DESIGN AND APPLICATION OF SYSTEM DYNAMICS MODEL FOR DOMESTIC WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA

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A Thesis Submitted to the School of Disaster Management and Humanitarian Assistance in Partial Fulfillment for the Requirements for the Degree of Doctor of Philosophy in Disaster Management and Sustainable Development of Masinde Muliro University of Science and Technology.

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DECLARATION

This research thesis is my original work prepared with no other sources other than those indicated and has not been presented elsewhere for a degree or any other award.

Signature.. Date………………………….

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled **"Design and Application of System Dynamics Model for Domestic Water Security in Informal Settlements in Nairobi County, Kenya".**

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DEDICATION

Dedicated to my late father, who taught me the value of hard work. You will forever influence my life and those that will come after me. Rest in peace dad!

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To the Almighty God, I say my simple prayer, "God bless my work".

My sincere thanks go to Prof. Stanley Omuterema and Prof. Edward Neyole, my Doctoral supervisors, who gave me support, guidance and encouragement to complete this study.

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To all of you I say, *Shalom.*

ABSTRACT

Attainment of water security in urban informal settlements in developing countries can be complex undertaking due to various factors that affect water service provision such insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others. In addition to this, the territorial behaviour and therefore a siloed approach of service providers propagates water insecurity. This situation has an impact on the socio-economic development, peace and political stability, water related disasters and waterborne diseases in many urban informal settlements in developing countries. The study sought to develop and apply a System Dynamics Model to help identify specific policies that will improve water security in the informal settlements. Data was collected from a sample of 388 households and 62 water vendors from nine slums in 12 sub-counties. Household questionnaire, KII, FGD guide, and observation checklist were used to collect data. Specifically, the study assessed water security characteristics in informal settlements in Nairobi County; evaluated the structure of the system of water service provision; evaluated water service provision integration approaches on water security; and finally, developed a system dynamic model to articulate the structure and function of a water supply system. From the findings, only 0.4% households met all the six parameters (availability, access, quantity, quality, affordability and reliability) of water security. Most of the households, 31.8% satisfied four parameters, 30% met three parameters, 20.8% met two parameters, 11.7% met 5 parameters and 5.3% met one parameter. This pointed to a situation where water security is a major concern in Nairobi's INSEs. The existing water structures of service provision influenced only three of the six water security factors, and that is, availability, access, and quality. The level of structure did not have any impact on quantity, affordability, reliability of water services. The study therefore concludes that, provision of infrastructure alone may not necessarily lead to overall household water security. The research findings show that, integration is possible along the three levels, water production, water delivery infrastructure, and service levels experienced by the households. It was however noticed that a household could depend on multiple sources and therefore experience various levels of services. From simulation of various scenarios, the integrated water service provision model (IWSP-M), reveals that it will be difficult to resolve water security in Nairobi's informal settlements without integrating the small-scale water service providers with those of NCWSC. Equally, reduction of Non-Revenue Water, drilling of high-yield boreholes and proper maintenance of reservoirs will help reduce water stress and therefore lead to improved domestic water security. The interactive IWSP-M allows for deep exploration of the cause-and-effect feedback loops between households and the systems governing water services in INSEs within Nairobi County. This will help policy makers on investment and targeted resource allocation. On the other hand, water service providers can use the results to have a better understanding of the existing potential for integration of services to improve water security in informal settlements.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADD	Average Daily Demand
AT	Algorithm Testing
BOT	Build Operate Transfer
BT	Behavioral Testing
CC	Climate Change
CLD	Causal Loop Diagrams
COK	Constitution of Kenya
CSM	Case Study Method
DFID	(The) United Kingdom Department of International Development
DSM	Dynamic Synthesis Methodology
DSS	Decision Support System
EA	Enumeration Areas
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
FSD	Flows and Stock Diagram
GIS	Geographic Information System
GoK	Government of Kenya
HRWS	Human Right to Water and Sanitation
IBT	Increasing Block Tariff
INSE	Informal Settlement
IUWM	Integrated Urban Water Management
KII	Key Informant Interview

KNBS	Kenya National Bureau of Statistics
KPI(s)	Key Performance Indicator(s)
LIA	Low Income Area
LMIC(s)	Low and Medium Income Country
LPCD	Liters per Capita per Day
MDG(s)	Millennium Development Goal(s)
NC	Nairobi County
NCG	Nairobi County Government
NCWSC	Nairobi City Water and Sewerage Company
NEPAD	New Partnership for African Development
NRW	Non-Revenue Water
PHC	Population and Housing Census
PPP	Public Private Partnership
RS	Remote Sensing
SD	System Dynamics
SDG(s)	Sustainable Development Goal(s)
SFD	Stock and Flow Diagram
SPA	Service Provision Area
SPSS	Statistical Package for Social Scientists
SSIP	Small Scale Independent Provider
ST	Structural Testing
SU	Sampling Unit
SUWM	Sustainable Urban Water Management

TIRWR	Total Internal Renewable Water Resources
UfW	Unaccounted for Water
UN	United Nations
UNDP	United Nations Development Programme
UNFPA	United Nations Population Fund
UNGA	United Nations General Assembly
UNICEF	United Nations Child Education Fund
WARMA	Water Resources Management Authority
WASH	Water, Sanitation and Hygiene
WASREB	Water Sector Regulatory Board
WE	WASH Enterprise
WHO	World Health Organization
WSL	Water Service Level
WSP	Water Service Provider
WSTF	Water Sector Trust Fund

OPERATION DEFINITION OF TERMS

Co-production: Is the process by which hybrid service provision modalities are generated as a consequence of the collaboration of water service system elements in order to achieve water security. It may be the result of the articulation of socio-political, economic, biophysical, and infrastructural variables, which interact to create novel practices.

Domestic water security: This is a state in which a household has water available, accessible, with enough quantity of water, of acceptable quality, it is affordable to the household and that this primary water source is reliable all through the year.

Formal water service provider: These are all forms of water suppliers that are licensed by the Water Service Regulatory Board (WASREB) and the County Government to operate within the legal framework of water management in a specific area. Nairobi Water and Sewerage Company (NWSC) and Runda Water Company are the entities that are included in this investigation and fall within the specified geographic area.

Informal settlements: This research defines informal settlement as residential areas characterized by the construction of housing units on land that occupants have no legal claim to or occupy illegally. It also includes unplanned settlements and areas where housing does not comply with current planning and building regulations, thus being considered unauthorized housing. People living in informal settlements are identified by their lack of sufficient access to clean water and sanitation, low-quality housing, overcrowding, uncertain legal status, and their presence in marginalized areas within urban regions.

Informal water service provider: Any water provider that does not have a license from the Water Service Regulatory Board (WASREB) or that does not adhere to the local regulatory framework for water management is considered "informal" in this context. Community groups, self-sufficiency programs, non-governmental organizations, and formal water distribution systems are all part of this study.

Plot 10: A phrase used to describe dwelling units in informal settlements in Nairobi County that have ten single rooms facing each other and share a shared bathroom and water source. A typical layout for plot 10 is a U-shaped dwelling with five rooms per side and an ablution building off to the side.

Poverty Penalty: The phenomenon whereby low-income families typically pay more than high-income households to have access to water is called the poverty penalty.

System dynamics: System dynamics is a method for modelling non-linear relationships in which input and output influence each other through feedback loops.

Utility: In this study, it is defined as benefits derived from a water service for household use.

Water access: This is the proximity of water source or water point to the household measured in time or distance. This is a measure of the convenience for a household measured in terms of distance to and from the water source and/or time taken for a round trip including queueing at the water source.

Water affordability: Water is said to be affordable if a household spends less than 3% of the household income on water bills or for purchasing water for household needs beyond for economic purposes. For people without household connection, this shall be measured as the cost of a 20L container can which should not be more than KSh.2 (US $0.0154) as per WASREB standard.

Water availability: Water availability is defined as presence of water flow at the time of the survey of household members participating as a respondent in this interview.

Water demand: This is the existing potential needs for water services computed from the average quantity of water needed per capita.

Water lord: This a property owner who rents out houses but also controls water access to his/her tenants.

Water quality: This is the biological water quality that does not lead to waterborne diseases but also generally acceptable to the community or household. Acceptability is based on sensory parameters – taste, colour.

Water quantity: Amount of water sufficient for household domestic needs that include – drinking, cooking and for sanitary use. This amount should not be less than 60 litres per person per day in the case of Nairobi.

Water Reliability: This is when water service is available to the household as per supply schedule.

Water safety: This is defined as the safe transport of water (through pipes or locomotives) and also includes safe handling at household level that does not subject it to contamination through the delivery system to the user or customer.

Water security: Water security is defined in terms of availability, access, quantity, quality, safety, affordability, and reliability of water services.

Water Service Integration: In this study, integration is defined as the process of coordinating and collaborating water service provision of various parts of a water-supply system in a certain area to ensure water security is achieved.

Water service provision system: Comprises of water service providers both formal and informal; the structures of water supply; and water service regulations that govern service provisioning.

Water stress: In this research, the definition is limited to service provision, in which water stress is defined as a ratio of water demand to actual water consumption.

Water supply: This is a system comprising of water harvesting, treatment, storage, and delivery to final users.

Water service levels: This is defined as both the mechanism and distance to point of collection and therefore ranked to no access, basic access, intermediate access and optimal access.

Water service structure: This is defined as the existing system of water production and treatment, storage and supply. Therefore four structural levels are conceived – no structure, basic structure, intermediate and complete structures.

CHAPTER ONE

INTRODUCTION

1.1. Background to the Study

Urban informal settlements in developing countries are faced with water insecurity issues, which can be traced to insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others (Hanna-Attisha, et al., 2016; Majuru, 2015; UNDP, 2011; Bruggen, et al., 2010). It is considered that, water insecurity has a direct correlation to socio-economic development, peace and political stability, water related disasters and waterborne diseases (UN Water, 2013). In order to mitigate this, countries experiencing insufficient water quantities have instituted measures like extension of distribution network, increasing production and storage capacity (Dziegielewski, 2003). The realisation of this is dependent on robust production and distribution strategies which sometimes is a challenge in most of the developing countries (Leigh & Heonyeong, 2019).

It has also been witnessed that development of alternative supply channels including drilling of boreholes and allowing for tank truck distribution have been used to address unreliable water-supply (Bartram et al., 2013; Griffin & Mjelde, 2000). Further, many developing countries are struggling with infrastructure development leading to under-coverage in low-income areas (LIAs) like in urban informal settlements. This has led to low water pressures in the water distribution system and due to aging pipes, huge water losses are experienced, hence high unaccounted for water (UfW) (Lai et al., 2020). Leigh & Heonyeong (2019) note that the main cause of these challenges in developing countries include non-adherence to formulated standards and uncoordinated water-supply systems.

Further, there seem to be lack of proper plans to exploring local alternative water sources to supplement the existing water quantities (Sapkota, et al., 2014; Marlow, Moglia, Cook, & Beale, 2013).

Moreover, a well-coordinated water-supply system that reflects on the context in terms of flexibility and adaptability in which it has been designed, has been considered to be key in addressing water insecurity (Ahlers et al. 2014; Rosenzweigh et al. 2011). However, it requires those with the responsibility of water service provision to explore diverse and flexible solutions (Brown, et al., 2011; Keith & Brown, 2009). Some of the ways to achieve this involved a system-wide collaboration among entities involved in the water provision. The UN Water (2015) notes that players involved in the water service provision tend to operate in silos. Whereas the ultimate goal is to ensure water security, the challenge of working in a collaborative manner is still a bottleneck. The application of system dynamics principles has been touted to be a possible way of tackling this (Sušnik et al., 2013; Abdi, 2009**;** Saysel, 2007).

Water security has been described to constitute availability, access to adequate quantity, quality, affordable and that is reliable (UN Water, 2013). Through these attributes, it is anticipated that people sustain access and livelihood, ensure human well-being, lead to socio-economic development and protection from water-borne pollution. In essence this leads to reduction in water-related disasters and preservation of ecosystems in a climate of peace and political stability.

For instance, the quantity of water accessed by a household has been a topic of interest since it affects human health. According to Stelmach & Clasen (2015), different amounts of water are required to sustain human health. The SPHERE Project (2004) sets out 15 litres per capita per day (15 lpcd) per person as a minimum standard for sustaining human life. Also, the World Health Organisation (WHO) cites a minimum for basic health protection of at least 20 lpcd, of which 7.5 litres is required for consumption, including direct hydration, survival, hygiene practices and cooking (WHO, 2011).

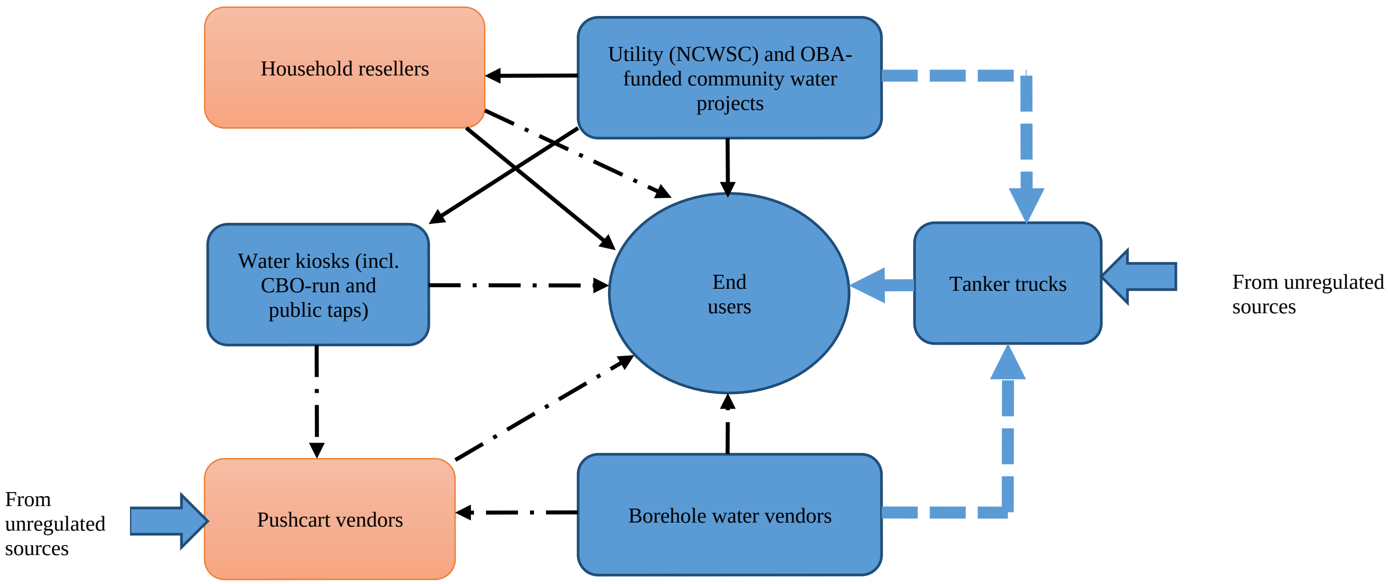
Recently, House et al., (2017), added that, the minimum quantity of drinking-water needed for survival is three to five litres per person per day depending on the temperature, and an individual's level of exercise. They postulate that quantities of water used per capita per day fluctuates with distances that have to be walked to collect water and that this usage increases with the improved convenience of a piped supply, when a new source nearer to the home is realized, or when income levels increase.

According to The World Bank (2012), the Government of Kenya (GoK) allocates a standard amount of 60 lpcd, which is considered the minimum quantity of water to sustain human life in Kenya. This is a stark contrast to the recommendations by SPHERE standards of 15 lpcd or WHO (2011) of 20 lpcd.

To achieve water security in informal settlements, the quantity of water to be accessed should lead to sustainable livelihood, socio-economic development of the people, reduction of water-related disasters, and foster coexistence. This calls for a well-defined water service provision system whose main players are regulated. Unfortunately, there exist some water service provision systems which are marked by informality. This therefore introduces what can be described as informal water service provision whose main players are unregulated.

The Government of Kenya (GoK, 2016) through the Water Act 2016 defines a formal water service provider as a company, non-governmental, organisation or other person or body providing water services under and in accordance with an agreement with the licensee within whose limits of supply the services are provided. The Act on the other hand, defines "informal" service providers as all types of water suppliers who are not operating in the legal framework of water management in a given area. Both informal and formal water service providers are characterised by public utilities, commercial organisations, community endeavours or by individuals, usually via a system of pumps and pipes (American Water Works Association (AWWA), 1974). These entities are supposed to work efficiently in a collaborative manner to ensure effective provision of appropriate quantities of water. For a household that depends on an efficient water service provision system, it should access a minimum of 20 lpcd when water is supplied through multiple taps continuously. This is sometimes difficult to attain in the informal settlements where the system of water provision is not well structured.

The unstructured nature of water provision in Nairobi County has been described by UNDP (2011), as shown in Figure CHAPTER ONE INTRODUCTION.1, to be that where the entities involved are supposed to operate within a defined and regulated system. What leads to unstructured nature of water provision is when the approved providers operate outside the defined service standards. For instance, as depicted in Figure CHAPTER ONE INTRODUCTION.1 , tanker trucks who are considered a formal service provider and licensed to transport water from safe sources, do actually also source water from unsafe sources a possible cause for water borne diseases (UNICEF & WHO, 2009; Jouravlev 2004; and Black, Morris & Bryce 2003).



	Piped water connection		Regulated providers
	Transported water (jerry can)		Unregulated providers
	Transported water (tank truck)		Water from non-improved or illegal sources

Figure CHAPTER ONE INTRODUCTION.1: Water Supply Chain in Nairobi County

Source: UNDP (2011)

On the other hand, Figure CHAPTER ONE INTRODUCTION.2 introduces a public water-supply system and shows how various water sources, treatment and storage facilities are interconnected to form an integrated scheme that makes it easier to account for water quantity and quality and hence a possibility of attaining water security.

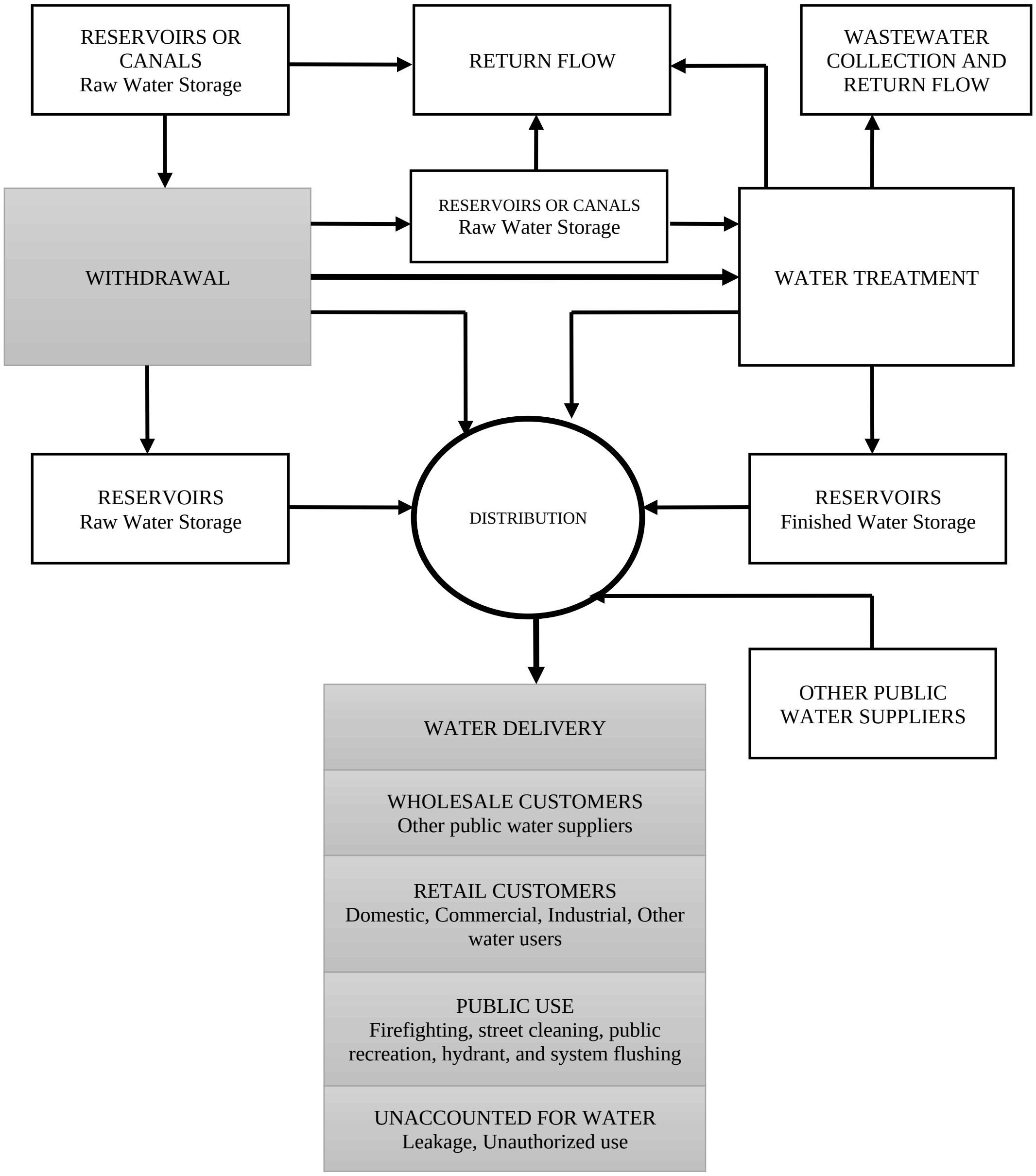


Figure CHAPTER ONE INTRODUCTION.2: An Organized Water Service Provision System

Source: US EPA (n.d.)

As depicted in Figure CHAPTER ONE INTRODUCTION.2 , a well-structured public water service provisioning is that which has a coordinated process of water source development, treatment, storage, and a dedicated distribution network.

Further, all other secondary public water suppliers plug into a central distribution network after which the water is then delivered to various customers. This network has been applied to create a hybrid system that involves co-production of water infrastructures (shared taps, water tanks) that involves connection of private providers to the municipal network in Tanzania and Ethiopia (Faldi, Rosati and Moretto, 2021). The goal of such a system is help account for the quantity of water delivered and also monitor the quality of water thereby addressing the problems of water insecurity. This can be made possible when entities involved in water service provision collaborate through a well-defined system – structure, which is not always the case in developing countries.

To have a well-defined system and structure in place a number of factors come into play. These factors can be considered to be supply and demand-related characteristics. Maryati & Humaira, (2018), have identified some of the supply and demand characteristics that influence water service provision to include water source, production, distribution, service coverage, tariff system, number of consumers, utilization, non-revenue water (NRW) and consumption. In urban informal settlements, these characteristics may be shaped by a number of other factors such as intermittence or reliability challenges, tenancy (a prove of land ownership) and existence of alternative sources or suppliers (The World Bank, 2019).

Underlying the supply and demand characteristics is the inherent utility derived from water. Considering the dynamic nature of household characteristics, the utility of water keeps on shifting. An adaptive system of water provisioning could address this. Informal settlements in urban setting tend to have shifting supply and demand characteristics hence making it a complex undertaking for water service providers (WHO, 2003).

In general, household water security is dependent on the existing water service provision system that is configured according to the existing household characteristics. The World Health Organization has provided that the amount of water accessed by a household is proportional to the service provision level experienced by that household (WHO, 2003). The attainment of this is sometimes a challenge. Many countries have tried to formulate approaches to tackle these challenges. Some of the approaches used to address the challenges include increasing production by exploring and developing new water sources due to increasing demand (Kuhn & Ciobanu, 2013), demand-side management including tariff setting and active campaigns on conservation and minimization of wastage including reuse (Beal et al., 2015) and reduction of non-revenue water resulting from technical and commercial losses (Lai et al., 2020). The latter approach includes efforts geared towards countering illegal connections from the licensed utility company.

In Kenya, the government has invested in developing new water sources to increase production and therefore making available quantities to be supplied by the service providers. For instance, in Nairobi, the government is investing in a new source dubbed the Northern Corridor Tunnel, 11.8 km long, 3.2 m diameter diverting water from Rivers Maragua, Gikigie and Irati to Ndakaini Dam and it is projected to add 140,000 m^3/day to the city and the neighbouring counties of Kiambu and Muranga (GoK, 2017).

As shown in Figure 1.1, there exists formal and informal water service providers in the provision of water services. This therefore calls for an integrated working relationship among these entities. Rosenzweigh et al., (2011) advice that, collaboration between informal and formal water service providers can be beneficial to people living in informal settlements. There are few examples where various forms of integration have been tried. For instance, in Mozambique, regulation of formal and informal water service providers in peri-urban areas of Maputo has been recommended (Matsinhe & Juizo, 2008). In Maputo, household water resellers and SSIPs cater for as many as 21% of unconnected households (Matsinhe & Juizo, 2008). Another example from Kenya is in Nairobi, where the Water Service Trust Fund (WSTF), through the pro-poor strategy developed a partnership model that was piloted in one urban slum - Mathare-Kosovo (Water Service Trust Fund (WSTF), 2010)). With the Kenya's water sector reform creating a conducive environment, the Mathare-Kosovo pilot project was initiated to carry out formalisation of water service provision. This partnership consisted of a strong cooperation and engagement of the community members, an NGO, the WSTF and a WSP (WSTF, 2010). Through this participatory approach, it was possible to design and implement a custom-made solution to formalise water supply in the Mathare-Kosovo area (in this case a mix of household connections, yard taps and water kiosks). The close partnership between the stakeholders made it possible to overcome the cartels, and the utility's pro-poor focus and comprehensive strategy to reach its low-income customers showed that these areas can contribute to an increase in revenue.

