

**DETERMINANTS OF HAND PUMP BOREHOLE PERFORMANCE AND  
EFFICIENCY IN RURAL AREAS OF UGANDA:A CASE STUDY OF KIBUKU  
DISTRICT**

**ELIZABETH SIKYAJULA**

**RSI4M45/022**

**A DISSERTATION SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND  
TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE  
OF THE MASTER OF SCIENCE IN WATER AND SANITATION OF UGANDA CHRISTIAN  
UNIVERSITY**

**October, 2025**



**UGANDA CHRISTIAN  
UNIVERSITY**

*A Centre of Excellence in the Heart of Africa*

## ABSTRACT

Uganda continues to face substantial challenges in ensuring safe, reliable, and equitable access to water, particularly in rural areas. Kibuku District in eastern Uganda exemplifies these challenges, with access rates ranging from 27% in Kabweri Sub-County to 95% in Kenkebu Sub-County, and an overall average of 58%. Despite significant government and donor investments in hand pump boreholes—the primary source of rural water—performance remains inconsistent due to frequent breakdowns, reduced yields, and compromised water quality. This study was undertaken to determine the technical, socio-economic, and environmental factors influencing the performance of hand pump boreholes and to develop predictive insights for enhancing their reliability and efficiency. The specific objectives were to: (i) assess the effect of technical factors on the performance and efficiency of hand pump boreholes, (ii) examine the relationship between socio-economic factors and borehole functionality, (iii) analyse the effect of environmental factors on borehole water quality, and (iv) develop an evidence-based predictive model for improving borehole reliability in Kibuku District. A cross-sectional research design was adopted, involving a sample of 384 respondents and 110 boreholes distributed across the district. Data on technical factors such as casing material, pump type, siting methods, yield; socio-economic factors such as user fees, local government support, spare parts availability, and environmental factors such as salinity, contamination, rainfall patterns were collected and analysed using analysis of variance (ANOVA) and multiple regression techniques. Results indicated that technical factors were the most influential predictors of borehole performance. Casing material emerged as the most significant determinant ( $\beta = 0.338$ ,  $p < .001$ ), followed by borehole siting mechanisms ( $\beta = 0.173$ ,  $p < .001$ ), pump type ( $\beta = 0.128$ ,  $p = .013$ ), and pump yield ( $\beta = 0.113$ ,  $p = .012$ ). Among environmental variables, salinity was the strongest predictor ( $\beta = 0.408$ ,  $p < .001$ ), with lower salinity levels associated with higher performance. Socio-economic analysis revealed that user fees ( $\beta = 0.085$ ,  $p = .048$ ), local government support ( $\beta = 0.637$ ,  $p = .019$ ), and spare parts availability ( $\beta = 0.871$ ,  $p = .003$ ) had significant positive effects on functionality, highlighting the importance of financial contributions, institutional support, and logistical readiness in sustaining rural water infrastructure. The study concludes that the performance and efficiency of hand pump boreholes in Kibuku District are primarily determined by technical standards, complemented by socio-economic governance and environmental suitability. Sustainable functionality requires improvements in casing material quality, hydrogeologically informed siting, appropriate pump selection, and structured maintenance. It is recommended that district water programs implement mandatory technical audits, train local technicians, and enforce standardized construction protocols to ensure the use of durable casing and context-appropriate pumps. Furthermore, policy frameworks should strengthen spare parts supply chains and institutional support systems. Future research should assess the long-term cost-effectiveness of casing materials across different hydrogeological zones and explore pump and groundwater interactions to optimize technology selection.

## **DECLARATION OF AUTHORSHIP**

I Sikyajula Elizabeth, declare that I am the author of this report and that any assistance I received in its preparation is fully acknowledged and discussed within the report. I have also cited other sources from which I used data, ideas or words, either quoted directly or paraphrased. I also certify that this report was prepared by me specifically for the partial fulfilment for the degree of Master of Science in Water and Sanitation of Uganda Christian University.

Sikyajula Elizabeth

July 2025

## APPROVAL

This dissertation entitled “Assessment of the Factors that affect the Functionality of Hand Pump Boreholes in Kibuku Sub-County and Kibuku Town Council”, has been written by Sikyajula Elizabeth, and submitted for the award of the degree of Master of Science in water and sanitation of Uganda Christian University.

Approved by;

Signature.....

Name

.....

Date

.....

## **DEDICATION**

This dissertation is dedicated to my parents who made all efforts to ensure that I am what I am, my husband Mr. Nsajju Jerome who encouraged me all through this achievement and to my sons Philip and Philemon whom I wish to always aim high with God as their guide.

## **ACKNOWLEDGEMENTS**

I thank the Almighty God for the precious gift of life, wisdom and power. For without Him, nothing would be possible for me to reach this far.

I would like to express my indebtedness to my supervisors Prof. S. Kizza Nkambwe and Dr. Mutyaba John for the precious time, assistance, guidance and tireless efforts in the course of my research and writing of this dissertation. This work wouldn't be possible without you.

I thank the Head of Department- Engineering and Environment for the support and tolerance throughout the course of my Master degree programme. I am very grateful.

I acknowledge with thanks the support of my family members, especially Mr. Nsajju Jerome, for all the resources and encouragement provided for my success.

May the Almighty God bless you all abundantly

## TABLE OF CONTENTS

<b>ABSTRACT</b> .....	<b>ii</b>
<b>DECLARATION OF AUTHORSHIP</b> .....	<b>iii</b>
<b>APPROVAL</b> .....	<b>iv</b>
<b>DEDICATION</b> .....	<b>v</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>vi</b>
<b>LIST OF TABLES</b> .....	<b>ix</b>
<b>ACRONYMS AND ABBREVIATIONS</b> .....	<b>xi</b>
<b>CHAPTER ONE</b> .....	<b>12</b>
<b>INTRODUCTION</b> .....	<b>12</b>
<b>1.0 Background of the Study</b> .....	<b>12</b>
1.1. Problem Statement.....	<u>15</u>
1.2___General Research Objective.....	<u>15</u>
1.3___Specific Objectives .....	<u>15</u>
1.4___Research questions .....	<u>16</u>
1.5___Justification .....	<u>16</u>
1.6___Significance of the study.....	<u>16</u>
1.7___Definitions .....	<u>17</u>
<b>CHAPTER TWO</b> .....	<b>19</b>
<b>LITERATURE REVIEW</b> .....	<b>19</b>
<b>2.0 Introduction</b> .....	<b>19</b>
2.1___Technical Factors .....	<u>21</u>
2.2___Social-Economic Factors.....	<u>22</u>
2.2.1___Constraints in Financial Management .....	<u>24</u>
2.2.2___Collection of the O & M Funds .....	<u>25</u>
2.3___The Environmental Factors .....	<u>25</u>
2.4___Efforts towards Achieving Sustainability of Water Facilities.....	<u>26</u>
2.4.1___istrict Roles and Responsibilities.....	<u>26</u>
2.4.2___District Hand Pump Association.....	<u>26</u>

2.4.3	Community Roles and Responsibilities .....	27
2.5	Siting of borehole.....	27
2.6	Conceptual Framework .....	28
2.6.1	Key Concepts and Relationships .....	28
2.6.2	Conceptual Model Components.....	29
2.7	Summary of the literature review.....	29
<b>CHAPTER THREE .....</b>		<b>31</b>
<b>METHODOLOGY .....</b>		<b>31</b>
<b>3.0</b>	<b>Introduction.....</b>	<b>31</b>
3.1	Study Area .....	31
3.2	Study design .....	32
3.3	Data Analysis .....	35
4.0	Results and Disussions .....	45
5.1	Conclusion .....	61
5.2	Recommendations .....	62
<b>APPENDIX.....</b>		<b>72</b>

## LIST OF TABLES

Table 1: Socio-demographic Characteristics of the respondents .....	41
Table 2: Functionality Assessment of Boreholes in Kibuku district.....	42
Table 3: Physiochemical Analysis of Ground water quality from sampled boreholes.....	46
Table 4: Comparative analysis of the field results against National Standard.....	49
Table 5: Relationship between technical factors and performance of hand pump boreholes.....	52
Table 6: Analysis of the Environmental factors.....	54
Table 7: Socio-economic factors affecting borehole functionality.....	58

## LIST OF FIGURES

	Page
Figure 1.1: Benefits from a sustainable hand pump borehole .....	14
Figure 1.2: A conceptual framework for a sustainable hand pump borehole.....	31
Figure 3.1: Map of Uganda showing the location of Kibuku district .....	34
Figure 3.2: Map of Kibuku showing the distribution of water sources monitored for domestic use.....	34
Figure 4.1: Poorly Managed borehole in Kibuku District.....	45
Figure 4.2: Abandoned Non-functional borehole.....	45

## **ACRONYMS AND ABBREVIATIONS**

O&M	Operation and Maintenance
WUC	Water User Committee
CDO	Community Development Officer
DWO	District Water Officer
HPM	Hand Pump Mechanics
FY	Financial Year
HA	Health Assistant
NGOs	Non-Government Organisations
WHO	World Health Organisation
MWE	Ministry of Water and Environment

# CHAPTER ONE

## INTRODUCTION

### 1.0 Background of the Study

Uganda, like many developing countries, faces significant challenges in ensuring access to safe and reliable water sources for its growing population. The country's water sector has witnessed substantial investment in recent decades, with efforts directed toward expanding infrastructure for improved rural water supply (Ministry of Water and Environment [MWE], 2023). Despite these initiatives, access to clean and safe water remains unevenly distributed, with rural communities experiencing higher levels of water insecurity compared to urban areas (Harvey & Reed, 2021). Hand pump boreholes have become a key component of Uganda's rural water supply strategy, providing a cost-effective and accessible means of extracting groundwater for household use. However, the performance and efficiency of these hand pump boreholes remain a pressing concern due to frequent breakdowns, reduced water yields, and deteriorating water quality (Foster et al., 2019).

Kibuku District, located in eastern Uganda, exemplifies the ongoing water access challenges facing many rural communities. While government and donor-funded projects have led to the construction of multiple boreholes in the district, access to safe water remains limited. Currently, the access rates in Kibuku district vary from 27% in Kabweri Sub-County to 95% in Kenkebu Sub-County (MWE, 2025). This disparity indicates systemic challenges in borehole sustainability, leading to increased dependency on unsafe water sources such as unprotected wells, rivers, and streams. The persistent water crisis can result in adverse socio-economic impacts, including increased cases of waterborne diseases and time lost in searching for alternative water sources, particularly among women and children (Schouten & Moriarty, 2018). Addressing these challenges requires a detailed understanding of the factors influencing hand pump borehole performance and efficiency in the district.

Hand pump boreholes in Kibuku District, like in many parts of Uganda, face operational inefficiencies due to a combination of technical, socio-economic, and environmental factors. Technical challenges such as poor construction, improper siting, and inadequate maintenance significantly contribute to the frequent failures of boreholes (Carter et al., 2020). Many hand pump boreholes are constructed with substandard materials, leading to structural weaknesses that compromise long-term functionality (Foster & Hope, 2017). Additionally, the absence of routine

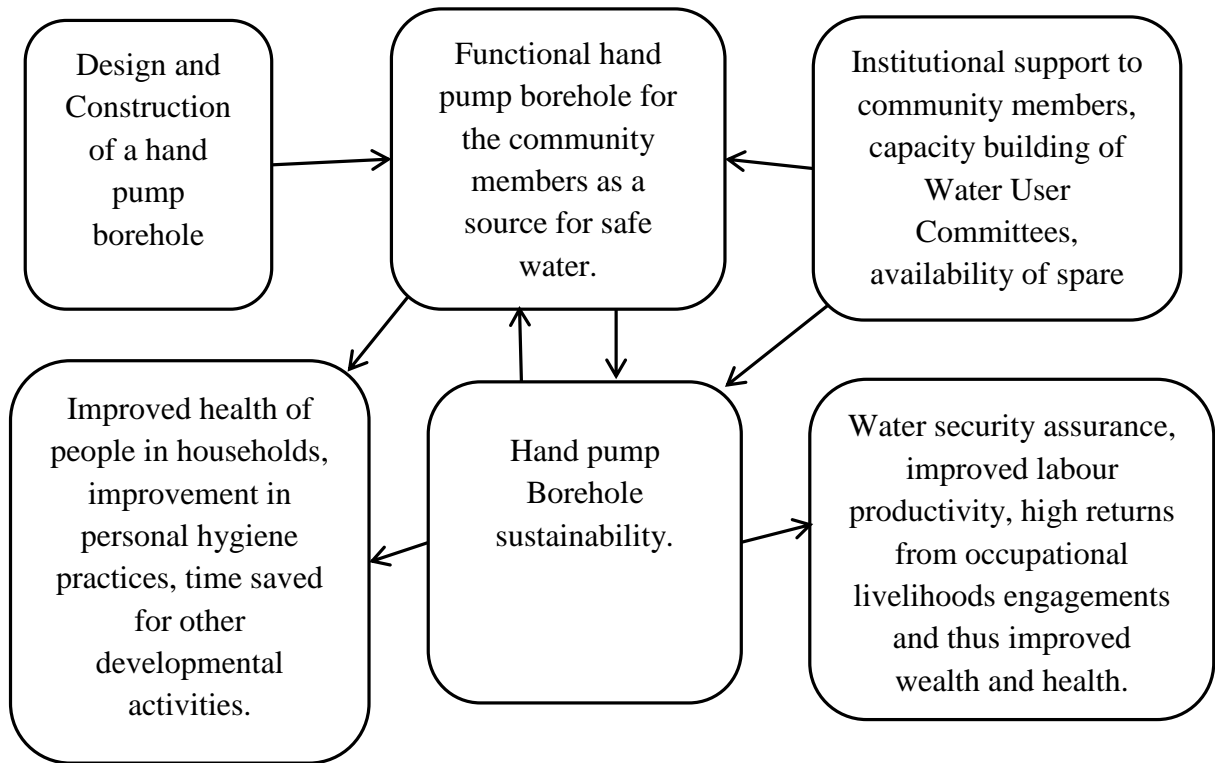
maintenance programs exacerbates mechanical failures, reducing borehole lifespan and water accessibility. Without adequate technical oversight, hand pump borehole projects risk becoming short-term solutions rather than sustainable water supply systems.

Socio-economic and environmental factors further complicate the sustainability of hand pump boreholes in Kibuku District. Community-based management approaches, which are essential for maintaining rural water sources, are often ineffective due to limited financial contributions from households and weak institutional support (Harvey & Reed, 2021). Low-income levels among rural residents make it difficult to raise sufficient funds for hand pump borehole repairs, leading to prolonged periods of non-functionality (MWE, 2023). Additionally, environmental factors such as seasonal rainfall variations and groundwater contamination affect hand pump borehole performance. Declining water tables during prolonged dry seasons often reduce hand pump borehole yields, while contamination from agricultural activities threatens water quality (MacDonald et al., 2021). These multi-dimensional challenges highlight the need for an integrated approach to improving hand pump borehole performance and efficiency.

Given the persistent water access issues in Kibuku District, this study aims to investigate the determinants of hand pump borehole performance and efficiency. By examining the role of technical, socio-economic, and environmental factors, the study will provide empirical evidence to guide interventions that enhance the sustainability of rural water supply systems. Furthermore, developing a predictive model based on these factors will contribute to optimizing hand pump borehole design, improving maintenance strategies, and strengthening water governance policies in Uganda. The findings will be instrumental in informing future investments in rural water infrastructure, ensuring long-term access to clean and safe water for vulnerable communities.

FIGURE 1.1 demonstrates the key factors, inputs, outputs, outcomes, and impacts of a sustainable hand pump borehole. Assessing hand pump borehole functionality is essential to ensure that the water produced is safe, reliable, and sustainable. The key factor is the functionality of the hand pump boreholes, as a need to improve sustainability to safe water accessibility. Once the hand pump boreholes are well maintained, there is a likelihood of improvement of the health of people in households, personal hygiene practices and other related benefits. The outcomes that will be reflected include water security assurance resulting in all year round availability of quality potable water. More so, there will be improved labour productivity from time gains on occupational livelihoods activities, as people are freed from worries related to water accessibility and instead

concentrate on other economic activities that will further improve household wealth and health. The impacts of hand pump boreholes sustainability will be establishment of a strong economic capacity, progressive wealth creation, improved quality of life, progressive poverty reduction, decent living and human dignity restored, human capability improvements and, financial capacity to contribute towards borehole sustainability.



**Figure 1.1: Benefits from a sustainable hand pump deep borehole (Author’s Construct)**

## **1.1 Problem Statement**

Hand pump boreholes serve as a primary source of clean water for rural communities in Uganda, yet their performance remains inconsistent, leading to frequent breakdowns, reduced water yields, and poor water quality (Foster et al., 2019). Despite continued government investment in borehole construction, access to safe water remains inadequate, particularly in Kibuku District, where only 58% of the population on average have access to reliable water sources (Ministry of Water and Environment [MWE], 2025). The persistent increase in water scarcity suggests systemic challenges in borehole sustainability.

