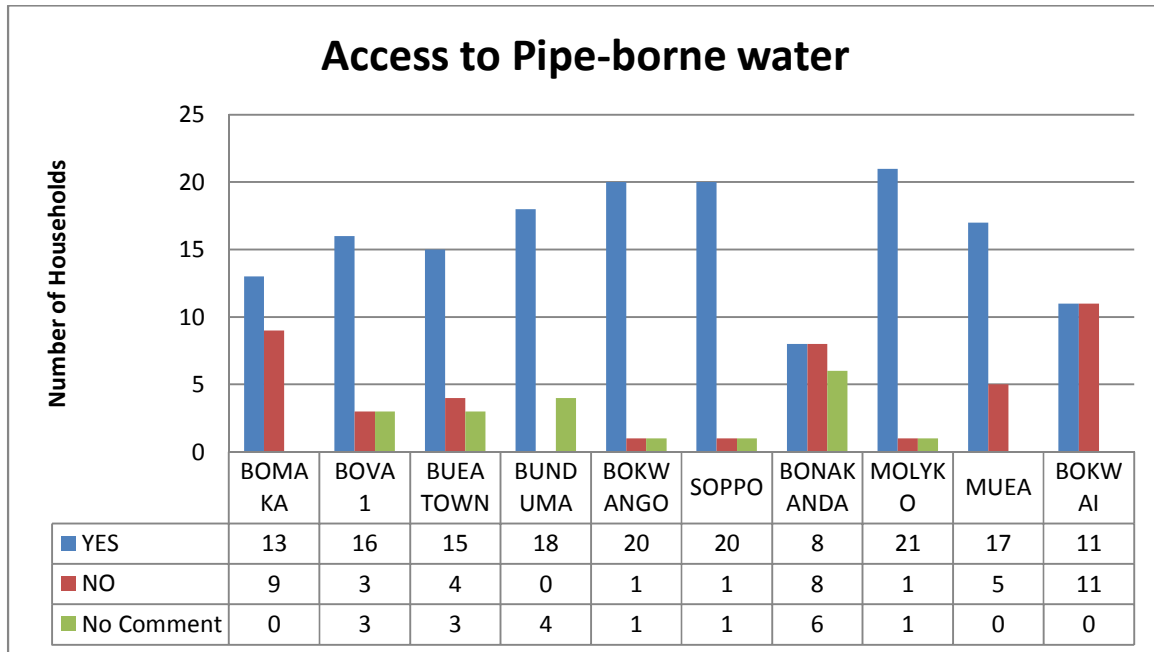


Figure 32: Households with access to pipe borne water in all 10 study areas in Buea

### 5.3.3 Source of water for households

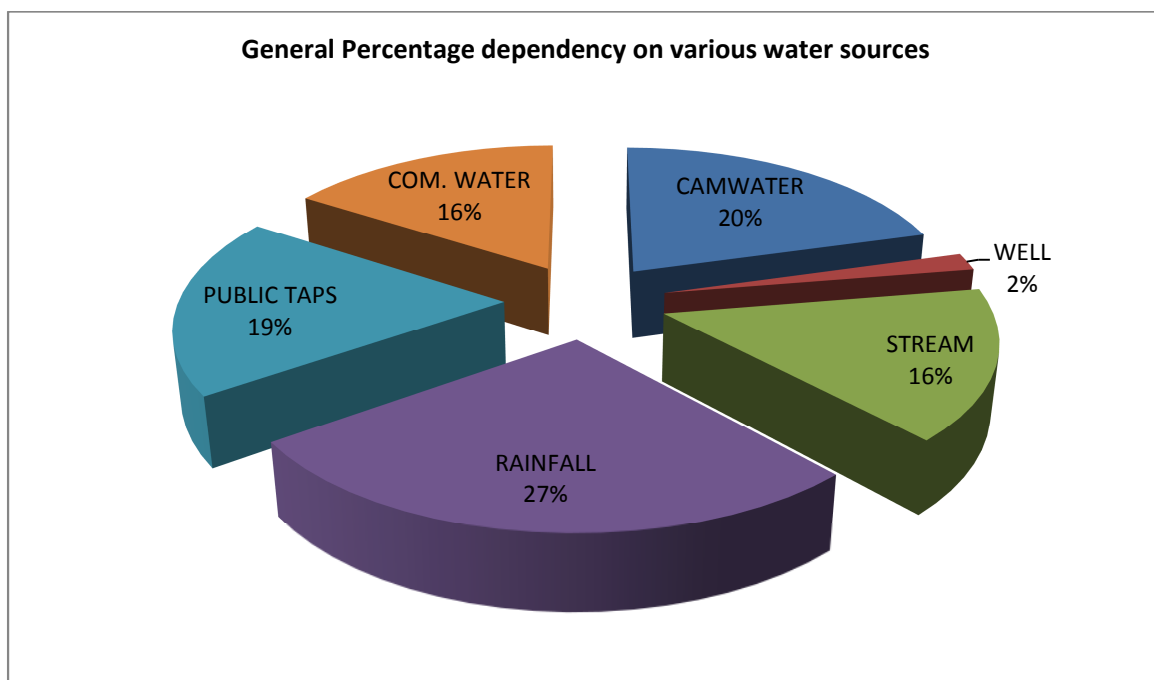


Figure 33: General percentage dependency on various water sources for all 10 study areas combined

#### **5.3.4 Discussion of the Results of water shortage, pipe borne water access and water source**

From figures above, the results of the domestic water consumption status quo can be clearly understood. After analyzing the results obtained from the 220 questionnaires equally distributed in all study areas with the aim of obtaining reliable data for the water demand and supply of the Buea municipality, the following information were determined:

- About 86% of the respondents are experiencing water shortage
- About 6% of the respondents are not experiencing water shortage
- The remaining 8% are indifferent, meaning they cannot confirm or deny if they are experiencing water shortage
- About 72 % of the respondents have access to pipe borne water
- About 19.5% of the respondents have no access to pipe borne water
- The remaining 8.5% cannot clearly respond if they have or don't have access to pipe borne water

The information obtained from the questionnaire survey portrays the fact that, CAMWATER's services are only offered to about half of the 90,000 residents of Buea. About 48% of the population is forced to rely on community water schemes, streams, wells, boreholes and rainwater to carry out their daily activities. Most of the residents that have access to pipe borne water also rely on alternative water supply methods. This is due to the frequent water cuts by CAMWATER. In the event of power failure, CAMWATER cannot pump water to most of its customers and a large portion of their water supply network shuts down. This justifies the exploitation of domestic RWH to make use of the available rainwater for domestic activities and recharge groundwater artificially in case of excess.