1.2. Statement of the Problem

Urban informal settlements in developing countries are faced with water insecurity issues, which can be traced to insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others (Hanna-Attisha et al., 2016; Majuru, 2015; UNDP, 2011; Bruggen, et al., 2010). Further, many developing countries are struggling with infrastructure development leading to under-coverage in low-income areas (LIAs) like in urban informal settlements. This has led to low water pressures in the water distribution system and due to aging pipes, huge water losses are experienced, hence high unaccounted for water (UfW) (Lai et al., 2020). Due to high levels of poverty of people living in these settlements, they end up sourcing water from unsafe sources leading to water borne diseases (UNICEF & WHO, 2009; Jouravlev 2004; & Black, Morris & Bryce 2003). In informal settlements and slums, water insecurity is seen as a critical public-health challenge (Adams et al. 2022).

There has been quite a lot of interest in urban water management globally. As noted by Wuysang and Soerymassoeka (2021), Integrated Water Resources management (IWRM) has been adopted by governments across the world. The IWRM process promotes the coordinated development and management of water, land, and related resources (Agarwal et al., 2000). By adopting this model of IWRM, countries experiencing insufficient water quantities have instituted various measures like extension of distribution network, increasing production and storage capacity (Dziegielewski, 2003). Other models such as the World Bank (2016) Integrated Urban Water Management (IUWM) and Marlow, Moglia, Cook and Beale (2013) Sustainability of Urban Water Management (SUWM), have been efforts to unbundle water service provision. On the other hand, development of alternative supply channels including drilling of boreholes and allowing for tank truck distribution have been used to address unreliable water-supply (Bartram et al., 2013; Griffin and Mjelde, 2000).

However, what is missing is a well-coordinated water-supply system that reflects on the context in terms of flexibility and adaptability in which it has been designed. This could be the case since the water service providers have not been able to explore diverse and flexible solutions through a system-wide collaboration among entities involved in the water service provision. It observed in Nairobi County that players involved in the water service provision tend to operate in silos or even compete with each other (UNDP, 2011). Whereas the ultimate goal is to ensure water security, the challenge of working in a collaborative manner is still a bottleneck. This advances that if these challenges were not addressed, there is continuation of non-adherence to formulated standards and uncoordinated water-supply systems. Further, this leads to lack of proper plans to exploring local alternative water sources to supplement the existing water quantities. In essence, this situation continues to have an impact on socio-economic development, peace and political stability, water related disasters and waterborne diseases.

While many scholars have proposed various water management models to be deployed to address water security, the focus has been basin-level with a view on water as a resource. However, due to their static nature, these models are developed to address water resource management within a specific basin and are therefore not applicable to an urban area within the context of service provision which indeed exhibits a complex behaviour. The application of system dynamics principles has been touted to be a possible way of tackling collaborative bottlenecks (Sušnik et al., 2013; Abdi, 2009**;** Saysel, 2007). Therefore, the study developed a System Dynamics methodology based on a combination of qualitative (case study research method) and the quantitative techniques (simulation models) research methods.

1.3. Research Objectives

The overall objective of the study was to design and apply a System Dynamics Model to domestic water service provision in the informal settlements within Nairobi County.

The study was supported by the following specific objectives:

i. To assess the domestic water security characteristics of existing water service provision systems in informal settlements within Nairobi County.
ii. To examine the different existing structures of water service provision systems against domestic water security in informal settlements within Nairobi County.
iii. To evaluate water service provision system integration approaches on domestic water security in informal settlements within Nairobi County.
iv. To design and apply a system dynamics model for integrating water service provision in the informal settlements within Nairobi County.

1.4. Research Questions

The main question this research sought to answer is, "can a System Dynamics Model for integration of water service provision system be developed to help tackle domestic water security challenges in informal settlements?"

To answer this research question, the research sought to address the following specific questions:

i. What are the domestic water security characteristics of existing water service provision systems in informal settlements in Nairobi County?

ii. How do the different structures (production, treatment, storage, and distribution) of the water service provision system relate with existing domestic water security in informal settlements within Nairobi Country?

iii. What are the various water service integration approaches used for domestic water provision in informal settlements within Nairobi County?

iv. How can a system dynamics model for integrating water service provision help in understanding domestic water security in informal settlements within Nairobi County?

1.5. Justification

This research has both practical application and make scientific contribution to water governance in urban informal settlements. This research sought to make an addition to the work of Ahlers *et al*., (2014) in governance, legitimacy, and institutionalisation of hybrid water services in informal settlements. The practical relevance of this study can be found in the fact that the informal water services play a significant role in water service provision in an urban system most importantly in the informal settlements. To measure up to the Human Right to Water and Sanitation (HRTWS), there is need to ensure access to sufficient quantity to safe water by addressing marginalization and disparities in access to services in urban informal settlements. People living in informal settlements can benefit from the collaboration between informal and formal water service providers, where possible (Rosenzweigh *et al*., 2011). In developing a system dynamic model, the research sought to demonstrate how integration of water service provision system can tackle water insecurity in informal settlements within Nairobi County, in Kenya. The findings and recommendations from this research, if implemented, would benefit the society given the negative health, social and economic impacts of water security. For instance, the role that society can play in supporting government in reduction of Non-Revenue Water (NrW) which will improve the water available for distribution while improving revenue collection for the water service providers. Policy makers benefits from the findings of this research, as the model informs decision-making related to water allocation for various service levels, NrW reduction and make it easier for government to identify where to invest both human and financial resources. Water service providers would understand the existing potential to integrate their supply systems in order to improve water security for people living in informal settlements.

1.6. Scope of the Research

The research was conducted in Nairobi County one of the 47 counties in Kenya. This is because studies conducted by APHRC (2002) in Kenya, found that infant and child mortality risks associated with water were particularly higher in the slums of Nairobi than those observed in other urban areas and in rural Kenya. The study indicated that under-five (U5) mortality rate was 35% higher among slum residents in Nairobi than among the rural population in Kenya a situation that was attributed to poor water and sanitation (APHRC, 2002). Equally, Nairobi County is not only the Capital City of Kenya but also a strategic economic hub for East Africa. The county has the biggest slum in Africa and houses the highest population of informal settlements in Kenya. The study targeted households living in the biggest informal settlements (Korogocho, Viwandani/Kaloleni, Kibera, Kawangware/Gatina, Majengo/Kiambiu, Mathare, Gitare Marigu/Njiru, Mukuru/Kayole Soweto, and Gitogoro), water service providers operating in those settlements, donors, NGOs, and CBOs involved in water service provision, Nairobi County Government, WASREB, and other actors in the water sector. Field data collection took place from December 2022 to February 2024. The research proposes a System Dynamics Model that can be used to aid in integration of water service provision systems to help tackle water security challenges in urban informal settlements. The problem this research assessed was the water security in Nairobi for the period 1999 and 2063 to align with the Vision 2030, the SDGs 6 and the Africa Agenda 2063.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter is organised into three key areas namely theoretical literature, empirical literature, and conceptual framework. Theoretical literature reviews relevant theories related to water security; water service provision; water service providers' integration and finally, system dynamics approaches in tackling complex water security management. Empirical literature reviews the empirical literature presenting information on water security, examples of water service provision in informal settlements, how integration of water service providers has happened in countries across the globe, what gaps exist in tackling water security and finally how system dynamics methodology can aid in integration of water service providers. The chapter then ends with a conceptual framework (Figure 2.1) for this research which guided the research methodology and on how findings were structured later in chapter four.

2.2 Water security

The concept of water security has gained a lot of interest in academic research, policy formulation and in sustainable development agenda globally. This interest may be associated due to the concern of its potential risk that is associated with either water scarcity (for humans and/or the environment), floods or harmful water quality (Hall & Borgomeo, 2013). The level of tolerance of society to these risks is what defines water security (Grey et al., 2013).

But still, there have been various arguments on what constitutes water security with some looking at basin level (Babel & Shinde, 2018) and others looking at urban level (Aboelnga, Ribbe, Frechen, & Saghir, 2019; Babel, Onsomkri & Shinde (2016)). There have also been water security studies that have summed it to imply reliability, that is, a water supply system that has no chance of future shortfall with optimal investment (Griffin & Mjelde, 2000). Further, attaining water security with the consumer preference is seen to be the most preferred approach (Griffin & Mjelde, 2000), thus providing for qualitative aspects. Depending on the area of research, other aspects of water security have emerged that include issues such as environment, mitigating risks, hazards and avoiding conflict over shared waters (Wuysang, Triweko & Yudianto, 2018).

To have a better understanding of what water security constitutes, it is important to break it down into the core principles, its drivers, and characteristics at global, national, and regional scales and how they manifest in urban informal settlements.

2.2.1. Core Principles of Water Security

Lankford et al. (2013) note that the concepts of water security are protecting the environment, working together, understanding how water is interconnected with things like making energy, meeting city needs, climate change, and food, and making sure that everyone has access to water fairly and equally. Two actions are taken to ensure environmental sustainability: the sustainable management of water as part of a green economy and the restoration of ecosystem services in river basins to enhance river health (Moumen et al., 2019). In addition, they assert that a sustainable environment can be achieved by preserving, enhancing, and valuing the environment and natural resources in the long term, as well as by addressing the risks and environmental impacts and maintaining the primary ecological balances.

The second water security principle, collaboration, is addressed at both the transboundary scale of water resource management and the service provision scale among participants in the water service provision. At the service level, Rosenzweigh et al. (2011) reaffirm the fact that informal and formal water service providers collaborate to the benefit of individuals residing in informal settlements.

United Nations (2014) asserts that water and energy are fundamental elements of human development, economic growth, and life, as evidenced by the independencies of water, including its function in energy generation. In light of the growing demand for energy to support the growing demands for water and food production, there is a fundamental imperative to transition to alternative sources (UN, 2014). In areas where water has been diverted for hydroelectric generation, these renewable energy alternatives may contribute to these water independencies.

The demand for water in cities is increasing as a result of economic growth and a changing lifestyle, resulting in a higher per capita consumption of water (Brears, 2016). Urban residents have increased their water consumption due to the demand for packaged food, sanitation requirements, and household equipment usage. The fifth principle is the integration of food and climate change in water security (Lankford et al., 2013). According to Misra (2014), water and food security are the primary challenges associated with climate change, as they are both extremely susceptible to the ongoing evolution of climatic patterns. Recent research has indicated that the average global temperature may rise by 1.4–

5.8°C, and there will be a significant decrease in agricultural yield and freshwater resources by the end of the 21st century. Additionally, Solomon et al. (2007) observe that regional precipitation fluctuations have been the consequence of climate change, and these fluctuations are anticipated to persist with increasing intensity in the future.

The sixth principle pertains to water and is characterized by equity and justice (Lankford et al. 2013). This necessitates that all individuals, regardless of their socio-economic status, have equitable access to water. This is further substantiated by the United Nations General Assembly (UNGA, 2010), which has pledged countries to the Human Right to Water and Sanitation (HRTWS). This necessitates that States furnish their citizens with water that is secure, sufficient in quantity, of acceptable quality, physically accessible, and affordable (UNGA, 2010).

2.2.2. Drivers of Water Security

The drivers of water security are the internal and external elements that might impact both the quality and quantity of water. According to Barry and Victor (2011), water security can be achieved when there is an ample amount of water available in a certain area and there is no threat of the water supply running out. Evans et al (2006) have categorized these drivers as having climatic, demographic, or economic characteristics. In addition, Brears (2016) identified urbanization and climate change as significant factors contributing to water security in the twenty-first century. Alaerts & Kaspersma (2009) contend that the challenges of water service provision are not just due to urbanization and climate change. They believe that the unsustainability elements and hazards associated with urban water management also have an adverse effect on the reliability of water resources.

Urban regions face a distinct challenge in ensuring water security, which is of particular concern. The specific challenges encompass heightened strain on water resources as a result of population expansion, migration, industrialization, water body pollution, and excessive extraction of groundwater (Babel, 2016). Conversely, it is argued that climate change and variability exacerbate the difficulties that urban water infrastructure in underdeveloped nations is already encountering (Poustie & Deletic, 2014). According to Satterthwaite (2008), it has been asserted that the majority of countries that are expected to experience significant limitations on the supply of freshwater due to climate change are nations with low and middle-income levels. Climate change has a disruptive impact on the water cycle and the process of precipitation. Scientists from the Intergovernmental Panel on Climate Change (IPCC) have stated that there is a high probability that human activities have impacted the global water cycle since 1960. These impacts include an increased chance of experiencing more severe droughts and precipitation events. Due to increased average temperatures and enhanced water-holding capacity of warmer air, there is a possibility of a pattern developing where extended periods of dry weather are interrupted by short but intense rainfall, perhaps leading to flooding. The fluctuation between periods of excessive dryness and heavy rainfall is occasionally referred to as "drought and deluge" or, more recently, “precipitation whiplash”.

The First Assessment Report of the Urban Climate Change Research Network (UCCRN), authored by Rosenzweigh et al., (2011), highlights the substantial impact of flooding and droughts on the availability and quality of water supply in numerous cities. Therefore, it is necessary for those in charge of water management to prioritize the improvement of their supply networks in order to optimize the utilization of current resources (Rosenzweigh et al., 2011).

Population increase, particularly in metropolitan areas, is a significant factor contributing to water security concerns. Migration from rural to urban areas has occurred since the advent of industrialization. People have diverse motivations for moving, including the pursuit of job, education, healthcare, social services, cultural experiences, and seeking refuge from unfavorable environmental conditions (Proust et al., 2012). According to the United Nations (2014), the urban population accounted for 30% of the global population in 1950, and it is estimated to reach 66% by 2050. According to the United Nations, in 2014, 54 percent of the global population lived in urban areas (UN, 2014). It is projected that all parts of the world will see more urbanization in the next decades. Africa and Asia are experiencing more rapid urbanization compared to other regions and are expected to reach urbanization rates of 56 and 64 percent, respectively, by 2050 (UN, 2014). The process of urbanization has become an increasingly difficult problem for the majority of African governments and planners. Despite being the least urbanized continent, Africa has recently shown the highest rate of urbanization globally. The continent is currently undergoing the most significant increase in urbanization, with a growth rate of 3.5 percent per year. This rate is projected to remain constant until the year 2050. The rates for other regions are as follows: Asia has a rate of 2.03 percent, Europe has a rate of 0.36 percent, Latin America and the Caribbean have a rate of 1.23 percent, and North America has a rate of 1.04 percent. Furthermore, the proportion of the African urban population was approximately 28 percent in 1990, but it is expected to increase to 52 percent by 2025. From 1990 to 2010, the urban population in Africa increased twofold, going from 205 million to 400 million. It is projected that by 2050, this number would triple to reach 1.23 billion. The rapid growth of the urban population has significantly transformed the physical environment of African cities and has also strained the limited financial resources available to city officials.

Urbanization in African cities has not brought about inclusive growth or substantial developments. Instead, it has led to the widespread emergence of informal settlements, generally referred to as slums. This has further exacerbated income gaps and increased urban poverty. Informal settlements, as defined by the UN Habitat Programme, refer to residential areas where housing units are built on land that the occupants have no legal claim to or occupy illegally. These settlements are also characterized by being unplanned and not in compliance with current planning and building regulations, making the housing unauthorized. These individuals are identified by their lack of sufficient access to clean water and sanitation, substandard housing conditions, overcrowding, unstable residence status, and their presence in marginalized areas within urban regions. Although slums have an informal character, they are progressively posing a significant dilemma for policymakers. According to the 2007 report on the State of the World by the United Nations Population Fund, 72 percent of urban people in sub-Saharan Africa live in conditions resembling slums. According to Angueletou (2007), in a research conducted in Mumbai, India, peri-urban areas are experiencing significant changes in terms of economic growth, urbanization, population dynamics, and environmental risks. These changes are directly affecting the availability and demand for water. These regions typically suffer from inadequate infrastructure, including a lack of piped water and sewerage systems. Additionally, essential services such as garbage collection and waste management are frequently absent (Pravettoni, 2011).

However, according to Brocklehurst (2004), the achievement of water security in informal settlements is hindered by a combination of financial and economic, institutional, political, and technological constraints. The financial and economic position of urban poor individuals may impede their ability to access and afford predetermined tariffs. Introducing defined norms in informal communities may provide technological challenges. The lack of prioritization and the prevalence of political rent-seeking contribute to the existence of political barriers. Similarly, institutional frameworks hinder the involvement of those residing in informal settlements in the decision-making process regarding water management in their own locations. In addition, Sinharoy, Pittluck, & Clasen (2019) have identified social and spatial variables as potential contributors to the obstacles in achieving water security, building upon the aforementioned issues. Social factors are considered to be influential in motivating the government to make favorable decisions to protect water service provision, in line with community collective action. On the other hand, spatial barriers, such as the location of a service area, can make the extension of water services costly or technically challenging (Dos Santos et al., 2017). Another contributing issue is the lack of information, which can hinder the creation and implementation of policies due to insufficient data for decision-making (Sinharoy et al., 2019).

2.2.3. Characteristics of Water Security

There are several views on what constitutes water security leading to lack of unified conceptual and methodological models to address its negative impact. Accordingly, key metrics for measuring water security have emerged. Table CHAPTER TWO

LITERATURE REVIEW.1

provides the description of these metrics.

Table CHAPTER TWO
LITERATURE REVIEW.1: Water Security Indicators

Description	Metrics	Implications	Source
Water security should include access to safe water at affordable cost to enable healthy living and food production, while ensuring the water environment is protected and water-related disasters, such as droughts and floods, are prevented.	Access Safety Affordability	Healthy living Food production Environmental protection Prevention of disaster	Cheng *et al.*, (2004)
Water security is focused on the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies.	Availability Quantity Quality	Healthy livelihood Ecosystem and production Acceptable risk (environment and economic)	Grey & Sadoff (2007).
Defined water security as, availability of water of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies.	Availability Quantity Quality Implications	Risk – disaster Environment Economic	Grey & Sadoff (2007)
Water insecurity is defined as insufficient and insecure access to adequate water for a healthy lifestyle (FAO, 2004; Stevenson, Ambelu, Caruso, Tesfaye, & Freeman, 2016).	Quantity Access	Health Lifestyle	Stevenson, Ambelu, Caruso, Tesfaye, & Freeman (2016)

Source: Multiple sources

However, there are two broad perspectives that emerge from these views; that of water management and that of the risks associated with either too little or too much water (Klatzel

& Murray, 2009). Depending on where a study is domiciled, and the utility to be derived, the need to align the water characteristics to the scope is important. For informal settlements, the utility derived from water is that of domestic use which focuses on water used for drinking, cooking, cleaning, sanitation, and personal hygiene (Howard & Bartram, 2003). For this case, the characteristics as may appear in several definitions in Table

CHAPTER TWO

reliability, quantity, quality, and affordability are the indicators to measure. Reliability is measured in terms of length of downtime per year and if seven (7) days in 365 days, it is acceptable. Quantity is measured in terms of litres per capita per day and globally, 50 l/c/d is acceptable, but this depends on country to country. Quality has both physical-chemical and biological parameters, but taste, odour and colour may also dictate acceptability. Affordability is measured in terms of cost per cubic meter of water but as a rule of thumb households should not spend more than 3% of their household income for water.

In the development world, other measures of water security include access, quantity, cost, availability, quality, safety, reliability, and affordability (GWP, 2000); UN-Water, 2013); FAO, 2004); & WaterAid, 2012).

It is also important to define urban water security with the goal in mind and that is to improve the quality of life for urban people (Wuysang, Triweko & Yudianto, 2018). This helps to contextualise the study, therefore making the study focused on those factors that are important. This is also clear from the various description provided in Table CHAPTER TWO LITERATURE REVIEW.2.

On the other hand, there have also been efforts to measure water security by developing a framework for water security at city level considering five dimensions, that is, domestic, economic, environmental, water related disasters as well as governance and management (Babel, Onsomkri & Shinde, 2016). This framework can be attributed to compute water security index at a basin level as some of the dimensions go beyond the focus of an urban environment where parameters like agriculture may not be prominent. Babel et al., (2016) alluded to the various dimensions.

The first dimension is that of domestic water security assesses two parameters; first is the capacity of water supply as proportion of coverage area in piped water supply system (percentage) and water consumption per capital (l/c/d) while second parameter is quality which is measured by computing the proportion of safe drinking water. The second dimension of water security is economic, which relates to two parameters, that is non-agricultural and agricultural use. The two parameters are then measured in terms of productivity or as unit of cost per cubic meter. Third dimension is environmental which measures water pollution and natural water resource by measuring the ratio of treated total wastewater (percentage) and water-body health in the city expressed as a range from 0 to 100. The higher the number, the less the pollution in the water body in the city. Water related disasters is the fourth dimension which looks at flood damage rainfall variation. The two are measured by measuring the flood depth in centimetres and deviation from normal rainfall in millimetres. The fifth dimension is water governance and management which looks at coping strategies and water use efficiency. While coping capacity is measured as GDP per capita, water use efficiency is further measured by two indicators – percentage of leakage in water supply system and the ratio of water reuse to the total wastewater from the system.

Table CHAPTER TWO LITERATURE REVIEW.2 defines the indicators, variables and how to measure them.

Table CHAPTER TWO
LITERATURE REVIEW.2: Indicators, variables, and measurements for water security

Indicator	Variable, k	What is assessed?	Measurement unit
Availability	The available volume of water resource for drinking purpose	Is the available water sufficient to fulfil the required water demand for the household purpose?	M^3 $cap^{-1}year^{-1}$
Accessibility	Improved water supply (treated and piped water supply) Water supply service duration	Is the accessibility of water supply service good enough in terms of access to piped water supply and service duration?	% of people with access to network Hours of service
Quantity	Adequate water for domestic consumption (per capita consumption)	Is the supplied water adequate enough to satisfy the required water consumption?	L cap^{-1} day^{-1}
Quality	Acceptable water quality for human health	How well is the supplied water quality for the health of human beings?	pH, mg L^{-1}, NTU
Affordability	Water tariff	Is the cost of water affordable to all types of community?	US$ m^{-3}
Water management efficiency	Water loss (NRW)	Does the distributed water reach efficiently to the customers?	% NRW in the network.

Source: Assefa et al., (2016)

By computing the parameters in each of the dimensions of water security, it is possible to frame the dimensional water security which does not offer an aggregate index. For instance, Assefa et al., (2016) have used six indicators (availability, accessibility, quantity, quality, affordability, and water management efficiency) to frame water security.

2.3 Water Service Provision System

Water service provisioning is characterised by system that is composed of three key elements. First element is that of service providers (formal, informal); system structures (water source development, treatment, storage, and delivery) and regulation which means that the system operates within certain laws and regulations also known as governance and management structures (Hodgson, 2003).

The level of investment of equipment and infrastructure put in place therefore dictates how the final user or customer accesses the water. There are water sources with minimal infrastructure and therefore access happens at or near the water source. As the systems develops to deliver water closer or to the customer through pipes, more complex structures start to emerge. These more complex systems also are accompanied with measures to manage the water without cause of conflict, and these are what form the regulatory frameworks. The latter may control who gets access and who makes decisions.

Water service provisioning has therefore two main components and those are the water supply system and the regulations that govern it. These are described in detail under 2.3.1 2.3.2 and 2.3.3.

2.3.1 Water Service Providers

Water service provision refers to the distribution of water by governmental utilities, commercial entities, community initiatives, or individuals, typically through a network of pumps and pipelines. A public water supply, as defined by the USG, refers to a water system, either public or private, that supplies water to a minimum of 25 individuals or has at least 15 service connections. Households relying on the water system can be categorized according to the level of access they have achieved. This level is determined by factors such as distance, time, reliability, and cost of water (WHO, 2003). Guy Howard and Jamie Bartram categorize levels of service into four distinct groups. The first category is "no service," which refers to situations where the water source is located more than 1000m away or requires more than 30 minutes to collect. The second category is "basic service," which applies when the water source is within a range of 100m to 1000m or can be collected within 5 to 30 minutes. The third category is "intermediate service," which involves delivering water through a single tap on the premises or within a distance of 100m or 5 minutes of collection time. The fourth and final category is "optimal service," which entails a continuous supply of water through multiple taps (WHO, 2003).

In developing nations, the provision of water services in urban informal settlements is mostly dominated by two main actors: official and informal. In accordance with Kenya's Water Act 2016, a formal water service provider is defined as a company, non-governmental organization, or any other entity that provides water services under an agreement with the licensee within the designated supply area. The term "formal" encompasses all water suppliers who operate within the legal framework of water management in a specific region. Conversely, "informal" service providers encompass all water suppliers who operate outside the legal framework of water management in a certain region. This research encompasses a variety of entities, such as community-based organizations (CBOs), self-supply schemes, non-governmental organizations (NGOs), institutional water delivery systems, tankers, private sources such as boreholes, carts, and illicit cartels. Many informal service providers lack a consistent water supply due to restricted capacity, which restricts them to provide just minimal services.

2.3.2 Structures of water service provision

The organization of water service provision determines how the development, treatment, storage, and distribution of water are interconnected to efficiently meet the needs. Figure 1.2 illustrates the transformation of a public water system from a basic supply system to a more intricate system in response to growing demand. Efficient functioning of the system also depends on important structural factors, such as design, construction, operation, and maintenance (Zyl, 2014).

The growth of water sources is determined by the need for water services. The need to accommodate a growing average daily demand (ADD) on the public water supply system requires the construction of larger sources, storage facilities, and distribution networks, leading to the gradual formation of the system shown in Figure CHAPTER ONE INTRODUCTION.2 . Extensive public water-supply systems consist of numerous reservoirs, either a single reservoir or multiple separate reservoir systems, as well as wells, well fields, and springs, from which water is extracted.

