KYAMBOGO UNIVERSITY

ENHANCING A SUSTAINABLE SAFE WATER SUPPLY FOR RURAL COMMUNITIES OF MABUNGO PARISH, KISORO DISTRICT

BY

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A RESEARCH DISSERTATION SUBMITTED TO KYAMBOGO UNIVERSITY GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN WATER AND SANITATION ENGINEERING OF KYAMBOGO UNIVERSITY

JULY 2019

Certification

The undersigned certify that I have read and hereby recommend for acceptance by Kyambogo University a research dissertation entitled: Enhancing a sustainable safe water supply for rural communities of Mabungo parish, Kisoro district, in fulfilment of the requirements for the award of a degree of master of science in Water and Sanitation Engineering of Kyambogo University.

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Declaration

I, Kwitegetse Penlope, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree of the university or other institute of higher learning, except where due acknowledgement has been made in the text and reference list.

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Kwitegetse Penlope

Acknowledgement

I greatly thank the Almighty Lord for giving me good healthy, Knowledge and his overwhelming love throughout my time in Kyambogo Pursuing this degree.

This dissertation would not have been possible without the help of my supervisors and many other people. I impressively express my heartfelt gratitude to my supervisors whose input and persistence has been instrumental in helping me turn this work into actual research.

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Lastly my heart goes out to my parents, my family members and classmates who have always stood by my side and without their support I would not have been studying at Kyambogo University and therefore my thanks to them for the excellence support

Dedication

This work is dedicated to my beloved parents Mr. James Semakuba and Mrs. Phoebe Semakuba, My husband Mr. Mugyenyi Raymond and my son Mugisha Brandon.

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BPT	Break Pressure Tank
CARE	Cooporation for Assistance and Relief EveryWhere
CBO	Community Based Organization
DDP	District Development Plan
DTC	Development Through Conservation
DWD	Directorate of Water Development
GFS	Gravity Flow Scheme
HH	Household
KDLG	Kisoro District Local Government
MDG	Millennium Development Goal
MGNP	Mgahinga Gorilla National Park
NEMA	National Environment Management Authority
NGOs	Non-Government Organizations
NPHC	National Population and Housing Census
NPHC	National Population and Housing Census
PSPs	Public Stand Posts
SDG	Sustainable Development Goal
SPR	Sector Performance Report
UBOS	Uganda Bureau of Statistics
VAT	Value Added Tax
WHO	World Health Organization

Abstract

Access to safe water is still a challenge in Africa, the biggest population that suffers the challenge being from sub-Saharan African countries where Uganda is part. The major cause of limited water access is that 85% of water supply systems stop supplying water after a short while from time of implementation. The situation escalates the water crisis forcing people to use raw water from the available water bodies. This involves trekking very long distances coupled with the risk of acquiring water-borne diseases. This study focused on Mabungo parish, in Kisoro district, and investigated the factors that influence sustainable supply of water systems in the area. Data was collected from 269 respondents within Kisoro district using questionnaires. The sustainability of the potential scheme in the Mabungo parish was also tested using the participatory research method, which came up with a community based model for sustainable water supply for the communities.

The results confirmed Kabiranyuma scheme to have potential for supplying Mabungo communities with safe water to the required level of sustainability.

Adopting a participatory approach among communities of Mabungo, has high opportunities of contributing towards achievement of sustainable development goal 6, which aims at ensuring universal access to clean water and sanitation by 2030. The approach prepares rural communities to manage their water supply systems themselves during and after implementation. Though full involvement of communities in operating and managing a water supply is the main way to ensure proper functionality and sustainability, It is important to note that, support from Local Government, the responsible Ministry or external entities in form of finance, technical back stopping, operational infrastructure, regular supervision, among others can do a great deal in boosting their performance. Communities were encouraged to practice rain water harvesting to be used as a supplementary water supply in the study area.

Keywords: Rural communities, water access, sustainability, enhancement, safe water

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

One of the targets for sustainable development goal (SDG 6) is to achieve universal and equitable access to safe and affordable drinking water for all, which has been one of the top priorities in developing countries over the past three to four decades (Akwaaba, 2009). It is reported by that 2.1 billion people worldwide lack safe drinking water at home (WHO, 2017).

While many developed regions have achieved universal access to clean water and met the millennium development goals (MDGs), improved drinking water access is still a challenge in Africa where 300 million people do not have access to safe drinking water (Habtamu, 2012) the biggest population being from sub-Saharan African countries (WHO/UNICEF, 2015) of which Uganda is part.

The total population of rural communities in Uganda that have access to safe water supply is still low compared to urban communities with percentages of 67% and 71% (Sector Performance Report, 2016) respectively. This is in line with findings from Directorate of Water Development, (DWD) which reported that a large number of rural sub-counties are still greatly underserved with safe drinking water infrastructure and experience high levels of poverty (DWD, 2008).

Kisoro district has a total population of 281,705 (UBOS, 2017) with 95% of the people being rural dwellers. Kisoro is one of the water-stressed districts in Uganda, with only 40% coverage where water is concentrated in the northern and eastern parts, whereas in Bufumbira South it is common for people to walk over 7km in search of water (Manishimwe, 2017).

Nyarusiza one of 13 sub-counties of Kisoro district in Uganda, is a rural area located in Bufumbira South constituency. The sub-county is composed of four (4) parishes with a total population of 25,000 people, and only 3,402 people served with clean water (DWD, 2016). A number of water systems have been provided to the sub-county but their impact lasted a shorter period than expected leaving the whole sub-county a water stressed region (KDLG, 2008).

Mabungo is one of the parishes in Nyarusiza sub-county, with 12 villages that are all water stressed exposing the communities in the area, to water-borne diseases (Kisoro DDP, 2011).

The major factors that contribute to the low water supply in Nyarusiza sub-county include; lack of exploitable surface water with a very deep ground water table, abandoned non-functional water points, lack of capacity capital to procure water infrastructure and inadequate technical expertise to develop less costly water systems and maintain the few available systems (NEMA, 2007).

In light of this situation, providing a sustainable water supply system suitable for providing safe and adequate water to the rural communities of Mabungo parish in Nyarusiza sub-county will help improve rural living standards and reduce incidences of water-related diseases and associated medical expenditures. It will help maximize time for productive activities and long-term human development.

1.2 Problem Statement

Safe water supply is majorly concentrated in urban areas yet communities in both urban and rural areas deserve adequate and safe water as a basic need for healthy living and commercial development. Inadequate facilities to supply adequate and safe water to rural areas continues to be a challenge to Kisoro district. The problem is further exacerbated by financial limitations and insufficient technical resources. The limitations result into failure of water supply systems, a short period after construction. The situation has pushed the large rural population into using raw water from lakes, swamps, unprotected springs, ponds and rivers that is also hard to access. Water access in Kisoro district is still a major challenge with some sub-counties like Nyarusiza, access as low as 11% . The situation is geared by limited surface water and very deep water table.

Mabungo parish with the highest population in Nyarusiza sub-county (UBOS, 2014) suffers most in form of long distance travels to nearby water sources, congestion at tapped water supply points and high charges attached on water sales. The problems result into water and sanitation related diseases, Low production and high poverty levels.

Therefore, enhancing a sustainable water supply system to work hand in hand with few existing water supply systems will help to improve on the quality and quantity of water supply and obtain an increased coverage in rural communities of Nyarusiza sub-county hence contributing towards development.

1.3 Objectives of the study

1.3.1 Main objective

The main objective of the study is to enhance a sustainable safe water supply system suitable for meeting water demands of rural communities of Mabungo Parish, Nyarusiza sub-county.

1.3.2 Specific Objectives

The study aimed at achieving the following specific objectives;

i. Assessing community perception on water access in Mabungo Parish, Kisoro district.
ii. Determine a water demand assessment in Mabungo parish
iii. Investigate the factors that influence the sustainability of water systems which used to supply water to Mabungo Parish
iv. Develop a model for sustainable water supply to Mabungo communities in Kisoro district

1.4 Research Questions

i. How do communities in Mabungo parish, perceive the water access in the area?
ii. What is the current water demand of communities in Mabungo Parish, Kisoro district?
iii. Which factors influence the sustainability of water systems that used to supply Mabungo parish?
iv. What can be done to ensure a sustainable water supply system capable for meeting water demands of Mabungo communities?

1.5 Justification

Irregularities in supplying water to communities of Nyarusiza sub-county combined with existing non-functional public water points, together with limited facilities to achieve economies of scale in water supply has pushed communities to use unsafe water from far distant available water sources which resulted into water-borne related diseases, low production and backwardness.

There is therefore, a need to improve the existing situation by providing a suitable water supply system to ensure sustainability of safe water supply so as to curb the outbreaks of water borne related diseases and improve the economy of communities in a most cost effective manner.

1.6 Research Significance

The study acts as an eye opener to individuals/ organisations with interest in improving safe water supply to gain deeper insight on how best to maximize the utilization of the few available water resources to ensure equitable distribution of water supply systems in all areas in Kisoro district.

It also gives a bigger opportunity to the rural communities in Mabungo parish and Nyarusiza at large to enjoy sufficient clean water in a most reliable and cost effective manner which will guarantee good health, increased production work and definitely poverty eradication.

The government of Uganda and its policy makers will also be provided with better understanding on required efforts needed for effective adoption, utilization and extension of the new system.

1.7 Scope of the Study

The study was carried out in Kisoro district with the main focus of developing a sustainable safe water supply system for communities of Mabungo parish. The study covered all 12 villages in Mabungo Parish.

The research first investigated the factors that influenced the performance of water systems that used to serve the communities in Mabungo and the rest of Nyarusiza sub-county. The entire research project cost Uganda shillings 4,000,000 (four million shillings only). It took 12 months to be completed i.e. from August 2017 to August 2018.

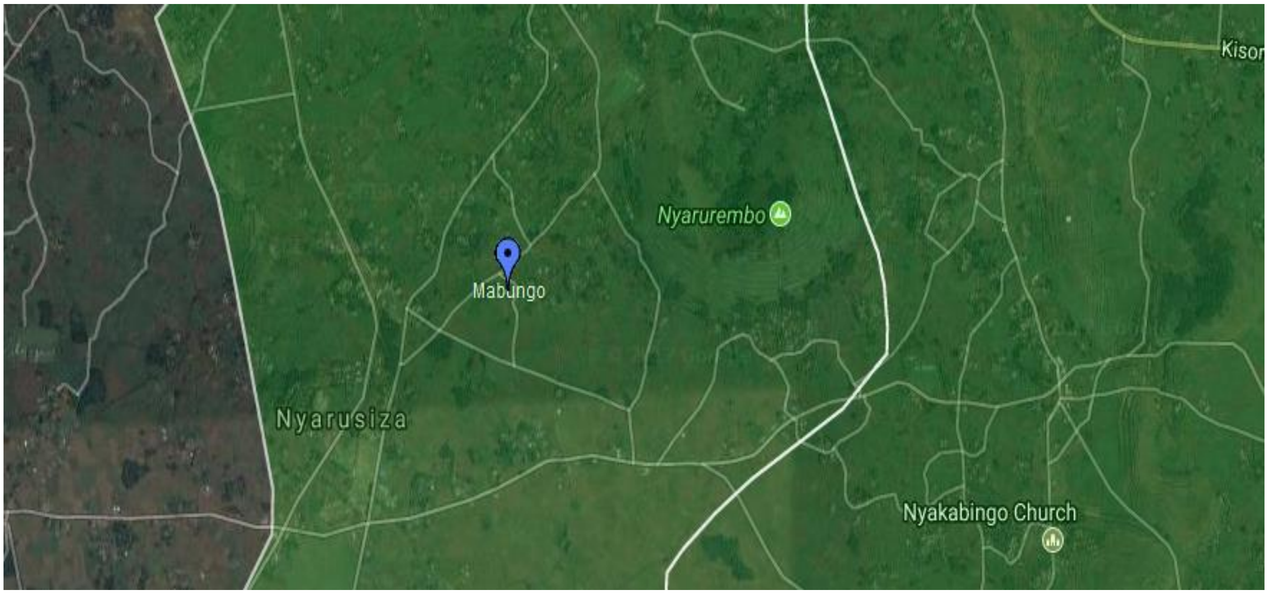


Figure1.1: Location of Mabungo parish in Nyarusiza sub-county, Kisoro district: Source: google imagery, 2017

1.8 Conceptual framework

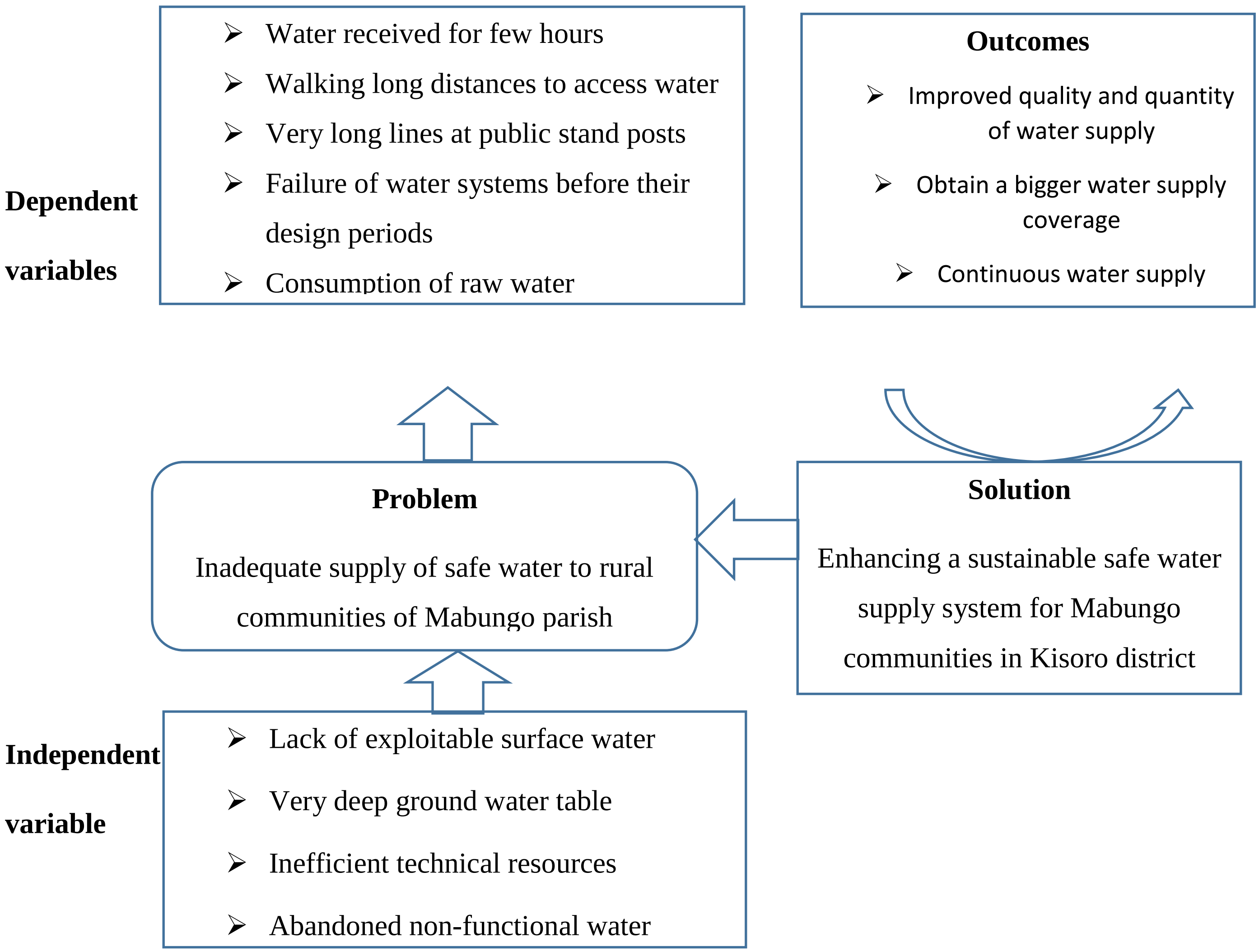


Figure 1.2: Conceptual framework of the study

1.9 Chapter Summary

Chapter one covered the background to the study, focusing on issues regarding clean water access globally, county-wide and at district level. The chapter also highlighted the problem statement, research objectives, justification, significance of the study, research scope and conceptual framework. The chapter emphasized that limited access to clean water, denies communities good health and development. It is therefore valuable to come up with enhanced measures to ensure improved access to clean water and sustainable utilization of water resources.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents and evaluates the existing literature from previous scholars and publications as well as scientific papers that give insight into aspects related to water resources categories, water supply systems and sustainability factors for water supply systems in rural areas. The chapter will study the factors considered in developing a gravity-fed system including system design requirements, typical layout of the system from the water source to distribution and its functional benefits to the users**.** The major components of a water supply system namely; water resource planning, pipeline route survey and design are discussed in this chapter.

2.2 Definition of Terms used in the Study

a) Sustainability means meeting the needs of the current generation without compromising the ability of future generations to meet their own needs.

b)Water sustainability refers to continuous supply of water to the targeted population for a given design period without harming the source. Schnoor (2010) defined water sustainability as the sufficient availability of water into the fore seeable future

c)Water access refers to the actual use of water by the population. According to the United Nations Population Division, access to safe water is measured by the proportion of the population with access to an adequate amount of safe drinking water located within a convenient distance from the user's dwelling.

2.3 A brief overview of Kisoro District

Kisoro district is located in the southwestern part of Uganda. The district is mountainous and hilly, at an average of 1,980 meters (6,500 ft) above sea level covering approximately 729.7 square kilometers (281.7 sq mi) with about 3.88% of the district covered by open water, another

2.95 percentant covered by wetlands and national forest reserves cover another 0.96% (Adventure Learning & Community Development, 2012).