Key factors such as poor construction, inadequate maintenance, and limited community participation in borehole management contribute to the high failure rates (Harvey & Reed, 2021). However, there is a lack of comprehensive data on the specific technical, socio-economic, and environmental factors influencing borehole functionality. This knowledge gap hinders efforts to optimize borehole design, improve operational efficiency, and ensure long-term water access (Whaley & Cleaver, 2017). Addressing this issue through empirical research is critical for enhancing rural water supply sustainability and informing policy interventions to improve water security in Uganda.

## **1.2 General Research Objective**

To analyse the technical, socio-economic and environmental factors affecting hand pump borehole performance and efficiency in Kibuku District in Eastern Uganda.

## **1.3 Specific Objectives**

1. To assess the effect of technical factors on the performance and efficiency of hand pump boreholes in Kibuku District in Eastern Uganda.
2. To assess the relationship between socio-economic factors and borehole functionality in Kibuku District in Eastern Uganda.
3. To analyse the effect of environmental factors on borehole water quality in Kibuku District, in Eastern Uganda.
4. To develop an evidence-based predictive model for improving the reliability and efficiency of hand pump boreholes in Kibuku District in Eastern Uganda.

## **1.4 Research questions**

1. How do technical factors affect the performance and efficiency of hand pump boreholes in Kibuku District in Eastern Uganda?
2. What is the statistical relationship between socio-economic factors and borehole functionality in Kibuku District in Eastern Uganda?
3. How do environmental factors affect borehole water quality and Efficiency in Kibuku District in Eastern Uganda?
4. What predictive model can be developed to improve the reliability and efficiency of hand pump boreholes in Kibuku District in Eastern Uganda?

## **1.5 Justification**

Access to clean and safe water is a fundamental human right and a key driver of public health, economic development, and social well-being. In Uganda, hand pump boreholes serve as a primary water source for millions of rural residents, yet their sustainability remains a challenge due to frequent breakdowns, low yields, and poor water quality (Foster et al., 2019). Despite government and donor investments in borehole construction, a significant proportion of rural communities, including those in Kibuku District, still lack reliable access to safe water (Ministry of Water and Environment [MWE], 2023). This research is justified by the urgent need to understand the technical, socio-economic, and environmental factors that influence the performance and efficiency of hand pump boreholes. By addressing these determinants, this study will contribute to improved borehole functionality, sustainability, and long-term water security in Uganda.

Furthermore, there is a knowledge gap regarding the interplay of these factors and how they collectively impact borehole efficiency. Previous studies have examined borehole failures in various contexts, but limited research has focused specifically on Kibuku District, where water access disparities persist (Whaley & Cleaver, 2017). This study will generate empirical data to inform water management strategies, ensuring that borehole interventions are evidence-based and context-specific. The findings will also support policymakers, engineers, and community leaders in making informed decisions to enhance rural water infrastructure resilience.

## **1.6 Significance of the study**

This study has both theoretical and practical significance. Theoretically, it will contribute to the body of knowledge on rural water supply sustainability by providing insights into the

interdependencies of technical, socio-economic, environmental factors and borehole performance. By developing a predictive model, the study will offer a scientific approach to forecasting borehole reliability, thereby bridging the research gap on water access sustainability in Uganda (Harvey & Reed, 2021).

Practically, the findings will benefit multiple stakeholders, including government agencies, development partners, and local communities. For policymakers, the study will provide evidence-based recommendations to improve borehole design, enhance maintenance strategies, and develop policies that promote sustainable water governance (Schouten & Moriarty, 2018). For non-governmental organizations and donor agencies, the study will guide investment decisions by identifying key areas for intervention to maximize the impact of water supply projects.

At the community level, the study will empower residents of Kibuku District by highlighting the importance of community-based management practices and financial contributions to borehole maintenance. Increased awareness and participation in borehole management will help ensure long-term functionality and reduce dependency on external support. Ultimately, by improving borehole efficiency and sustainability, this study will contribute to enhanced public health, economic productivity, and overall quality of life for rural populations in Uganda.

## 1.7 Definitions

The operational highlighted terms as used in this research have been defined:

- i. **Functionality of a hand pump borehole** refers to a state when the hand pump borehole is physically working and producing water at the time of the survey visit, with a minimum design yield and that the availability of the water is reliable all year round (Bonsor, 2018).
- ii. **A borehole** is a hole dug with the aid of a machine or manual auger to intercept an aquifer (Kidochukwu, 2018)
- iii. **A hand pump borehole** refers to a borehole which is drilled in the ground and partially or fully lined for the abstraction of groundwater using a hand pump (MWE,2007).
- iv. **Maintenance** refers to the activities required to sustain the hand pump borehole in a proper working condition.
- v. **Operation** refers to the everyday running and handling of the hand pump borehole for its optimum use. (MWE, 2007).
- vi. **Safe water** implies water that is fit for human consumption.

- vii. **Water coverage** refers to the proportion or percentage of the population who enjoy an improved water service (WHO/UNICEF, 2012).
- viii. **Water User Committee** refers to a form of community management, formed to handle all activities on a hand pump borehole that include managerial, operational, technical and financial aspects. (MWE, 2020).

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.0 Introduction**

The Government of Uganda is committed to improving the lives of her people through sustainable supply of safe water. It is estimated that 28.4 million (82%) of Ugandan's population lives in the rural areas and depends on rural water with the main source of safe water being hand pump boreholes at 44 % (MWE, 2020).

In the year 2015, world leaders agreed to 17 global goals referred to as sustainable development goals aimed at creating a better world by 2030. Among the global goals agreed upon was sustainable goal 6 that aimed at ensuring availability and sustainability management of water and sanitation for all (WHO/UNICEF, 2021). Although the Government of Uganda and some aid agencies prioritize piped water supply, rising population rates, financial constraints, and hydrogeological limits for piped supply mean that the majority of the population will remain dependent on hand pumps many decades into the future (Harvey, 2021).

Many hand pump boreholes continue to under-perform, breakdown and are abandoned. The lack of safe water for even a short period result in the use of unsafe surface water, or movement of long distances to access safe water (Danert, 2022). The use of unsafe water for domestic use is not only an inconvenience but can negatively impact on the human health and positive developments (Baguma, 2017). Clear roles of the players in the operation and maintenance of boreholes needs to be defined and monitored, to track the performance of these safe water systems (MWE, 2020).

With the existing approach in maintenance of hand pump boreholes based on voluntary community-based management, with communities taking on the burden of maintenance themselves, with limited support from external agencies, the functionality of hand pump boreholes will not be sustainable. The community-based management model has struggled to ensure that the rural water supply infrastructure is adequately maintained for a range of reasons including lack of follow up support, low technical capacity, poor levels of tariff collection leading to the inability to carry out repairs, and breakdown of the water sources (Lockwood, 2021).

Despite the United Nations declaration that no-one would be left behind, without step- changes in commitment, know-how, and resources, many rural households will still be struggling for their

daily water supply in 2030 and beyond (Carter, 2021). Sustainable water sources can only be achieved with effective long- term operation and maintenance without which the water sector will fail to meet the SDG for rural populations. It is therefore critical to find more effective and durable solutions to the challenge of poor functionality and limited sustainability of the hand pump boreholes as a source of safe water.

The factors that affect the functionality of hand pump borehole include poor management, inaccessible spare parts, inadequate external support, poor record keeping, irregular community engagements, non-paid care takers, lack of capacity to do minor repairs by committees, poor financial management, environmental changes, vandalism, poor siting, poor construction, excessive siltation, inefficient monitoring, non-motivated committees, water quality dissatisfaction (Danert, 2022).

The functionality of a borehole is described as the ability of the borehole to deliver safe water, and therefore maximizing functionality over the long term is the goal of sustainability. Several factors influence how long a water point will function after the initial intervention. Several factors also influence whether and how long until a water point will return to a functional status after a breakdown. The factors include mechanical breakdown, environmental factors like drought and flooding, external factors like the availability of spare parts, repair professionals and availability of funds required to restore the maintenance requirements (WHO/UNICEF, 2017). All of these requirements are more difficult to meet in rural and remote areas.

Rural water supply coverage has also been so poor because the focus of Governments, donors and NGOs has often been on numerical outputs of boreholes drilled, hand pumps fitted, and the number of people that, by inference, would then have access to an improved water supply. Preventive maintenance of the hand pump boreholes is often neglected. One of the major issues is that while pumps are generally purchased by government and NGO programmes, it is expected that repairs are made by the community. Community based management systems ensures that the communities with the leadership of the Water User Committees and support from the Hand Pump Mechanics manage all the minor repairs (MWE, 2020).

Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water that is located on premises, available when needed, and free from faecal contamination (UNDP, 2021). Local Governments have a role and responsibility of planning and implementing water sector activities in their communities (MWE, 2020). The major aim is to

ensure that the communities have access to clean and safe water at all times. Thus, the district local governments have a principal responsibility of constructing water facilities in rural areas and supporting communities in operation and maintenance activities. This is achieved through community-based management systems with support from Government of Uganda through Ministry of Water and Environment and from donor agencies (MWE, 2020).

Despite all efforts done in providing access to safe water in rural areas by a number of agencies, poor performance of hand pumped boreholes has been a persistent problem in Africa. Borehole functionality is often compromised due to various technical, environmental, and social-economic factors. An examination done by a team of researchers to examine the functionality of boreholes equipped with hand pumps in Ethiopia, Malawi and in Uganda, found out that although up to 80% of hand pumped boreholes may be producing water, much fewer (often  $\leq 50\%$ ) are able to deliver the hand pump design yield reliably for more than 11 months of the year (MacAllister, 2019).

In Ghana, the communities that are privileged to have access to water facilities are not active to have a thorough knowledge about events preceding their sustainability (Brammah, 2016).

In Burkina Faso and Niger, local governments instruct water user associations not to manage maintenance because of the reforms that exist of contracting the hand pump mechanics to collect the annual maintenance fees as well as do the technical advice. This implies that, advocacy campaigns are necessary at all levels to avoid wastage of resources in constructing a water source and then abandoning it once it stops functioning (Debus, 2019).

The performance and efficiency of a hand pump borehole may be categorized into technical, social-economic and environmental factors as detailed below:

## **2.1 Technical Factors and performance of hand pumps**

The life expectancy of a borehole will be limited if it is incorrectly designed or not constructed for maximum efficiency. Choosing a borehole site is a critical part in efforts of having a reliable hand pump borehole. The proper siting of the borehole provides a foundation for its success and long term performance and efficiency. A borehole has to be properly designed, professionally constructed and carefully drilled. However, there is lack of engineers who can design new water systems, control the quality of drilling companies, and maintain pumps (Holtslag, 2022). If a borehole is properly designed, constructed with the correct materials, and given regular attention, it can produce water for 50 years or more (Danert, 2010). Regular and preventive maintenance

can help achieve the goal of sustainable safe water supply. Regular preventive maintenance is rarely provided, increasing failure of the water sources (Cord, 2019).

The term borehole failure as used in this research study refers to a situation in which a borehole which is deemed 'successful' at the time of drilling subsequently fails to deliver a sufficient yield of safe water throughout the year. The primary reason for the hand pump borehole failures, and hence low sustainability of deep boreholes, is insufficient attention to operation and maintenance of the borehole and all its installations. Borehole failures result from many causes including improper well design and construction, incomplete well development, poor groundwater potential, borehole stability problems, incrustation build-up, biofouling, corrosion, low recharge, seasonal water level variations due to climatic factors, over-pumping called groundwater mining, operation and maintenance challenge (Ali, 2017).

The minor repairs include; repair of damaged parts, replacement of damaged slow wearing parts like the handle, chain, rods, and cylinder and also repairs of cracks to the platform. The delivery of sustainable rural water service requires approaches to sustain and repair the water source across its life cycle. The replacement of components before they fail through preventive and timely maintenance is crucial for the continued serviceability of the hand pump, reducing the cost of premature failure. Major repairs are usually left to the local government to plan and manage. The major repairs include fishing of dropped pipes and rods; de-silting of borehole casings and screens; and replacement of rising mains. It is not just the physical hardware that wears out over time; the community institutions can run down too, as people lose interest and fail to make contributions towards the minor maintenance of the borehole. The village water committees need external support, like the pump itself, to include training, monitoring, and advice, financial resources or technical assistance. In order to achieve the flow of water from a hand pump borehole throughout its design life, there must be money for all expenses and for the special repair, there must be acceptance from the consumers of the service, the source supplying the service must be adequate, the design must be properly done and there must be sound construction (Truslove, 2021). From this above discussion and literature, the following hypothesis can be generated

H1: Technical factors have a positive significant effect on performance of hand pumps in Uganda

## **2.2 Social-Economic Factors and performance of hand pumps**

Improved access to water has various impacts on the overall social and economic development of communities. Some of them include poverty reduction, alleviation of hunger, improvement of

health and education and environmental sustainability. The presence of water thus leads to better health, reduced time in looking for safe water and these results into improved income generation and reduced costs for medicine, leading to socio-economic development (WHO/UNICEF, 2017). Community ownership is a core strategy in ensuring borehole sustainability. Community involvement in the operation and maintenance (O&M) of water facilities is assumed to be a cost-effective means of ensuring sustainable provision of water to rural communities (Brammah, 2016). Communities are structured to provide leadership, conduct social and religious activities, and attend to legal, property, and economic matters affecting their members. The establishment of local water committees is an effective way to give rural communities the organization and voice it needs to work collectively to maintain a safe water source over time. Water committees are groups of local individuals who have the authority and responsibility to protect and maintain a source of safe water (WHO/UNICEF, 2017). An effective water committee has the following characteristics:

- Understands its community;
- Represents a community;
- Understands the water point itself and how to prolong its functionality;
- Establishes savings to pay for the long term costs;
- Maintains relationships with local officials and professionals;
- Meets regularly

Water committees need to be made stronger through trainings in their roles and responsibilities in the general operation and maintenance of the water sources.

Much as communities are required to manage their hand pump boreholes, there is still a gap in building on the existing local knowledge and management capacities. More emphasis on capacity building is usually made to communities with newly constructed hand pump boreholes, forgetting that the old management structures can change due to a number of factors to include:

1. Voluntary inputs from members, which they may do for a while but do not want to do in the long term;
2. Dropping out or death of key individuals;
3. Loss of interest and respect in the Water User Committee;
4. Failure of community members to contribute maintenance fees; and

5. Lack of contact of communities with local government or the implementing NGO, which lead to demotivation as the communities feel that they are abandoned.

Once communities are involved in all aspects from planning, decision making, implementation, monitoring and evaluation, there will be an increased community commitment to improve on the failure rate of the hand pump borehole, through a better understanding of the causes and effects of failures. Community involvement also empowers communities, increases community interest of having a well-maintained hand pump borehole and possible improvement of willingness to pay for operation and maintenance costs, hence reduced overall government costs on rehabilitation of hand pump boreholes. This will result in improved reliability and sustainability of hand pump boreholes (Chintalapati, 2020).

Operation and maintenance of any water source largely depend on the availability of financial resources. Engagement of hand pump mechanics and the purchase of spare parts require finances. At the district level, the local governments require funds to facilitate personnel to undertake the monitoring and continuously sensitize communities. At national level, the government requires funds to construct more water facilities. Even for private sector and civil society actors, availability of funds determines the investments and interventions. Financial management is therefore a key issue in any sustainable operation, along with the consideration that goes into setting a tariff structure (UNICEF, 2020).

However, the current financing towards O & M is not adequate and without properly agreed tariffs, hand pump boreholes will not be sustainable, as either the members will feel they are paying too much money or there will be no funds at all to pay for operation and maintenance.

### **2.2.1 Constraints in Financial Management**

Many often, after the communities have received the hand- pump borehole, they tend not to completely own it as in some cases, they either abandon it after its failure or they report the failure to the bodies that constructed the water source. Usually, a disagreement over the cost each one is to contribute becomes a problem since the levels of income differ between the different households. This thus leaves the hand-pump borehole in a state of non- functionality until probably a donor comes in to rescue the situation. Training in financial management by officers with an understanding of finances, therefore, become an important issue in the planning and operations of the hand-pump boreholes for sustainability purposes.

### **2.2.2 Collection of the O & M Funds**

An efficient collection of the operation and maintenance funds is characterized by the following principles:

1. Accurate to minimize complaints;
2. Convenient to consumers;
3. Safe cash handling;
4. Fair in terms of equal distribution amongst community members and;
5. Enforceable, that is to say, defaulters should be punished (Chintalapati, 2020).

Collected funds need to be handled safely and accountability needs to be provided to the communities, or else, the community members may cease to contribute these funds and thus lead to deterioration of the hand pump borehole water sources. In practice, no documentation is used or sometimes where some records are kept, the available information leaves some doubts in the members who contributed the funds. This, therefore, requires a proper set of records to be used so as to clear doubts of the community members. Thus, it can be assumed that;

H2: Social-economic factors have a significant effect on the performance of hand pumps in Uganda

### **2.3 The Environmental Factors and performance of hand pumps**

There is a trend that links water supply and environmental protection and thus effects on the operation and maintenance of a given hand pump borehole. Drilling of boreholes in different geological formations require different technical approach. These approaches are designed models to manage drilling activities to sooth the underlying aquifer bearing rock, manage soil structure, reduce environmental impact and manage groundwater contamination (Kidochukwu, 2018). Borehole drilling companies both local and foreign owned spring up daily, managed by pure businessmen whose motive is profit and no consideration on the environmental impact of their activities nor efforts to conserve this threatened resource.