Water treatment can be classified into progressively more intricate treatment systems. The spectrum of treatment options for water can vary from a basic approach of no treatment or simple chlorination, to a more intricate system that incorporates corrosion control chemicals, coagulation, flocculation, sedimentation, and filtering. An uncomplicated method for treating groundwater extracted from boreholes involves the processes of aeration and chlorination. However, treatment facilities become significantly more intricate when surface water is utilized as a source of supply.

Water storage occurs at multiple stages, including raw water storage, clear water storage after treatment by the supplier, storage along delivery lines by the supplier, and ultimate storage by the water consumer at the household level.

Consumptive use mainly occurs as water evaporates from open reservoirs and canals while it flows through the system. This is particularly significant in arid regions or areas with extensive open water bodies. Following the treatment process, water is typically directed to either finished water storage or directly into the distribution system.

The distribution process involves supplying water to three primary groups: (1) wholesale customers, which are other water suppliers; (2) retail customers, including domestic, commercial, industrial, thermoelectric, mining, and agricultural users; and (3) public users, such as municipal buildings, parks, and for activities like street washing, firefighting, and hydrant and system flushing. The presence of unaccounted water in the distribution system is caused by leaks, unlawful consumption, or erroneous meter readings.

Water service provision refers to the distribution of water through pumps and pipelines by governmental utilities, commercial organizations, community efforts, or individuals. The American Water Works Association (AWWA, 1974) has defined the water distribution system as encompassing all the components of a water utility that are responsible for distributing finished or potable water. This distribution is achieved through the use of gravity storage feed or pumps, which are connected to distribution pumping networks. The purpose of this system is to supply water to customers or other users, including distribution equalizing storage. Thus, an urban water system encompasses the processes of water source establishment, purification, storage, and distribution. A public water supply, as defined by the US EPA, is a water system, either public or private, that serves at least 25 individuals or has a minimum of 15 service connections for a duration of at least 60 days per year. Such water systems are required to adhere to certain fundamental principles. These principles include maintaining a distribution system that prevents contamination, ensuring adequate pressure throughout the system, providing enough water for firefighting purposes, ensuring uninterrupted water flow to all consumers even during repairs, laying distribution pipes at least one meter away from or above sewer lines, and minimizing leakage to reduce water losses.

2.3.3 Water Service Regulation

Water service regulation involves establishing a governance framework that outlines the operational procedures for water service structures and providers. Its purpose is to guarantee water security within the designated service area. The origins of the initial statutory restrictions for drinking water may be traced back to 1914, when they were established by the US Public Health Service (PHS). In 1948, a more comprehensive regulatory framework was established with the enactment of the Water Pollution Control Act, which was based on the principles of the germ theory. Due to increased public knowledge and concern, modifications were made in 1972 to regulate water contamination. The amendment enacted in 1972 resulted in the establishment of a statute that is now generally recognized as the Clean Water Act (CWA).

Although numerous developing countries have since implemented these laws, they pose challenges when it comes to implementation in urban informal settlements inside these countries. The reason for this could be attributed to the existence of two main types of governance systems in informal settlements for water service provision: formal systems, which are based on policies, and informal systems, which are based on practices (Allen et al., 2004). Additionally, the distinction is derived from the fact that one is grounded in established policies and formalized processes, while the other is based on unwritten rules and informal practices (Allen et al., 2004).

In 2006, the United Nations' World Water Assessment Programme stated that the fragmented institutional system, lack of coordination and cooperation mechanisms, and insufficient political will and financial resources are major obstacles to effectively addressing the significant threat posed by water-related disaster risks. New Institutional Economics (NIE) has made a noteworthy and intellectually stimulating contribution to the discourse on institutional reforms. The significance of transaction costs, property rights, and technological progress has been especially highlighted in this context (Kurian & McCarney, 2010).

Rosenzweigh et al. (2011) suggest that the cooperation between informal and formal water service providers can be advantageous for individuals residing in informal settlements. There are limited instances in which different types of water governance have successfully removed obstacles to water access for individuals residing in informal settlements. This has been accomplished through regulation, strategic acknowledgment, and collaboration.

For instance, in Mozambique, regulation of formal and informal water service providers in peri-urban areas of Maputo has been recommended (Matsinhe & Juizo, 2008). In Maputo, household water resellers and SSIPs cater for as many as 21% of unconnected households (Nelson & Dennis, 2008). Another example from Kenya is in Nairobi, where the Water Service Trust Fund (WSTF), through the pro-poor strategy developed a partnership model that was piloted in one urban slum: Mathare-Kosovo (WSTF, 2010). According to The World Bank study by Garrick, O'Donnell, Damania, Moore, Brozović, & Iseman (2019), regulation can address price, quality, and water resource abstractions. Further, it can be used as part of entry conditions to protect consumers from extortion by water vendors.

There are many instances where there are no clear institutional instruments to recognize the role of the informal water service providers. In a way, government is aware of the key role these providers are playing but they fear that, allowing them to formally operate may lead to commodification of water. To manage this situation, government may consider what in this research is termed as "Opportunistic Recognition". Some examples that exist include, Ho Chi Minh City in Vietnam, where in 2001 authorities fearing that the water utility was unlikely to meet the MDG targets for water provision, contracted small suppliers to provide water for a limited time (Dagdeviren et al., 2009; Conan & Paniagua, 2003). Another case is that in Abidjan, Côte d'Ivoire, where the municipal authority licensed small providers to resell water within informal settlements (The World Bank, 2002).

Alternatively, partnership can be considered as a component of water service providing governance. The Water Service Trust Fund (WSTF) in Nairobi implemented a partnership approach in the Mathare-Kosovo urban slum as part of its pro-poor policy (WSTF, 2010). The Mathare-Kosovo pilot project was launched to formalize water services provision in Kenya, taking advantage of the supportive climate created by the water sector reform. The cooperation acknowledges the sector reforms and is in line with the national structures, policies, and strategies, such as WSTF's Urban Project Cycle (UPC). The collaboration involves active participation and involvement of community residents, a non-governmental organization (NGO), the Water Services Trust Fund (WSTF), and a water service provider (WSP). By employing a participative approach inside the UPC, we successfully devised and executed a tailored solution to establish a formal water delivery system in the Mathare-Kosovo region. This involved a combination of residential connections, yard taps, and water kiosks.

The strong collaboration among the stakeholders facilitated the successful eradication of the cartels, while the utility's emphasis on serving the impoverished population and its all-encompassing approach to engaging with low-income consumers demonstrated the potential for these sectors to generate higher revenue.

In order to attain this level of accomplishment, the pilot partnership project was led by several crucial ideas, with the most significant ones being:

- The licenced and regulated provider (WSP) who guarantees adherence to minimum service standards is in charge of the water supply in metropolitan areas. Community management of the urban supply system is never appropriate.
- People living in low-income neighborhoods are WSP customers, just like any other customer.
- The combination of supply alternatives (e.g., water kiosks, household and yard connections) should match the desires and abilities of the residents. Water must be paid for, but residents should pay no more than the regulated rate.
- To guarantee sustainability and effective client services, the business must make a big impression in the low-income neighborhood. For this, the WSP ought to aggressively encourage the establishment of groups and committees based in the community.
- Under contract with the utilities, locals should run the kiosks.

Up scaling this partnership approach can guarantee the respect of human rights to water and sanitation while also helping to close the urban underserved gap, which has risen in the last 20 years from 13.4 million to 27.02 million (WSTF, 2010).

2.3.4 Structures and Governance of Water Service Provision in Kenya

The Kenyan Constitution of 2010 acknowledges, as Figure CHAPTER TWO LITERATURE REVIEW.3 , that a fundamental human right is having access to safe and adequate water. Article 21 requires the government to gradually fulfil the right to appropriate levels of cleanliness and clean and safe water in sufficient amounts that is established by Article 43. It also gives the 47 counties responsibility for sanitation and water supply. Aligned with the COK 2010, is the Water Act of 2016. County governments name or establish Water Service Providers under the Act to act as authorized water operators.

The National Water Harvesting and Storage Authority was established under the Water Act of 2016. Its functions include developing and maintaining national public water works for the purpose of storing water resources and controlling floods, collecting and providing information to the Cabinet Secretary for the purpose of formulating national strategies for these things, creating and enforcing water harvesting policies, responding to droughts on the government's behalf, and advising the Cabinet Secretary on matters pertaining to national public water works. Making this move is meant to guarantee that an adequate amount of water is generated, processed, and stored. Additionally created by the Act is the Water Resources Authority (WRA), which is in charge of overseeing the development of water resources. The Water Resources Authority enforces rules, procedures, and standards for the management and use of water resources and issues licenses to developers of water sources.

County administrations are required by the 2016 Act to set up Water Service Providers (WSPs). Delivery of water inside the licenced area is the responsibility of these WSPs. Water Services Regulatory Board (WASREB) was established to control participants in the national water service delivery industry. The development of a network of pumps, storage tanks, and pipes is another requirement of the WSPs to provide the produced water to final customers. Within a specific service provision area (SPA), it is anticipated that the WSPs will provide every individual. In areas where WSPs are unable to reach, the 2016 Act creates the Water Sector Trust Fund (WSTF), whose mission is to provide counties conditional and unconditional grants to help finance the creation and administration of water services in underprivileged areas or any other area that the Board of Trustees deems unserved or underserved. The act further stipulates that water service providers that are created as public institutions and who run and deliver water services must maintain the public trust over the assets of the county or national public water services.

As a part of the extensive changes in the water industry, the Services Regulatory Board (WASREB) was founded in March 2003 and is now a non-commercial State Corporation under the Water Act 2016. Supervision of the application of policies and plans related to the supply of water and sewage services is the institution's responsibility. WASREB establishes guidelines and upholds standards to direct the industry in the direction of guaranteeing consumer protection and availability to effective, reasonably priced, and environmentally friendly services. Among other things, they grant licenses for the supply of water services; set guidelines for the provision of water services to customers; and keep an eye on adherence to set guidelines for the planning, building, running, and upkeep of facilities for water services. WASREB assesses every WSP in order to rank their performance in relation to Key Performance Indicators (KPIs).

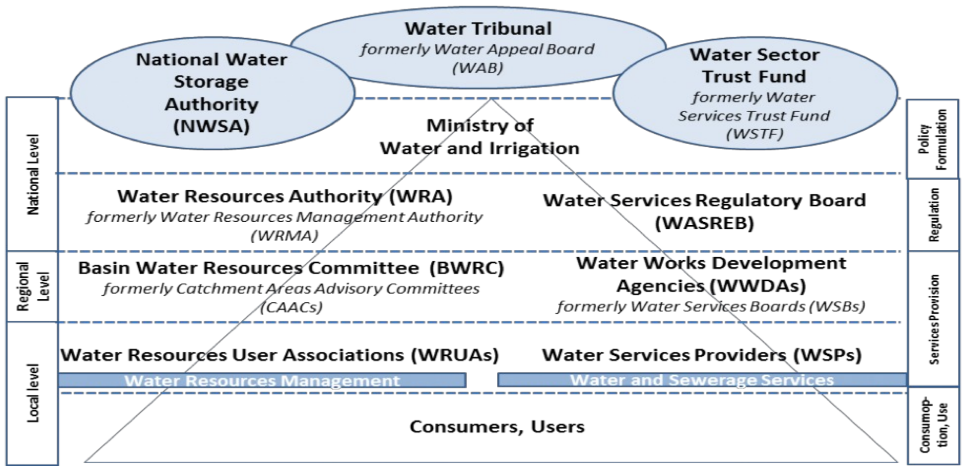


Figure CHAPTER TWO
LITERATURE REVIEW.3: Governance Structure of the Water Sector in Kenya

Source: GoK, 2016

2.4 The Integration Approaches

Although there have been numerous definitions of integration as a process, they all appear to be convergent in that it is a process of integrating various components into a cohesive whole. Sara et al. (2018) have proposed a more comprehensive definition of integration as the process of constructing a unified entity from interdependent and distinct organizational components. Integration is primarily intended to benefit service consumers or providers (Richardson and Patana, 2012). Additionally, the integration of services can occur through the physical or virtual collocation of complementary services, collaboration among professionals across different sectors, or a combination of these (Richardson and Patana, 2012). Integration is a process that occurs in both horizontal and vertical directions (Singer et al. 2020). Engagement, communication, joint planning, sustainability, and process integration are the primary components of integration models (Robinson, et al., 2008).

However, it is important to note that, there is limited literature available on water service integration. This could be true because, water supply has always been perceived as a free service to be provided by government and therefore little or no motivation in developing integration frameworks to help optimize its utility. Given the foregoing, this study has made reference to the health sector service integration models that can be adopted in the water sector.

2.4.1. Types of Service Integration

There are five distinct forms of integration of services, as stated by Singer et al. (2020). Some of these types are process, normative, interpersonal, and structural. Teams and organizations within a health system collaborate through physical, operational, financial, or legal relationships, according to Singer et al. (2020). In addition, Functional integration, according to Singer et al. (2020), include formal, documented policies and procedures for actions that facilitate accountability, decision-making, and coordination among entities. Functional integration, in their view, is more concerned with activity protocols than structural ones.

Singer et al. (2020) states that normative integration in a health system is characterized by a shared culture and an attitude that values integrating patient care across different departments and organizations. In addition, normative integration acknowledges the ever-changing relationship between the policies and leadership at the organizational level that facilitate culture and the norms and behaviors at the front lines that put it into effect (Singer et al. 2020).

Collaboration and teamwork among experts from different fields and companies is called interpersonal or "professional integration" (Singer et al. 2020). Even more so, Singer et al. (2020) points out that patients, families, and nonprofessional caregivers like community health workers were left out of the health system's professional integration, leading them to suggest interpersonal integration as a more inclusive model.

The process of integrating patient care services into a single coordinated process across people, functions, and operating units over time is characterized by Singer et al. (2020) as encompassing organizational actions or activities. This is also known as clinical integration in the health system. According to some scholars, process integration entails taking into account the hierarchical organization of tasks across time and space (Robinson, et al., 2008). In addition, they identified three primary components of process integration as follows: procedures for managing change, procedures for regular and procedural systems, and collaborative activities involving many professions.

Figure CHAPTER ONE INTRODUCTION.4 shows the five types of integrations as nodes in a logic chain that Singer et al. (2020) proposed, wherein the occurrence of each node is affected by contextual circumstances, which in turn affect the consequences. The authors defined contextual factors as aspects of the market and the organization’s environment that influence the kinds of integration. The external market factors include market structure, the extent and types of value- and risk-based payments, the level of legal and regulatory factors, the availability of community-based resources, and the internal organizational characteristics such as size, number of practice sites and provider organizations in a health system, specialty-mix, ratio of nonphysician staff to physicians, physical proximity of clinicians, and financial health of the organization (Singer et al., 2020).

In addition, according to Singer et al. (2020), there are different types of integration. The first two deal with organizational features like systems and structures. The third type, interpersonal and normative, deals with social features like beliefs and group behavior. Lastly, process integration describes a series of actions or activities related to care delivery, like referral management and using shared care plans.

Organizational, social, and activity integration were all aimed at producing integrated patient care as a result of this health system (Singer et al., 2020). There may be complicated and mixed linkages between the types of integration resulting to mixed results, which can be examined empirically, as they pointed out.

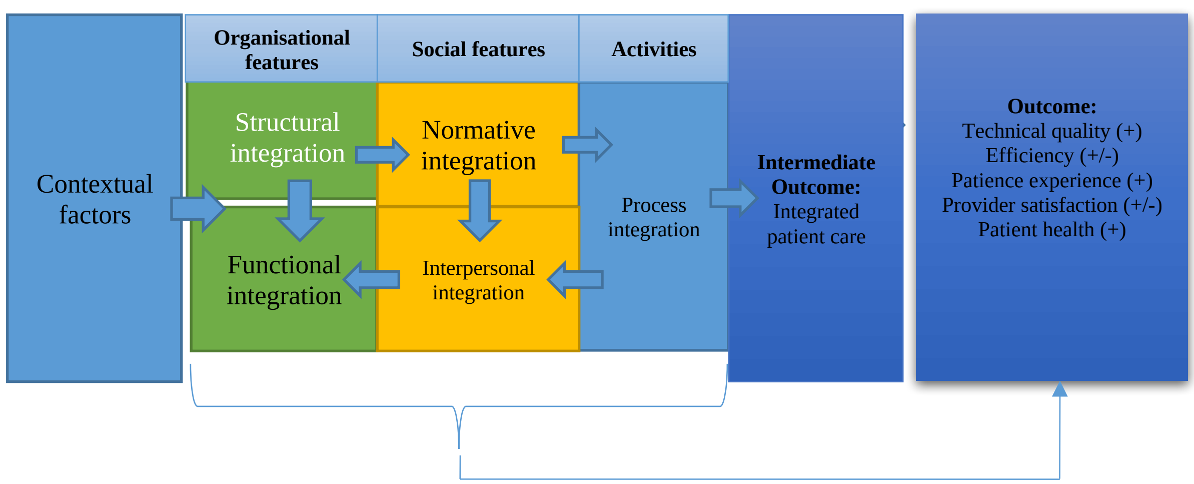


Figure CHAPTER ONE INTRODUCTION.4: Conceptual Model for Integration Types

Source: Singer et al., (2020)

2.4.2. Service Integration Frameworks

Aiming to improve service delivery, literature indicates the presence of integration mechanisms, also known as integration frameworks (Browne et al., 2004). Formal networks, committees, or alliances of local organizations, agencies, and development partners tasked with planning, coordinating, and providing all-inclusive local services could constitute these integration structures.

A variety of things affect how well integration frameworks perform. Provan and Milward (2001) lists these elements as network members or integrated service providers, service users, and community members including legislators, development partners, and other locals. Browne et al. (2004) suggested the creation of a measuring standard that takes into account the viewpoint of every stakeholder in order to evaluate the effectiveness of integration framework. They also advise adding, to the criterion, a metric of the integration's results, such as community well-being.

For instance, Browne et al. (2004) have put up a three-dimensional integration framework for human services that concentrates on measurable aspects of the breadth, depth, and extent of the effort. Moreover, the framework may be applied to pinpoint the networks' connected and productively cooperating sectors, services, and agencies as well as the sectors and/or agencies that might improve their cooperative efforts. The three-dimensional integration framework put out by Browne et al. (2004) is seen in Figure CHAPTER TWO

LITERATURE REVIEW.5.

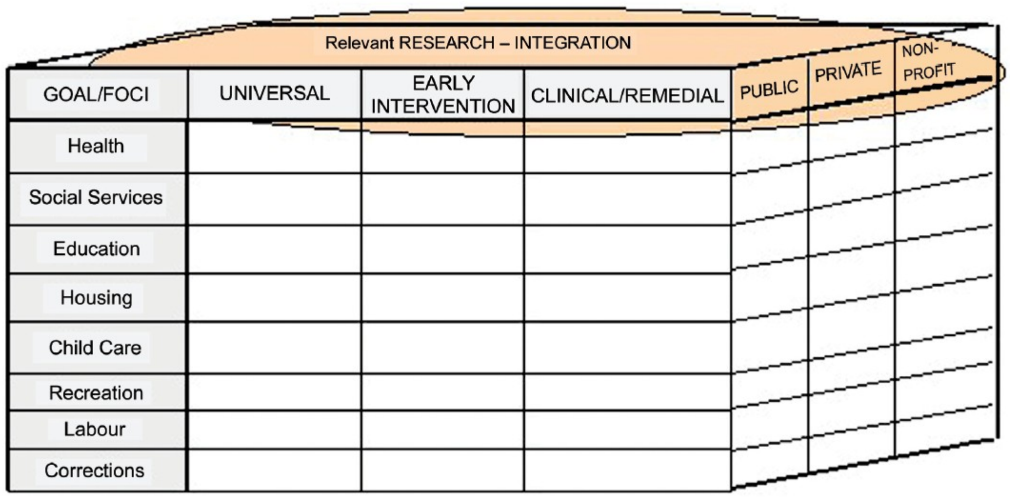


Figure CHAPTER TWO
LITERATURE REVIEW.5: An integration framework applied to services for families with young children.

Source: Browne et al. 2004

On the one hand, the framework takes into account eight different industries; on the other, it analyzes three different kinds of services; and on the third, it considers three different primary funding and resource sources. According to the model, integration along the three dimensions of cross-sectoral cooperation, continuum of service, and financing would be most beneficial to comprehensive human services. Coordination across several service sectors is necessary for cross-sectoral integration. Services and programs within an industry must work together to ensure a continuous flow of services. To promote and enable cross-sectoral and interdisciplinary integration in publically supported systems, finance integration necessitates the pooling of all resources.

Worldwide, water resource management has garnered a great deal of attention. Wuysang and Soerymassoeka (2021) point out that governments across the board and at every economic development level have embraced integrated water resources management

(IWRM) as a framework for managing water resources. One definition of IWRM offered by the Global Water Partnership (2000) is “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” The demands of humans and the environment are both taken into account by this expansive definition (Wuysang and Soeryamassoeka, 2021). There are various scales at which IWRM can be implemented. Although its ideas are most commonly used in relation to river basin management, they are applicable at all spatial scales, from the neighborhood to the global stage (Biswas 2008). For many reasons, including its proximity to preexisting water infrastructure and administrative and political units, the city offers a theoretically and pragmatically attractive level for the implementation of IWRM.

Improving water-related circumstances for human wellbeing is the overarching goal of both water security and integrated water resources management (IWRM). Because of factors such as unpredictable weather, ever-increasing demand, and finite financial resources, water security is an unattainable goal. Improvements in water security can be achieved by IWRM, but the success of this endeavor is highly dependent on the resources that are put into it. The ongoing IWRM planning cycle takes into account the mutually beneficial relationship between IWRM and water security (Figure 2.4). The scenario analysis is a critical part of the planning process since it is where the issues are discovered and the objectives are established. Water security helps put a number on such aspirations by outlining the many aspects of water security and providing indicators to gauge it, ideally with measurable goals in mind. When put into practice, IWRM provides a structure for dealing with difficulties and challenges that pertain to water (Beek and Arriens 2014).

Connecting urban water security to the overarching framework of integrated water resource management (IWRM), Wuysang et al. (2018) introduces an additional facet of water service provision integration. In addition, according to Wuysang et al. (2018), the goal of both water security and IWRM is to improve water-related circumstances for human wellbeing. Urban water management affects water resource management in river basins, as shown in a framework that maps the links between IWRM and water security (Beek, Eelco van., and Arriens, Wouter L., 2014; Wuysang et al., 2018). The mutually beneficial nature of this partnership is seen in Figure CHAPTER TWO LITERATURE REVIEW.6.

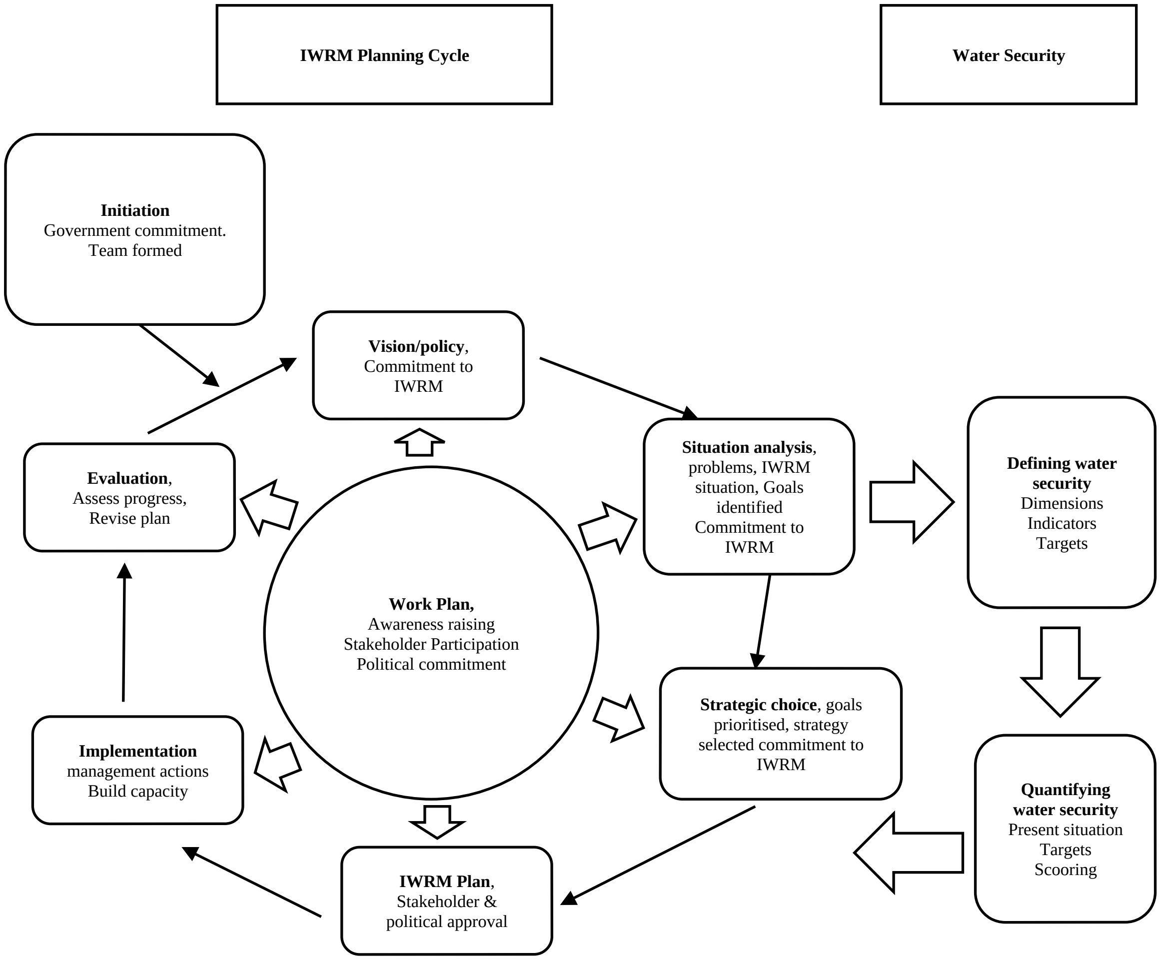


Figure CHAPTER TWO
LITERATURE REVIEW.6: Factoring Water Security into the IWRM Cycle

Source: Beek & Arriens (2014)

2.4.3. Achieving Integration Through Co-Production Technique

In water service provision, co-production has been framed as an approach that promotes water service integration. As argued by Kurian and McCarney (2010), co-production offers an effective way of service delivery especially to the poor in a cost-effective way by enhancing community participation and hence influencing policy formulation and implementation. Further, co-production allows for localized planning against the expensive centralized systems that are only implemented by government experts (Kurian & McCarney, 2010).