According to state of environment report for Kisoro district 2007/2008, the district experiences two rainy seasons, one from September to December and another from March to May. The district has two major water sources i.e. Kabiranyuma and Chuho springs.

2.3.1 Water access in Kisoro District

In the whole district**,** only 44% of the total population has access to safe water with 43% rural and 57% urban (DWD, 2017) which explains a big gap that still exists in the district. It is not a surprise why incidences of cholera, dysentery and other water related diseases outbreaks are common in the district. The situation is even worse for sub-counties like Nyarusiza, Chahi, Nyakabande and Bukimbiri where water access levels still range between 11% and 13% (DWD,2017).

According to Radio Network news by Samuel Amanya (2017), severe shortage of water affected two sub-counties of Nyarusiza and Muramba where all clean water sources got dried up following a dry spell that hit the area towards the end of year 2016 and residents would trek over 10-kilometers to fetch water from Chuho water source in Nyakabande Sub-County.

2.3.2 Water Supply in Kisoro District

The district has only 2 pumped water schemes sourced from Chuho and supplies almost all parts of Kisoro Town Council and Nyakabande sub-county (NEMA, 2007). Jinya spring located in Muramba sub-county has been in existence for over 30 years but undeveloped and it has been the source of water to communities mainly in Muramba sub-county and few from Nyarusiza sub-county. The water is collected by communities who dig holes and fetch using cups. According to Manishimwe (2016), Jinya spring which is about 2 kilometers from Democratic Republic of Congo border is the sole source of water for about 30,000 people from the sub-counties of Muramba and Nyarusiza in Bufumbira South constituency.

Detailed information related to water access and the population served per sub-county in Kisoro district is illustrated in the in the table 2.1 below:

Table 2.1: Detailed information related to water access and the population served per sub-county in Kisoro District.

Sub-county	**Urban /rural**	**Population**	**Population served**	**Access**	**Functionality**			**Protected springs**			**Shallow wells**	
Bufumbira					**R**	**U**	**Wfp**	**F**	**NF**	**Tot**	**F**	**NF**
Northern Div	Urban	5,729	NWSC	NWSC	-	100 %	-	-	-	-	-	-
Chahi	Rural	19,901	2,412	12%	92%	-	-	-	-	-	-	-
Murora	Rural	20,303	11,386	56%	82%	-	100%	17	9	26	-	-
Nyarusiza	Rural	31,962	3,591	11%	80%	-	-	-	-	-	-	-
Nyabwishenya	Rural	15,981	15,182	95%	98%	-	-	62	1	63	-	-
Rubuguri TC	Rural	2,312	2,196	95%	96%	-	-	40	2	42	-	-
Bukimbiri	Rural	16,282	2,181	13%	99%	-	-	8	1	9	-	-
Muramba	Rural	38,696	3,336	9%	96	-	-	-	-	-	-	-

					%							
Nyondo	Rural	13,870	12,720	92%	90%	-	-	56	7	63	-	-
Nyakinama	Rural	20,805	6,428	31%	87%	-	-	6	1	7	-	-
Kirundo	Rural	18,896	14,312	76%	100%	-	-	64	-	64	-	-
Sourthern Div	Urban	5,930	NWSC	NWSC	-	100%	-	-	-	-	-	-
Kanaba	Rural	16,986	10,609	62%	55%	-	-	16	7	23	-	-
Busanza	Rural	18,896	17,951	95%	87%	-	-	90	15	105	-	-
Nyarubuye	Rural	20,001	16,130	81%	95%	-	-	54	4	58	-	-
Nyakabande	Rural	26,233	2,854	11%	85%	-	-	7	1	8	-	-
Total		**292,783**	**127,931**	**44**	**89**	**100**	**100**	**420**	**48**	**468**	**0**	**0**

Source**:** Directorate of Water Development (2017): F= functional, NF=nonfunctional, wfp = water for production, Tot = total, U= urban, R= rural.

2.4 Forms of Water Supply Systems

Water is mainly supplied using systems in two different forms; gravity fed systems and pumping pressure systems

2.4.1 Pumping Pressure Systems

These systems basically supply water by the help of pumps which draw water either from surface or underground water bodies. The water is either pumped directly to the users' taps or borehole, or sometimes it is first pumped to storage tanks or valley dams before it is again pumped to the distribution units. Pumping into storage tanks or into valley dams is of great importance because it ensures constant supply of water irrespective of disruptions in pumping. A pump and pressure tank are the major components that ensure effective performance of a pumping system.

2.4.1.1 Brief description of pumping system

According to Clean Water Store (2014), the water is pumped by a well pump, from the water source to a storage tank which is designed in such a way that the float switch in storage tank automatically turns it on whenever the tank is almost emptied. The booster pump is for a special purpose, which is mainly to sense the pressure within the pipe. The booster pump is controlled by Pressure tank from cycling on and off promptly. The pump continues to build water pressure in the pressure tank even when there is no demand for the water, so that when the demand for water rises, water pressure first comes from pressure tank until the pressure switch senses lower pressure, turning on the booster pump again and repeating the cycle. The system is illustrated in the figure 2.1.

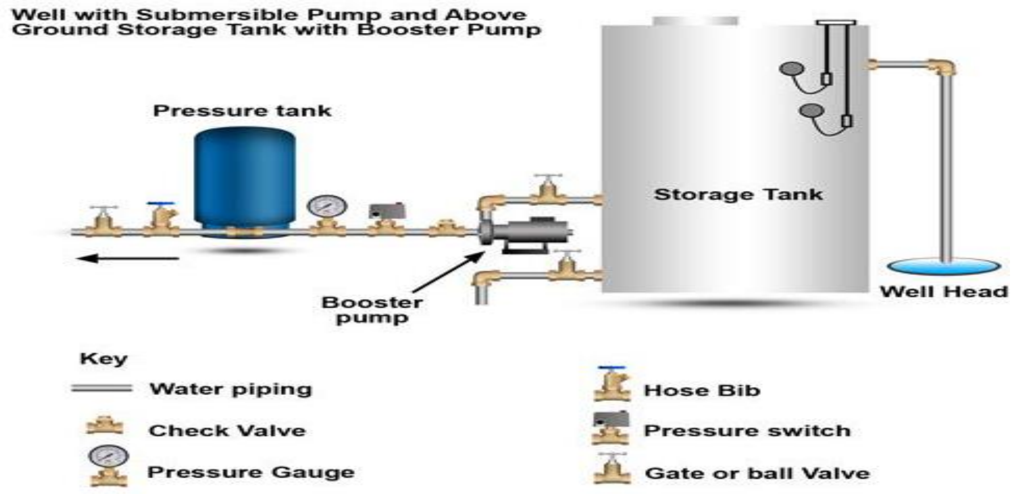


Figure2.1: Description of pumping system
Source: Clean water store, 2014

2.4.2 Gravity-Fed Water Supply System

Gravity-fed system uses the laws of gravity to move water from point A to point B and C if necessary and there are no pumps of any sort required for this system or electricity for that matter (Mile, 2017). The system involves low operational costs since it fully uses natural forces as long as the water source is at higher elevation compared to the point being supplied. It is mostly applicable in areas where power is very expensive or complicated to access.

2.4.2.1 Phases in Gravity Water Supply System Development

a) Water Source

The common sources of water for gravity systems are springs and streams which supply ground water. Springs are the most desired sources of ground water due to the fact that they are imposed to high pressure that result into supply of large quantities of water. They contain the best portable water compared to other sources, therefore well-developed designs are required to ensure good maintenance of the water quality standards. Continuous supply of water in all seasons of the year is a very important aspect in determining the appropriate source.

More steps involved in development of gravity water supply system are briefly explained by WaterAid (2013) as given in the next section.

i) Design

If the project is considered feasible, the surveyor must then conduct a survey on topography and the route of the pipeline from the intake to the storage tank, and then make a drawing of the optimum hydraulic gradient line, in order to determine the pipe size needed to deliver the design flow.

ii) Main pipeline

In rocky areas, the main pipeline will probably be laid above ground and will be made of galvanised mild steel tubing, anchored on saddles. Elsewhere, the pipeline will be laid in trenches, to protect it from damage, and will usually be plastic pipe (MDPE – medium density polyethylene)

iii) Break-pressure tanks

To reduce operating pressures it is sometimes necessary to introduce break-pressure tanks, which are usually made of concrete or ferrocement. If break-pressure tanks are used, the hydraulic gradient starts again at the tank water level. If suitably sized, these tanks can be used within the system as storage tanks to meet peak demand.

iv) Reservoir storage tanks

Reservoir storage tanks serve to store water provided by the source during low demand periods (overnight) for use during high demand periods (early morning). They are usually constructed within the system to provide a total volume of storage equivalent to one day's consumption.

If there are no break-pressure tanks, Reservoir storage tanks may be used to limit the maximum pressure in distribution pipelines or to sustain a pressure of at least three metres head at each tap stand, while meeting the peak demand in the morning and evening. Capacities of tanks range from 10 to 100 cubic metres, depending upon the size of the population to be served.

In flat areas, tanks may have to be elevated on block work support structures. Tanks are roofed and, typically, are provided with a float controlled inlet valve, twin outlet pipes with stop valves, a scour pipe at low level for emptying and cleaning out, and an overflow pipe led well away from the tank.

v) Distribution pipelines and tap stands

A distribution system of small diameter MDPE pipes, laid in trenches, feeds tap stands around the village. Each tap stand should serve about 150 people and should be positioned so as to uniformly reduce the maximum distance people have to carry water. Tap stands have several components: a concrete post supporting a 15 millimeter mild steel riser pipe from the pipeline up to a bibcock which should discharge at least 0.1 liters per second; a concrete stand on which to place a bucket; a concrete apron to collect spillage; a gutter and drainage to a soak-away in order to prevent the breeding of mosquitoes and to keep the area clean. Tap stands should have a fence around them to keep animals away and each should have a caretaker to keep the area clean and tidy. A typical gravity-fed system with its components is illustrated in the figure 2.2.

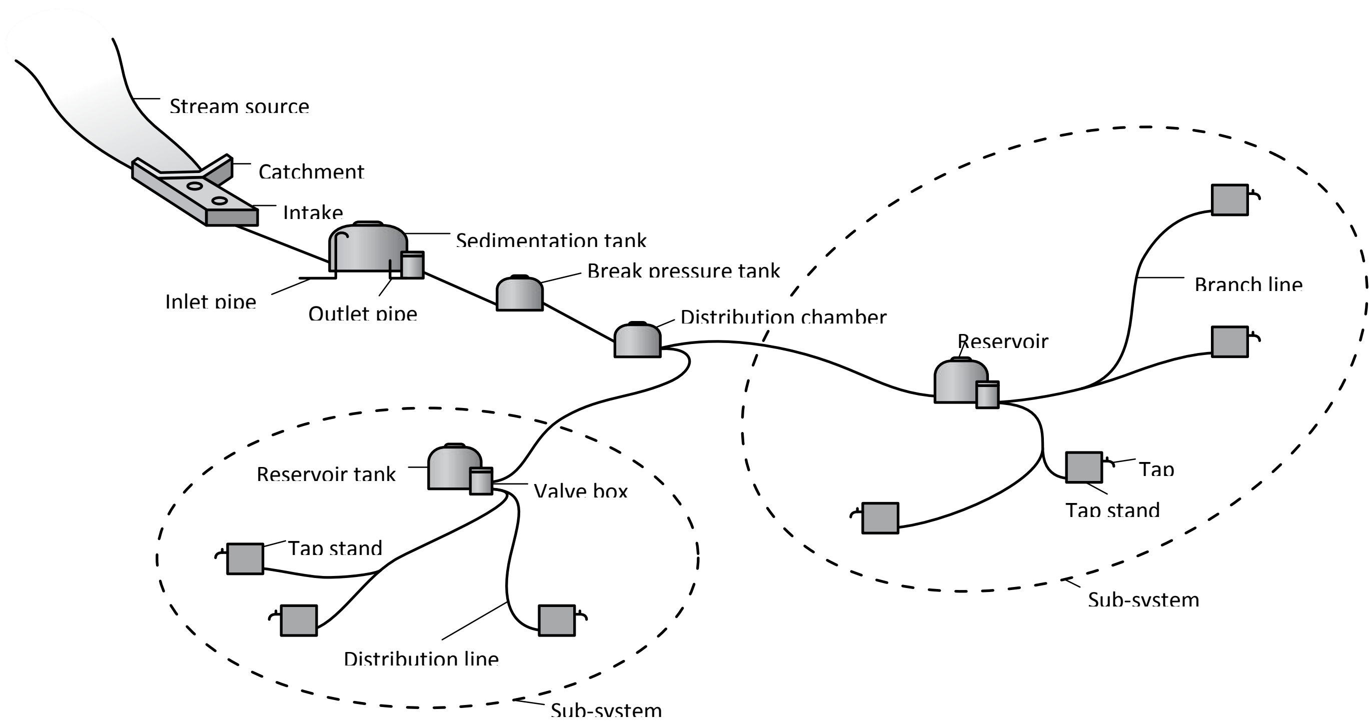


Figure 2.2: Components of a typical gravity-fed system. **Source:** WaterAid, 2013

2.5 Design Parameters for Gravity- Flow Water Systems

The following are important parameters used in design of gravity-flow water systems as described by Thomas (1980)

i) Maximum Pressure Limits: The taps and valves closed state, should be the maximum pressure condition for the system. Maximum head limits for the pipe work will be used to carry out the calculations. This scenario is used at the start of the design to be able to place any break-pressure tanks that may be required.

ii) Safe Yield: The safe yield is the minimum flow from the water source. It is important to not draw more than this supply from the system at any point. If this happens then spring boxes and/or break pressure tanks will run dry and air will enter the system.

iii) Negative or Low Pressure Head: If the pressure head (P in the Bernoulli Equation) becomes negative at any point in the system then two things may happen. Firstly a siphon effect is occurring which is trying to suck water into the system. This is undesirable as polluted groundwater may be introduced into the system. Secondly, large negative pressures can cause air to come out of solution in the water and cause air-blocks. Therefore the pressure head should, if possible, not fall below 10m (98100 Pa pressure) anywhere in the system and never go negative.

iv) Velocity Limits: The flow velocity in the pipelines should not be too great as particles suspended in the water will cause excessive erosion. Also if the velocity is too low then these particles will settle out of the flow and may clog the pipes at low points. This then requires washouts at low points in the system. Therefore the minimum velocity should be 0.7m/s and the maximum 3.0m/s.

v) Natural Flow: Natural flow may be allowed to occur in the system at some sections of pipe. Natural flow can be problematic in that the water velocity may exceed the set velocity limits and/or increase the flow rate above the safe yield parameter. Close attention should be made to these situations.

vi) Residual Head: The residual head at a tap stand or valve is important. If it's too high it will cause erosion of the valve and if it is too low then the flow will be minimal. Jordan(1980) suggests the following limits: absolute minimum =7m, low end of desired range=10m, most desirable=15m, high end of desired range=30m, absolute maximum= 56m.

vii) Air-blocks: These occur when there are topographic features between the source and the collecting tank that are lower than the collecting tank. Energy is lost from the system as these air-blocks are compressed and can result in no flow. Therefore the following design practices to avoid air-blocks are recommended:

- Arrange pipe sizes to minimize the frictional head loss between the source and the first air-block.
- Use larger-sized pipe at the top and smaller sized pipe at the bottom of the critical sections where air is going to be trapped.
- The higher air blocks are the more critical ones and should be eliminated or minimized first.
- Air valves can be designed into the system to allow trapped air to escape.

viii) Cost: Wherever possible smaller pipe diameters should be used, as they are cheaper. Combinations of pipes can often produce cheaper solutions than using just one pipe size. However pipe lengths should be rounded to the nearest 100m length. Also the number of concrete structures such as break-pressure tanks should be minimized.

2.6 Summarized Guidelines for Water Supply System Design

Table 1: 2: Guidelines for water supply system design

Parameter	**Guidelines**
Water Quality	Selected source should be tested first to ensure that the quality of water meets the standards. If not, then water treatment methods are recommended.
Walking Distance	The maximum walking distance to water distribution point should be 500 metres in rural areas and 250 metre in urban areas. The minimum walking distance both in rural and urban areas should be zero (0)
Number of Users per tap	The maximum number of users per tap should be 300 people in rural areas and 250 people in urban areas. The minimum number of users both in rural and urban areas should be 1 person per tap.
System operation time	The gravity flow transmission and distribution system is assumed to operate 24 hours per day. The pumping stations will however operate for a maximum of 16 hours per day.

Source: Thomas 1980

2.7 Factors that influence Sustainability of Water Supply Systems in Rural Areas

The determinant factors for the sustainability of rural water supply systems are classified into pre implementation factors and post implementation factors (Gebrehiwot, 2006). The major pre-iplementation factors for rural water supply systems is demand responsive approach and Community water management approach.

2.7.1 Demand responsive approach

In this approach, 'demand' is defined as the quantity and quality of water, where community members will choose to consume at a given price (Gizachew, 2005). In supplement, Gebrehiwot (2006), noted that in a demand responsive approach, beneficiaries should feel the need for safe drinking water supply, in order to identify safe drinking water supply projects.

2.7.2 Community water management approach

The approach necessitates participatory processes among communities to create a sense of ownership while operating, maintaining and managing their water supply systems themselves. Services provided are modified to demand levels of the communities, and the main responsibilities of sustainable water supply are put squarely with communities (Mohamed, 2004).

Key elements and ingredients for developing the community management of rural water supplies model to enable communities manage their water supplies system effectively and sustainably include; policies, legislation, ownership, technology, financial issues, preparation of the community, institutional linkages, and support structure (Mohamed, 2004).

The major factors that influence the functionality of rural water supply systems, especially in developing countries include; Lack of involvement of the community in selection of site and technology, implementation, operation and maintenance of the water source, use of complicated technology without proper capacity-building at community level, lack of finances at the community level for operation and maintenance of water sources, deep-water table, poor quality of water, among others (Habtamu, 2012) as well as inappropriate designs for the water supply systems.