More active protection of catchment areas is needed, which involves a systematic appraisal of catchment areas for groundwater sources and the identification of environmental factors related to land use. Re-afforestation programmes coupled with anti-erosion, soil, and water conservation techniques need to be considered essential for the improvement of many water source failures. However, at the present time, many more trees are cut down than planted. Community - based

maintenance and management of water supply systems is a good starting point for a more integrated approach to water source protection and environmental conservation.

## **2.4 Efforts towards Achieving Sustainability of Water Facilities**

Over the past years, the community-based management model sought to empower communities to own the operation and maintenance of their water points. This was viewed as a swift solution to ensuring functionality of the water sources with the available hand pump mechanics compared to waiting for solutions from central government. However, while studies found community involvement in planning and management-related decision-making contributes to positive sustainability outcomes, taking on more complex technical roles does not (Chintalapati, 2020). The available local human resource lacks all the required capacity for the technical failures usually encountered. Furthermore, water committees are often unable to collect enough funds to pay for maintenance and repairs fully. Cited reasons include a lack of trust in water committees due to misuse of money, and a lack of payment enforcement by committee. Access to spare parts is essential for maintenance, but a lack of consistent spare parts supply has left communities with few options when a breakdown occurs. Support from government is key in all efforts of achieving a universal sustainably managed water access.

The government of Uganda has thus set different roles for the different categories of stakeholders, to ensure that the hand pump boreholes continue functioning for the designed life.

### **2.4.1 District Roles and Responsibilities**

The various departments within the district support each other in the planning and implementation of water sector activities. The District Water Office takes the lead in the implementation of all the water activities, which include; planning, supervision of contractors, contract management and ensuring operation and maintenance of water facilities by the water user committees. However, there might be limitations within the water office that hinder the effectiveness of ensuring that all the said activities are done in the best way possible and thus the need to assess this area and find out where the gaps could be.

### **2.4.2 District Hand Pump Association**

The Ministry of Water and Environment initiated the formation of hand pump mechanics associations in the various districts, to manage the repairs of hand pump boreholes in the Sub-

Counties. It is assumed that the members are supposed to be trained and equipped with tools to facilitate their operations. Before their engagement within the various districts, these associations are supposed to enter into performance contracts and clearly define their targets. These associations do exist in the district of Kibuku and they do carry out some repairs on the boreholes. However, they lack the required tools to effectively manage the repair needs and thus the community seems not to be satisfied with their services (MWE, 2020).

### **2.4.3 Community Roles and Responsibilities**

To ensure that the activities undertaken in the water sector are demand- responsive, the Ministry of Environment recommends that the process of improving water sources should be participatory. Communities are expected to make written requests showing the need for a safe water source. In this way, the safe water source provided is likely to be well managed because the community identified the need. Many communities in Kibuku district have received hand pump boreholes through various ways like donations from political leaders, which defers from that recommended approach by the Ministry of expressing interest of the safe water source and thereby applying for one. This affects the level of the community's commitment to their maintenance and thus affects their sustainability (MWE, 2020).

The Ministry of Water and Environment not only provide hardware activities but also goes ahead to finance activities that are not tangible but help in achieving sustainability of the hardware facilities (software activities). Among the software activities that are implemented, is the formation of the water user committees, which are supposed to oversee the operation and maintenance of the hand pump boreholes. Routine maintenance of the boreholes is important to avoid reductions in the water that is discharged. It, therefore, necessitates communities to have operation and maintenance plans in order to avoid the failures of their water sources (MWE, 2020).

## **2.5 Siting of boreholes**

The selection of a contractor type in borehole construction is essential in ensuring the sustainability of a borehole. The process of borehole construction begins with a successful siting exercise. The siting and drilling are undertaken as two separate assignments. The siting consultant, who should investigate and understand the geology or hydrogeology of a site before drilling, usually directs the driller where to drill and also does the supervision works on the drilling contractor. If the borehole is unsuccessful, the implementing agency pays the driller all the work

done and material used. In Uganda, having separate contracts is less applied and instead turnkey contracts rose to prominence as implementing agencies became increasingly frustrated with the number of unsuccessful boreholes that were being drilled, when consultants were conducting the siting works (Liddle and Fenner, 2018). The project managers were being made to look incompetent with the unsuccessful boreholes drilled and thus a solution was found to have the consultants removed and handover all the responsibility for finding water to the driller in a type of contract referred to as turnkey. Turnkey contracts operate on the principle of ‘no water no pay’, and the siting and drilling is awarded to one contractor as a single contract. The contractors submit a quotation with a fixed price per borehole, without providing the details of the costs per unit quantity for each activity and each material that will be used. If the driller drilled unsuccessful borehole, they would not be paid as they were the ones responsible for siting the boreholes.

Despite recommendations and technical guidelines of engaging in different contracts for siting and drilling formulated by Ministry of Water and Environment as a measure for quality control, turnkey contracts which combine siting, drilling, casing and installation all to a single contractor are still used in Kibuku district. This sometimes tempts the contractors to drill shallow wells with few strikes of water and they proceed with the installations and at the end, these boreholes dry up in the dry season.

H3: Environmental factors have a significant effect on the performance of hand pumps in Uganda

## **2.6 Conceptual Framework**

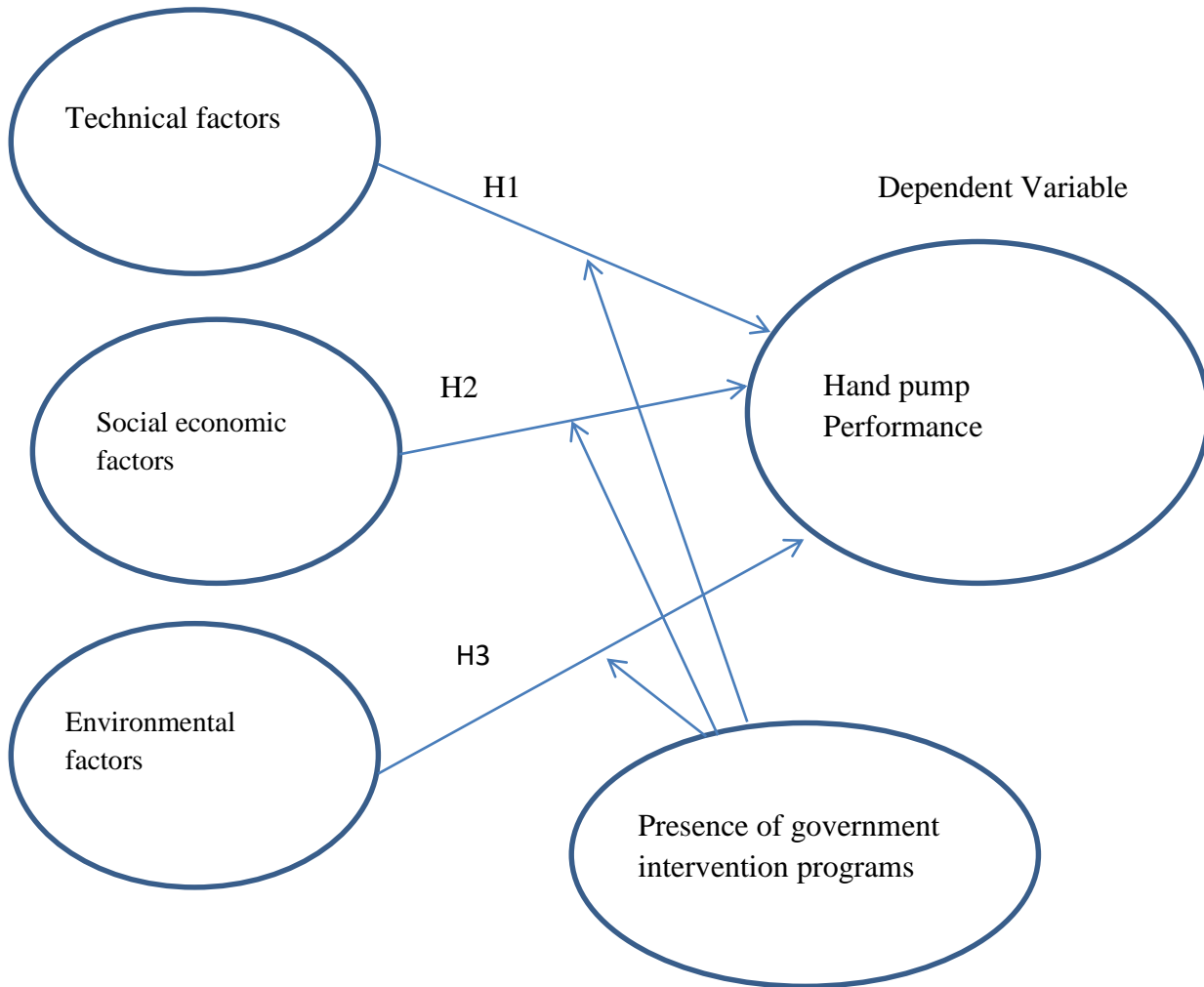
Proper assessment of technical, social-economic, and environmental factors in borehole performance can lead to several expected incomes. These include informed decision making by policy makers, risk reduction in making investments and long-term sustainability of the boreholes.

### **2.6.1 Key Concepts and Relationships**

The conceptual framework illustrates the relationships between technical, socio-economic, and environmental factors and how they influence the performance, efficiency, and sustainability of hand pump boreholes in Kibuku District. Technical factors include: Borehole depth (M), Pump type, Frequency of maintenance (No. /month), Casing material, Pump yield (L/time), Borehole construction quality, Water siting mechanisms. Socio-Economic factors include : Household income levels (USD), User fees (USD), Community-based management practices (numbers), Local government support (Yes/no), Water usage patterns, Availability of spare parts (Yes/no), Community involvement in maintenance (Yes/no). Environmental factors include: Seasonal rainfall variations (Rain/Dry), Groundwater recharge rates, Water table depth (M), Contamination from agricultural activities (Yes/No), Salinity levels, Environmental degradation (Yes/no)

## 2.6.2 Conceptual Model Components

Independent Variables



**Figure 1.2: Conceptual framework for a sustainable hand pump borehole (Author's Construct)**

## 2.7 Summary of the literature review

Lack of a sustainable safe water source results in a number of setbacks in the communities to include technical, social, financial, gender, equity and empowerment, institutional and environmental.

Many hand pump boreholes have failed before the intended design life and there has been limited research done on the assessment of the whole process of acquiring the hand pump borehole, its installation, usage and maintenance to ascertain the gaps that lead to their premature failure. This

has thus left the safe water access to remain stagnant in many communities and in other communities, access has dropped or a little increase has been achieved in other communities. Therefore, this research aims on studying the gaps from the installation of the hand pump boreholes and the maintenance practices of the hand pump and thereby recommend ways of ensuring that the hand pump boreholes remain functional throughout their design life.

## CHAPTER THREE

### METHODOLOGY

#### 3.0 Introduction

This chapter presents the approach that was employed in executing this study. It comprises of the study area, study design, sample size determination, sampling techniques and data analysis.

#### 3.1 Study Area

The study was conducted in Kibuku district, located in Eastern Uganda as shown in Figure 3.1. The main source of domestic water supply in Kibuku district is borehole, installed with hand pumps and these are distributed in the entire district as shown in Figure 3.2. This study sought to assess the factors that affect the performance and efficiency of hand pump boreholes in Kibuku district. The area has a relief which is generally low and flat characterized by shallow seasonal wetlands. Its altitude ranges from 900-1200m above sea level (average of 1145m above sea level). The drainage system is dominated by rivers flowing from Namatala and Lwere swamp complexes and end up in Mpologoma Swamp, which have their water sheds mainly on the slopes of Mt. Elgon. The water source to these swamps is mainly surface flow, precipitation and ground water (Profile of Kibuku District, 2017).

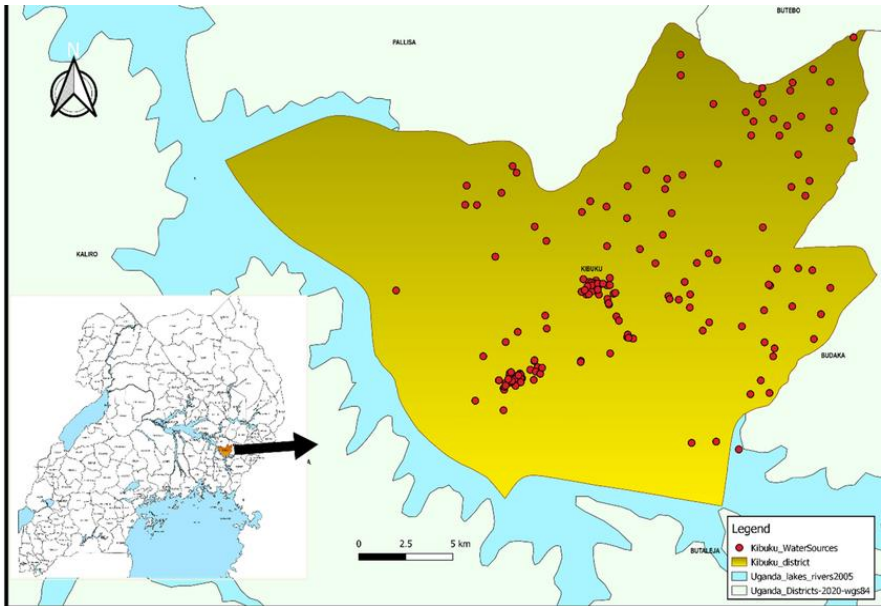
The area has two main soil types; ferralitic and hydromorphic. Ferralitic, the dominant type is reddish-brown, sandy-loams, and pH value below 5. Hydromorphic soils are common in areas occupied by permanent/seasonal swamps/wetlands characterised by water logging (Profile of Kibuku District, 2017).

The vegetation cover has been largely modified by cutting down trees, grazing, annual or biennial grass fire (burning) compounded by an overload of traditional farming systems. The dominant grass is savannah grassland. The swampy vegetation is very common along the major wetlands of the District. Over 70 percent of the wetland forests have been converted into paddy rice cultivation by encroachers (Profile of Kibuku District, 2017).

There are two rainfall seasons, the main one from March to June and the second from August to November, although in some instances the rainfall patterns may become irregular. The District annual average rainfall is 1465mm with a monthly average of 122.08mm and the annual temperature ranges between 16.20 and 28.7<sup>0</sup> with the monthly mean temperature being 17.0<sup>0</sup>



**Figure 3.1: Map of Uganda showing the location of Kibuku District**



**Figure 3.2: Map of Kibuku Showing the distribution of water sources monitored for domestic use**

**3.2 Study design**

In this section, the criteria used to measure the different variables for the study is described. The independent variables included:

**Technical Factors:** (e.g., borehole depth, pump type, frequency of maintenance, casing material, pump yield, borehole construction quality, and installation of water-lifting mechanisms)

**Socioeconomic factors** (e.g., household income, user fees, community-based management practices, local government support, water usage patterns, access to spare parts, and community involvement in maintenance)

**Environmental factors** (e.g., seasonal fluctuations in rainfall, groundwater recharge rates, water table depth, contamination from nearby agricultural activities, salinity, and environmental degradation)

On the other hand, hand pump performance was the dependent variables for this study.

To quantitatively assess the functionality and efficiency of hand pump boreholes, various indicators and measurement techniques were used as described in the structured approach below:

### **1. Functionality Assessment**

Functionality refers to whether the borehole is operational and able to provide water when needed. It was measured using the following indicators:

#### **a) Borehole Operational Status**

- **Fully functional** – Borehole operates without any issues.
- **Partially functional** – Borehole produces water but with reduced yield or intermittent failures.
- **Non-functional** – Borehole is completely broken down or abandoned.
- **Measurement method:** Field surveys, interviews with users, and physical observations were conducted.

#### **b) Downtime (Breakdown Frequency and Repair Time)**

- **Indicator:** This refers to the number of days a borehole is non-functional due to breakdowns within a given period (e.g. per year).
- **Measurement method:** Maintenance logs, interviews with local water committees, and borehole monitoring records were done.

### c) Reliability of Water Supply

- **Indicator:** Percentage of time the borehole provides water as expected.
- **Measurement method:** Observations, user records, and water availability surveys across seasons were taken.

### d) User Satisfaction and Accessibility

- **Indicator:** Number of people served per borehole and user satisfaction levels.
- **Measurement method:** Household surveys, key informant interviews, and focus group discussions.

