Kwame Nkrumah University of Science and Technology, Kumasi

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DEPARTMENT OF AGRICULTURAL ENGINEERING

Assessment of Water Sources in Terms of Availability, Use and Sufficiency in the Northern Region of Ghana

By

Seidu Yussif

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ASSESSMENT OF WATER SOURCES IN TERMS OF AVAILABILITY, USE AND SUFFICIENCY IN THE NORTHERN REGION OF GHANA

By

Seidu Yussif,
(B.Sc. Geodetic Engineering)

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of a University, except where due acknowledgement has been made in the text.

Seidu Yussif	……………………	……………..
Student (PG 4859110)	Signature	Date
Certify by		
Prof. N. Kyei-Baffour	……………………	………………
Supervisor	Signature	Date
Dr. E. Ofori	………………………	……………..
Supervisor	Signature	Date
Prof. E. Mensah	………………………	……………..
Head of Department	Signature	Date

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ABSTRACT

Water is an essential resource for our well-being. The availability and sufficiency of water sources in the Northern Region has been questioned due to water scarcity. Therefore, there was the need to assess water sources in terms of availability, use and sufficiency in the Northern Region of Ghana. Questionnaires were administered and measurement of yield of water supplies and infiltration tests in Savelugu-Nantong, Karaga and Gushiegu Districts were done. In addition, information on meteorological and crop data were collected for the study. Analysis of the water sources showed that boreholes, wells, rivers, streams and dug-outs were seasonally affected in terms of the water availability and supply with few boreholes having the potential of meeting domestic and irrigation water requirements in the dry season. Results from measured domestic water consumption by households in the study area showed that they were insufficient for healthy lifestyles. The low consumption level was due to insufficient water supply options, thus resulting in water consumption levels not equating demand. Results from the current and projected population showed that water sources were insufficient in the study area leading to congestion at water supply points with more communities likely to be vulnerable to water scarcity. The prevalence of water-related diseases except guineaworm was still high in the study area. The high prevalence of water-related diseases was, however, attributed to poor sanitation and hygiene practices. Results of the study also revealed poor management and sustainability of the water sources due to inappropriate siting, geological limitations, poor design and construction of water sources. Other factors include inactive Water and Sanitation Committees, lack of community's sense of ownership and inability to generate sufficient incomes. Generally, stand pipes can be recommended for the people since the water is clean, safe and accessible without much use of human energy as is the case with the other sources.

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ACRONYMS

AMs	Area Mechanics
AWDR	African Water Development Report
BHs	Boreholes
CDF	French Development Bank
CIDA	Canadian International Development Agency
COM	Community Ownership and Management
CWR	Crop Water Requirement
CWSA	Community Water and Sanitation Agency
CWSD	Community Water and Sanitation Division
CWSP	Community Water and Sanitation Programme
DANIDA	Danish International Development Agency
Das	District Assemblies
DRA	Demand Responsive Approach
DWSTs	District Water and Sanitation Teams
DOW	Dug-out water
ET_c	Crop Evapotranspiration
ET_o	Reference Evapotranspiration
EU	European Union
FAO	Food and Agriculture Organisation
GIWR	Gross Irrigation Water Requirement
GPS	Global Position System

GWCL	Ghana Water Company Limited
GWRC	Ghanaian Water Resources Commission
GWRESP	Ghanaian Water Resources and Environmental Sanitation Project
GRWP	Ghana Rural Water Projects
GWSC	Ghana Water and Sewerage Corporation
HDWs	Hand Dug Wells
HHs	Households
IDA	International Development Association
IWR	Irrigation Water Requirement
K_c	Crop Coefficient
MWH	Ministry of Works and Housing
MWRWH	Ministry of Water Resources, Works and Housing
NCWSP	National Community Water and Sanitation Programme
NGOs	Non-Governmental Organisations
NORPREP	Northern Region Poverty Reduction Programme
NORWASP	Northern Region Water and Sanitation Programme
NWP	National Water Policy
PHC	Population and Housing Census
POs	Partner Organizations
PSP	Public Stand pipe
PURC	Public Utilities Regulatory Commission
PWD	Public Works Department
RWH	Rain water harvest
RWST	Regional Water and Sanitation Team

SARI	Savana Agricultural Research Institute
STRM	Stream
TREND	Training Research and Networking for Development
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
WATSAN	Water and Sanitation
WHO	World Health Organisation
WRC	Water Resources Commission
WSD	Water Supply Division
WWDR	World Water Development Report

DEDICATION

This thesis is dedicated to my lovely mother, Mrs. Seidu Salamatu, who has been my backbone in my achievements and to the loving memory of my dear father, Abubakar Seidu

CHAPTER 1

INTRODUCTION

1.1 Background Information

Among all the natural resources available to mankind, water holds a prominent place, particularly because of its importance for human livelihood sustenance. All people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs (Doe, 2007). Water availability, as well as the amount of water use is a significant factor for social and economic activities (Stanhill, 1982). The challenges facing many countries in the world today in their struggle for economic and social development are increasingly related to water. There are still at least 1.1 billion people around the world who do not have access to safe drinking water. Majority of these people live in rural areas and are among the poorest and most vulnerable in the world (IAH Burdon Ground Water Network, 2007). It is documented that less than 10 advanced countries have about 60% of the globally accessible water (Swaminathan, 2001), suggesting inequitable distribution of water. The variation in the amount of water supplied to each person is enormous, the value depending partly on objective factors such as climate, water sources and level of technology and partly on subjective factors such as lifestyle and social attitude. The lower limit to this usage is set by human metabolic requirements. With a changing global environment, the water supply-demand balance would come under constant pressure. Some of these trends are already underway. Population growth directly or indirectly is expected to shift about 55 % of the world's population towards water stress or severe water scarcity over the next generation (Rockstrom, 2001). Genuine concerns are therefore being raised about future water scarcity because of the important role water plays in sustainable development and quality of life. One of the international goals set for the year 2015 in the United Nations Millennium Development Goals (UNMDGs) and in the plan of implementation of the world summit on sustainable development is reducing the proportion of people without adequate access to water and basic sanitation by one-half. While access to sufficient and clean drinking water may be taken for granted in the developed world, problems with access are more severe in the developing world, where more than 15 million people perish every year from water related diseases, and more than one billion people suffer without access to water for their basic needs (Nicholas, 2005).

The water scarcity situation is severe in developing countries, with an estimate of about 1.2 billion people in 20 “water- scarce” developing countries without access to “safe water” (Asare, 2004). The World Resources Institute (2000) estimated that more than one billion people in developing countries do not have access to clean water whilst 2 billion lack adequate sanitation. Africa’s share of global freshwater resources is about 9 %. These water resources are distributed unevenly across Africa, with western and central Africa having significantly greater precipitation than northern Africa, the horn of Africa and southern Africa. Africa is therefore noted to have large disparities in water availability, and the lowest water supply and sanitation coverage in the world. These difficulties have led to dangerous health situations in many regions, where hunger and water related diseases are regular threats. In the case of Sub-Saharan Africa, Rosen and Vincent (1999) estimated that about 67 % of the rural population (about 250 million people) lack safe and accessible water supply whilst 81% did not have access to sanitation facilities. Sub-Saharan Africa is making the slowest progress in meeting the Millennium Development goals (MDGs) target, one-third of the population still need safe drinking water (UN, 2008). Although the Millennium Development Goals (MDGs) target seeks to "halve by 2015 the proportion of people without access to safe drinking water and sanitation" (UNDP, 2005), it is anticipated that Sub-Saharan Africa will only reach the water target by 2040 (Sutton, 2008). But still, some 400 million of the people living in Sub-Saharan Africa will be left without access to safe water with a majority of them being women and children living in rural households (Sutton, 2008). In response to the problems of water supply, water resources development and management in Africa, UN-Water/Africa took a decision in April 2001 in Niamey to develop an African Water Development Report (AWDR) as an integral part of the World Water Development Report (WWDR). The AWDR provided African countries and other stakeholders the necessary information for obtaining tools and skills to monitor the goals and targets of the African Water Vision, which was summed up as water can make an immense difference to Africa's development if it is managed well and used wisely.

In Ghana, rainfall is not scarce and several rivers do not cease to flow, but clean water has been denied millions of people. Similar to the rural water sector in many developing countries, there are serious constraints to meeting the challenges to provide adequate water to all rural residents. Water supply shortages and quality deterioration are among the problems which require greater attention and action. Various strategies are being developed to make water accessible to all inhabitants. However, due to the insufficient structures coupled with rapid population growth, the gap between demand and supply of water continues to widen (Doe, 2007). The study area which includes Savelugu-Nantong, Karaga and Gushiegu Districts of Northern Region are characterised by unpredictable rainfall patterns with periodic and perennial water shortages. Although the water situations in the three districts have improved since 1996, the potable water coverage in the area (the three districts) is still unbearably low. Less than 50% of the populations have access to safe water (CWSA, 2004). The problem of potable water in the area is quite enormous especially in the rural areas. Since more than 50 % of the population are without potable water, the effect of lack of water on health and productivity is great. A typical lean water season in the area exudes a rush for water of all kinds. The distance people have to travel to fetch water and the man-hours wasted in the search for water affect productivity. The dependence on non-potable water for domestic consumption is responsible for the upsurge of water borne diseases in the area. This study therefore aims at assessing water sources in terms availability, use and sufficiency in the three districts of the Northern Region as a case study.

1.2 Problem Statement

Fresh water is vital for socio-economic development and the provision of ecological services, but this resource is gradually becoming a scarce commodity in Ghana. The main sources of water for household use are piped supply, rivers, boreholes, wells, ponds, lakes, harvested rainwater and streams. The Global Water Project (GWP) forecast that six West African Countries, including Ghana and Burkina Faso, may experience water scarcity by 2025 mainly due to the expected rate of growth in population (Global Water Partnership, 2000). Current annual population growth rate of 2.4 % (Ghana Statistical Service, 2010) coupled with expansion in the rural and urban areas suggest future increases in water demand. Already, water demand outstrips supply (Karikari, 1996) and projected per capita renewable freshwater availability by 2025 will be 1,400 m^3 (Asare, 2004), which is within the water-stress range.

The link between inadequate access to safe and affordable water and public health problems, cannot be over-emphasised. It is estimated that about 70 % of the diseases in Ghana are the result of inadequate rural water supply coverage [International Fact Finding Mission on Water Sector Reform in Ghana (IFFM), 2002]. In the study areas, inadequacy of potable water supply is recognised to be a major contribution to human disease such as cholera, typhoid, river blindness, hepatitis and malaria. The minimisation of these health problems is contingent on the choices made by household's regarding available water supply sources as this has health and agricultural productivity implications. Household water quality perceptions also contribute to the use of water sources for specific domestic activity.

Most rural communities in Ghana live in extreme poverty and find it difficult maintaining water facilities without assistance, the worst affected being the Northern Savannah Regions (Tay, 2005a). As a result, most hand pumps in these communities have broken down and need to be rehabilitated.

1.3 Study Objectives

The general objective of the study was to assess water sources in terms of availability, use and sufficiency in the Savelugu-Nantong, Karaga and Gushiegu Districts of the Northern Region.

1.3.1 Specific Objectives

The specific objectives of the study were to:

- Identify and examine factors that influence preferential use of water sources in rainy and dry seasons,
- Identify factors limiting continues water supply for do32mestic and small scale rural industrial activities,
- Determine the sufficiency of water use on per capita basis for domestic and small scale rural industrial activities,
- Determine the major factors affecting the management and sustainability of water sources,
- Determine the potential of the water sources for dry season small scale irrigation and
- Make projections for future domestic water demand and draw implications of the results in terms of vulnerability of the districts to water stress.

1.4 Research Questions

1. What are some of the factors that influence preferential use of water sources in the dry and rainy seasons?
2. What are the factors limiting continues water supply for domestic and small scale rural industrial activities?
3. What is the level of sufficiency of water supplies for domestic activities in the three districts?
4. What is the level of sufficiency of water supplies for small scale industrial activities in the three districts?
5. What are the major factors affecting the management and sustainability of water sources?

6. What is the potential of the water sources for dry season small scale irrigation?
7. What is the future demand of water for domestic activities?

1.5 Significance of the Study

It is important to recognise that as the basic amount of fresh water supplied by the hydrological cycle does not change, water demand is said to be increasing in Ghana (Karikari, 1996). This may lead to water scarcity which can threaten economic sectors, especially irrigated agriculture and hydropower generation. Seckler *et al* (1999) and Luijtena *et al* (2001) noted that water scarcity represents the single greatest threat to food security, human health and the natural ecosystem. Hence, the efficient and sustainable use of water in the districts is very paramount. The need therefore arises to examine the extent of water accessibility and empirically quantify water demand for purposes of structural analysis, forecasting and policy evaluation.

Little is known about the nature and extent of water availability, accessibility, use and sufficiency in the districts concerned. More attention has rather been focused on the supply and equitable distribution of water to urban populations largely to the neglect of rural areas. Assessing the current situation in rural areas is therefore necessary for sound planning. This study is therefore expected to increase the knowledge and provide up-to-date information on rural water sources in terms of availability, use and sufficiency. It will also serve as a working document to policy makers in the water sector and non-governmental organizations. The study further serves as a benchmark data for any further investigation. This study finally serves as a useful material for academic purposes and also adds to existing knowledge.

CHAPTER 2

LITERATURE REWIEW

2.1 Introduction

This chapter examines the definitions of water, water sources and supply, national water policy and programme, sustainability and water sufficiency in terms of demand-supply water balance, water dependency, water sources constraints and water deficit as well as types of water use and how these uses would be altered under selected global changes. It also examines the projection for future water demand as provided in literature.

Water sources have been the subject of a significant number of studies. However when these studies are viewed from their disciplinary focus, one finds that most of them have been carried out in the field of hydrology, with a few pertaining to project planning and appraisal (Kulshreshtha, 1993). Thus economic aspects of water sources planning and management have not been the focus of many studies. The primary purpose of this study was to examine issues related to water sources availability in the Northern Region and to develop a basis for the examination of sufficiency of the region to water availability, first based on a review of other studies and then focusing on results of the study.

2.2 The Definition, Nature and Importance of Water

Water, according to Symons *et al* (2000) is a transparent, odourless, tasteless compound of hydrogen and oxygen, H_2O. At a pressure of one atmosphere (101.3 kilopascals), water freezes at 0^{o} C and boils at 100° C. Water, in a more or less impure state, constitutes rain, oceans, lakes, rivers and other such surface water bodies as well as groundwater.

Water, an abundant natural resources, is critical for the sustenance of human life. Water occupies a central position in the basic needs of humans to the extent that it is next to oxygen in order of importance (Ogunnowo, 2004). Literally then, water means life and prosperity. Water is a key determinant of sustainable development that should be carefully managed to make for suitable and sustainable human health cum well-being (Ogunnowo, 2004).

The basic purpose for which water is domestically required includes drinking, bathing, cooking and general sanitation such as laundry, flushing of closets and other household chores. Other important uses of water are for economic activities, livestock and irrigation. Thus, an assured supply of water both qualitatively and quantitatively for these purposes greatly improves the social and economic activities of people (Fanira, 1977; Oyebande, 1986, cited in Ogunnowo, 2004). The fact that water is a major constituent of all living matter, explains that water therefore is a basic necessity for life. It is very much needed in all aspects of life. This implies that water gives life. Both plants and animals need it for survival and growth. Any shortage or pollution of such a vital resource hinders growth and development. Therefore there is the need to harness sources to explore and develop existing water sources and manage them to ensure adequate quantity and quality supply at all times for survival and growth.

Even though Africa is generally considered as a continent endowed with abundant water, both urban and rural people in the continent lack adequate and safe drinking water and face food security risks, coupled with exposure to preventable water-related diseases (AWDR, 2006). This situation is attributable not only to lack of water but also to the very low level of access to safe drinking water and adequate sanitation facilities. The inadequate access to water and water scarcity affect women and girls disproportionately, especially in rural areas, due to great disparities in rights, decision-making power, tasks and responsibilities over water for productive and domestic activities (AWDR, 2006).

2.3 Water sources of Ghana

Africa is considered globally as a continent endowed with abundant water and Ghana is one of the Sub-Saharan African countries that are well endowed with water resources. For instance, according to FAO (2008), the Volta river system that consists of the Oti, Daka, Pru, Sene and Afram rivers as well as the White and Black Volta rivers, takes 70% of the country's surface area. The southwestern river system watershed consisting of the Tano, Ankobra, Bia and Pra rivers also covers 22% of Ghana's total surface area. The remaining 8% of the country is covered by the coastal river system watershed, consisting of the Ayensu, Densu, Tordzie, Ochi-Nakwa and Ochi-amissah rivers. Groundwater is also available in commercial yields in Mesozoic and Cenozoic sedimentary rocks and in sedimentary formations underlying the Volta basin. Indeed, the Volta lake, the largest in Ghana, is one of the world's largest artificial lakes with a surface area of 8,500 km^2 and a catchment area of 165700 km^2 within the the country (Karikari, 2000: FAO, 2008), Ghana's total actual renewable water resources are therefore, estimated to be 53.2 billion m^2 per year (FAO, 2008).

With regards to climate, Karikari (2000) reported that the climate of Ghana is generally tropical with a wide variation of rainfall, influenced by the southwest monsoon. The country's mean annual rainfall varies from 2000 mm in the southwest coastal area to about 850 mm in the eastern coastal area and 1000 mm in the north.

With all the endowed water resources, water demand far outstrips supply in Ghana just as is the case in most parts of Sub-Saharan Africa. Even though varying from place to place depending on the hydro-geological conditions and financial resources, Karikari (2000) noted that the main sources of water for households are piped supply from treated water sources; untreated piped water from groundwater sources; shallow boreholes; wells and ponds; springs, lakes, harvested rainwater, rivers and streams.

2.4 Sources of water supply

2.4.1 Urban sources

Generally urban communities in Ghana take the larger share of their water supply from rivers at dams and diversion structures which need to be treated to meet health standards. Surface water sources can probably serve all urban needs for the near future through corresponding programmes of development and conservations (Karikari, 2000). For convenience sake, however, private individuals who can afford rely much on groundwater supplies through either hand-dug wells without pumps or boreholes fitted with pumps.

2.4.2 Rural sources

Most rural communities in Ghana have traditionally relied on surface and groundwater sources for their supply needs. In order words, these communities have a mix of protected and unprotected water sources. Gyau-Boakye (2001) indicates that the surface water sources used by these communities include dug-wells, ponds, dugouts, impoundments from dams, ephemeral streams and rainwater harvesting from roofs whilst the groundwater supplies are obtained from hand-dug wells with or without hand pumps, boreholes fitted with hand pumps, and springs. Gyau-Boakye and Dapaah-Siakwan (1999) further noted that as part of the official policy to provide potable and safe drinking water for all rural communities in Ghana, the various stakeholders have adopted the rural water supply schemes which are exploited mainly from groundwater sources particularly through hand-dug wells and boreholes fitted with hand pumps.These traditional systems, according to Gyau-Boakye and Dapaah-Siakwan (2000) are often insufficient both in quantity and quality.

According to Karikari (2000), the quality of groundwater in Ghana is generally good and accounts for a large share of the potable-water supply in rural communities, except in some few areas like Bongo and Prestea where the water contains iron, manganese and fluoride deposits.

Indeed, groundwater sources appear to be the key to the development of rural water supply and this reflects in its exploitation by the various stakeholders in the rural water sector and should therefore be managed and utilised on sustainable basis to meet future challenges. However, it has to be emphasized that due to geological limitations it is not everywhere that groundwater is available especially in the required quantities. Some rural communities therefore have to rely solely on surface water sources whilst others have to resort to conjunctive use of both surface and groundwater sources.

2.5 Ghana water history and recent developments

2.5.1 History

Gyau- Boakye and Dapaah-Siakwan (1999) noted that in 1844, during the pre-colonial era, individuals, trading, mining and timber companies and small communities were responsible for their own water supplies. Dug-wells, ponds, dug-outs, streams and rainwater harvesting from roofs were the main sources of these supplies at the time.

The colonial government, however, assumed some responsibility for public water supply in the urban and rural areas as a result of periodic droughts, population growth and the emergence of larger communities later in about 1900. Consequently, a Public Works Department (PWD) was formed to explore urban water supplies. As a result of frequent droughts in the northern sector, the Geological Survey Department was established in 1937 was detailed with dealing with the severe water supply problems in northern and the south-eastern parts of the country. The provision of water to both rural and urban areas of Ghana was then put under the responsibility of the Water Supply Department (WSD). The WSD was later separated from the PWD and put under the Ministry of Works and Housing (MWH) following Ghana's independence in 1957.

Later a number of challenges occurred in the institutional set up for water supplies in the country and as a way to revamp the sector it necessitated the change of WSD to Ghana Water and Sewerage Corporation (GWSC) in 1965 by the legal Act (Act 310) GWSC was set-up as a mandated public utility in charge of the provision of urban and rural water supply for public, domestic, and industrial purposes as well as the provision, operation, and control of sewerage systems. The policy of GWSC was to supply potable water to rural communities based mainly on groundwater sources (Gyau-Boakye and Dapaah-Siakwan, 1999).

To address the problems that confronted the Ghana water sector, the government took a decision to restructure the sector; hence various reforms have been adopted since 1993. The main aims of the reforms were to separate rural and urban water supply services, to introduce independent regulatory agencies, as well as to include private sector participation (CWSA, 2004).

In line with the reforms, the Community Water and Sanitation Division (CWSD) was introduced in 1994 as a semi-autonomous division of GWSC to be responsible for the water supply and sanitation in rural areas. In 1998, it was transformed into Community Water and Sanitation Agency (CWSA) by Act 564, and became fully independent (GWRESP, 2008; TREND, 2007). In the same vein, the GWSC was also replaced by the publicly owned Ghana Water Company Limited (GWCL) in 1999. The responsibility for rural water supply and sanitation was then decentralized to the District Assemblies (Water Aid, 2005a).

These later developments mandated GWCL to remain responsible only for urban water supply, whilst the water systems in over 110 small towns were decentralized to District Assemblies, which receive support from the CWSA. As a way of instilling responsibility in the people, demand–driven and community–managed approach was introduced in the latter case (UN, 2004).

The other development has been the shift of the regulation of water supply from the government to independent agencies. The Public Utilities Regulatory Commission (PURC) and the Water Resources Commission (WRC) were two commissions created in 1997 to regulate the sector (CWSA, 2004). The PURC was mandated to be responsible for formulating as well as approving appropriate pricing mechanisms aimed at full cost recovery, as the subsidization of water services was being phased out by the government in

2003 (OECD, 2007). The PURC regulates only the services of GWCL and for that matter has no hand in the services of community-managed water systems. The Water Resources Commission (WRC) on the other hand only regulates water resources. In other words, it takes the responsibility of licensing water abstraction and waste water discharges (Water Aid, 2006). The other institution created under the sector, restructuring process is a Water Directorate at the Ministry of Water Resources, Works and Housing to coordinate water sector activities (Water Aid, 2006).