Sustainability rate of rural water supply systems increases as a result of communities' owning and managing their schemes, existence of management organization at the village level, protection of the water point, communities cost recovery for operation and maintenance, technology type and availability of their spare parts and recognition of women. (Habtamu, 2012)

Habtamu (2012) also noted that the key causes for sustainability failure of a water system are mainly inappropriate policy or legislation, insufficient institutional support, unsustainable financing mechanisms, ineffective management systems and lack of technical backstopping.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Research Design

Analytical study was employed to conduct the water demand assessment for Mabungo community and to establish the factors that influenced the sustainability of Kabiranyuma gravity flow scheme in Kisoro district. Analytical study was used to identify and quantify relations, test hypotheses, identify causes and determine whether a suggestion exists between variables.

The sustainability issues were studied using both qualitative and quantitative data with the main interest being on the community's perception, social-economic activities, operation and management issues, technological and capacity issues.

The data collected was used to come up with an overview of factors that influenced the scheme's sustainability and provided guidance in developing possible for water sustainability in the area of study.

3.2 Sample Size Determination

This study targeted respondents residing in all villages of Mabungo parish, Nyarusiza sub-county. The sampling involved both probability and non-probability methods so as to attain sufficient and reliable responses.

The respondents included local leaders and residents of Mabungo parish, officials from Kisoro water department, NWSC and CARE whose names were not mentioned so as to maximize confidentiality. This is according to (Gall,2007) who pointed out that a good ethical rule to follow is to minimize the number of people who know the identity of the research participants. The sample size of respondents was selected using Slovin's formula 3.1

$n = N / (1 + N e^2)$ ……………………………………………………………(Equation 3.1)

confidence level was assumed at 95% (Andale, 2012), hence error limit, e = 5% (0.05).

N = total number of households in Mabungo parish and n = sample size.

The total number of households in each village was obtained from their respective Local leaders and was applied in the above formula to determine the sample size for each village. The interval of households was obtained by dividing the total number of households in each village by its determined sample size.

A total sample size of 308 persons was selected including 300 members of households, 4 officials from district water department, 2 officials from NWSC, and 2 from CARE. The households were randomly selected whereas officials at the district, NWSC and CARE were selected using the purposive sampling method. The purposive method was found applicable to the officials because it involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Palinkas, 2013 cited in Cresswell and Plano, 2011).

A largest sample size was selected from households because local communities in the households were considered as the main beneficiaries of the scheme and therefore their views were the most appropriate for the study. The households were randomly selected in order to provide equal opportunity to every member of a given household and ensure collection of information that was free from bias.

3.3 Data collection methods

Data was largely collected from Kisoro district. Primary data was collected using questionnaires and semi-structured interview questions. Secondary data was obtained from district reports, census data and demographic information as well as related websites. The secondary data was used to fill the gaps that were identified during primary data collection.

3.4 Methods for attaining research objectives

3.4.1. Semi-structured interview method

a) Community perception on water access

Semi-structured interviews were conducted on households selected by stratified random sampling. The interviews were conducted between the researcher and the local residents of Mabungo Parish to determine the performance of available water supply systems.

The interviewer engaged the respondents were engaged in a formal interview, guided by semi-structured interview guide developed by the interviewer (Cohen, 2006). The interview guide enabled many respondents to be interviewed in a systematic and comprehensive manner that kept the interview focused on the desired line of action (DiCicco-Bloom, 2006).

The interviews were flexible in that the interviewer could alter the sequence of the questions so as to probe for more information. The respondents were also free to answer the questions in any way they choose (KENPRO, 2012). The researcher kept on recording each respondent’s reply on the interview schedule.

3.4.2 Questionnaires and Secondary data (UBOS data)

b) Water demand assessment

Both questionnaires and secondary data were used to determine the current demographics of the Mabungo communities so as to estimate their water demand with the guidance of the DWD design manual.

UBOS data enabled the researcher to understand the current population size in Mabungo parish and the population growth rate. Questionnaires mainly focused on household sizes in the parish, current quantity of water consumed, sufficient amount of water required by the community and the rate at which the population consumes water.

The questionnaires were used to obtain more accurate information since the method gave the respondents sufficient time to read and answer the questions from research instrument at their conveniences and they could be able to ask for clarifications on questions not easily understood.

3.4.3 Design review, water quality and quantity assessment

c) Factors that influence the sustainability of water systems

Influence on systems' sustainability was investigated while taking the water quantity, quality, system design and management to be the critical factors.

In the first step, data about changing characteristics of water sources available within the neighborhood of Nyarusiza sub-county was captured using questionnaires to determine their availability and reliability in form of water supply relative to existing demand.

i) **Design review**: Firstly, the existing design reports for both Kabiranyuma and Chuho schemes were obtained from Kisoro District Water Department and reviewed to study the effectiveness of the designs in comparison with the current population demand.

ii) **Water quantity**: Data on water discharge was collected in order to determine the quantity of water that can be supplied by water sources. The data for two different seasons i.e. dry and wet seasons was collected. The data included that of April in the rainy season and July in the dry season in order to fully capture the capacity of the sources in both seasons of the year.

Part of the data on flow rate for Kabiranyuma spring was obtained from CARE reports in periodically collected information using hydrological monitoring equipment which was installed in Kabiranyuma swamp by a consultant hired by CARE-DTC. The equipment comprise of three piezometers (water depth), two rain gauges (rainfall) and two V-notch weirs (water outflow rates). One piezometer and one rain gauge are installed in the upper swamp, the second piezometer in the middle swamp whereas the third piezometer and second rain gauge were installed in the lower swamp. The V-notch weirs are located 30m below the boundary between the upper and middle swamp, and 100m upstream of the intake of the Gravity Scheme.

The researcher further used bucket method to practically measured the yield with assistance of the installed V-notch weirs above the intake of the gravity scheme. The yield was measured in litres per second (l/s) both in the dry and wet seasons. The measurements were taken four times a day in a week, for a period of four weeks i.e. two days in two weeks of April and two days in two weeks of July.

The method is simple and practical, as it only required two people to carry out the exercise. One person would collect water in a container, while the other one would measure the time taken to fill the container. At the end of each day, four readings would be taken and the average day readings calculated. After the study period of four weeks, the minimum and maximum yields were determined. The results are presented in table 4.11 of chapter four.

iii) **Water quality**; Microbiological analysis of water was carried out to determine the presence of coliforms i.e. faecal and total coliforms using membrane filter technique. A sample of water was collected from the source using a container and taken to the laboratory for testing. The results were ready on the following day for analysis and interpretation.

The technique was selected because it is capable of assessing relatively large numbers of samples, yields results more rapidly in about 18 hours, with high precision and it is economical (Bartram and Pedley, 1996).

The turbidity meter was used to measure the turbidity of the water. The method was used because it is simple, accurate, portable, requires low cost, no consumables and is suitable for all water sources (Myre, 2006).

Information about the water sources' present ownership, system management and present use was also obtained from respondents using questionnaires.

3.4.4 Participatory research using questionnaires and perspectives method

d) Sustainable water supply model

using results from specific objective iii), the sustainability index for Kabiranyuma GFS was determined after assessing the critical factors responsible for reducing the sustainability of the scheme. Following the methodology by Mimrose et al, (2011), The index used for sustainability assessment includes four sub-indicators, namely; a) financial management, b) operation & maintenance practices, c) consumer satisfaction, and, d) willingness to sustain the system. Each sub-indicator was given 9 to 10 questions making a total of 39 questions. A multiple-choice questionnaire was distributed among 308 respondents but only 269 participated. Their responses were then used to assess the sub-indicator scores.

A sustainability model for Kabiranyuma GFS was developed basing on the perspective method which guided in identification of vulnerabilities and adaptation possibilities (Haasnoot, 2011) as well as achievable opportunities.

3.5 Data analysis

SPSS V 16.0 (Statistical Package for the Social Scientists) was used to analyze data so as to determine the average amount of water required by per capita in Mabungo parish mainly for domestic use. This was achieved by first organizing, then entering the data which was collected from households, district officials in water department and officials from NWSC and CARE, into Microsoft excel, and then run into the SPSS.

In Mabungo, respondents were coded with numbers to ensure proper analysis of the situation in each village within the parish, and responses from respondents were easily documented using value labels. After coding the data, it was entered into the template that corresponded to the computer program (SPSS V 16.0). The template was then run in the computer program where mean and percentages were computed.

The above method was used because it consists of a versatile package that allows many different types of analyses, data transformations, and forms of output (Arkkelin, 2014).

3.6 Chapter Summary

The chapter explains the methodology that was applied in the research. The major methods that were used in the study included; data collection methods and model development. Data collection methods were thoroughly implemented, with the aim of studying the elements and issues concerning water supply in Mabungo parish and the factors that influence the sustainability of water supply systems which used to supply water to Mabungo Parish.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

This chapter presents all the findings that were obtained during this study. It includes the findings from the primary data that was collected using questionnaires and conducting interviews with various participants in Kisoro district especially the local leaders, residents, district officials and officials from NGOs. Secondary data which was collected from the textbooks, reports, census data and demographic information have also been included. The collected data was then used in the development of a model for enhancing sustainable safe water supply in the study area.

4.1.1 Demographic Characteristics of the Study Area

Mabungo is the one of four (4) parishes in Nyarusiza sub-county found in Bufumbira south constituency, Kisoro district. The parish has twelve villages namely; Bigina, Bikoro, Buhangura, Buhima, Burakeye, Gasenyi, Mabungo, Nshora, Nyamushungwa, Rusisiro, Sagitwe 1 and Sagitwe 2. Mabungo parish is entirely covered by land with a total population size of 7,663 people, who occupy 1,678 households. Mabungo parish has the second highest population in the four parishes of Nyarusiza sub-county (UBOS, 2014). The Kisoro district report (2012) also indicated that Mabungo is the worst-hit parish in terms of walking distances to the nearest safe water supply points. The population sizes for the parishes in Nyarusiza sub-county are elaborated in the table 4.1

Table 4.1:Demographic characteristics of study area

Total Population by Sex, Total Number of Households and proportion of Households headed by Females in Nyarusiza Sub-county Kisoro district, 2014					
Parishes	**Males**	**Females**	**Total**	**Households**	**% of Female Headed HHs**
Gasovu	3,054	3,964	7,018	1,539	21.2
Gitenderi	3,518	4,736	8,254	1,838	18.5
Mabungo	3,495	4,168	7,663	1,678	23.0
Rukongi	3,257	4,116	7,373	1,658	18.5

Source*; UBOS, (2014).*

4.1.2 Questionnaire Response Rate

The study targeted 308 respondents including; 300 house hold members, 4 officials from local government and 4 officials from NGOs (NWSC and CARE) all from Kisoro district. Two hundred sixty four (264) households, three (3) officials from local government and two (2) officials from NGOs (1 from NWSC and 1 from CARE), responded and returned the questionnaires which made up to 87.3% response rate

This response rate was sufficient and representative as highlighted by (Della,2002) that; 60% response rate is marginal, a response rate of 70% is reasonable and that of 80% is good, whereas a response rate above 80 is excellent. The rate at which questionnaires were filled and returned is illustrated in table 4.2.

Table 4.2: Questionnaire response rate

Respondents	**Targeted**	**Returned**	**Percentage (%)**
District officials	4	3	75
Officials from NGOs	4	2	50
Households	300	264	88
Total	**308**	**269**	**87.3**

The results above were obtained due to detailed briefing of respondents and continuous follow-up to ensure that, they filled and submitted the questionnaires in time.

4.2 Community Perception on Water Access in Mabungo Parish

Results from the research showed that water is not only scarce in Mabungo parish but in Nyarusiza sub-county at large. Of the 264 respondents who returned their questionnaires, 75% explained that they always trek over 4 km to get water for domestic use from the few available surface water sources. The surface water sources include; swamps, unprotected springs, ponds and broken pipelines.

Installation of various clean water supply systems for communities of Nyarusiza sub-county ranging from boreholes, rain harvesting tanks and public stand posts have been attempted by the government of Uganda through the district and other development organizations but the functionality of these systems has always been influenced by sustainability inefficiencies. The major reasons that contribute to the sustainability failure were found to be; inadequate sensitization to the beneficiaries, technical breakdown, vandalism, lack of feel for the system ownership by the beneficiaries/ system users, poor operation and maintenance of the systems, which confirmed the findings of the Harvey, (2007) report that revealed that major community issues that contribute to low sustainability rates of water supply systems, include perceived lack of ownership, lack of education on water supply and sanitation, poor management system and limited demand.

The whole of Nyarusiza sub-county is characterized by a deep water table (NEMA, 2007) which makes the ground water sources completely scarce and so the efforts of drilling boreholes in some villages did not yield any fruits because they all dried up and have been abandoned.

The district officials emphasized that the failure of most of the water systems was majorly caused by operation and maintenance inefficiencies resulting from inadequate community sensitization.

In the whole Mabungo parish, the communities obtain clean water from; rain water harvesting, Kisoro town water system (kiosks) and few existing Kabiranyuma taps with walking distances exceeding the maximum recommended which should be 500 metres in rural areas and 250 metre in urban areas (Thomas, 1980). This is because Kisoro town water supply system only supplies part of the areas that were connected to Kabiranyuma GFS.

District officials highlighted that efforts to have water supply coverage improved in the area were constrained by lack of potential springs, reliable aquifers for deep boreholes and shallow wells. The statement agreed with (NEMA, 2007) in the state of environment report for Kisoro district which revealed that, Nyarusiza sub-county lacks exploitable surface water and it has a very deep ground water table.

4.2.1 Water from Jinya spring

Currently, Jinya spring from saddles of Mgahinga is the main source of water for communities in Nyarusiza and Muramba sub-counties (UWA, 2007). The spring has been in existence for over 30 years, but not developed, and has been the source of water to communities mainly in Muramba sub-county and few from Nyarusiza sub-county.

Water from this spring is commonly harvested using hoes and sticks by communities who dig holes around the source until water oozes out of the soil. The communities pick water using cups or bottles as they pour into their jerry cans until the jerry-cans get full. The water collected is dirty as it gets mixed up with soil and other pollutants on ground surface. Communities devise local mechanisms of filtering the water by placing eucalyptus leaves or grass into the dug holes to separate soil and other particles from the water being fetched. This makes water look somehow clear but of course not purely clean. Matters are worsened by dirty cups and bottles used to collect the water and even children who play within those areas and even animals that contribute to polluting the water. Miti (2009) also related the area to a death trap that seems to be slowly caving to the footsteps of the hill due to floods that trouble the area during rainy seasons and that it appears to be a den of dangerous animals, snakes and insects.

However, at the time of data collection, a move by Kisoro Foundation for Rural Development, to develop the spring started in 2016, and by July 2017, part of the development was commissioned and is currently providing clean water to communities in Muramba sub-county.

4.2.2 Water from Kabiranyuma GFS

The Kabiranyuma gravity flow scheme used to obtain water from Kabiranyuma swamp which is located within three volcanoes i.e. Muhabura, Mgahinga and Sabyinyo, and the swamp retains water all year round. The scheme used to serve three sub-counties of Nyarusiza, Muramba and Chahi. The state of environment report for Kisoro district 2007/2008 states that, Kabiranyuma scheme used to provide water by gravity and serve the sub-counties through taps, but the scheme is not functional at the moment though it can be restored. By 1998, access to Kabiranyuma tapped water was hazardous, demanding a climb of 10m up the outside of the raised tank and dipping water through a hole in its roof (ADAMS, 1998).

This research discovered that, there are a few remaining taps of Kabiranyuma GFS located near the boundaries of Mgahinga National park. These taps still provide water to the surrounding communities, though not enough to meet the demand. The limited supply is due to broken pipelines and blockages within the pipes.

Due to high demand, communities walk as far as towards the protected areas of Mgahinga Gorilla National Park (MGNP) to collect water from part of Kabiranyuma swamp, and risk encountering with dangerous wildlife and even park staff. It was, however, found out that the so-called protected areas with water within MGNP are no longer well protected because the fences are already broken down. This makes it very easy for some wild animals within the park like mountain gorillas to access the water points and pollute them with their waste.

4.2.3 Water from Chuho spring

The government of Uganda through Kisoro District Local Government provided clean water supply through public stand posts to some areas of Nyarusiza sub-county. This water is sourced from Chuho spring and it reaches Nyarusiza by pumping. Chuho spring is located in Nyakabande Sub-County, about 8 kilometers from Nyarusiza, and is the main water spring in Kisoro district (Bitariho, 2015). The government installed 22 public tap stands in kisoro district. Nyarusiza sub-county obtained 5 public stand posts and Mabungo parish got only two (2) kiosks.

The study findings indicate that, the two (2) kiosks are still functional though with major challenges of poor maintenance. These kiosks are therefore very few compared to the population that depend on them. They are also unevenly distributed.

The study also found that water is supplied in Mabunngo parish for only 6.5 hours in a day i.e. from 8am to 2:30pm. Beyond that, water runs out which respondents said attracts high congestion at each tap stand. People are forced to rise up early in the morning around 6am to go to nearby kiosks, book places in the lines and wait until 8am when water starts flowing. Those who fail to line up early get into the last queue positions and in most cases, water runs out before their turn to fetch water reaches.

Each Jerry-can of water costs 100 Uganda shillings, but as congestion increases, the kiosk attendants create separate lines for those who can afford 300 Uganda shillings per jerry-can and the latter are given priority. This arrangement leaves those who can’t afford the increment in the fee, helpless even when they have managed to reach the lines early.

The regulatory arrangement of water supply from the posts, where the clean water is pumped to each post twice in a week to ensure equal proportionality in supply was majorly pointed out as the main cause for congestion and scramble for water. Figures 4.1 and 4.2 show communities at Kiosks in lines waiting for water.