Moretto et al. (2018), builds on the discussion on co-production saying that, it is premised on citizen-government synergies throughout the process of service provision starting with resource management through to delivery of water services. Two features that emerge in co-production is that of institutional arrangements on the public side and active involvement of citizens in production of public goods and services. These features are innovations that are localized solutions, leading to decentralization of services and that are needs-driven (Moretto et al. 2018). Another perspective on co-production is offered by Ahlers et al. (2014). They define it as an approach where new practices are formed through the interaction of socio-political, economic, biophysical, and infrastructure drivers, leading to the production of hybrid service provision modalities. According to Kurian & McCarney (2010), one way to improve service delivery is through co-production.

In essence, co-production seeks to ensure that social and physical issues are addressed by bringing to understanding on who is involved and how on the social end; to physical characterization leading to selected technologies as well as devices used to produce and process resources taking into consideration the environment or space under which this is happening (Moretto et al. 2018).

According to Monstadt (2009), there are three interconnected parts to the complex system of water sector co-production (Figure CHAPTER TWO LITERATURE REVIEW.7): There are three parts to the service's accessibility: the first is the managerial, which encompasses relationships among users, intermediaries, and providers; the second is the techno-environmental, which includes the technical infrastructures for treating and distributing resources; and the third is the spatial, which reacts to the socio-spatial configuration of service accessibility (Giuseppe et al., 2019). In addition, the two values that co-production embodies—the normative value, which can lead to a more engaged citizenry and more collaborative governance, and the instrumental value, which can enhance service efficiency and quality—make it an ideal tool for fostering horizontal and collaborative relationships (Nabatchi et al., 2017; Giuseppe et al., 2019).

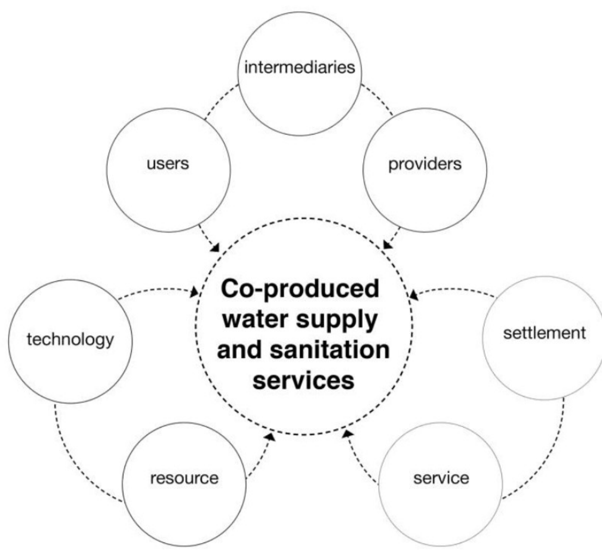


Figure CHAPTER TWO
LITERATURE REVIEW.7: A framework of co-production: Actors - Flow – Area

Source: Giuseppe et al., 2019.

The framework is to be used in identification of co-production cases, in identification of key factors to be considered for understanding water and sanitation service co-production, and in undertaking comparative analysis (Giuseppe et al., 2019).

In practice, this structure has been witnessed in Tanzania and Ethiopia where sharing of water infrastructures (shared taps, water tanks) has been achieved through connection of private providers to the municipal network (Moretto et al., 2021).

From the foregoing literature, it is evident that there is little or no frameworks that have been developed in integration of water service providers, generally and specifically in the urban informal settlements. However, the health sector has dominated this area of research with most of the models relating to health service integration. On the other hand, frameworks in the water sector have largely focused on integration of "resources" and so the popular Integrated Water Resource Management (IWRM) models.

Two possible reasons for lack of integrated water service provision models are attributed to: one, there is a general assumption that water is a natural resource and therefore the attitude of people is that it should be free. However, given that its production, supply and operation and maintenance of the system, it is actually a service. Reason number two, is that provision of water services involves many players, different environments and a mix of human behavior that introduces some level of complexity. This therefore means that linear models or frameworks may not sufficiently present an integrated water service provision. This research used system dynamics approach to help frame the water service provision system.

2.5. Methodological Review of System Dynamics

2.5.1. Introduction System Dynamics Modelling Methodology

According to Xia & Poha (2013) and Cronin (2009), system dynamics modeling (SDM) is a method for figuring out how complicated issues act over time. The idea that input and output influence each other through feedback loops is a radical change from linear models that view behavior as an input-output relationship. Consequently, it is used in situations where feedback is present (Garcia, 2006). In addition, the fact that endogenous (from within) or exogenous (from outside) influences cause a system's state to change over time defines it as dynamic.

According to Garcia (2006), the fundamental goal of system dynamics is to shed light on the underlying structural factors that influence a system's behavior and to increase our comprehension of those factors. In addition, distinct elements of the system produce different behaviors when their functions are better understood, which allows for an evaluation of how an action affects those sections. Xia & Poha (2013) argue that SD's capacity to provide quantitative simulation of different policy alternatives makes it stand out as a decision support tool for testing and selecting strategic policies.

According to Katrina et al. (2012), the four main ideas in the System Dynamics method are endogenous behavior, feedback, fluxes, and stocks. Dymanic models depict stocks as accumulations of intangible and tangible assets. Factors such as the quantity of water in a dam or reservoir, the stock of a store, the density of a city's population, the quantity of cars on the road, the prevalence of a given sickness, etc. When the disparity between a "container"'s inflows and outflows is integrated over time, accumulation happens.

When a system undergoes a flow, it alters the stock levels. Flows are more accurately referred to as "state-change processes" because stocks are the state variables of a system. The amount of a stock rises when money flows into it, and falls when money leaves it. Only when capital flows in or out can the value of a stock fluctuate. The process flow rates determine the rate of change in the system's state. The overall shape of a system's behavior over time is dictated by its stock-and-flow structure. Rather than influencing one another directly, stock prices interact via flows. One stock's level can influence another's level through influencing the pace of flow. A characteristic of sound systems thinking is the ability to differentiate between stocks (accumulations) and flows (processes). The input of water into rivers is one type of flow.

A dynamical system's feedbacks are its causal loops. Depending on the direction of the causal loop, a shift in stock price can have the opposite effect or exacerbate the initial shift. A "reinforcing" feedback loop is a type of feedback structure that increases the rate of change. A "balancing" (negative) feedback loop is a feedback system that fights against change.

An exogenous driver is not necessary for a system to exhibit its endogenous behavior, which is produced by feedback within the dynamical system (Richardson, 2011). As Garcia (2006) puts it, "if a system contains the elements that cause the problem, it also has those that can be used to solve it." The system's internal dynamics determine its response to applied external forces.

According to Sušnik et al. (2013), the SDM method starts with conceptual modeling, which involves qualitatively defining the main interactions of a system. The main product of this process is causal loop diagrams (CLDs), which represent the relationships between elements (Sušnik et al. 2013). This phase is useful for defining data needs, assisting with system definition, and directing the construction of the quantitative model. According to Sušnik et al. (2013), quantitative models that lack feedback loops and omit certain finer details are constructed to check three things: (a) the model's overall correctness; (b) the model's continued alignment with the study's goals; and (c) the model's ability to qualitatively produce genuine system behavior. To determine the model's efficacy, this is utilized (Barlas, 1994). According to Sušnik et al. (2013), the process continues until either the required level of complexity is reached or the system is completely represented according to what is understood. This process's output is shown in the SFD, or Stock and Flow Diagram. To make sure the model's structure, goal, and output are realistic representations of the real world, validation is the last step of an SD model.

Abdi (2009) claimed that planning and managing water resources needs analytical tools to help make choices about how to grow, use, and consume water resources. The use of SDM has proven fruitful in researching demography, economic growth, company development, management of water and natural resources, and environmental systems (Xia & Poha (2013); Sušnik et al. (2013)). According to Xia & Poha (2013), SD models have primarily been used in water resource management in empirical studies, such as those involving the Yellow River in China, irrigation water in Spain, Canadian water resources, Mono Lake in

California's water balance, and Singapore's water resource management. Another study looked at the water supply and demand problems faced by a small municipality in South Africa using System Dynamics (Holmes et al., 2014).

2.5.2. Software Packages in System Dynamics Modelling

Various modelling softwares have emerged since that may comparatively offer advantages and applicability depending on problem is being modelled. Bureš, (2015)., has provided an analsysi of seven main software packages developed for system dynamics modelling, Table

Table CHAPTER TWO LITERATURE REVIEW.3: The Main Software Packages for System Dynamics Modelling

Name	Web pages	Licence	Logo
Stella, iThink	www.iseesystems.com/	Commercial	
AnyLogic	www.anylogic.com/	Commercial	AnyLogic
Vensim PLE	vensim.com/	Has student freeversion	Vensim.
TRUE	www.true-world.com/	Freeware	
Insight Maker	insightmaker.com/	Open-source	INSIGHT
Powersim Studio	powersim.com/	Commercial	Powersim SOFTWARE
Sysdea	sysdea.com/	Commercial	

Source: Bureš, (2015).

A detailed analysis of the advantages of each software package was provided in the Table

CHAPTER TWO LITERATURE REVIEW.4

as provided by Bureš, (2015).

Table CHAPTER TWO
LITERATURE REVIEW.4: Comparative analysis of software packages

Software Package	Features
Stella, iThink	• Purchased version available at US $199. • Student version runs on iPad. • Trial version limited to 30 days
AnyLogic	• A bit pricey for students, 1,190 Euro • Limited trial version of 30 days • Not very user friendly for new users as it prevents one from moving to next step if there is an error.
Vensim PLE	• Student free version available • Available as long as used used for non-commercial use • User-friendly as it allows to proceed with other steps and make changes later
TRUE	• Free after registration • No available courses and certifications • Poor flexibility for new users and does not allow edits of outputs during simulation
Insight Maker	• Freely available but costs US $199 for tutorials • Effect of re-usability of developed models is low • Complicated and difficult to configure outputs and sometimes not easy to get desired results
Powersim Studio	• Free but limited to 180 days after that it will cost US $186 • Available courses offered at a fee. • Very advanced user interface may make it difficult to use for new modellers.
Sysdea	• Not free as it costs US $216

- Cheaper version has limited functionality
- Minimalistic user interface

Source: Bureš (2015).

From the foregoing comparative analysis, Vensim PLE was the preferred software package that was picked for this study. Equally, it presented the author with an opportunity to make online querries since it offers 24/7 support from peers and from advanced model builders.

2.5.3. Vensim PLE System Dynamics Model Design

Vensim is built from Venapp builder, which in programming languages include Visual Basic, C, Delphi, Excel, C++, Visual C++, and multimedia authoring tools, or in Sable. In Vensim PLE, a system dynamic model is built from hypothetical relationships that exist between variables that make up a system. The relationship is depicted by applying a branch of mathematics known as algebra. It uses direct and inverse proportionality to show direction of change. For instance, when an increase in A results in an increase in B, or a fall in A causes a fall in B, this is a positive relationship, which is expressed as shown in Figure CHAPTER TWO

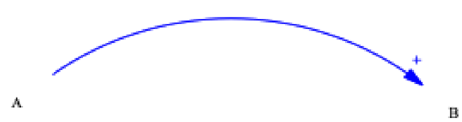


**Figure CHAPTER TWO
LITERATURE REVIEW.8: Positive relationship loop**

Equally, when an increase in A results in a fall in B, or a fall in A causes an increase in B, this is a negative relationship, which is expressed as shown in Figure CHAPTER TWO LITERATURE REVIEW.9.

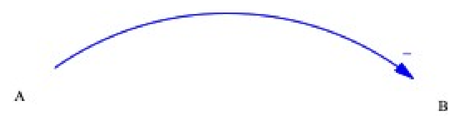


Figure CHAPTER TWO
LITERATURE REVIEW.9: Negative relationship loop

The Figure CHAPTER TWO LITERATURE REVIEW.10 shows the various parts of an SD model using population growth as an example. Population is the stock; Births and Deaths are flows into and out of the stock, population. Births increase population (positive feedback loop with '+' sign); while Deaths decrease the population (negative feedback loop with '-' sign). On the other hand, Birth Rate and Death Rate are Auxiliary Variables. The blue arrows are the connectors depicting relationship between stocks, flows and auxiliary variables. According to Nguyen and Nguyen, a variable is "anything that can affect, or be affected by, another variable or set of variables." This could be anything from a circumstance or situation to an action or decision.

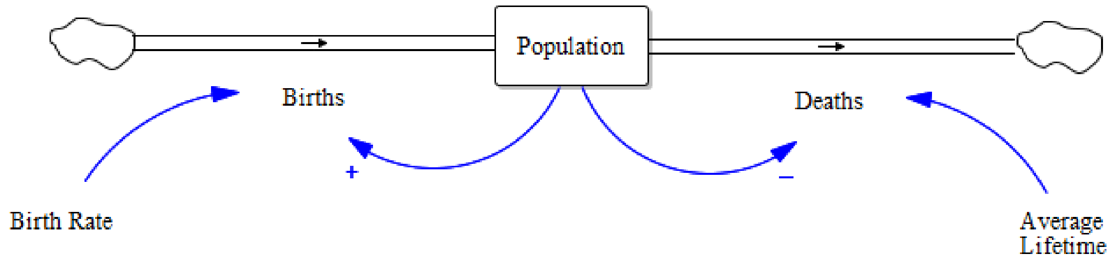


Figure CHAPTER TWO
LITERATURE REVIEW.10: Example of a System Dynamic Model of Population Growth

Source: Garcia (2013)

The stock changes with the in-flows and out-flows, in this case births and deaths; which are also influenced by birth rate and average lifetime (or death rate) respectively. In almost all cases, stocks are not linear as they may exhibit second, third- or even more-degree relationships, hence calling for integration (summing up the parts to find the whole)- Figure CHAPTER TWO

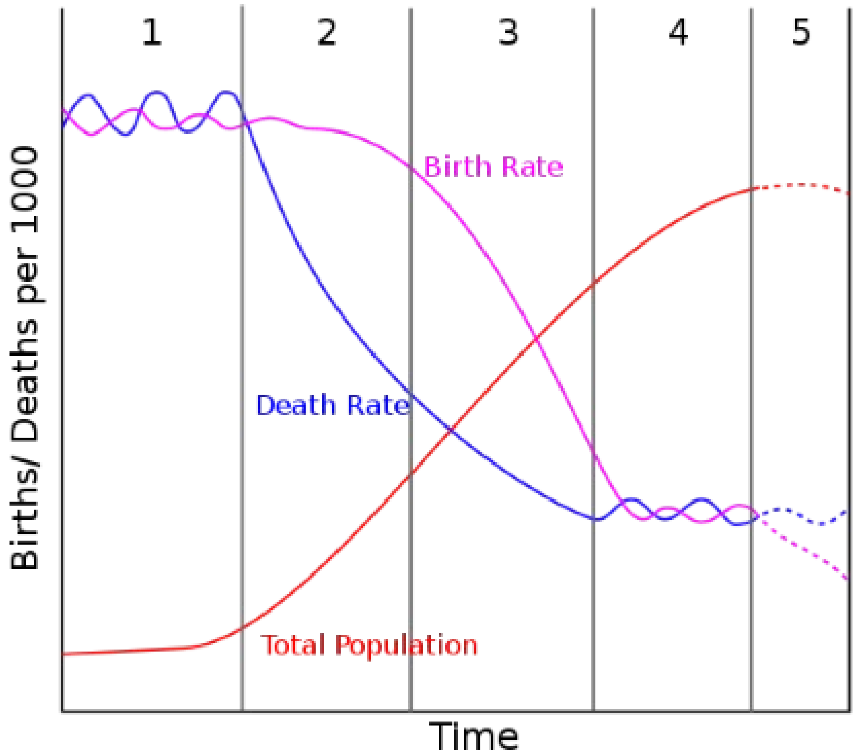


Figure CHAPTER TWO
LITERATURE REVIEW.11: Population stock with flows - births and deaths

Source: Open University (2024)

System dynamics then deploys two methods to undertake integration of stocks and flows over a period of time; Euler and Runge Kutta. Because of its capability to undertake implicit and explicit iterations, Euler Method is preferred and was therefore recommended for this study.

2.6. A Conceptual Model for Integration of Water Service Providers

From the literature review, there were no published studies that have applied SD in understanding water security in urban informal settlements in Nairobi County. This study aimed to fill this gap by designing a model for integrating water service provision systems to ensure water secure urban informal settlements using a system dynamics approach. The water service provision system makes up the independent variable which was measured through four factors, that is, water service providers both formal and informal; water service regulations that govern service provision, and the water service system structures which also depicts inherent service levels for various customers or users.

A Conceptual Framework for integrating water service provision for a water secure settlement is as depicted in Figure CHAPTER TWO LITERATURE REVIEW.12.

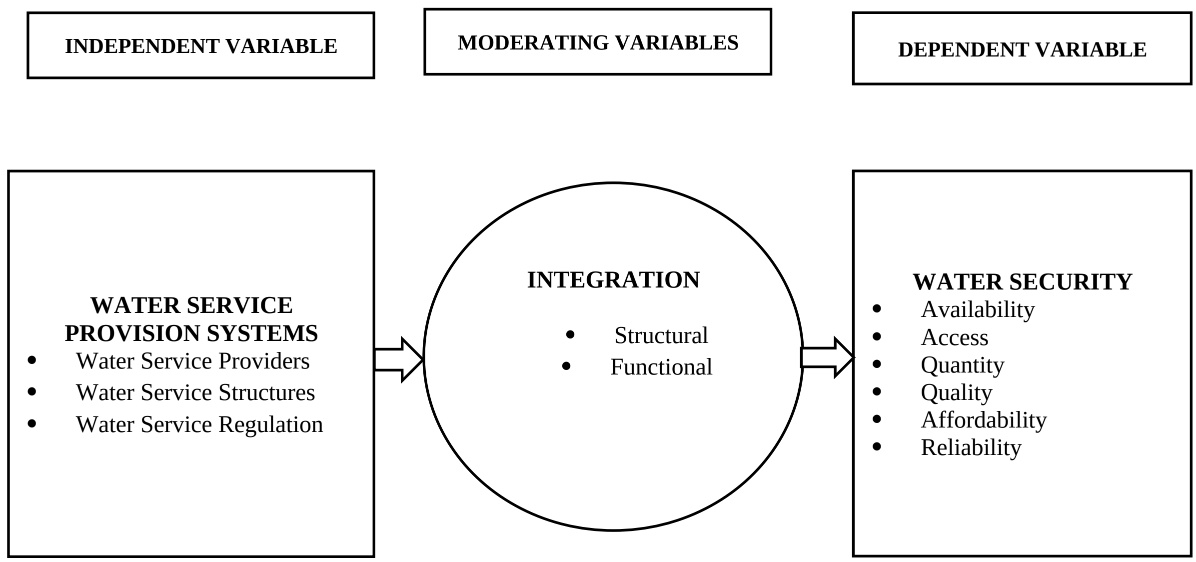


Figure CHAPTER TWO LITERATURE REVIEW.12: A Conceptual Framework for Integrating Water Service Provision

Source: Author, 2023

The dependent variable is the water secure informal settlement that was achieved through six factors namely water availability, access, quantity, quality, affordability, and reliability. Both structural and functional integration (see section 2.4.1) were used in this study.

Therefore, when water service provision systems are well integrated structurally and across functions, then this is likely to lead into a water secure urban informal settlement.

To measure water service provision through self-supply, Not-for Profit (NGOs), Private suppliers, and public suppliers, the research examined the quantity of water harvested or produced, quantity of water treated, quantity of water stored, and the quantity of water delivered. Water service regulations evaluated the laws that govern development of water sources, and its distribution or transportation and quality standards for domestic use. System structures of water supply reviewed source to customer processes and included examination of water sources, treatment, distribution and the Design, Operation and Maintenance (DOM). Service levels for various customers or users were examined through the four categories of access, that is, no service, basic service, intermediate access, and optimal access. Within the overall framework of demand and supply of water services in urban informal settlements, a dynamic model was proposed to offer insights into how integration of the water service providers, water service regulation, and system structures could be used to inform strategic decisions that can lead to water security for people living in informal settlements in Nairobi County.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This chapter provides information on the research methods and materials that were used during the study. In detail, the chapter discusses the study area, study population, research design, sampling strategy, data collection tools, data analysis, data presentation, reliability, validity, ethical considerations, and assumptions made under this study.

3.2. Study Area

Nairobi is the capital city of Kenya, and one of the 47 counties. It is situated at 1°17′S 36°49′E; 1.283°S 36.817°E and 140 kilometers (87 miles) south of the Equator. It is 1795 meters (5889 feet) above sea level, occupying 696.1 square kilometres. It borders Machakos County to the Southeast, Kajiado County to the South and Kiambu County to the North. Nairobi County is classified to be within a subtropical highland climate. Administratively, Nairobi County has 17 sub-counties and 85 wards. Its population has grown rapidly from 350,000 in the 1962 census to 4,397,073 in the 2019 census (KNBS, 2019).

Figure CHAPTER THREE MATERIALS AND METHODS.13 shows the map of NCC and the location of informal settlements with respect to the sub-counties.