### 5.3.5 Estimate of the Average Daily Water Consumption

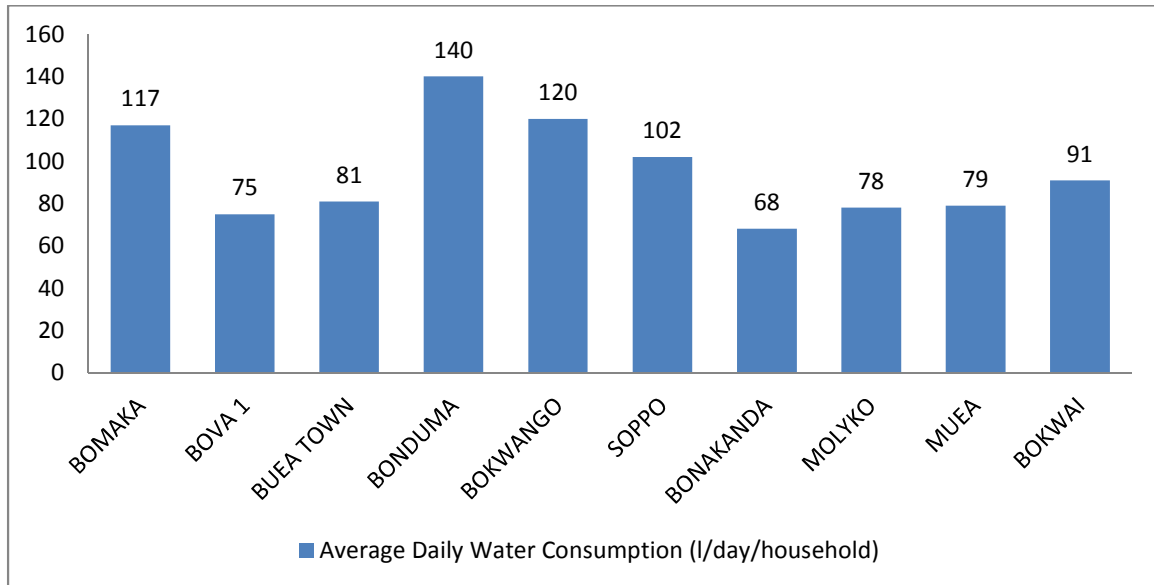


Figure 34: Estimated average daily water consumption of a typical household in all study areas

### 5.3.6 Estimate of the Mean Annual Water Consumption

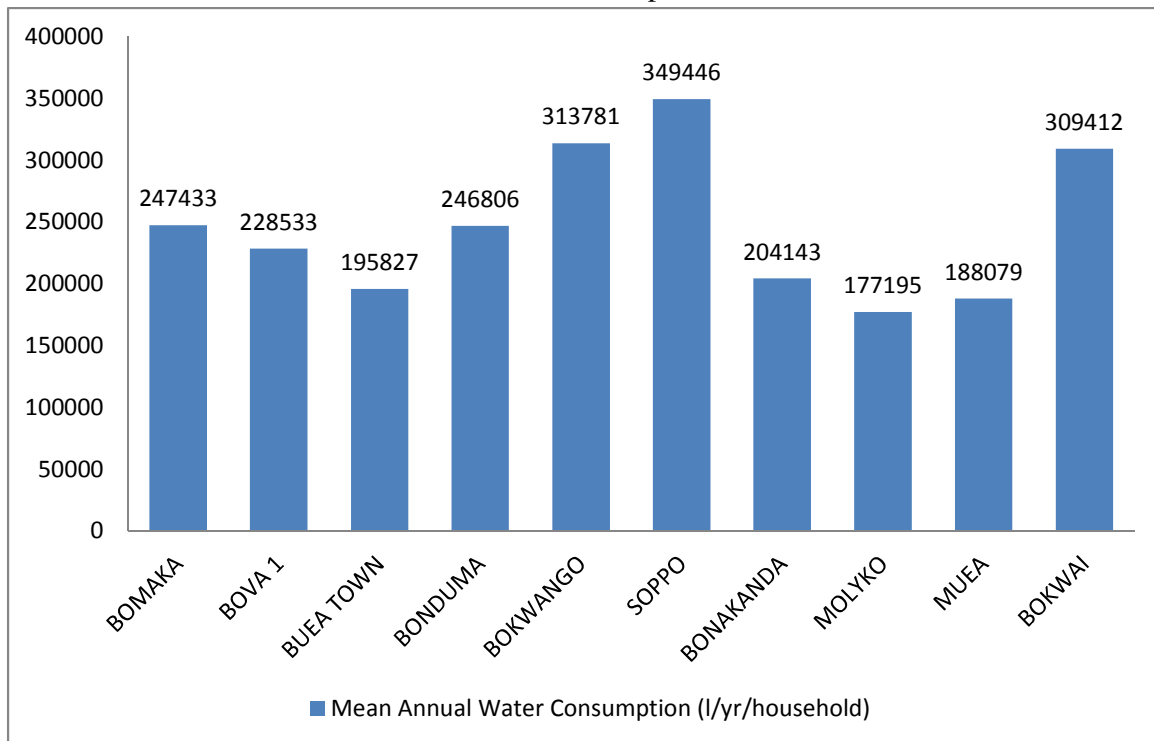


Figure 35: Estimated mean annual water consumption of a typical household in all study areas

### 5.3.7 Discussion of the Results of Domestic Water Consumption

The results obtained from the water consumption estimate show that:

- The minimum average daily water demand per capita in Buea is about 24 liters.
- In Buea, CAMWATER currently supplies about 1.1 million liters per day.
- Buea’s current daily water demand is about 2.1 million liters.
- CAMWATER’s daily deficit in Buea is about 1 million liters.
- CAMWATER caters only for about 52 % of the population of the Buea Municipality.

With the present situation, the services of CAMWATER are far below acceptable standards. Being able to supply water only to about half of the population requires the exploitation of other water supply sources and RWH is the perfect case for Buea. CAMWATER customers still complain of water shortage in the dry season.