Figure 4.1: Locals from Mabungo parish in lines to obtain water from one of the Kiosks

Figure 4.2: Locals in lines at second kiosk in Mabungo parish

The District Water Officer, explained that the arrangement of supplying water in parts at a time, was determined basing on the quantity of water available to reach the distant places like Nyarusiza. The District Official further highlighted that the water pumped from Chuho spring cannot serve all the posts at the same time due to limited volume, which prompted the Water Department to devise means of pumping in such a way that on specific days, the clean water reaches specific communities in uniformity mode.

The District Official also highlighted that, the community was informed of the days on which water is supplied to different posts so as to easily allocate it. Communities were also advised to always fetch in specified quantities so as to equally share the opportunity. Each household is, therefore, limited to at most four (4) jerrycans per supplied day.

Some members of the community however complained that the arrangement of fetching in specific quantities is not always followed because when the demand for water increases, communities in Mabungo parish with a large population are forced to fight and injure themselves in scramble for water and only able-bodied people get water in time while the less able especially women and girls spend almost the whole day in lines waiting to get water and in most cases especially in dry season, water gets runs out before they are given opportunity to access the taps. This is unfortunate because as stated by Liliosa (2017) citing the report of the UN MDGs (2012), that in sub-saharan Africa, 71% of the burden of collecting water for households falls on women and girls. This greatly affects the daily activities of women and girls hence limiting their production levels. Liliosa, 2017 also discovered that the time women and girls spend walking to water collection points and the water-borne diseases they may contract from the water, keep them from attending school, going to work and attending to their families.

Some other respondents however, noted that sometimes some members of the community volunteer to maintain order at the kiosks and they fetch peacefully following the queues. Fetching water in lines saves time and also gives opportunity to women and children to collect water. Respondents further noted that the disorderly way of fetching water results into destruction of the kiosk's taps, doors and even fences.

It was further established that, the pressure at which water is supplied varies with time of the day, with morning hours having high volumes of water supplied with high pressure, but the pressure keeps varying as the day progresses. The changes in pressure determine the time each jerrycan (20 litres) takes to get full. The variations in period for jerrycans to get filled with water are illustrated in the table 4.3

Table 4.3: Variations in pressures at which water is supplied

Time of the day	**Time spent to fill a jerry can (seconds)**
8am – 10am	45
10am – 12pm	60
12pm – 2:30pm	30

Most people prefer trekking long distances to collect water directly from chuho source, than waiting in lines for pumped water, where they have limited hope of obtaining it. Figure 4.3 shows the situation in Mabungo parish and Nyarusiza at large.

Figure 4.3: Some of people trekking to and from Chuho spring to collect water

4.2.4 Water from swamps and unprotected springs

From the research, it was observed that some members of Mabungo parish collect water from swamps and unprotected springs of neighboring sub-counties. This is in agreement with NEMA,

(2007) which noted that, in rural areas where the gravity flow schemes and purified water cannot be accessed, wetlands are looked at as the main source of sufficient and clean water.

The residents collect water from swamps which are jointly shared with animals and therefore evidently dirty, unsafe and not fit for human consumption, a situation that residents said is exposing them to diseases.

However, rapid population increase in the district, (UBOS, 2014) has led to land shortage for agriculture, yet it is the main economic activity for citizens in the district (NEMA, 2007). The rural people have remained with no other option apart from cultivating in the few available wetlands hence further escalating the water crisis. This is in agreement with (Tera, 2012) who noted that, some of the factors contributing to the increase in scarcity of water resources include the phenomena of population growth, land fragmentation and poor land use practices.

Figure 4.4: One of the encroached swamps where people share water with animals
Source: Amanya, 2017

Communities however, admitted that the water they collect from swamps and unprotected springs can be dirty. They explained that the water sources are mostly polluted by high rates of erosion due to steep slopes, poor agricultural practices in the area, animals and sometimes humans who do open defecation.

figure 4.5 shows one of the unprotected springs that Mabungo communities depend on for water supply.

Figure 4.5: Unprotected spring that provides water to some communities of Mabungo parish

Respondents explained that they opt to such raw water because it is always available and does not require making long lines or even struggling to fetch it, even though it requires one to first walk long distances to reach the sources. They also added that the main factor that drive them to use the raw water is its free access unlike the clean one, which requires payment of 100 or even 300 shillings for each jerrycan. This is in agreement with (Habtamu, 2012), who said that the preference for raw water, is its being free, with quantity unlimited and usually requires less waiting time.

Rampant outbreak of water borne diseases was reported to have been attributed to locals sharing drinking water with animals. The diseases which were pointed out by the respondents include; malaria, typhoid, diarrhoea , flu, dysentery, cholera, cancer, kidney damage and other skin and eye diseases like skin rashes and trachoma especially in children.

4.2.5 Water from rain harvesting tanks

Institutions like schools and health units, adopted the rainwater harvesting method from roof catchments. These institutions mainly installed plastic tanks to collect water during rainy seasons so as to meet their water demands.

Rain water harvesting has been supported by the favorable climate of Kisoro which is composed of both tropical and savannah with wet and dry seasons (NEMA, 2007). In the wet season, rainfall received occurs with two peaks in the year i.e. March and April, then from October-December and the average rainfall is about 1650mm per year (ADAMS, 1998). However, communities reported that in some years they experience climatic variations.

The reports at the district showed that the rainfall received ranges between 1200mm and 2000mm. This good climate encourages the performance of rain water roof catchments such as community tanks, household tanks and water jars.

Of the 300 households visited, 80 had rainwater harvesting facilities in different sizes ranging from 1000 to 10000 litres depending on financial capacity of a family. Most of the tanks found in the households were provided by the Diocese of Muhabura under Compassion International that supports orphan children and those from very poor families.

Figure 4.6: One of the rain harvesting tanks provided by Compassion international

Other rain water harvesting facilities functioning at household level include concrete tanks (both underground and above the ground), plastic tanks and jars. Some of these facilities were no longer functional at the time of data collection due problems like leakages, vandalism of taps, blockage, significant cracks, among others.

Individuals with big rainwater harvesting tanks use the opportunity of the dry season to sell their water at prices as high as 1000 shillings per jerry-can especially in the months of June and July, which the respondents said exploits them.

The respondents revealed that, though not within Mabungo parish, some rainwater harvesting tanks funded by the Japanese embassy were installed in neighboring parishes, in five (5) different sites i.e. Gitenderi Primary School, Rurembwe Primary School, Masasa community, Gasovu Healthy Centre and Kabaya community where they also fetch water. They however noted that when the demand increases (many people in lines), the opportunities for water collections are only given to members of those parishes. As a result, members of Mabungo are denied access to the tanks.

The tanks provided are made of plastic with titles of funders labelled on them as one in the figure 4.7.

Figure 4.7: One of the rain harvesting tanks provided by Japanese embassy

Other stakeholders that have rendered a hand in the construction of rainwater harvesting tanks and jars include; Africare and BMCT.

4.3 Water Demand Assessment in Mabungo Parish

4.3.1 Meaning of terms used in the study as per (Water Supply Design Manual second edition, 2013).

Initial Year; This is the year when the water supply scheme is expected to be commissioned into operation, which may be assumed to be 5 years from the date of commencement of the feasibility studies.

Future Year; This refers to 10 years ahead of "Initial Year".

Ultimate Year; This stands for 20 years ahead of "Initial Year". It is normally based on life expectancy of electro-mechanical components

Safe yield; this refers to the amount of water an aquifer or well can yield for consumption without producing negative effects to the aquifer and the environment.

Over 80% of 264 respondents in all the 12 villages explained that each household uses 20 to 60 litres per day. The water is used sparingly to ensure that it serves the major needs like cooking, drinking, bathing and washing. Basing on an average household size of 6 members, the current water use in Mabungo Parish contradicts with WHO recommended quantity of water use, which indicates between 50 and 100 litres of water per person per day, to ensure that most basic needs are met.

Communities, however, noted that, though they use that amount of water for all the domestic needs, it is too little to satisfy even the major household needs. This situation was attributed to limited supply of clean water from public tap stands and rain water harvesting tanks and also long distances one has to walk to reach the available water sources.

In rainy seasons, the amount of water used per household increases from 60 to 100 litres per day meaning that if there was improved water supply near to the communities, the amount of water used by each household would be at least double the current one.

Women and girls complained that their personal hygiene is highly affected because they are limited on the amount of water they can use for bathing and washing. They feel this has played a big role in contributing to diseases like candida, skin diseases and even barrenness.

4.3.2 Water demand calculations

The Geometric method **($P = P_o (1+r)^n$)** was used to determine the population projections for Mabungo Parish in order to forecast the future demand for water which helped to determine the quantity of water that could be supplied sustainably to the communities and in line with recommendations of WHO.

According to population records that were obtained from local leaders (LC1), the average household size for Mabungo parish was found to be 6 persons with a population growth rate of 2.21% (NPHC, 2014). It is anticipated however, that the study will have a positive impact on the people in Mabungo parish and Nyarusiza sub-county at large as they enjoy the safe water supply throughout the year.

Basing on the current population size of Mabungo parish which is at 7,663 with the growth rate of 2.21% (NPHC, 2014), the population projections were obtained using the equation

$$P = P_o (1+r/100)^n \qquad \text{Equation 4.1}$$

P = Projected population after n years,

P_o = Initial population

r = annual growth rate

n = number of years

Design Horizon = 15 years

Base year population = 7,663

The yearly projected populations were obtained as given in the table 4.

Table 4.4: yearly projected populations

r = 2.21%							
Sub-county	**Parish**	**No. of households**	**Average household size**	**Populations**			
				Base year (2018)	**initial year (2023)**	**future year (2033)**	**Ultimate year (2038)**
				$\mathbf{P = P_o (1+r/100)^n}$			
Nyarusiza	Mabungo	1,678	6	7,663	8,548	10,636	11,864

Therefore, design population is 8,548

a) Water service levels in Mabungo parish derived from social economic study

Table 4.5: Water service levels derived from social economic study

Service level	**Demand**	**% Populations**			
	l/c/d	**Base year**	**Initial year**	**Future year**	**Ultimate year**
		2018	**2023**	**2033**	**2038**
Point sources	20	70%	20%	5%	0%
public Stand posts	20	30%	80%	85%	70%
Yard tap	40	0%	0%	10%	20%
House connections	50	0%	0%	0%	10%

b) Summarized Population Projections by service levels

Table 4.6: Population Projections by service levels

	Service level	Demand	% Populations			
		l/c/d	Base year	Initial year	Final year	Ultimate year
			2018	2023	2033	2038
	Point sources	20	70%	20%	5%	0%
	Public Stand posts	20	30%	80%	85%	70%
	Yard tap	40	0%	0%	10%	20%
	House connections	50	0%	0%	0%	10%
R= 2.21%						
Sub-county	**Parish**	**HH**	**populations (P)**			
			Base yr	**Initial yr**	**Future yr**	**Ultimate yr**
			2018	**2023**	**2033**	**2038**
Nyarusiza	Mabungo	1,678	7663	8,548	10,636	11,864
			% Population * population(P)			
		Public Stand posts	2,299	6,838	9,040	8,305
		Yard tap	0	0	1,064	2,373
		House connection	0	0	0	1,186
		Total	2,299	6,838	10,104	11,864

c) Service Level Demand

Table 4.7: Service level Demand

Service level Demand	**l/c/d**
Point sources	20
Public Stand posts	20
Yard tap	40
House connections	50

d) Population Projections by service levels

Table 4.8: Population Projections by service levels without losses

Service levels	**Initial year**	**Future year**	**Ultimate year**
	2023	**2033**	**2038**
Public stand posts	6,838	9,040	8,305
Yard tap	0	1,064	2,373
House connection	0	0	1,186
	Sum(Service level* population projected)/1000		
Domestic (m^3d)	136.76	223.36	320.32

Table 4.9: Population Projections by service levels including losses

	Initial year, 2023	**Future year 2033**	**Ultimate year 2038**
Domestic(m^3d)	136.8	223.4	320.3
	15% losses		
	Initial year	**Future year**	**Ultimate year**
Domestic(m^3d)	157	257	368

Ultimate Year Domestic Demand = **368m^3/day.**

Using DWD Water supply design manual Second edition ;

Average day demand (**ADD)** = 368$\mathbf{m^3}$/day

Maximum day demand (MDD) = ADD*1.3

=368*1.3

MDD = 478.4 $m^{3/}$day

Storage Calculation

MDD *30%

478.4*30%

= **143.52**$\mathbf{m^3}$

Hydraulic Simulation of distribution line

Peak Hour Demand, PHD = MDD *2

= 143.52* 2

PHD = 287$\mathbf{m^3}$

For a water supply system, to sufficiently serve the communities of Mabungo parish for 15 years with clean water, it must supply a maximum amount of water worth **478.4** $\mathbf{m^{3/}}$**day**, with storage capacity of **143.52**$\mathbf{m^{3.}}$

4.4 Factors that Influence the Sustainability of Water Systems used to Supply Mabungo Parish

During data collection, it was discovered that, Kabiranyuma Gravity flow scheme, is the only scheme which was once developed and used to serve the whole of Nyarusiza sub-county with clean piped water. Bitariho, (2015) also confirmed that, Kabiranyuma swamp which supplies the scheme, is a major source of water supply for the local people living around MGNP (where Nyarusiza sub-county belongs) in Kisoro district.

Another major water source in the district, is Chuho water scheme, but it only serves people living in Kisoro town and few surrounding communities because it is located further north within a distance of about 20 Km from MGNP (Bitariho, 2015).

Jinya spring is currently a developed spring and serves mainly communities of Muramba sub-county.

Other water sources such as swamps, water tanks and unprotected springs were discovered not to be reliable for continuous supply because their water volume greatly decreases or even disappears with change in climate i.e. during the dry season. Characteristic changes of water sources vis-à-vis climate are summarized in table 4.10 below.

Table 4.10: Characteristic changes of water sources vis-à-vis climate

Water source	**Flow consistency**	**Water quality**
Chuho	Continuous flow	Recommendable throughout
Jinya	Slightly reduce in dry season	Deteriorates with agricultural seasons
Kabiranyuma	Slightly reduces in dry season	Green colour increases in rainy season
Swamps	Highly reduce in dry and agricultural seasons	Continuously deteriorates in dry season
Unprotected springs	Highly reduces with agricultural seasons	Keeps deteriorating with surrounding activities
Rain tanks	Completely disappears in dry season	Recommendable throughout

The investigation about the factors that influence the sustainability of water supply systems in Mabungo sub-county revealed that only Kabiranyuma GFS which had sufficient capacity to supply water to the study area. Kabiranyuma GFS was therefore, taken up as a case study.

4.4.1 Brief Background of Kabiranyuma Water Scheme

Kabiranyuma Gravity Water Scheme was upgraded from the previous water scheme in 1997 to increase efficiency of water extraction and storage (Bitariho, 2015). The scheme used to be supplied by Kabiranyuma swamp through river Kabiranyuma.

Kabiranyuma, is one of the swamps that originates from the saddles between the three volcanoes i.e. Muhabura, Mgahinga and Sabyinyo which retain water all year round. The swamp lies between Muhabura and Mgahinga volcanoes within Mgahinga Gorilla National Park (MGNP) in the furthest corner of southwestern Uganda, in the outskirts of Kisoro town and about 5 km from the town centre (UWA,2007). The swamp is at an altitude of 10,000 feet and it provides water through gravity.

Kabiranyuma swamp is the main source of the north-flowing surface water in the Muhabura - Mgahinga saddle, and is an important source of water for the populations around, which does not dry up completely during the dry months of June to August (UWA, 2007). Part of Kabiranyuma swamp is shown in figure 4.8

Figure 4.8: A scene of Kabiranyuma swamp
Source: *Bitariho, (2015)*

CARE- DTC installed a camera within the swamp which takes various successive photographs that serve as a baseline to track changes in the area of the swamp basing on the theory that, as the swamp water level drops, the swamp area seen will shrink.

The swamp is composed of three channels through which water gravitates to the intake, then continues through the main channel to the main reservoir.

To effectively investigate the actual factors that influenced the performance of Kabiranyuma GFS, a number of steps including reviewing the existing design, analyzing the quality and quantity of Kabiranyuma's water, and assessing other related information were conducted.

4.4.2 Existing Design of Kabiranyuma Gravity Flow Scheme

The gravity flow scheme was designed to supply water to a population of about 21,000 people (Bitariho, 2015) within three sub-counties of Nyarusiza, Muramba and Chahi in Kisoro district.

The water was being sourced from Kabiranyuma swamp located in the mountain about 4km from the main reservoir and at an elevation difference of 800m with a total safe yield of 3l/s (10m3/day).

The scheme had drainage channels both in the upper and lower swamps that used to convey water into a dug out reservoir found near the lower swamp. Water would then be conveyed through a pipeline by gravity into a storage tank of 250m^3 capacity located on the park boundary in a place called Kukyanyirabutari.

The scheme had a transmission main with a length of 4000m and pipe material GI ND 75mm class B to the main supply tank at Kukyanyirabutare few meters into the game park on Mt. Muhavura. A series of five (5) break pressure tanks were also distributed along the transmission main.

From the storage tank, water would be distributed to the surrounding local communities through pipelines of length equivalent to 45 km and then to the 54 public stands posts which were distributed in all the three sub-counties.

The total capital investment cost for the existing design including VAT of 18%, was Ushs. 769,669,513.

During data collection, the following information about Kabiranyuma GFS was established from Kisoro district report under Department of Water;

The existing transmission main of ND 75mm GI class B was still in good state;

All the five break pressure tanks on the main transmission are down but have the potential of being rehabilitated;

The existing pressed steel tank is still in good shape but some fittings are faulty;

A safe yield of 3l/s was assumed yet in actual sense, the yield at the peak of the dry season reduces to as low as 1l/s (3.6m3/hr).