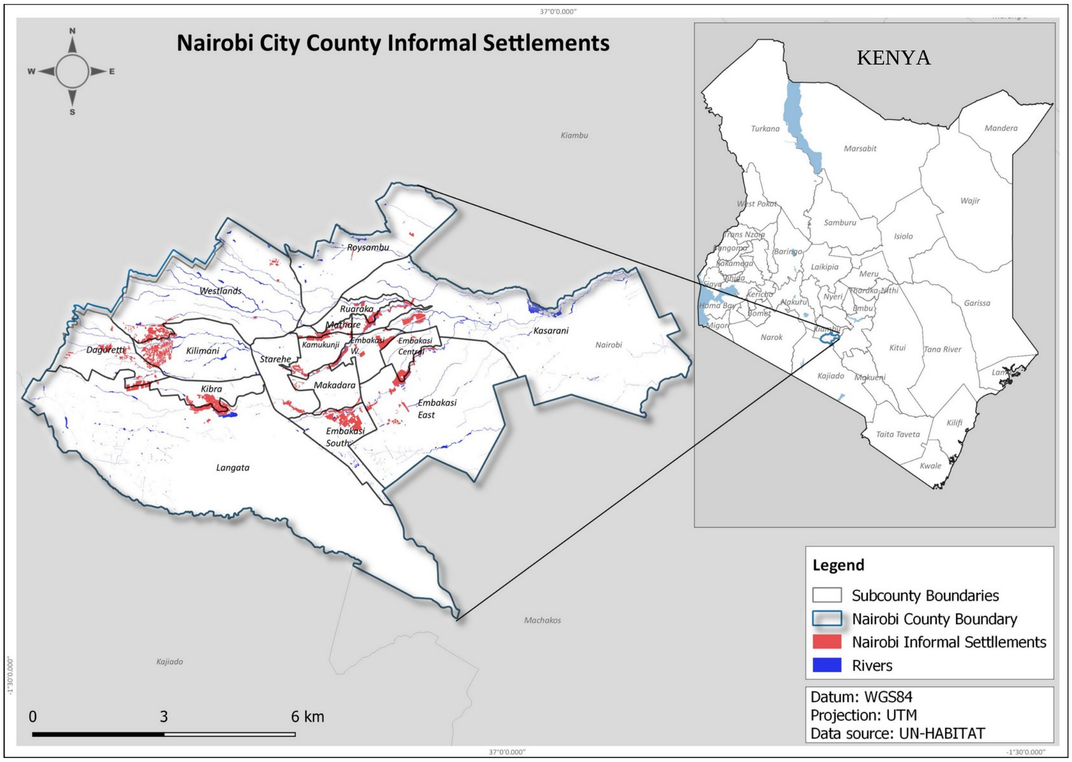


Figure CHAPTER THREE
MATERIALS AND METHODS.13: Map of Study Area

Source: Author, 2023

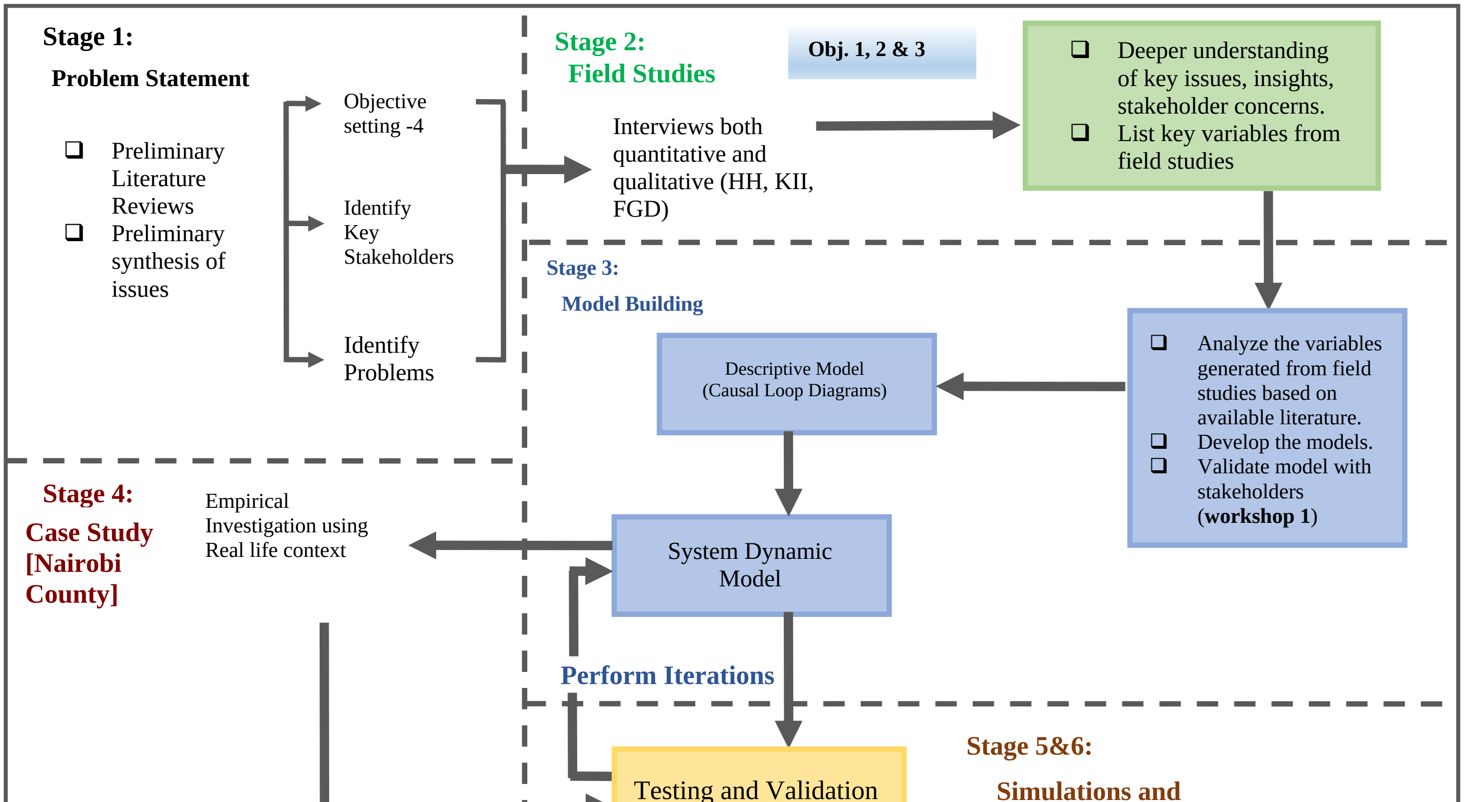
The formality and informality in terms of demography in Nairobi can be seen in how water services have been provided with some areas having large slums. The phenomenon that structured settlements in Nairobi was the residential segregation with its origin traced back to the emergence of colonization (K'akumu & Olima 2007). It is said that, by the year 1900, a racially segregated Nairobi measuring 18km^2 had been created (K'akumu & Olima 2007). Upon independence, the British zones were inherited by high income, and elite Africans; the middle-income Africans joined the Asians while the low-income residents became squatters in informal settlements or slums (Jimmy et al., 2020).

3.3. Research Design

This was a mixed methods cross-sectional research with emphasis on designing of a simulation model. The research built conceptual framework or "dynamic hypothesis" of the complex water management in an urban water system and therefore establish water security characteristics of existing water service provision systems in informal settlements within Nairobi County. A System Dynamics Model of water services provision systems integration was generated using Vensim PLE Version 10.1.5. To perform a structural and algorithmic validation of the system dynamic model of water services provision systems integration using data from water service providers and consumers in informal settlements within Nairobi County. The model was applied to a real scenario using the case data from Nairobi County's informal settlements to test its performance an integrated water service provision system in addressing water insecurity challenges. According to Sušnik et al. (2013), the SDM method starts with conceptual modeling, which involves qualitatively defining the main interactions of a system. The main product of this process is causal loop diagrams (CLDs), which represent the relationships between elements (Ford, 1999 as referenced in Suůnik et al. 2013). During this phase, we were able to further characterize the system, which in turn helped us shape the quantitative model and identify what data we would need. From the case study data set, constructs (factors) were characterized as endogenous, exogenous, and excluded variables; these variables formed the basis of the model boundary (see Table 7.1). To make sure that the model is generally correct, stays aligned with the study's goals, and qualitatively gives realistic system behavior, quantitative models without many feedback loops and lacking in finer details are constructed (Sušnik et al, 2013). Following that, more and more detail is added until the amount of complexity that is needed or until the system is fully represented and understood (Sušnik et al., 2013). A Stock and Flow Diagram (SFD) was the ultimate result; this kind of diagram can be used to mimic model results and, in turn, to suggest policies.

The model then underwent three levels of testing (structural, algorithm and behavioural) to ensure that the SD Model was appropriate and represented the real system (Sušnik *et al.*, 2013). The first test was the Structural Testing (ST) to ensure the model structure was generally correct; the Algorithm Testing (AT) through review of the equations to ensure that the model was still aligned to the aims of the study; and lastly; Behavioural Testing (BT) which was done by simulation and using case study data to determine if the model was qualitatively giving realistic system behavior. The BT is important since it is used to gauge the "usefulness" of the model (Barlas, 1994).

The detailed steps followed in establishing water security characteristics, model formulation, testing and validation, and generation are summarized in Figure 3.2.



Source: Author (2023)

3.4. Study Population

The research targeted a population of 2,511,991 people (KNBS, 2019) living in the informal settlements and 544 water service providers (formal utilities and small-scale vendors) operating in the informal settlements. For model calibration, Nairobi County forms the study area. Specifically, the study was carried out in nine informal settlements selected for study (Korogocho, Viwandani/Kaloleni, Kibera, Kawangware/Gatina, Majengo/Kiambiu, Mathare, Gitare Marigu/Njiru, Mukuru/Kayole Soweto, and Gitogoro) in Nairobi County. These are the biggest informal settlements in Nairobi which experience perennial water challenges, and many have also been reported to be Cholera hotspots over the years (MoH, 2021).

3.5. Sampling Procedure

Both probabilistic and non-probabilistic sampling methods were used in this study. The probabilistic sampling used multistage cluster sampling. The probabilistic sampling methods helped in identifying respondents especially among the informal households while the non-probabilistic sampling including purposive sampling and convenient sampling were used to identify respondents for key informants' interviews and in observations. This approach helped in choosing the person with the most representative characteristic as desired in line with the study objectives. The study also sampled water companies and vendors operating in Nairobi and carry out key informant interviews with government institutions, formal or licensed utility companies and private water source owners. For quantitative data, the unit of study was household head. The total population of Nairobi was

4,397,073 people with a total of 1,506,888 households with an average household size of 2.9 members (KNBS, 2019). There are divergent views on what proportion of people make up the informal settlements in Nairobi. For instance, Practical Action (2005) estimates INSE population of Nairobi at 60%; while African Population and Health Research Centre (APHRC), (2014) estimates this population as between 60 and 70 percent. Given these divergent views, we assume that the proportion of people living in INSEs in Nairobi is unknown; and therefore, use Godden (2004) and Ibrahim, (2009) sample computation formula which generates a sample size of 385 households.

3.5.1. Household Sample Size Computation

This sought to collect a quantitative data set from households as the unit of study.

Sample size:

Equation 1: Household Sample Size Computation

Where:

z = Standard normal Deviation

(It is 1.96 for 95% confidence level)

P= the proportion of the population having the characteristics being measured (if the proportion is unknown set P = 0.5). The population in informal settlements is fairly homogeneous.

q =1-p

M = The level of accuracy desired, or the sampling error; (often set at 0.05) Also known as level of statistical significance or margin of error.

Given the sample size adjustment as computed based on PPS, a total of 388 people were interviewed.

3.5.2. Key informant sample size determination

A cross-sectional survey design was used to enable the collection of data across the sample population at the one time. The study targeted urban Informal Settlements (INSEs) from 12 sub-counties. It is therefore apparent that the population size and socio-economic factors of each community differed from each other. Therefore, a proportional stratified sampling technique giving equal chance for a household from the 12 subcounties to participate was used. This was done to help reduce any possible bias emanating from selection of participants.

The KII was used to collect qualitative data from the water service providers (water kiosk, boreholes, water cart and water truck owners), water governance institutions (Nairobi County Government officials, NCWSC, WASREB, WASTF and other donors). Largely, for the KII data collection, purposive sampling approach was used for all units of study. For the water service providers, the study picked utmost 10% of the number of the providers or until saturation was attained (Hennink and Kaiser, 2022). Saturation is when responses from multiple responses tend to be the same/repetitive.

The Table CHAPTER THREE MATERIALS AND METHODS.5 , details the sample size for each category of water service provider. To select a specific water service provider in each cluster category, a random probabilistic method was employed.

Table CHAPTER THREE
MATERIALS AND METHODS.5: Sample size of water service providers in each category

REF	Informal settlement	Sub County	Water kiosks		Boreholes and shallow wells		Water carts		Water boozers of truck suppliers	
			Total # of Water kiosks	# of kiosks sampled	Total # of boreholes & shallow wells	# of boreholes & shallow wells sampled	Total # of water carts	# of water carts sampled	Total # of trucks suppliers	# of trucks sampled
1	Korogocho	Ruaraka	12	2	4	1	40	4	5	1
2	Viwandani/ Kaloleni	Makadara	8	1	4	1	15	2	4	1
3	Kibera	Lang'ata	24	5	7	1	25	3	6	2
4	Kawangware/ Gatina	Dagoretti North	6	1	15	1	20	2	14	1
5	Kawangware/ Gatina	Dagoretti North	6	1						
6	Majengo/ Kiambiu	Kamukunji	7	1	8	1	30	3	8	1
7	Mathare	Starehe	7	2	5	1	40	4	10	1
8	Mathare	Mathare	7	1						
9	Ruaraka	Ruaraka		1						
10	Gitare Marigu/Njiru	Kasarani	6	1	18	2	30	3	12	1
11	Mukuru/Kayole Soweto	Embakasi South	30	5	12	1	80	8	7	1
12	Gitogoro	Westlands	4	1	4	1	12	1	2	1
	Total sample sizes		**107**	**12**	**77**	**10**	**292**	**30**	**68**	**10**

Source: Author (2023)

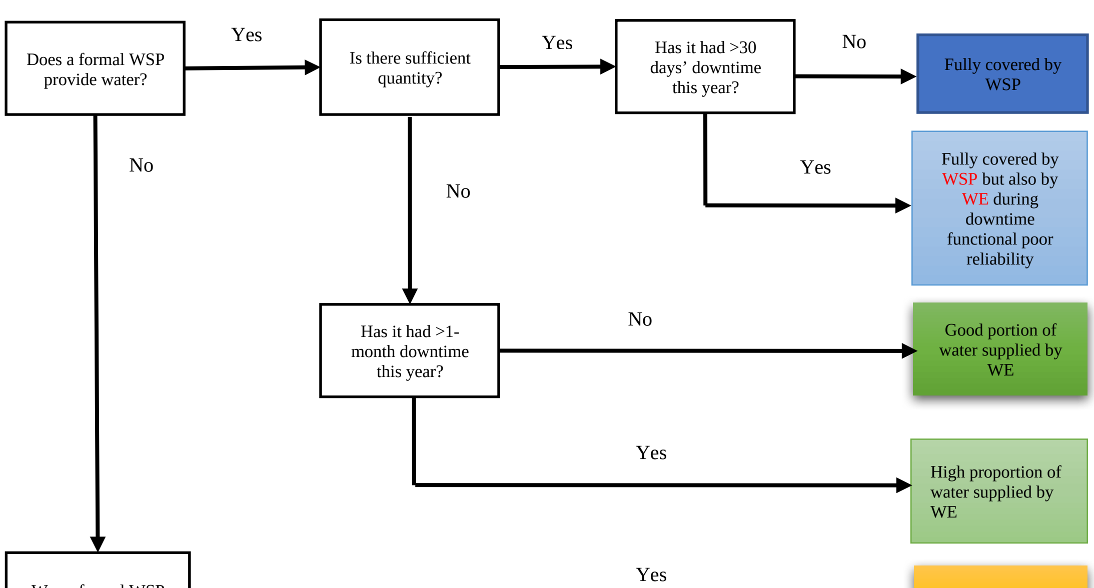
3.6. Sampling Frame

For both quantitative by use of household questionnaire and qualitative data targeting Key Informants and FGDs, the sampling frame was drawn from Nairobi County's informal settlements. This targeted the 12 Sub Counties including Dagoretti North, Dagoretti South, Embakasi South, Kamukunji, Kasarani, Kibra, Langata, Makadara, Mathare, Ruaraka, Starehe, and Westlands who house the main informal settlements in NCC. The sampling frame was drawn from the 2019 Kenya National Bureau of Statics (KNBS) Population and

Housing Census (PHC) enumeration areas (EA) as sampling units (SU). The KNBS has divided Nairobi into about 4700 EAs, of which 1263 are categorized as "EA5" or "informal settlements." EA5s are characterized by poor-quality sub-standard housing and poor infrastructure. A random sample of EAs was selected from the subset of 1263 EA5s falling within the nine informal settlements selected for study (Korogocho, Viwandani/Kaloleni, Kibera, Kawangware/Gatina, Majengo/Kiambiu, Mathare, Gitare Marigu/Njiru, Mukuru/Kayole Soweto, and Gitogoro) and weighted by population. The study also sampled the water utilities and vendors operating within the 12 Sub-Counties. The other key source of data was purposive sample of water points within the study area.

3.6.1. Cluster selection

To aid in sampling and selection of clusters to participate in interviews, the research developed a cluster selection tree that guided selection of a cluster given the varying levels of either formal or informal service provision. This helped in linking a household to the nature of service provision structure. Figure 3.4, formed the basis of linking the predominant water service provision structure and whether it is formal or informal. This categorization was important in identifying how each cluster performs against the water security characteristics.



Source: Author (2023)

3.6.2. Household Selection

A systematic sampling was followed during the field data collection. Households were selected using the household selection grid. Table CHAPTER THREE

MATERIALS AND METHODS.6

gives the sample of the households interviewed in each cluster.

Table CHAPTER THREE
MATERIALS AND METHODS.6: Sampling Frame for the 12 Sub-Counties

Sub County	Sub County Population	Estimated Slum Cluster Population	Proportion of Population (%)	Number of households to be sampled
Dagoreti North	133,504	24,899	18.65	18
Dagoreti South	160,718	7,281	4.53	30
Embakasi	663,211	60,684	9.15	66
Kamukunji	220,659	22,882	10.37	26
Kasarani	525,624	54,507	10.37	43
Kibra	212,261	13,606	6.41	27
Lang’ata	178,282	8,790	4.93	9
Makadara	160,434	7,909	4.93	15
Mathare	193,416	9,535	4.93	19
Ruaraka	283,449	42,404	14.96	89

Starehe	159,709	37,723	23.62	18
Westlands	247,102	18,236	7.38	28
Totals	**3,138,365**	**308,456**	**100**	**388**

Source: KNBS 2019 Population Census

Within each sampled enumeration area, the field team identified a starting point. Typically, this was a street or a conspicuous landmark. Upon identifying the starting point, the interviewer randomly selected the first household to be interviewed. Guided by the left hand (anti-clockwise) rule, skip interval and successful interviews, the interviewers were then randomly picked subsequent households to be interviewed in that area. The skip interval was determined based on population density but a conservative interval of five households were used. For flats, only one interview was conducted per flat. In instances where the household head was not available at the time of the visit, the household was substituted with the next immediate household restarting the skip interval. A two-stage cluster Sampling was used with distribution based on population proportional to size (PPS).

3.7. Data Collection and instruments

The data collection sought to obtain both quantitative and qualitative data from both primary data and secondary data sources using methodological triangulation approaches. These approaches included a mix of Focus Group Discussions (FGD), Key Informants Interviews, and secondary data review form. The purpose of collecting the secondary data was to: designate physical boundaries, establish data gaps and sources of key informants, to help in review/design of the primary data collection tools (household questionnaires), to provide and establish the reliability of existing data and comparison and collation. This included data on the physical characteristics of the area, social-economic characteristics, population characteristics and distribution, institutional arrangements in place, environmental issues including water and sanitation, NGOs and other stakeholders implementing water and sanitation programmes, and institutional elements of the area. The following tools were used to collect data for the study.

3.7.1. Household Questionnaire

The researcher designed a household questionnaire capturing essential questions in line with the research objectives. This questionnaire was used to collect quantitative data and therefore used close-ended questions giving the interviewees options to select from. The use of questionnaires was for collection of descriptive data on views and perceptions of respondents. The information collected by this tool included the household demographics, the source of water or service provider, the structure of service, the tariff or payment system if any, information flow and any existing alternative water sources, the water availability, access, quantity, quality, price and reliability.

3.7.2. Focus Group Discussions

Focus Group Discussion (FGDs) helped provide new information and additional data with regard to the research objectives. The rationale of including this instrument was its strength in providing rich qualitative data and ability to provide information that may not be covered by the other instruments and also to provide further insights into data obtained from other instruments. Selection of those to participate was purposively done based on age, gender, diversity, and membership to community groups etc. Participants were therefore a cross-section of people including water users, water vendors, Community Based Organizations

(CBOs) members, NGOs, and local leaders. For each type of organization appropriate open-ended questions were developed. The tool was used to collect information about ownership, capacity of various WSPs, opportunities for collaboration, representation or decision-making and any market challenges. The information was used to examine opportunities for water service integration. A total of nine (9) FGDs were conducted targeting the major informal settlements.

3.7.3. Key Informant Interview

There was a face-to-face interview with key informants on the collaboration of formal and informal water service providers for water security in the informal settlements in Nairobi. Other key informants to be interviewed include community leaders, committees, project staff, relevant ministries, and representatives of partner organizations. A structured interview schedule was designed to guide the interview during a face-to-face interaction with the potential Key Informants (KI). The KI was sampled through purposive sampling in order to identify stakeholders operating water service provision in the informal settlements in Nairobi. Information obtained from this instrument was focused on ownership and management of the WSP, the structure of the WSP, their area of coverage, policies of the WSP, the cash flows based on water sales and operation and maintenance, any innovative approaches deployed in service provision in the INSEs, and any collaborations exercised by the WSP. Overall, the information helped in the understanding of some of the existing opportunities or informal integration practiced by the WSPs.

3.8. Reliability and Validity of the Instruments

To establish the reliability and validity of the data instruments, a pilot survey was conducted in Roysambu sub-county slums to ensure clarity and proper interpretation of the questionnaires and interview schedules by the potential respondents. Mugenda & Mugenda (2003), posits that pilot survey is crucial in capturing comments and suggestions from respondents which, later enables the researcher to improve the instruments and adjust data collection approaches to maximize response rate. This therefore ensured that data collection instruments are reliable and valid.

Validity sought to comprehensively determine if the results matched the research goals. Regarding validity, the study examined construct validity: Does what the test is trying to measure get measured? Content validity: Is what the exam attempts to evaluate accurately represented by it? Face validity is the test's material seeming to be appropriate for its goals. Validity criteria: Are the results a good reflection of the specific outcome they are intended to quantify?

On the other hand, reliability measured consistence of the data collected (Saunders, *et al.*, 2007). Statistically, the research used internal consistency through a split-half reliability test by use of the Cronbach Alpha method. The reliability of all the items opinions was calculated for all the five sub-scales in the questionnaire as shown in Table CHAPTER THREE

The findings from this table showed that the questionnaire items were very suitable for data collection with Cronbach's Alpha values > 0.7 and thus they measured the constructs which they were supposed to measure.

Table CHAPTER THREE
MATERIALS AND METHODS.7: Cronbach's Alpha Reliability Test Results

Reliability Statistics

Scale	**N of Items**	**Cronbach's Alpha**	**Conclusion**
V1	9	.884	Reliable
V2	35	.815	Reliable
V3	17	.838	Reliable
V4	19	.853	Reliable
V5	10	.816	Reliable

Source: Author (2023)

The pilot study was conducted in one of the informal settlements. This included following the sampling agreed upon. Before testing the research instruments, a consent was sought from the respondents to ensure research ethics were adhered to. The purpose of the pilot study was to help evaluate the completeness and accuracy. Therefore, the pilot helped address the followings aspects: (1) whether each question and section of the questionnaire was well understood; (2) the terms or words used in the instruments are appropriate; (3) if there are any clarifications sought by the respondents; (4) the convenience or inconvenience in terms of time reported by the respondents. The selection of respondents for the pilot followed the sampling procedure designed for each data collection instrument. Upon completion of the pilot, the questions, their flow, and their relevance was reviewed based on the feedback of the respondents and a final tool developed.

3.9. Data Analysis

Household survey quantitative data was analysed using the statistical software for social scientists (SPSS) version 27.0. There was a descriptive analysis of the produced quantitative data. Descriptive statistics was the study of data organization and summary. Using frequency distribution and percentages, the analyzed data was displayed. Developing frequency distributions, computing percentages, and properly tabulating them is the most often used approach of reporting descriptive surveys (Gay et al., 2011).

Three phases were followed in processing and analysing the qualitative data obtained from focus group talks, observations, and key informant interviews. Data were initially arranged and summed up according to the thematic areas. Preliminary report production required a description of the summary sheets as the second phase. The preliminary report was methodically analyzed and interpreted in the third stage, and the quantitative data were included into the final report. Other methods that were used in analysis of raw data included use of computer software like GIS and RS for spatial analysis.

A summary of data analysis as per objective has been provided in Table CHAPTER THREE

Table CHAPTER THREE
MATERIALS AND METHODS.8: Summary of Data Analysis

Objective	Measurable Variable	Sample Size	Sampling Strategy	Data analysis
1. To assess the water security characteristics of existing water	Availability Access Quantity** Quality	388	Simple random sampling	The unit of analysis is the households. To assess water security characteristics, in various informal settlements, two

service provision systems in informal settlements within Nairobi County.	Affordability Reliability			levels of statistical analysis was undertaken. Descriptive statistics to measure frequencies, central tendency, variations, and position of water security parameters (availability, access, quantity (national and sphere standards), cost, quality, reliability, and affordability). The second level of analysis was inferential statistics through a Chi-square test to measure variation between various groups of informal settlements. Association between various independent variables and water security. Interpret P- values to measure level of significance of the specific independent variable on water security.
2. To examine the different existing structures (production, treatment, storage, and distribution) of water service provision systems against water security in informal settlements within Nairobi County.	Production, Treatment, Storage, and Distribution	388 HHs 12 kiosks 10 boreholes 30 water carts 10 water trucks	Simple random sampling	The unit of analysis in this objective was the households or water users/customers. This was undertaken by a **logistical regression** to assess household water security based on existing water service provision structure. A household is either water secure or water insecure (dichotomous).
3. To evaluate water service provision system integration approaches on water security in informal settlements within Nairobi County.	Structural Functional	12 kiosks 10 boreholes 30 water carts 10 water trucks NCWSC Informal Sector	Cluster sampling to choose water service provider categories. Systematic sampling to choose participating provider.	The unit of analysis was the water service providers (formal WSPs, private WSP, informal WSPs, water vendors, water kiosk owners). Chi square analysis of various water service providers integration approaches or a combination of services versus water security. On the other hand, a logistic regression was also undertaken to assess which integration

				approach, or a combination of approaches leads to either water security or water insecurity. Arbitrary scores were attached based on the level of service with no service, 0; basic service, 1; intermediate service, 2; and optimal service, 3.
4. To develop a system dynamics model for integrating water service provision that addresses water security in the informal settlements within Nairobi County.	Production Treatment Storage Reticulation	SD Model	Case of Nairobi County INSEs	The process here was building a system dynamic model made of three sub-models (population submodel, informal water supply submodel and formal water supply submodel). The inputs were the analysis results from objectives 1 to 3 and undertaking simulations using Vensim PLE version 10.2.2. Qualitative data analysis was undertaken in line with key themes associated with water security.

Source: Author (2023)

3.10. Data presentation

Qualitative data sets from FGDs and KIIs was analysed through thematic analysis and narrative analysis. On the other hand, the quantitative data was analysed using SPSS latest version. The analysed information was presented in tables, charts, bar graphs for quantitative data and in form of narrative reports for the qualitative data collected from the focus group discussions and key informants.

3.11. Ethical Consideration

The researcher obtained approval of the proposal from the Directorate of Postgraduate Studies (DPS) of Masinde Muliro University of Science and Technology, which served as a clearance to proceed with data collection. This then followed a research permit from

National Commission of Science, Technology, and Innovation (NACOSTI) and an authorization from County Commissioner, Nairobi to collect data from the sub-counties of interest. Last but not least, an oral consent was sought from the respondents for both households, FGD and KII participants. The respondents were informed on their rights to (decline) to participate in the research without coercion of intimidation, or incentive. The research assistants were debriefed on the research process and its purpose. The researcher also ensured that data was stored confidentially without names or personal attributes and only used for academic purposes (Rivera et al., 2003).