### 5.3.8 Financing of domestic RWH systems with 50% subvention from Government

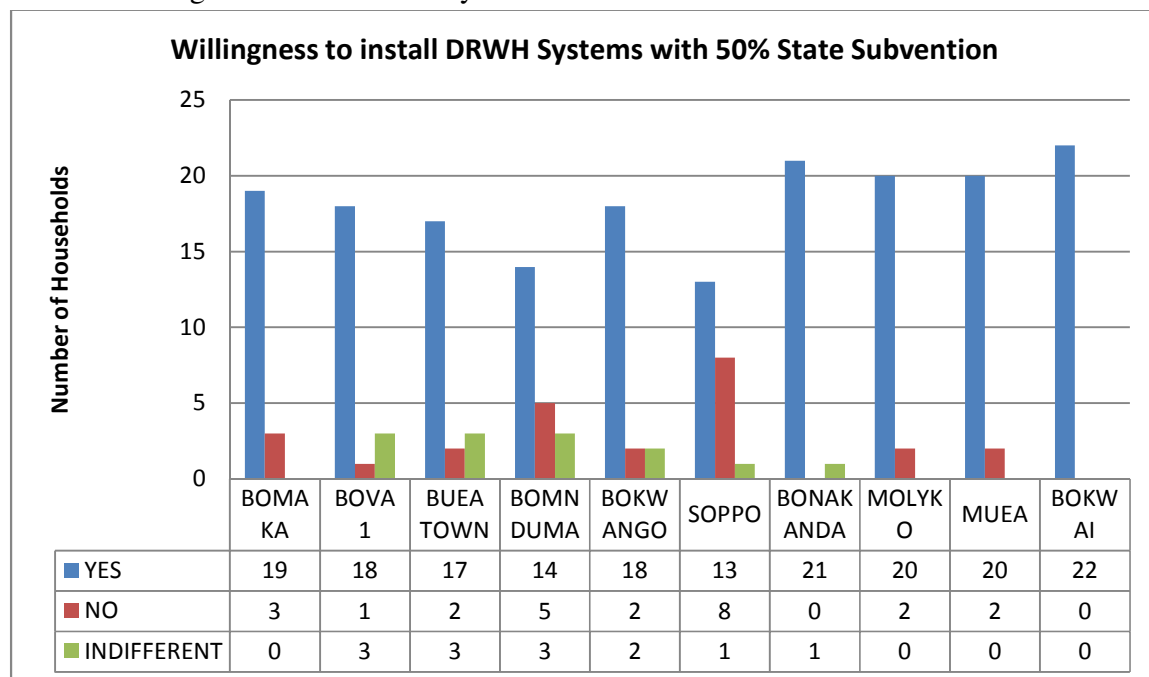


Figure 36: Willingness to install domestic RWH systems with 50% subvention by the State

### **5.3.9 Discussion of the financial aspect in setting up a RWH system in homes**

Finance is a major aspect in any project, be it in developing or developed countries. The State by way of the local administration or the municipal council has the obligation to provide water (which is a basic necessity for life) to its people. Given that domestic RWH systems are costly to install but cheaper to maintain, respondents were asked if they are willing to participate in the installation of RWH systems in their homes with government (state) financial assistance on a 50% basis. Sharing the cost will actually make it fair for both parties. 182 respondents which is proportional to about 83% are willing to participate in the installation of a domestic RWH system if the State funds half the cost of the system. 38 respondents were either not willing or totally against installing a RWH system in their homes. These respondents expressed frustration with those responsible for water management because their complaints about the lack of water have always been taken for granted. Little or nothing has been done to satisfactorily ameliorate this predicament. Also, they were not willing because of their private financial situations. They simply cannot afford such a system because they are unemployed and barely make ends meet. After further comprehension, it was clear that those who were indifferent had little water supply problems because they lived by a stream or had a well in their yards. This means that the 25 respondents (about 11%) are not willing to incur any expenditure with regards to the improvement of their water supply situation. The 13 respondents (6%) who are indifferent are those that had a hard time understanding RWH systems and rely firmly on the recent promises made by the government to improve on the Buea water supply. Furthermore, the highest level of willingness was showed by the respondents in Bokwai because they have the lowest pipe borne water access in this study and as such they experience the most water shortage as shown by the results above. The time and cost of them fetching water could as well be used for the installation of a RWH system at their homes and save them a lot of time which could be used for other important activities. Some respondents even expressed intentions of taking loans from micro financial institution to install a RWH system in their homes and this portrayed how serious their water problems are.

In Muea for instance, community water project supplies the inhabitants with water. Some respondents still prefer installing a domestic RWH system so as to augment their supply and be less dependent on the Community water management board. The board decides on water

distribution and the fee to be paid by each household benefiting from the water project. The board is not well structured and there is very low cooperation with the population leading to some sort of miscommunication and lack of participation by the people to keep the water project alive. This tends to make people insecure and as such they will prefer an alternative water supply source just in case of unforeseen circumstances. There have also been reports of nepotism, where indigenes are favored in decision making and non-indigenous folks are sidelined. Exploiting other water supply sources like bore holes cost comparatively a lot more because of drilling. The drilling companies are mostly in Douala and moving their equipment to Buea for drilling purposes as well as the cost of drilling the bore holes is very high and most people will not involve themselves in such expensive projects. Another reason for the overwhelming willingness regarding domestic RWH system with 50% subvention from the government is the issue of independence in terms of controlling their water supply system by themselves. This includes no water bills and no surprised water cuts without prior information or notice.

## 6.0 CONCLUSION, RECOMMENDATIONS AND PROSPECT

### 6.1 CONCLUSION

The nation Cameroon actually has enormous renewable water resources but access to portable water is a national challenge. Actually about 25% of the population has no access to clean drinking water and about less than half have access to good sanitation facilities. The situation will be better if the communities participate in water management as prescribed by IWRM. Figure 37 below, shows the main actors of the water supply system in Cameroon:

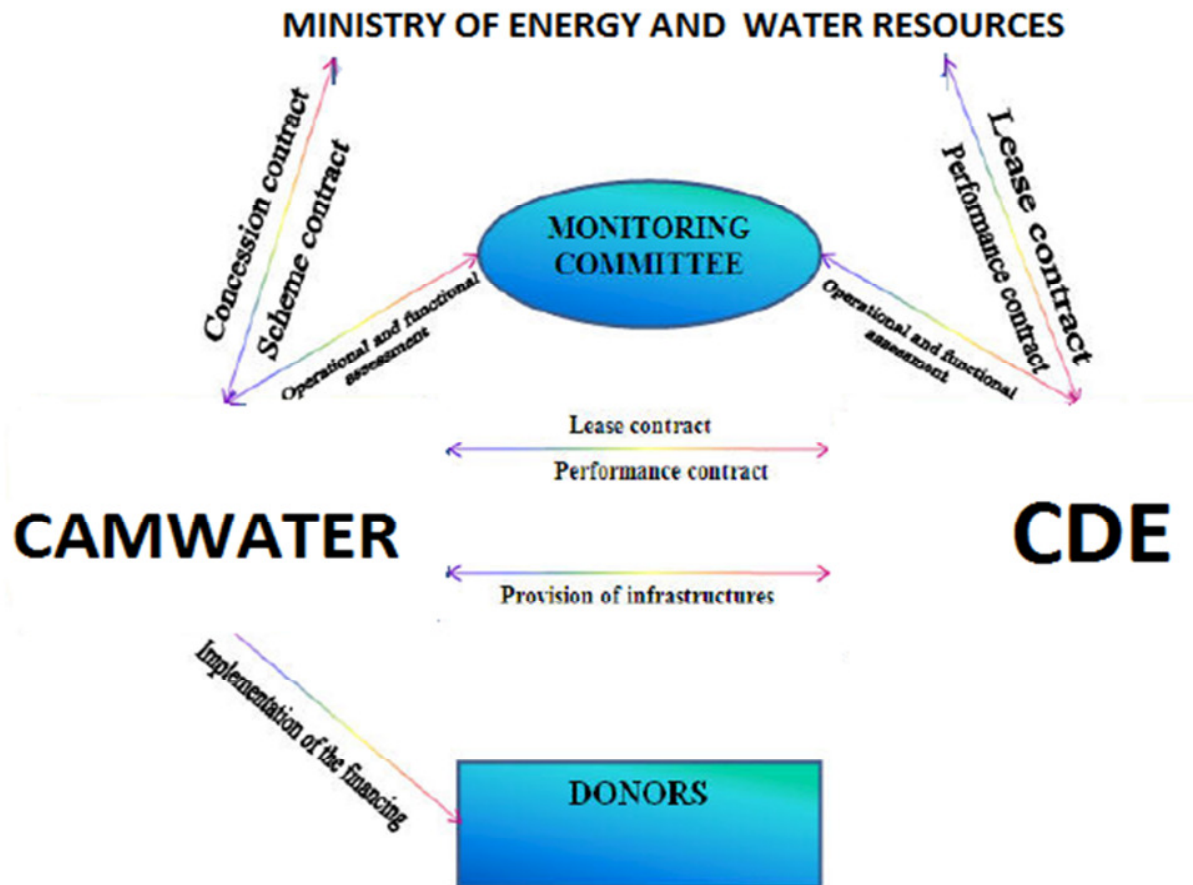


Figure 37: The Actors of Cameroon Water Supply Sector

(Source: adapted from Torres and Foster, 2011)



Figure 37 shows that the water supply system in Cameroon is mainly in the hands of the government. This has partly caused the unreliable manner in which the issue of water scarcity is prioritized. Public participation is significant. The achievement of some aspects of the MDG with regards to the eradication of poverty and hunger, and ensuring environmental stability seem possible but the progress is slow in Cameroon. In 2005, the Cameroon government created the Global Water Partnership Cameroon (GWP-Cmr) which was assigned to put together a robust IWRM plan for the nation has not completed its assignment till date. This is responsible for the sluggish progress with regards to water access by those in desperate need. As seen by the results of this study, there is no doubt that including domestic RWH in IWRM of the Buea municipality will increase the amount of water available per capita and improve on health and sanitation.

Buea is the provincial capital of the South West Region and it is large and developed enough not have a water crisis of such an alarming magnitude. The Cameroon Water Utilities Corporation (CAMWATER) supplies only about 52 % of the municipality by way of individual home pipeline supply and public water points (taps). Their supply is not reliable characterized with frequent water cuts as result of power failure, maintenance and water deficiency. In the event of power failure, CAMWATER is not able to pump water to most of its consumers. CAMWATER inherited old structures and pipelines from SNEC and they often undergo maintenance to keep them working properly. During the dry season, the volume of water flowing from the German Spring (main water source) decreases tremendously and this results to rationing of water. The rationing of water occurs from time to time and implies that some consumers are supplied on a given day and others are not supplied on that day and vice versa.

The local population is generally not in a good financial space to afford for the most recent RWH technology. A low budget but effective RWH system is financially feasible considering subventions by the government to those individuals who are interested and willing to install such a system in their homes. Furthermore, a community based water management scheme with the inclusion of RWH practices is more preferable because it involves the entire community and better results are achieved. RWH is easy to comprehend with little technical know-how. Involving the community will enhance the use of labor intensive methods which will create employment and boost socio economic development in the municipality. The material resources are locally available and this means a decrease in cost of installation. Community based water

management with regards to domestic rainwater harvesting should be explored from the grassroots. Grassroots initiatives in this direction have been successful in many African and Asian countries applying traditional low budget technics which have been in use for centuries. Community based RWH will reduce the level of dependency on the Water Utilities Company (CAMWATER) and provide a sense of ownership to individuals making them directly responsible for their own water supply. Also the community will play a role in not only the implementation but also the planning and developments of ideas and initiatives. In this case, the community will not blame the government but itself in case of irregularities.

Local inhabitants will involve themselves much more with respect to the protection of water resources when they are involved in every aspect of its management. This is because they feel they are responsible and what they do will only come back and affect them.

Another aspect favoring domestic RWH in Buea is the fact that there is no existing legislature governing the handling of rainwater. This is a loophole can be exploited at the moment before the situation changes like in some developed countries. Some parts of the United States (Colorado) rainwater laws are very tight. Land owners need permission to collect or divert rainwater. This is not the case in Cameroon and it is good to make hay when the sun shines. This implies that there is less bureaucracy in setting up a domestic RWH system in homes. Also, there are no taxes levies on such installations for the collection of free rainwater.

From all indications it is safe to confirm that the water scarcity issue in Buea is primarily due to ineffective water management practices. The question of physical water availability is out of question. Buea has abundant precipitation and it is not effectively exploited. CAMWATER's capacity is not sufficient to serve the Buea population. Therefore the people of Buea have to get into other water supply sources and the best of all will be RWH due to its numerous advantages. The fact that RWH can be smoothly integrated into socio-economic development programs make it attractive enough for sponsorship by donor organization especially the United Nations in its attempt to eradicate poverty and foster environmental sustainability as per the MDGs.