2.5.2 The Progress of the Sector in Recent Times

2.5.2.1 National Water Policy and Programme

General water sector policies for both rural and urban areas are set by the Water Directorate within the Ministry of Water Resources, Works and Housing (MWRWH). Furthermore, the ministry solicits funding from external support agencies, monitors, and advises the Cabinet (Water Aid, 2005b). The Water Sector Restructuring Secretariat, created in 1997 in the MWRWH, oversees the process of private sector participation in the sector (Doe, 2007). Although the sector has made substantial progress, a lack of coherence in policy formulation resulted in a multitude of implementation strategies which led to new problems. The existence, of a multitude of institutions with overlapping responsibilities is one main new problem which partly arose from the recent reforms. To overcome the lack of coordination between the numerous institutions which were created since 1993, a National Water Policy (NWP) was launched in February 2008, to introduce a comprehensive sector policy and focus on three strategic areas: (i) water resources management; (i) urban water supply; and (iii) community water and sanitation (GWRC, 2008).

In other words, the aim of the NWP was to formulate a comprehensive sector policy which includes all relevant actors in the sector. According to the MWRWH, the NWP could make it easier for development partners to provide the necessary support to the sector (Appiah, 2008). The NWP has been prepared by the Ghana Water Resources Commission (WRC) since 2002 and is based on the Ghanaian Constitution of 1992, the Ghana Poverty Reduction Strategy (GPRS), international agreements and conventions, and other national programmes (GWRC, 2008).

2.5.2.2 Rural Water Policy

For the rural water sector, the National Policy is operated on the Demand Responsive Approach (DRA) where acquisition of potable water supply starts with the application for assistance filed by communities through the District Assemblies (DA). This mostly applies to point sources. One of the key principles of the National Community and Sanitation Policy is the requirement that beneficiary communities pay 5-10% cash contribution towards the capital cost of the least-cost, technically feasible water facility option with the intent of involving the beneficiary communities to demonstrate their commitment, sense of ownership and responsibility (Water Aid Ghana, 2003).

2.6 Rural Water Sector Provision

2.6.1 Community Water and Sanitation Agency (CWSA)

The CWSA is in charge of coordinating and facilitating the implementation of the National Community Water and Sanitation Programme (NCWSP) in rural areas using the decentralized structure at the district and community levels as prescribed in the Act (CWSA, 2008). The CWSA does not directly construct, operate, and maintain utilities for water supply and sanitation. Instead, its role is to coordinate the work of a number of actors which carry out the services in rural areas, including public sector organization, local beneficiary communities, private sector organizations, and NGO's. The CWSA is also expected to ensure that financial support from development partners is effectively used and to provide rural areas and small towns with hygiene education. To carry out its tasks, the agency operates ten regional offices besides its head office in Accra (CWSA, 2004).

2.6.2 National Community Water and Sanitation Programme (NCWSP)

The NCWSP which was launched by the government in 1994 is managed by CWSA through its national and regional offices. It is a national programme tasked to deliver rural water supply and sanitation facilities and funded by a number of donors and the Government of Ghana. The main donors are the International Development Association (IDA), Danish International Development Agency (DANIDA), Canadian International Development Agency (CIDA), and the French Development Bank (CFD) (CWSA, 1997). The real implementation of the NCWP is carried out by the District Assemblies (DA's) through the District Water and Sanitation Teams (DWSTs). The NCWSP focuses on three main objectives in order to achieve health improvements: safe water supply, hygiene education and improved sanitation (CWSA, 2004). These objectives are outlined by CWSA (2008) as:

- To provide access to water and sanitation services for rural communities and small towns in Ghana,
- To ensure the sustainability of water and sanitation facilities provided and
- To maximize health benefits by integrating water, sanitation and hygiene promotion.

2.6.3 Policy of the NCWSP

As outlined by CWSA (2008), the underlining policy of NCWSP is Community Ownership and Management (COM) of the water and sanitation facilities installed in the beneficiary communities and the use of the private sector to support the process. A standard implementation strategy, focusing on community management and the demand responsive approach is adopted by NCWP. The key elements and principles of NCWSP are also outlined by CWSA (2008) as follows:

- Demand responsive approach
- Decentralized planning, implementation and management
- Community ownership and management
- Community contribution to capital cost
- Private sector provision of goods and services
- Integration of hygiene promotion with provision of water and sanitation facilities
- Public sector facilities and
- Gender mainstreaming at all levels

2.7 Sustainability of Community Projects

2.7.1 What is sustainability?

Sustainability as a term has received many definitions from different scholars with different interpretations. However, the generally accepted definition of sustainability was given by the Brutland World Commission on Environment and Development in 1997. Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their needs. This definition has received many interpretations and thus difficult to put into practice. The concept of sustainability may continue to be viewed imperfect until better procedures for assessment and evaluation are drawn and universally established. Nevertheless, the concept can be usefully employed in development projects even with the present imperfections in the definition.

In the case of projects initiated by funding agencies such as rural water supply facilities, sustainability refers to the capability of local institutions to continue both the process and outputs of the facilities once external support is withdrawn (Fecade, 1994). Even though sustainability may be ideally assessed from project pre-implementation through post-implementation, the scope of this research is limited to the post- implementation stage due to limited time and resources.

2.7.2 Sustainability of rural water facilities

Studies have shown that some communities manage to keep their water systems going. However, for most communities, sustainability of their water facilities is still a distant dream. Thematic Group (2005) observes that the main factors that lead to problems of management of rural water facilities in these communities are: Limitations within the communities which include community dynamics, political or social conflict, inability to generate sufficient income for maintenance, failure to account transparently for funds generated, lack of preventive maintenance, lack of community cohesion and lack of capacity.

Constraints external to the community include poor design of water systems, poor construction, political interference in planning and sources allocation, lack of spare parts, lack of supportive policies, and legislation and, most importantly, failure to support communities in terms of major repairs, conflicts, etc.

Biswas and Tortajada (2002) indicate that the sustainability of the community water project depends on the sustainability and efficiency of the institution that will be responsible for managing them. This means that in order to evaluate the sustainability of the projects, it is necessary to evaluate the institutional efficiency and sustainability of the board and for that matter the various committees at the community level.

In the same vein, CWSP (1993) indicated that sustainability of rural water projects can be achieved by building problem-solving capacity in communities and partnership agencies to resolve problems as they arise. CWSP (1993) envisage sustainability. As a recommendation therefore, CWSP points out that the ability to maintain and derive benefits from the rural water supply systems would be achieved if:

- Beneficiaries perceive the need for clean drinking water
- Water is available in sufficient quantity and is easily accessible and
- Appropriate priority is granted to social or ethnic groups, and beneficiaries feel responsible for their system.

Following its mapping work in the Afram Plains, Water Aid (2005c) indicated that sustainability of rural water facilities is a real problem in Ghana. It, however, observed that the new partnership strategy adopted by NCWSP as a measure to improve the sustainability of facilities may avert the situation if reinforced. The new NCWP partnership is to involve the Community and Government through CWSA and DA/ DWST as well as the private sector. CWSA (1997) outlined the structure and roles adopted by NCWSP to improve the sustainability of community water facilities as follows:

2.7.2.1 The Community

NCWSP has adopted a Community Ownership and Management (COM) strategy under which the community owns the facility by playing a major role in planning, siting, financing and sanitation committee (WATSAN) to manage it and handle a day-to-day preventive maintenance and repair needs by trained two pump caretakers. Women are to play a key role in planning and decision-making and to be leaders of the WATSAN committee as NCWSP believes water is “women’s business”. Generally the membership of WATSAN is seven (7) which includes the chairperson and vice, secretary, treasurer, hygiene educator, and two pump caretakers. According to the NCWSP, the facility does not receive any cross-subsidies and 5% of the cost of providing it is paid by the beneficiary community (Nyarko, 2004). To NCWSP, underpinning community management is the demand-responsive approach where community contributes 5% of capital costs.

2.7.2.2 Decentralized and Pragmatic Strategy

The government’s role is played through two institutions:

2.7.2.2.1 The Community Water and Sanitation Agency (CWSA)

The overall coordination is nationally carried out by CWSA through its teams at the national and regional level. The Regional Water and Sanitation Team (RWST) selects, organizes training, and monitors the work of Partner Organizations (POs) and other contractors by working closely with DA and DWST in each district.

2.7.2.2.2 The District Assembly (DA)

The DA is the key actor at the district level. It works through DWST, which develops plans for water and sanitation in the district; promotes community demand for the facilities; supervises the work of POs and other contractors; and provides advice and necessary assistance to the community in respect of operation and maintenance. Although the communities are expected to independently operate and maintain their water supply systems, they are to receive technical assistance from DWST at the district level, consisting of an engineer, a hygiene expert, and community mobilizer (Komives *et al*, 2008).

2.7.2.3 The private sector

Communities and CWSA are enabled to contract individuals, private sector consulting or NGOs, to provide technical assistance, goods and services. Local companies are also contracted in the provision of boreholes and hand-dug wells (Water Aid Ghana, 2005c). They include:

2.7.2.3.1 Partner Organisations (POs)

PO is an NGO or a small company with skills in community development, hygiene education and technical issues contracted to work for NCWSP in respect of helping communities to plan and manage the water facilities as well as hygiene promotion. The specific roles of POs are:

- Help to build a participatory process of community discussion and decision-making with particular attention to women playing a major role
- Help the community WATSAN identify how best to raise funds, organize safe keeping and record-keeping, buying of parts
- Educate the community on hygiene practices in order to derive health benefits from the facility
- Help the community plan the new water facility, select and train caretakers and organize pump maintenance.

2.7.2.3.2 Area Mechanics (AMs)

Major maintenance and repair needs are undertaken by district area mechanics (AMs) at the request of and paid by the community. They also help to install pumps and train community caretakers.

2.7.2.3.3 Spare Parts Suppliers

They are retail shops that stock spare parts and sell directly to communities. A National Supply Network System supplies parts nationwide. The supply points have been zoned into three with Tamale Supplying the northern sector, Kumasi for the middle sector and Accra for the southern sector.

Tay (2005b) has indicated that the cost of operation and maintenance of rural water facilities can become an added burden on the rural poor if appropriate technologies are not selected or the financial capacity of the communities being built to really take on this task. However, the new sustainability measures being adopted as outlined already seem to have overlooked this fact.

2.7.2.3.4 Water and Agriculture

For many developing countries like Ghana and for that matter the northern sector of the nation, agriculture is a key determining factor of the livelihoods of the people. In other words, agriculture is fundamental for local livelihoods and economic development at all scales. Indeed, agriculture is, and will continue to be for a long time, a key sector for economic development in low-income countries.

However, limited and unreliable access to water for domestic, industrial and irrigation use is a determining factor in agricultural productivity in many of these districts. Water sources and water supply in many communities can have so much effect on these activities. The effect may be in the form of time spent in accessing water and guineaworm eradication.

Guineaworm which is also known as dracunculiasis, scientifically, has been known in Ghana for decades. Most endemic communities have a myth surrounding it, may call it the preventer, keeping farmers from their farms for whole planting seasons. The effect normally causes a significant loss to agricultural production during periods of extensive out breaks (Nyarko, 2008). In simple terms, it therefore means that the provision of potable water supply to these communities is expected to bring not only health benefits but also a significant improvement in agricultural productivity. Eradicating guineaworm has many positive repercussions beyond health. The infection affects livelihoods and food production. With a little more work, Ghana can free all its communities from these burdens (Water Aid, 2006).

2.8 Water Sufficiency

Four ways of measuring a district's sufficiency in water resources are presented as: demand supply balance, water dependency, water resources constraint and water deficit.

2.8.1 Water Resources Constraint Criterion

This type of approach has been used by Shaw *et al* (1991). The population and per capita use of water are related in a linear fashion. The region would not be lacking sufficient water if its water use was lower than the availability of water, but the degree of sufficiency decreases as water use moves closer to the availability of water.

2.8.2 Water Dependency Criterion

This approach to measurement has been suggested by Brouwer and Falkenmark (1989). In this approach, a regions (district) water scarcity increases as the number of inhabitants per unit quantity of water increases.

2.8.3 Water Deficit Criterion

In this criterion, water availability and its use are studied over a period of time. A certain level of water supply is assumed to remain unchanged. As the water use increases, as a direct result of economic activities in the district, the district may change from not insufficient of water to extremely insufficient of water using the quantity of water deficit as the criterion.

2.8.4 Demand- Supply Balance Criterion

In this approach, water supply (availability) and use is compared on a per capita basis. Such an approach has been used by Brouwer and Falkenmark (1989). The degree of water scarcity (not sufficient) of a district increases as, for a given supply, its use increases.

In this study, the criterion used for determining a district's vulnerability to water resources was based on a combination of available supply (per capita basis) and its relative utilization. A district may have a surplus, for example, if the availability is more than 10,000 m^3 per capita, and its utilization is less than 60% of the total. Similar interpretations of the other three categories can be made.

2.9 Major Types of Water Uses

2.9.1 Water Use Typology

The various uses of water can be broadly divided into two types: withdrawal use and *in-situ* or in-stream use. Under the first type of water use, water is withdrawn from its original source. The quantity withdrawn is commonly called “water intake.” Part of this water is lost (or consumed) in the specific use. The remaining quantity is returned to the original source in some form. The amount of water not returned back to the water body is commonly termed the “water consumption.”

The second type of water use refers to that use which is associated with activities that do not require the withdrawal of water from its original source. For example, water in rivers or lakes that are used during water-based recreational activities. In this case, water need not be withdrawn from the body of water. This type of water is commonly referred to as “non-consumptive” or *in-situ* use of water.

Major withdrawals of water are made for domestic, agricultural, and industrial purposes. These uses are also partially consumptive in that only part of the water withdrawn is returned to its original source. However, in some regions (districts), thermal electric power generation and support of wildlife habitats may also be important uses of water. When a water course is shared with other jurisdictions (national or international), a certain amount of water is to be released (or left in the water body). This water use is commonly called “apportionment” water use. Part of the water left in the bodies of water (rivers and lakes) is lost to the atmosphere. Withdrawal from natural evaporation is also a significant use, particularly in arid and semi-arid climates.

Various *in-situ* uses of water include recreation, generation of hydroelectric power, and support of the ecosystem. Since water is not withdrawn for these uses, it is almost impossible to estimate the actual quantity of water required.

2.10 Global Changes Affecting Regional Water Sufficiency

District water may become insufficient as a result of the following changes:

- Decreased water availability
- An increased level of water use
- A combination of decreased water availability and increased water use level
- The availability of water is determined through natural factors, precipitation, percolation and evaporation would eventually affect water availability. Changes in water use levels may result from two major driving forces:
- Changes in population and district policies to achieve a certain level of economic development.

2.10.1 Population Growth

The growth in the population of a district would have both a direct effect and an indirect effect on the water use level. The direct effect would come through increased domestic water use and the use of bodies of water for waste disposal. Several factors, notably, the urbanization pattern, the degree of adoption of water-conserving technology, and institutional factors governing directly or indirectly, the degree of demand management in the district, may also play a significant role in determining the water use level for domestic purposes.

The indirect effect of increasing population would be the growing need for food and non-food products. The demand for agricultural products would have an impact on water use through two major streams: firstly, the demand for food; secondly, the demand for non-food (industrial) products, including inputs to farm production. Demand for food products can be met through one or more of the following measures:

- Expanding rain fed (dry land) area
- Improving the productivity of rain-fed (dry land) agriculture
- Expanding irrigated area
- Improving the productivity of irrigated agriculture and
- Importing food from other countries.

The measure to be adopted in a (district) would be determined through a political process and would vary from one region to another. However, assuming that this increased food deficit has to be met by increasing the size of an irrigated area, there would be significant impacts on the water use level.

The second major effect of an increasing population would be an increase in the demand for industrial products and their inputs. One such input is electrical energy, which would have some significant implication for industrial water use levels.

2.10.2 Economic Development Level

Besides agricultural pursuits, major economic development activities include boosting industrial production through personal income levels. In this study, the impact of economic development is limited to non-agricultural industrial activity.

Subject to limitation of financial resources through investment and other natural resources, most developed and developing countries aspire to achieve a higher level of industrial development as a means to improve the quality of life for their citizens. Such aspirations translate into higher income levels and increases in the demand for food and non-food products. These demands then translate into an increased water use level.

2.11 Water Demand Forecasting

Water demand forecasting is a process achieved through several techniques and is typically used to predict future water requirements for uses including municipal and agriculture, and for the planning of dams and reservoirs. The type of technique used depends on the breadth of the data needed, the general scope of the region for which the forecast is being conducted, and the resources available to the organization for which the forecast is being conducted. For all intents and purposes, future water is derived from basic functions. For instance, domestic municipal demand is generally projected using population size and the number of households, industrial demand is often based on number of employees, and agricultural demand commonly relies on crop type and irrigated hectarage.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter presents a description of the general characteristics and socio-economic infrastructure situation in Savelugu/Nantong, Gushiegu and Karaga Districts of the Northern Region to provide basis for the assessment of water sources in terms of availability, use and sufficiency and sustainability of the rural water projects. Also described are the concept and scope of water use, materials and methods used including appropriate means for data analysis and presentation (delivery in the districts). Also highlighted is the assessment of existing water and sanitation delivery in the districts which is finally followed by an explanation of the procedure for projecting future domestic water demand.

3.2 Profile of the Study Areas

3.2.1 Physical Characteristics (Savelugu-Nantong District)

3.2.1.1 Location and Size

Savelugu/Nanton District is one of the 20 Administrative Districts of the Northern Region. It was established by PNDC Law 207 under the Legislative Instrument 1450 of 1988. It was carved out of the Western Dagomba District Council, which included Tolon/Kumbungu and Tamale Metropolitan Assembly. The District is located roughly between latitudes 9° 45’N and longitudes 0° 50’W. It shares boundaries with West Mamprusi in the North, Karaga to the East, Tolon/Kumbungu in the West and Tamale Metropolitan Assembly to the South. The District’s total land area is 1790.70 km^2.

3.2.1.2 Topography and Drainage

The District is generally flat with gentle undulating low relief. The altitude ranges between 122 - 244 m above sea level with the southern part being slightly hilly and sloping gently towards the North.

The main drainage system in the District is made up of the White Volta and its tributaries. The effect of the drainage system is felt mostly in the northern part of the district covering the areas between Nabogu and Kukuobilla. These areas are prone to periodic flooding during the wet season, thus making them suitable for rice cultivation. One of the tributaries of the White Volta, Kuldalnali, stretches to constitute a natural boundary between the District and Tolon/Kumbungu District. Only the White Volta is perennial. All the others dry up completely during the long dry season but flood the immediate surrounding land during the rainy season.

3.2.1.3 Climate and Rainfall

The area receives an annual rainfall averaging 600mm, considered enough for a single farming season. The annual rainfall pattern is erratic at the beginning of the rainy season, starting in April, intensifying as the season advances raising the average from 600mm to 1000mm.

Temperatures are usually high, averaging 34ºC. The maximum temperature could rise as high as 42ºC and the minimum as low as 16ºC. The low temperatures are experienced from December to late February, during which the North-East Trade winds (harmattan) greatly influence the District. The generally high temperatures as well as the low humidity brought about by the dry harmattan winds favour high rates of evaporation and transpiration, leading to water deficiencies.

3.2.1.4 Vegetation

The District finds itself in the interior (Guinea) Savanna woodland which could sustain large scale livestock farming, as well as the cultivation of staples like rice, groundnuts, yams, cassava, maize, cowpea and sorghum.

The trees found in the area are drought resistant and hardly shed their leaves completely during the long dry season. Most of these are of economic value and serve as important means of livelihood especially for women. Notable among these are shea trees (the nuts which are used for making sheabutter) and *dawadawa* that provides seeds used for condimental purpose. The sparsely populated north has denser vegetation mostly with secondary forest. The vegetation in the populous south on the other hand, is depleted by human activities such as farming, bush burning and tree felling among others.

3.2.1.5 Geology and Soil

The Middle and Upper Voltaian sedimentary formation characterise the geology of the District. The middle Voltaian covers the northern part of the District and comprises sandstone, shale and siltstone. The Upper Voltaian covers the southern part of the District and consists of shale and mudstone. Underground water potential is generally determined by this underlying rock formation, which has varying water potential for underground water compared to the upper Voltaian formation. Consequently, borehole drilling is expected to have a higher success rate in the northern rather than the southern section.

3.2.1.6 Population Size and Density

The population of the district was 139,283 (2010 population census) with a growth rate of 4%. This is broken down into 67,531 male and 71,752 females. The population density is about 67 Persons /km^2.

3.2.1.7 Water Situation

Less than 55% of the populace have access to safe water, namely treated water, boreholes and hand dug wells. As at May 2007, 55,134 representing 50.37% of the population had access to safe water.

3.2.1.8 Farming System

The district is predominantly agricultural with about 97% of the District economically active population (18-54 years) involved in farming of staple food crops. The major food crops include maize, rice, yam, groundnut, cowpea and soya beans.

3.2.1.9 Livestock and Poultry Production

Animals reared in the district include cattle, sheep, goats, pigs, local fowls and guinea fowls. In majority of cases, cattle belong to an ethnic group of farmers or family or even a whole village. The farmers also rear poultry birds for economic reasons.