## 2. Efficiency Assessment

Efficiency refers to how well the borehole performs in terms of water output, energy use, and operational sustainability. It was measured using the following indicators:

### a) Water Yield (Discharge Rate)

- **Indicator:** Volume of water pumped per unit time (liters per minute or liters per hour).
- **Measurement method:**
  - **Field test:** A stopwatch and container was used to measure water output per pump stroke over a given period.

### b) Pumping Efficiency (Water Output per Effort)

- **Indicator:** Volume of water obtained per pump stroke.
- **Measurement method:** The amount of water drawn with a fixed number of pump strokes was measured

### c) Water Losses and Leakages

- **Indicator:** Amount of water lost due to leakage in the pump system.
- **Measurement method:** Physical inspection of hand pumps, testing for leakage during pumping was done.

#### d) Cost Efficiency (Operational and Maintenance Costs)

- **Indicator:** Cost per cubic meter of water supplied.
- **Measurement method:**
  - Records of repair, spare parts, and maintenance expenses was collected and studied.
  - The cost per liter pumped over a defined period was calculated.

### 3. Data Collection Methods

- **Field Measurements:** Conducted physical assessments of borehole performance.
- **Household Surveys:** Interviewed community members on borehole reliability and satisfaction.
- **Water Point Monitoring:** Collected real-time operational data.
- **Focus Group Discussions:** Engaged local water committees for qualitative insights.
- **Hydrogeological Testing:** Evaluated water recharge rates and borehole sustainability.

#### 3.3 Data Analysis

A structured approach was used to facilitate a comprehensive understanding of the factors influencing borehole sustainability in Kibuku district. This included:

Descriptive statistical analysis of the socio- demographic characteristics of borehole water users as well as attributes of the sampled boreholes and water quality indicator.

Analysis of variance (ANOVA) was used to examine the variations in borehole functionality and efficiency.

A multiple regression model quantified the relationship between independent variables (technical, socio-economic, and environmental factors) and dependent variable (hand pump performance

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon$$

Where:

- $Y$  = Borehole Performance Index (BPI)
- $X_1$  = Technical Factors Index
- $X_2$  = Socio-Economic Factors Index
- $X_3$  = Environmental Factors Index
- $\beta$  = Coefficients representing the strength of each factor's influence
- $\epsilon$  = Error term

The model output helped to forecast the borehole reliability and guide policymakers in optimizing maintenance strategies.

### 3.4 Target Sample Size and Targeted Respondents

The sample size and selection of respondents was based on the study objectives, statistical power, and representativeness of the population in Kibuku District.

#### 1. Target Sample Size Determination

The sample size was determined using Cochran's formula for large populations (Cochran, 1977):

$$n = \frac{Z^2 \cdot P \cdot (1-P)}{e^2} \dots\dots\dots(2)$$

Where:

$n$  = Required Sample Size

$Z$  = Z-Score (1.96 for 95% confidence Interval)

$P$  = Estimated proportion of functional boreholes (assumed at 50% or 0.5 for maximum variability)

$e$  = Margin of Error (5% Or 0.05).

Hence:

$$n = \frac{1.96^2 \cdot 0.5 \cdot (1-0.5)}{0.05^2} = 384 \dots\dots\dots(3)$$

Therefore, adjusting for a finite population using the Cochran's correction formula (Israel, 1992), with assumption that the total boreholes in Kibuku District are known, the sample can be calculated as:

$$n_{adj.} = \frac{n}{1 + (\frac{n}{N})} \dots\dots\dots (4)$$

Where;

$N$  = Refers to the total number of boreholes in the district. Therefore, with help of records in the District Water Department, Kibuku (DWDK), the sample size for this study was recalculated as:

$$n_{adj.} = \frac{384}{1 + (\frac{384}{150})} = 110 \dots\dots\dots (5)$$

Hence,

A sample size of **110** boreholes was considered appropriate for this study. Additionally, with an assumption that unknown number ( $X$ ) households share one borehole and ( $X_i$ ), keeps on varying community by community, a formular proposed by Kothari, (2004) was employed:

$$n = \frac{PQZ^2}{E^2} \dots\dots\dots(6)$$

Where;  $n$ = Sample size;  $Z$ = confidence level ( $\alpha= 0.05$ );  $p$ = proportion of the population containing the main characteristics of interest;  $q=1-p$  and  $E$ = allowable error. Since the proportion containing the major characteristics of interest is unknown ( $X_i$ ),  $p= 0.5$ ,  $q=0.5$ ,  $Z=1.96$  and  $E= 0.05$ . This resulted into a sample of approximately 384 respondents.

Hence, the targeted respondents included; Households using borehole facilities in the District, the water user committee members, the local Government officials, borehole technicians, environmental technicians and environmental officers in the study area.

## 2. Sampling Techniques

- **Borehole Selection:** Stratified random sampling was used based on geographical location (McGarvey et al., 2008).
- **Households: Systematic random sampling** was done to determine the household to interview. (Mugenda & Mugenda, 2003).
- **Water User Committees & Technicians: Purposive sampling** was done by selecting those directly involved in borehole management (Yin, 2014).
- **Government Officials & Environmental Officers: Expert purposive sampling** was done to select those with direct oversight of water projects (Patton, 2002).

## **CHAPTER FOUR**

### **RESULTS AND DISCUSSIONS**

#### **4.1 Introduction**

This chapter is organized into four main sections, each corresponding to a specific component of the data analysis process. The first section presents the results of the general descriptive statistical analysis, focusing on the socio-demographic characteristics of borehole water users, as well as key attributes of the sampled boreholes and water quality indicators. The second section provides an analysis based on inferential statistics, particularly examining variations in borehole functionality and efficiency using analysis of variance (ANOVA) and related statistical tests. The third section presents the results of econometric modelling, aimed at determining the empirical effects of selected technical, socio-economic, and environmental variables on the performance and efficiency of the borehole facilities. This structured approach facilitates a comprehensive understanding of the factors influencing borehole sustainability in Kibuku District.

#### **4.2 Socio-Demographic Characteristics of Respondents**

Table 1 presents the socio-demographic characteristics of the respondents. The findings reveal that a majority of the sampled respondents were female, comprising 56.2% of the total sample. In terms of age distribution, the largest proportion of respondents (29.7%) fell within the 18–30 years age group. This was followed by those aged 31–43 years (28.4%), 44–56 years (21.9%), and respondents aged 57 years and above, who accounted for 20.0%. Regarding household size, the highest proportion of respondents (55.7%) lived in households with between 5 and 10 members. Households with fewer than 5 members constituted 26.6% of the sample. Those with 11 to 16 members represented 10.7%, while only 7.0% of households had more than 16 individuals. In terms of primary occupation, the results indicate that a substantial majority (83.9%) of respondents were engaged in farming as their main source of livelihood. Formal employment accounted for 10.2% of respondents, while business or trade-related activities represented 6.0%. With respect to average monthly income, over half of the respondents (54.9%) reported earning less than UGX 200,000 (approximately USD 54.1). Respondents earning between UGX 200,000 and 500,000 (USD 54.1 to 135.1) comprised 32.3% of the sample, whereas only 12.8% reported monthly incomes exceeding UGX 500,000 (USD 135.1). In addition, educational attainment among respondents varied considerably. A majority (59.4%) had attained primary-level education. Respondents with secondary-level education accounted for 21.6%, while 12.8% had

not received any formal education. Only 3.9% had completed tertiary-level education, and a small proportion (2.3%) reported having attained a university degree.

**Table 1:** Socio-demographic Characteristics of the respondents (*n=384*)

<b>Variable</b>	<b>Attribute</b>	<b>Freq.</b>	<b>Percent</b>	<b>Cum.</b>
<b>Gender</b>	Male	168	43.8	43.8
	Female	216	56.2	<b>100.0</b>
<b>Age</b>	18 – 30 Years	114	29.7	29.7
	31 – 43 Years	109	28.4	58.1
	44 – 56 Years	84	21.9	80.0
	57 and above	77	20.0	<b>100.0</b>
<b>Household Size</b>	< 5 persons	102	26.6	26.6
	5 – 10	214	55.7	82.3
	11 – 16	41	10.7	93.0
	17 and above	27	7.0	<b>100.0</b>
<b>Primary Occupation</b>	Business	23	6.0	6.0
	Farming	322	83.9	89.8
	Formal employment	39	10.2	<b>100.0</b>
<b>Average Income</b>	<200,000	211	54.9	54.9
	200,000 – 500,000	124	32.3	87.2
	Above 500,000	49	12.8	<b>100.0</b>
<b>Level of Education</b>	Informal level	49	12.8	12.8
	Primary Level	228	59.4	72.2
	Secondary Level	83	21.6	93.8
	Tertiary Level	15	3.9	97.7
	University Level	9	2.3	<b>100.0</b>

### 4.3 Evaluation of Borehole Functionality in the Study Area

Several performance indicators were assessed across all sampled 110 boreholes in Kibuku district using a standardized checklist tool adapted from Carter and Ross (2016). The key metrics evaluated included operational status, water availability, pump condition, presence of leaks or malfunctions, discharge rate (litres per minute), water flow consistency, and frequency of maintenance. These variables were selected to provide a comprehensive assessment of borehole functionality and sustainability. The results of the assessment are summarized in Table 2.

**Table 2:** Functionality Assessment of Boreholes in Kibuku District (*n* = 110)

Variable	Attribute	Freq.	Percent	Cum.
<b>Operational status</b>	Fully functional	72	65.5	65.5
	Partially functional	31	28.2	93.7
	Not functional	7	6.3	<b>100.0</b>
<b>Water availability</b>	Water available	103	93.6	93.6
	No water available	7	6.4	<b>100.0</b>
<b>Borehole condition</b>	No visible damage	82	74.6	74.6
	Minor damage	16	14.5	89.1
	Major damage	12	10.9	<b>100.0</b>
<b>Leaks/ malfunctions</b>	No leaks	89	80.9	80.9
	Observed leaks	14	12.7	93.6
	Other malfunctions	7	6.4	<b>100.0</b>
<b>Discharge rate(l/min)</b>	Less than 10l/min	06	5.5	5.5
	10 - 20l/min	53	48.2	53.7
	21 – 30 l/min	49	44.5	98.2
	More than 30l/min	02	1.8	<b>100.0</b>
<b>Water flow</b>	Steady flow	92	83.6	83.6
	Intermittent flow	11	10.0	93.6
	No flow	7	6.4	<b>100.0</b>
<b>Maintenance frequency</b>	Monthly	18	16.4	16.4
	Quarterly	76	69.1	85.5

Annually	12	10.9	96.4
No monitored	04	3.6	<b>100.0</b>

Table 2, shows an assessment of the operational status of boreholes in Kibuku District revealed that out of the 110 sampled water points, the majority (65.5%) were classified as fully functional. These boreholes consistently delivered water with minimal interruptions, suggesting proper maintenance and infrastructure reliability. Partially functional boreholes constituted 28.2% of the total, indicating intermittent operation often due to mechanical wear, inadequate community management as shown in figure 4.1, or seasonal fluctuations in groundwater levels. A smaller fraction, 6.3%, were found to be completely non-functional an example shown in figure 4.2, potentially reflecting long-term neglect, vandalism, or technical failure (Ministry of Water and Environment [MWE], 2021).



**Figure 4.1: Partially functional borehole**



**Figure 4.2 Abandoned, non- functional borehole**

Water availability was confirmed in 93.6% of all sampled boreholes, highlighting relatively widespread access to groundwater across the district. This figure reflects a strong presence of aquifers in the region, although accessibility and reliability may still be influenced by fluctuating rainfall patterns and pump functionality, particularly in dry seasons (Sutton et al., 2022). Regarding borehole structural integrity, the study established that 74.6% of the sampled boreholes exhibited no visible damage. This implies a fair level of infrastructure resilience and regular community oversight. However, 14.5% showed signs of minor damage—such as cracked concrete aprons or worn-out handles, while 10.9% presented with major structural defects, including collapsed well heads or broken rising mains. These findings align with previous studies in eastern Uganda, where aging infrastructure and limited maintenance budgets frequently compromise rural water points (Nsubuga et al., 2021).

Leakage and mechanical integrity were further assessed. The results indicated that 80.9% of boreholes were free from observable leaks, whereas 12.7% had leaks, and 6.4% experienced other mechanical malfunctions, such as faulty valves or missing pump heads. Such issues not only reduce the efficiency of water collection but can also pose contamination risks, particularly in boreholes with compromised sanitary seals or inadequate drainage (World Health Organization [WHO], 2017). Further, the analysis of borehole flow performance in the study area revealed significant variation in discharge capacities. Approximately 5.5% of the boreholes delivered less than 10 litres per minute, indicating low efficiency and potentially limited utility for community water needs. Nearly half (48.2%) of the boreholes discharged between 10 and 20 litres per minute, representing the most prevalent flow range. Additionally, 44.5% of the boreholes exhibited higher discharge rates, ranging from 21 to 30 litres per minute. Only a small proportion (1.8%) recorded flow rates exceeding 30 litres per minute. These findings suggest that the majority of boreholes in the study area operate within a moderate efficiency range, with flow rates suitable for basic domestic water supply needs.

Regarding flow characteristics, the data indicated that the majority (83.6%) of boreholes provided a steady and uninterrupted water supply. In contrast, 10.0% of boreholes experienced intermittent water flow, and 6.5% were reported as non-functional, with no water delivery at all during the period of assessment. These flow patterns are critical indicators of operational reliability and influence both user satisfaction and water access outcomes at the community level. With respect to maintenance frequency, only 16.4% of boreholes were reported to undergo monthly servicing. A larger proportion, 69.1%, were maintained on a quarterly basis, while 10.9% received

maintenance annually. Alarming, 3.6% of the boreholes were not monitored or maintained at all, a condition that presents a substantial risk to their long-term functionality and sustainability. Inadequate maintenance and lack of routine monitoring may accelerate wear and failure, particularly in boreholes already exhibiting intermittent or low flow. These findings align with the broader literature on rural water point management. Studies by Fisher et al. (2020) and Opryszko et al. (2013) emphasize the critical importance of routine maintenance and steady water delivery in sustaining the functionality of groundwater infrastructure. Their work demonstrates that consistent performance is positively correlated with proactive community management and investment in maintenance practices, especially in areas reliant on hand pump boreholes as a primary water source.

#### **4.4 Physicochemical and Microbiological Quality of Borehole Water**

The results presented in Table 3, show the analysis of pH levels across the sampled boreholes in Kibuku District revealed that the majority (79.1%) of the water sources fell within the acceptable range of 6.5 to 7.5, in accordance with the standards set by both the Uganda National Bureau of Standards (UNBS) and the World Health Organization (WHO). This suggests that most borehole water in the district is chemically balanced and safe for human consumption. However, a subset of the boreholes (5.4%) exhibited acidic conditions ( $\text{pH} < 6.5$ ), which can lead to the corrosion of metallic pump components and contribute to undesirable taste. Conversely, 15.5% of the boreholes had pH values exceeding 7.5, indicating slightly alkaline water, which may also influence taste and long-term plumbing integrity.

In regards to the Total Dissolved Solids (TDS) levels serve as a key indicator of groundwater quality, reflecting the presence of dissolved minerals and salts. In this study, 69.1% of the boreholes registered TDS concentrations within the moderate range of 500 to 1,000 mg/L, aligning with WHO recommendations for palatability. However, a notable proportion (27.3%) of boreholes exhibited TDS levels exceeding 1,000 mg/L, a concentration that may affect taste, consumer acceptability, and long-term health if ingested consistently. Only 3.6% of the sampled boreholes had TDS concentrations below 500 mg/L. According to Howard et al. (2003), elevated TDS levels can be attributed to geological formations, land use practices, and anthropogenic activities that enhance groundwater mineralization. Additionally, Salinity measurements showed that 67.3% of the boreholes had acceptable salinity levels below 1,000 mg/L. However, 26.4% recorded salinity values between 1,000 and 2,000 mg/L, which, while not immediately hazardous, may reduce the suitability of the water for drinking and irrigation. A smaller fraction (6.3%) of

boreholes exceeded the 2,000 mg/L threshold, a level that presents potential health concerns and poses risks to soil quality when used for agricultural purposes. As Foster et al. (2018) note, high salinity concentrations in groundwater can stem from natural dissolution processes or anthropogenic contamination, including poor sanitation practices and fertilizer runoff.