The best way to manage floods in Buea is by getting rid of the runoff. The issue of floods in Buea is important because the town located on the foot of the mountain and with high precipitation, it is prone to floods. Flood management can be done by collecting as much rainfall as possible by

way of domestic RWH systems, storing the collected water and then infiltrating the excess. Infiltrating the runoff will stop the flooding and at the same time recharge the groundwater aquifers sustainable. The results of the hydrogeological investigations the study areas in Buea have relatively high infiltration rates and this favors infiltration technics for artificial groundwater recharge.

Small scale agriculture (subsistence) in the form of garden can also be practiced in the dry season with the aid of stored rainwater collected by domestic RWH system. There are a lot of subsistence agricultural activities in Buea on farmlands and such a system can also sustain such agricultural activities. In Buea the cultivation of vegetables at the backyard and fruits in orchards near homes will benefit greatly from domestic RWH systems in the dry season.

Domestic RWH is the solution to the water crisis in the Buea municipality. Water is a vital human resource and it should be available to all human beings. With the high degree of acceptance by inhabitants as shown by the results of this study, there is a great potential for this alternative to augment and in some cases replace commercial water supply and other water supply sources. But this can only be achieved by a smooth cooperation between the government and the local community. Both parties have to work hand in glove to combat water scarcity in Buea. The government has a responsibility to cater for its citizens and the citizens also have the responsibility to cater for themselves. If it can work in Kenya, India, and other developing countries, it can work in Buea (Cameroon). As **John F. Kennedy** once said “Change is the law of life. And those who look only to the past or present are certain to miss the future”. It is prudent to always consider the future. Let domestic RWH be the future for the Buea population suffering from water scarcity and its related issues.

## 6.2 RECOMMENDATIONS

There are some pragmatic recommendations which are bound to serve the purpose of ameliorating the present water crisis status quo of the Buea municipality. If these recommendations are implemented properly, the water crisis will eventually decrease and most people will be relieved from the stress they go through on a daily basis in the struggle to fulfill their water needs. The following recommendations will extenuate the water crisis:

### ➤ Environmentally Friendly Trees

Trees are important for the protection of water catchments. Eucalyptus trees have been planted close to the mountain in Buea. This was an attempt to carry out reforestation for positive environmental purposes. The intention was good but the choice of tree was bad. Eucalyptus trees have very deep roots which could possibly reach the aquifer and extract large amounts of groundwater. Eucalyptus trees consume so much water and this can be seen simply by cutting part of the tree and observing the amount of water oozing out. These trees should be cut down and replaced with water friendly trees (trees that do not consume a lot of water). Examples include Palm trees, Banana and Plantain trees. These trees are environmentally friendly and will also generate financial income. Tea can also be planted amongst other trees. Planting water friendly trees will ease the pressure exerted on the groundwater resource of Buea by those Eucalyptus trees.

### ➤ Construction of Water Mills (Small scale water power plants)

Water mills have been in existence since the middle age. Back then, water powered mills were built in places with sufficient amount of water flow. Flowing water drives a water wheel and the water wheel converts energy from falling water into mechanical energy. One fifth of the world's electricity is produced by way of hydro power. Also, hydro power is responsible for one third of the electricity produced in developing countries. Furthermore, the magazine Finanz und Wirtschaft (2012) states that in 2010 drinking water power plants and sewage treatment plants produced much more electric power than solar and wind energy combined. They have a high efficiency of close to 90% making them more energy efficient than other technologies. It can be

easily predicted by simply comprehending the annual precipitation pattern of the area. This technology is durable and can last for more than 30 years. Besides the production of electric power, the water that goes through the turbines can also be used for drinking. For this reason special materials should be used to avoid contamination and corrosion. Water mills provide job opportunities for the local population. Water mills increase the retention time of water and as such can hold water till the dry season period. This water could be used for groundwater recharge. They are some sort of RWH systems. In the case of Buea, the cost of such a system should be covered by CAMWATER and CDE because the primary aim is to obtain drinking water and energy is secondary. Reservoirs have to be constructed at higher altitudes on the mountain slope to provide water to the system during the dry season. This will be a sustainable approach to manage the streams and springs flowing down the mountain during the rainy season on one hand and then mitigating flooding on the other hand. Such an environmental innovative system that produces energy, drinking water and provides job opportunities is needed on the eastern slopes of Mt Cameroon.



Figure 38: A small scale water mill

(Source: Blaldernock Water Mills, 2011)

➤ Infiltration Basins and Trenches

Infiltration basins and trench systems are specifically for storm water runoff. The high precipitation with large storm events results to surface runoff which gradually evaporates to the atmosphere if not infiltrated. They are lined with geotextile material, covered with gravel and then top soil. Infiltration trenches also mitigate flooding and they recharge the groundwater and base-flow of nearby streams. They are basically applied in small sites and improve surface water quality. They are suitable on gentle slopes and they filter water removing fine sediments, trace metals and bacteria. Buea has a high infiltration rate and this is a good condition for the success of infiltration trenches. Infiltration basins also collect and infiltrate storm water, filtering and removing pollutants and sediments. They are preferably applied in wide areas which are out of the densely populated areas. Infiltration basins should be constructed in less populated areas like Bova (high infiltration). As for infiltration trenches, can be constructed by the sides of gutters and buildings. An observation well has to at the middle of the trench in order to monitor the drainage of water from the trench. In Buea recharge or Infiltration trenches will help solve the problems caused by runoff (e.g. flooding due to lack of culverts in residential areas) and recharge groundwater aquifers. An example of an infiltration basin is shown on figure 39 below:

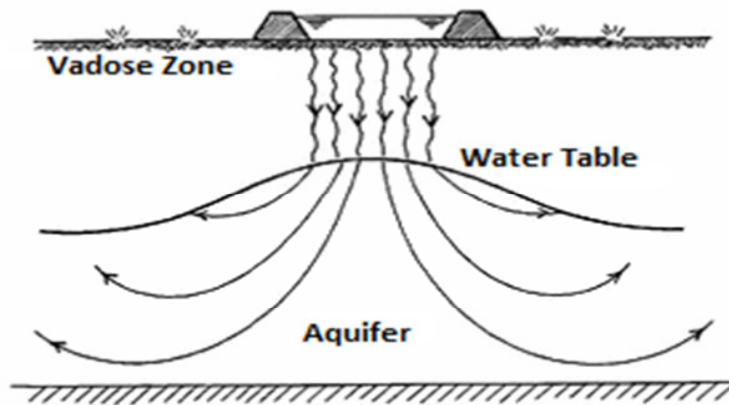


Figure 39: AGR system with Infiltration Basin

(Source: Bouwer, 2002)

➤ Education, Training and Scientific Research

A free internet services for students and academicians is great for education. The price for internet services is on the decline but it is still not accessible to most people. NGO's and government could provide such services to promote academic development. Acquiring knowledge with respect to water resource management will be very beneficial for individuals and for Buea as a whole. Innovation backed by scientific research is the way to make old technologies better and sometimes even cheaper and affordable. The government should encourage and promote RWH by offering training seminars for young professionals who are interested in water management. Also, the University of Buea should include courses in IWRM in their curriculum aiming at solving water management issues in the municipality. Building their capacities will increase their technical know-how impacting the society positively.