Currently, residents of Nyarusiza sub-county who neighbor the source, still obtain water from the overflow of the main reservoir for Kabiranyuuma GFS, about 4 functional taps along the distribution system and other broken pipes.

The majority of the communities in Nyarusiza sub-county access water from Kabiranyuma, at points of damaged pipes. At such points, water is collected using cups to fill the jerrycans but it involves a lot of scramble where only strong people fetch it in time, then women and children obtain the opportunity in the late hours of the day.

Figure 4.9 Local communities scramble to fetch water from a broken water pipe in Gitenderi parish, Nyarusiza

4.4.3 The Quantity of Water in Kabiranyuma Swamp

CARE-DTC hydrological data showed that during the dry season, water flow rate in the pipeline ranges between 3.2 and 1.1 litres/sec. In the wet season, the flow rate increases to about 5.06 litres/sec.

Experimental results showed that for both dry and wet seasons, the minimum and maximum yields for Kabiranyuma GFS is 1.21l/s and 5.06l/s respectively. The obtained results are given in the table 4.11

Table 4.11: Experimental results for Kabiranyuma flow rate

Season		**Readings (litres/second)**				**Average day reading**
Wet season		1st	2nd	3rd	4th	
	1st week	4.98	6.42	5.35	6.51	5.8
	3rd week	5.15	4.18	4.18	4.30	4.45
Dry season						
	1st week	3.42	3.67	3.52	3.46	3.52
	4th week	1.32	1.25	1.13	1.14	1.21

From the measured results, Kabiranyuma scheme has capacity of supplying 518.4m3/day in wet season and 86.4m^3/day during driest months of the year.

4.4.4 The Quality of Water in Kabiranyuma Swamp

Results from Kisoro water quality laboratory, showed that the quality of water from Kabiranyuma swamp is good with high transparency, low turbidity and low E. coli count. The results are described in the table 4.12.

Table 4.12: Water quality analysis results for Kabiranyuma water source

Parameter	**Units**	**Parameter value from this study**	**National standard for portable water**	**Maximum allowable**	**WHO guidelines**
PH		6.3	5.5 – 8.5	5.0 – 9.5	-
Electrical conductivity	µs/cm	51	1000	-	-
Total dissolved solids	Mg/L	33	700	-	-
Total suspended solids	mg/L	3	0	-	0
Turbidity	NTU	2.1	10	30	5
Colour apparent	Ptu	56	15	-	-
Total alkalinity	mg/L$caco_3$	26	500	-	-
Total hardness	mg/L$caco_3$	20	600	800	500
Total iron	mg/L	0.1	1	2	0.3
Magnesium	mg/L $Mgco_3$	2.4	50	-	-
Calcium	mg/L $caco_3$	12	75	-	-
Bicarbonate	mg/L $caco_3$	26	500		
Sulphate	mg/L so_4^{2-}	0	200		
Fluoride	mg/L F^-	0.3	1		
Nitrate-N	Mgl/L	0.001	10	-	-

From table 4.12, the high color value is attributed to organic matter for decayed vegetation that remained in water due to the fact that the existing design did not consider a screening chamber to get rid of both course and fine particles.

The low E.coli count is attributed to the spring's freedom from feacal contamination since the source area is not inhabited and does not contain any concentrations of harmful chemical constituents.

The results prove that, the quality of water from Kabiranyuma swamp satisfies the National and WHO standards and does not require major treatment. Only minor treatment including screening and sedimentation processes are required. Therefore, from the analysis, the water has satisfactory physio-chemical quality hence safe for domestic use.

4.4.5 Actual factors that influence the Sustainability of Kabiranyuma Gravity Flow Scheme

According to existing design, the scheme was over stretched basing on an assumed safe yield of 3l/s instead of the actual one of 1l/s. The scheme was serving a population of 21,000 from three sub-counties which was far beyond its capacity.

The scheme was mismanaged after completion with only a few of the beneficiaries paying for the water while others getting it free of charge. Low interest of beneficiaries paying a fair water tariff as was being charged was caused by the community's perception that water is a free resource. The management team did not do enough to sensitize the communities and enable them understand the need for paying the fee. As a result, the system could not recover its operation and management costs.

The system was poorly implemented with water reaching the main reservoir but not most of the distribution lines. As a result of high demand from the system with a low supply capacity, some residents from the worst hit areas turned hostile towards the project and started cutting and stealing the pipes of the distribution lines. This resulted in the total collapse of the scheme whose operation and maintenance was already poor due to unwillingness of people to pay.

The only water source for the communities surrounding MGNP is Kabiranyuma swamp located inside the protected area and thus animals also share water source with human beings and in the process ended up destroying gravity water pipes of the scheme (UWA, 2014).

Distribution pipelines were not buried below ground but exposed on the surface, so they were highly vandalized. Also break pressure tanks and yard taps were not fenced which increased their risks of being destroyed.

Other factors that contributed to sustainability failure of the scheme included breakage of pipes, inadequate skills and blockages of pipes among others, as graded in the table 4.13

Table 4.13 Factors and their percentage contribution to water system sustainability failure

Challenges that affect constant supply	**Percentage of non-functionality**
Low yield	10
Breakage of pipes	20
Blockage of pipes	15
Alternative nearby	5
Vandalism	35
Inadequate skill	15

4.5 Sustainability Model for Kabiranyuma Gravity Flow Scheme

4.5.1 Re-design of Kabiranyuma scheme

With the actual safe yield of 1l/s at the peak of dry season for Kabiranyuma GFS, the scheme can only serve smaller population than that provided for by the previous design. Mabungo parish, a worst-hit area in terms of walking distances to the nearest safe water supply was considered. The supply is only through kiosks without any tap yard, since yard taps were previously mismanaged unlike kiosks. A number of major components that have been re-designed are discussed below;

a) Spring intake

The existing intake was maintained but developed by providing a fence around it to provide the required protection and to ensure that the required yields are obtained throughout the 15 years design horizon.

b) Sedimentation tank

A sedimentation tank made of reinforced brick masonry with a capacity of $10m^3$ was developed to help remove vegetation organic matter and other solid particles. The capacity of the sedimentation tank was based on the safe yield of 1l/s in dry season and up to 5l/s in rainy season, which provided an average safe yield of 2.5 l/s. The formula of Q = C*T was used to determine the capacity of the sedimentation tank.

Q = C*T……………………………………………………………………………….Equation 3

where;

Q = volume of sedimentation tank (m^3)

C = raw water flow rate (m^3/hr)

T = detention time (hrs)

Because raw water from Kabiranyuma source contains suspended particles (decayed organic matter particles) and silt, a detention time of 3600 seconds was considered to ensure effective settling of particles.

$Q = 2.5x3600$

$= 9000litres = 9m^3$

Therefore, for sufficient settling of suspended particles, a capacity of $10m^3$ for the tank was considered.

c) Transmission main

The existing transmission line has a pipe material of GI ND75mm class B of length 4000m to the main supply tank at Kukyanyirabutari few meter into the game park of Mt. Muhavura, and it was found to be in good condition. The same transmission line was maintained

.

d) Break pressure tanks

Five (5) break pressure tanks each of capacity $1m^3$ were developed along the transmission line to avoid pipe bursts due to high static pressure. Each break pressure tank is capable of breaking 100m excess pressure of water column, giving a total pressure drop of 500m.

e) Storage tank

The existing storage tank of capacity $250m^3$ located at Kukyanyirabutari is still in good position and therefore the same tank was mantained.

f) Distribution network pipeline

Only existing pipeline network along Mabungo parish were maintained to supply water to the kiosks. All the pipes to be in trenches 1m deep to avoid being damaged and embezzled.

g) Public Kiosks

With supply of $86.4m^3$/day i.e (3.6m3/hr x24), the number of serving points (kiosks) were reduced to Six (6) to ensure that water demand by targeted group is equally met even in the dry season. The kiosks were evenly distributed within the parish with each kiosk serving two villages. Each kiosk has two taps and a meter. All these kiosks are under one operator who appoints an attendant per kiosk . Water will flow from the source through all the above sections to the service points by means of gravitation.

Communities agreed that paying 100 Uganda shillings per jerry-can is fair and affordable by every member within Mabungo parish. The money has to be paid to the kiosk attendants who will hand-over the collected money to their respective village committees on weekly basis. The scheme operator will regularly cross-check whether the money reported by kiosk attendants is equivalent to the units on the meter readings. The village committee will keep on banking the money to the committee’s account and keep the receipts for accountability. This money will purposely be used for operation and maintenance of the system.

With this self-finance project, communities will also be in position to generate more money through lending it on interest to interested community members. The profits made will be used for facilitating the private operator and members of the committee

4.5.1.1 Kabiranyuma scheme layout

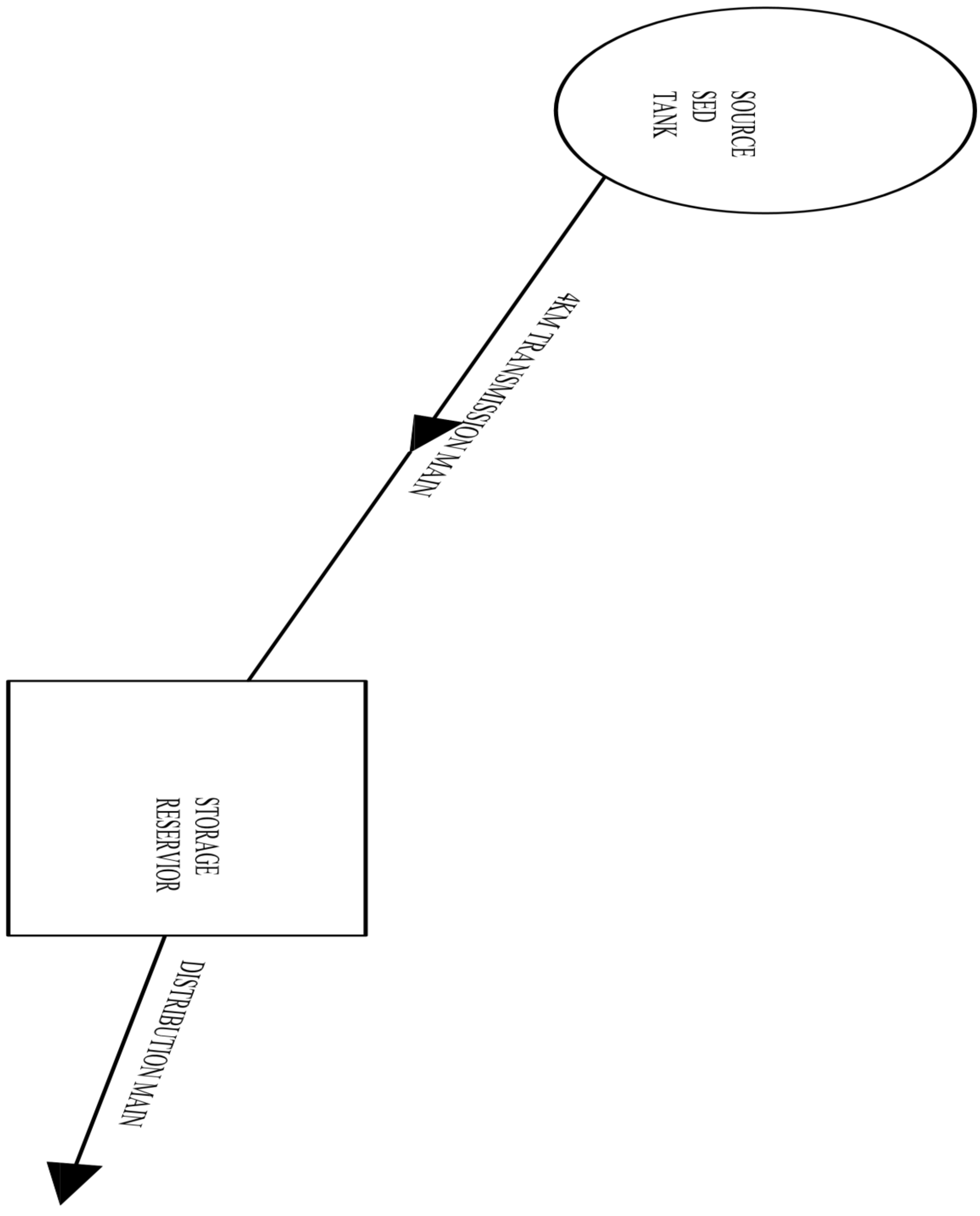
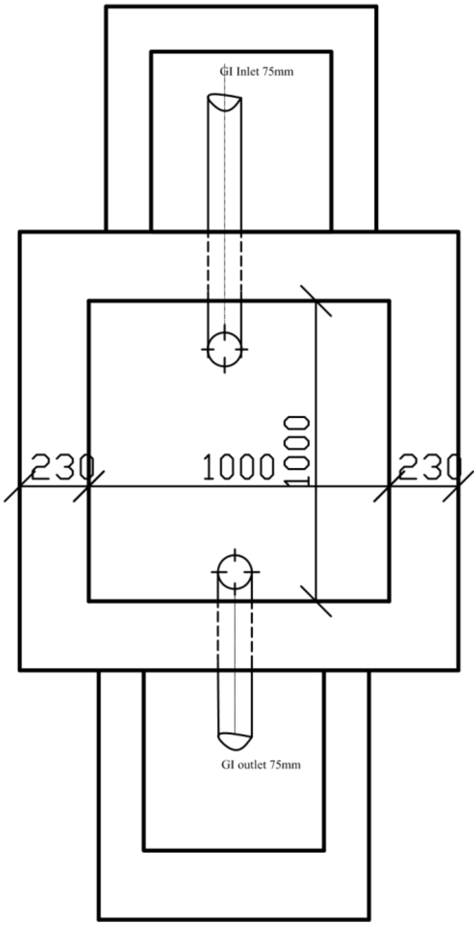
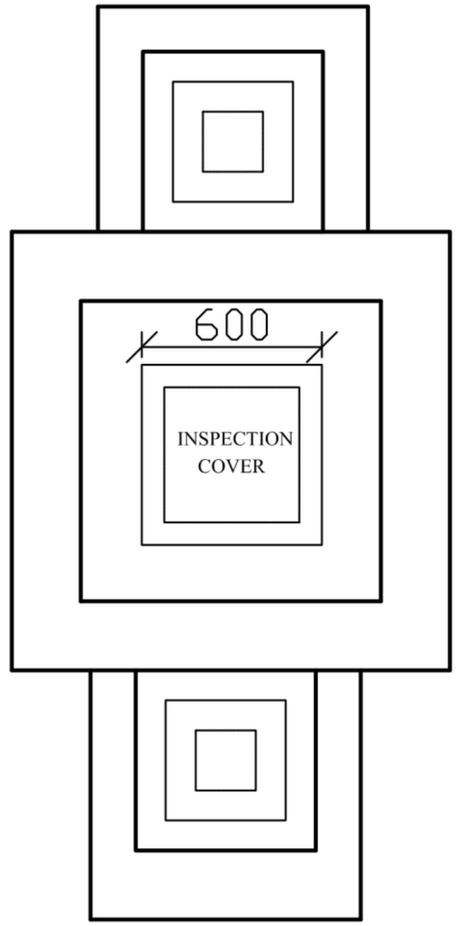


Figure4.10: Kabiranyuma scheme layout

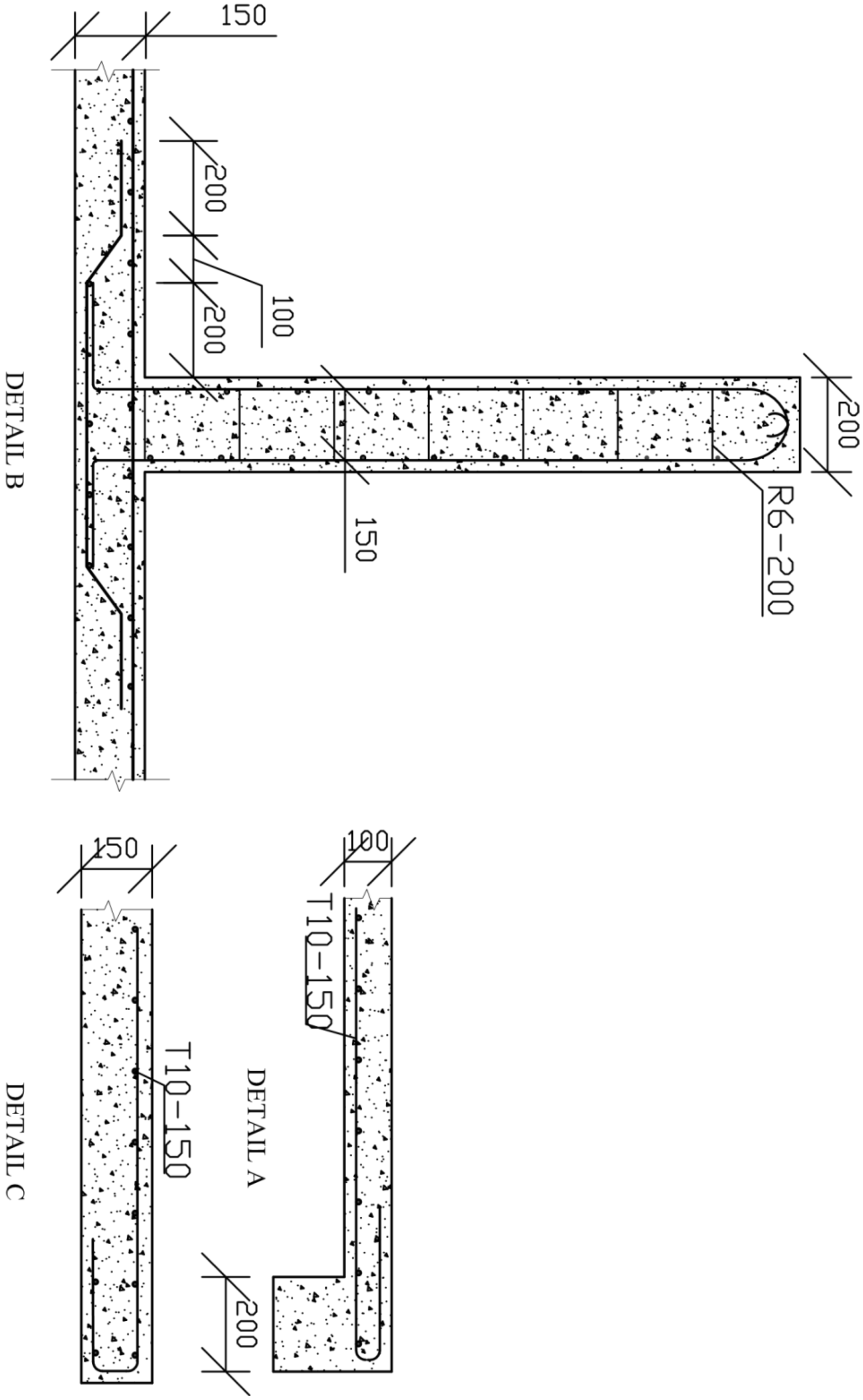
4.5.1.2 Design drawing for Sedimentation tank and Break pressure tank