3.12. Assumptions of the Study

The study made the following assumptions:

i. The study presumed that there existed both formal, informal and a mixed pool of agents of water service providers in the informal settlements in Nairobi County.

ii. There existed water challenges based on availability, access, quantity, quality, affordability, and reliability.

iii. There existed potential integration practices by water service providers that could lead to water security in informal settlements in Nairobi County.

iv. The study presumed that all data sought from households, water service providers, the KIIs and FGDs would be available.

3.13. Limitation of the Study

The research oversaw the following limitations:

i. **Physical access to the informal settlements was a great challenge during the data collection based on the structural inaccessibility of the household.** Informal settlements can be challenging for people living in other well-planned areas because of their sanitary challenges. The researcher addressed this limit in two ways: one was to give research assistants proper briefing on the situation and involving them in the pretesting exercise giving a recce exposure to the situation before the main data collection. This also ensured that the research assistants were appropriately dressed to manage the challenges. Number two, the researcher had a mix of research assistants from informal settlements who understood the environment to help guide the rest of the team.

ii. Inadequate information from the informal water providers in fear of victimisation. The researcher addressed this limitation by ensuring that the respondents understood that research ethics were followed as spelled above and therefore building confidence to share information. Equally, information collected was triangulated against the quantitative data collected through household questionnaires, Key Informant Interviews, Focus Group Discussions, and secondary data.

CHAPTER FOUR

WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY

4.1. Introduction

The chapter sought to assess water security characteristics of existing water service provision systems in informal settlements within Nairobi County. The chapter starts with the household characteristics of the respondents. The characteristics analysed includes; gender, age of respondent, education level, income levels of household head, employment status, main source of income, length of stay of respondent in the current location and where the respondent came from.

Research has demonstrated that factors of the home influence water access and, thus, water security. According to research by Zambrano-Monserrate et al. (2024), in Ecuador, a developing nation, there are a number of factors that affect a family's ability to get clean water, including the family's income, the level of education of the head of the household, the type of housing tenure, the water supply and source, the family's location (urban or rural), and the surrounding natural environment.

The data was collected from all the sampled households in the 12 sub-counties targeting informal settlements. As shown in Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.17, the GPS locations of households where data was collected was captured.

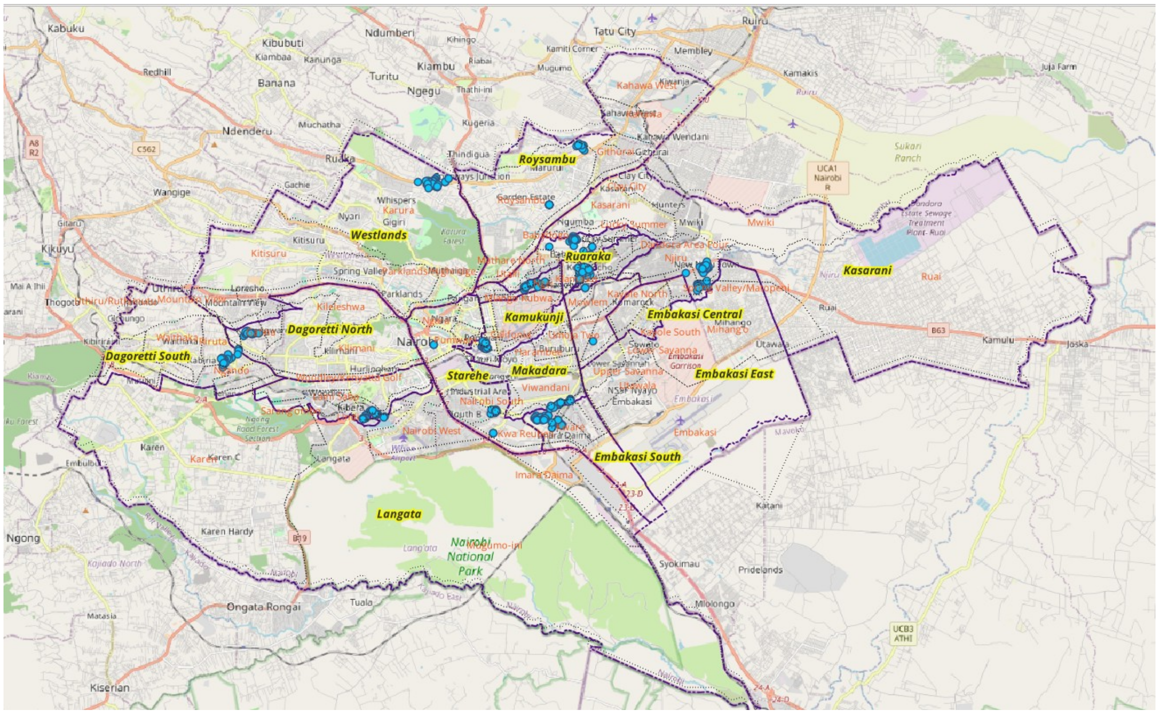


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.17: GPS Locations of Households Respondents

Source: Author based on field data, 2023

4.2. Background Characteristics of Households

4.2.1. Sub-county residence of household head

The study distributed the respondents into the various sub-counties in Nairobi County. From the findings in Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.18, found that 22.9% of the respondents were from Ruaraka sub- County followed by 17.0% from Embakasi south. The other respondents were; 11.1% Kasarani, 7.7% Dagoretti south and 7.0% Kibra, 6.7% Kamkunji, 7.2% Westlands, 4.6% Starehe, 4.6% came from Dagoreti North, 3.9% were from Makadara, 4.9% from Mathare, 2.3% were from Langata.

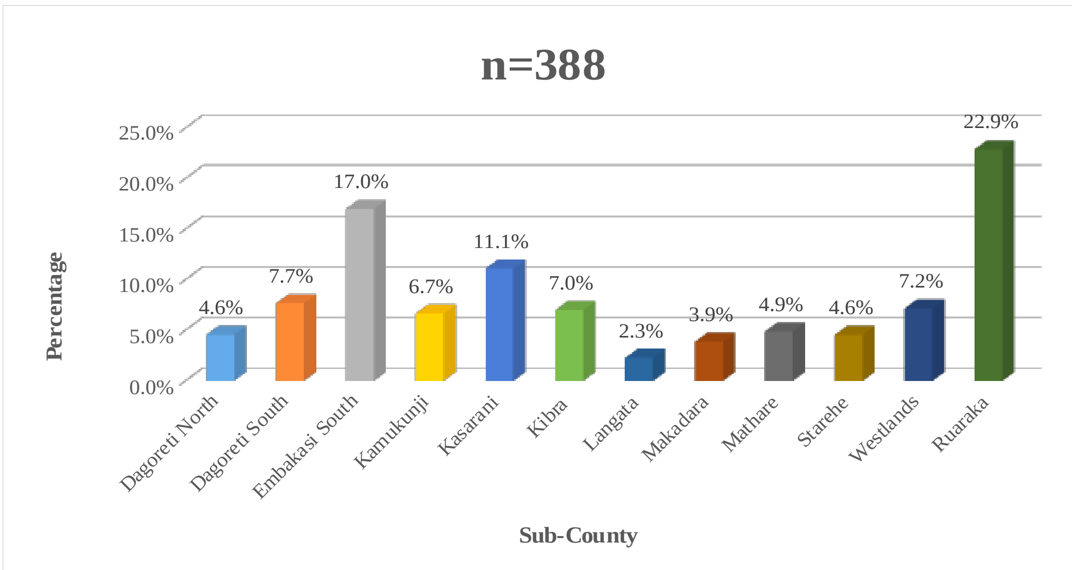


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.18: Sub-County distribution of respondents

Source: Field data, 2023

Spatial analysis based on geo-political factors is an important aspect in understanding water security. For instance, Puranik et al. (2021) found significant spatial water access disparity in districts in India. Spatial analysis is important as it can be used in locating the areas that lack access to improved sources of drinking water and can therefore help inform targeted intervention (Puranik et al., 2021).

4.2.2. Gender of respondents

The study analysed the various variables of the respondents' background characteristics. From the findings (Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.19), the study found out that majority of the respondents were females 275 (71.0%) while the men were 113 (29.0%). This aligns with a research in Kitui County by Bukachi et al. (2021) which finds that women are the primary water collectors in households and rely on social capital during hard times, particularly in the dry season. When it comes to choosing a water source for the family, males in male-headed homes mostly depend on their financial means and sometimes on friendship. It is then the responsibility of the women to regularly gather water for their homes. A different study by Wambugu (2021) revealed that women made up the majority of the responders, followed by men. Additionally, a study by Kimeu (2022) found out that there were more females that males who participated in the study which involved issues of water quality in the households. According to Geere & Cortobius (2017), water collection is more typically described as a woman's responsibility in both rural and urban locations in Sub-Saharan Africa.

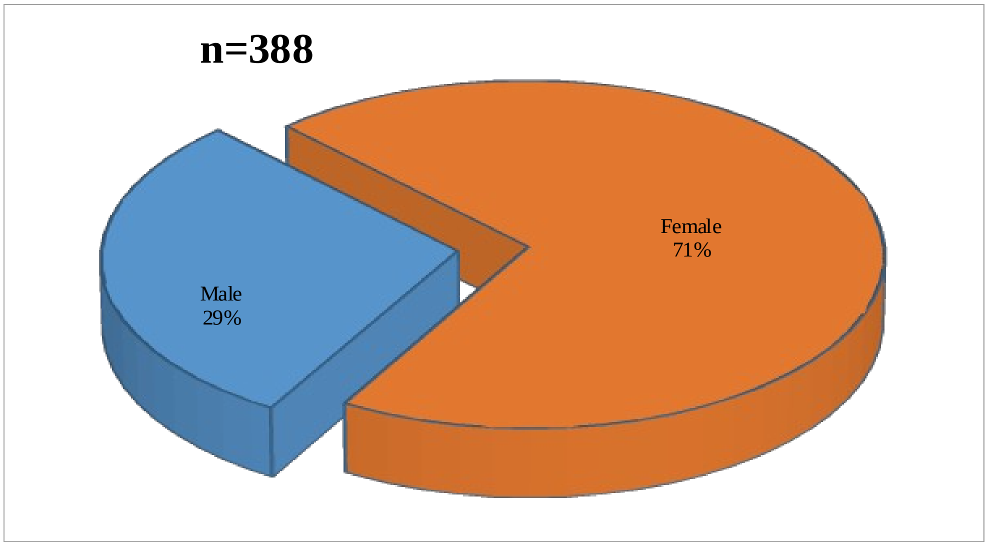


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.19: Gender distribution of respondents

Source: Field data, 2023

4.2.3. Age of respondents

The study also established the age bracket of household heads. From Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.20, 50.5% of respondents were between 18-35 years whole 47.2% were 36-64 years. Only 2.3% of the respondents indicated that they were above 65 years. This was an indication that, there are more youthful population living in informal settlements, with very few elderly people. This could be the case because, informal settlements present social and environmental challenges that elderly people may not cope with.

When calculating one's level of water security, age plays a significant role. The most likely demographic to have access to both individual and combined basic WASH services was those whose heads of home were 30 and older, female, and educated (Gaffan, 2022).

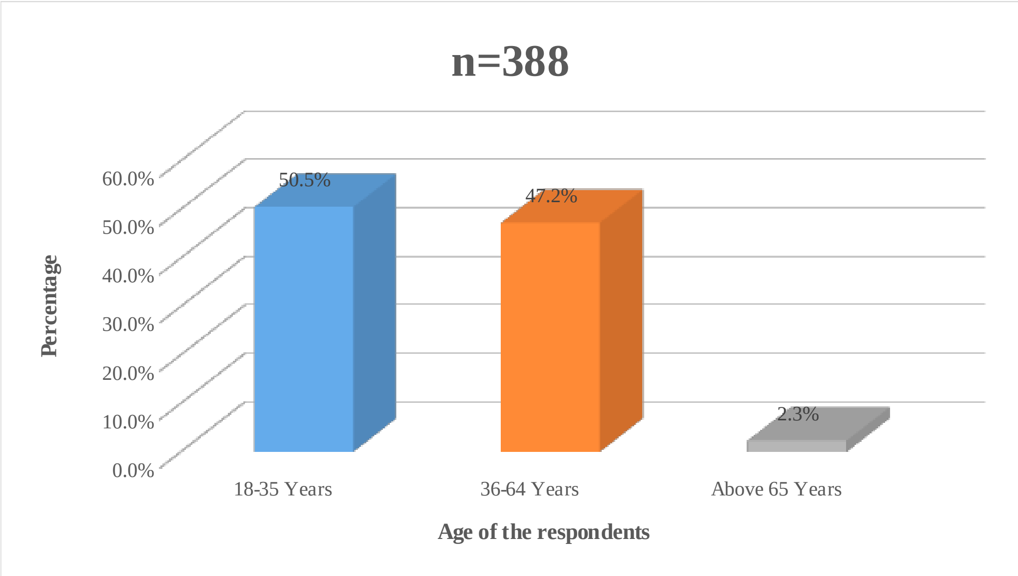


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.20: Age of respondents

Source: Field data, 2023

4.2.4. Level of education of household head

In terms of the level of education of the respondents, Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.21, the study established that 131 (33.8%) had completed the secondary education then followed by those 88 (22.7%) who had completed primary education. This showed significantly low levels of education compared to the national average of 2019 with 49.8% completed primary and 24.5% completed secondary education respectively (Cowling, 2023). A study in Benin by Gaffan et al. (2022), found that household water access increased significantly with the level of education of the household. In this study therefore, the significance of the level of education attained shall be measured to see how it impacts the various water security parameters.

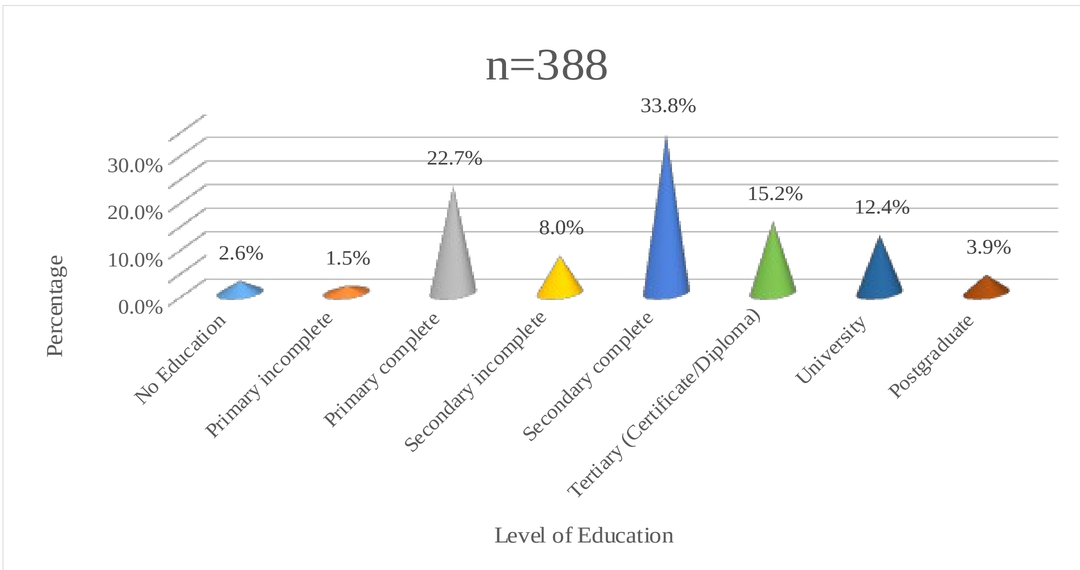


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.21: Level of education of respondents

Source: Field data, 2023

4.2.5. Employment status of household head

The study established the employment status of household head in the study area. From Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN

INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.22, those who were not employed were 99 (25.5%), employed salaried 53 (13.7%) employed casual labourer 82 (21.2%), self-employed 152 (39.2%) and Student 2 (0.5%).

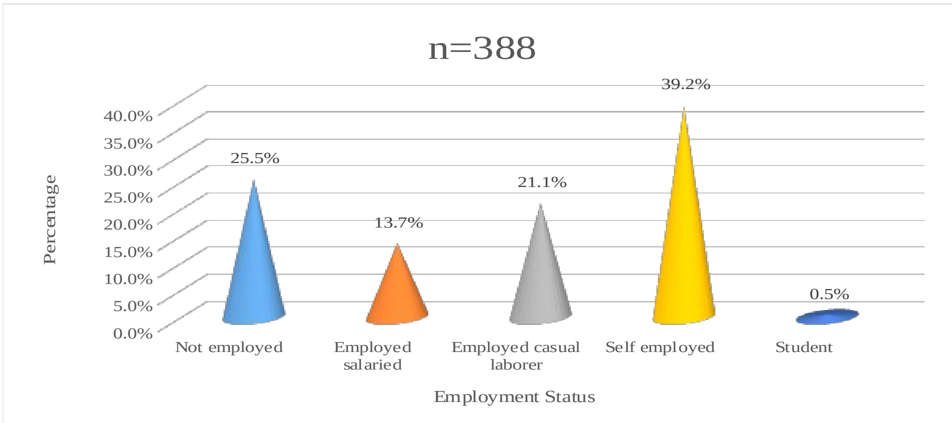


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.22: Employment status

Source: Field data, 2023

4.2.6. Monthly income of households

The researcher asked the respondents to state their monthly income. From Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.23, the findings indicates that 12% of them had income of between KSh. 23,671 to KSh. 119,999 while 88% had income less than KSh. 23, 670.

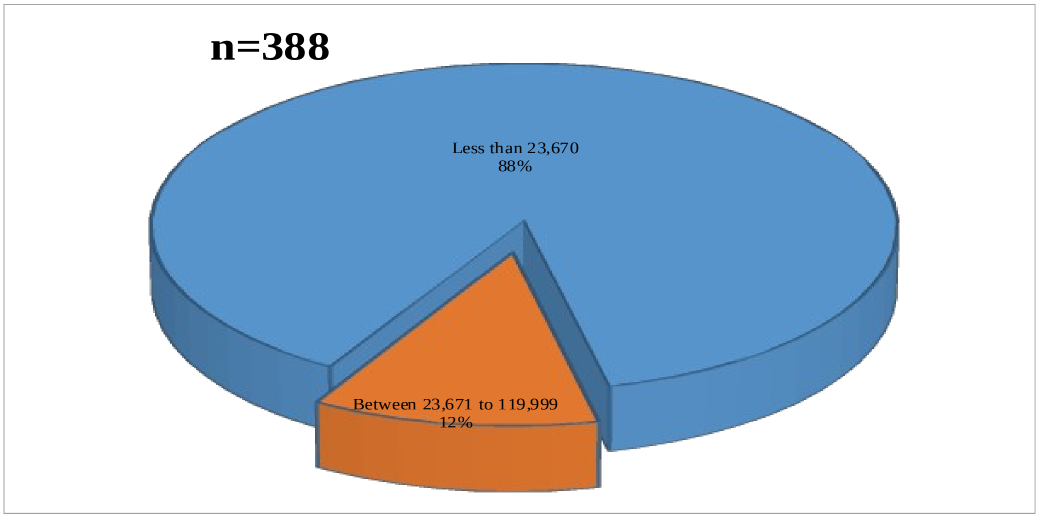


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.23: Monthly income of household head

Source: Field data, 2023

Accordingly, this shows that a majority (88%) of people in the informal settlements fall within the lower income category who earn a monthly income of KSh. 23,670 and below. A lower percentage of households, 12%, in the informal settlements are in the middle income category with a monthly income of between KSh. 23,671 to KSh. 119,999. No household interviewed (N=388), reported being in high income category with KSh. 120,000 and above. This findings agree with the categorization of informal settlements in Nairobi as LIAs.

4.2.7. Main source of income of household head

The study established the main source of income of household head. From the findings, Aid/Cash transfer 2 (0.5%), Formal employment 47 (12.1%), Remittance from relatives 15 (3.9%), Small scale trade 199 (51.3%), Wage earner 125 (32.2%) (Figure CHAPTER FOUR WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.24).

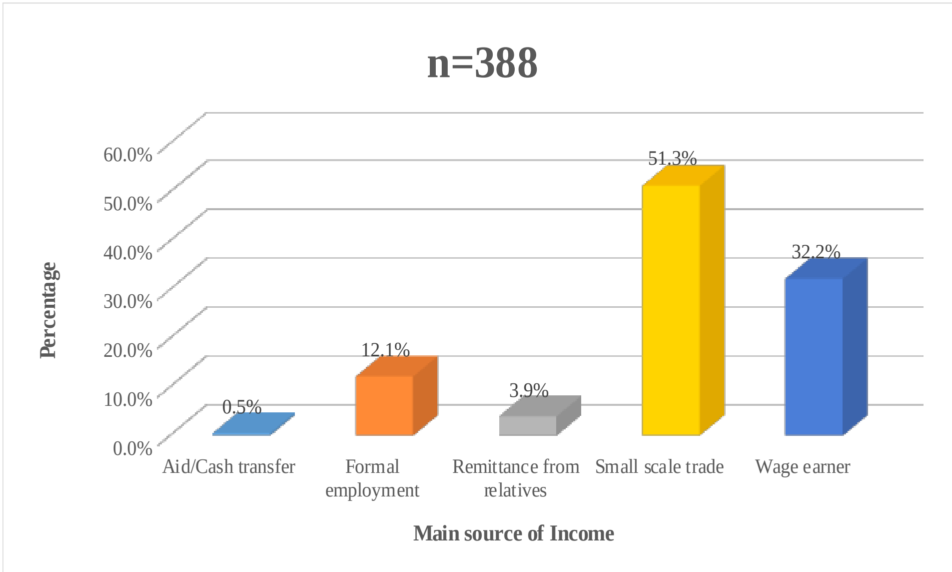


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.24: Main source of income

Source: Field data, 2023

A majority of people living in Nairobi's informal settlements depend on the informal sector as source of household income. This therefore means that they get their income in a very irregular basis (daily, weekly, months) and in most cases very uncertain as it depends on the performance of the informal sector. They accordingly prefer to pay for services including water, in a manner that is convenient to them. A Pay-As-You-Go (P.A.Y.G) model works better for them and this will largely define the water security they experience in their households.

4.2.8. Length of stay of respondents

The research sought to find out the length of stay of the respondents in the current location. As shown in Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.25, a majority of those households interviewed, 310 (79.7%) had lived in their current informal settlement for more than two years; while those who had lived between one and two years were 33 (8.1%), between six months and one year represented 3.4%; 3-6 months were 5.4% and less than 3 months were 3.4%.

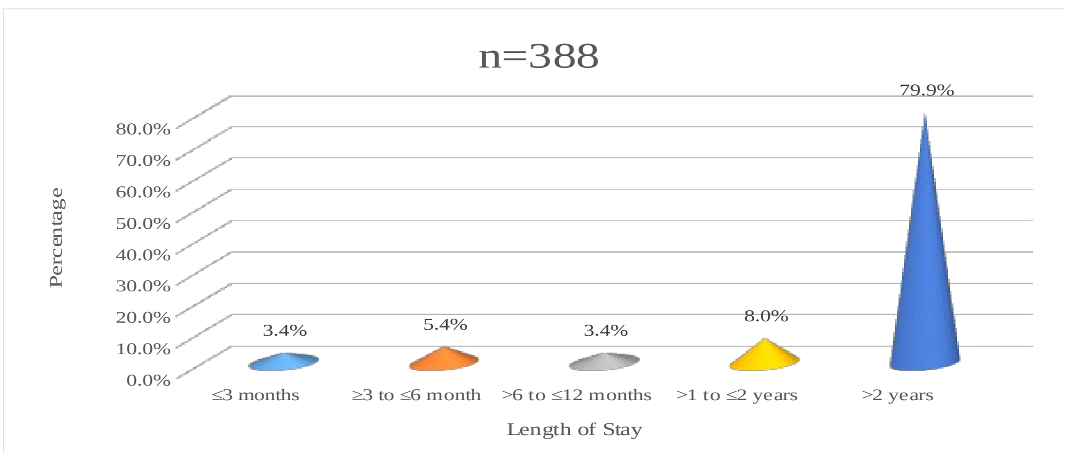

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.25: Length of stay of respondent in the area of residence

Source: Field data, 2023

It is expected that, if people lived longer in a specific area, there could be reliability of water services and vice versa. A study conducted by Kuhn & Ciobanu (2013), in Istanbul Turkey, showed that, the city became unattractive when water stress increased. But there could also be other determining factors such as availability of housing, the general cost of living or proximity to their employer.

4.2.9. Where the respondent came from

The question on where the respondent came from to the current residing location, 159 (41.0%) indicated that they had come from another urban area other than Nairobi while 95 (24.5%) of them had moved from another informal settlement within Nairobi County. Those who had moved from a rural area and were born there were 61 (15.7%) and 63 (16.2%) respectively (Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.26).