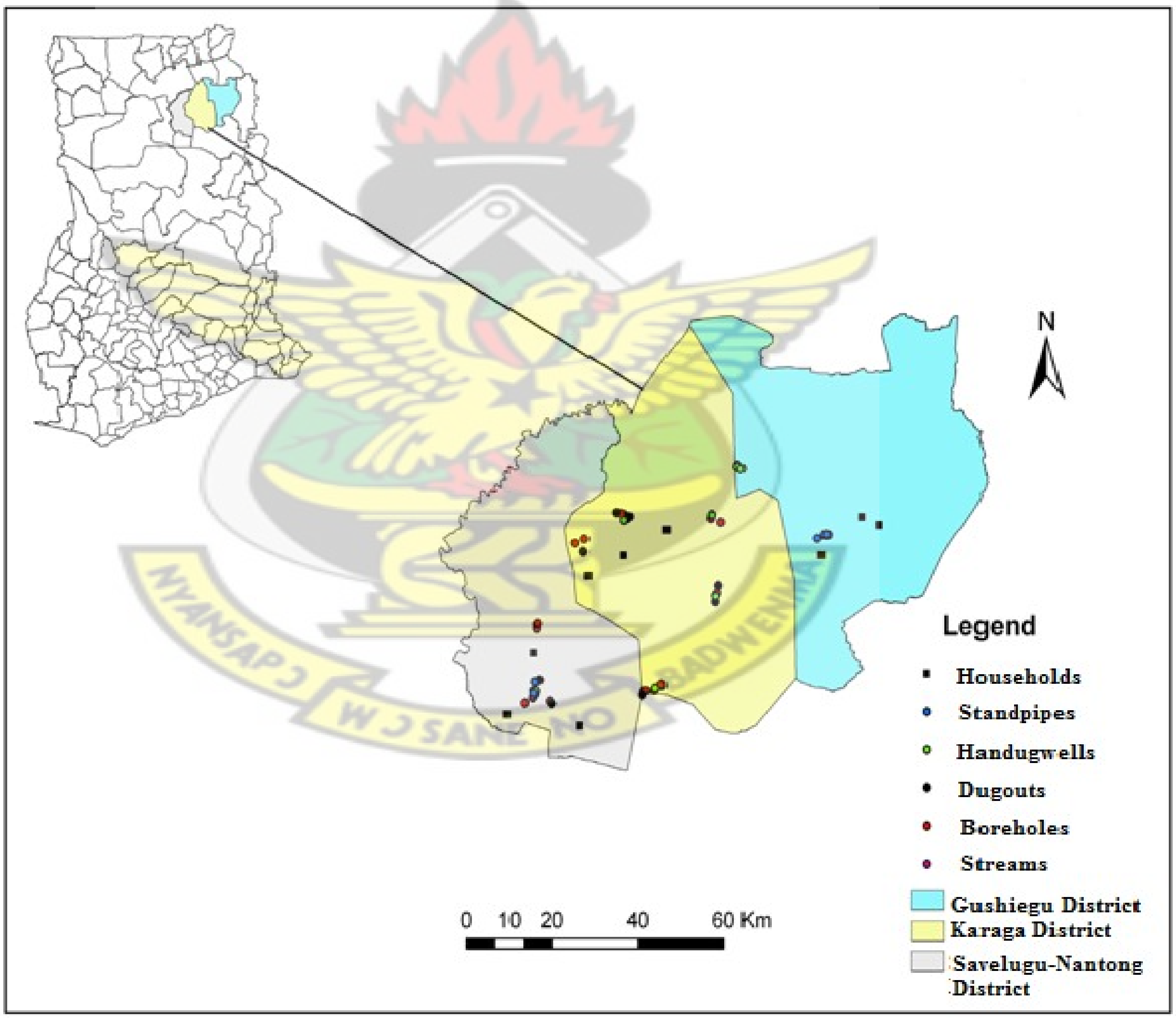

Figure 3.1: A map of Ghana showing the location of Savelugu-Nantong, Karaga and Gushiegu Districts with water facilities and households

3.2.2 Physical Characteristics (Gushiegu District)

3.2.2.1 Location and Size

Gushegu District is located in the north eastern corridor of Northern Region, roughly between latitudes 9° 55’ 17’’N and longitudes 0° 13’ 06’’W. The district was carved out of the Eastern Dagomba District in 1988. It is bordered by four other districts in the region, namely; Savelugu/Nanton and Karaga Districts to the west, Saboba/Chereponi to the east, East Mamprusi to the north, and Yendi to the South. The total land area of the district is approximately 5,796 km^2. It has a population density of 22 persons/ km^2. The district has 270 communities, with the capital located in Gushegu, which is about 114 km from Tamale.

3.2.2.2 Topography and Drainage

The topography of the land is generally undulating with elevations ranging from 140m at valley bottoms to 180m at highest plateaus. Being mostly watershed of rivers, the district is endowed with many small valleys. Larger valleys can only be found towards the periphery of the district where the small streams merge into larger ones. These large valleys can be found at Gaa, Katani, Sampemo and Sampegbiga areas. The size of all valleys in the district is estimated at 220 hectares. Out of this, only about 13% are bunded.

The district lies entirely within the Volta basin dominated by coarse lateritic upland soils and soft clay soils in the valley bottoms. The land is strewn with several streams, most of which are tributaries of major rivers in the northern region. The major river running through the district is the Nasia, which flows between Nambrugu and Bagli.

The head waters of the Daka River are found in the district. Only the Nasia River is perennial. All the others dry up completely during the long dry season but flood the immediate surrounding land during the rainy season.

3.2.2.3 Climate and Rainfall

Gushegu District is covered by a tropical climate marked by the alternation of dry and rainy season. The district has a tropical climate which is typical of the Northern Region. The unique rainy season, influenced by South-East winds lasts from May to October (rainfalls vary between 900 and 1,000mm); very strong rainfalls are recorded in July and August. As far as dry season is concerned, it lasts from November to March and is characterized by the predominance of North-East winds, where harmattan is hot and dry. Temperatures are high throughout the year with a maximum of 36ºC (or 40°C sometimes) recorded mainly in March and April. Low temperatures are recorded between November and February (the harmattan period).

3.2.2.4 Vegetation

Vegetation is typical of Guinea savannah, characterized by high and tall grasses interspersed with drought resistant trees like *shea* and *dawadawa*.

3.2.2.5 Geology and Soil

The district lies entirely within the Voltarian sandstone basin dominated by sandstones, shales, siltstones and minor limestones. The northern tip of the district is underlain by lower Voltarian which consist of rocks, dominated by shales and sandstones. The soils are mainly savannah ochrosols, groundwater laterites formed over granite and Voltaian shales.

The continuous erosion over many years has removed most or all of the topsoil and depleted or destroyed its organic matter content. Such a situation does not allow the soil fauna to thrive and keep the topsoil layers open and aerated for healthy plant roots to develop. It results in serious compaction, with considerable reduction in rainfall infiltration rate.

3.2.2.6 Population Size and Density

The analysis of the demographic situation in Gushegu District was made on the basis of population and housing census (PHC) in 2010 published by Ghana Statistics Service during the population and housing census in 2010. However, an evaluation of Gushegu population is made on the basis of those data; it is estimated at 111,259 inhabitants. The male population is 54,186 and the female population is 57,073 with a population growth rate of 3.6%.

3.2.2.7 Water Situation

Although the water situation in the district has improved since 1996, the potable water coverage in the district is still unbearably low. Currently, the potable water coverage in the district stands at 46%. This translates to 57,698 out of the 125,430 people. That is, 67732 people in the district are without access to potable water.

As more than 50% of the population is without potable water, the effect of lack of water on health and productivity is great. A typical lean water season in the district exudes a rush for water of all kinds. The distance people have to walk to fetch water and the man-hours wasted in the search of water affect productivity. The dependence on non-potable water for domestic consumption is responsible for the upsurge of water-related diseases in the district. This aggravates the already poor health situation of the people.

3.2.2.8 Farming systems

The farming system prevailing is mixed farming. Besides crop production, the average farm family raises a wide variety of livestock and poultry. With regards to crop production, semi-permanent to shifting cultivation is practiced in the remote areas of the district where land availability is not a constraint and population density is low. Mixed cropping dominates the cropping pattern. Sole cropping activities in the district are relatively large commercial rice and maize farms. Commercial rice farming is located in the valley basin of the tributaries of the Black Volta and Oti Rivers.

3.2.2.9 Livestock and Poultry Production

Animals reared in the district include cattle, sheep, goats, pigs, local fowls and guinea fowls. In majority of cases, cattle belong to an ethnic group of farmers or family or even a whole village. Traditionally, most farmers in Northern Ghana rear cattle for socio-religious reasons to serve in ritual events. Two factors of tradition and customs are of great importance to cattle rearing in the region: the prestige of the herd and its value as a self-sustaining investment.

The situation is quite different for poultry, where the rearing of these birds is seen as an economic venture and tends towards ownership by individuals. The poultry may be used as security in cases where inadequate rainfall may fail the subsistence farmer. They may also be sold for the purchase of inputs such as seed and fertilizer during the cropping season and also used in the performance of traditional and religious ceremonies.

3.2.3 Physical Characteristics (Karaga District)

3.2.3.1 Location / Size

The District is located in the North-Eastern part of Northern Region, roughly between, latitudes 9º30' South and 10º30' North and longitudes 0º East and 45' West. It has a total area of 2,958 km^2. It shares boundaries with four districts in the Northern Region, West and East Mamprusi to the North, Savelugu/Nanton to the West and Gushegu (the mother district) to the South and East. Karaga the district capital is 24km from Gushegu and 94km from Tamale.

3.2.3.2 Topography and drainage

The topography of the district is generally undulating with numerous small streams draining it. The district has a number of smaller valleys with larger valleys found towards the periphery where smaller streams merge into larger ones. Such valleys are found in the Sakulo and Nambungu areas.

The only major river identified is the Nasia River which flows between Namburugu and Bagli. The Nasia and it tributaries divide the district into two (north and south) making the northern half inaccessible especially during the rainy season. Areas to the north are thus appropriately tagged "overseas". Tributaries of the Nabogu river also flow between Dibolo and Namburugu.

All the streams can be described as intermittent. The Nasia reduces in volume during the long dry season whereas all other streams dry up completely. In the rainy season, however, all the rivers bounce back to "life," they increase in volume and flood the immediate land thereby cutting off most communities during the period. Most roads are also rendered unmotorable.

3.2.3.3 Climate and Rainfall

The climate reflects a typical tropical continental climate experienced in northern Ghana. There is a rainy season that lasts from May-October, peaking in August and September. The rest of the year is virtually dry. Rainfall amount is between 900 and 1000mm per annum. Temperatures are high throughout the year with a high of 36 °C or above in March and April. Low temperatures are experienced between November and February (the harmattan period).

3.2.3.4 Vegetation

The vegetation is a typical guinea savannah type, characterized by tall grasses interspersed with drought resistant trees such as the shea and *dawadawa*.

3.2.3.5 Geology and Soil

The district lies entirely within the voltaian sandstone basin dominated by sandstones, shales, siltstones and minor limestones. The northern tip of the district is underlain by lower voltain, which consist of rocks, dominated by shales and sandstones.

The soils are mainly savannah ochrosols, groundwater laterites formed over granite and voltain shales. Small areas of savannah ochrosols with some lithosols and brunosols are very low. The laterites are similar in acidity and nutrient level to the ochrosols, but are poorer in physical properties, with substantial amounts of concretionary gravel layers near the top horizons and more suited for road and other constructional works than supporting plant roots systems.

Despite slopes, the soils are highly vulnerable to rill and interrill erosion and in some areas, gully erosion also occurs. This condition occurs primarily because of the annual burning of the natural vegetation, leaving the soils exposed to the normally high intensity rains (up to 200mm/h) at the beginning of the rainy season.

3.2.3.6 Population Size and Density

The current population of the district is estimated at 77,706 from a PHC 2010 at a growth rate of 2.2%. At the current growth rate the population will double in 20 years. The sex composition of the district shows that females constitute 40,370 of the population while males form 37,336.

3.2.3.7 Water Situation

The major sources of water supply in the district are, streams, dams and dugouts, shallow wells, ponds, boreholes and dug wells with pumps. There is no piped-system in the district, though Karaga has been earmarked for supply of pipe borne water through the small town water system. Currently there are three limited mechanization systems in the Karaga Township and work on the small town water system under NORST is on-going.The main source of supply of potable water is through boreholes and dug wells. The district currently has 114 boreholes, 78 of which are functional. There are 15 hand dug wells with pumps. This gives potable water coverage of about 43.89%. Karaga the district capital with a population of 12,800 (Population and Housing Census, 2000) with 11 boreholes (8 functional) has a coverage of only 19 %.

3.2.3.8 Livestock and Poultry Production

Animals reared in the district include cattle, sheep, goats, pigs, local fowls and guinea fowls. In majority of cases, cattle belong to an ethnic group of farmers or family or even a whole village. Traditionally, most farmers in Northern Ghana rear cattle for socio-religious reasons to serve in ritual events. Two factors of tradition and customs are of great importance to cattle rearing in the region: the prestige of the herd and its value as a self-sustaining investment.The situation is quite different for poultry, where the rearing of these birds is seen as an economic venture and tends towards ownership by individuals.

3.2.3.9 Farming System

The farming system prevailing is mixed farming. With regards to crop production, semi-permanent to shifting cultivation is practiced in the remote areas of the district where land availability is not a constraint and population density is low. Mixed cropping dominates the cropping pattern. Mono cropping activities in the district are relatively large commercial rice and maize farms. Most of the rice farms are located in the valley basins.

3.3 Concept and scope of water use in the study areas

The water use in these study areas were measured as “water withdrawn” from a body of water. Thus, only major withdrawal types of water uses were included in the study areas. The *in-situ* uses of water were not included partly due to difficulties in their measurement and partly due to specific data needs which could not be fulfilled from available secondary sources. Of the various withdrawal types of water uses, only three were included in this study: domestic, small scale industrial water use and irrigation water requirement. The choice was determined primarily by the availability of data.

3.4 Population Growth to the Year 2025

If current population were to continue to the year 2025 would some regions/districts face shortages of water to meet their needs? To answer this question, population forecasts for Savelugu-Nantong, Karaga and Gushiegu districts of Northern Region for the year 2025 were obtained for each of the three districts as follow:

$$P_n = P_o \quad e^{nt}$$

[3.1]

Where; P_n = Projected population

P_o = Present population

n = Period of projection

t = Population growth rate

3.4.1 Methodology

In making projections under this scenario, three assumptions were made:

- Changes other than population are not significant determinants of vulnerability to water resources
- Water use pattern remains unchanged from the 2000 level on a per capita basis and
- Water supply remains unchanged from the 2000 level.

The level of water use in 2025 was estimated under these assumptions.

3.4.2 Future domestic water use

The domestic water use for the year 2025 was estimated by assuming that the per capita use in the year 2025 would be at the same level as it was in 2010. Thus the only factor that affects the level of water use for domestic purposes is the growth in population. The following assumptions were made:

- There is no significant increase or decrease in the availability of water within the areas.
- No significant institutional policy is implemented that would promote water conservation during the 2010-2025 period.

3.4.3 Per capita water consumption

Information was collected on the quantity of water consumed daily (Qv) by households in terms of drinking, cooking, bathing, washing and other domestic purposes (performance of ablution, cleaning) in Savelugu-Nantong, Karaga and Gushiegu Districts for the wet and dry seasons. Women and children who are the main people who fetch water were interviewed. The quantity of water consumed by households was calculated based on their recall of water quantity consumed daily. The average quantity consumed (Qv) by households in each community was computed and the per capita water consumption (C) was also determined for each of the three districts as follows;

$$C = \frac{Qv}{n} \quad \text{l/p/day} \qquad [3.2]$$

Where; n = Average household size

3.5 Materials

Materials that were employed in the study included: A pump, a global position system (GPS), a tape measure, a car tyre tube, a 100 m rope, a double ring infiltrometer, a stop watch, a steel rule, a mallet, a spirit level, a digital camera and a personal computer for data entry and storage.

3.6 Methods

Data for this study were from both primary and secondary sources. Data collection methods, both qualitative and quantitative were used including literature survey, discussions with local communities and stakeholders of the rural water supply schemes in the three districts. In addition, field surveys and experiments were conducted together with interviews using questionnaires.

Other secondary data were obtained from Community Water and Sanitation Agency (CWSA), Environmental Protection Agency (EPA) and Water Aid. Focus group discussions were also used to gather information on the perceptions and beliefs on water and its sustainability, water related diseases and causes. A local language (*Dagbani*) that is well understood by the people was used in the focus group discussions. A detailed household survey was conducted together with the use of household questionnaires to help address some of the objectives of the study.

3.6.1 Sampling Design

In this study, simple random sampling technique was used to select respondents for the questionnaires. The cluster sampling method was used to select four communities from each district. In Savelugu-Nantong District (Libga, Bunglung, Savelugu and Nabogo were chosen). Nangunayilli, Nanduli, Pishigu and Bagurugu were also selected in Karaga District and Limo, Gushiegu, Gaa and Zinindo were selected in the Gushiegu District.

The case control method was used such that the water situation in the three districts can be compared with one another to identify vulnerable district(s) to water sources. Twelve (12) communities were randomly selected so that information acquired would be representative of the three districts. To ensure that the information obtained is a true representation of the situation, 20 households were sampled in each community.

3.6.2 Questionnaire Information

Information from the community's perspective on water sources, water supply and domestic activities, water supply and small scale rural industrial activities as well as the sustainability of the water facilities in the areas were collected using a household questionnaire. A sample size of 240 households from twelve communities in the area was used for the study. Data obtained from the questionnaires provided information on the sources of water used, common water related diseases in the area, water usage for small scale rural activities, household water usage for domestic purpose, factors affecting the management and sustainability of water sources. Appendix A contains a sample household questionnaire for the study.

3.6.3 Focus Group Discussions

Focus group discussions were also used to gather information specifically on the sustainability of the water facilities from the community water and sanitation committees (WATSANs) and some community members. Appendix B1 has a sample of the leading questions used during the discussions.

3.6.4 Interviews

Both formal and informal interviews were used to gather information on water sources, influence of water supply on small scale industrial and domestic activities, measures for sustainability of the facilities, water sources usage preference and and problems limiting water supplies. These were granted to health services, district assemblies, providers of water supply groups like NGOs as well as women at water fetching points. Appendix B.2 shows a sample of leading questions of formal interview with the group of economic activist.

3.6.5 Infiltration Rate Tests

Soil infiltration rate tests using the double ring infiltrometer were conducted at three locations each of the three districts with functional water facilities namely, Libga, Bunglung and Nabogo in Savelugu-Nantong District, Nangunayili and Nanduli in Karaga District and Limo in Gushiegu District. This was carried out at a place of the community's choice for possible dry season vegetable irrigation. Specific locations of infiltration test in each of the districts were determined using GPS as shown in Fig 3.2.

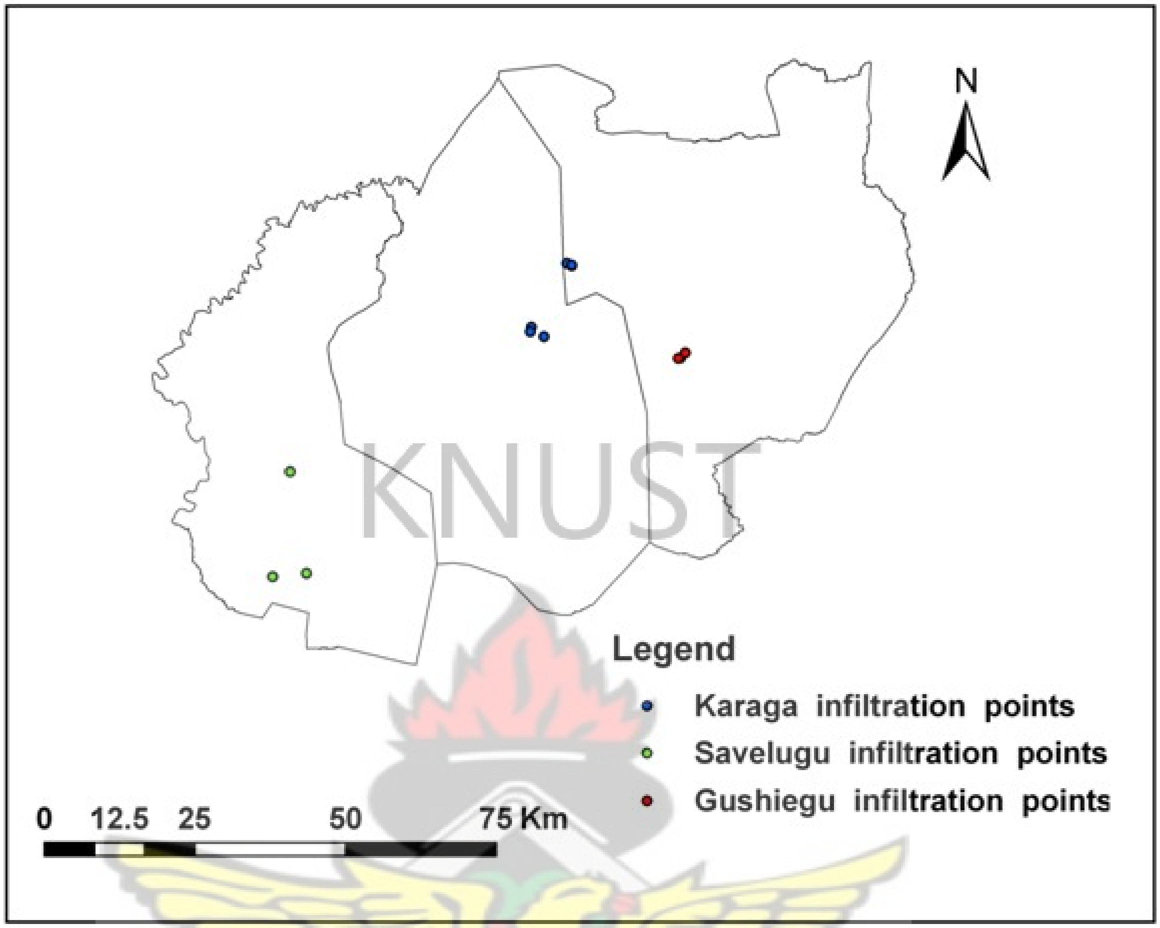

Figure 3.2: Map showing locations of infiltration points in Savelugu-Nantong, Karaga and Gushiegu Districts

3.6.6 Climatic Data

Representative climatic data for the study areas included rainfall, temperature, wind speed, relative humidity, sunshine duration and evaporation and these were obtained from Tamale Meteorological station. These were used in the estimation of the irrigation water requirement.

3.6.7 Crop data

Crop data which included crop coefficient (K_C) and reference evaporation (ET_O) derived from 30 years mean monthly climatic data to compute crop evapotranspiration (ET_C) were also obtained from the Savanna Agricultural Research Institute (SARI), Tamale (Nyankpala). These were also used in the estimation of the irrigation water requirement.

3.6.8 Available yields of the water systems

Available water yield test were conducted on water facilities in the study communities. These included boreholes, hand dug wells, public stand pipes and dams. This data is required to establish whether the supply yields were capable of meeting domestic and small scale industrial water needs.

3.6.8.1 Available yield of hand dug wells

In this study, recuperation test was considered in determining the yield of the well. In this method, water level in the well was depressed by pumping to any level below the normal level. Then the pumping was later stopped and time taken by the percolating water to fill the well to any particular level was noted. The total quantity of water flowing into the well was calculated by knowing the cross-sectional area and rise in the water-level after stoppage of pumping. The yield of the well was determined by dividing the quantity of water by the time. All yield tests were carried out in the driest period (January, February and March) in order that worst conditions will be taken into account.

3.6.8.2 Available yield of a borehole

Since the boreholes in these rural communities are fitted with hand-pumps, the yields would be dependent on human power, hence the available yield was measured based on human power. The following steps were used:

- Ten different people fill a 15 litre bucket each by pumping and the time for each was noted
- The average time taken to fill the 15 litre bucket by pumping was found
- The average yield of the borehole was then determined : (15litre/average time)

3.6.8.3 Estimating the average daily discharge of a public stand pipe (PSP)

The Water Company operating in Savelugu-Nantong and Gushiegu districts made the inhabitants to pay for the use of the stand pipes daily. This means that the daily discharge of each of the stand pipes in the two districts was paid to the agents of the Water Company. This quantity of water consumed and paid for, was also recorded by the agents and sent to the company. The average daily discharge was obtained from the recorded daily discharge of the stand pipes.

3.6.8.4 Estimating volume of water in a dugout dam

An empirical equation developed for use in determining the storage capacity of a dug-out by Gulik *et al* (2003) was used for estimating the volume of water in a dug out. This is given as:

$$V = L \times W \times D \times 0.00081 \qquad [3.3]$$

Where: V is the volume of dugout in cubic metres

L is the average length of dugout in metres

W is the average width of dugout in metres

D is the average depth of dugout in metres

0.00081 is a constant

To measure the average length and breadth of the dugout, a rope and a tape measure were used. For an average depth, the depth of the dugout was measured at regular intervals of about 10 metres across the length and breadth and the average computed.