**Table 3:** Physicochemical Analysis of Groundwater Quality from Sampled Boreholes ( $n=110$ )

<b>Variable</b>	<b>Attribute</b>	<b>Freq.</b>	<b>Percent</b>	<b>Cum.</b>
<b>pH level</b>	<6.5	06	5.4	5.4
	6.5 – 7.5	87	79.1	84.5
	>7.5	17	15.5	<b>100.0</b>
<b>Total Dissolved Solids (TDS)</b>	<500mg/l	04	3.6	3.6
	500 – 1000mg/l	76	69.1	72.7
	>1000mg/l	30	27.3	<b>100.0</b>
<b>Salinity</b>	<1000mg/l	74	67.3	67.3
	1000 - 2000mg/l	29	26.4	93.7
	>2000mg/l	07	6.3	100.0
<b>Presence of contaminants</b>	No contaminants	88	80.0	80.0
	Contaminants present	22	20.0	<b>100.0</b>
<b>Bacterial contamination</b>	No pathogen detected	62	56.4	56.4
	Coliform detected	33	30.0	86.4
	E-coli detected	11	10.0	96.4
	<i>Salmonella</i> spp. detected	4	3.6	<b>100.0</b>
<b>Water Clarity</b>	Clear	81	73.6	73.6
	Cloudy	20	18.2	91.8
	Murky	9	8.2	<b>100.0</b>

Further, the analysis of water quality from the sampled boreholes in Kibuku District revealed that a significant majority (80.0%) showed no evidence of physical or chemical contaminants, indicating relatively clean groundwater sources. However, 20.0% of the boreholes tested positive

for contaminants, including nitrates and trace heavy metals. The presence of such substances, even in small concentrations, raises concerns about the influence of agricultural practices, waste disposal, and other anthropogenic activities on groundwater quality.

Microbiological analysis further revealed a varied bacterial load across the sampled boreholes. More than half (56.4%) of the boreholes showed no detectable presence of pathogens, suggesting effective natural filtration and limited exposure to faecal contamination. However, coliform bacteria were identified in 30.0% of the samples, signifying potential faecal contamination and compromised water safety. Notably, approximately 10.0% of boreholes tested positive for *Escherichia coli* (*E. coli*), an indicator of recent faecal intrusion and high health risk. In addition, 3.6% of the boreholes were found to contain *Salmonella* species, which are known to cause serious waterborne illnesses. These results underscore the vulnerability of boreholes to contamination, especially in areas characterized by shallow aquifers or intensive agricultural activity that facilitates runoff into groundwater sources.

Water clarity assessments indicated that the majority of boreholes (73.6%) produced visibly clear water, reflecting minimal turbidity and good aesthetic quality. In contrast, 18.2% of the water samples were classified as cloudy, while 8.2% appeared murky. These conditions may be indicative of suspended particulates or microbial activity, often arising from surface water infiltration or poor wellhead protection. Elevated turbidity not only affects water appearance but can also shield harmful microorganisms from disinfection efforts, thereby compounding health risks.

#### **4.5 Implications for Public Health and Sustainability**

The findings on contamination and clarity point to critical public health concerns in certain communities, particularly those relying on poorly constructed or inadequately maintained boreholes. The presence of coliforms, *E. coli*, and *Salmonella* in some samples indicates a tangible risk of waterborne disease outbreaks. Such risks necessitate the implementation of robust water quality monitoring and targeted interventions aimed at source protection, regular disinfection, and community education. These results reinforce the importance of achieving Sustainable Development Goal 6, which advocates for universal access to safe and affordable drinking water. Strengthening local water governance and enhancing routine surveillance can ensure that groundwater sources remain both safe and sustainable for the residents of Kibuku District.

#### **4.6 Water Quality Assessment of sampled Boreholes against National Standards**

The study further evaluated the safety and suitability of borehole water for human consumption and domestic use by comparing field-measured values with benchmarks established in the Uganda National Water Quality Standards (UNWQS).

The assessment focused on a set of key water quality indicators that are widely recognized for their relevance to public health and environmental sustainability. These parameters included pH, Total Dissolved Solids (TDS), salinity, the presence of chemical contaminants, microbial contamination, and water clarity. Each parameter was selected based on its capacity to reveal critical information about the physicochemical and microbiological condition of groundwater resources, as well as its implications for health risks and infrastructure integrity. The findings in Table 4, provide evidence-based insights into the status of rural water sources in the district and contribute to ongoing efforts to promote safe water access in line with Sustainable Development Goal 6. The results also offer a basis for informed decision-making on water quality management, local-level monitoring frameworks, and community-level interventions.

**Table 4:** Comparative analysis of the field results against National Standards

Variable	National Standard (UNWQS)	Field Distribution (n=110)	% Meeting Standard	Standard Deviation (SD)
<b>pH level</b>	6.5 – 8.5	<6.5 = 5.4% 6.5–7.5 = 79.1% >7.5 = 15.5%	<b>94.6%</b>	0.53
<b>Total Dissolved solids</b>	<1000 mg/L	<500 = 3.6% 500–1000 = 69.1% >1000 = 27.3%	<b>72.7%</b>	354.27 mg/L
<b>Salinity</b>	<1000 mg/L	<1000 = 67.3% 1000–2000 = 26.4% >2000 = 6.3%	<b>67.3%</b>	420.52 mg/L
<b>Presence of Contaminants</b>	Zero detectable chemical/physical contaminants	80.0% no contaminants 20.0% contaminated	<b>80.0%</b>	0.40
<b>Bacterial contamination</b>	Zero detectable bacterial	56.4% no 30.0% coliform 10.0% E. Coli 3.6% Salmonella spp.	<b>56.4%</b>	0.79
<b>Water Clarity</b>	Clear (Visual)	Clear = 73.6% Cloudy = 18.2% Murky = 8.2%	<b>73.6%</b>	0.63

**Note:** Standard deviations were estimated using category midpoints

The results in Table 4, indicate the analysis of groundwater pH across the sampled boreholes revealed that 94.6% of the observations fell within the acceptable range of 6.5 to 8.5, as defined by national and international drinking water standards. This finding indicates limited concerns related to acidity or alkalinity in the district's groundwater supply. The consistency in pH levels was further supported by a low standard deviation ( $SD = 0.53$ ), suggesting minimal variation across sampling locations. As regards to the Total Dissolved Solids (TDS) measurements showed that 72.7% of the boreholes had concentrations below the recommended threshold of 1,000 mg/L, indicating acceptable water quality in the majority of cases. However, 27.3% of the samples exceeded this benchmark, raising concerns about possible mineral leaching, groundwater-rock interaction, or contamination from anthropogenic sources such as agricultural inputs or waste disposal. The standard deviation for TDS ( $SD = 354.27$  mg/L) was relatively high, reflecting substantial variability in the dissolved mineral content of groundwater across the study area.

Salinity levels were within acceptable limits in 67.3% of boreholes, while the remaining 32.7% recorded salinity values above 1,000 mg/L. This elevated salinity in nearly one-third of the samples may be indicative of saline intrusion, particularly in shallow aquifers, or the influence of fertilizer runoff in zones of intensive agricultural activity. These results underscore the spatial variability of groundwater quality and the need for localized mitigation strategies in areas with elevated salinity or TDS. A comparison of chemical and physical contaminants revealed that 20.0% of the sampled boreholes contained detectable levels of potentially harmful substances, while the remaining 80.0% met established safety thresholds. Although the majority of water sources were compliant, the detection of contaminants in one-fifth of the boreholes highlights the need for improved source protection and regular inspection of borehole infrastructure to ensure integrity and safety over time.

Microbiological analysis indicated substantial concerns regarding waterborne pathogens. Only 56.4% of the boreholes tested were free from bacterial contamination. Coliform bacteria were detected in 30.0% of samples, *Escherichia coli* (*E. coli*) in 10.0%, and *Salmonella* species in 3.6%. The presence of these microorganisms signifies faecal contamination, likely stemming from inadequate sanitation, shallow aquifer depths, or poor borehole siting and construction. These findings are inconsistent with the Uganda National Water Quality Standards (UNWQS), which stipulate the absence of pathogenic bacteria in potable water sources. Water clarity, assessed as a key physical and aesthetic quality indicator, was acceptable in 73.6% of the boreholes. However, 26.4% of samples were classified as either cloudy (18.2%) or murky (8.2%). This turbidity may

be attributable to suspended sediments, surface infiltration, or microbial activity and could diminish consumer confidence while also posing a risk of harbouring harmful microorganisms.

In summary, the study findings reveal that while the majority of boreholes in Kibuku District comply with national standards for pH and water clarity, considerable concerns remain regarding Total Dissolved Solids (TDS), salinity, and microbiological contamination. The detection of *E. coli* and *Salmonella* species in a subset of water samples presents an urgent public health concern. These results emphasize the need for targeted interventions, including borehole rehabilitation, point-of-use water treatment, and improved sanitary infrastructure. To ensure long-term water safety, routine water quality monitoring and continuous community sensitization on hygiene, sanitation, and groundwater protection are strongly recommended.

#### **4.7 Relationship between technical factors and Performance of Hand Pump Boreholes.**

To examine the extent to which technical factors influence the performance of hand pump boreholes in Kibuku District, an Analysis of Variance (ANOVA) was employed within a multiple regression framework. The model incorporated seven technical predictor variables: borehole depth, pump type, frequency of maintenance, casing material, pump yield, borehole construction quality, and borehole listing mechanisms. These variables were selected based on their theoretical and practical relevance to the functionality and sustainability of rural water infrastructure.

The overall, ANOVA output, revealed that the model was statistically significant,  $F(7, 368) = 28.95$ ,  $p < .001$ . This finding implies that the inclusion of the technical variables significantly improves the model's ability to predict borehole performance compared to a model with no predictors. The total variability (sum of squares) in borehole performance was 55.664, of which 19.769 was explained by the regression model and 35.895 remained unexplained (residual). These findings align with prior research that underscores the role of engineering and construction quality in rural water supply system sustainability (Foster et al., 2020; Bonsor et al., 2018).

**Table 5:** Relationship between technical factors and performance of Hand pump Boreholes

<b>Predictor</b>	<b>B</b>	<b>Std. Error</b>	<b>Beta</b>	<b>t.</b>	<b>Sig.</b>
Borehole Depth	0.015	0.067	0.013	0.221	0.825
Pump Type	0.128	0.053	0.019	2.164	<b>0.013</b>
Frequency of Maintenance	0.086	0.047	0.094	2.032	<b>0.024</b>
Casing material	0.338	0.051	0.306	6.469	<b>&lt;0.002</b>
Pump yield	0.113	0.045	0.143	2.531	<b>0.012</b>
Borehole Construction Quality	0.074	0.061	0.076	1.181	0.197
Borehole listing mechanism	0.106	0.173	0.185	4.174	<b>&lt;0.001</b>
<b>Cons.</b>	0.181	0.204	-	0.876	0.383

**F (7, 368) = 28.95, p < .001**

The findings in Table 5, indicate that among the seven predictors, casing material was the most statistically significant and influential variable ( $\beta = .338, p < .001$ ). This suggests that the type and quality of casing material are central to the structural durability and operational lifespan of boreholes. Poor casing materials have been previously associated with rapid deterioration due to corrosion or mechanical failure, particularly in aquifers with aggressive groundwater chemistry (Kelly et al., 2019). As such, the choice of robust and corrosion-resistant casing materials such as PVC or stainless steel appears pivotal for maintaining borehole functionality over time.

Similarly, borehole listing mechanisms, which encompass the geophysical and hydrogeological methods used in borehole siting, were found to be a significant positive predictor of performance ( $\beta = .173, p < .001$ ). This reinforces the argument that scientifically guided siting using methods such as electrical resistivity and hydrogeological mapping leads to higher yielding and more sustainable water points (MacDonald et al., 2012). Inadequate or improperly conducted siting has been linked to low yields, high failure rates, and poor water quality outcomes in sub-Saharan Africa (Sutton et al., 2021). Therefore, adherence to best practices in borehole siting is essential to optimize groundwater abstraction and reduce failure risk.

Notably, pump yield ( $\beta = .113, p = .012$ ) and pump type ( $\beta = .128, p = .013$ ) emerged as significant positive predictors of borehole performance. These findings suggest that the selection of high-yield pumps, along with context-appropriate pump designs, contributes meaningfully to the overall efficiency and reliability of rural water systems. According to Foster et al. (2020), higher-yield pumps are more likely to meet community water demands and reduce user fatigue, particularly in densely populated rural areas. Moreover, the compatibility of pump type with groundwater depth and user demand is a critical factor influencing sustainability, ease of use, and maintenance (Carter & Ross, 2016).

Another variable with significant predictive power was the frequency of maintenance ( $\beta = .086, p = .043$ ), highlighting the crucial role of regular servicing and minor repairs in sustaining optimal borehole functionality. Routine maintenance reduces the risk of mechanical failure, extends pump lifespan, and maintains water quality by preventing contamination through worn-out seals or broken components (Banks & Furey, 2021). This aligns with prior studies that associate preventive maintenance strategies with improved uptime and cost-efficiency in rural water infrastructure (Kayser et al., 2022). Community-led maintenance models, when properly resourced and monitored, have also been shown to enhance the operational sustainability of hand pump systems in sub-Saharan Africa.

Conversely, borehole construction quality ( $\beta$  not significant,  $p = .198$ ) and borehole depth ( $\beta$  not significant,  $p = .824$ ) did not demonstrate statistically significant associations with performance, despite showing positive coefficients. These findings suggest that while deeper boreholes and higher construction standards are theoretically beneficial, their impact may vary considerably across locations due to differing hydrogeological conditions, contractor practices, and overlap with other variables such as casing material or pump type. As MacDonald et al. (2012) noted, deeper boreholes do not necessarily equate to higher yields or better performance, especially when groundwater is found at shallower depths or when aquifer recharge rates are low. Additionally, inconsistent enforcement of construction standards and quality control measures may attenuate the expected benefits of higher construction quality (Sutton et al., 2021).

#### **4.8 Relationship between Environmental factors and Performance of Hand Pump Boreholes.**

To examine the extent to which environmental factors influence the performance of hand pump boreholes in Kibuku District, an Analysis of Variance (ANOVA) was employed within a multiple regression framework. The model incorporated six environmental predictor variables: seasonal

rainfall variations, groundwater recharge rates, water table depth, and contamination from agricultural activities, salinity levels, and environmental degradation. These variables were selected based on their theoretical and practical relevance to the functionality and sustainability of rural water infrastructure.

The model generated a multiple correlation coefficient (R) of 0.564, indicating a moderate positive relationship between the environmental predictors and the dependent variable. The coefficient of determination ( $R^2 = 0.318$ ) suggests that 31.8% of the variation in borehole performance and efficiency is explained by these environmental factors. The adjusted  $R^2 = 0.306$  corrects for the number of predictors in the model, and the standard error of the estimate (SEE) = 0.321 denotes a moderate level of prediction error.

**Table 6:** Analysis of the Environmental factors

Variable	Unstandardized B	Std. Error	Beta	t.	Sig.
Seasonal rainfall variations	0.024	0.028	0.091	1.359	0.175
Groundwater recharge rates	0.039	0.032	0.046	0.653	0.514
Water table depth	0.021	0.030	0.020	0.373	0.709
Contamination from agric. Activities	-0.054	0.025	-0.124	-2.232	<b>0.026*</b>
Salinity levels	0.185	0.027	0.408	6.911	<b>0.000*</b>
Environmental degradation	0.077	0.072	0.175	2.851	<b>0.005*</b>
<b>Cons.</b>	2.076	0.065	-	31.749	<b>0.000</b>

**F (6,369) = 28.615; p<0.001; Significant at p<0.05.**

The regression results presented in Table 6 highlight the significant role of environmental variables in determining the performance and efficiency of hand pump boreholes in Kibuku District. Among the variables analysed, three were found to exert statistically significant effects, with salinity levels emerging as the most influential. Specifically, salinity exhibited a strong and positive association with borehole performance ( $\beta = 0.408, p < .001$ ), indicating that lower salinity levels (implying higher water quality) are predictive of enhanced borehole efficiency. This relationship suggests that water with reduced salinity content is not only more acceptable for

domestic use but also contributes to the longevity and mechanical reliability of hand pump systems. High salinity water can lead to the corrosion of pump components and render the water unpalatable, thereby reducing user satisfaction and increasing maintenance costs (Mukherjee & van der Hoek, 2021).

These findings are consistent with prior empirical evidence that links groundwater quality parameters, especially salinity, to the sustainability and community acceptance of rural water supply systems (Bain et al., 2014; Godfrey et al., 2020). Boreholes located in areas with elevated salinity levels often face operational challenges and user complaints, which can result in system abandonment or underutilization. Moreover, such conditions may necessitate frequent repairs and compromise the long-term viability of community-managed water sources (Adu-Manu et al., 2019). Further, the results on the environmental degradation had a statistically significant positive influence on borehole inefficiencies, with a standardized beta coefficient ( $\beta$ ) of 0.175 and a p-value of 0.005. This result indicates that increases in environmental degradation—measured in terms of deforestation, soil erosion, and human encroachment, are associated with increased vulnerability of borehole infrastructure. Specifically, higher levels of surface run-off, pollution, and siltation in recharge zones contribute to reduced water yield and mechanical failure in hand pump boreholes.

This finding corroborates earlier research by Kigundu et al. (2022), who established that land use change significantly affects the sustainability of rural water supply systems in Uganda. Their study found that anthropogenic activities such as logging, poor agricultural practices, and settlement expansion contribute to the contamination and physical degradation of groundwater recharge areas. Consequently, such ecological disturbances increase the frequency of borehole breakdowns, maintenance demands, and water scarcity in vulnerable communities.