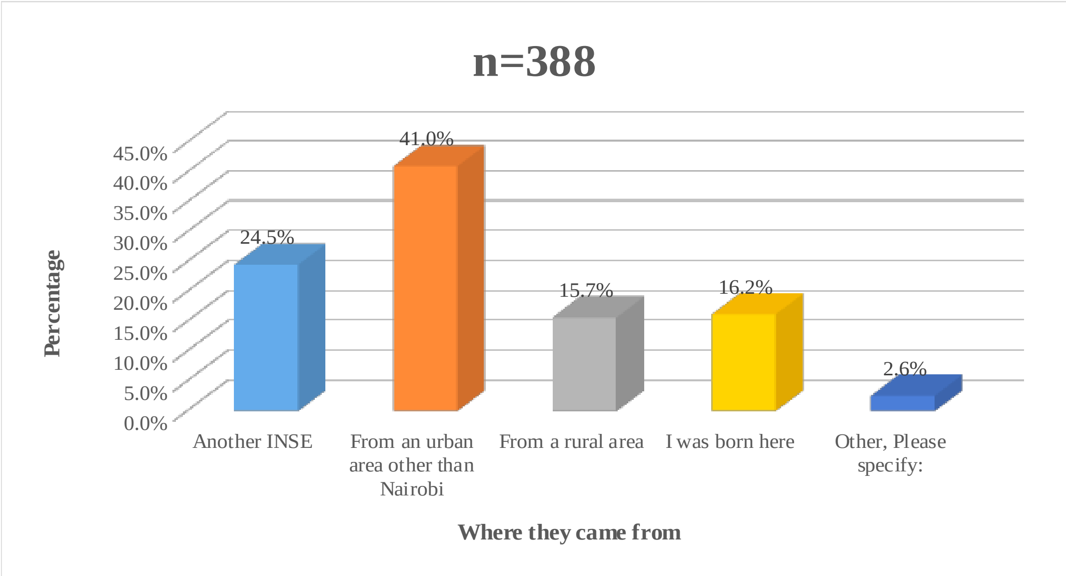

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.26: Where respondents migrated from

Source: Field data, 2023

According to Beguy et al., (2010), high circular population movements in Nairobi's informal settlements was due to the insecurity of livelihoods, land tenure, and poor basic amenities and social services characteristic in the slum settlements. It was found that migration was more intense for the age bracket of 20 to 24 year, but it was also seen to be more intense among women compared to men.

4.3. Water Sources

The study sought to determine the sources of water for the respondent. The findings indicates that the main sources of water obtained from a water kiosk at 132 (33.9%). Those who shared water connection next to their dwelling at 114 (29.3%) followed this. Those who shared a plot connection were 43 (11.1%). The least source of water used in the study area was the rainwater harvesting which was at 2 (0.5%). The other sources that were used included; water from a private borehole or well 23 (6.0%), water from a public borehole or well at 22 (5.8%), water obtained from individual piped water connection 19 (4.8%), water from a hand-cart vendors at 11 (2.9%) and water from a private water tanker at 9 (2.2%) (Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.27). Ochungo et al. (2019) reported the results of their investigation into the consequences of irregular water supply in metropolitan areas. The research region of vendor water cost in Langata sub county, Nairobi City, Kenya, revealed that the utility water company supplies 90% of the water demands of homes. More than 90% of the population is reliant on water tankers and bottled water supply at the same time due to the deficit.

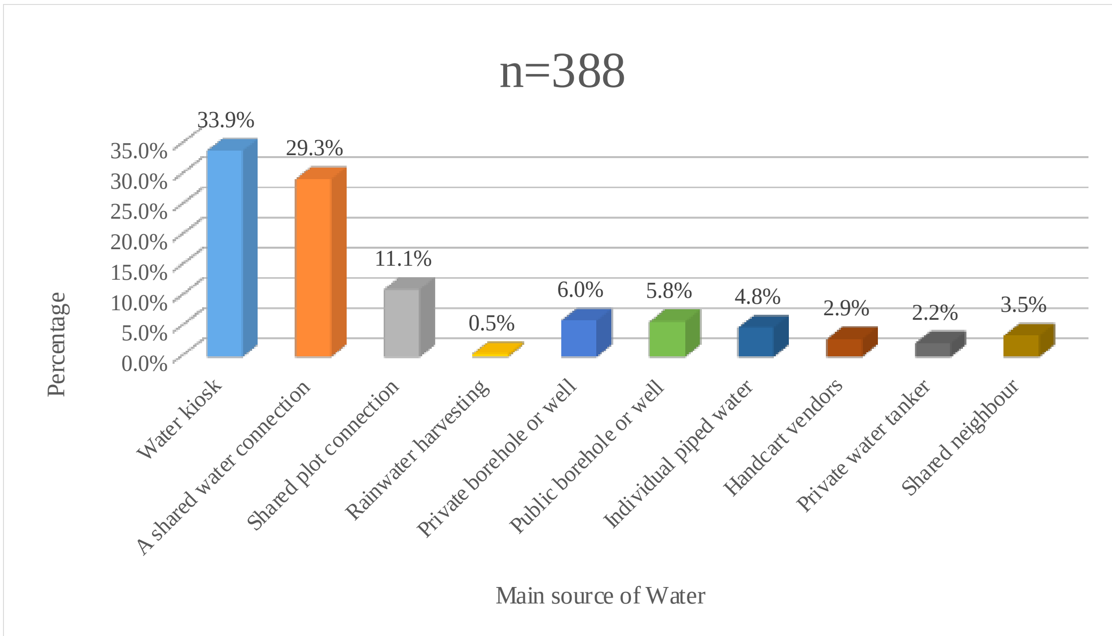

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.27: Water sources in Nairobi County

Source: Field data, 2023

Ondigo et al. (2018) states that the people living in informal settlements in Kisumu city face the biggest challenge due to the poor and often unpredictable water delivery. These locals acquire their water supply from a variety of sources, including private wells, public water mains, boreholes, springs, and unregulated vendors. Since tap water in Kisumu city might be polluted and harmful to humans, there is no way to know for sure if it is safe to drink from the faucet. This led to the widespread use of water dispensers and bottled water. Additionally, 60% of the families surveyed in Adams's (2018) "Thirsty slums in African cities: household water insecurity in urban informal settlements of Lilongwe, Malawi" relied on pooled water from communal kiosks. Private or neighboring taps accounted for 11% of all water sources, making them the second most prevalent. Household taps or shared compound taps were available to only 9.3% of houses. As a whole, 37% of homes did not use the common water kiosks but instead relied on a neighbor's tap, a compound tap, a protected well, or a borehole. Despite the fact that elevated water sources were available to 91% of homes (Adams, 2018).

It is therefore shows that, dependency on multiple water sources could be a common phenomenon in INSEs in many cities across Africa. This multiplicity is driven both by demand from the people living in the INSEs; but also due to supply deficit identified by informal water service providers who seek to bridge the gap with alternative sources.

4.4. Water Availability

Water availability is defined as presence of water flow from their main source, at the time of the survey of household members participating as a respondent in this interview. The objective set to assess the water security characteristics of existing water service provision systems in informal settlements within Nairobi County.

4.4.1. Water availability Sub-Counties

The study sought to determine the water availability per sub-county within Nairobi County. As the results inTable CHAPTER FOUR

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.9, indicate, the analysis showed that there was no Sub-County with universal water availability. Household water availability ranged between 10.5% being the lowest (Mathere Sub-County) and highest was 68.7% (Makadara sub-county). Further, from the Chi-Square analysis ($\chi^2_{12,0.05}$=59.784, $p<0.05$) showed that there was a strong association between Sub-County setting and the water availability. Additionally, Mathare sub-county was the leading with water not readily available as indicated by 17 (89.5%) respondents while Makadara sub-county had the least with water not readily available as indicated by 5 (31.3%) respondents.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.9: Water availability versus Sub-County

		Not Readily available		Readily available		Total		
		F	%	F	%	F	%	X^2
Sub-County	Dagoretti North	12	66.7	6	33.3	18	100.0	
	Dagoretti South	13	41.9	18	58.1	31	100.0	
	Embakasi South	28	41.7	39	58.3	67	100.0	
	Kamukunji	22	80.8	5	19.2	27	100.0	
	Kasarani	17	40.0	26	60.0	43	100.0	
	Kibra	10	37.0	17	63.0	27	100.0	
	Langata	8	80.0	2	20.0	10	100.0	59.784
	Makadara	5	31.3	10	68.7	15	100.0	(**0.001**)
	Mathare	17	89.5	2	10.5	19	100.0	
	Ruaraka	62	73.1	22	26.1	84	100.0	
	Starehe	6	31.6	13	68.4	19	100.0	
	Westlands	10	35.5	18	64.5	28	100.0	
	Total	**210**	**53.4**	**178**	**46.6%**	**388**	**100.0**	

Source: Field data, 2023

4.4.2. Water availability and level of education

The study established the relationship between water availability and the level of education of the household heads. As shown in Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.28, the results shows that those with water not available was; no Education 4 (45.5%), Primary incomplete 0 (0.0%), Primary complete 41 (46.2%), Secondary incomplete 22 (70.6%), Secondary complete 72 (54.5%), Tertiary (Certificate/Diploma) 28 (46.8%), University 29 (58.8%) and Postgraduate 10 (62.5%). On the other hand, those with water readily available was; No Education 6 (54.5%), Primary incomplete 1 (100.0%), Primary complete 48 (53.8%), Secondary incomplete 9 (29.4%), Secondary complete 60 (45.5%), Tertiary (Certificate/Diploma) 32 (53.2%), University 20 (41.2%), and Postgraduate 6 (37.5%). From the chi-square computed ($\chi^2_{7,0.05}$=9.679, $p>0.05$), it was established that there was no association between education level of the respondent and water availability.

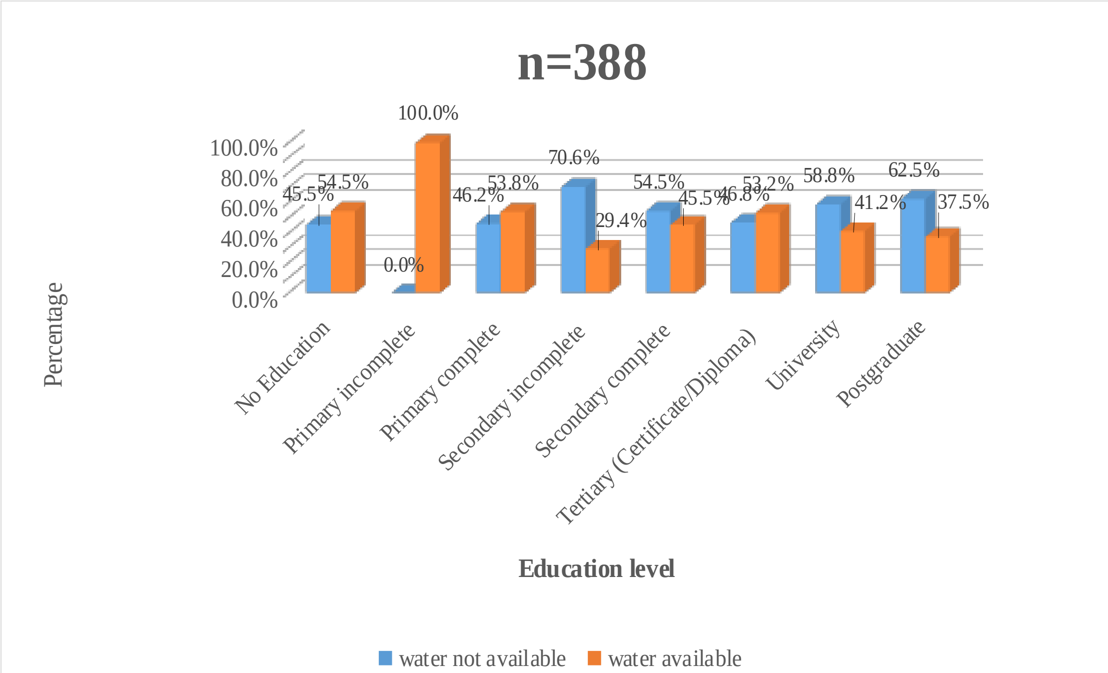

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.28: Water availability versus highest level of education of the household head

Source: Field data, 2023

4.4.3. Water availability and employment status

The study established the relationship between water availability and the employment status of the respondents. As shown in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.29, the results shows that those with water not readily available was; not employed 51 (51.4%) employed salaried 26 (50.9%), employed casual labourer 49 (60.5%), Self-employed 80 (51.5%) and Student 1

(50.0%). On the flip coin, those with water readily available was; Not employed 48 (48.6%), Employed salaried 25 (49.1%), Employed casual labourer 32 (39.5%), Self-employed 75 (48.5%) and Student 1 (50.0%). From the chi-square computation between water availability and employment status of the household head, it was established that there was no significant relationship between the two variables. The chi-square value was ($\chi^2_{4,0.05}$=2.261, p>0.05).

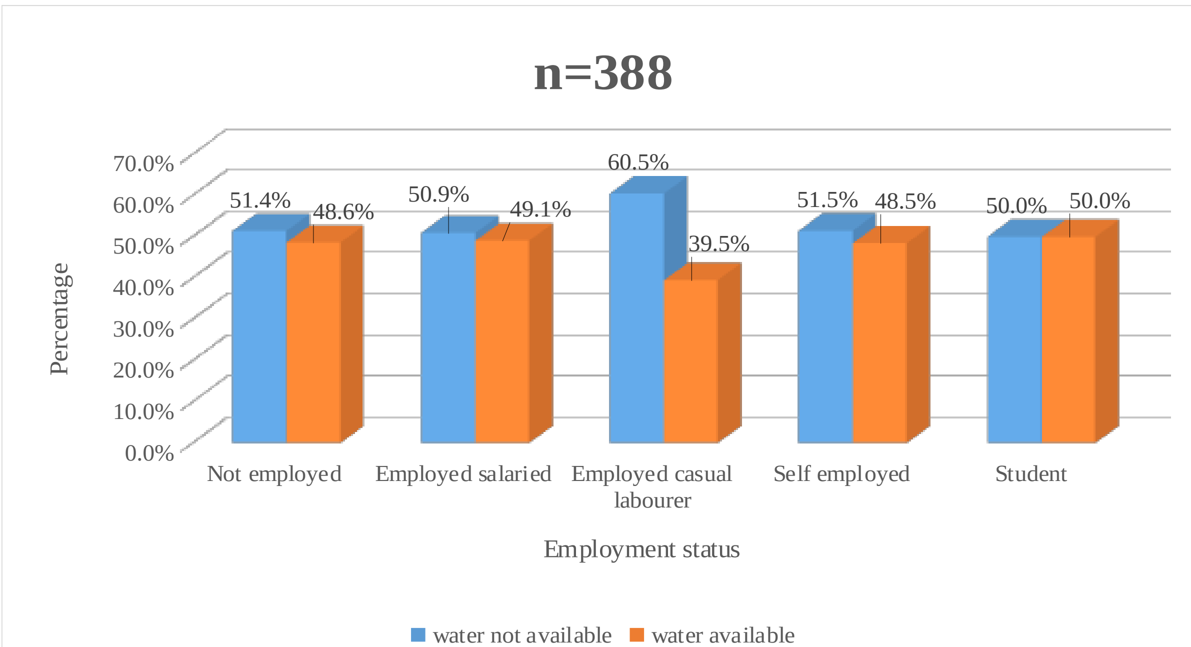

Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.29: Water availability versus employment status of household head

Source: Field data, 2023

4.4.4. Availability versus monthly income of the household

The study sought out to determine the relationship between water availability and the monthly income of the household in Kenya Shillings. From the Figure CHAPTER FOUR

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.30, it can be observed that those that earn Less than KSh. 23,670 and did not have water readily available were 186 (54.4%) and those earning between KSh. 23,671 to KSh. 119,999 and did not have water readily available were 22 (48.0%). A chi-square computation was carried out to determine whether there is any significant association or not. From the computation, it was established that there was no significant relationship between the two variables ($\chi^2_{1,0.05}=0.714$, $p>0.05$). This means that the monthly income of the household does not mean that the household will have water available in their houses.

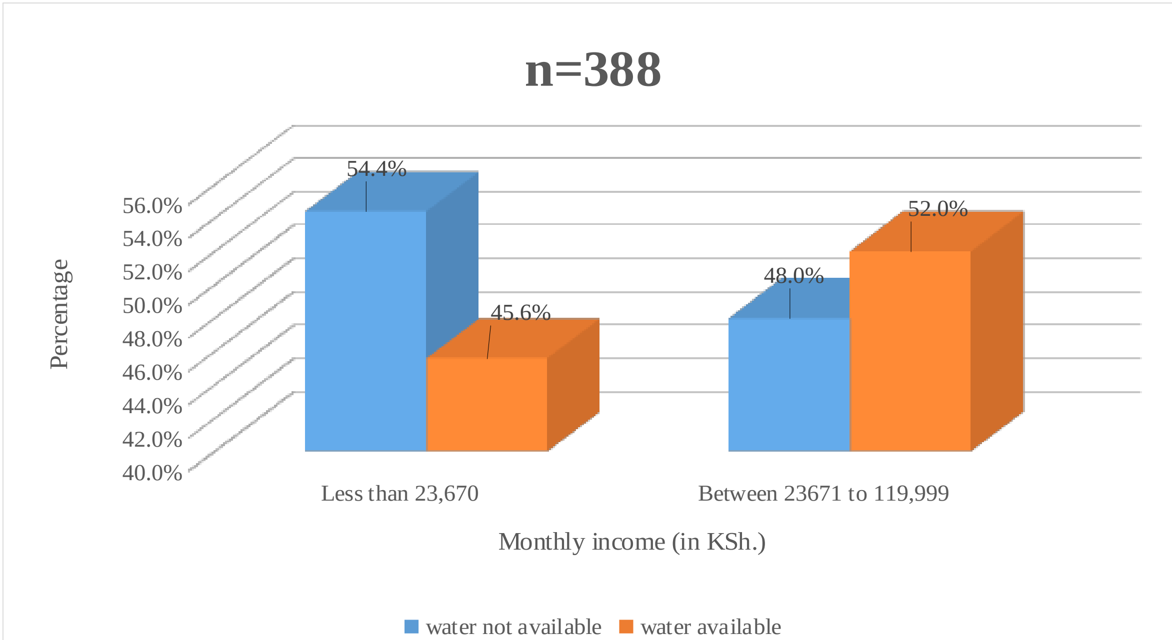

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.30: Water availability versus monthly income of the household head

Source: Field data, 2023

4.4.5. Availability and main source of income

The study established the relationship between availability and the main source of income. From the findings shown in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.31, those with no water available was, Aid/Cash transfer 2 (100.0%), Formal employment 16 (38.0%), Remittance from relatives 6 (35.3%), Small scale trade 120 (60.5%) and Wage earner 63 (50.4%). On the other hand, those with water availability were; Aid/Cash transfer 0 (0.0%), Formal employment 30 (62.0%), Remittance from relatives 11 (64.7%), Small scale trade 78

(39.5%) and Wage earner 62 (49.6%). A chi-square computed showed that there was a statistical significance between water availability and sources of income. The chi-square was ($\chi^2_{4,0.05}$=13.370, p<0.05).

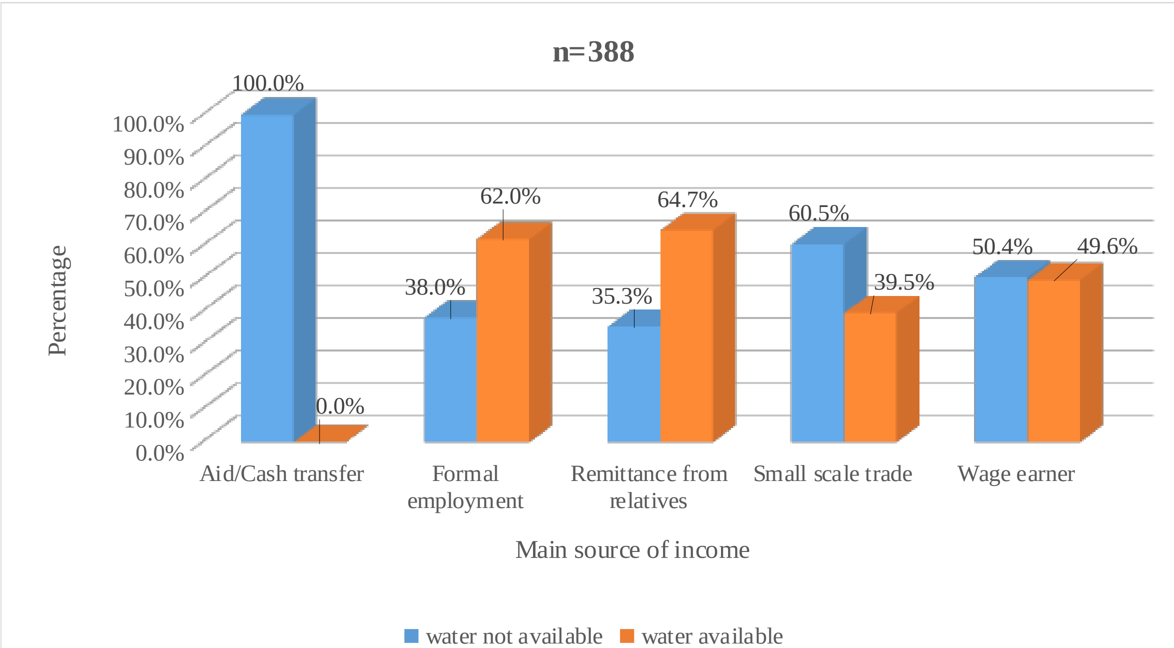

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.31: Water availability versus main source of income

Source: Field data, 2023

4.4.6. Availability versus type of house

The study determined the relationship between water availability and type of house (Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.10). From the findings, it can be noted that those whose houses were made from sticks and mud walls 19 (63.6%), made of timber with iron-sheet cladding 76 (56.9%), Made of sticks, cartons, and other assorted materials 4 (100.0%), made of concrete walls 107 (49.2%) and ohers were 1 (50.0%) did not have water readily available. On the other hand, those who had water readily available was; made from sticks and mud walls 11 (36.4%), made of timber with iron-sheet cladding 58 (43.1%), made of sticks, cartons, and other assorted materials 0 (0.0%), made of concrete walls 111 (50.8%) and others were 1 (50.0%). A chi-square ($\chi^2_{4,0.05}$=7.288, p>0.05) showed that there was no significant relationship between water availability and the type of house based on construction materials.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.10: Water availability versus type of house

		Not Readily available		**Readily available**		**Total**		
		F	**%**	**F**	**%**	**F**	**%**	**X^2**
House type	Sticks and mud wall	19	63.6	11	36.4	30	100.0	
	Timber with iron sheet	76	56.9	58	43.1	134	100.0	
	Sticks and other assorted materials	4	100.0	0	0.0	4	100.0	7.288 (0.121)
	Concrete walls	107	49.2	111	50.8	218	100.0	
	Others	1	50.0	1	50.0	2	100.0	
	Total	**210**	**53.4**	**178**	**46.6**	**388**	**100.0**	

Source: Field data, 2023

In their study in Nairobi’s informal settlements, Joshi et al. (2023), found that tenants experienced higher water insecurity levels compared to the homeowners in the informal settlements. Concluding that, improving housing tenure and raising rates of home ownership may help in lessening water insecurity among people living in informal settlements.

4.5. Access Analysis

This is the proximity of water source or water point to the household measured in time or distance. This is a measure of the convenience for a household measured in terms of distance to and from the water source and/or time taken for a round trip including queueing at the water source. The study sought to determine the overall water access among respondents in Nairobi County. From the findings, it was observed that 262 (67.5%) of them, the distance of the water source from the house was less than 100m while 113 (29.1%), the distance was between 100-200m. However, only 13 (3.4%) were moving a distance of more than 200m from their houses to the nearest water source (Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.32).

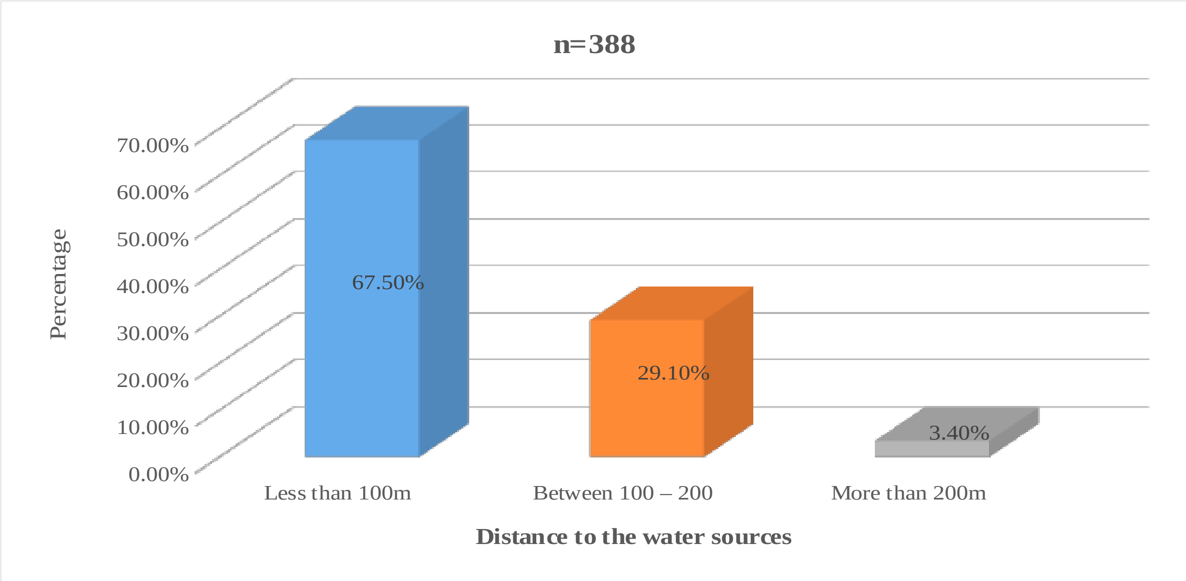

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.32: Distance to water source

Source: Field data, 2023

4.5.1. Time taken to water source

To compute access, the time parameter was used. This is because in an INSE set-up, due to the un-planned nature of settlement, distance tends to be elusive and therefore people are likely to give wrong estimates. Therefore, the study investigated the time taken by the members of the household to collect water from the source. As summarized in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.33, the findings shows that 255 (65.7%) used around 1- 15 minutes to collect water. Those who spent 16-30 minutes were 81 (20.9%), those who used between less than a minute were 24 (6.3%) while 14 (3.6%) used around 31- 45 minutes. The respondents who spend between 46-60 minutes were 9 (2.4%). However, only 4 (1.0%) were using more than one hour to get to the water source (Figure 4.16). According to Geere & Cortobius (2017), the average time taken for urban households to get water from an off-plot water source (i.e., 'elsewhere') and return home ranged from 10 minutes to 65 minutes.