3.6.9 Irrigation water requirement (IWR)

Food and Agriculture Organisation (FAO) Modified Penman-Monteith method was used to determine ET_c and hence IWR. The relation given as:

$$ET_c = K_c \times ET_o \qquad [3.4]$$

$$IWR = ET_c - Pe \qquad [3.5]$$

Where; ET_C = Crop evapotranspiration

K_C = Crop coefficient

ET_o = Reference evapotranspiration

Pe = Effective precipitation

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This Chapter presents the analysis of responses from the study data both quantitatively and qualitatively. It presents the demographic characteristics of respondents, sources of water supply, factors limiting effective water supply, assessment of the sufficiency of water supply for domestic and small scale rural industrial use, discussion on total and per capita water use patterns, assessment of the degree of vulnerability of the various districts to the availability of water sources, Major factors affecting the management and sustainability of rural water supply systems and small scale irrigation potential of these systems.

4.2 Demographic Characteristics

The background information of the respondents took into account variables such as age distribution, gender, level of education, occupation, ethnicity, religion and length of time lived in the community. It should be clearly indicated, however, that the respondents here refer to the household representatives who led the responses of the household in the house during the interview. The responses in this study are therefore those of the entire household, but for convenience sake, the respondent in this write up shall always refer to the person who led the responses during the interview.

4.2.1 Age Distribution

Out of 80 respondents interviewed in each of the three districts, the largest age group for the three districts fell within 31-40 years with 35 (43.75%) for Savelugu-Nantong District, 28 (35%) for Karaga District and 25 (31.25%) for Gushiegu District. However, the lowest and oldest age group interviewed was 51 years and above as shown in Fig. 4.1. Indeed, each of the respondents interviewed was at least 10 years old. This outcome is in line with the survey objective, which employed purposive sampling technique. This technique was employed in order that the largest segment of people was at least 10 years who was born or have at least 10 years experience in the community. This way, one was at least sure that, the people interviewed had some reliable information on water sources in the districts.

Fig. 4.1: Age distribution of respondents

4.2.2 Gender Distribution

Another significant part of the survey worth mentioning is the gender distribution. The distribution of the sample according to gender shows that out of the 80 respondents interviewed in each district, 69 (86.25%) were females whilst 11 (13.75%) were males in Savelugu-Nantong District, 61 (76.25%) were females whilst 19 (23.75%) were males in Karaga District and 75 (93.75%) were females whilst 5 (6.25%) were male in Gushiegu District. The results of the distribution does not necessarily depict the gender distribution of the entire population of the districts but in conformity with the objective of the survey that targeted the people who had fair knowledge and information about the water situation in the communities. It was noticed that in all the communities in the three districts, women were directly responsible for fetching water and for that matter most of the questions were directed to them.

4.2.3 Years Lived in the Community.

Responses reveal that 30 (37.5%) of the respondents had lived in the communities for 21-30 years in Savelugu-Nantong District whilst 28 (35%) of the respondents in Karaga District and 32 (40%) of the respondents in Gushiegu district had lived in the communities for 31-40 years as shown in Fig. 4.2. A number of these respondents had lived in these communities for over 30 years, some being born there. This way, one was at least sure that, the people being interviewed had lived in these communities for at least 10 years to have some reliable information about water situation in these communities.

Fig. 4.2 Years Lived in the Community by Respondents

4.2.4 Household income

Household income also serves as an indicator of household poverty status despite the fact that poverty is sometimes defined in terms of household expenditure (Forster, 1994, cited in Asare, 2004). This study uses household income per month as an indicator of household poverty. It is a common observation that, the income level of a household determines the ability of a household or community to own and maintain water facility. Table 4.1 depicts the income levels of the various districts.

Table 4.1 Household income of respondents

District	Household income	Frequency	Percent (%)
Savelugu/Nantong	< Gh¢ 100	15	18.75
	Gh¢100-200	10	12.5
	Gh¢201-300	10	12.5
	Gh¢301-400	35	43.75
	> Gh¢ 400	10	12.5
Total		80	100
Karaga	< Gh¢ 100	20	25
	Gh¢100-200	33	41.25
	Gh¢201-300	17	21.25
	Gh¢301-400	6	7.5
	> Gh¢ 400	4	5
Total		80	100
Gushiegu	< Gh¢ 100	19	23.75
	Gh¢100-200	40	50
	Gh¢201-300	9	11.25
	Gh¢301-400	7	8.75
	> Gh¢ 400	5	6.25
Total		80	100

Responses reveal that 35 (43.75%) of the respondents in Savelugu-Nantong District earn the highest income of more than Gh¢ 300 in a month with Karaga and Gushiegu Districts having the lowest income as shown in Table 4.1.

4.2.5 Level of education

Education plays a vital role in every field of production, and issues on water supply and management are no exception. Formal education helps individuals to make informed decisions that affect their health and well-being. It also helps to increase community participation in the decision making process at every level of programme implementation in water supply, sanitation and hygiene issues in the communities. It also assists in the management of community water facilities. In other words, through education, the community mobilization becomes easier and cooperative. This enhances their ability in mobilizing women's groups and community members towards effective management and sustainability of water facilities.

Table 4.2: Literacy rate of respondents

Districts	Illiterates	Tertiary level	Senior high	Junior high
Savelugu-Nantong	51%	5%	15%	29%
Karaga	65%	3%	14%	18%
Gushiegu	68%	2%	13%	17%

Although the studied communities in Savelugu-Nantong District seem to have the highest educational level, the level of educational attainment in the studied communities of the three districts is still low. About 51% are illiterates without formal or informal education in

Savelugu-Nantong District with 65% and 68% illiteracy rate in Karaga and Gushiegu Districts respectively as shown in Table 4.2. The high percentage of Junior High School Leavers in Savelugu-Nantong District may be due to the fact that more children go to school in Savelugu-Nantong District than Karaga and Gushiegu District. This also explains Fig. 4.1 why more children of school going age are into water fetching in Karaga and Gushiegu District than Savelugu-Nantong District.

4.3 Factors that Determine / Influence Preferential use of Water Sources in the Rainy and Dry Seasons

4.3.1 Preferential use of water sources in the rainy season

In the selected communities of each of the districts, households had a mix of both protected and unprotected water sources. Protected water sources here meant only the boreholes (BH), hand dug-wells (HDW) fitted with hand pumps and public stand pipes (PSP). Unprotected water sources include dug-outs or dams (DTs), streams (STRMs), rain water harvesting (RWH) and small water systems (SWS) like ponds and small dugouts.

Table 4.3: Water sources in the Study Communities in Dry Season

Water sources	Districts	Communities	Facilities
Borehole (BH)	Savelugu-Nantong	Savelugu	4 BHs, 3PSPs and 2 dug-outs
		Libga	2 BHs and a dum
Hand dug-well (HDW)		Bunglung	1 BHs and a dum
		Nabogu	4BHs, 3HDWs and a stream
Public stand pipe (PSP)	Karaga	Nangunayili	4 BHs and a 1HDWs
		Nanduli	3 BHs and 2HDW
Dug-out / Dam (DT)		Pishigu	6 BHs, HDW and 3 dug-outs
		Bagurugu	2BHs and 2 dug-outs

Stream (STRM)	Gushiegu	Limo	2 BHs, 1HDW and a dug-out
		Zinindo	3 BHs ,3HDW and 2 dug-outs
Rainwater harvest (RWH)		Gaa	2 BHs and 2dug-outs
Small water system (SWS)		Gushiegu	3PSPs,4BHs and HDW

In order to identify the types of water sources for each of the districts during the rainy season, respondents were required to indicate from a list of water sources which they used. Responses showed that in Savelugu-Nantong District, groundwater sources were relied on. Rain water harvesting, boreholes and open hand dug-wells are the major sources of water for the district in the rainy season. For four (4) communities that were among the twelve (12) studied, Figure 4.3 shows the results of the choices of water sources in the rainy season with corresponding reasons. The survey reveals that the patronage for borehole (BH) and hand dug-well (HDWs) water is higher represented by 52.5% due to the fact that, the water is free from germs and therefore good for their health. Some 23.8% of the respondents also indicated that public stand pipe (PSP) is their choice of water source in the rainy season because it is free from germs and has a better taste than that of groundwater. 18.8% indicated that dams/ dug-outs (DTs), rainwater harvested (RWH) and streams (STRMs) are their sources of water in the rainy season because they are easy to access and do not waste much time. The rest of the respondents from the four (4) communities representing 5% prefer small water systems (SWS) like ponds and small dug-outs because it is not time consuming and also because they do not spend money in using it.

In Karaga District, however, surface water is the major source of water for the district in the rainy season. The survey reveals that in the district, the patronage for rainwater harvest, dug-outs/dams and streams is high due to easy access, represented by 56.3%. Some 31.3%

of the respondents also indicated that boreholes and hand dug-wells fitted with hand pumps are their sources of water in the rainy season because it is good for their health. 12.5% indicated that they cannot access rainwater and therefore depend on small water systems like ponds and small dug-outs because it is easy to access, not time consuming and also because they do not spend money in using or accessing it. However, there is no single household or community with pipe connection in Karaga District.

Gushiegu District in comparison with Savelugu-Nantong District is the same in terms of public stand pipe, but for higher patronage of water sources it is the same as Karaga District since higher percentage of the respondents depend on surface water sources. In Gushiegu District, however, the patronage for rainwater, dug-outs/dams and streams is high, represented by 43.8%. This is due to their respoonses that most of the groundwater is too salty for their taste and therefore prefers surface water to groundwater except in communities like Gushiegu town that are blessed with public stand pipes. 25% of the respondents indicated that, they depend on public stand pipes because it has good taste and free from germs. 12.5% depended on boreholes and hand dug-wells fitted with hand pumps because it is free from germs even though the taste is not all that good. 18.8% indicated that, they depended on small water systems because it has good taste, although the water is not clean and safe for drinking.

Figure 4.3: Choice of Water Sources in the Three Districts of Northern Region of Ghana in the Rainy Season

4.3.2 Preferential use of water sources in the dry season

Respondents were also asked to indicate their choice of water sources in the dry season. Figure 4.5 presents the relative responses for choice of water source in the dry season for all the three districts. Out of the 80 respondents of the communities of Savelugu-Nantong District with water facilities, 37.5% indicated public stand pipe, because it is the only source that is closer, free from germs and has good taste. 53.8% indicated boreholes and hand dug-wells fitted with hand pumps since they are the only sources which are affordable and free from germs and 8.7% indicated dam/dug-out water due to easy access and affordability. However, all the dug-outs dried out in Savelugu-Nantong District except Libga and Bunglung Irrigation Dams which have been dredged and expanded.

In the Karaga District, however, groundwater becomes the major source of water for the district in the dry season. The survey revealed that in the district, the patronage for water from boreholes and hand dug well fitted with hand pumps is 76.3% and 23.7% for dugouts. The high patronage of groundwater is due to the fact that in the dry season all the dug-outs, streams, and hand dug-wells dry up resulting in long queues and people sleeping at borehole water points in the night for water.

Fig. 4.4: Long queues formed with stone and other containers waiting for water at Pishigu in Karaga District

In the Gushiegu District, the patronage of dug-out water for drinking is still high due to the fact that borehole water is too salty for drinking and cooking. Communities which are blessed with public stand pipes like Gushiegu depend on the pipe alone as their source of water. The survey revealed that 20% of the respondents used water from boreholes and hand dug-wells fitted with hand pumps since it is the only source of water for them in the dry season. 48.7% also indicated that, dug-outs become their source of water in the dry season since most of the groundwater is too salty for their taste. However, one of the respondents in Limo communities told the researcher that because of the salty content of the groundwater, people mix borehole water with the muddy surface water from the dug-outs that almost dried out in order to reduce the salt content of the groundwater. This is later treated by addition of potassium aluminuim sulphate (alum) and filtering. 31.3% also indicated that public stand pipe is their source of water since it is available and closest source to them.

In the driest period of the year when most dug-outs, streams and wells dry up, members in Savelugu-Nantong District travel a distance of about 1.5 km away whilst people in Karaga and Gushiegu Districts travel a distance about 2-3 kilometers in search of water from existing boreholes, hand dug wells, stand pipes and dams. This is due to the fact that in the Savelugu-Nantong District more stand pipes exist in many of the communities with Gushiegu having stand pipes centred in Gushiegu alone and Karaga having no stand pipes at all. Savelugu-Nantong District may be better than Gushiegu and Karaga Districts in terms of improved water supply, potable water coverage and also reduction of long distances commuted to water sources. This may be due to the existence of more water facilities in Savelugu-Nantong District than in Gushiegu and Karaga Districts.

Fig. 4.5: Choice of Water Source in the Three Districts of Northern Region of Ghana in the Dry Season

4.4 Factors Limiting Continues Water Supply

This study found that there are a number of factors, which have led to the ineffective provision of water in the three districts. The factors range from environmental, technological to social reasons.

4.4.1 Environmental /Geological limitation

The study area falls within the Voltaian formation system and this reflected in the poor yields of most of the facilities especially the hand dug wells (HDWs). Indeed the hand dug wells proved to be not suitable in the area due to the very deep groundwater table, especially in the dry season. A lot of boreholes and wells dried up during the dry season. Indeed all the HDWs in the studied communities except two HDWs at Zinindo in Gushiegu District and Pishigu in the Karaga District were all found dried up during the survey. Physical constraints (e.g. poor aquifer with limited storage) seem to be a contributory factor in limiting water supplies in the three districts. However, inhabitants claimed that subsequent providers did not carry out any site exploration and never consulted them but went ahead and sited the facilities. Some of the boreholes which were provided at the suggested site with a very good yield have been abandoned due to the alleged high salt content. One of the respondents at Limo in Gushiegu District said they know places where the groundwater did not have high salt content where they have dug small water systems like shallow hand dug-wells, but when they alerted the providers, they did not listen to them.

Figure 4.6: The state of some water facilities at (A) Nanduli, (B) Zinindo and (C) Libga in Karaga, Gushiegu and Savelug-Nantong districts respectively

4.4.2 Engineering shortcomings

Some engineering flaws were also identified to have contributed to the ineffective supply of water in the studied communities. These flaws were identified mainly in dugout facilities. All the dugouts provided in the studied communities had failed to sustain water in the dry season except Libga and Bunglung irrigation dams. There were two types of failures identified in all of them: Overtopping failures and structural failures. These were all due to poor engineering designs and shoddy works. Large cracks resulting from, among others, poor compactions were some signs of structural failures of embankments. Overtopping due to lack of proper spillways had caused all the dugouts to lose parts of their embankments leading to failure and subsequently the inability of some of the dugouts to sustain water in the dry season. Even though all the dugouts function in the rainy season despite failure of parts of their embankments due to overtopping, the dugouts are still suffering from many engineering design defects. For instance, the upstream of most of the dugouts are used as walk ways leading into the dugouts with some open to settlements, even though these could have been avoided. Not only do they collect dirt and sediments from the nearby houses, the dugouts are suffering from serious siltation as a result of sand transported by runoff through the open end and walk ways into the dugouts. This is due to poor catchment management. The beds of the dugouts are very muddy; a sign of siltation. Indeed if no urgent measures are taken to save the dugouts from their current states, it is most likely that the dugouts will collapse completely and will not be able to store water even in the rainy season. The irrigation dams at Libga and Bunglung communities are likely to start drying if no urgent measures are taken. The dugouts may need dredging and closing of embankments towards human settlements as well as prevention of encroachment by settlement structures. The pictures in Appendix E (Figs. XV-XXXI) depict the states of dugouts in the three districts.

4.4.3 Distance to water sources

People travel long distances to collect water though the distance varied in each district and also for households. In Savelugu-Nantong District, the average distance to the water sources in the rainy season is 1.4 km, for Gushiegu District it is 2 km and for Karaga District it is 2.5 km with corresponding average time of 1.5, 2.2 and 2.3 hours for Savelugu-Nantong, Gushiegu and Karaga Districts respectively. The shorter time and distance for Savelugu-Nantong District may be due to the availability of more public stand pipes in the district than Karaga and Gushiegu Districts. The number of respondents travelling a specific distance for each district is shown in Figure 4.7. This result is based on the 80 responses from each of the three districts.

Figure 4.7: Average distance to water sources in rainy season in the three districts

30 respondents from Savelugu-Nantong District, 40 respondents from Karaga District and 55 respondents from Gushiegu District travel more than 1 km to collect water mainly by women who transport the water home on their heads. However, those who travel short distances of less than 1km are those who collect water from personal sources and or buy from neighbours during the rainy season. However, during the dry season, most of the dugouts and traditional wells dry up and people then travel to alternative sources which are mainly boreholes, hand dug wells and public stand pipes to collect water.

Figure 4.8: Average distance to water sources in dry season in the three districts

The average distance to the alternative water supply sources in the dry season in the three districts are 2, 2.5 and 3km with corresponding average time of 6.7 , 7.1 and 7.2 hours for Savelugu-Nantong, Gushiegu and Karaga Districts respectively. These distances are too long to travel while carrying 20 litres bucket of water on one's head. The means of collecting water from such water sources is not easy and actually 70% of the respondents in Savelugu-Nantong District, 85% of the respondents in Gushiegu District and 91% of the respondents from Karaga District said that such sources are not easily accessible. However, it was evident that the 30% of the respondents from Savelugu-Nantong District, 15% from Gushiegu District and 9% from Karaga District who said the traditional water sources are easily accessible may be those who lived closer to such sources and they do not have to queue as it is the case with boreholes.

4.4.4 Skilled personnel

It was revealed that (the communities in the three districts that) most of the damaged boreholes existed could not be repaired even if the community had wanted to repair it because they lacked the knowledge on how to repair them. For instance, at Zinindo in Gushiegu District, one non-functional borehole had been left for three years due to lack of skilled personnel. It was noted that the three districts experienced poor institutional organization for the operation and maintenance of communal facilities. The WATSAN members were not well trained to take up major repairs to avoid expenses in calling on outside mechanics. This is coupled with the fact that many young and knowledgeable men who could take up the task of WATSAN have left the communities for obvious reasons. For instance at Nanduli community in the Karaga District, about 126 young men and women who were energetic enough were reported to have left the community for Accra and Kumasi in search of “greener pastures”.

4.4.5 Ignorance and lack of awareness about ownership of water facilities

A major factor thought to be contributing to the problems of ineffective water provision is ignorance and lack of full awareness by the communities. Many are still not awake to the fact that they own the facility and need to contribute for its sustainability. Assessment of the progress made in the area has shown that donors have done a tremendous job but this dangerously created a donor-dependency syndrome within receiving communities. Most of the boreholes in these communities are in dilapidated states. In all the communities, some inhabitants expressed ignorance at the state of these boreholes since they are viewed to belong to the providers. The communities also expressed ignorance on the dangers of drinking unprotected water.

4.4.6 Rapid population growth

Increased number of people with few boreholes was cited as a contributing factor to frequent breakdowns of the boreholes in the districts. In Bunglung community in Savelugu-Nantong District for instance, there is only one borehole used by the whole community with a population of 898. Because of this, the respondents complained that, they spent long periods of time at the facility which made the borehole breakdown every two months thus affecting their water supply and maintenance capacity to fix the breakdown (Fig 4.9).

Figure 4.9: Long periods spent at water facilities due to high population with limited water facilities at (A) Bagurugu, (B) Gaa and (C) Bunglung in Karaga, Gushiegu and Savelugu-Nantong, Districts respectively

4.4.7 Social Dimension to the Problem of Community Participation

The involvement of the community in all aspects of the provision of water facility is very critical not only to ensure sustainability of the facility but also to ensure that the community actually patronized and used it. Especially in siting the facility, the community thinks they best know places that should be avoided since they know their own environment. As already mentioned in the preceding sub-bsection, it was revealed that most water facilities were sited without consultation or in some cases disregarding the community's suggestions. This has led to the abandonment of some faicilities. For example, at Limo in the Gushiegu District, the respondents expressed concern that they had advised the providers not to site their boreholes at their current place not only because the place was waterlogged but also the water tasted salty. Unfortunately their suggestion was dismissed and the facility was sited there. This facility has since been abandoned due to the alleged high salt content of the water.

4.5 Sufficiency of Water Used for Domestic and Economic Activities

In this approach, water supply (availability) and use are compared on a per capita basis. Such an approach has been used by Brouwer and Falkenmark (1989). The degree of vulnerability of a region increases for a given supply as its use increases.

4.5.1 Sufficiency of Water Use for Domestic Activities

Water consumption levels show significant seasonal variations across the three districts of the Northern Region of Ghana. Savelugu-Nantong District records the highest per capita water consumption in the rainy and dry seasons whilst Karaga and Gushiegu Districts show the lowest daily per capita water consumption levels. Generally, more water is consumed in the rainy season than in the dry season.

Average daily household water consumption in the three districts was 274, 210, 190 litres per day in the rainy season for Savelugu-Nantong, Karaga and Gushiegu Districts respectively. In the dry season, the average daily household water consumption dropped to 200, 161, 148 litres per day for Savelugu-Nantong, Karaga and Gushiegu Districts respectively (Table 4.4). The quantity of water consumed by households in the dry season was lower because of water scarcity during this period, which makes households to adapt to lower water consumption strategies. Also, women and children can only carry small quantities for the long distance. The average per capita water consumption in the rainy season was 30.4, 26.3, 27.1 l/p/day taking into account 9, 8 and 7 persons per household for Savelugu-Nantong, Karaga and Gushiegu Districts respectively. The average per capita water consumption in the dry season was 22.2, 20.1, 21.1 l/p/day taking into account 9, 8 and 7 persons per household for Savelugu-Nantong, Karaga and Gushiegu Districts respectively. These quantities exceed the World Health Organisation (WHO, 1996) estimated minimum amount of 20 l/c/d of safe water needed for metabolic, hygienic and domestic purposes. Note that the basis for the WHO standard has been questioned by Rosen and Vincent (1999). Gleick (1998), (cited in Asare, 2004) estimates 50 l/c/d as adequate: 25 l/c/d for drinking and sanitation and another 25 l/c/d for bathing and cooking. According to the United Nations Development Programme (UNDP, 2006) report, the per capita water consumption in Ghana is 36 l/day/p. Considering Gleick's and UNDP estimates, the quantities of water used by households in the three districts, regardless of seasonal variation are insufficient for healthy lifestyles. A possible reason for the low consumption levels may be insufficient water supply options, as exemplified in rural Ghana, thus resulting in water consumption levels not equating demand (London Economics, 1999). There was little variation in household water consumption in the three districts. The relatively high household water consumption in Savelugu-Nantong District may suggest the availability of water facilities which are closer to households since individuals travelled shorte distances and uses less time in water collection as shown in figure 4.8. However, the facilities are rather very far from the households in Karaga and Gushiegu Districts due to the difficult hydrogeological condition of the area. The convenience of location of water source is a significant determinant of water consumption levels (Demeken, 2009). This means that households located nearer to the water source are likely to use water more than others located farther away.