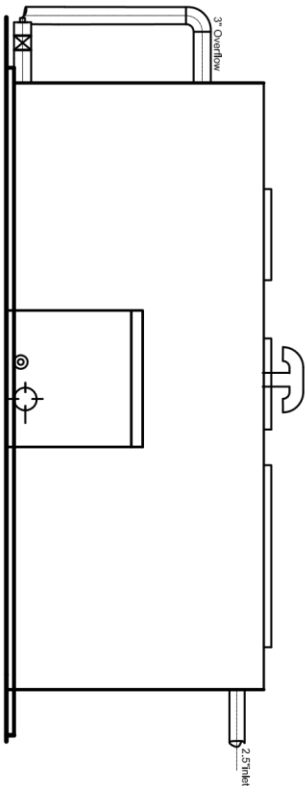


BPT $1M^3$
GROUND PLAN

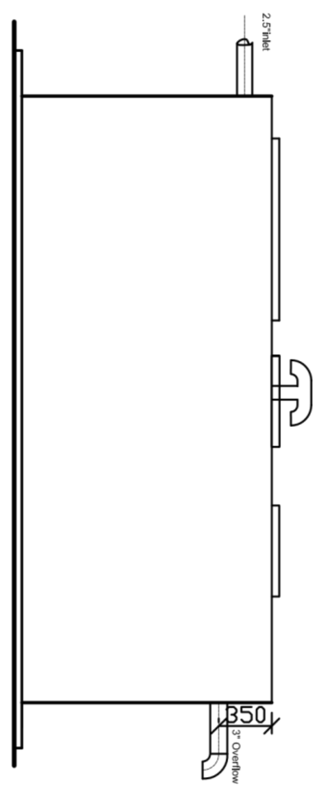


BPT $1M^3$
ROOF PLAN


DETAIL B
150
200
100
200
150
200
R6-200
DETAIL C
150
T10-150
DETAIL A
100
T10-150
200

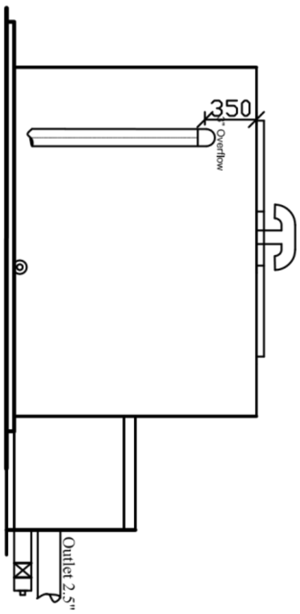


ELEVATION D

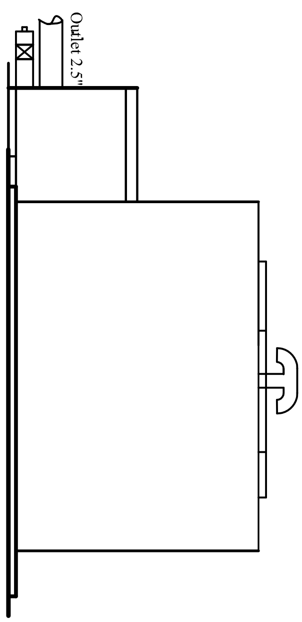


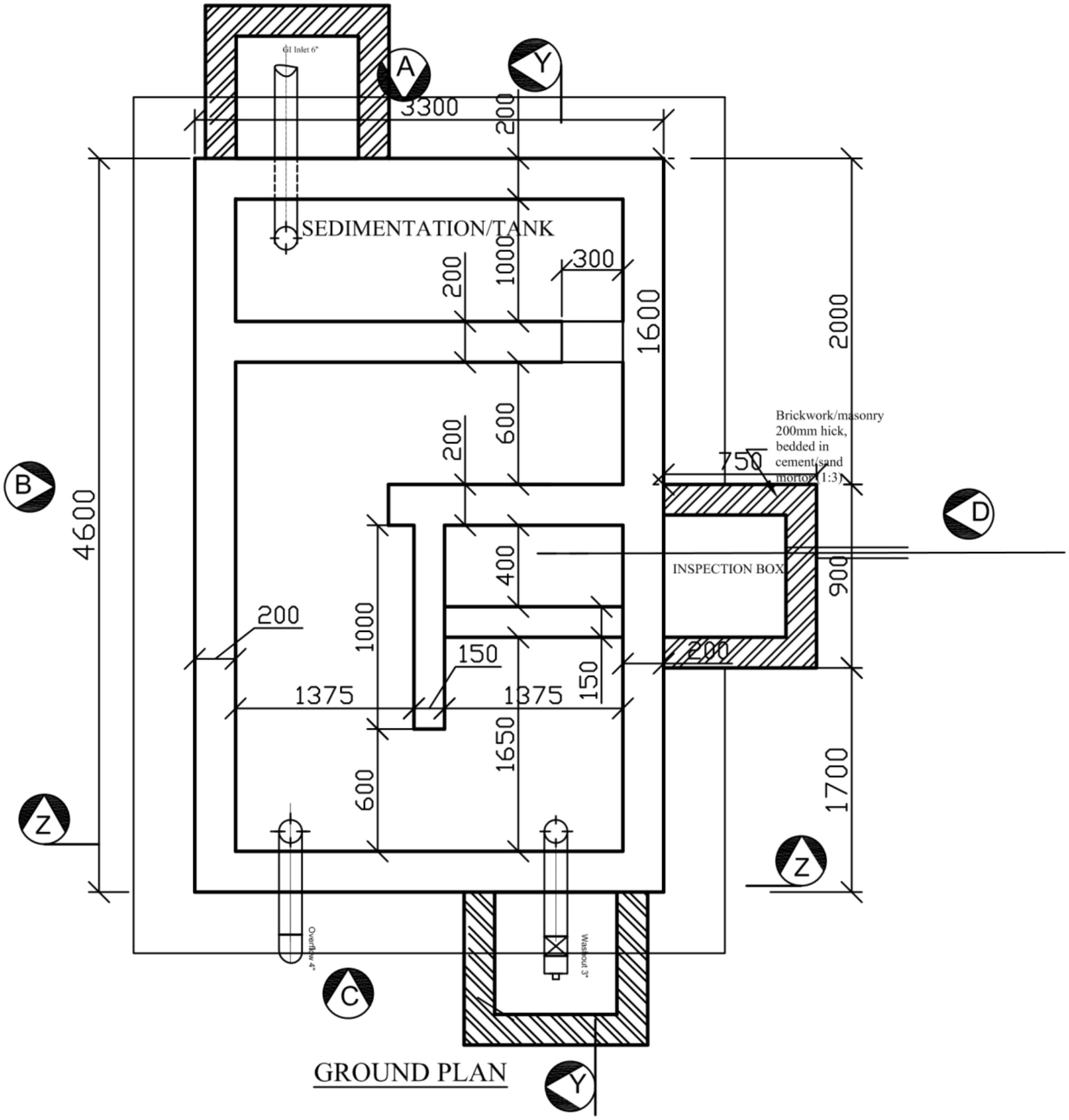
ELEVATION B

ELEVATION C



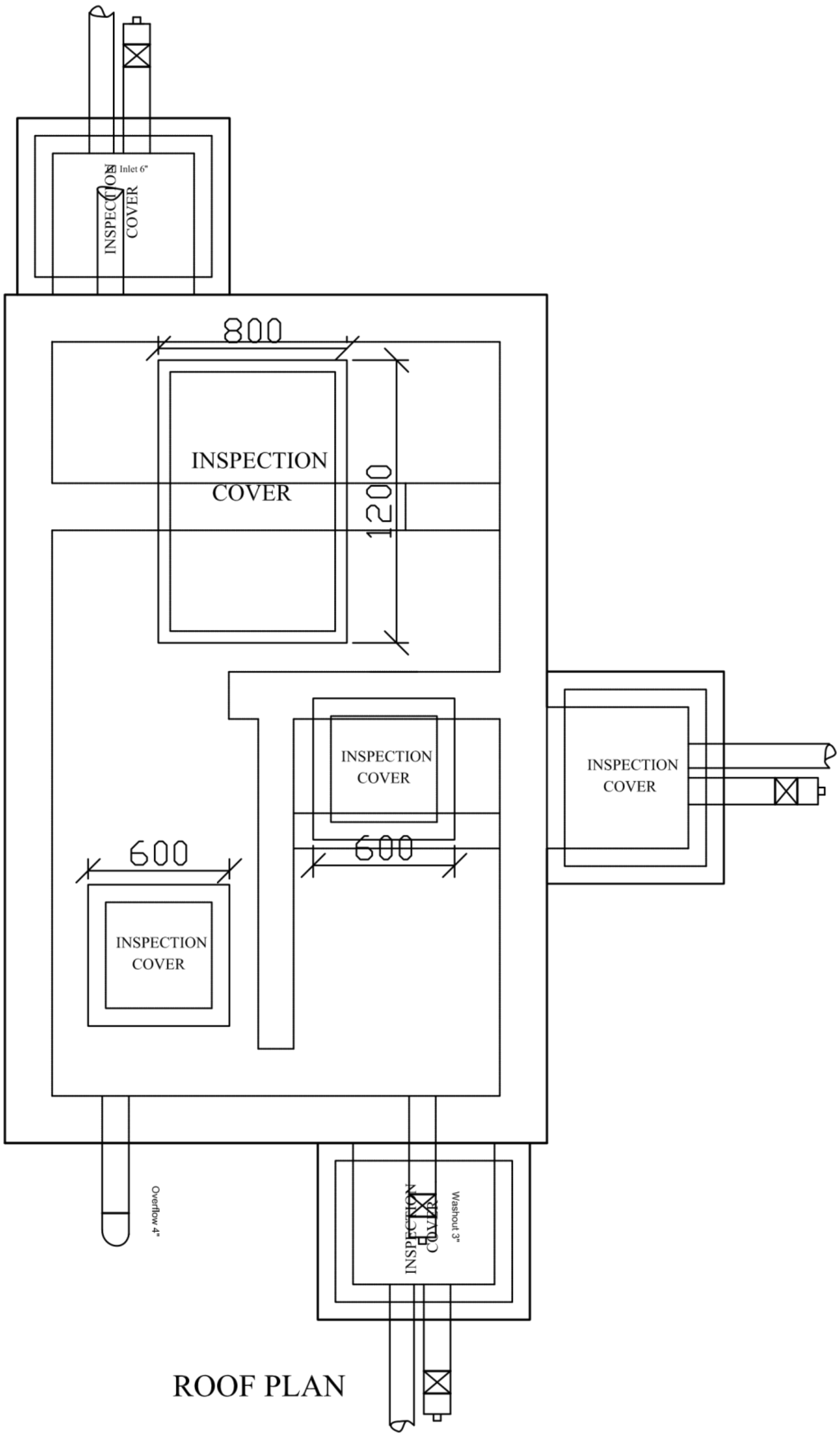
ELEVATION A



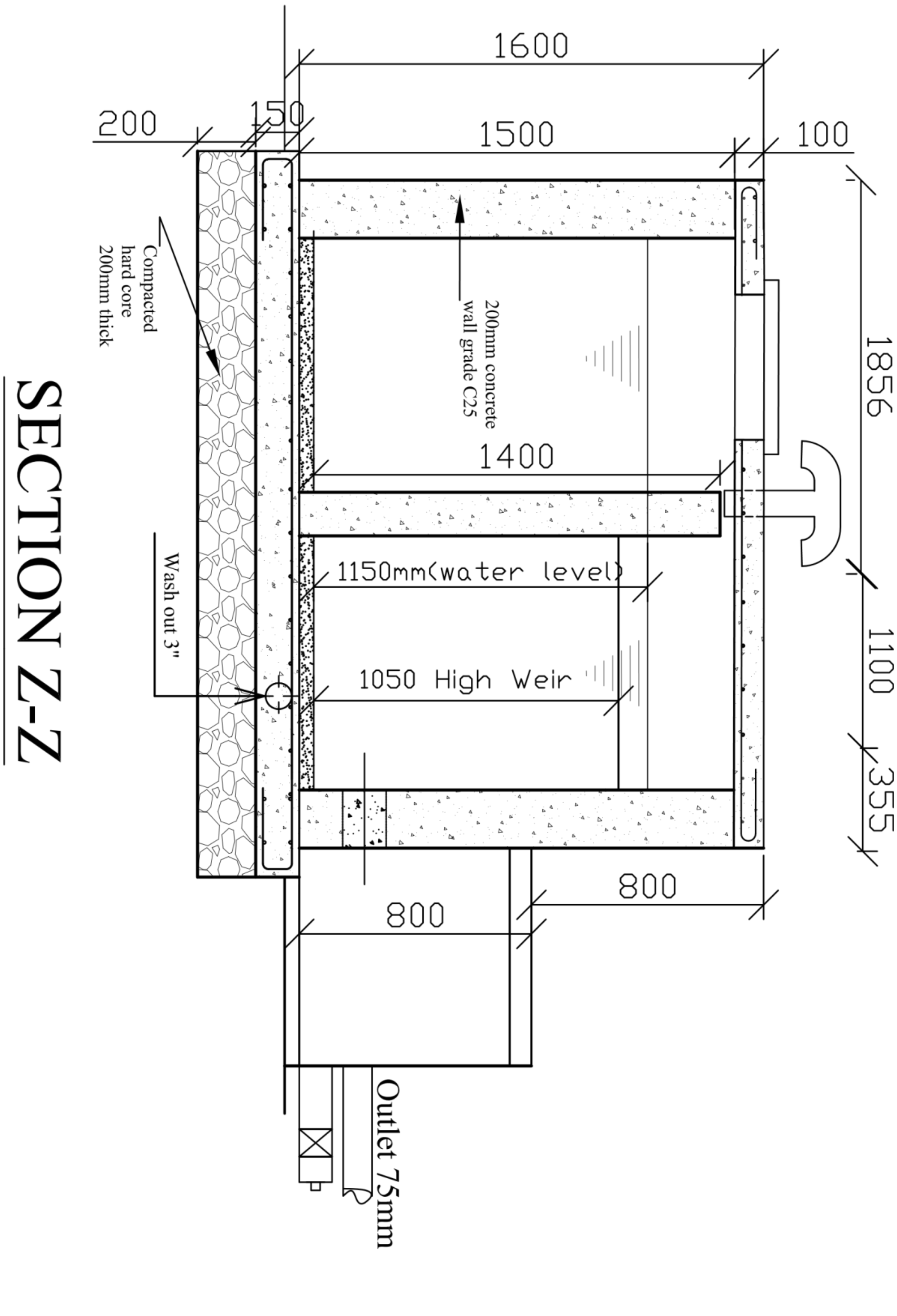


GI Inlet 6"
3300
200
SEDIMENTATION/TANK
1000
300
200
1600
2000
600
200
Brickwork/masonry
200mm hick,
bedded in
cement/sand
mortor (1:3)
750
400
INSPECTION BOX
900
4600
200
1000
150
200
150
1375
1375
1650
600
1700
Overflow 4"
Washout 3"