Environmental degradation thus emerges as a key predictor of water point sustainability, underscoring the need for integrated land and water management strategies. As argued by Foster et al. (2020), maintaining ecological integrity within watersheds is critical for the long-term functionality of groundwater-based rural water systems. Moreover, this relationship emphasizes the importance of adopting community-based conservation practices and enforcing environmental regulations aimed at safeguarding natural water recharge zones (UN-Water, 2023).

In the same vein, contamination from agricultural activities was a statistically significant predictor. Specifically, contamination from agricultural activities exhibited a negative and

significant association with borehole performance ( $\beta = -0.124, p = .026$ ). This finding aligns with previous studies which have highlighted the detrimental impact of agrochemical runoff—particularly nitrates and pesticides—on groundwater quality and infrastructure sustainability (Adeyemi et al., 2022; Kimani et al., 2020). Prolonged infiltration of chemical residues from fertilizers and pesticides contributes to nitrate pollution in aquifers, which can reduce water potability and accelerate the deterioration of borehole structures (Nyenje et al., 2013).

In contrast, other environmental variables assessed in the model, including seasonal rainfall variations ( $p = .175$ ), groundwater recharge rates ( $p = .514$ ), and water table depth ( $p = .709$ ), did not exhibit statistically significant effects on borehole performance at the 5% level. Despite their lack of significance in this model, these variables remain theoretically relevant and have been documented in literature as critical to groundwater dynamics (MacDonald et al., 2012; Tindimugaya, 2008). The absence of statistical significance may reflect users' adaptive strategies during dry seasons, such as water rationing or shifting to alternative sources, as well as the potential short-term stability of groundwater levels in the Kibuku District due to consistent aquifer recharge. It is also plausible that the temporal scope of the study was insufficient to capture the full variability of these environmental drivers. For instance, groundwater recharge and water table fluctuations often exhibit delayed effects on borehole yield, depending on hydrogeological conditions and land use practices (Howard & Griffith, 2009). Future longitudinal studies are recommended to capture these delayed interactions and to further disentangle the compound effects of climate variability and land use on groundwater systems.

#### **4.9 Relationship between Socio-economic factors and Performance of Hand Pump**

##### **Boreholes.**

To assess the influence of socio-economic factors on the performance of hand pump boreholes in the study area, multiple regression was conducted. The model included seven predictor variables: household income, user fees, community-based management practices, local government support, water usage patterns, availability of spare parts, and community involvement in maintenance. These variables were selected based on their theoretical and practical relevance to the functionality and sustainability of rural water infrastructure.

#### 4.9.1 Regression Model Summary

A logistic regression model was employed to examine the influence of selected socio-economic variables on the functionality of boreholes in Kibuku District. Borehole functionality was treated as a binary dependent variable, categorized as either operational (1) or non-operational (0). This analytical approach allowed for the estimation of the likelihood that a borehole remains functional based on the socio-economic characteristics of the surrounding community. The regression results yielded several key insights, as detailed below.

The results presented in Table 7, revealed that user fees were positively associated with borehole functionality ( $\beta = 0.085$ ,  $p = .048$ ), indicating a statistically significant but modest effect. This suggests that where users contribute financially to water infrastructure, the systems are more likely to remain functional. These findings align with previous studies emphasizing the importance of community financial responsibility in sustaining rural water services (Sansom et al., 2020; Foster et al., 2019).

Furthermore, local government support emerged as a significant predictor ( $\beta = 0.637$ ,  $p = .019$ ), highlighting the crucial role of institutional backing in sustaining borehole operations. Government support may include budget allocations, technical assistance, or coordination of water user committees—factors that reinforce long-term water infrastructure viability (Carter & Ross, 2021; World Bank, 2023). The availability of spare parts showed a strong positive relationship with functionality ( $\beta = 0.871$ ,  $p = .003$ ), confirming that logistical readiness is a foundational requirement for system maintenance. This aligns with research indicating that the presence of supply chains and decentralized spare part markets enhances repair efficiency and reduces downtime (Nagel et al., 2022; Lockwood & Smits, 2020).

Additionally, community involvement in maintenance also had a statistically significant effect ( $\beta = 0.598$ ,  $p = .014$ ), reinforcing the importance of local participation in technical and managerial aspects of water point sustainability. Active community engagement is linked to increased ownership, accountability, and timely reporting of faults (Marks & Davis, 2019; UNICEF, 2022). Collectively, these findings underscore that borehole functionality in rural settings is not merely a technical issue but deeply embedded in social, economic, and institutional frameworks. Integrated approaches that combine financial contributions, local governance, logistical infrastructure, and participatory management are likely to yield more sustainable outcomes.

The results on water usage patterns revealed a significantly and positively influenced the functionality of borehole systems,  $\beta = 0.129$ ,  $p = .001$ . This suggests that frequent and consistent use of water points is associated with improved functionality. Regular use likely helps to maintain the mechanical components of the infrastructure and enables community members to detect and report faults early, thus promoting timely maintenance and repair. These findings are consistent with previous studies that have shown that usage frequency contributes to the sustainability of rural water points (Katuva et al., 2022; Foster et al., 2018). Although community-based management practices also exhibited a positive relationship with borehole functionality ( $\beta = 0.042$ ), this association was not statistically significant at the conventional 5% level ( $p = .092$ ). The marginal result may suggest a weak or context-specific effect of community participation on infrastructure outcomes. While local management is widely advocated as a key strategy for enhancing sustainability (Schaaf & Ssozi, 2021), its effectiveness may depend on the strength of community institutions, clarity of roles, and enforcement mechanisms.

**Table 7:** Socio-economic Factors Affecting Borehole Functionality (n = 110)

Variable	Coef.	Std. Err.	Z	P >  z	95% Conf. Inter.	Odds Ratio
Household income (USD)	-0.012	0.031	-0.39	0.696	[-0.072, 0.049]	0.988
User fees (USD)	0.085	0.043	1.98	<b>0.048</b>	[0.001, 0.169]	1.089
Community-based mgt practices	0.042	0.025	1.68	<b>0.092</b>	[-0.007, 0.091]	1.043
Local government support (Yes = 1)	0.637	0.271	2.35	<b>0.019</b>	[0.106, 1.169]	1.891
Water usage patterns	0.129	0.039	3.31	<b>0.001</b>	[0.053, 0.205]	1.138
Availability of spare parts (Yes = 1)	0.871	0.295	2.95	<b>0.003</b>	[0.293, 1.448]	2.389
Community involve. in maintenance	0.598	0.242	2.47	<b>0.014</b>	[0.124, 1.072]	1.818
<b>Cons</b>	-2.134	0.668	-3.19	<b>0.001</b>	[-3.444, -0.823]	0.118

On the other hand, household income did not significantly predict borehole functionality ( $p = .696$ ), implying that economic status at the household level may play a limited role in sustaining communal infrastructure (Table 7). This outcome aligns with literature highlighting that behavioural, institutional, and collective action factors often outweigh individual economic capacity in maintaining shared resources (Marks et al., 2020; Whaley & Cleaver, 2017). In rural settings, particularly where services like water provision are shared communally, social cohesion and accountability frameworks may be more crucial than income levels in determining operational success.

The findings underscore the importance of behavioural and institutional variables over economic variables in explaining water infrastructure performance. Promoting consistent usage and strengthening community engagement mechanisms could be more impactful than income-targeted interventions. The statistically significant influence of usage patterns emphasizes the value of functional dependency, where reliance on a water source creates incentives for collective action toward maintenance. However, the limited significance of community-based management practices points to the need for capacity building and better governance structures within local user committees. Finally, the insignificance of household income reaffirms that water point functionality is more strongly linked to shared responsibility and governance than individual economic advantage.

#### **4.10 Summary of Key Findings**

##### **Relationship between Technical Factors and Performance of Hand Pump Boreholes**

The study examined the influence of technical factors on the performance of hand pump boreholes, identifying key engineering and design elements that contribute to operational sustainability. One of the core technical considerations was the type of casing material used during borehole construction. The analysis identified casing material as a critical determinant of borehole functionality. This underscores the relevance of durable and corrosion-resistant materials in enhancing the operational longevity of rural water infrastructure, as emphasized in technical water engineering guidelines. Another significant technical factor investigated was the mechanism used to determine borehole siting. Scientifically guided siting, including the use of hydrogeological surveys and geophysical mapping, emerged as an important factor associated with improved borehole performance. This reflects the broader consensus in water resource management

literature regarding the importance of appropriate site selection to ensure access to reliable aquifers and minimize risks of seasonal depletion and poor recharge.

The study also assessed the relevance of pump type and yield in influencing borehole efficiency. Both pump characteristics were found to be associated with system performance, suggesting that matching pump specifications to site-specific groundwater conditions is an essential technical requirement. This observation reinforces existing engineering practices which advocate for the deployment of context-specific technologies suited to local aquifer conditions. Furthermore, the study explored the role of maintenance frequency in sustaining borehole functionality. Regular maintenance schedules, encompassing both preventive and corrective activities, were linked to improved borehole operations. This supports water systems management approaches that emphasize the necessity of ongoing technical oversight and structured maintenance cycles to reduce downtimes and system failures.

Conversely, borehole depth and construction quality did not significantly influence performance within the study context. This suggests that while these factors are theoretically important in engineering design, their practical influence may be constrained by localized hydrogeological conditions or inconsistencies in implementation. The absence of statistical significance for these variables calls attention to the need for more granular technical assessments that consider field-specific variability in construction and groundwater characteristics.

### **Relationship between Environmental Factors and Performance of Hand Pump Boreholes**

The investigation into environmental factors revealed their substantial influence on borehole functionality, underscoring the importance of ecological conditions in sustaining rural water systems. Salinity levels emerged as the most influential environmental variable associated with borehole performance. Lower salinity levels were linked to better operational outcomes, suggesting that the geochemical composition of groundwater significantly affects the usability and longevity of borehole installations. The study also evaluated the impact of environmental degradation, particularly deforestation and soil erosion, on borehole performance. Findings indicated a significant negative association between degraded landscapes and borehole functionality. This highlights the environmental dimension of water infrastructure planning, where land use changes and ecological disruption can adversely affect aquifer stability, recharge capacity, and sediment infiltration into borehole systems.

In addition, contamination from agricultural activities was assessed as a determinant of borehole performance. The presence of agrochemical runoff and land use intensification in farming zones was negatively associated with borehole efficiency. This highlights the implications of surrounding land management practices on groundwater quality and underscores the necessity for protective zoning and integrated land and water management strategies. However, some natural hydrological factors—such as seasonal rainfall variation, groundwater recharge rates, and water table depth—did not exhibit statistically significant relationships with borehole performance in this context. While these factors are commonly viewed as essential in groundwater replenishment theory, their limited influence in this case may reflect unique local conditions or the temporal scope of data collection. This underlines the importance of localized environmental assessments that account for both natural and anthropogenic influences in borehole sustainability planning.

### **Relationship between Socio-economic Factors and Performance of Hand Pump Boreholes**

The relationship between socio-economic factors and borehole performance was examined with a focus on financial, institutional, and community-related dynamics. Financial contributions by community members, particularly through user fees, were found to positively influence borehole functionality. This finding supports the argument that shared financial responsibility fosters ownership and ensures the availability of resources for ongoing operation and maintenance activities. Support from local government entities also emerged as a key socio-economic factor contributing to borehole sustainability. Institutional involvement through policy coordination, technical oversight, and administrative support was positively associated with borehole performance. This indicates the importance of robust institutional frameworks and collaborative governance structures in maintaining rural water infrastructure.

Another significant factor was the availability of spare parts. The presence of functional supply chains for replacement components contributed substantially to borehole functionality, emphasizing the role of logistical support in minimizing downtime and ensuring prompt repairs. This reinforces the principle that infrastructural readiness is as vital as financial or organizational inputs in rural water management. Community involvement in the operation and maintenance of boreholes was also positively associated with system performance. Active participation in decision-making, repair oversight, and monitoring contributed to better functionality outcomes, reflecting the central role of community engagement in sustainable rural development. Similarly, consistent water usage patterns, indicative of routine engagement with the borehole, were

associated with enhanced system reliability, suggesting the functional value of usage consistency in early fault detection and maintenance responsiveness.

In contrast, community-based management practices, while generally positively aligned with borehole performance, did not show a statistically significant impact in this study. This nuance suggests variability in the effectiveness of such models, potentially influenced by institutional maturity, leadership continuity, and community capacity. Furthermore, household income was not a significant predictor of borehole performance, indicating that the sustainability of shared water resources may depend more on collective organizational and institutional factors than on individual economic capacity.

....

## **CHAPTER FIVE**

### **CONCLUSION AND RECOMMENDATIONS**

#### **5.0 Introduction**

The general research objective was to analyse the technical, socio-economic and environmental factors affecting hand pump borehole performance and efficiency in Kibuku District in Eastern Uganda. This chapter presents a summary of key findings, the conclusions drawn from the study findings and provides recommendations based on the research objectives. It also outlines areas for further research to build on the current study's contributions.

#### **5.1 Conclusion**

The findings clearly demonstrate that technical variables are critical determinants of borehole performance in Kibuku District. Notably, casing material, siting guided by hydrogeological surveys, pump type, and regular maintenance showed statistically significant relationships with functional outcomes. In contrast, traditionally emphasized factors such as borehole depth and construction quality showed limited predictive power in this local context. These results suggest that enhancing technical standards—particularly material quality and site-specific pump compatibility—could substantially improve borehole reliability and lifespan. Consequently, interventions aimed at improving rural water infrastructure in Kibuku District must prioritize technical audits, skill-based training, and stringent construction protocols as part of a localized engineering framework.

Environmental factors were found to significantly shape borehole performance, accounting for nearly one-third of the observed variability in outcomes. Salinity emerged as the most detrimental constraint, while environmental degradation and agricultural runoff also negatively impacted water quality and hardware durability. Surprisingly, conventional hydrological indicators such as rainfall and water table depth did not show a significant effect, indicating that anthropogenic environmental degradation may override natural determinants. These findings underscore the necessity of integrating environmental risk assessments especially related to land use, salinity, and ecosystem health—into borehole planning and management processes. Thus, ensuring the long-term functionality of rural water infrastructure in Kibuku District requires harmonizing water development initiatives with sustainable environmental conservation strategies.

Socio-economic variables significantly influenced borehole sustainability, with factors such as local financing, spare parts availability, government involvement, and community participation strongly contributing to system reliability. Among these, the availability of spare parts and institutional support were the most powerful predictors, highlighting the operational importance of logistical systems and governance structures. While community-based management showed a positive, though statistically weak, relationship, household income did not significantly predict performance, challenging the notion that poverty alone undermines sustainability. These outcomes emphasize the need for policy frameworks that reinforce decentralized, yet institutionally backed, water management systems. For Kibuku District, strengthening public-private partnerships, developing spare parts supply chains, and building technical and managerial capacity at the community level are crucial to achieving sustained rural water service delivery.

## **5.2 Recommendations**

Based on the study findings, it is recommended that efforts to improve hand pump borehole performance in Kibuku District prioritize strengthening technical standards through mandatory technical audits, enhanced training for local technicians, and strict enforcement of construction protocols that ensure the use of durable casing materials and hydrogeologically appropriate pump types. Environmental risk assessments should be systematically integrated into borehole planning to address issues such as salinity, land degradation, and agricultural runoff, which significantly affect water quality and hardware longevity. Simultaneously, water development initiatives must be harmonized with sustainable environmental management practices to safeguard groundwater resources. On the socio-economic front, there is a need to improve spare parts availability through the development of local supply chains and to reinforce institutional support mechanisms by fostering effective public-private partnerships and building the technical and managerial capacities of community water committees. These integrated interventions will collectively enhance the reliability, sustainability, and long-term functionality of rural water infrastructure in the district.

## **5.3 Contribution to the body of knowledge**

This study contributes to the body of knowledge by providing empirical evidence on the multifaceted determinants of hand pump borehole performance in a rural Ugandan context, specifically highlighting the critical role of technical, environmental, and socio-economic factors. Unlike previous studies that have often generalized performance outcomes, this research

distinguishes context-specific variables such as casing material quality, site-specific pump compatibility, salinity, and institutional support as key predictors of borehole functionality. By demonstrating that conventional indicators like borehole depth and rainfall are less predictive in this setting, the study challenges prevailing assumptions and emphasizes the importance of localized, interdisciplinary approaches to rural water infrastructure management. The findings offer a nuanced framework for policymakers, engineers, and development practitioners to design targeted interventions that align technical engineering practices with sustainable environmental management and community-centered governance models.

#### **5.4 Areas for further Research**

Based on the study findings, three areas for further research are recommended. First, there is a need to explore the long-term cost-effectiveness and durability of different casing materials in varied hydrogeological zones, to better guide material selection in rural borehole construction. Second, future studies should investigate the interaction between pump type and groundwater characteristics such as salinity, depth, and recharge rate, to develop more context-specific pump sizing and selection protocols. Third, it is important to examine how maintenance frequency and technical capacity within local communities influence the lifespan of hand pump boreholes over time, especially in relation to the availability of spare parts and the effectiveness of training programs for local technicians.