Table 4.4: Average per capita water consumption by communities and season in the three districts of Northern Region of Ghana

		Household water consumption (litres/day)		Water consumption (Litres/capita/day)	
Districts	Communities	Rainy Season	Dry season	Rainy Season	Dry season
Savelug-Nantong	Savelugu	274	195	30.44	21.67
	Bunglung	275	206	30.56	22.89
	Nabogu	273	199	30.33	22.11
	Libga	274	200	30.44	22.22
Gushiegu	Limo	196	144	28.00	20.57
	Zinindo	189	152	27.00	21.71
	Gushiegu	185	149	26.43	21.29
	Gaa	190	147	27.14	21.00
Karaga	Pishigu	211	153	26.38	19.13
	Bagurugu	210	169	26.25	21.13
	Nangun-nayilli	209	158	26.13	19.75
	Nandulli	210	164	26.38	20.50

4.5.1.1 Water usage patterns

Water is usually collected from multiple sources for different uses. Little or no distinction is made between water source and usage purpose. With the exception of bottled water (which for obvious reasons would not be for bathing), water from all available sources is used for drinking, bathing, cooking, washing, sanitation and hygiene purposes. Because rainwater, rivers, public stand pipes and boreholes are important sources to households, they consume more from these sources. It is assumed that the quantity consumed depends on household characteristics such as household size, gender composition, number of water carriers and season. It indirectly depends on amounts needed for domestic activities such as bathing, cooking, washing and domestic hygiene. Water from private vendors is considered an option mainly in dry seasons when water accessibility is difficult. Delivery of vended water is through trolley pushing and the use of donkeys at a cost of 1 GH¢ for a drum and wealthier households usually patronise this source.

Irrespective of the season, households on a daily basis use more water for bathing and washing purposes. These activities are sometimes undertaken in rivers and streams. Cooking is the second highest water used. However, people drink more water in the dry season than in the rainy season. This may be due to high evaporation of water from the human system resulting in more water consumption. Quantities consumed per activity show little or no seasonal variation as shown in Figures 10 and 11.

Fig. 10: Average daily household water consumption and type of domestic activity for the rainy season

Fig. 11: Average daily household water consumption and type of domestic activity for the dry season

4.5.2 Sufficiency of Water Use for Rural Industrial Activities

The research revealed that the dominant small scale industrial activity which takes place in the communities is shear nut processing with a higher water consumption of 486, 243 and 162 l/c/d in Savelugu-Nantong, Gushiegu and Karaga Districts respectively. The respondents contended that there is high profit. They get assistance from NGOs and other organizations that travel from Europe and other countries to buy and also give them contracts. This has attracted many people into the communities into the shear nut processing business. This is followed by rice processing with per capita water consumption of 324 l/c/d in Savelugu-Nantong District, 162 l/c/d in Gushiegu District and 121.5 l/c/d in Karaga District. However, the economic activity with the lowest per capita water consumption is pito brewing which records 162 l/c/d in Savelugu-Nantong, 121.5 l/c/d in Gushiegu and 81 l/c/d in Karaga Districts. This is due to the fact that most of the people in these communities are Muslems and are therefore forbidden to take alcohol. However, most of the respondents in the three districts have agreed that they are not meeting their water demand for these activities because of insufficient water supply and lack of storage containers. It also revealed that the higher water consumption for rural industrial activities in Savelugu-Nantong District than that of Gushiegu and Karaga Districts may be due to the availability of more water facilities and raw materials in the district.

Most small scale industrial water users in the three districts are comparatively small groups, with relatively low water needs. In most cases, economic activists draw their water from dug-outs, boreholes and wells. In many cases, the water used from wells and boreholes for industrial purposes is not suited for other uses due to their poor quality. For instance, one of the respondents in Karaga District contended that water from boreholes and wells is not suitable for shear nut processing. This is due to the fact that, the final product is too soft instead of being thick and the colour looks white instead of yellow. However, because of water scarcities, high cost of water from water vendors, longer time in water collection spent at borehole points and low profit, most women do not produce shear butter in the dry season. However, women in the communities have a working day of 10-11 hours throughout the year. On average, women from all the studied communities spend 2 hours and 7 hours of this time in fetching water during the rainy and dry seasons respectively.

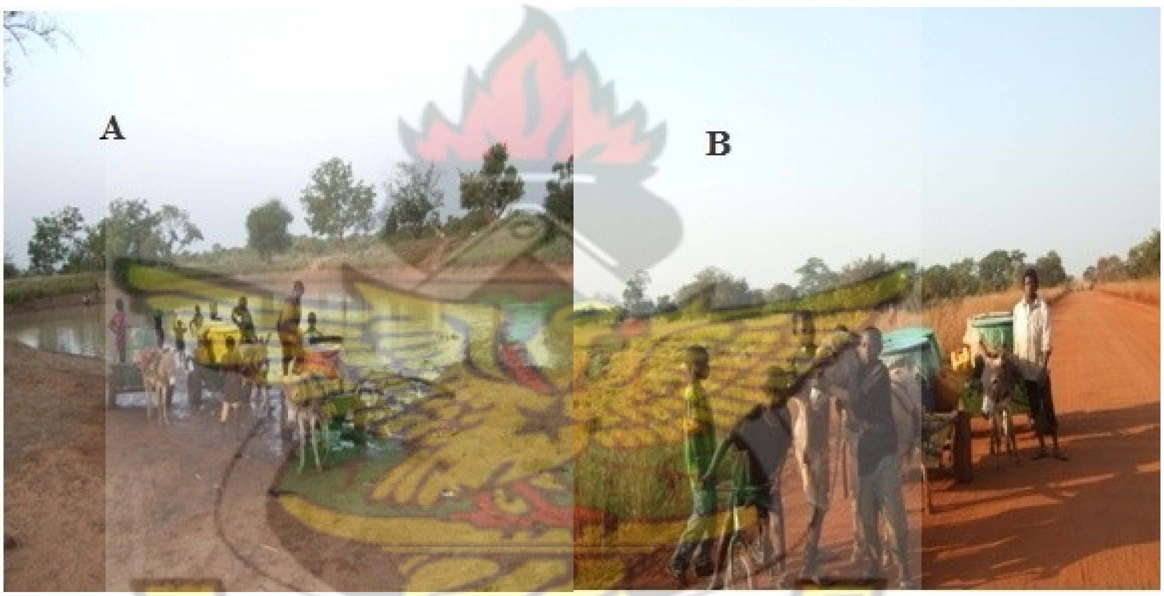

Figure 4.12: Water vendors at (A) Bagurugu (B) Limo

The study also found that apart from shear nut processing, rice processing and *pito* brewing, women in the area provide income to the family by farming on the land of the household, by engaging in food selling, vegetable gardening and also by hiring themselves out as daily wage farm labourers, as well as some operating micro-enterprise work like hair salons in bigger communities like Gaa, Pishigu and Nabogu. Beside shear nut processing, rice processing and pito brewing, it was also revealed that most women from Bunglung and

Libga communities which have an irrigation dam are able to fetch water overnight during the dry season and spend the rest of the day time at the dam site on vegetable gardening where they could make between GH¢ 25-30 per week. Although some women in the communities were also engaged in dry season vegetable gardening, they were relatively very few as they spent much of their time fetching water from far sources, 2-3 km away. It means that indirectly, water facilities are not sufficient in all the three districts since most small scale industrial activities like shear nut processing, rice processing and pito brewing come to a halt because of water shortages even though women were ready to spend extra time overnight and even to the extent of sleeping at borehole water points for water.

Figure 4.13: Water consumption in litres per capita per day for shear nut processing, rice processing and pito brewing in the three districts of Northern Region

4.6 Management and Sustainability of Rural Water Supply Systems

Management and sustainability of water supply systems ensures continues flow of water and improves sanitation and hygine practices in the various communities. The Community Water and Sanitation Agency (CWSA) is in charge of coordinating and facilitating the implementation of the National Community Water and Sanitation Programme (NCWSP) in rural areas, which is carried out directly by the communities and their District Assemblies. The main objectives of the NCWSP are to achieve health improvements, safe water supply, hygiene education and improved sanitation. For the sustainability of Rural Water Supply System the following factors were taken into consideration:

- Managerial sustainability
- Sanitation and hygiene of facility
- Repairs and maintenance of facility
- Financial sustainability

4.6.1 Managerial Sustainability

The survey in the study area revealed that there were lot of management problems at the community level and were serious threats to the sustainability of the facilities. This was clearly revealed in the state of the facilities in the twelve communities studied. For instance, out of a total of 50 hand pump water facilities in the twelve communities studied – 39BHs and 11 HDWs fitted with pumps, only 38 were functional whilst the rest of the 12 facilities were broken down or abandoned. The breakdown is shown in Table 4.5. Spare parts for hand pump repairs, replacement, installation of pumps, the survey revealed, are not readily available in the communities. This besides the preceding reason accounted for the state of the water facilities in the districts. As a result of poor management at the community level, the use of some of the water facilities is not regulated and therefore accounted for frequent breakdowns.

Table 4.5: Summary of Statistics on Potable Water Facilities by Type, Total Number, Functionality, Rehabilitation and Privately-Owned

Districts	Communities	Type and number of facilities	State of the facilities		Number rehabilitated	Privately-Owned
			Functional	Non-functional		
Savelug-Nantong	Libga	2 BHs	2 BHs	Nil	Nil	Nil
	Bunglung	1 BH	1 BH	Nil	Nil	Nil
	Savelugu	4 BHs,	3 BHs,	1 BH	1	Nil

		3 PSPs	3 PSPs			
	Nabogu	3 BHs	2 BHs	1 BH	Nil	Nil
Karaga	Nangunayili	4 BHs, 2 HDWs	2 BHs	2BHs, 2 HDWs	Nil	Nil
	Nanduli	3 BHs, 2 HDWs	3 BHs	2 HDWs	Nil	Nil
	Pishigu	6BHs, HDW	6BHs, HDW	Nil	Nil	Nil
	Bagurugu	2 BHs	2 BHs	Nil	Nil	Nil
Gushiegu	Limo	2 BHs,	2 BHs,	Nil	Nil	Nil
	Zinindo	4 BHs, 1 HDW	3BHs, 1HDW	1 BHs,	Nil	Nil
	Gaa	2 BHs, HDW	2 BHs	HDW	Nil	Nil
	Gushiegu	3 BHs, HDW 3 PSPs	2 BHs 3PSP	BHs, HDW	Nil	Nil

Table 4.5 depicts the state of the water facilities and the functionality of these facilities in the three districts as was observed during the field survey. Averages of 25% of the point sources in the communities were not functioning with most of the functional facilities having devastating sites. However, only one out of the 12 non-functional facilities has been rehabilitated, a signal to the fact that the sustainability of these sources was at a great threat if appropriate measures were not taken. In Savelugu-Nantong District out of 13 facilities, 11 (84.62%) are functioning, in Karaga District out of 20 facilities, 14 (70%) are functioning and in Gushiegu District out of 16 facilities 12 (75%) are functioning. This clearly indicates that water facilities management in Savelugu-Nantong District may be

better than that of Gushiegu and Karaga Districts. This is also confirmed in Table 4.1 why Savelugu-Nantong records the highest monthly income compared to those of Gushiegu and Karaga Districts.

One thing was clear, the WATSAN Committee were still in existence except at Nanduli, a community in Karaga District. In Nanduli community all the WATSAN members left for greener pasture and hence their departure led to the collapse of the committee and has since not been reformed. However, all respondents from the other eleven communities were aware of the existence of the committee. Nevertheless, it was revealed that almost all the committees were inactive in one way or the other except those in Savelugu-Nantong District. In Savelugu-Nantong District, 71% of the respondents indicated that the committee was active as against 29% who refuted the activeness of the committees, in Karaga District 31% indicated that the committee was active as against 69% and in Gushiegu District 43% indicated that the committee was active as against 57% who refuted the activeness of the committee blaming it on the lack of sacrifice as members were much engaged in their farm activities and never met to deliberate on issues affecting the facilities.

An interview with household respondents showed that out of a total number of 80 respondents for each district, 54 respondents representing 67.5% in Savelugu-Nantong District indicated that the communities were the sole owners of the provided water facilities as against the 32.5% who still thought that the providers were the owners. In Karaga District 26 (32.5%) indicated that the communities were the sole owners as against 54 (67.5%) and in Gushiegu District 41 (51.25%) of the respondents indicated that the communities were the sole owners of the facilities as against 39 (48.75%). It was clear that most communities in Karaga and Gushiegu Districts still felt no sense of ownership and responsibility for the water facilities despite being so called demand-driven.

To conclude, the management of community water facilities is a process that seeks to involve the entire stakeholders in the Community Water and Sanitation Programme (CWSP) aside the WATSAN Committee, particularly DWST/DA, POs, Service Providers and Area Mechanics (AM), in collaboration and consultation in order to address problems that might arise beyond the ability of the WATSAN Committee.

Table 4.6: The state of dug-out facilities in the study areas in the dry season

Districts	Communities	Number of dug-out/dam	State of the facilities in dry season	
			Functional	Non-functional
Savelugu-Nantong	Libaga	1 Dam	Dam	Nil
	Bunglung	1Dam	Dam	Nil
	Savelug	3 Dug-outs	Nil	3 Dug-outs
	Nabogu	1 Dug-out	Nil	Dug-out
Karaga	Nangunayili	Nil	Nil	Nil
	Nanduli	Nil	Nil	Nil
	Pishigu	3 Dug-outs	Nil	3 Dug-outs
	Bagurugu	2 Dug-outs	Nil	2 Dug-outs
Gushiegu	Limo	Dug-out	Nil	Dug-out
	Zinindo	2 Dug-outs	Nil	2 Dug-outs
	Gaa	2 Dug-outs	Nil	2 Dug-outs
	Gushiegu	Nil	Nil	Nil

Table 4.6 depicts the state of the dug-out facilities in the districts as was observed during the field survey. It also shows the validation of this finding and the assessment record of the districts on the functionality of these water facilities in the districts in the dry season. It clearly shows that out of the 16 dug-outs/dams in the studied communities only 2 dams in Savelugu-Nantong District were functioning in the dry season.

4.6.2 Sanitation and Hygiene of Facility

Water related health status is generally used to determine the impact of a water facility in a community. The main aim for the provision of any water facility therefore is to improve health by reducing general mortality and socio-economic losses caused by preventable waterborne diseases through access to safe and reliable water points. This will be a mirage if the environment of the facility is not hygienically kept. Hygiene education and sanitation are therefore promoted along with any water supply. According to NORPREP (2007) guidelines for WATSANs, adequate sanitation and hygiene is expected to be maintained at all types of water sources be it protected groundwater sources or unprotected surface sources through:

- Maintaining facility site cleanliness
- Proper water collection
- Proper water transportation and
- Proper storage of water.

Some water contamination sources were identified during the interviews with some service providers as:

- Bathing/weeding/washing in or near water sources
- Farming and application of agro-chemicals near water sources
- Siting of water points close to cemetaries
- Pit latrines situated near water sources
- Closeness of community refuse dumps to water points

- Indiscriminate defecation around water bodies and
- Stagnant water or dirty pools near water points.

It is the responsibility of the volunteer health and hygiene educators in the WATSAN Committee to act as motivators in ensuring proper sanitation and hygiene practices by stimulating the participation of other community members in hygiene and sanitation activities as well as encourage and promote hygiene and sanitation best practices to prevent disease transmission. In other words, they have the following specific roles to play as was identified during interviews with providers:

- Maintain water site cleanliness
- Make sure hygiene promotion works
- Stimulate the participation of other community members in hygiene and sanitation activities and
- Encourage proper storage and use of water.

Even though each of the communities in the three districts interviewed had hygiene educators who demonstrated little knowledge about their role, the realities on the ground proved their inactiveness except in Savelugu-Nantong District. Critical observation at all the borehole sites in all the 12 communities studied suggested that the sanitary conditions there were nothing to boast of except Savelugu-Nantong District. This is because only one facility was sited with a bad sanitary condition with weeds. Sites of other facilities in Karaga and Gushiegu Districts were found to be weedy, and in most instances eroded gutters and troughs filled with stagnant waters poured from washed clothing, muddy and possible breeding places for mosquitoes. So astonishing and disturbing were instances where children are found sitting on the pump handle of water facilities. Figure 4.14 depicts the attitude of the users of the facility and the sanitary conditions at BHs sites in the studied communities. The situation is the same or worse off at the other communities in Karaga and Gushiegu Districts (see Appendix E).

Figure 4.14: Borehole with sanitation threats: scene at (A) Savelugu, (B)Zinindo and (C) Pishigu in Savelugu-Nantong, Gushiegu and Karaga districts respectively

The research found no evidence of good sanitation and hygiene practices among the respondents especially those in Karaga and Gushiegu Districts. For instance, to a question as to what constitute good sanitation and hygiene at a water facility site during focus group discussion with the WATSANs, the committee members easily mentioned things like weeding, cleaning, sweeping, repairing of pad, gutter or trough. However, site observations during this study showed nothing better than the pictures in Figure 4.14. This prompted the researcher to assess the health-based view that has been the driver of most rural water programmes. Information obtained from the District Heath Services has confirmed that cases of these water related diseases in the three districts have been very high among the top ten diseases in recent years which include diseases like typhoid, diarrhoea, malaria, intestinal worms and skin diseases with typhoid and malaria taking an upward trend especially during the rainy season. Cases of guineaworm were, however, rare and not found in the three districts. It is indeed, a proof of guineaworm eradication in the three districts; a success and progress that in the researcher's view could only be attributed to the efforts of the educational programmes on guineaworm eradication centred on water treatment by boiling and filtering. Statistics obtained from the three district health service departments on common water related diseases are as shown in Table 4.7.

Table 4.7 Cases of water- related diseases in the districts (NRC = No Reported Case)

Districts	Diseases	Cases recorded during the past three years		
Savelugu-Nantong		2009	2010	2011
	Guinea worm	47	6	0
	Typhoid	2	3	1
	Diarrhoea	4	6	6
	Intestinal worm	NRC	NRC	NRC
	Malaria	90	58	23
	Skin disease	1818	2478	3003
Karaga	Guinea worm	3	1	0
	Typhoid	NRC	NRC	NRC
	Diarrhoea	1567	1760	1868
	Intestinal worm	NRC	NRC	NRC
	Malaria	9456	8419	10342
	Skin disease	201	178	170
Gushiegu	Guinea worm	1	0	0
	Typhoid	655	480	NRC
	Diarrhoea	2293	2011	3329
	Intestinal worm	495	NRC	518
	Malaria	19864	22195	19196
	Skin disease	1050	1337	1983

Source: Savelugu-Nantong, Karaga and Gushiegu District Health Services (2009-2011)

Six cases of water-related diseases in Table 4.7 were not different among the three districts except that, cases of intestinal worms were not recorded in Savelugu-Nanton and Karaga Districts with Gushiegu District having an upward trend. It is therefore not clear if indeed, water sources and supply is sufficient enough to improve the lives of these rural folk economically and domestically. Comparing the cases of these diseases in the three districts, some upward differences exist in diarrhoea and skin diseases with Karaga alone having no report on cases of skin diseases. However, there were downward differences in the cases of typhoid disease with Karaga having no records. It is important to note that even though there are some differences in the prevalence of these diseases in the three districts, in reality the assessment of water sources in the three districts cannot be derived from these results. This is because the prevalence of each disease is equally high to the same extent in all the three districts. For instance the cases of malaria have reached an alarming stage in the three districts followed by diarrhoea with diarrhoea affecting both children and adults. However, all Community Health Nurses interviewed in all the three districts attributed it to the use of unsafe water sources coupled with poor hygiene and sanitation.

4.6.3 Repairs and Maintenance of Facility

The survey revealed that only one of the 13 broken boreholes was repaired with the rest being abandoned due to their inability to repair them and 15 out of the 17 dug-outs also have eroded embankments with high risk of siltation. Most of the mechanics and skilled personnel left the district for obvious reasons. This was confirmed by the community members and personal observation by the researcher. There is the likelihood that more facilities will be abandoned in the near future if there is no serious attention given to the facilities. It is therefore incumbent on all the community members, WATSAN Committees, DWST, and area mechanics to come together for effective fund raising and ways of accessing spare parts to take care of future breakdowns.

Figure 4.15: The state of most BHs in the study areas: (A) Zinindo, (B) Nangunayili

The survey reveals the criteria used by DWST, the providers as well as the WATSAN Committee in selecting the trained volunteer and his or her responsibilities. The criteria identified were as follows:

- Both sexes should be involved
- They should be good at working with the hands
- They should be young so that they have the strength and good eyesight to do the job
- They should be hardworking, reliable and trusted by the community and
- They should be resident in the community and available on regular bases.

It was commonly known in the communities that the caretaker concept is a determinant factor in the sustainable operation and management of water supply facilities. In the study areas, the common type of pump found was the submersible AFRIDEV hand pump with identified main integral parts as pump head, pump cylinder, rising main and pump rod. One of Nira AF-85 types were also found at Nunduli community. The fast wearing parts designed for only two years life span was also identified as in Table 4.8.

Table 4.8: Fast wearing parts

Parts	Functions
U-seal	Supports for plunger
Bearings	For fulcrum and Hunger
Valve Bobbins	Plunger and Foot-valve
O-ring	Support for Foot-valve
Centralizers	For Pump rod

Source: NORPREP Sponsored Watsan TOT Training

Pump repairs and maintenance are often required to be conducted on the pump when there is a problem and need a well trained person who is conversant with the right steps and troubleshooting. The following were the identified steps for repairs and maintenance of hand pumps during interviews with providers:

- Know the cause of the problem and determine the solution needed
- Dismantle and go straight to the problem area of the pump
- Replace defective part/ parts and reassemble or mount back pump and
- Then record details of the repairs.

As a facility repairer, the study found that the most important skill required of the personnel is the ability to troubleshoot. Table 4.9 presents some troubleshooting in hand pump repairs.

Table 4.9: Troubleshooting in pump repairs

Problem	Cause	Remedy
Abnormal noise	Worn out bearings, handle fork touches pump head	Replace bearings
No water	Defective plunger seal, rods	Replace seal

	disconnected	
Delayed flow	Leak valve and pipe joint	Replace valves and properly join pipes
Reduced discharge	Worn out valve bobbins	Replace parts

Source: NORPREP Sponsored Watsan TOT Training

Even though, the criteria for the selection of caretakers especially spelt out the need for gender balance, this was not observed in the studied communities. Not only were they all male and may not be sensitive to water supply issues, most of them were old and seemed not to be energetic enough. Explaining why that contrast, most of the communities noted that because it was voluntary and no remuneration attached, young ones did not want to take up the task.

An attempt was made to assess the knowledge of the caretakers about their responsibilities as well as problem detecting abilities, otherwise known as troubleshooting. All committees in the studied communities admittedly revealed that apart from replacing defective plunger seal which is relatively easy for them, they could make no other attempt on the borehole. They all further admitted that until a problem was reported to them, they conducted no routine maintenance on the facility. A close examination of all the boreholes revealed that none was lubricated; all parts were dried and noisy when in operation. This suggests that apart from being inactive, the caretakers were not well-trained.