GROUND PLAN

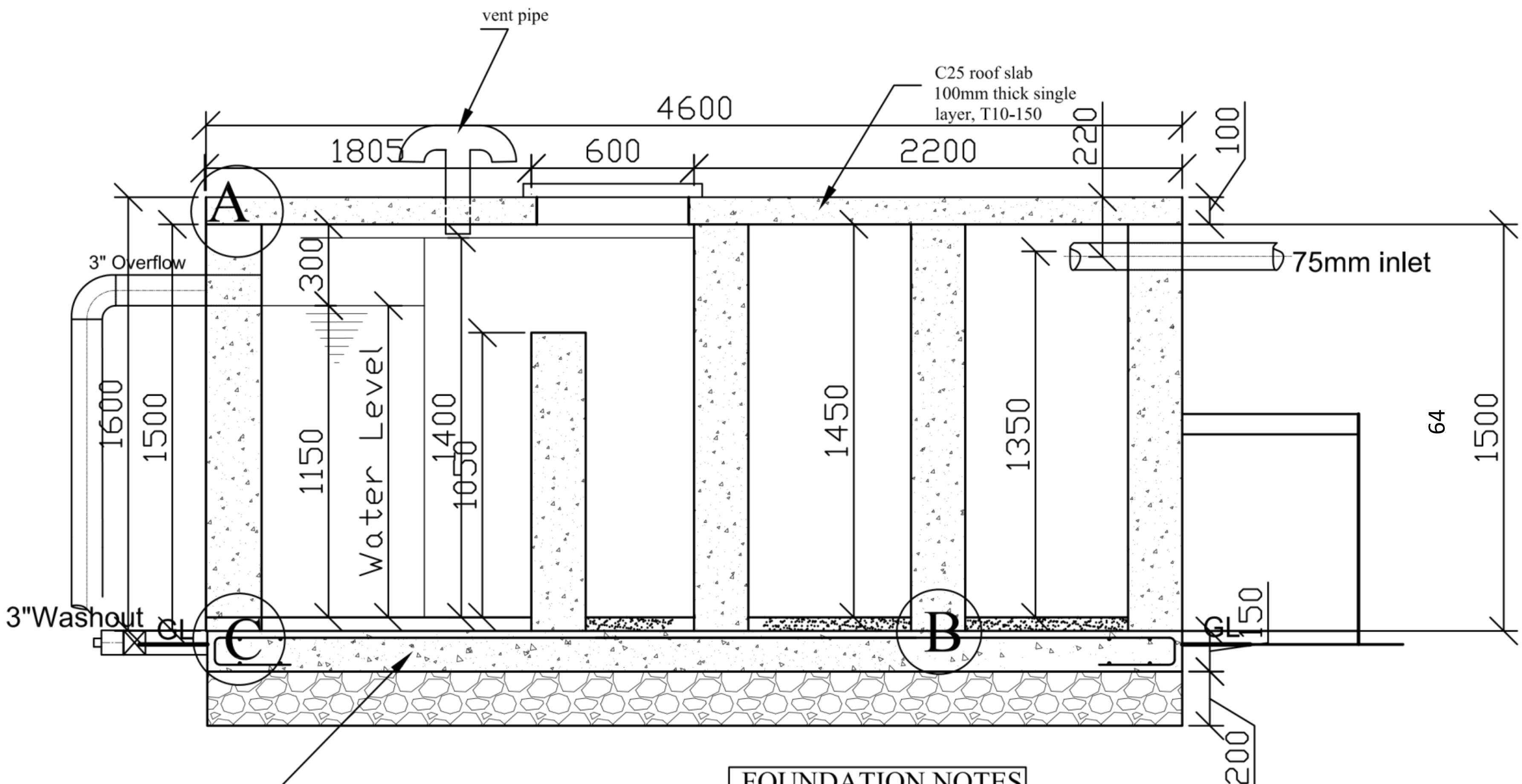

Inlet 6"
INSPECTION COVER
800
INSPECTION COVER
1200
INSPECTION COVER
600
INSPECTION COVER
600
INSPECTION COVER
Overflow 4"
INSPECTION COVER
Washout 3"

ROOF PLAN



1600
200
150
1500
100
Compacted
hard core
200mm thick
200mm concrete
wall grade C25
1856
1400
1150mm(water level)
1100
Wash out 3"
1050 High Weir
355
800
800
Outlet 75mm

SECTION Z-Z



SECTION Y-Y

FOUNDATION NOTES

50mmcement sand screed on
150mm RC on mix (1:2:4)
50mm blinding on
200mm well compacted hardcore
on firm ground.

4.5.2 Assessment of Sustainability Level

The study first assessed the sub-indicators of sustainability for Kabiranyuma to determine the level of the scheme's sustainability, as given in table 4.14.

Table 4.14: Sustainability sub-indicators and their details

Sub indicator	**Details**
Financial Management	Criteria for setting user fee, regular payment of the fee, presence and potential of the banker, capacity of beneficiaries to pay the tariff, etc. Assessment was based on 10 questions.
Consumer Satisfaction	satisfaction with quantity and quality of water received, hours of supply, reliability of supply, tariff collection methods, participation in decision making, etc. Assessment was based on 10 questions.
Operation and maintenance practices	Existence of skilled system operators, availability of spare parts, durability of system's equipment, and capacity to purchase them, etc. Assessment is based on 9 questions.
Willingness to Sustain	Community perception on paying the user fees, owning the system, financial capacity of the community to sustain the system, willingness further develop the system, etc. Assessment is based on 10 questions.

Sustainability was measured using a scoring method developed by UNDP and World Bank which ruled that sustainability score can lie between 0 and 10, so that any sub-indicator scoring lower than 5.00 are considered "unsustainable", between 5.00 and 6.67 are considered "potentially sustainable," and systems scoring above 6.67 are considered "sustainable (Sara and Katz, 1997).

From the results, the sub-indicator scores were fairly consistent and all above 6 for Kabiranyuma scheme. The performance of financial management came up the highest (9.58) whereas the performance of Operation &Maintenance consumer satisfaction became the lowest with (6.14). the results are detailed in table 4.15

Table 4.15: Scores of sustainability indicators of community water supply schemes

Scheme	**Financial management**	**Consumer satisfaction**	**Operation & Maintenance**	**Willingness to sustain**	**Overall sustainability**
Kabiranyuma	9.58	8.00	6.14	9.09	8.45

From table 4.15, sub-indicators; financial management, consumer satisfaction, and willingness to operate proved to be sustainable, whereas operation and maintenance was found to be potentially sustainable, and the overall sustainability of 8.45. therefore Kabiranyuma scheme proved to be sustainable.

4.5.3 Model Development

The community Based Organization Management model which places the beneficiary community in the center of the process was developed for Mabungo parish. In areas where CBOs have been used to manage water supply schemes, they have been proved to function at very satisfactory levels, where the support and assistance are given by the Local Authorities (De.Silva).

The model was based on qualitative data which was collected from 269 respondents about Kabiranyuma gravity flow scheme while concentrating on issues related to the scheme's potentials, challenges and opportunities for its re-installation and utilization in a sustainable manner.

A sustainable water supply model for Mabungo sub-county considered five key activities, i.e., limit supply coverage, scheme rehabilitation, rain harvesting system, management and monitoring actions as in figure 4.11.

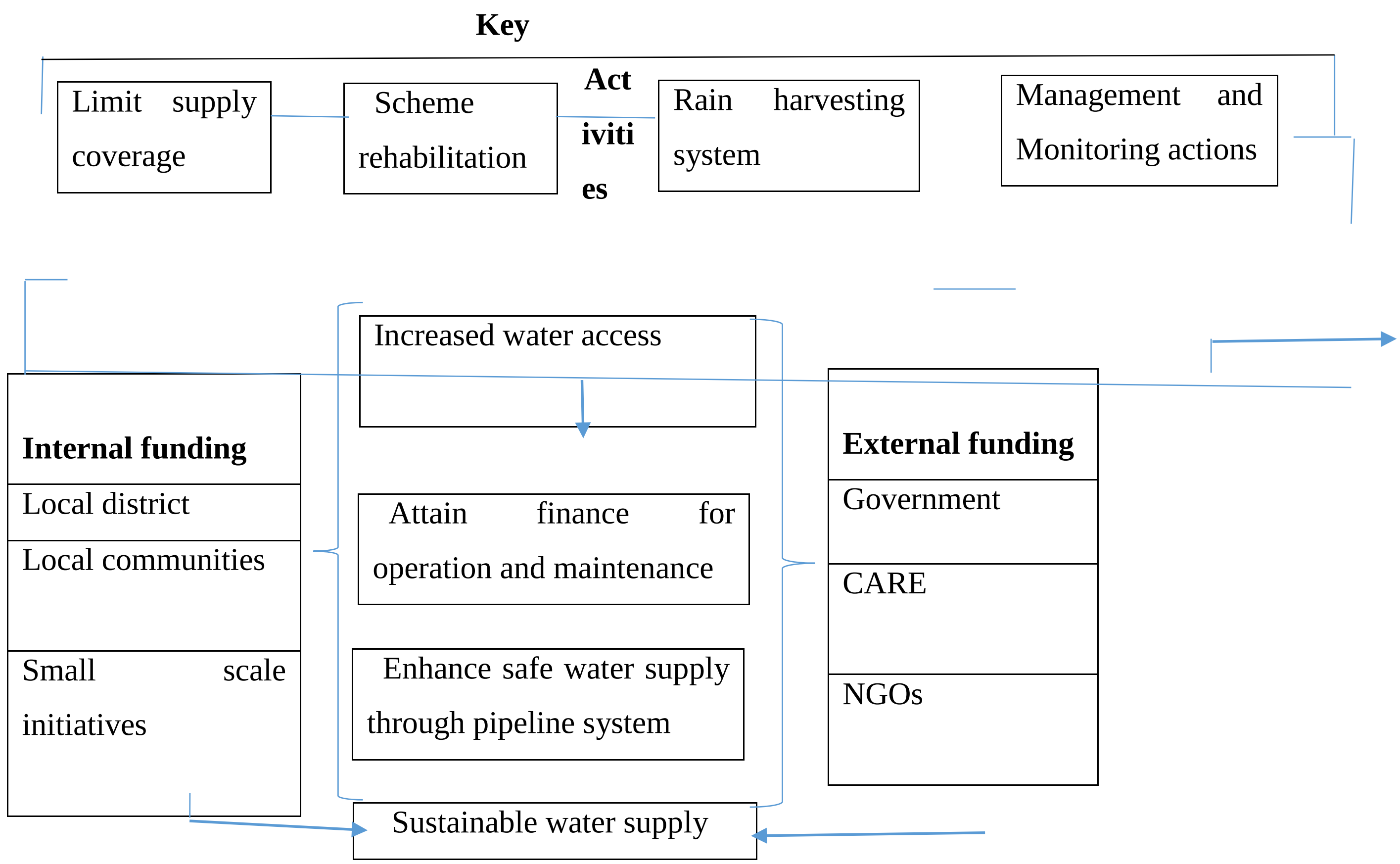


Figure 4.11: Developed Model for sustainable water supply in Mabungo parish

Over stretching of Kabiranyuma scheme beyond its capacity highly contributed to scheme failure. To limit supply coverage, it is necessary to concentrate the supply to worst-hit areas of Nyarusiza sub county which the study found to be Mabungo parish.

This could be made possible by encouraging communities of Muramba sub-county who previously depended on Kabiranyuma water to utilize and safeguard the newly developed Jinya scheme in the area. Other parishes in Nyarusiza i.e. Kasovu, Gitenderi and Rukongi were also encouraged to safely utilize the springs within their localities and rain harvesting tanks which were provided to them by the Japanese embassy.

On this basis, the Water Department in Kisoro District has to lobby for more rain water harvesting tanks to work as supplementary water supply for communities. This will help to sustain the actual Kabiranyuma safe yield of 1l/s even with increasing population.

The action is expected to attract high population accompanied with high demand for land for agriculture, to the area if water crisis is stabilized.

Kisoro district is however gifted with favorable climate composed of both tropical and savannah (NEMA, 2007) which guarantees great achievement, if resources from local district and small scale initiatives are galvanized and a tax be paid by the local communities through service fees to enable the obtaining and implementation of large-scale water harvesting appliances which can enlarge potable water supply for the population. This creativity could also be supported by the government, CARE and NGOs since it essentially targets community development.

Managing finance has always been a major problem to many people or even projects. This model introduces simple approaches for ensuring proper management and utilization of finances, through daily record keeping, accountability, reporting and quarterly financial management trainings.

A hydrological monitoring station connected to a wireless receiver with a screen, was inroduced. A portable wireless receiver which uses dry cells displays the condition of the scheme. The receiver has to be kept in scheme attendant's house which was considered to be next to the station in a place called Kukyanyirabutare. The performance status of the system will be monitored using colors as pre-scribed in table 4.16.

Table 4.16: Color indicators for monitoring the performance status of Kabiranyuma scheme

No.	**Color**	**Indication**
1	Green	Good condition and well-functioning of the tanks
2	Yellow	Fair functioning of the tanks
3	Red	Poor condition of the tanks
4	Blue	Reduction in the quantity of water
5	Black	Reduction in the quality of water

Green color on the screen will indicate that all the tanks (storage tank, break pressure tanks and sedimentation tank) are in good condition and properly functioning.

When the screen indicates yellow color it will mean that the functioning of the system's one or more tanks has lowered or has got a fault and therefore the technical team needs to identify the exact tank with a problem and service it. However, in this condition the system is still able to keep on supplying water though it is not good for the system. Therefore yellow color will act as a whistle blower to the concerned team to prepare and do the required mantainance in time.

Display of red color on the screen will mean that the system may stop functioning any time. In this state, the system will have gone into critical condition of performance. Therefore the servicing action will have to be done in the shortest time possible before it completely breaks down.

Blue color will mean that the quantity of water supplied has gone down. According to (Bitariho, 2015) Reduction in water supply from Kabiranyuma scheme is attributed to lowering of the water table at the source and blocking of distribution pipes. In this state, the technical team will survey to find out the exact cause and will advise accordingly.

With black color on the screen, the indication will be poor quality of water supplied. Pollution of Kabiranyuma water was attributed to decayed vegetation, animals from the park and a dirty reservoir (Kisoro district report, 2012). The team in charge of water quality maintenance will always do the needful to find out the source of pollution and corresponding measures will be taken.

Also the existing hydrological monitoring system installed within Kabiranyuma swamp, will guide in regulating the consumption levels of communities in accordance with the changes in the water table of the swamp (water quantity). This means that, in case the water table (quantity of water) greatly lowers, the consumption levels of communities will be advised to be minimized up to what the swamp can provide, this will protect the source from being over drained and incapacitated. Communities will also be encouraged to properly use and safeguard their water.

All the monitoring and servicing will be done remotely at low costs. This will ensure continuous performance of the system and therefore, continuous water supply to communities

However, a major challenge to this action is the high cost involved in obtaining technical resources to implement and maintain the station. The model considered pooling together resources from Small scale initiatives within Nyarusiza sub-county, through an organized association and support the system.

Efforts by the Government of Uganda to supply safe water to communities have been more realized in urban areas with little attention given to rural areas. The model, in response to recover the issue, introduces the community water management approach within Mabungo parish and Nyarusiza at large. The approach necessitates participatory processes among communities to create a sense of ownership while operating, maintaining and managing their water supply systems themselves.

Communities are motivated to willingly provide the required contributions, after realizing that they are the very people to benefit from the system, at the same time to suffer if the system is poorly operated.

It makes more sense embracing such creativity to enable rural communities achieve equal developments towards overcoming water crisis and its associated problems, majorly through their own efforts. The community can initiate a development scheme and solicit help from the government and other rural development agencies (Kimengsi, 2018) such as Corporation for Assistance and Relief Every Where (CARE), Uganda Wildlife Authority (UWA) and other NGOs that support community development.

Adopting the participatory approach among communities of Mabungo, has high opportunities of contributing towards sustainable development goals 6, which aims at ensuring universal access to clean water and sanitation by 2030.

Rainwater harvesting should be encouraged to be adopted by communities with some support from District both at communal and domestic levels, to serve as an additional source of water. The area is blessed with favourable climate i.e. it receives rainfall for seven (7) months with two peaks in the year i.e. March to April and October to December, and the average rainfall is about 1650mm per year (ADAMS, 1998). Constructing rainwater harvesting tanks capable of collecting and storing water during rainy seasons was found promising in acquiring a reliable additional source of water supply during the dry season.

Kabiranyuma swamp being one of the rarest swamp habitats in Uganda, is sensitive to extreme changes in water levels and any water drainage systems that are likely to increase the natural drainage systems of the swamp will affect the swamp ecosystems (Bitariho, 2015). With water harvesting tanks along the swamp, It is therefore healthier for the swamp to continuously supply to its capacity while sharing the burden with the water harvesting system especially in dry seasons.

Kisoro District Water Department was engaged to come up with a proposal to solicit funds from either the Government or NGOs that support community development, to sponsor safe water supply to the population of Mabungo. It is obvious that such a proposal, once properly addressed will attract high support basing on how vital clean water is, towards community development.

Designing a Water Management Plan which takes into consideration all the possible ways of rehabilitating and operating the scheme, as well as providing alternative actions to water supply is very essential. The plan focused at connecting water from the scheme through pipeline system to the local communities.

The plan involves mainly local communities, the district officials, officials of CARE, UWA officials and small scale initiatives, all having a common purpose of promoting the wise use of Kabiranyuma swamp for the collective benefits of the population. This is in line with argument of Musonda (2004), that effective community organizations, ability of the community to operate and maintain facilities, ability of the community to raise adequate user fees for purchasing spare parts, and strong backup support from external parties at the district level to solve major breakdowns are the factors that contribute to the sustainability of water supply systems.