➤ Tax Exemptions

Since the dawn of the new millennium, the government of Cameroon has waived importation taxes on computer hardware and some other IT components. This has facilitated the influx of computers and associated products all over the country. The government should put a custom duty waiver (tax exemption) for RWH components and technological equipment coming in from abroad. This will motivate and promote technology transfer from develop nations. The result of this will be a booming RWH industry in Buea as well as nationwide especially in the Northern part where the water crises is much more severe. Furthermore, the municipal council and the delegation of town planning and housing should promote the installation of RWH systems during the construction of new homes. Reduction of council taxes by these authorities will absolutely encourage the population.

### **6.3 PROSPECTS**

The future of RWH in Buea will eventually be beyond domestic water supply. Buea is very attractive to agriculture as a result of its fertile soils (Andosols). Population is on the rise and water scarcity as well. An alternative water supply means is the fastest way to rescue the situation. With RWH utilization, the future actually lies in the past. Ancient civilizations used RWH for most of their water needs and this was successful. The future lies in modernizing the ancient methods and using them all over again. Using a renewable resource will make the society much more sustainable because of the negligible environmental impacts associated with this system. Water scarcity will increase certain parts of the world and RWH will be the solution. With the rise in the population that depends on RWH, its potential becoming the best alternative water supply means (second only to CAMWATER's commercial pipe borne water in Buea is feasible).



## ANNEXES

### ANNEX 1. QUESTIONNAIRE ON RAINWATER HARVESTING

#### SECTION A

1) Name of village \_\_\_\_\_

2) What is your gender? Male  Female

3) To which age group do you belong?

15-19years  20-29years  30-39years  39-40years  40-49years  50-59years   
60years and above

4) What is your level of education?

No formal education  Primary school  Secondary school  University  Others

#### SECTION B

5) Do you experience water shortages? Yes  No  Don't Know

6) Do you have access to pipe borne water? Yes  No

7) What is the source of the water used in your household?

CAMWATER (MAIN)  Well  Stream  Rainfall  Public taps  Community water

8) Who is in charge of supply for your village?

Community based  CAMWATER  PRIVATE  NGO

9) Proximity to water supply source. Near  Far  Very Far

#### SECTION C

10) Do you understand the term "Rainwater Harvesting" Yes  No

11) Have you ever been educated on or attended any seminar on RWH? Yes  No

12) Do you practice any form of RWH? Yes  No  Don't know

13) Are you willing to participate in RWH to improve on your domestic water supply if government provides 50% of the installation costs? Yes  No  Don't Know

#### SECTION D

14) How many persons leave in your house? \_\_\_\_\_

15) What is the total water consumption of your home per day in liters? \_\_\_\_\_

16) What is the total water consumption per person per day in liters? \_\_\_\_\_

17) What is the number of household members?

Children \_\_\_\_\_

Young \_\_\_\_\_

Adults \_\_\_\_\_

18) When do you consume more water? Dry season  Rainy season  the same for both

19) Volume of water used by home/day in dry and rainy season?

Dry season \_\_\_\_\_

Rainy season \_\_\_\_\_

20) Are you satisfied with your daily water consumption? Yes  No  Don't Know

21) Is there any member of the family who stays out for at least half of the year? Yes  No

22) If yes, how many \_\_\_\_\_

## ANNEX 2. LETTER OF INTRODUCTION FOR DATA REQUEST



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### Letter of Introduction

#### To whom it may concern:

This is to introduce the bearer, **Mr Roy Mbu**, whom I personally know as being a trustworthy, determined and brilliant student. He is a PhD student at my department, the department of Environmental Geology at the Brandenburg University of Technology Cottbus in Germany.

He is at the last phase of his program and will be in Buea, Cameroon to obtain qualitative and quantitative information (data) for his Doctoral Thesis titled "Rainwater Harvesting for the stabilization of the water supply of Buea".

I sincerely ask for your co-operation in assisting him carry out his field work without any complications. This research will eventually help to stabilize water supply in the Buea municipality.

Sincerely,

Univ.-Prof. Dr. rer. nat. habil. H.-J. Voigt

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## ANNEX 3. LETTER FOR THE REQUEST FOR DATA ON WATER DEMAND AND WATER SUPPLY FOR THE BUEA MUNICIPALITY

### UNIVERSITY OF BUEA

**Prof Cornelius Mbifung Lambi**  
B.Sc., M.Sc. (Fourah Bay), Ph.D (Salford)  
F.R.G.S., F.G.S. (London)  
(Former Vice-Chancellor)  
Cell: (237) 95 33 12 85



Department of Geography  
Faculty of Social and  
Management Sciences  
P. O. Box 63, Buea  
Cameroon.

To the Director,  
CDE, Limbe,  
Cameroon.

#### REQUEST FOR DATA ON WATER DEMAND AND WATER SUPPLY FOR THE BUEA MUNICIPALITY FOR 2007-2012

I am happy to write this letter of introduction of Roy Mbua who is a young Cameroonian studying for a Doctor of Philosophy Degree (Ph.D) at Bredenburg University of Technology, Cottbus, Germany. He is doing his Doctoral studies in the Faculty of Environmental Engineering at the said University under Prof. Dr. rer. nat. habil. Hans-Jurgen Voigt.

For his Doctoral Thesis, he is working on Water Harvesting on the Eastern Slopes of Mount Cameroon, with a view to supplement the current water supply for the Buea municipality. In view of this research, he would need data on water demands, and water supply for the Buea Municipality for the period dating 2007-2012 or thereabout. There is no doubt that your company-CAMEROUNAISE DES EAUX S.A has been doing tremendous work in order to ensure that the people of the Buea Municipality are adequately served with water. But there is however a rapidly growing population which today has outpaced supply. In the circumstances therefore, there is the need for all stakeholders of that municipality to have a deeper reflection on alternative ways of supplying water to the local population. This is why the concept of water harvesting arose and it is our view that if the waters in the form of runoff and floods could be successfully harvested and treated, it could go a long way to alleviate the water problem or water crisis and even the Buea municipality. This is why the candidate embarked on this topic.