For instance at Nanduli in Karaga District, it was revealed that all the caretakers had left the community for greener pastures in the south. This has affected the facilities. Training more women may be a solution since men often travelled more than women in the area. In the event of major faults they indicated that they called mechanics from different communities who come to repair at a cost borne by the community. They, however, lamented that the repair charges by the hired mechanics are most at times very high compelling them to abandon the facility.

Noteworthy, was the fact revealed during an interview with the provider that, some parts such as rod (Afridev) and sleeve bearing (Nira), can easily be damaged if children play with the pump. Even though these parts are noted to be very expensive, it was noted that children are fond of playing and sitting on the borehole facilities. At Gaa and Zinindo communities in Gushiegu District for instance, children were sighted climbing and playing with the BHs (Fig 4.9) whilst some adults watched on unconcerned, an indication that they saw nothing wrong.

Figure 4.16: Children play with boreholes: (A) Gaa, (B) Zinindo

4.6.4 Financial Sustainability

Weak financial resources is another factor that contributes to the problems of ineffective water provision and maintenance sustainability in most of the communities especially in communities where the income of the inhabitants is not regular. For instance in communities like Nangunayili and Nanduli in Karaga communities, most of the respondents said they do not have money to repair the facilities when breakages occur and therefore leave the responsibility for the providers and other good Samaritans like the area chiefs and other wealthy people. It is therefore the responsibility of the DWST to honour or establish the contribution during the follow up work.

4.6.4.1 Fund raising methodologies

During the interviews with the providers, the following ways of raising funds for maintenance were identified for the communities:

- **Cash contributions:** This includes:

a) Levying individual adults, family or compound and

b) Paying on seasonal basis and regular basis, eg monthly.

- **Communal farms or labour:** This is where a community may decide to establish a community farm or organize communal labour to generate income for maintenance.
- **Levy on each *Garawa* or Bucket Fetched**: Some communities may decide to levy at the water point each *Garawa* or bucket of water fetched.
- **In kind contribution**: Some farming communities may agree to deduct some specified amount of each farmer's produce as an annual contributions for maintenance.

Indeed, it is the entire community that should decide on which method and amount will work best for them and not only the WATSAN. This way, they are more likely to support the fund raising. However, investigation for the studies revealed that most of the communities do not make regular or seasonal contribution for the maintenance of these facilities. For instance, all the respondents interviewed in Nanduli and Nangunayili in Karaga District said they do not have money for contribution, therefore if a problem occurs in one of the facilities, they leave it for the providers to repair. Table 4.10 depicts the mode of contribution and amount paid for operation and maintenance of water facilities.

Table 4.10: Mode of contributions and amount paid

Districts	Communities	Mode of contribution if any	Amount paid
Savelugu-Nantong	Libga	Contribute when breakages occur	No fixed amount
	Bunglung	Monthly contribution	GH¢ 1.00
	Savelugu	Pay as you fetch system	5 GHp for garawa
	Nabogu	Contribute when breakages occur	No fixed amount
Karag	Nangunayili	No contribution	Nil
	Nanduli	No contribution	Nil
	Pishigu	Pay as you fetch system	5 GHp for garawa
	Bagurugu	No contribution	Nil
Gushiegu	Limo	No contribution	Nil
	Zinindo	No contribution	Nil
	Gaa	Contribute when breakages occur	No fixed amount
	Gushiegu	Pay as you fetch system	5 GHp for each garawa

It is clear from Table 4.10 that all the communities in Savelugu-Nantong District contribute money in one way or the other for the operation and maintenance of the water facilities, but some communities like Pishigu in Karaga District and Gushigu town in Gushigu Distict have some fixed amount that they normally contribute for operation and maintenance of the water facilities. The rest of the communities which constitute 50% do not make any contribution towards the operations and maintenance of these facilities. Indeed, many have admitted that ineffective contribution has been the cause of delays in repairs any time a fault developed. Also revealed was the fact that all the communities in the three districts have no bank accounts since the provision of the facilities even though communities in

Savelugu-Nantomg District appeared to take contribution toward management and maintenance of water facilities seriously. This explains why most BHs are abandoned especially in the communities in the Karaga and Gushiegu Districts. It brings to light that most communities in the research areas are weak with regards to fund raising methodologies towards operations and maintenance of the provided water facilities. Availability of funds at all times and proper accounting will ensure quick repairs and maintenance works on the boreholes to be carried out whenever there is a breakdown.

Table 4.11: Some basic information from the communities

Districts	Communities	Population (2010)	Cash at hand (GH¢)	Cash at bank (GH¢)	Total cash (GH¢)
Savelugu-Nantong	Libga	643	Nil	Nil	Nil
	Bunglung	898	45	Nil	45
	Savelugu	33662	69	Nil	69
	Nabogu	1296	Nil	Nil	Nil
Karaga	Nangunayili	503	Nil	Nil	Nil
	Nanduli	365	Nil	Nil	Nil
	Pishigu	4473	54	Nil	54
	Bagurugu	2180	Nil	Nil	Nil
Gushiegu	Limo	1191	Nil	Nil	Nil
	Zinindo	3022	Nil	Nil	Nil
	Gaa	1794	16	Nil	16
	Gushiegu	18484	58	Nil	58

Table 4.11 shows the financial background of all the twelve communities studied in the three districts. Although Savelugu-Nantong District is better than Karaga and Gushiegu Districts in terms of fund raising, this is still woefully inadequate to maintain and sustain

any type of rural water supply facility. Indeed, considering the importance of water as a basic necessity of life, human, material and financial resources should be necessarily mobilized to ensure its sustainability.

The cost of spare parts for maintenance of hand pumps was also noted to have been frequently increased in recent years. This is due to the fact that the spare parts are not made locally but imported. The communities therefore need to improve upon their fund raising methodologies and raise enough funds for repair and maintenance purposes.

4.7 Potential of water systems for dry season small scale irrigation

The surplus water available of most of the water facilities in the dry season shows water availability and potential of these water supply systems for small scale irrigation of vegetables. The potential of these water facilities would depend on a number of factors that include the:

- Adequacy of the systems
- People's willingness to use the facilities for this purpose and
- Availability of market for the produce.

The adequacy of the systems further depends on the yield, type of crop to be grown, soil characteristics, climatic and water management factors. With regard to the people's willingness to use the facilities for the purpose of small scale vegetable irrigation, 61% in Savelugu-Nantong District indicated their readiness to use provided it becomes a unanimous decision by the entire community, 19% of the respondents at Libga and Bunglung communities indicated that they are already using some of the facilities and 20%

of the respondents expressed concern about the inadequacy of the systems due to poor yield of these water facilities.

In Karaga District, 15% of the respondents indicated their readiness provided they would get support from the government and 55% expressed concern about the inadequacy of the systems due to poor yield and 30% do not just have interest in irrigation especially communities like Bagli and Nambrugu where the White Volter river passes. This river flows throughout the year with no irrigation farming near it. One of the communities members said to the researcher that they do not believe that there is economic gain in irrigation farming and also do not have seeds and the necessary equipment to help them carry out irrigation farming. That is why they depend solely on rainfed agriculture. In Gushiegu District, however, 78% indicated their readiness to use the facilities for irrigation and 22% also expressed concern about the inadequacy of the systems due to poor yield.

An interview with some farmers at Libga and Bunglung communities in Savelugu-Nantong District, who engaged themselves in small scale dry season vegetable irrigation using irrigation dams revealed that there was a good market for all kinds of vegetables especially amarantus, spinach (*ayoyo*), tomatoes and pepper.

However, an interview with the managers of these two irrigation dams indicated that, the total land area cultivated at Bunglung and Libga communities in Savelugu-Nantong District in 2000 were 65 acres (26 hectares) and 80 acres (32 hectares) respectively and in 2010 the areas have increased to 150 acres (60 hectares) at Libga and 100 acres (40 hectares) at Bunglung community with about 0.4 hectares of the irrigated land in Bunglung depending on shallow dug wells and ponds which have high watertables. An annual cost of water consumption on an acre of land at Libga is Gh¢7.5 and that of Bunglung is Gh¢7. It was, however, confided to the researcher by one of the managers at Libga that some of the farmers do not want to pay for the usage of the water and others are illegally cultivating at places prohibited by the irrigation authority. This allowed sand, debris and other impurities to be carried into the dam during the rainy season, thereby endangering the sustainability of this facility for future use. It was also revealed to the researcher by the farmers that, averagely 4 bags of pepper and 5 boxes of tomatoes are produced from one acre of land in one season with a bag of pepper costing Gh¢ 100 and a box of tomato costing Gh¢ 45. This implies the farmers may be making enough profit and good income from the irrigation dams.

Figure 4.17: Irrigated Land Areas at Libga and Bunglung Communities in the Savelugu-Nantong Districts

The study has also revealed that, by 2025 there is the likelihood that, the land area used for irrigation in the two communities would have to double as population at that time is likely to double. This means that the demand for food at that time would also increase; thereby increasing the demand for conversion of rainfed agricultural land into irrigated land for production of more food crops in the dry season. Table 4.12 presents all the provided facilities in the study communities and their functionality in the dry season.

Table 4.12: State of water sources in the Study Communities in dry season

Districts	Communities	Facilities	State of facilities		Remarks
			Functional	Non-functional	
Savelugu-Nantong	Savelugu	4 BHs, 3PSPs and 2 dug-outs	3 BHs and 3PSPs	1 BHs and 2 dug-outs	Urgent attention
	Libga	2 BHs and a dum	2 BHs and a dum	Nil	Less attention
	Bunglung	1 BHs and a dum	1BHs and a dum	Nil	Less attention
	Nabogu	4BHs, 3HDWs and a stream	2 BHs	2BHs, 3 HDWs and Stream	Urgent attention
Karaga	Nangunayili	4 BHs and a 1HDWs	2 BHs	1 BHs 1HDW	Urgent attention
	Nanduli	3 BHs and 2HDW	3 BHs	2 HDWs	Urgent attention
	Pishigu	6 BHs, HDW and 3 dug-outs	6 BHs and a HDW	3 dug-outs	Urgent attention
	Bagurugu	2BHs and 2 dug-outs	2 BHs	2 dug-outs	Urgent attention
Gushiegu	Limo	2 BHs, 1HDW and a dug-out	2 BHs	3BHs, 1HDW and a dug-out	Urgent attention
	Zinindo	3 BHs ,3HDW and 2 dug-outs	3BHs and a HDW	4BHs, 2HDWs and 2 dug-outs	Urgent attention
	Gaa	2 BHs and 2dug-outs	2 BHS	2 dug-outs	Urgent attention
	Gushiegu	3PSPs,4BHs and HDW	2 BHs, 3 PSP	2BHs and HDW	Urgent attention

4.7.1 Water Supply Availability in the Districts

Savelugu-Nantong District

a). Libga community

Two functioning BHs and an earth dam

i) First BH available yield $= 4\times10^{-2}\ m^3/min$ $= 2.4\ m^3/h$

ii) Second BH available yield $= 3.4\times10^{-2}\ m^3/min$ $= 2.04\ m^3/h$

iii) Estimated volume of water in the dam = 17407 m^3

b). Bunglung community

One functioning BH and an earth dam

i) BH available yield = 6.0×10^{-2} m^3/min = 3.6 m^3/h

ii) Estimated volume of water in the dam = 5801.13 m^3

c). Nabogu community

Two functioning BHs

i) First BH available yield = 4.4×10^{-2} m^3/min = 2.64 m^3/h

ii) Second BH available yield = 4.6×10^{-2} m^3/min =2.76 m^3/h

d). Savelugu town

Three BHs and three public stand pipes (PSP)

i) First BH available yield = 2.5×10^{-2} m^3/min = 1.5 m^3/h

ii) Second BH available yield = 2.0×10^{-2} m^3/min = 1.2 m^3/h

iii) Third BH available yield = 1.8×10^{-2} m^3/min = 1.08 m^3/h

iv) First public stand pipe (PSP) available yield = 270.16 m^3/d

v) Second public stand pipe (PSP) available yield = 277.54 m^3/d

vi) Third public stand pipe (PSP) available yield = 282.73 m^3/d

Karaga District

a). Nangunayili community

Two BHs

i) First BH available yield = 7×10^{-2} m^3/min = 4.2 m^3/h

ii) Second BH available yield =6.5×10^{-2} m^3/min = 3.9 m^3/h

b). Nanduli community

Three BHs

i) First BH available yield = 3×10^{-2} m^3/min = 3.9 m^3/h

ii) Second BH available yield = 3.5×10^{-2} m^3/min = 2.1 m^3/h

iii) Third BH available yield = 3.1×10^{-2} m^3/min = 1.86 m^3/h

c). Pishigu community

Six BHs and a HDW

i) First BH available yield = 3.0×10^{-2} m^3/min = 1.8 m^3/h

ii) Second BH available yield = 3.0×10^{-2} m^3/min = 1.8 m^3/h

iii) Third BH available yield = 3.3×10^{-2} m^3/min = 1.98 m^3/h

iv) Fourth BH available yield =3.0×10^{-2} m^3/min = 1.8 m^3/h

v) Fifth BH available yield = 3.1×10^{-2} m^3/min = 1.86 m^3/h

vi) Sixth BH available yield = 2.9×10^{-2} m^3/min = 1.74 m^3/h

vii) Available yield of a HDW = 2.6×10^{-2} m^3/min = 1.56 m^3/h

d). Bagurugu community

Two BHs

i) First BH available yield = 1.4×10^{-2} m^3/min = 0.84 m^3/h

ii) Second BH available yield = 1.2×10^{-2} m^3/min = 0.72 m^3/h

Gushiegu District

a). Limo community

Two BHs and a HDW

i) First BH available yield = 3.5×10^{-2} m^3/min = 2.1 m^3/h

ii) Second BH available yield = 3.2×10^{-2} m^3/min = 1.92 m^3/h

iii) Available yield of HDW = 2.9×10^{-2} m^3/min = 1.74 m^3/h

b). Zinindo community

Three BHs and one HDW

i) First BH available yield = 4.0×10^{-2} m^3/min = 2.4 m^3/h

ii) Second BH available yield = 4.5×10^{-2} m^3/min = 2.7 m^3/h

iii) Third BH available yield = 3.0×10^{-2} m^3/min = 1.8 m^3/h

iv) Available yield of HDW = 2.8×10^{-2} m^3/min = 1.68 m^3/h

c). Gaa community

Two BHs

i) First BH available yield = 4.0×10^{-2} m^3/min = 2.4 m^3/h

ii) Second BH available yield = 4.6×10^{-2} m^3/min = 2.76 m^3/h

d). Gushiegu town

Two BHs and three public stand pipes (PSP)

i) First BH available yield = 2.0×10^{-2} m^3/min = 1.2 m^3/h

ii) Second BH available yield = 2.2×10^{-2} m^3/min = 1.32 m^3/h

iii) First PSP flow rate = 91.00 m^3/d

iv) Second PSP flow rate =76.43 m^3/d

v) Third PSP flow rate = 93.73 m^3/d

According to Gyau-Boakye and Dapaah-Siakwan (2000) for hand pumps and BHs meant to supply rural communities in Ghana, a successful yield is considered to be at least 13 l/min (0.78 m^3/h) or more. This minimum yield per BH is designed to meet the demand of communities with population ranging between 200-2000 of providing per capita water consumption of 25L.

All things being equal and supposing an average pumping period of seven hours per day (7h/day) as inferred from household respondents, Table 4.13 presents an estimated available groundwater supply from the current functioning facilities in the various communities.

Table 4.13: Water demand and available water in the study communities in the dry season

Districts	Communities	Current Population (2010)	Average per capita water demand	Total domestic water demand	Total available yield of groundwater	Surplus water available for any	Total surplus water available

			(litres)	per day (m^3)	facilities per day (m^3)	activity per day (m^3)	over dry period of six months (m^3)
Savelugu-Nantong	Libga	643	22.22	14.29	31.08	16.79	3022.2
	Bunglung	898	22.89	20.56	25.20	2.31	415.8
	Nabogu	1296	22.11	28.66	37.80	9.14	1645.2
	Savelug	33662	21.67	729.46	18.90	Nil	Nil
Karaga	Nangunayili	503	19.75	9.93	56.70	46.77	8418.6
	Nanduli	365	20.50	7.48	55.02	47.54	8557.2
	Pishigu	4473	19.13	85.57	87.78	2.21	397.8
	Bagurugu	2180	21.13	46.06	10.92	Nil	Nil
Gushiegu	Limo	119	20.57	2.45	40.32	37.87	6816.6
	Zinindo	3022	21.71	65.61	60.06	Nil	Nil
	Gaa	1794	21.00	37.67	36.12	Nil	Nil
	Gushiegu	18484	21.29	393.53	17.64	Nil	Nil

From Table 4.13, it implies that the estimated total surplus available water from the current functioning water supply facilities for any activity over the six months dry period in the various communities of the three districts are:

a). In Savelugu-Nantong District

i) For Libga community: 3022.2 + 17407 = 20429.2 m^3

ii) For Bunglung community: 835.2 + 5801.13 = 6636.33 m^3

iii) For Nabogu community: 1645. 2m^3

b). In Karaga District

i) For Nangunayili community: 8418.6 m^3

ii) For Nanduli community: 8557.2 m^3

iii) For Pishigu community: 397.8m^3

c). In Gushiegu District

i) For Limo community: 6816.6 m^3

For Savelugu town in Savelugu-Nantong District, the total surplus water available might increase if the two broken boreholes are repaired and the three dug-outs which always dry up in the dry season are also dredged to sustain its water throughout the year. For Bagurugu community in the Karaga District, Zinindo, and Gaa communities in Gushiegu District even though do not have surplus water available over the dry period of six months, water supply would have been adequate for domestic purposes or prevail in excess if the non-functional dug-outs in the communities are properly dredged to ensure that the capacity of the facilities are able to sustain water in conjunction with other groundwater facilities for the communities throughout the year. For Gushiegu town in Gushiegu District, however, the supply may still not be adequate for domestic purposes upon repairs of the broken down facility. It was revealed to the researcher that most of the dug-outs in the selected communities of the three districts dry up in the dry season and need to be dredged except those at Libga and Bunglung communities in the Savelugu-Nantong District. This, however, revealed to the researcher that, the leading district in irrigation farming among the three districts is Savelugu-Nantong District. This also shows why Savelugu-Nantong District is better than Karaga and Gushiegu Districts in terms of water sufficiency and potable water coverage.

4.7.2 Soil Infiltration Rate

Infiltration is the downward entry of water into the soil from the surface. The velocity at which water enters the soil is infiltration rate. Water from rainfall or irrigation must first enter the soil for it to be of value. Infiltration is an indicator of the soil's ability to allow water movement into and through the soil profile. Soil temporarily stores water, making it available for root uptake, plant growth and habitat for soil organisms.

The infiltration rate can be restricted by poor management. Under these conditions, the water does not readily enter the soil and it moves down slope as runoff or ponds on the surface, where it evaporates. Thus, less water is stored in the soil for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure that can further decrease the infiltration rate. Soil basic infiltration rates at three points each in six of the studied communities with operational facilities are shown in Table 4.14.

Table 4.14: Soil infiltration rates in the study areas

Districts	Communities	Soil type	Basic Infiltration Rate (mm/h)			Average Basic Infiltration Rate
			First Point	Second Point	Third Point	
Savelugu-Nantong	Libga	Sandy loam	27	26	25	26.00 ±1.00
	Bunglung	Sandy loam	27	26	26	26.33 ±1.00
	Nabogu	Sandy loam	25	24	24	24.33 ±1.00
Karaga	Nanduli	Sandy loam	28	30	30	29.33 ±1.00
	Nangunayili	Sandy loam	24	25	25	24.67 ±1.00
Gushiegu	Limo	Sandy loam	25	25	26	25.33 ±1.00

4.7.3 Irrigation Water Requirements

The estimated total crop water requirement (CWR or ETc) and irrigation water requirement (IWR) of tomato crop grown in the field for 180 days in the study areas during the period of Oct-Mar/April were 1015.03mm and 852.17 mm respectively in Savelugu-Nantong District, 1015.03mm and 872.17mm in Karaga District and 1015.03mm and 860.23mm in Gushiegu District. Gross irrigation water requirement (GIWR) was therefore 1217.39 mm, 1245.96mm, and 1228.90mm for Savelugu-Nantong, Karaga and Gushiegu Districts respectively taking into consideration the irrigation efficiency of 70% for watering cans likely to be used. The difference in the estimated values of this research in the three districts may be due to the number of years of climatic data used in the estimation. According to Agodzo (1998), CWR of tomato in Tamale are 668 and 604 respectively during the period of Nov-Feb/Mar. For Limantol (2009), CWR of tomato in Saboba-Cheriponi are 1012.61 mm and 847.35 mm respectively during the period of Oct-Mar/April. Keraita and Drechsel (2007) also observed for vegetables grown in the field for 90-120 days, the crop water requirements ranged between 300 mm and 700 mm depending on the climatic conditions and the season of the crop at the location. The difference between the estimated values in this research and those of literature (Agodzo, 1998) and (Limantol, 2009) may be due to irrigation frequency, number of days, and the irrigation efficiency as well as the number of years of climatic data used in the estimation. A daily irrigation frequency was used in this research. In the savannah areas where ETc is very high, daily application is the appropriate frequency for vegetables if they are to look fresh and give good yield. However, daily frequency means higher CWR and IWR hence the above values. In view of water scarcity in the area, it would be prudent if the farmers use drip irrigation method with higher efficiency in order to reduce water wastage and hence low IWR. This will be best done by pumping water into overhead tanks especially where yields are very low. It will also reduce the labour intensiveness and drudgery of the traditional method of using watering cans.

4.7.4 Irrigation Potential of the Available Water

Considering the GIWR of tomato being 1217.39 mm (≈1.22 m), 1245.96mm (≈1.25 m) and 1228.90mm (≈1.23 m) in Savelugu-Nantong, Karaga and Gushiegu Districts respectively, it implies that to irrigate a hectare of tomato, the total amount of water required in each of the distrcits can be calculated as:

a) For Savelugu-Nantong District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.22 m ×10000 m^2 = 12200 m^3 /ha.

b) For Karaga District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.25 m ×10000 m^2 = 12500 m^3 /ha.

c) For Gushiegu District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.23 m ×10000 m^2 = 12300 m^3 /ha.

This pre-supposes that for the facilities in Savelugu-Nantong District, the current functioning facilities at Libga are capable of meeting domestic water demand and to irrigate about 1.67 ha of tomatoes, those at Bunglung can irrigate about 0.51 ha of the same crop whilst at Nabogu, irrigating about 0.23 ha is also possible.

For Karaga District the current functioning facilities at Nangunayili are capable of irrigating 0.67 ha of tomatoes and those at Nanduli can irrigate 0.69 ha of tomatoes. However, in Gushiegu District the only community that has the facilities capable of meeting domestic water demand and can irrigate about 0.55 ha of tomatoes is Limo community. The potential may be higher in all the three districts, if crops with lower CWR like okro, *ayoyo*, or other leafy vegetables are grown as well as upon repairs of the broken-down water facilities in the various communities.