## BIBLIOGRAPHY

Adank, M., van Koppen, B., Smits, S., & Mikhail, M. (2013). "Governance and Sustainability of Rural Water Supply: Case Studies from Uganda". International Water and Sanitation Centre.

Adeyemi, O., Jegede, O., & Adebayo, W. (2022). Groundwater contamination from agricultural practices: A review of nitrate and pesticide impacts in Sub-Saharan Africa. *Environmental Earth Sciences*, 81(5), 1–12. <https://doi.org/10.1007/s12665-022-10231-0>.

Adu-Manu, K. S., Tuffour, I., Asenso, H., & Owusu-Nimo, F. (2019). Assessing the impact of water quality on rural water supply sustainability in Ghana. *Water Practice and Technology*, 14(4), 958–967. <https://doi.org/10.2166/wpt.2019.082>.

Alan, Terry (2015). Improving the Effectiveness of Uganda Water User Committees.

Allison, Fechter N (2017). Water Committee Activities and Characteristics Affecting Water System Management in Northern Ghana; [https:// core. ac.uk](https://core.ac.uk). Accessed 20/02/2021

Baguma, Carter A (2019). Groundwater and Resilience to Drought in the Ethiopian Highlands.

Bain, R. E. S., Cronk, R., Hossain, R., Bonjour, S., Onda, K., Wright, J., ... & Bartram, J. (2014). Global assessment of exposure to faecal contamination through drinking water based on a systematic review. *Tropical Medicine & International Health*, 19(8), 917–927. <https://doi.org/10.1111/tmi.12334>.

Bonsor, H. C., Oates, N., Chilton, P. J., Carter, R. C., Casey, V., MacDonald, A. M., & Etti, B. (2018). A hidden crisis: Strengthening the evidence base on the sustainability of rural groundwater supplies. *Science of the Total Environment*, 653, 1445–1456. <https://doi.org/10.1016/j.scitotenv.2018.10.110>.

Bonsor, MacDonald H (2018). The Need for a Standard Approach to Assessing the Functionality of Rural Community Water Supplies, *Hydrogeology Journal*. Accessed 25/01/2019.

Borgen (2022). <https://www.borgenmagazine.com/boreholes-in-the-horn-of-africa>

Carter, R (2021). Rural Community Water Supply: Sustainable Services for All: Practical Action Publishing; <https://practicalactionpublishing.com/book/2556/rural-community-water-supply> accessed on 10/11/2021

Carter, R., & Ross, I. (2021). Sustainable water services: A framework for aligning technical and institutional components. *Water Alternatives*, 14(2), 220–238.

Carter, R. C., Tyrrel, S. F., & Howsam, P. (2010). "The impact and sustainability of community water supply and sanitation programmes in developing countries". *Water and Environment Journal*, 15(4), 294-299.

Chintalapati, Pranav (2020). Maintenance Approaches to Improve the Sustainability of Rural Water Supplies: <https://www.globalwaters.org> accessed on 22/06/2021

Cochran, W. G. (1977). "Sampling Techniques" (3rd ed.). John Wiley & Sons.

Cord, Walters C (2019). Moving Toward Prevention: Rural Water Maintenance and Sustained Service Delivery. <https://digitalcommons.georgetox.edu> accessed on 11/03/2020

Danert, K., Armstrong, T., Adekile, D., Duffau, B., Ouedraogo, I. & Kwei, C. (2010) Code of Practice for Cost Effective Boreholes.

Danert, P (2022). Stop the Rot Report I: Handpump Reliance, Functionality and Technical Failure. Action Research on Hand Pump Component Quality and Corrosion in Sub-Saharan Africa pg 46-48 viewed on <https://www.researchgate.net/publication> on 11/03/2020

Danert, K., Butterworth, J., & Sutton, S. (2019). Professionalising community-based management of rural water services. *Waterlines*, 38(1), 3–22. <https://doi.org/10.3362/1756-3488.18-00002>.

Debus, Philippe J (2019). Sustainability Index of Rural Water Services: Burkina Faso and Niger.

Foster, S., MacDonald, A., & Chilton, P. (2020). Groundwater sustainability strategies: Balancing environmental and water supply needs in low-income settings. *Hydrogeology Journal*, 28(3), 849–860. <https://doi.org/10.1007/s10040-020-02116-w>.

Foster, T., Furey, S., Banks, B., & Willetts, J. (2018). Functionality of handpump water supplies: A review of data from sub-Saharan Africa and the Asia-Pacific region. *International Journal of Water Resources Development*, 34(4), 633–646.

<https://doi.org/10.1080/07900627.2017.1324092>.

Foster, T., Furey, S., Banks, B., & Willetts, J. (2020). Functionality of handpump water supplies: A review of data and evidence on causes of failure. *Water*, 12(1), 86. <https://doi.org/10.3390/w12010086>.

Foster, T., Furey, S., Banks, B., & Willetts, J. (2020). Functionality of handpump water supplies: A review of data and evidence on causes of failure. *Water*, 12(1), 86. <https://doi.org/10.3390/w12010086>.

Foster, T., Willetts, J., Lane, M., & Thomson, P. (2019). Risk factors associated with rural water supply failure: A 30-year retrospective study of handpumps in sub-Saharan Africa. *Science of the Total Environment*, 652, 703–713. <https://doi.org/10.1016/j.scitotenv.2018.10.263>.

Foster, S. (2013). "Groundwater and Rural Water Supply in Sub-Saharan Africa". World Bank.

Francois, (2000). Operation and Maintenance of Rural Water Supply and Sanitation System

Godfrey, S., Labh, A., McIntyre, P., Souter, R., & Smits, S. (2020). Management models for the sustainability of rural water supply services: A systematic review. *International Journal of Water Resources Development*, 36(5), 839–861. <https://doi.org/10.1080/07900627.2019.1681262>.

Harold, Lockwood P (2022). A Roadmap for System Strengthening for Professionalized Rural Water Maintenance Services: <https://www.globalwaters.org> accessed on 10/02/2022

Harvey, A (2021). "Ten Factors for Viable Rural Water Services." SWS, UCB Research Report; USAID. <https://www.globalwaters.org/resources/assets/ten-factors-viable-rural-water-services>

Harvey, P. A., & Reed, R. A. (2004). Rural water supply in Africa: Building blocks for handpump sustainability. *WEDC, Loughborough University*. <https://wedc-knowledge.lboro.ac.uk>.

Harvey, P. A., & Reed, R. A. (2007). "Community-Managed Water Supplies in Africa: Sustainable or Dispensable?" *Community Development Journal*, 42(3), 365-378.

Henk, Holtslag (2022). Practical Ideas to Reach SDG6.1 and Water Related SDGS in Rural Africa <https://smartcentregroup.com> accessed on 02/ 01/2023

Hope, R., Foster, T., & Thomas, M. A. (2021). Is community water management failing?

Evidence from Kenya. *Water Economics and Policy*, 7(1), 2150003. <https://doi.org/10.1142/S2382624X21500035>.

Howard, G., & Griffith, K. (2009). Protecting groundwater for health: Managing the quality of drinking-water sources. World Health Organization.

Imoro, Braimah (2016). The Effectiveness of the Local Management Systems of Rural Water Facilities for Sustainable Service Delivery: A Case Study of the Sekyere Esat District, Ghana.

Israel, G. D. (1992). "Determining Sample Size". University of Florida Cooperative Extension Service.

Jay, Hawkins W (2004). Uses of the Borehole Camera in Hydrologic Investigations.

Katuva, J., Thomas, E., Whaley, L., & Hope, R. (2022). Groundwater sustainability under institutional and climate stress: Evidence from rural Kenya. *Water Resources Research*, 58(5), e2021WR031697. <https://doi.org/10.1029/2021WR031697>.

Kelly, E., Cronk, R., & Bartram, J. (2019). A multi-country study of factors influencing functionality of rural water sources. *Environmental Science & Technology*, 53(9), 5225–5231. <https://doi.org/10.1021/acs.est.8b07173>.

Kendra, Chery (2019). How Does the Cross-Sectional Research Method Work

Kiggundu, N., Kabonesa, C., & Twinomucunguzi, R. (2022). Impact of land use change on rural water point sustainability in Uganda: A case of borehole functionality. *African Journal of Environmental Science and Technology*, 16(4), 149–158. <https://doi.org/10.5897/AJEST2022.3134>.

Kimani, M. W., Kithiia, J., & Makokha, M. (2020). Agricultural activities and their impacts on groundwater quality in peri-urban areas of Nairobi, Kenya. *Water Practice and Technology*, 15(2), 507–518. <https://doi.org/10.2166/wpt.2020.035>.

Kidochukwu, Mekwunye P (2018). Environmental Impact of Unregulated Borehole Drilling on Ground Water Resource and Soil Structure; <https://www.linkedin.com> accessed on 21/11/2021

Koehler, J., Thomson, P., & Hope, R. (2015). Pump-priming payments for sustainable water

services in rural Africa. *World Development*, 74, 397–411.  
<https://doi.org/10.1016/j.worlddev.2015.05.020>.

Liddle, E (2018). Review of Hand Pump-Borehole Implementation in Uganda, Nottingham, UK: Bgs (Or/18/002). Available from <https://nora.nerc.ac.uk/id/eprint/520591/> accessed On 19/03/2020

Lockwood, H., & Smits, S. (2020). Sustaining rural water: A comparative study of maintenance models in African contexts. IRC International Water and Sanitation Centre.

Lockwood, H., & Smits, S. (2011). "Supporting Rural Water Supply: Moving Towards a Service Delivery Approach". IRC International Water and Sanitation Centre

MacAllister, DJ (2019). A Methodology for Assessment of the Physical Sub-System of Hand Pumped Boreholes.

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. E. Ó., & Taylor, R. G. (2012). Quantitative maps of groundwater resources in Africa. *Environmental Research Letters*, 7(2), 024009.  
<https://doi.org/10.1088/1748-9326/7/2/024009>.

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. É. Ó., & Taylor, R. G. (2012). Quantitative maps of groundwater resources in Africa. *Environmental Research Letters*, 7(2), 024009.  
<https://doi.org/10.1088/1748-9326/7/2/024009>.

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. É. Ó., & Taylor, R. G. (2012). Quantitative maps of groundwater resources in Africa. *Environmental Research Letters*, 7(2), 024009.  
<https://doi.org/10.1088/1748-9326/7/2/024009>.

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. E. Ó., & Taylor, R. G. (2021). Groundwater and resilience to climate change in Africa. *Environmental Research Letters*, 16(2), 024001.  
<https://doi.org/10.1088/1748-9326/abdfd0>

Marks, S. J., & Davis, J. (2019). Does user participation lead to sense of ownership for rural water systems? Evidence from Kenya. *World Development*, 123, 104619.  
<https://doi.org/10.1016/j.worlddev.2019.104619>.

Marks, S. J., Komives, K., & Davis, J. (2020). Community participation and water supply

sustainability: Evidence from handpump projects in Ghana. *Water Resources Research*, 56(6), e2019WR026175. <https://doi.org/10.1029/2019WR026175>.

McGarvey, S. T., Buszin, J., Abdelhameed, S., et al. (2008). "Water Supply and Health in Sub-Saharan Africa: An Epidemiological Perspective". *International Journal of Environmental Health Research*, 18(4), 287-297.

Mukherjee, S., & van der Hoek, W. (2021). Corrosion and salinity impact on rural hand pump infrastructure: A review of water quality interactions in sub-Saharan Africa. *Water Research*, 189, 116611. <https://doi.org/10.1016/j.watres.2020.116611>.

MWE (2007). District Implementation Manual Version 1, 31 March 2007 by Ministry of Water and Environment.

MWE (2012). Performance Review of Water Sector

MWE (2013). District Implementation manual- Revised.

MWE (2014). District Implementation Manual

MWE (2020). National Framework for Operation and Maintenance of Rural Water Infrastructure In Uganda

MWE (2022). Directorate of water Development, Ministry of Water and Environment, Republic of Uganda.

Mugenda, O. M., & Mugenda, A. G. (2003). "Research Methods: Quantitative and Qualitative Approaches". ACTS Press.

Nagel, C., Beach, J., Iribagiza, C., & Thomas, E. (2022). Evaluating supply chains for rural water service maintenance in East Africa. *Water Resources Research*, 58(1), e2021WR030895. <https://doi.org/10.1029/2021WR030895>.

Nyenje, P. M., Foppen, J. W., Uhlenbrook, S., Kulabako, R., & Muwanga, A. (2013). Nutrient pollution in shallow aquifers underlying pit latrines and domestic solid waste dumps in urban slums. *Science of the Total Environment*, 409(19), 1909–1917. <https://doi.org/10.1016/j.scitotenv.2010.02.033>.

Patton, M. Q. (2002). "Qualitative Research & Evaluation Methods" (3rd ed.). Sage Publications.

Sansom, K., Franceys, R., & Njiru, C. (2020). Financing sustainable rural water services: The role of tariffs and subsidies. *International Journal of Water Resources Development*, 36(5), 837–856. <https://doi.org/10.1080/07900627.2019.1634000>.

Schaaf, M., & Ssozi, D. (2021). Participation and performance in decentralized water governance: Lessons from Uganda. *World Development*, 138, 105250. <https://doi.org/10.1016/j.worlddev.2020.105250>.

Schouten, T., & Moriarty, P. (2018). Community water, community management: From system to service in rural areas. Earthscan.

Shaw, David (2012). An assessment of Rural Water Supply Sustainability in Monze District, Zambia.

Sutton, S., Butterworth, J., & Batchelor, C. (2021). Systems approaches for sustainable rural water services: A conceptual framework and a review of its application. *Water Alternatives*, 14(2), 389–409. <https://www.water-alternatives.org/index.php/alldoc/articles/vol14/v14issue2/633-a14-2-9/file>.

Sutton, S., Butterworth, J., & Batchelor, C. (2021). Systems approaches for sustainable rural water services: A conceptual framework and a review of its application. *Water Alternatives*, 14(2), 389–409.

Sutton, S. (2008). "The Risks of Poor Borehole Siting and Construction". Rural Water Supply Network.

Tindimugaya, C. (2008). Groundwater governance in Uganda: A case study. *Water Policy*, 10(S1), 49–62. <https://doi.org/10.2166/wp.2008.052>.

Truslove, J.P (2021). Behaviors and Trends toward Routine Maintenance and Major Repairs of Afridev Handpumps in Rural Malawi. Viewed on <https://doi.org/10.3390/w13121666>

Uganda Bureau of Statistics (2016). The National Population and Housing Census 2014- Main Report, Kampala, Uganda [https://www.ubos.org > uploads](https://www.ubos.org/uploads) accessed on 15/03/2015

UNDP (2021). Roadmap for the Implementation of the Sustainable Development Goals in Uganda. <https://www.undp.org> accessed on 11/04/2022

UNICEF (2020). Technical Guidelines for the Construction And Rehabilitation Of Drilled Water Wells. <https://www.humanitarianresponse.info> accessed on 21/12/2022

UNICEF. (2022). Strengthening operation and maintenance for rural water services: Community engagement strategies. United Nations Children's Fund. <https://www.unicef.org/documents/rural-water-services>.

UN-Water. (2023). Progress on integrated water resources management: Tracking SDG 6 target 6.5. United Nations. <https://www.unwater.org/publications/progress-integrated-water-resources-management-2023>

Whaley, L., & Cleaver, F. (2017). Can 'functionality' save the community management model of rural water supply? *Water Resources and Rural Development*, 9, 56–66. <https://doi.org/10.1016/j.wrr.2017.04.001>

WHO (2017). "Guidelines for Drinking Water Quality". World Health Organization.

WHO (2022). Fact sheet <https://www.who.int/news-room/fact-sheets/detail/drinking-water>- 21 March 2022

WHO/ UNICEF (2021). Progression Household Drinking Water, Sanitation and Hygiene 2000-2020: Five Years into the SDGs

WHO/UNICEF (2017). San Lui Obispo, California. Sustainability and Rural Water Development.

World Bank. (2023). Building resilient water supply systems: Institutional frameworks for long-term sustainability. World Bank Publications.

Yamane, Taro (1967). *Statistics-An introductory Analysis*, 2<sup>nd</sup> Ed, New York.

Zhang N (2015). Strengthening Borehole Configuration from the Retaining Roadway for Green House Gas Reduction.

## APPENDIX

### APPENDIX A: SURVEY QUESTIONNAIRE

Dear Respondent,

My name is Elizabeth Sikyajula, a student at UCU. I am pursuing a Master's of Science in Water and Sanitation. As part of the degree award, I am carrying out a study on Determinants of Hand Pump Borehole Performance and Efficiency in Rural Uganda: A Case Study of Kibuku District. You have been selected as a valuable stakeholder to assist in providing your insights as contained in the survey questionnaire below.

Participation in the study is voluntary; however, I would appreciate your honest opinions and experiences relating to the research subject. All information provided will be treated with total confidentiality and the data collected will only be used for this study.