In order for him to be able to make a valuable contribution to this domain, it will be necessary for him to have any existing data on water which will be useful in this respect. As he will be returning to Germany after one month of data collection in Cameroon, I should therefore be much obliged seeing that I am the Cameroon-based supervisor of this work if you would give him access to the relevant data to facilitate his doctoral research.

Thank you very much for the work you have been doing so far to enable that the Cameroonian population of the eastern slope of Mount Cameroon are supplied with water. Once more, accept my hearty congratulations for a job well done.

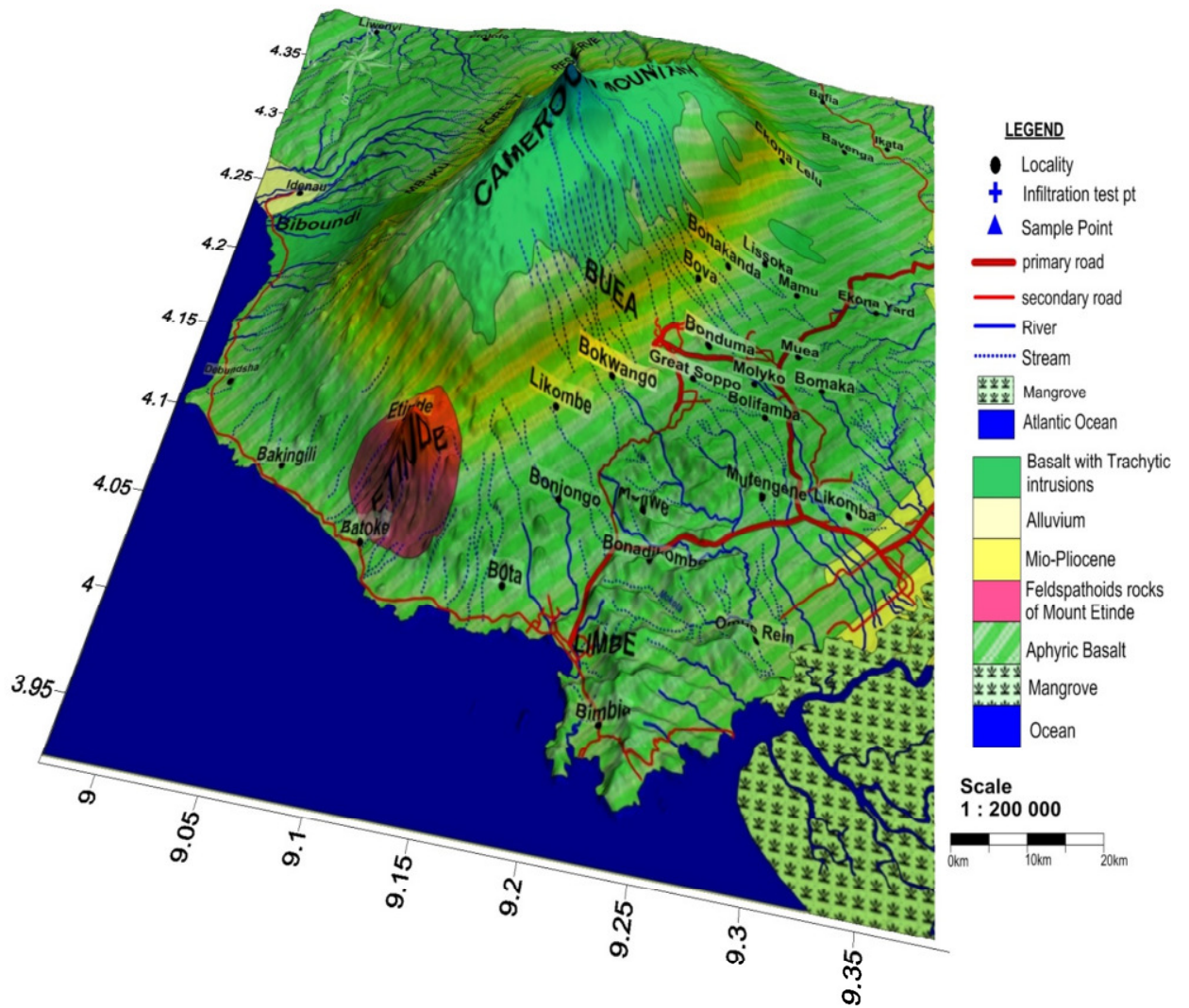
**Prof. Cornelius Mbifung Lambi**  
B.Sc., M.Sc. (Fourah Bay), Ph.D (Salford)  
F.R.G.S., F.G.S (London)  
(Former Vice-Chancellor)