According to Gyau-Boakye and Dapaah-Siakwan (2000), although the BH yields in the Voltaian System are relatively low compared with the Basement Complex and the Coastal Provinces which have yields ranging from 2.7-12.7 and 3.9-15.6 m^3/h respectively, the Voltaian System is less densely populated compared with those two other hydrogeologic units of Ghana. This simply implies that groundwater extraction in the Votaian System may be less.

4.8 Future Domestic Water Demand

4.8.1 Population Growth

Future population forecast is used to assess the level of future domestic water requirements and the vulnerability of various districts to water stress. Table 4.15 depicts future population growth of the three districts from 2000 to 2025 using equation 3.1.

Table 4.15: Projected Population Growth to the Year 2025

Districts	Communities	2000	2005	2010	2015	2020	2025
Gushiegu	Limo	882	1025	1191	1384	1608	1868
	Zinindo	2239	2601	3022	3511	4079	4739
	Gushiegu	13693	15909	18484	21475	24950	28988
	Gaa	1329	1544	1794	2084	2421	2813
Savelugu-Nantong	Savelugu	24937	28973	33662	39110	45439	52793
	Nabogu	960	1115	1296	1506	1750	2033
	Libga	476	553	643	747	868	1009
	Bunglung	665	773	898	1043	1212	1408
Karaga	Nangunayili	431	493	503	576	659	754
	Nanduli	279	319	365	418	478	547
	Pishigu	3414	3908	4473	5110	5849	6694
	Bagurugu	1664	1905	2180	2495	2856	3269

Ghana's population increased by 28.1% from 18,912,079 in 2000 to 24,223,431 in 2010. Annual intercensal growth rate in 2010 is 2.4%. Population density has increased from 79 in 2000 to 102 in 2010. Not all districts have shown the same rate of growth. In fact, the data presented in Table 4.14 indicates that the highest relative increase in population that is likely to occur during this period (2000-2025) is in the Savelugu-Nantong District which is closely followed by Gushiegu and Karaga Districts respectively. In fact, all the three districts have shown population growth in excess where it is observed that, the population may double during this period from 2000 to 2025.

4.8.2 Vulnerable of Districts to Water Stress

Vulnerability of a district to water stress is presented using the combined water availability-demand measure. Various districts are shown by per capita availability and demand.

Table 4.16: Vulnerability of Districts to Future Water stress in the Dry Season

Districts	Communities	Average water demand (l/c/d)	Projected population to 2025	Projected average domestic water demand per day (m^3) to the year 2025	Total available water per day (m^3)
Savelugu-Nantong	Savelugu	21.67	52793	1144.02	849.33
	Nabogu	22.11	2033	44.95	36.96
	Libga	22.22	1009	22.42	17438.08
	Bunglung	22.89	1408	32.23	5826.33
Gushiegu	Gushiegu	22.29	28988	646.14	278.8
	Gaa	21.00	2813	59.07	36.12
	Zinindo	21.71	4739	102.88	60.06
	Limo	20.57	1868	38.43	40.32
Karaga	Pishigu	19.13	6694	128.06	87.78
	Bagurugu	21.13	3269	69.07	10.92

Nangunayili	19.75	754	14.89	56.70
Nanduli	20.50	547	11.21	55.02

In Savelugu-Nantong District, Libga and Bunglung communities which are relatively small water users would not become vulnerable to water stress in 2025 due to large availability of water. However, three factors should be kept in mind:

- The balance of supply and use of water is based on district average domestic demand.
- Inter-year variations in water availability are not taken into account. It is conceivable that during low supply years, some districts may become vulnerable to water sources supply and availability and
- Seasonal variability in the availability of water and its use is also not considered.

From Table 4.16 it is obvious that districts endowed with large sources of water, such as those at Libga and Bunglung communities in Savelugu-Nantong District, may not face any serious vulnerability to water stress in 2025 due to the two existing irrigation dams and more stand pipe water facilities.

In communities, such as Limo, Gushiegu, Zinindo and Gaa in the Gushiegu District, water demand in 2025 may be higher than water supply. This situation has significant implications for their sustainable development in the future. Because the rate of water withdrawal would exceed the net recharge, mining of groundwater occurs, which may result, as suggested by Al-Ibrahim (1991) in a variety of problems including fast depletion of groundwater resources and deterioration of their quality. This would have serious socio-economic implications for the communities and the district as well. Unlike Pishigu and Bagurugu communities which may become vulnerable to water stress in 2025, communities like Nangunayili and Nanduli in Karaga District may not face water scarcities.

It is, however, shown in Table 4.16 that due to the existence of the two large irrigation dams at Bunglung and Libga communities with other stand pipes and groundwater facilities in Savelugu-Nantong District, it is the only district among the three districts that may not be vulnerable to water stress in 2025.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This Chapter presents the major findings, conclusions and recommendations from the analysis made in relation to the results for the study.

5.2 Summary of major findings

It is clear that in the Savelugu-Nantong, Karaga and Gushiegu Districts of the Northern Region, most of the people still do not have easy access to water. The average distance to the alternative water supply sources which include boreholes, hand dug wells public stand pipes and dams / dug-outs in the dry season in the three districts are 2, 2.5 and 3 km with corresponding average time of 6.7 , 7.1 and 7.2 hours for Savelugu-Nantong, Gushiegu and

Karaga Districts respectively. This did not only hinder effective water supply to the communities but had a negative impact on the status of women and children who are responsible for collecting water. This is because people travelled a distance of more than 1km or spend more than 30 minutes to collect water in the dry season and to carry it on their heads. The means with which they transport water to their households raises more concerns especially on water quality even though some of the inhabitants are using improved water sources such as stand pipes, boreholes and hand dug wells fitted with pumps.

There was congestion and frequent breakdown of boreholes making it quite hard fetching water because of long queues, with most of the boreholes having poor yield, salty taste and inconvenient siting or location (siting facilities far away and in waterlogged areas) especially in Karaga and Gushiegu Districts. As a result most people resorted to unsafe traditional water sources, which expose the household members to water borne diseases.

It is significant that public stand pipes had a positive impact in Savelugu-Nantong and Gushiegu Districts in terms of reducing the distance travelled. But this is limited to those households who lived closer and could afford to buy water from these facilities.

The study also showed that lack of sanitation facilities, poor hygiene and poor sanitation practices have been the cause of the high prevalence of water related diseases which increases general mortality and socio-economic losses in the three districts. However, Savelugu-Nantong District in comparison with Karaga and Gushiegu Districts was better in terms of hygiene and sanitation practices because only one borehole was identified as having been sited in a place having poor sanitation in the Savelugu-Nantong District.

It was found that ineffective water supply in the three districts has affected many economic activities which involved intensive use of water. This has also discouraged many women to engage in different economic activities especially in the driest periods of the year.

Rapid population growth in the three districts has brought forth a situation of water stress and water scarcity. This conclusion was drawn from the results in Table 4.16. Vulnerability problems are also faced by Karaga and Gushiegu Districts. However, under present trends of water use and population growth, vulnerability to water resources would be faced by Karaga and Gushiegu Districts in 2025 than at present.

The research identified that dugouts were found to have been poorly engineered. There are two types of failure identified on all of them: overtopping failures and structural failures. The dugouts also need dredging and closing of embankments towards human settlements as well as prevention of encroachment by settlement structures.

It was also found out that almost all the groundwater facilities in Savelugu-Nantong District have high water table with high water yield while many groundwater facilities in Karaga and Gushiegu Districts have low watertable with poor yield because the providers did not consult these communities in siting and location of the water facilities and this has affected the sustainability of the systems. It was also identified that lack of a sense of ownership had affected the communities support for management and the sustainability of the water systems.

The study also found that some water facilities in the communities in the three districts were capable of meeting the people's domestic needs and for small scale dry season vegetable irrigation.

5.3 Conclusions

The study focused mainly on water consumption for domestic and small scale rural industrial activities, future domestic water demand, potential for small scale irrigation and operational sustainability of rural water sources in Savelugu-Nanton, Karaga and Gushiegu Districts in the Northern Region. In relation to domestic and small scale rural industrial activities, the research revealed that availability, quality and access of rural water sources had influence on domestic and rural industrial activities in the three districts. With regard to domestic water consumption, the water sources contributed to reducing the drudgery associated with fetching water for domestic activities. In terms of small scale rural industrial activities, the water sources contributed to the establishment of small scale businesses such as *pito* brewing, rice milling and shear nut processing. The contribution of rural water sources to the activities outlined was in terms of increasing the geographical access of the communities to water. Health wise results of this research have shown that the provided rural water supply sources in the three districts have had insignificant health impacts on rural communities as a result of poor sanitation and hygiene practices in the three districts.

About two-thirds of the population of the studied areas representing two districts (Karaga and Gushiegu) may become more vulnerable to availability and use of water under current projections of population growth as shown in Table 4.16. Under population growth, more people would face water management problems and water stress or water scarcity.

The determination of the yields of the water sources revealed a potential of some facilities for small scale irrigation. However, limited attempts were made in that regard due to lack of awareness of the potential.

The community members in the three districts made comments and proposal for sustainable water source management and maintenance. These comments are relevant for all the stakeholders in water supply and management in the Northern Region. The respondents on behalf of all the community members requested the government to provide spare parts and water guard outlets in the community, train members and give them toolkits to take care of the maintenance of boreholes. They also said that there was the need to build community capacity and initiatives on maintenance. This can be achieved through training and strengthening of the water user committee. They acknowledged the role played by the WATSAN Committee but some of them remarked that most WATSAN Committee were not very active and therefore they needed to be active, if not, new committee members would be elected.

They advocated for local participation in the maintenance of the water source. This was mainly through women empowerment in water source management. They said that women should not just be members but also be actively involved in the decision making process. By-laws on the maintenance of the water sources should be set. They said that this should be done by the government because if left to the community, people will undermine it, therefore the districts should take the responsibility of introducing by-laws.

They also demanded for more water sources especially stand pipes as they are the main reliable source of clean and safe water and also one does not have to use much energy as in the case of boreholes during the dry seasons. They added that stand pipes were too expensive for the community members to construct by themselves and therefore government, NGOs and donors should help in the construction and then the community members can contribute for maintenance. They also said the committee members should properly account for the funds collected from the community on operation and maintenance. They also urged for the reconstruction of traditional wells by protecting and fencing to greatly improve water quality and reduce the risk of accidents and water borne diseases. There was also the need for community mobilization and sensitization to give technical advice to the management teams and the entire community.

5.4 Suggestions for future improvement

Special emphasis should be laid upon the active involvement of women by giving priority to their needs and ideas in the planning, implementation and management of the water projects in these communities.

- Build community capacity and initiatives on maintenance through training and strengthening of water user committee
- Local participation on the maintenance of the water source
- Educating and subsidising rainwater harvesting facilities to support rainwater harvesting in large quantities.
- People in Savelugu-Nantong, Karaga and Gushiegu Districts should be provided with stand pipes which was their desire because they are reliable and can provide

clean and safe water without using much energy as in the case of boreholes. Supporting the communities' desire will significantly increase access to clean water at the household level.

- Women need to be involved in top management positions especially as main leaders and financial controllers and they also need to be motivated. However, this can only be possible if clear policies and guidelines are strengthened through community based management systems to empower women.
- Construction of wells

5.5 Recommendations

- To effectively come up with more reliable estimates of water consumption for domestic and small scale industrial activities, it is recommended that future studies employ actual (observed) quantities of water consumed on these activities.
- Research is further needed to establish the actual average distances to various water sources using the theodolite and time spent on these facilities in the districts. This will be essential for public health reason.
- Because the production and delivery of improved water to rural households is costly, future studies could investigate and find solutions to this questions: What is the willingness to pay for improved water supply?

REFERENCES

Agodzo, S. K. (1998). *Water management study of six selected irrigation projects in Ghana*. Development of support Structure for Irrigated Agriculture. FAO-GIDA Project No. TCP/GHA/6613T. Kumasi, Ghana. 109p.

Al-Ibrahim, A. A. (1991). *Excessive Use of Groundwater Resources in Saudi Arabia:* Impacts and Policy Options, Ambio, Saudi Arabia. 20:34-37pp.

Appiah, I. (2008). *Govenment tackles water issue*, Ghanaian Times. Accra, Ghana. [http://www.newtimesonline.com/index.php?option=com_contents&task=view&id=14378&Itemid=181&month=2&year=2008], (accessed 20th September,2011).

Asare, Y. B. O. (2004). *Household Water Security and Demand in the Volter Basin of Ghana*. [Master's Thesis], Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. 52p

African Water Development Report (AWDR). (2006). Water for Sustainable Socio-EconomicDevelopment. [http://www.uneca.org/awich/AWDR%202006/Introduction%20%20Water%20for%20Socio-Economic%20Development.pdf], (accessed 14th October, 2011).

Biswas, A. and Tortajada, C. (2002). *Impact Evaluation of Greater Colombo Water Supply Project*, Third World Centre for Water Management. Colombo, Sri Lanka 50p.

Brouwer, F, and M. Falkenmark (1989). *Climate- Induced Water Availability Changes in Europe.* Environmental Monitoring and Assessment. New York: Academic Press. 13:75-98pp.

Community Water and Sanitation Agency (CWSA). (1997). *Manual for District Water and Sanitation Teams*. Accra, Ghana. 3p.

Community Water and Sanitation Agency (CWSA). (2004). *Strategic Investment Plan 2005-2015*. Community Water and Sanitation Agency, Accra, Ghana [<http://www.cwsagh.org/documents/SIP 2005-2015.pdf], (accessed 8th December, 2011).

Community Water and Sanitation Agency (CWSA). (2008). *Corporate Brochure*. Community Water and Sanitation Agency, Accra, Ghana. p. 4.

Community Water and Sanitation Programme (CWSP, 1993). Capacity Building of Local and Central Government Institutions. Sher-e-Banglar Nagar, Dhaka, Senegal. [<http: // www.cwsp.org], (accessed 14th August, 2011). 2p

Demeken, A. (2009). *Determinants of Household Participation in Water Source Management*: Achefer, Amhara Region, Ethiopia [Master‟s Thesis]. Cornell University, Ithaca, NY. USA. 21-24pp.

Doe, H. W. (2007). *Assessing the Challenges of Water Supply in Urban Ghana: The case of North Teshie* . (EESI Master Thesis). Stockholm: Department of Land and Water Resources Engineering, Royal Institute of Technology. Stockholm, Sweden. [http://www.1wr.kth.se/publikationer/PDF Files/LWR EX 07 06.PDF.], (accessed 14th October, 2011). 1-2pp

Food and Agricultural Organisation (FAO). (2008). Ghana Country Overview. FAO. [http://www.definethis.org/word/Water supply and sanitation in Ghana.html]. (accessed 10th November, 2010).

Fecade, W. (1994). *Local Departments of Development Sustainability*. A Study of Development Projects in Tanzania, SPRING Centre, Series No.7, University of Dortmund. Dortmund, Germany. 217p.

Ghana Water Resources Commission (GWRC). (2008). *National Water Policy*. GWRC, Accra, Ghana [http://www.wrcgh.org/nationalwaterpolicy.html]. (accessed 12th October 2011).

GhanaWater Resources and Environmental Sanitation Project (GWRESP). (2008). *Water Supply and Sanitation in Ghana*. Ghanaian Water Resources and Environmental Sanitation Project, Accra, Ghana. [http://www.wresp.org/wsesingh.php#history]. (accessed 10th August, 2011).

Global Water Partnership (GWP). (2000). Integrated water resources management, Global Water partnership. Stockholm, Sweden.

GSS (Ghana Statistical Service). (2010). Population and housing census. Summary report on provisional results. Medialite Co. Ltd. Accra.

Gulik, V. (2003). *Farm Water Storage*. Ministry of Agriculture, Food and Fisheries, Abbotsford, B.C. Canada vol. 3: 4p.

Gyau-Boakye, P. and Dapaah-Siakwan, S. (1999). *Groundwater: Solution to Ghana's Rural Water Supply Industry*? Water Resources Research Institute (CSIR), Accra, Ghana. [http://home.att.net/africantech/GhIE/ruralwtr/ruralwtr.htm]. (accessed 13t August, 2011).

Gyau-Boakye, P. and Dapaah- Siakwan, S. (2000). Hydrogeologic frame work and borehole yield in Ghana. *Hydrogeology Journal, Water Resources Research Institue (CSIR), Accra, Ghana*. 8: 405-416pp.

Gyau-Boakye, P. (2001) *Sources of rural water supply in Ghana*. Water International, International Water Resources Association, 26(1): 96-104pp.

IAH Burdon Groundwater Network. (2007). Groundwater *and Rural Water Supply inAfrica* IAH Burdon Groundwater Network. [http://www.iah.org/downloads/occpub/IAH_ruralwater.pdf], (accessed 10/06/2011).

IFFM (International Fact-Findint Mission, 2002). Report of the International Fact-Finding Mission on Water Sector Reform in Ghana. Centre for Economic and Social Rights, Ghana.

Karikari, K. (1996). *Water Supply and Management in Rural Ghana: Overview and Case Studies*. [www.idrc.ca/books/focus/804/chap12.html], (accessed 16th August, 2011).

Karikari, K. (2000). *Water supply and management in rural Ghana: Overview and case studies*. In "*Water Management in Africa and the Middle East. Challenges and Opportunities*" (Edited by E. Rached, E. Rathgeber, and D.B. Brooks, Eds). IDRC, Ottawa, Canada. 25-31pp

Keraita, B.N. and Drechsel, P. (2007) *Agricultural Use of Untreated Urban Wastewater in Ghana*. International Water Management Institute (IWMI), West African Sub-Regional Office, Accra, Ghana. [http://www.idrc.ca/en/ev-68337-201-1-D0 TOPIC.html]. (accessed 4th July 2011)

Komives, K, Akanbang, B., Thorsten, R., Tuffuor, B., Wakeman, W., Larbi, E., Bakaian, A. and Whittington, D. (2008) "*Post-construction Support and the Sustainability of Rural Water Projects in Ghana*". Paper presented at the 33rd WEDC International Conference-Access to Sanitation and Safe Water: Global Partnerships and Local Actions., Ghana. p.2.

Kulshreshtha, S. N. (1993). *World Water Resources and Regional Vulnerability: Impact of Future Changes.*[Master's Thesis], University of Saskatchewan, Laxenburg, Australia. 7p.

Limantol. A.M (2009). *Impats of rural Water Supply Systems in Farming Communities* [An Unpublished Master's Thesis], Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Luijtena, J.C., Knapp, E.B. and Jones, J.W. (2001). *A tool for community-based assessmentof the implications of development on water security in hillside watersheds, AgriculturalSystems*, 70, 603–622 pp

London Economics (1999). Ghana urban water sector-willingness and ability to pay, demand assessment and tariff structure study, Final report, July 1999.

Northern Region Poverty Reduction Programme (NORPREP). (2007). *WATSAN Training of Trainers Programme for DWST in the Yendi Zone*. NORPREP, Tamale, Ghana. 9-23 pp.

Nicholas, C. (2005). *Challenges to clean water worldwide. America Geological Institute, America.* Retrieved November 20, 2011, [http://www.geotimes.org/may05/feature_worldwater.html], (accessed 20 November, 2011).

Nyarko, K. B. (2004) *"Institutional challenges for small towns' water supply delivery in Ghana", in Chaoka*, T. R. et al., Water Resources of Arid and Semi Arid Regions, International Conference, London: Taylor and Francis Group, pp. 217-226.

Nyarko, S. (2008). *Winning the war against Guinea Worm under the MDGs: A myth or reality*? Ghana's The Stateman's newspaper of Thursday, 2 nd April, 2009.

Organisation for Economic Co-operation and Development (OECD). (2007). African Economic Outlook 2007-Ghana Country Note. [http://www.oecd.org/dataoecd/26/51/38562673.pdf], (accessed 4th October 2011)

Ogunnowo, C. O. (2004). Coping With Domestic Water Supply Problems in NigerianUrban Centres: The Ijebu-Ode City Experience. *International Journal of Environmental Issues* 2(1): 201-205pp.

Rockström, J. (2001). Green water security for the food makers of tomorrow: windows of opportunity in drought-prone savannahs.*Water Science & Technology*, 43 (4), 71–78 pp.

Rosen, S. and Vincent, J.R. (1999). *Household water resources and rural productivity in Sub-Saharan Africa*: a review of the evidence, Development discussion paper No. 673, Harvard Institute for International Development, Harvard University.

Seckler, D., Barker, R., Amarasinghe, U. (1999). Water scarcity in the twenty-first century.*Water Resources Development*, 15, 29–42 pp.

Shaw, R, G. Gallopin, P. Weaver, and S. Oberg. (1991). *Sustainable Development: A System Approach*, Working Manuscript, Laxenburg, Austria.

Stanhill, G. (1982). The World Water Problem.In *The Search for Absolute Values and the Creation of the New World.* New York: *The International Cultural Foundation Press.*

Sutton, S. (2008), *The risks of technology-based MDG indicator for rural water supply*, [www.rwsn.ch], (accessed 10th October, 2011).

Swaminathan, M.S. (2001). *Ecology and Equity: Key Determinants of Sustainable Water Security, Water Science and Technology*, 43 (4), 35-44 pp. Water Security for 21stCentury-Innovative Approaches, the 10th Stockholm Water Symposium, August 14-17,2000.

Symons, J.M., Bradley, L. C. Jr., Theodore, C. C. (2000). *The Drinking Water Dictionary,* American Water Works Association. p. 468.

Tay, V. (2005a) *The Poverty Millennium Development Goal: What water, sanitation and hygiene can do for Ghana?* Country Note 1.1, TREND, Kumasi, Ghana. pp. 1-4.

Tay, V. (2005b). *The Education Millenium Development Goal: What water sanitation and hygiene can do for Ghana*? Well Country Note 2.1, TREND, Kumasi, Ghana. 1-4 pp.

Thematic Group. (2005). *Scaling Up Rural Water Supply; A framework for achieving sustainable universal coverage through community management* [on line]. Thematic Group [http://www.scalingup.watsan.net], (accessed 10th January 201).

TREND (2007). *Contribution and lessons of decentralised management of rural water to decentralisation in Ghana* "Institute of Local Government Studies Conference on Decentralized Management in the Context of GPRS and MDBS" [on line]. TREND, Kumasi, Ghana [cited 9th July 2008]. http://www.discap.org/Publications/Ghana_Decentralised_Mngmnt_of_Water_Discap

UNDP (United Nation Development Programme) 2005. *Millennium development goals* www.undp.org/mdg/goal7

UNDP (United Nations Development Programme) 2006. Human Development Report-Average water use per person per day. [www.data360.org], (accessed 30/08/2011).

United Nations (2004). Freshwater Country Profile: Ghana. [http://www.un.org/esa/agenda21/natlinfo/countr/ghana/waterghaa04f.pdf] (accessec 8th July 2011)

UN (United Nations) (2008). The Millennium Development Goals Report 2008. [www.un.or./milleniumgoals/pdf/mdg2007.pdf], (accessed 20/08/2010).