4.6 Structure of water management plan

It describes the roles of various stakeholders at different levels as in figure 4.12

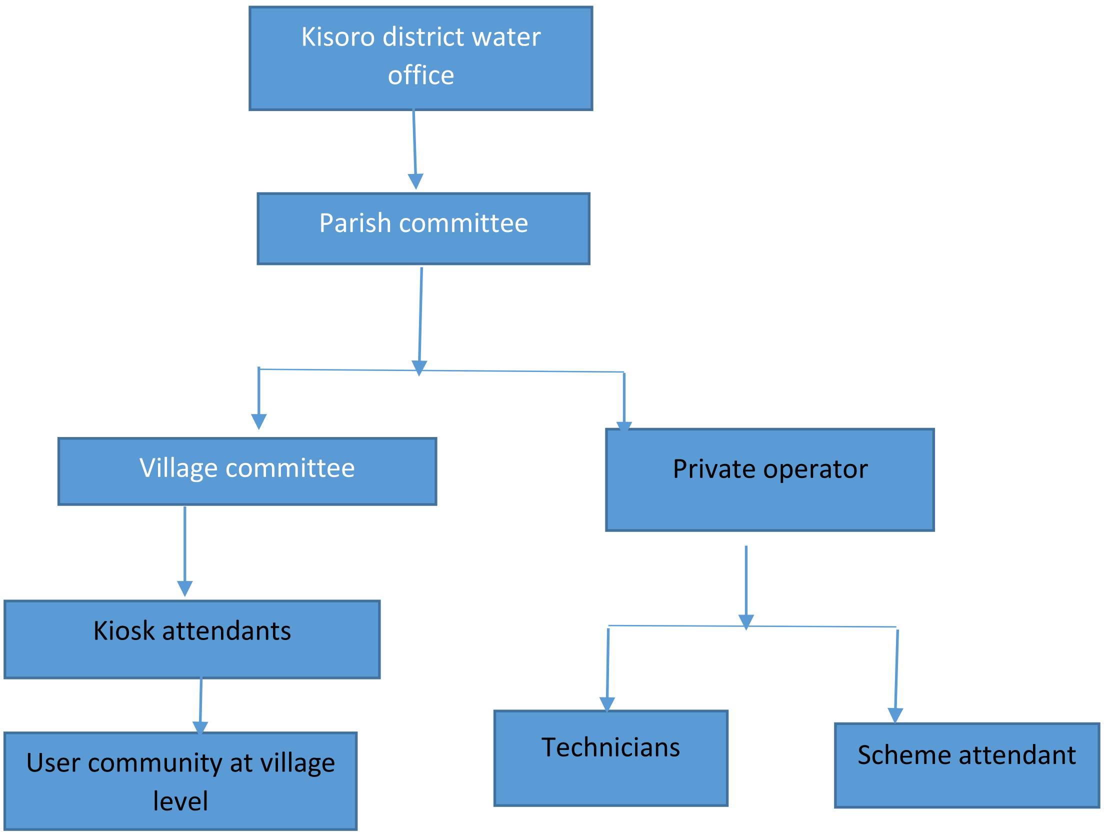


Figure 4.12; Kabiranyuma scheme management structure

a) District Water Office

The office provides technical backup and sensitization to the communities in Mabungo parish in activities related to operation and maintenance of the system.

b) Parish Committee

i. Supervise the works of both village committees and scheme operator
ii. Liaise with the district water department to handle all the schemes technical issues
iii. Procurement of private operator

iv. Come up with proposals to the government requesting for backstopping or any other support if need be.

c) Village Committee

This committee is responsible for the following;

i. Collection and banking of the user fee
ii. Approve procurement of required material and provide accountability
iii. Approve funds for operation and maintenance
iv. Carry out general monitoring of the system's performance, plan for its improvement and sustainability
v. Provide supervision during communal works and report faults to private operator
vi. Prepare and Present a monthly report on matters of performance of the scheme to the parish committee

d) Kiosk Attendants

These **are** responsible for the following;

i. Supplying water to communities at their respective points
ii. Report any fault to private operator
iii. Collect money from water users
iv. Report the collections to the treasurer on the village committee

e) Private Operator and Technicians

The private operator is in charge of the following;

i. Checking and rectifying any faults on kiosk taps
ii. Handling all technical operations within the system
iii. Carrying isout repairs on pipelines, tanks and meters
iv. Providing monthly report on system performance to the parish committee

f) Scheme attendants

These are responsible for the following duties

i. Taking daily readings from the wireless receiver and keeping the recordings for review by the responsible team
ii. Monitor and report any changes that occur at the spring intake, sedimentation and storage tanks
iii. Ensure good security to the source, wireless receiver and other system items

The shared contributions by the internal and external supporters towards the implementation of these goals will result into increased water access, attainment of finance for scheme operation and maintenance and enhancement of safe water supply at public levels. This reflects a positive indicator for sustainable safe water supply in Mabungo parish.

4.6.1 Scheme management rules and regulations

Committee members will be elected from and by local communities of Mabungo parish. Elections will be confidential, free and fair using the secret ballot. The committee will be in-charge of regular supervision of the maintenance works, managing the money collected from water sales, effective animal control and other related developments.

Members on the committee will be selected on contract basis for a period of five (5) years which will be renewable depending on performance.

The members of the committee will be motivated with a regulatory monthly pay which will be agreeable by the rest of the local members and it must be within the community's financial capacity.

Monthly communal works is a must for every member within Mabungo community. The works involves unblocking of drainage channels, clearing the bush around the reservoirs and public stand taps (kiosks), cleaning inside the reservoirs and maintaining the fences around the reservoirs and Kiosks.

A fine of twenty thousand Uganda shillings must be charged to every member who does not participate neither represented for community works. This money will always be banked and added to the finance of the scheme.

A person who caught embezzling or tampering with the scheme's equipment for his/her selfish gains will be liable for a fine which is enforceable in the courts of law

Contributions to the cost of operation and maintenance must be adhered to by every beneficiary. The contributions are in form of money, items and labour. However these contributions are fair and affordable by at least every community member.

Simple and affordable technology was considered in rehabilitating, operating and monitoring the system. All the equipment to be used will be locally produced and shouldn't require international experts to operate.

Capacity building among communities will be carried out through quarterly trainings and sensitization from the sub-county and schools, and will be spearheaded by district officials.

Gender balance was critically observed to ensure that all categories of people understand, own and enjoy the services from the system. Women are encouraged to take up the positions and confidently play their role without any limitations. Men are also advised to empower their wives towards decision making, protection and development of the system.

For a person to be elected to the committee, they must have stayed within Mabungo parish for more than thirty years. A birth certificate, national ID, and a recommendation letter from LCI chairperson have to be presented for nomination.

The minimum age for a member to be nominated to committee is 30 years. At this age, a person is expected to be mature, well acquainted with environment around him/her, free to take decisions and accountable for his/her decisions.

Basic levels of education were pre-determinant for members to be elected to the committees and procurement of technical teams. Education levels vary depending on the position given to a member as presented in the table 4.17

Table 4.17: Required qualifications to be selected as a committee member

S/n	Position	Qualification
1	Scheme operator	Diploma in plumbing
2	Technicians and scheme attendants	Certificate in plumbing
3	Kiosk attendant	Ordinary level
4	Treasurer	Diploma in accounting
6	Chairperson	At least a diploma in any field
7	Other members	Completed primary seven

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Implementation of water supply systems will increase access to safe drinking water (Habtamu, 2012), but the water systems must be properly managed to ensure continuous supply. The fundamental cause of systems' failure after construction proved to be limited or no involvement of the community in their implementation and management.

The analysis of the data showed that communities in the study area, have capacity to own their water supply system. Therefore full involvement of the community in operating and managing their water system is the main way to ensure proper functionality and sustainability. Therefore, the approach of community management plays a key role in attaining effective sustainability of rural water supplies.

Kabiranyuma gravity flow scheme has the potential to supply equitable water to the population of Mabungo parish for fifteen years, without causing any harm to the source. Rain water harvesting system is the efficient supplement to serve water alongside the scheme most especially in dry seasons where the water table for Kabiranyuma swamp drops.

This research presents the actual factors that contributed to sustainability failure of Kabiranyuma scheme which are all zeroed on limited involvement of scheme's beneficiaries right away from implementation, operation and management which worked hand in hand with improper system design and limited skills among the then system operators.

Proper management of water is an instrument for poverty alleviation and economic recovery but if water is poorly managed, it can rather serve as a limiting factor in poverty alleviation, resulting in poor health and low productivity, food insecurity and constrained economic development (Kimengsi, 2018 cited World Water Forum, 2000). The model brought in both internal and external actors to the board to provide necessary support towards rehabilitation and proper management of Kabiranyuma GFS while the community beneficiaries take the central role of owning the system. This contributes positive results in ensuring sustainable water supply.

Much as ownership and responsibility of the scheme will belong to the community, it cannot be ignored that support from local government, responsible ministry or external entities can do a great deal in boosting their performance. The support can be inform of finance, technical back stopping, provision of operational infrastructure, regular supervision, among others. Extra support from these organs can definitely improve the environment in which the communities are operating and managing the scheme. It also gives the communities the esteem that, what they are doing is developmental and equally recognized, hence motivated for continuous performance and development.

5.2 Recommendations

More support from government and other donors should continuously be provided to communities through technical backstopping, sensitization, funds and monitoring to strengthen the capacity of water committee members both at sub-county and village levels in operating and maintaining the water supply system. Creation of an effective and strong link between line agencies and Community Based Organizations is required to ensure the sustainability of this concept.

In acquiring supplementary supply, much emphasis should be put in the practice of water harvesting since the study area was found to be blessed with favourable climate which receives rainfall for seven (7) months with two peaks in the year.

Well skilled technical personel should be employed to operate the system to ensure its safe and continuous functioning, since previous team that was operating Kabiranyuma scheme did not have minimum required skills and contributed much in letting the scheme down..

The district of Kisoro with support from the government should come up with strict rules to fight against vandalism of water supply system's equipment. The government should help to enforce the developed rules.

Further studies should be undertaken in other sub-counties in Kisoro with related challenges of water crisis like Muramba and Chahi to generate more findings on factors that influence sustainable water supply in the areas as well as developing more adaptable solutions.

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APPENDICES
APPENDIX A

QUESTIONNNAIRE

Dear Sir/Madam,

I am **Kwitegetse Penlope,** a Masters student of Water and Sanitation Engineering from Kyambogo University**,** conducting a study on '**ENHANCING SUSTAINABLE SAFE WATER SUPPLY SYSTEM TO RURAL COMMUNITIES OF MABUNGO PARISH, KISORO DISTRICT.**

The main objective of this questionnaire is to collect information about the actual causes that influenced the sustainability of Kabiranyuma gravity flow scheme. You are kindly requested to provide valuable information to this study by filling this questionnaire a suitable response. The responses you provide in this study will be confidential and treated with integrity. Please feel free to seek clarification where the questions are not clear to you. I highly appreciate your cooperation.

Yours faithfully,

……………………………

Kwitegetse Penlope

Section A: Demographic Characteristics of Respondents: (please tick only once)

1. **Gender**

   a) Male ☐

   b) Female ☐

2. **Age** (**Please tick only once)**

   a) 18 – 24 ☐

   b) 25 – 29 ☐

   c) 30 – 34 ☐

d) 35 and above ☐

3. **Marital status: (Please tick only once)**

a) Single ☐

b) Married ☐

c) Divorced ☐

d) Widowed ☐

4. **Religion: (Please tick only once)**

a) Roman Catholic ☐

b) Anglican ☐

c) Moslem ☐

d) Pentecostal ☐

e) Other (specify) _______________

5. **Highest education level: (Please tick only once)**

a) None ☐

b) Completed Primary ☐

c) Completed ‘O’ Level ☐

d) Completed ‘A’ Level ☐

e) Completed Diploma ☐

f) Completed Degree ☐

g) Others (specify) _________________

6. **What is your occupation**

a) peasant ☐

b) civil servant ☐

 ☐

c) Business

d) Others (specify)___________________

7. **What is your average income per month?**

a) > 100,000
b) 100,00-200,000
c) 200,000 – 500,000
d) 500,000 – 100,000
e) <100,000

8. **How long have you been in this area?**

a) >1 year ☐

b) 1 – 10years ☐

c) 10 – 30 years ☐

e) Above 30 years ☐

Section B: Assessing community perception on the performance status of water supply systems currently available in Mabungo Parish.

1. What is the main source of water used by your household?

   …………………………………………………………………………………………………

2. How long does it take to reach the water source and come back?

   …………………………………………………………………………………………………

3. How long do you stand in line before accessing the water?

   ………………………………………………………………………………………………

4. Who usually goes to this source to fetch the water for your household?

   …………………………………………………………………………………………………

5. How consistent is the water source in its supply?

a) Daily

b) Twice a week

c) Once a week

d) Others specify…………………………………….

6. How satisfied are you with the availability of water for your household?

a) Excellent

b) Very good

c) Good

d) Fair

6. What is your observation on the color of water that you use in your home?

a). clear

b). somehow clear

c). green

d). black

7. What is your perception on the taste of water?

a). excellent

b). good

c). fair

d). poor

8. Do you treat your water in any way to make it safer to drink?

a) Yes

b) No

9. If yes, how do you always treat it?

…………………………………………………………………………………………

…………………………………………………………………………………………

10. Is water collected at any fee?

a) Yes
b) No

11. If yes what is the cost of water service?

……………………………………………………………………………………………………

12. Do community members have financial capacity to pay the mentioned fee?

……………………………………………………………………………………………………

13. What are common health problems of household members?

…………………………………………………………………………………………………
………………………………………………………………………………………………….

Section C: Assessment on the current water demand of communities in Mabungo Parish so as to forecast the future water demand

1. How many members do you have in your family?
2. How much water is consumed by each member of your family?
3. How much water do you use per day?
4. If availability of water in this area is improved, how much water do you think can be enough to each member of your family?
5. What do you think is the sufficient amount of water required to satisfy all the needs of your household per day?

Section D (i): Investigate the actual factors that influenced the performance of Kabiranyuma Gravity Flow Scheme

1. Who brought the idea of developing Kabiranyuma gravity flow scheme?

a). Community members

b). Officials at the district

c). Ministry of water

d).NGOs

e). others specify……………………………………

2. Whose idea was it to choose the technology used in developing and operating the scheme?

a). Community members

b). Officials at the district

c). Ministry of water

d) NGOs

e). others specify……………………………………

3. What was the source of the project funding?

a). Community members

b). Officials at the district

e). Ministry of water

d) NGOs

e). others specify……………………………………

4. Who was in charge of operation and maintenance of the scheme?

a). Community members

b). Officials at the district

c). Ministry of water

d) NGOs

e) Others specify……………………………………

5. Could those who were in charge of operations and maintenance respond to issues effectively?

a) Yes

b) No

Briefly justify your point…………………………………………………………………………

…….

6. Were you ever involved in any activities regarding development of the scheme?

a) Yes

b) No

7. If yes, what area did you participate in?

a) Paid cash

b) Decision making

c) Provided labour

d) Contributed materials

e) Part of committee members

f) Others specify……………………………..

8. If no, what prevented you from being involved?

……………………………………………………………………………….

………………………………………………………………………………………

9. Have you ever experienced any water-related problems in your area?

a) Yes

b) No

10. How severe are the problems?

a) Very high

b) High

c) Fair

d) Low

11. What are possible contamination points of concern to the water resource?

………………………………………………………………………………………

………………………………………………………………………………………

12. Were you in any way provided with trainings regarding safe use and protection of water?

a). Yes

b). No

c). Not sure

13. If yes, what did you benefit from the trainings?

……

……………………………………………………………………………………………………….....

14. What do you think should be put in place to ensure effective sustainability of the scheme, once restored?

Section D (ii): Questionnaires for officials at the district and related NGOs

1. Does the district have a laboratory for water quality testing?
   a) Yes
   b) No
2. If yes, does the laboratory have the standard capacity for microbiological testing (total coliforms, fecal coliforms, E. coli)?
   a)Yes

b) No

3. If so, what methods are used to assess the quality of water?

   a) Membrane filtration

   b) Multiple tube fermentation

4. . Is the laboratory certified and by who?

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

5. Did you have a sustainability plan for Kabiranyuma gravity flow scheme?

   a) Yes

   b) No

6. If yes, how effective was it?

   a) Very effective

   b) Less effective

   c) Not effective

7. If No, how were you ensuring the continuous supply of water from the scheme?

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

8. Were the stakeholders effectively involved in the operation and maintenance of the scheme?

   a)Yes

   b) No

9. If no, why

   ……………………………………………………………………………………

   ……………………………………………………………………………………

10. Did you have any policies or measures established by your department which were used to ensure effective utilization and management of Kabiranyuma scheme?

    a) Yes

    b) No

11. If yes, how would nonconformity to the established policies, be dealt with? ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………

12. Does the beneficiary community have the capacity to sustainably manage the scheme themselves?

a) Yes

b) No

13. What do you think should be put in place to ensure effective sustainability of the scheme, once restored?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Appendix B: Supplementary Tables

Household education status

No.	Education status	Percentage (%)
1	Degree	2
2	Diploma	5
3	Certificate	10
4	UACE	8
5	UCE	15
6	Below UCE	60

Purpose of water used at parish level

S/n	Purpose of water	Percentage (%)
1	Domestic use	80
2	Landscaping	1

3	Feeding animals	15
4	Irrigation	4

Type of water sources currently being used

S/n	Type of water source	Percentage of population that use the source
1	Public stand posts	35
2	Unprotected springs	4
3	Broken pipe lines	20
4	Water harvesting tanks	5
5	Dug holes	26
6	Kabiranyuma taps	10

Level of consistency of clean water supply from available water sources

Clean water source	Level of consistence			
kisoro town water system (kiosks)	high	Medium	Low	Very poor
Rank	0	65	30	5
existing kabiranyuma taps	high	Medium	Low	Very poor
Rank	25	55	20	0
Rain water tanks	high	Medium	Low	Very poor
Rank	0	10	85	5

Demand patterns for water supply in Mabungo parish

s/n	Time range (minutes)	Hours	Percentage of water consumption
1	8:00am to 10:00am	2	45
2	10:00am to 1:00pm	3	10
3	1:00pm to 2:30pm	1.5	45
4	2:30pm to 8:00am	17.5	0

Distance covered to access a water source

s/n	Distance range (km)	Percentage population (%)
1	0.5 to 1	15
2	1 to 2	15
3	2 to 3	20
4	3 to 4	50

Household perception on quality of water for different sources

	Water sources	**Quality**		
Households' perception		**Good**	**Fair**	**Poor**
	Broken pipeline	15%	30%	55%
	Springs	2	78	20
	Public stand posts	100	0	0
	Dug ponds	0	18	82
	Kabiranyuma taps	100	0	0

Current amount of water used per capita per day

s/n	Amount of water (litres)	household response%
1	5 -10	5
2	10 – 15	82
3	15 – 20	8-
4	20 – 40	5
5	Above 40	0

Communities' thinking on sufficient amount of water required by per capita per day

s/n	Range for the mount of water (litres)	Household response (%)
1	>5	**0**
2	5 – 10	**0**
3	10 – 20	**0**
4	20 – 40	**5**
5	40- 60	**70**
6	<60	**25**

Payment made by communities to obtain water from different water sources

S/n	Water source	Payment (shillings)
1	Public stand posts	100 or 200
2	Ponds	0
3	Institutional tanks	200
4	Broken pipelines	0
5	Private tanks	600
6	Kabiranyuma taps	0