#### 1. Household Head Water Users Survey Questionnaire

##### General Information:

- Survey ID: \_\_\_\_\_
- Date: \_\_\_\_\_
- Location (Sub – County and village): \_\_\_\_\_
- Enumerator Name: \_\_\_\_\_
- Respondent Name: \_\_\_\_\_
- Household Size: \_\_\_\_\_

##### Section A: Demographic Information

1. Age of respondent: \_\_\_\_\_
2. Gender of respondent:
  - a)  Male
  - b)  Female
3. Occupation:
  - a)  Farmer
  - b)  Businessperson
  - c)  Other (Specify): \_\_\_\_\_
4. Household income per month (UGX):

- a)  Less than 200,000 UGX
- b)  200,000–500,000 UGX
- c)  500,000–1,000,000 UGX
- d)  More than 1,000,000 UGX

**Section B: Borehole Usage and Functionality**

5. How often do you use the borehole for water?

- a)  Daily
- b)  Weekly
- c)  Rarely

6. How far is the nearest borehole from your household?

- a)  Less than 200 meters
- b)  200–500 meters
- c)  More than 500 meters

7. What is the condition of the water provided by the borehole?

- a)  Clean and clear
- b)  Cloudy
- c)  Murky or contaminated

8. Have you experienced any issues with the borehole? (e.g., no water, broken pump, or leakage)

- a)  Yes (Specify the issue): \_\_\_\_\_
- b)  No

9. How satisfied are you with the current water supply from the borehole?

- a)  Very Satisfied
- b)  Satisfied
- c)  Dissatisfied
- d)  Very Dissatisfied

**Section C: Water Usage and Accessibility**

11. How many people in your household rely on this borehole for water? \_\_\_\_\_
12. How accessible is the borehole during the dry season (e.g., June–September)?
- a)  Very Accessible
  - b)  Moderately Accessible
  - c)  Not Accessible
13. Does the borehole ever stop providing water due to breakdowns or repair work?
- a)  Yes
  - b)  No
14. How long does it usually take to get the borehole repaired?
- a)  Less than 1 day
  - b)  1–3 days
  - c)  More than 3 days
  - d)  Never repaired

#### **Section D: Downtime and Functionality**

15. How often do you experience a breakdown of the borehole?
- a)  Never
  - b)  Rarely
  - c)  Occasionally
  - d)  Frequently
16. When the borehole is not functioning, where do you get water from?
- a)  Other borehole
  - b)  Stream/rivers
  - c)  Rainwater harvesting
  - d)  Other (Specify): \_\_\_\_\_

#### **Section E: Borehole Usage and Functionality**

17. How often do you use the borehole for water?
- a)  Daily
  - b)  Weekly
  - c)  Rarely
18. How far is the nearest borehole from your household?

- a)  Less than 200 meters
- b)  200–500 meters
- c)  More than 500 meters

19. How would you rate the overall condition of the water from the borehole?

- a)  Very Good
- b)  Good
- c)  Fair
- d)  Poor

20. Have you experienced any issues with the borehole in the last month?

- a)  Yes
- b)  No

▪ If yes, what issues? (Check all that apply)

- a)  Water not available
- b)  Pump malfunction
- c)  Water contamination
- d)  Other (Specify): \_\_\_\_\_

21. How satisfied are you with the current water supply from the borehole?

- a)  Very Satisfied
- b)  Satisfied
- c)  Dissatisfied
- d)  Very Dissatisfied

22. On average, how long does it take to repair a broken borehole?

- a)  Less than 1 day
- b)  1–3 days
- c)  4–7 days
- d)  More than 7 days

**Section F: Water Usage and Accessibility**

23. How many people in your household rely on this borehole for water?

- a)  1–2 people
- b)  3–5 people
- c)  6 or more people

24. How far is the alternative water source when the borehole is not functioning?

- a)  Less than 200 meters
- b)  200–500 meters
- c)  More than 500 meters

25. Does the borehole ever stop providing water due to breakdowns or repair work?

- a)  Yes
- b)  No

26. How many days in the past month was the borehole unavailable due to repairs or maintenance?

- a)  0 days
- b)  1–3 days
- c)  4–7 days
- d)  More than 7 days

## **PART 2. Borehole Observation Checklist**

### **General Information:**

- Borehole ID: \_\_\_\_\_
- Location (Sub - County and village): \_\_\_\_\_
- Date of Observation: \_\_\_\_\_
- Observer Name: \_\_\_\_\_

### **Section A: Borehole Status**

#### **1. Operational Status:**

- a)  Fully functional
- b)  Partially functional
- c)  Non-functional

#### **2. Water Availability:**

- a)  Water available
- b)  No water available

#### **3. Pump Condition:**

- a)  No visible damage
- b)  Minor damage (Specify): \_\_\_\_\_
- c)  Major damage (Specify): \_\_\_\_\_

#### **4. Leaks or Malfunctions:**

- a)  No leaks
- b)  Leaks observed (Specify location): \_\_\_\_\_
- c)  Other malfunctions (Specify): \_\_\_\_\_

### **Section B: Water Yield**

#### **5. Discharge Rate (Liters per Minute): \_\_\_\_\_ L/min**

- a)  Less than 10 L/min
- b)  10–20 L/min

- c)  21–30 L/min
- d)  More than 30 L/min

**6. Water Flow:**

- a)  Steady flow
- b)  Intermittent flow
- c)  No flow

**Section C: Maintenance and Repairs**

**7. Last Maintenance Date:**

- a)  Within last 30 days
- b)  1–3 months ago
- c)  4–6 months ago
- d)  More than 6 months ago

**8. Frequency of Maintenance:**

- a)  Monthly
- b)  Quarterly
- c)  Annually
- d)  Not monitored

### **PART 3: Water Quality Testing Sheet**

#### **General Information:**

- **Borehole ID:** \_\_\_\_\_
- **Location (Sub - County and village):** \_\_\_\_\_
- **Date:** \_\_\_\_\_
- **Tester Name:** \_\_\_\_\_

#### **Section A: Water Quality Parameters**

##### **1. pH Level:**

- a)  Less than 6.5
- b)  6.5–7.5
- c)  More than 7.5

##### **2. Total Dissolved Solids (TDS):**

- a)  Less than 500 mg/L
- b)  500–1,000 mg/L
- c)  More than 1,000 mg/L

##### **3. Salinity:**

- a)  Less than 1,000 mg/L
- b)  1,000–2,000 mg/L
- c)  More than 2,000 mg/L

##### **4. Presence of Contaminants (e.g., nitrates, heavy metals)**

- a)  No contaminants detected
- b)  Contaminants present (Specify): \_\_\_\_\_

##### **5. Bacterial Contamination:**

- a)  No contamination
- b)  Coliform present
- c)  E. Coli detected
- d)  Other (Specify): \_\_\_\_\_

##### **6. Water Clarity:**

- c)  Clear
- d)  Cloudy
- e)  Murky

#### **PART 4. Key Informant Interview Guide**

##### **General Information:**

- **Interviewee Name:** \_\_\_\_\_
- **Organization:** \_\_\_\_\_
- **Position:** \_\_\_\_\_
- **Date:** \_\_\_\_\_

##### **Section A: Borehole Functionality and Efficiency**

1. How would you rate the overall functionality of the hand pump boreholes in Kibuku District?
  - a)  Very Good
  - b)  Good
  - c)  Fair
  - d)  Poor
2. How often are boreholes non-functional in the district?
  - a)  Rarely
  - b)  Occasionally
  - c)  Frequently
  - d)  Very Frequently
3. How long does it typically take to repair a non-functional borehole in your area?
  - a)  Less than 1 day
  - b)  1–3 days
  - c)  4–7 days
  - d)  More than 7 days

4. In your experience, how effective are community-based management practices for maintaining borehole functionality?
- a)  Very Effective
  - b)  Effective
  - c)  Ineffective
  - d)  Very Ineffective
5. How satisfied are the community members with the maintenance and repair of boreholes in Kibuku District?
- a)  Very Satisfied
  - b)  Satisfied
  - c)  Dissatisfied
  - d)  Very Dissatisfied

**Section B: Technical and Socioeconomic Factors**

6. How do socioeconomic factors (e.g., household income, education level) affect borehole functionality in Kibuku?
- a)  Strongly Positive Impact
  - b)  Moderate Positive Impact
  - c)  No Impact
  - d)  Negative Impact
7. How would you rate the availability of spare parts for borehole repairs in the district?
- a)  Very Good
  - b)  Good
  - c)  Fair
  - d)  Poor

## **Focus Group Discussion (FGD) Guide**

### **General Information**

- **Interviewee Name:** \_\_\_\_\_
- **Organization:** \_\_\_\_\_
- **Position:** \_\_\_\_\_
- **Date:** \_\_\_\_\_

### **Section A: Technical Factors**

1. What are the most common technical failures observed in hand pump boreholes?
2. How often do hand pumps require part replacements, and which parts are most frequently replaced?
3. What role does borehole depth and construction quality play in their performance and efficiency?
4. Are there standard procedures followed in the installation and maintenance of hand pump boreholes?
5. How accessible are spare parts and skilled technicians for borehole repair in Kibuku District?

### **Section B: Socioeconomic Factors**

6. How do socioeconomic factors (e.g., household income, education level) influence borehole maintenance and efficiency?
7. How does community ownership and willingness to contribute financially affect borehole sustainability?
8. What mechanisms are in place to collect and manage funds for borehole maintenance and repairs?
9. How does population growth and water demand impact borehole performance and efficiency?

### **Section C: Environmental Factors**

10. How does seasonality (dry vs. rainy seasons) impact borehole functionality and efficiency?
11. What environmental factors (e.g., soil type, water table depth, climate change) influence borehole longevity?
12. Have there been instances of boreholes drying up? If so, what were the causes?

13. What measures are in place to mitigate environmental risks affecting borehole performance?

#### **Section D: Borehole Performance Metrics**

14. How do you assess the efficiency of hand pump boreholes in Kibuku District?

15. Are there any key performance indicators used to monitor borehole functionality?

16. How often are boreholes inspected and evaluated for performance?

17. What steps are taken when a borehole is identified as underperforming?

#### **Section E: Borehole Efficiency**

18. How would you describe the overall functionality of hand pump boreholes in Kibuku District?

19. What are the most common reasons for borehole breakdowns in the district?

20. How frequently do boreholes become non-functional in this area?

21. What is the average duration it takes to repair a broken borehole?

22. Who is primarily responsible for borehole maintenance and repairs?

23. How effective are the existing community-based management structures in maintaining borehole functionality?

24. What are the main challenges faced in ensuring boreholes remain operational?

#### **Section F: Institutional Support & Policy Environment**

25. What role does the local government play in supporting borehole functionality and efficiency?

26. Are there existing policies or programs aimed at improving borehole performance? If so, how effective are they?

27. What are the key institutional or organizational challenges in borehole management?

28. Are there partnerships between local communities, NGOs, and government agencies to support borehole sustainability?

29. How can policy interventions improve borehole efficiency in Kibuku District?

#### **Section G: Recommendations**

30. What strategies can be adopted to improve borehole performance and efficiency in Kibuku District?

31. What improvements should be made in borehole maintenance and repair systems?

32. How can community participation in borehole management be enhanced?
33. Are there any best practices from other districts that could be implemented in Kibuku?
34. What additional support or interventions are needed from government and development partners?

***END***

<b>Category</b>	<b>Estimated Sample Size</b>	<b>Tool</b>
Household Head Water Users	314 respondents	Questionnaire
Local Government Officials	15 officials	KII guide
Borehole Technicians	20 respondents	KII guide
Environmental Officers	5 respondents	KII guide
Local Leaders & Technocrats	30 respondents	FGD Guide
<b>Total Participants</b>	<b>384 Respondents</b>	
<b>Total Boreholes sampled</b>	<b>110 Boreholes</b>	

UGANDA CHRISTAIN UNIVERSITY (UCU)

POSTGRADUATE RESEARCH CORRECTION MATRIX

PROGRAMME: MASTER OF SCIENCE IN WATER AND SANITATION

NAME OF STUDENT: SIKYAJULA ELIZABETH

REG. NO.: **RSI4M45/022**

SIGNATURE:

DATE: 14th August 2025

**Correction Matrix**

**Research Title:** *Determinants of Hand Pump Borehole Performance and Efficiency in Rural Areas of Uganda: A Case Study of Kibuku District*

<b>Title/Heading and Numbering</b>	<b>Areas of Correction</b>	<b>Correction</b>	<b>Page(s)</b>
<b>4.7 Relationship between Technical Factors and Performance of Hand Pump Boreholes</b>	Method used for Objectives; Meaning of B = 0.338 and others	The study examined the extent to which technical factors influence the performance of hand pump boreholes in Kibuku District using <b>Analysis of Variance (ANOVA)</b> integrated within a <b>multiple regression framework</b> . In multiple regression, the beta coefficient ( $\beta$ ) represents the expected change in the dependent variable for a one-unit change in	Pg. 49–51

		the predictor variable, holding other factors constant. A $\beta$ value of 0.338 indicates that a one-unit improvement in the type and quality of casing material used is associated with a 0.338-unit increase in borehole functionality, <i>ceteris paribus</i> .	
	Then, the meaning of level of significance measured by p-values meant.	The p-Values in presented in the results section (Chapter 4). The p-value reflects the statistical significance at the 5% threshold ( $\alpha = 0.05$ ). A p-value below 0.05 indicated significance, with values below 0.01 was considered to be highly significant, implying a minimal likelihood that the observed relationship is due to random variation. And the discussions for each significant predictor was interpreted statistically alongside the theoretical and contextual explanations.	Pg. 49–60
	Explain levels of significance: 0.05 vs 0.09	The p-value threshold of 0.05 (5% significance) was the primary decision rule for statistical inference. Coefficients with p-values less than 0.05 were interpreted as statistically significant. Variables with p-values between 0.05 and 0.10 (e.g., 0.09) were treated as <b>marginally significant</b>	Pg. 49–60

		and discussed in relation to their practical implications for borehole performance.	
<b>4.9 Relationship between Socio-economic Factors and Performance of Hand Pump Boreholes</b>	Objective 2 – State findings, method, results.	Objective 2 assessed the relationship between socio-economic factors and borehole performance. Data were collected via structured quantitative questionnaires administered to the 384 sampled borehole and complemented by the 30 selected key informants. Analysis was conducted using <b>logistic regression</b> . Findings indicated that user fees ( $\beta = 0.085$ , $p = 0.048$ ), local government support ( $\beta = 0.637$ , $p = 0.019$ ), and spare parts availability ( $\beta = 0.871$ , $p = 0.003$ ) were significant determinants of borehole Performance.	Pg. 56
	Measurement of deforestation and soil erosion; evidence and data presentation.	Data on deforestation and soil erosion were sourced from the structured questionnaires and key informant interviews within district the study area. The findings indicated that increase in environmental degradation, measured in terms of deforestation, soil erosion, and human encroachment, are associated with increased vulnerability of borehole infrastructure. Specifically, higher levels of surface run-off,	Pg. 52 - 60

		<p>pollution, and siltation in recharge zones contribute to reduced borehole performance in terms of water yield and mechanical failures captured in the study.</p>	
<p><b>4.4 Physicochemical and Microbiological Quality of Borehole Water &amp; 4.6 Water Quality Assessment of Sampled Boreholes against National Standards.</b></p>	<p>Objective 3 – Tabular presentation of results, laboratory tests, values, and interpretations.</p>	<p>Objective 3 involved assessing borehole water quality through <b>physicochemical and microbiological tests</b>. Laboratory analyses were conducted at the Ministry of Water and Environment’s accredited facility and included: pH, TDS, salinity, turbidity, nitrate levels, total coliform count, and E. coli presence. A total of <b>110 boreholes</b> were sampled. Results were presented in Tables 3 and 4, showing compliance levels against <b>Uganda National Bureau of Standards (UNBS) water quality benchmarks</b>. Total Dissolved Solids (TDS) values were within acceptable limits (&lt;1000 mg/L) in 95% of samples, indicating no adverse effects on taste or health. The justification lies in WHO and UNBS guidelines, which associate TDS levels below 1000 mg/L with potable water. Percentages were</p>	<p>Pg 43–48</p>

		recalculated to directly reflect the test results and interpretations provided in the discussion section.	
<b>A suggestion to combine all the explanatory variables to run a multivariate regression in relation to the Dependent variable which was identified as Hand bore hole performance</b>	For socio-economic factors, technical factors and environmental factors against the hand bore hole performance	It was not possible to combine all the socio-economic, technical, and environmental variables into a single multivariate regression model of hand pump borehole performance because doing so violated key econometric assumptions. The variables exhibited <b>high multicollinearity</b> , especially between technical and environmental indicators, which inflated standard errors and destabilized coefficient estimates. In addition, the <b>limited sample size relative to the number of predictors</b> created degrees of freedom constraints and risked overfitting, thereby undermining the reliability of results. The mixed measurement scales of the variables also raised risks of <b>model misspecification and heteroskedasticity</b> , further weakening the validity of OLS estimates. For these reasons, the explanatory variables were analyzed in grouped models rather than as a single combined regression.	