Water Aid Ghana. (2003). *The Newsletter of WaterAid-Ghna Programme*,Dawuro, 1(3):4-10.

Water Aid Ghana. (2005a). *The Newsletter of WaterAid-Ghana Programme*, Dawuro, No.11, 49pp

Water Aid Ghana (2005b) *Assessment of National Sanitation Policies: Ghana case*. Final Report . Accra, (Ghana [assessed 30th November, 2011).

[http://wedc.1boro.ac.uk/projects/proj_contents0/WEJEH%20Sanitation %20Policy/www/outputs/Ghana%20Policy%20Assessment%20Report.pdf]. Ghana

Water Aid (2005c) *National Water Sector Assessment*, Ghana,WaterAid, London, UK. . 2-6pp Ghana

Water Aid (2006). Reducing guinea worm in Ghana. WaterAid, Durham Street, London, SE11 5JD, UK. [http://www.wateraid.org/international/what_we_do/where_we_work/ghana/4728.asp], (accessed 15th February, 2011).

WHO. (1996). Water and Sanitation, Fact Sheet No. 112. WHO. [http://www.who.org/inf/fa/fact 112 html], (10th MAY, 2011).

World Resources Institute. (2000). World Resources 2000–2001. People and Ecosystems: The Fraying Web of Life. World Resources Institute, Washington.

APPENDICES

APPENDIX A: QUESTIONNAIRE FOR HOUSEHOLD RESPONDENTS

(A) BACKGROUND INFORMATION

1a. Location ………………………………………………

2a. Age i) 10 - 20 ii) 21-30[ ] iii)31-40 [ ] iv)41-50 [ ] v)51-60 [ ] vi)61and above [ ]

3a. Sex: i) Male [ ] ii) Female [ ]

4a. Educational Status: i) None [ ] ii) Primary [ ] ii) Junior high [ ]

iii) Senior high [ ] (iv) technical [ ] v) Tertiary [ ] vi) Others (specify) ……………

5a. Major occupation/profession ....

6a. Religion i) Christian [ ] ii) Islam [ ] iii)Traditional[ ] v) Others (specify) ………..

7a. Number of years lived in the community..

8a. How many persons live in your household………………………………………

9a. How many are :Below 18years……….., above 18 years………….

10.a What are the main sources of income in your household?

i) Farming [ ] ii) Fishing [ ] iii) Trading [ ] iv) Others (specify) …………………..

11a.What is the average monthly income of your household in all?

i) Gh¢ i) > Gh¢100 ii) Gh¢ 100 – 200 [ ] iii) Gh¢ 200 – 300 [ ] iv) Gh¢ 300 – 400 [ ] (v) < Gh¢ 400 [ ]

(B)WATER SOURCES

Note the following abbreviations used: BH = Borehole, HDW = Hand-dug well

1b. What is/are your source(s) of water supply in the rainy season? i) BH [ ] ii) HDW [ ] iii) Dam/Dug-out [ ] iv) Rain Harvest [ ] v) River [ ] vi) Stream [ ] vii) Small water system [ ] viii) Others (specify)

2b. Why do you use the source(s) chosen in the rainy season?

i) It is easily accessible (not far from my house) [ ] ii) I do not waste time in this source []

iii) I do not spend money on water from this source iv) It is free from germs or safe [ ]

v) The water taste and smells good [ ] vi) Spiritual reasons [ ]

vii) Others (specify)……………………………………………………………………………

3b. What is /are your source(s) of water supply in the dry season? i) BH [ ] ii) HDW [ ]

iii) Dam/Dug-out [ ] iv) Rainwater harvest [ ] v) River [ ] vi) Stream [ ]

vii) Small water system [ ] viii) Others (specify)………………………………

4b. Why do you use the source(s) chosen in the dry season?

i) is easily accessible (not far from my house) [ ]iv)I do not waste time at this source []

ii) I do not spend money on water from this source [ ] v) It is free from germs or safe [

iii) The water tastes and smells good [ ] vi) Spiritual reasons [ ]

viii) Others (specify) ....

5b. Would you say the source of water you mainly depend on serves all your water needs throughout the year? i) Yes [ ] i) No [ ]

6b. If no why does it not serve you throughout the year? ………………………………

5b. Do you face seasonal water shortages? i) Yes [ ] ii) No [ ]

7b. If yes, during what season do you face the shortage?

i) Dry Season [ ] ii) Rainy Season [ ] iii) Other, (specify)………………….

8b. How do you cope or manage with the water situation during periods of water shortage? …………………………..…………………………………….

(C) WATER SUPPLY AND DOMESTIC ACTIVITIES

1c. How much water do you use in your household on the following activities? Please specify in gallons per day.

Activity	Rainy season (gallon/day)	Dry season (gallon/day)
Drinking		
Cooking		
Washing		
Bathing		
Others (specify)		

2c. Do you pay for using water? i) Yes [ ] ii) No [ ]

3c.If yes, how often?

i) Every time [ ] ii) Sometimes [ ] iii) Rarely [ ] iv) I don't know

4c. How much does the household spend in a day on water for the whole household's domestic water consumption? GH¢ ……..........

5c. How long (minutes, hours, etc) does it take you in a day to fetch all the water you need for the house during the dry season? ....

6c.How long (minutes, hours, etc) does it take you in a day to fetch all the water you need for the house during the rainy season?...

7c. How many round trips do you make in a day before you can access all the water you fetch for use in a day during the dry season? ....

8c.How many round trips do you make in a day before you can access all the water you fetch for use in a day during the rainy season? ………………………………………………

9c.How far do you travel to obtain water?

i) I don’t travel since I have in-house water supply facilities [ ]

ii) Less than 100 metres [ ] iii) 100 – 200 metres [ ]

iv) 200m – 1 Km [ ] v) Beyond 1 Km [ ]

WATER SUPPLY AND ECONOMIC ACTIVITIES

D) Small scale Industrial Activity Water Demand

1d. Which of the following activity do you use water for?

i) Pito brewing [ ] ii) Agro-processing like shear nut processing [ ]

iii) Rice milling, iv) Others, (specify)...

2d. How many '*Garawa'* of water do you use in a day for these activity? ....

3d. Do you pay for using the water? i) Yes [ ] ii) No [ ]

4d. If yes how much do spend in a day on water for the activity? GH¢ ……….........

3d. If no (to Q.1d), what is/are your reason(s) for not engaging in such activities?

i) No adequate water [ ] ii) Lack of time due to other activities [ ] iii) Do not consider it profitable [ ] iv) Others, (specify)……………………………………………………..

E) Agricultural Water Demand (Irrigation and Livestock Water Use)

1e. Do you practice irrigation farming? i) Yes [ ] ii) No [ ]

2e. If yes what type of crop(s) do you cultivate? ………………………………………

3e. How many acres of land do you use for the farming activity? ……………………

4e. How many ‘Garawa’ of water per day do use for irrigation in the:

i) dry season a) ………………… ii) rainy season b) …………………

5e. Do you pay for the use of the water? i) Yes [ ] ii) No [ ]

6e. If yes, how much do spend in a day on water for the activity? GH¢ ………...........

7e. If no (to Q. 1e), what is/are your reason(s) for not engaging in such activities?

i) No adequate water [ ] ii) Lack of time due to other activities [ ]

iii) Do not consider it profitable [ ] iv) Others, (specify) …………………

H) MAJOR FACTORS AFFECTING THE MANAGEMENT AND SUSTAINABILITY OF WATER SOURCES IN THE COMMUNITIES (BH, HDW AND DUGOUTS)

1h. How many boreholes do you have in the community?

i) 1 [ ] ii) 2 [ ] iii) 3 [ ] iv) 4 [ ] v) 5 and above [ ] vi) None [ ]

2h. How many hand-dug wells do you have in the community?

i) 1 [ ] ii) 2 [ ] iii) 3 [ ] iv) 4 [ ] v) 5 and above [ ] vi) None [ ]

3h. Have these facilities been helpful to your community? i) Yes [ ] ii) No [ ]

4h. Give reason(s) to your answer in (Q.3h) ………………………………………...

5h. Who owns the water facility?

ii) District assembly [ ] iii) The community [ ] iv) NGO'S [ ]

v) Religious body [ ] vi) Other (specify)…………………………………………….

6h. Have the hand dug wells properly covered? i) Yes[ ] ii) No [ ]

7h. Have the borehole(s) ever broken down? i) Yes [ ] ii) No [ ]

8h. If yes, how often does this water facility breakdown in this community?

i) Daily [ ] ii) Weekly [ ] iii) Monthly [ ] vi) Others, (specify)..............................

9h. How long does it take for a broken down borehole to be repaired? ……………………

10h. Give reason(s) to your answer (in Q 10h) ……………………………………….

11h. Who repairs the water facility when it breaks down?

i) Hired personnel [ ] ii) Those who provided them [ ] iii) Community Members [ ]

1 2h. Who bears the cost of repairs?

i) The providers [ ] ii) The community [ ] iii) Others (specify)…………………

13h.What is the cause of the breakdown of the borehole(s)? ………………

14h. To what extent can you say that the water facility site is hygienically kept in this community? i) Good [ ] ii) Very good [ ] iii) Poor [ ] iv) Very poor [ ]

15h. What is/are your source(s) of funds for the maintenance and management of the water facilities in the community?

i) Contributions [ ] ii) Earnings from community farm [ ]

iii) Funds raised from sale of water [ ] iv) Others, (specify)..........................

16h. Do you get enough funds for the maintenance of the water facilities? i) Yes [ ] ii) No [ ]

17h. If no, how do you make for the short fall? …………………………………………

18h. How does this affect the maintenance of the facilities? ……………………………..

19h. Do you face problems in the maintenance of the facilities? i) Yes [ ] ii) No [ ]

20h. If yes, enumerate these problems …………………………………………………

21h. What efforts are being made by the community to combat the problems you have identified? ……………………………………………………………………………

22h. Do you have access to spare parts for maintenance of the boreholes? i) Yes [ ] ii) No [ ]

23h. Do the community assist in the maintenance of the boreholes? i) Yes [ ] ii) No [ ]

24h. If no, why? ……………………………………………………………

25h. How often is routine maintenance carried out?

i) Daily [ ] ii) Weekly [ ] iii) Monthly [ ] iv) Yearly [ ] v) When it breaks [ ]

26h. Who does the routine maintenance?..

27h. How many dams/dugouts do you have? ………

28h. Do the dams/dugouts completely dried out? i) Yes [ ] ii) No [ ]

29h. If yes, how many get dried and in what season? ………………………………….

30h. Have you ever dredged any of the dams/dugouts? i) Yes [ ] ii) No [ ]

31h. If yes when was the last time? i) Last year ii) Two years ago iii) Others (specify) ……

32h. Is the upstream of the dams/dugouts open to the community? i) Yes [ ] ii) No [ ]

33h. If yes do you think the rain washes sand and other materials from the community into the dams/dugouts? i) Yes [ ] ii) No [ ]

34h. Do you have trees planted around the dams/dugouts? i) Yes [ ] ii) No [ ]

35h. Do they practice bush burning around the dams/dugouts? i) Yes [ ] ii) [ ]

36h. Do they fish in dams/dugouts? i) Yes [ ] ii) No [ ]

37h. If yes, by what method(s)? i) Hook and line ii) Net [ ] iii) Others (specify) …………

38h. Who manages the water facilities? ……………………………………………………..

39h. What are the duties and responsibilities of the management team? …………………………

40h. What roles do the community play in the management of the water facility/water point?...

41h. From all what you have said, can you say that the water facilities are well managed and maintained in this community? i) Yes [ ] ii) No [ ]

42h. If no, what ways would you suggest to ensure proper management and maintenance of water facilities in the community? …………………………………………………………………

APPENDIX B: INTERVIEWS WITH MANAGERS OF WATER AND SANITATION (WATSAN) COMMITTEE

B.1 WATSAN Committee

NAME OF COMMUNITY ……………………………………………………………

FACILITY AND OWNERSHIP

1. How many boreholes do you have in the community? ……………..
2. How many are not functioning? ……………………………
3. How many hand-dug wells do you have in the community? ………………
4. How many are not functioning? ……………
5. How helpful have these facilities been to the community? …………………………
6. Who owns these water facilities?..

7. **REPAIRS AND MAINTENANCE**

8. How often does the water facility breakdown in this community? …………………
9. What is the cause of the breakdown of the water facility? ……………………………

10. How long does it take for a broken down hand pump to be repaired? ……………….

11.Who repairs the water facility when it breaks down?...

12. Averagely how much does it cost to repair your broken down facility? ....

13. Who pays for the cost of repairs and general maintenance of the facility? …………

14. Who does the routine maintenance and how often is it carried out? ………………

15. What sort of training has the maintenance team received? …………………………

16. Do you have any problems in respect of maintenance of the facilities? i)Yes [ ] ii) No [ ]

17. If yes, enumerate them...

18. What efforts have you made to combat these problems? …………………………

19. Do the members assist in the maintenance of the facilities? Yes[ ] No [ ]

20. If no, why? ………………………………………………………………………

SANITATION

21.Who are responsible for ensuring good sanitation at the facility site? ………………

22.Have they been trained on sanitation promotion? Yes [ ] No [ ]

23.What do you think constitutes good sanitation or hygiene at the water facility site?

……………………………………………………………………………………………

.24.What measures have been taken by the sanitation team to ensure good sanitation at the water facility site?

……………………………………………………………………………….

25.How often do they weed and clean around the water facility site? …………………

26. Do people wash at the site of the water facility? Yes [ ] No [ ]

27. Do people farm around the site of the water facility? Yes [ ] No [ ]

28. Do you think the application of chemicals, washing and flow of dirt to the immediate surroundings of the water facility can affects it? i) Yes [ ] ii) No [ ]

29. Give reason(s) to your answer in (Q.27) ……………………………………………

30. Do you think that the facility site is hygienically kept always in this community? …...

31. How many dams/dugouts do you have? ………

32. Do the dams/dugouts completely dried out? i) Yes [ ] ii) No [ ]

33. If yes, how many get dried and in what season? ………………………………….

34. Have you ever dredged any of the dams/dugouts? i) Yes [ ]   ii) No [ ]

35. If yes when was the last time? i) Last year ii) Two years ago iii) Others(specify) ………

36. Is the upstream of the dams/dugouts open to the community? i) Yes [ ] ii) No [ ]

37. If yes do think the rain washes sand and other materials from the community into the dams/dugouts? i) Yes [ ]   ii) No [ ]

38. Do you have trees planted around the dams/dugouts? i) Yes [ ]   ii) No [ ]

39. Do they practice bush burning around the dams/dugouts? i) Yes [ ]   ii) [ ]

MANAGEMENT

39.What are the duties of the management team? ……………………………………

40. Does the community respect the work of the committee and give them the necessary support? ……………………………………………………………………………….

41.Can you say that water facilities are well-managed and maintained in this community?

42. What other ways would you suggest to ensure proper management and maintenance of water facilities in the community? ……………………………………………………….

43What is the expected role of the community members? ……………………………….

44.How often do you assess the performance of the management team and the facilities? …

45 How often is the routine maintenance on the water facility supposed to be carried out? ……………………………………………………………………………………………

46.How do you assist in the repairs and maintenance of the facilities? …………………

APPENDIX B2: INTERVIEWS WITH GROUP OF ECONOMIC ACTIVIST

1. Do you use water for any economic activity? i) Yes [ ] No [ ]

2. If yes, what kind of economic activity do you operate?

i) Pito brewing [ ]   (ii) Agro-processing like shear nut processing [ ]

iii) Rice milling [ ]   iv) Others, (specify) …………………………………………………

3.How many are you in a group? ……………………………………………………………

4. How many garawa of water do you use in a day for these activities? ……………………

5 Do you pay for the use of the water? i) Yes [ ]   ii) No [ ]

6 If yes, how much do spend in a day on water for the activity? GH¢………………………

7. How would you described your water supply for the activities in (Q.2)

8. Do you practice any agricultural activities using water in your community? i) Yes [ ]

ii) No [ ]

9. If yes, what agricultural activity do you practice?

i) Aquaculture [ ] ii) Crop irrigation [ ] iii) Others, (specify)………………………………

10.If crop irrigation, what type of crop do you cultivate?

i) Tomatoes [ ]   ii) Pepper [ ] iii) Okro [ ]   iv) Garden eggs [ ] v) Others, (specify) …

11. How many Garawa of water do you use in a day for this activity? ……………………

12 What is your source of water for this activity?

i) Boreholes [ ] ii) Hand-dug well [ ] iii) Dug-outs [ ] iv) River[ ] iv) Others, (specify)……

13.How many acres of land do use for the farming activity?   ……………………………

14.Do you pay for the use of the water? i) Yes [ ] ii) No [ ]

15.If yes, how much do you in a day on water for the activity? GH¢………………………

16. How would you describe your water supply for the activities in

i) Very sufficient [ ] ii) Quite sufficient [ ] iii) Insufficient [ ]

17. What is the expected yield of the crop(s) in kilogram?

18. How you describe the yield of the crop (s)? i) Good ii) Average iii) Bad

APPENDIX C: CROP WATER REQUIREMENT FOR TOMATOES IN THE THREE DISTRICTS

C.1 Crop Calendar for Tomato (*Lycopersicon esculentum*)

Crop development stage	No. of days	Date	Kc
Initial	35	15th Oct-18th Nov	1.05
Crop development	45	19th Nov-2nd Jan	1.054
Mid season	70	3rd Jan- 13Tth Mar	1.15
Late season	30	14th Mar-12th April	0.90

C.2: Estimation of Crop Water Requirement of Tomatoes (*Lycopersicon esculentum*) in Savelugu-Nantong District

Months	ETo (mm/d)	Kc	ETc (mm/d)	No. of days	ETc /month	Effective rain fall (ρe) in mm/ month
October	4.44	1.05	4.67	17	79.39	70.04
November	4.55	1.05	4.78	30	143.4	4.49
December	4.84	1.10	5.32	31	164.92	2.19
January	5.14	1.12	5.76	31	178.56	1.67
Februay	6.01	1.15	6.91	28	193.48	3.59
March	6.16	1.00	6.16	31	190.96	12.07

April	5.95	0.90	5.36	12	64.32	68.81
Total				180	1015.03	173.86

Kc, ETo and Pe were derived using 30 years climatic data from meteorological station.

Pe = 0.8ρ where the mean monthly rainfall, ρ > 75mm /month and

Pe = 0.6ρ where the mean monthly rainfall, ρ < 75mm /month

Irrigation water requirement (IWR) = Etc/month – ρe = 1015.03 – 162.86 = 852.17 mm

C.2: Estimation of Crop Water Requirement of Tomatoes (*Lycopersicon esculentum*) in Karaga District

Months	ETo (mm/d)	Kc	ETc (mm/d)	No. of days	ETc /month	Effective rain fall (ρe) in mm/ month
October	4.44	1.05	4.67	17	79.39	67.69
November	4.55	1.05	4.78	30	143.4	1.65
December	4.84	1.10	5.32	31	164.92	0.65
January	5.14	1.12	5.76	31	178.56	0.48
Februay	6.01	1.15	6.91	28	193.48	1.15
March	6.16	1.00	6.16	31	190.96	6.59
April	5.95	0.90	5.36	12	64.32	64.65
Total				180	1015.03	142.86

Irrigation water requirement (IWR) = Etc/month – ρe = 1015.03 – 142.86 = 872.17 mm

C.2: Estimation of Crop Water Requirement of Tomatoes (*Lycopersicon esculentum*) in Gushiegu District

Months	ETo (mm/d)	Kc	ETc (mm/d)	No. of days	ETc /month	Effective rain fall (ρe) in mm/ month
October	4.44	1.05	4.67	17	79.39	72.78
November	4.55	1.05	4.78	30	143.4	1.86
December	4.84	1.10	5.32	31	164.92	0.91
January	5.14	1.12	5.76	31	178.56	0.44
Februay	6.01	1.15	6.91	28	193.48	1.57
March	6.16	1.00	6.16	31	190.96	9.53
April	5.95	0.90	5.36	12	64.32	67.71
Total				180	1015.03	154.80

Irrigation water requirement (IWR) = Etc/month – ρe = 1015.03 – 154.80 = 860.23 mm

APPENDIX D: INFILTRATION RATES

Fig. D1: Soil infiltration rates at three locations in Libga community

Fig. D2: Soil infiltration rate at three locations in Bunglung community

Fig. D3: Soil infiltration rate at three locations in Nabogu community

Fig. D4: Soil infiltration rate at three locations in Nanduli community

Fig. D5: Soil infiltration rate at three locations in Nangunayili community

Fig. D6: Soil infiltration rate at three locations in Limo community

Fig. D7: Cumulative depths of infiltration at three locations in Libga community

Fig. D8: Cumulative depths of infiltration at three locations in Bunglung community

Fig. D9: Cumulative depths of infiltration at three locations in Nabogu community

Fig. D10: Cumulative depths of infiltration at three locations in Nanduli community

Fig D11: Cumulative depths of infiltration at three locations in Nangunyili community

Fig. D12: Cumulative depths of infiltration at three locations in Limo community

APPENDIX E: SANITATION SCENES AND ENGINEERING FLAWS IN THE STUDY AREA

Fig. I: Washing cloths in a broken apron

Fig. II: Animals tumbling water fetching points

Fig. III: Broken trough with growing algae Fig. IV: Growing grass at BH site

Fig. V: Unhealthy gutter created at BHs site Fig. VI: Broken trough and erosion at BH site

Fig. VII: Mud and stagnant water at BH site

Fig. VIII: Stagnant water at BH site

Fig. IX: Broken trough with stagnant water

Fig. X: Collapsed trough with mud and water

Fig. XI: Dirt and sediments gathered at HDW site

Fig. XII: Filth created at BH site

Fig. XIII: Children bathing in dugout

Fig. XIV: Uncovered local HDW

Figs. I – XIV: Sanitation scenes of the water facilities

XV **XVI** **XVII**

Figs. XV, XVI and XVII: Paths leading directly into dugouts

Fig. XVIII: Dugout opened towards settlements

Figs. XV-XVIII: Dugout opened towards settlements with paths leading directly into them

Fig. XIX: Eroded embankment

Fig. XX: Eroded embankment

Fig. XXI: Eroded embankment

Fig. XXII: Erosion at dugout

Fig. XXIII: Dugout A in rainy season

Fig. XXIV: Dugout A in dry season

Fig. XXV: Dugout B in rainy season

Fig. XXVI: Dugout B in dry season

Fig. XXVII: Dugout C in rainy season

Fig. XXVIII: Dugout C in dry season

Fig. XXIII-XXVIII: States of some dugouts in the rainy and dry seasons

Fig. XXIX: Failure due to overtopping at Bagurugu

Fig. XXX: Failure due to poor compaction at Pishigu

Fig. XXXI: Failure due to poor compaction at Savelugu

Fig. XXXII: Infiltrometer being used

Fig. XXXIII: Measuring soil infiltration rate

Fig. XXXIV: Determining average depth of dugout

Fig. XXXV: Width of the dugout

Fig. XXXVI: Measuring yield of a HDW

Fig. XXXVII: Depth measurement in well