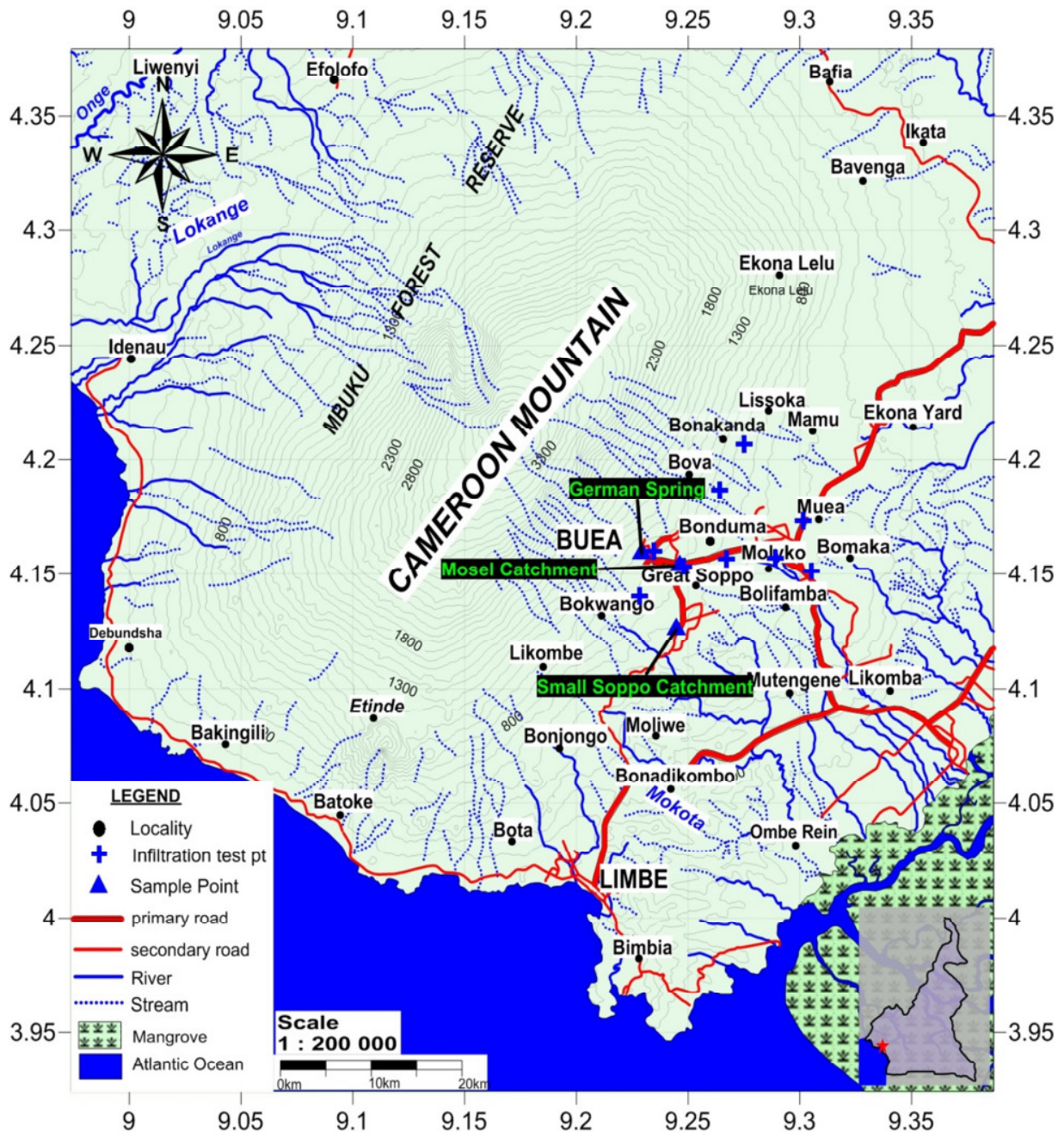
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## ANNEX 4. DRAINAGE AND GEOLOGY MAP OF BUEA IN 3D FORM

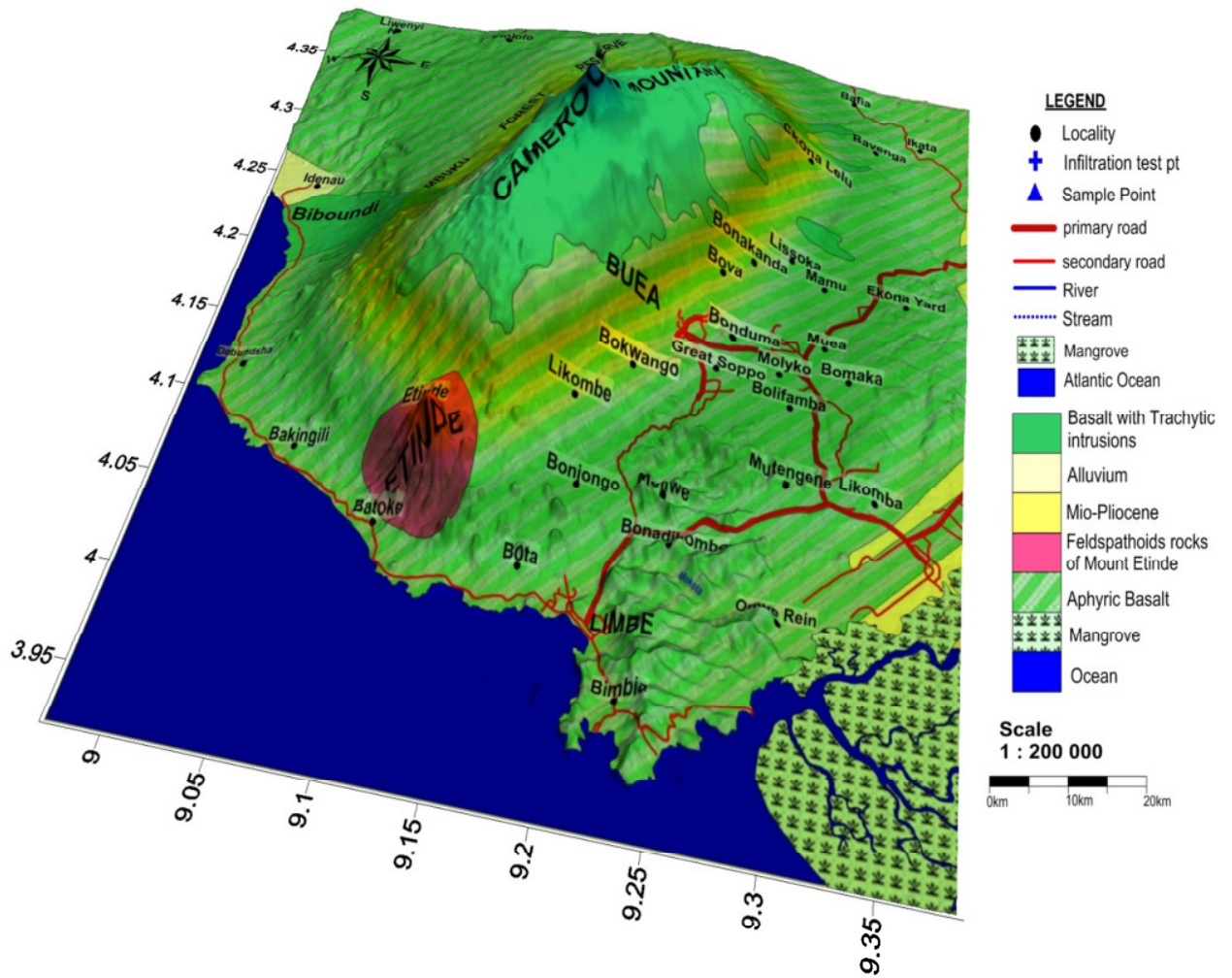


## ANNEX 5. DRAINAGE MAP OF BUEA WITH INFILTRATION TEST POINTS AND WATER CATCHMENTS





## ANNEX 6. SIMPLE GEOLOGICAL MAP OF BUEA WITHOUT SAMPLE POINTS



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