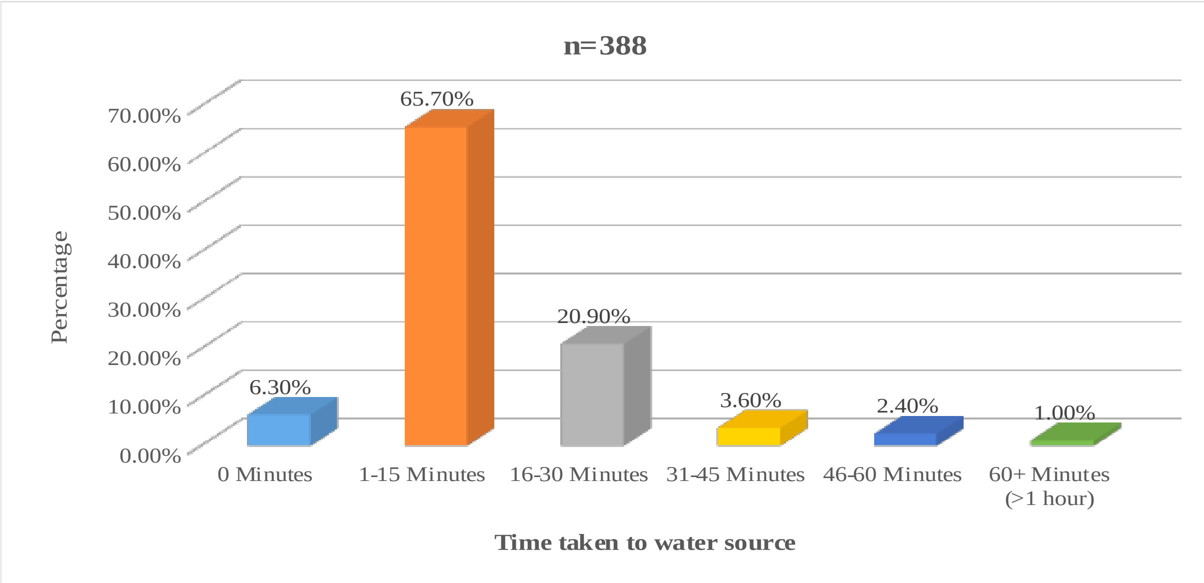

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.33: Time taken to main water source

Source: Field data, 2023

A majority of the repondents seemingly stayed near water sources. Though at this level the study didn’t find out the type of source and/or the exact distance to source, it is important to note that, water business in the informal settlements in Nairobi County, and therefore vendors are positioned every part of the INSE.

4.5.2. Water Access versus sub-county

For the study to establish water security in the informal settlements, it conducted and analysis of the water access variable. Water access was measured using two variables, distance to water source and time taken to and fro the water source including queueing time. The results of the analysis were as tabuled in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.11.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.11: Water access versus Sub-County

		Unacceptable water access		Acceptable water access		Total		
		F	%	F	%	F	%	X^2
Sub-County	Dagoretti North	4	27.8	12	72.2	16	100.0	
	Dagoretti South	3	9.7	27	90.3	30	100.0	
	Embakasi South	14	20.8	54	79.2	68	100.0	
	Kamukunji	11	46.2	13	53.8	24	100.0	
	Kasarani	23	48.0	25	52.0	48	100.0	
	Kibra	9	33.3	17	66.7	26	100.0	
	Langata	2	22.2	7	77.8	9	100.0	28.522
	Makadara	1	6.2	14	93.8	15	100.0	(**0.005**)
	Mathare	6	31.6	12	68.4	18	100.0	
	Ruaraka	21	23.7	69	76.3	90	100.0	
	Starehe	6	38.7	10	61.3	16	100.0	
	Westlands	10	35.5	18	64.5	28	100.0	
	Total	**110**	**28.3**	**278**	**71.7**	**388**	**100.0**	

Source: Field data, 2023

From the analysis, it was established that those with unacceptable water access were; Dagoretti North 4 (27.8%), Dagoretti South 3 (9.7%), Embakasi South 14 (20.8%), Kamukunji 11 (46.2%), Kasarani 23 (48.0%), Kibra 9 (33.3%), Langata 2 (22.2%), Makadara 1 (6.2%), Mathare 6 (31.6%), Ruaraka 21 (23.7%), Starehe 6 (38.7%) and Westlands 10 (35.5%). On the flip coin, those with acceptable water access per sub-county included; Dagoretti North 12 (72.2%), Dagoretti South 27 (90.3%), Embakasi South 54 (79.2%), Kamukunji 13 (53.8%), Kasarani 25 (52.0%), Kibra 17 (66.7%), Langata 7 (77.8%), Makadara 14 (93.8%), Mathare 12 (68.4%), Ruaraka 69 (76.3%), Starehe 10 (61.3%), and Westlands 18 (64.5%). A chi-square established that there was a significant relationship between water access and sub- county of the respondents. ($\chi^2_{12,\ 0.05}$=28.522, P<0.05).

4.5.3. Water Access versus highest level of education

On the relationship between water access and the level of education, it was found out that those with unacceptable access and level of education included; No Education 2 (18.2%), Primary incomplete 0 (0.0%), Primary complete 26 (28.0%), Secondary incomplete 10 (32.4%), Secondary complete 42 (31.5%), Tertiary (Certificate or Diploma) 15 (24.2%), University 10 (23.5%) and Postgraduate 4 (25.0%). On the other hand, those with acceptable access includes; No Education 7 (81.8%), Primary incomplete 1 (100.0%), Primary complete 67 (72.0%), Secondary incomplete 20 (67.6%), Secondary complete 90 (68.5%), Tertiary (Certificate or Diploma), 49 (75.8%), University 33 (76.5%) and Postgraduate 12 (75.0%) (Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.34).

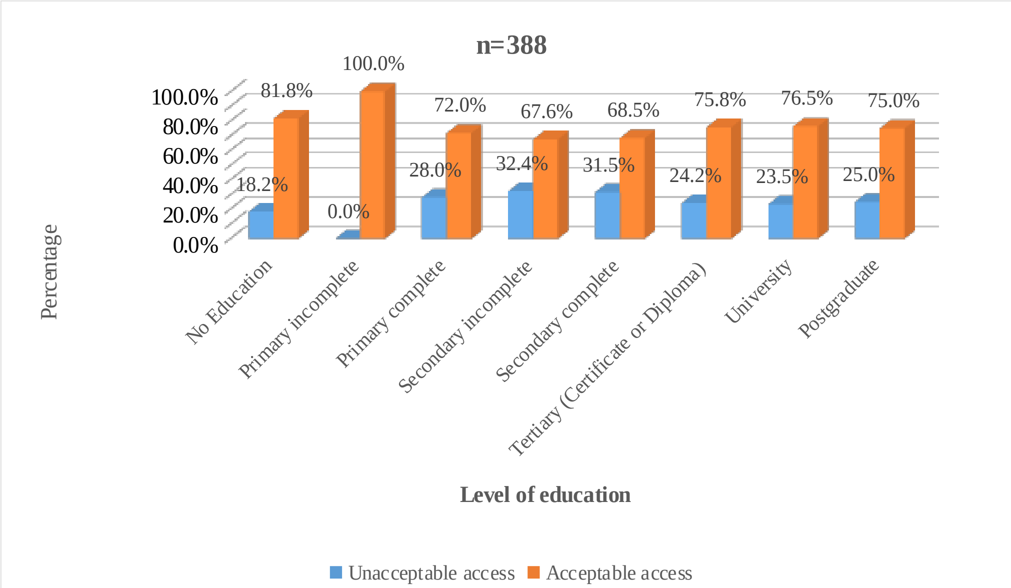

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.34: Water access versus highest level of education attained by household head

Source: Field data, 2023

4.5.4. Access versus Employment

The study sought to determine the relationship between water access and employment. Those with unacceptable access to water were as follows; Not employed 12 (12.4%), Employed salaried 16 (30.9%), Employed casual labourer 31 (38.4%), Self-employed 48 (31.3%), and Student 1 (50.0%). Those who had acceptable access were; Not employed 88 (87.6%), employed salaried 37 (69.1%), employed casual labourer 50 (61.6%), Self-employed 104 (68.7%), and Student 1 (50.0%) (Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.35). A chi-square value of

($\chi^2_{4,0.05}$=18.888, P<0.05) was computed. This indicates that there was a significant relationship between water access and employment status.

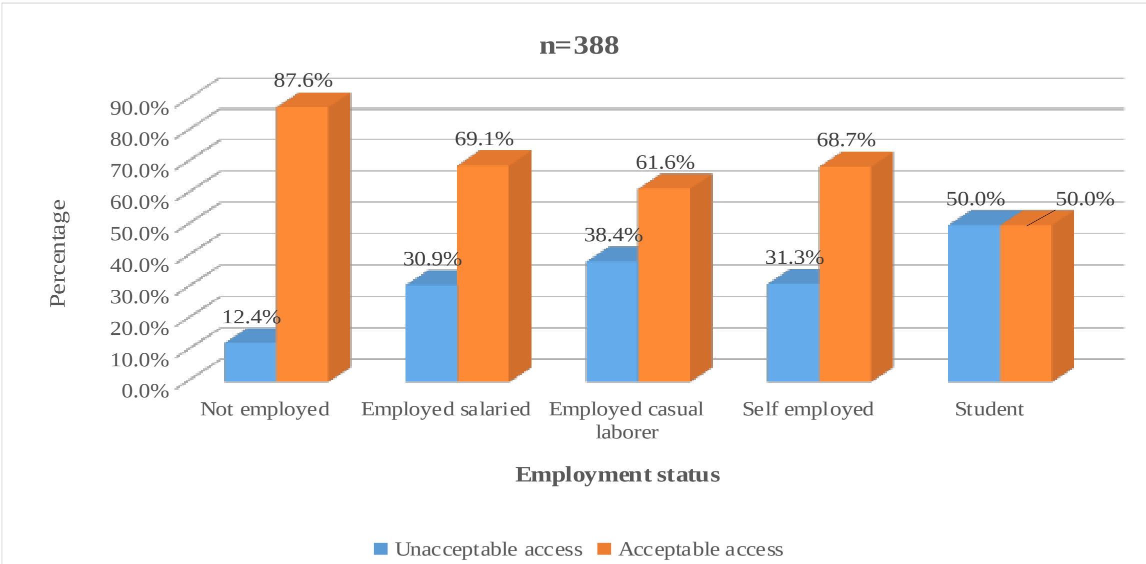

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.35: Water access versus employment status of household head

Source: Field data, 2023

4.5.5. Access versus monthly income

In terms of the relationship between water access and monthly income of households, the study established that those whose income was less than 23,670 and had unacceptable access were 101 (29.6%) while those with income between 23,671 to 119,999 with unacceptable access were 9 (20.0%). The computed chi-square was ($\chi^2_{1,0.05}$=1.977, P>0.05). This therefore indicated that there was no significant relationship between the two variables.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.12: Water access versus monthly income of household

		Unacceptable access		Acceptable access		Total		
		F	**%**	**F**	**%**	**F**	**%**	X^2
Income	Less than KSh. 23,670	101	29.6	240	70.4	341	100.0	
	From KSh. 23671 to KSh. 119,999	9	20.0	38	80.0	47	100.0	1.977 (0.160)
	Total	**110**	**28.4**	**278**	**71.6**	**388**	**100.0**	

Source: Field data, 2023

4.5.6. Water access versus main source of income

The study established the relationship between water access and the main source of income for the household heads. From Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.13, the following results can be observed; Aid/Cash transfer 1 (50.0%), Formal employment 12 (24.0%), Remittance from relatives 9 (58.8%), Small scale trade 62 (31.7%) and Wage earner 26 (20.6%) had unacceptable access of water. Those with acceptable water access was; Aid/Cash transfer 1 (50.0%), Formal employment 38 (76.0%), Remittance from relatives 6 (41.2%), Small scale trade 133 (68.3%), Wage earner 100 (79.4%). A chi-square computation of ($\chi^2_{4,0.05}$=13.686, P<0.05) was arrived at. This showed that there is a significant relationship between the two variables.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.13: Water access versus main source of income

		Unacceptable water access		Acceptable water access		Total		
		F	%	F	%	F	%	X^2
Sub-County	Aid cash transfer	1	50.0	1	50.0	2	100.0	
	Formal employment	12	24.0	38	76.0	50	100.0	
	Remittance from relatives	9	58.8	6	41.2	15	100.0	13.686 **(0.008)**
	Small scale trade	62	31.7	133	68.3	195	100.0	
	Wage earner	26	20.6	100	79.4	126	100.0	
	Total	**110**	**28.4**	**278**	**71.6**	**388**	**100.0**	

Source: Field data, 2023

4.5.7. Water Access versus type of house

As shown in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.36, the study established relationships between water access and the type of house that the respondents were living. From the findings, it was established that those who were staying in Sticks and Mud Walls were 10 (30.3%), Timber with Iron-sheet cladding 43 (31.4%), sticks, cartons, and other assorted materials 1 (25.0%), Concrete walls 62 (26.3%) and Others 0 (0.0%). On the flip coin those with acceptable access were as follows; Sticks and Mud Walls 69.7%, Timber with Iron-sheet cladding 68.6%, sticks, cartons, and other assorted materials 75.0%, Concrete walls 73.7% and Others 100.0% On the chi-square computed value ($\chi^2_{4,0.05}$=2.000, P>0.05) indicated that there was no significant relationship between water access and the type of house that the household head lived.

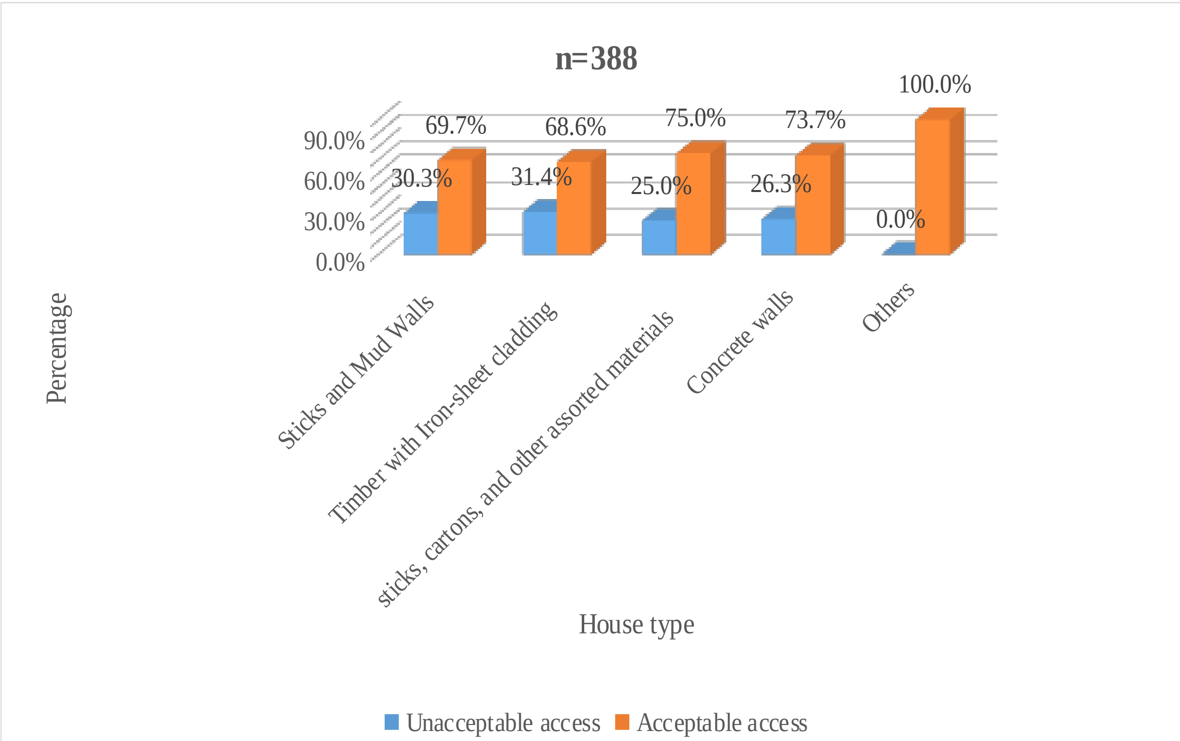

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.36: Water access versus type of house

Source: Field data, 2023

In a study carried out in a Abuja, an INSE in Accra, it was found that, the main water service providers were private vendors, and households developed key coping strategies included purchase of drinking sachet water, paying extra to get water elsewhere, minimizing water use, and fetching water on credit. It was also found that these coping strategies manifested through determinant factors such as land/housing tenure status, how long the household had stayed in the location, the household size and social network of the household.

4.6. Water Quantity

The analysis under this variable assessed, the water quantity accessed in litres per person per day (lpcd). Two standards were computed from the collected data; one was the National water quantity standard set by GoK at 60 lpcd and Sphere standard quantity set at 15 lpcd. For the purpose of the model in chapter 7, a computation of demand versus consumption shall be deduced.

4.6.1. National water quantity standard versus Sub- County

The study did a comparison of water quantity in the various sub-counties with the national standards of water quantity. From the findings, Dagoretti North 18 (100.0%), Dagoretti South 28 (90.3%), Embakasi South 71 (98.6%), Embakasi West 1(100.0%), Kamukunji 16 (94.1%), Kasarani 46 (93.9%), Kibra 30 (100.0%), Langata 8 (88.9%), Makadara 21 (100.0%), Mathare 23 (100.0%), Ruaraka 66 (98.5%), Starehe 18 (94.7%), and Westlands 31 (100.0%) had household consuming less than 60 lpcd of water. However, Dagoretti North 0 (0.0%), Dagoretti South 3 (9.7%), Embakasi South 1 (1.4%), Embakasi West 0 (0.0%), Kamukunji 1 (5.9%), Kasarani 3 (6.1%), Kibra 0 (0.0%), Langata 1 (11.1%), Makadara 0 (0.0%), Mathare 0 (0.0%), Ruaraka 1 (1.5%), Starehe 1 (5.3%), and Westlands 0 (0.0%) were consuming water greater than or equal to 60 lpcd (Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.37). A chi-square of ($\chi^2_{12,}$

$_{0.05}$=14.077, P>0.05) was established indicating that there was no significant relationship between the variables.

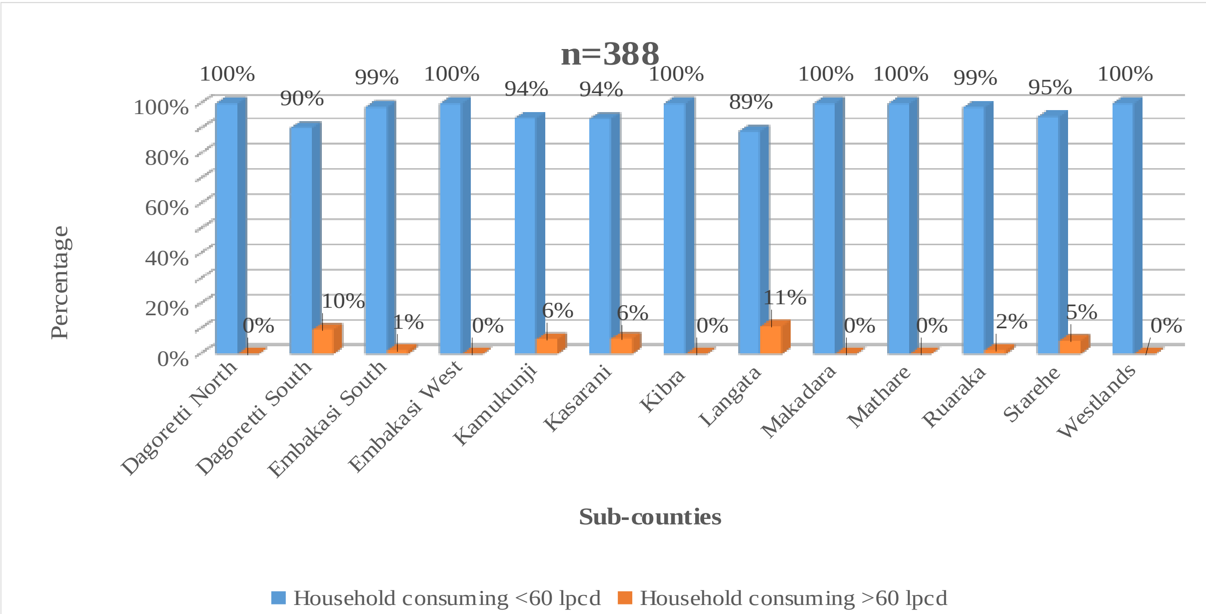

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.37: National standard water quantity versus Sub-County

Source: Field data, 2023

4.6.2. Standard water quantity standard versus highest level of education

The study conducted a relationship between the standard national water quantities against the level of education. From the Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.14, it found out that those households consumed less than 60 lpcd were; No Education 10 (100.0%), Primary incomplete 1 (100.0%), Primary complete 81 (98.8%), Secondary incomplete 44 (100.0%), Secondary complete 127 (96.9%), Tertiary (Certificate/Diploma) 53 (94.6%), University 47 (95.9%), Postgraduate 14 (93.3%). On the other hand, those who were consuming greater than or equal to 60 lpcd were; No Education 0 (0.0%), Primary incomplete 0 (0.0%), Primary complete 1 (1.2%), Secondary incomplete 0 (0.0%), Secondary complete 4 (3.1%), Tertiary (Certificate/Diploma) 3 (5.4%), University 2 (4.1%), Postgraduate 1 6.7%. A chi-square computed was ($\chi^2_{7,0.05}$=4.197, P>0.05) indicating that there is no significant relationship consumption quantity and level of education.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.14: National water quantity standard versus highest level of education attained by household head

		Less than 60 lcpd		More than 60 lcpd		Total		
		F	**%**	**F**	**%**	**F**	**%**	**X^2**
Education level	No Education	10	100.0	0	0.0	10	100.0	
	Primary incomplete	1	100.0	0	0.0	1	100.0	
	Primary complete	81	98.8	1	1.2	82	100.0	
	Secondary incomplete	44	100.0	0	0.0	44	100.0	
	Secondary complete	127	96.9	4	3.1	131	100.0	4.197 (0.757)
	Tertiary (Certificate/Diploma)	53	94.6	3	5.4	56	100.0	
	University	47	95.9	2	4.1	49	100.0	
	Postgraduate	14	93.3	1	6.7	15	100.0	
	Total	**377**	**97.1**	**11**	**2.9**	**388**	**100.0**	

Source: Field data, 2023

4.6.3. National water quantity standard versus employment status

The relationship between the national standard water quantity and employment status is as shown in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.15, the findings indicates that those households who consumed less than 60 lpcd were; Not employed 93 (96.9%), Employed salaried 53 (98.1%), Employed casual labourer 92 (100.0%), Self-employed 137 (95.1%), Student 2 (100.0%). Additionally, those who consumed more than 60 lpcd of water included; Not employed 3(3.1%), Employed salaried 1 (1.9%), Employed casual labourer 0 (0.0%), and Self-employed 7 (4.9%). A chi-square of ($\chi^2_{4,0.05}$=4.520, P>0.05) was computed which showed that there was no significant assocation between the quantity of water used and employment status of the household head.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.15: National water quantity standard versus employment status

		Less than 60 lcpd		**More than 60 lcpd**		**Total**		
		F	**%**	**F**	**%**	**F**	**%**	**X^2**
Employment status	Not employed	93	96.9	3	3.1	96	100.0	
	Employed salaried	53	98.1	1	1.9	54	100.0	
	Employed casual labourer	92	100.0	0	0.0	92	100.0	4.520 (0.340)
	Self employed	137	95.1	7	4.9	144	100.0	
	Student	2	100.0	0	0.0	2	100.0	
	Total	**377**	**97.1**	**11**	**2.9**	**388**	**100.0**	

Source: Field data, 2023

4.6.4. National water quantity standard versus household income

On the quantity of water used and the household income, the study established that those who were earning less than KSh. 23,670 were 316 (96.0%) and between KSh. 23,671 to KSh. 119,999 were 51 (86.4%) who were consuming less than 60 lpcd of water. On the contrary, those with less than KSh. 23,670 were 13 (4.0%) and between KSh. 23671 to KSh. 119,999 were 8 (13.6%) who consumed more than 60 lpcd. Chi- square value of ($\chi^2_{1,0.05}$=1.914, P>0.05) showed that there was no significant relationship between consumption and household income.

The results of national water quantity standard versus household income have been summarized in Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.16.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.16: National water quantity standard versus household income

		Less than 60 lcpd		More than 60 lcpd		Total		
		F	**%**	**F**	**%**	**F**	**%**	X^2
Income (in KSh.)	Less than 23,670	316	96.0	13	4.0	329	100.0	
	Between 23671 to 119,999	51	86.4	8	13.6	59	100.0	1.914 (0.167)
	Total	**367**	**94.5**	**21**	**5.5**	**388**	**100.0**	

Source: Field data, 2023

4.6.5. National water quantity standard versus main source of income

The quantity of water and the main source of income was established in this study. The findings indicated that; Aid/Cash transfer 1 (100.0%), Formal employment 48 (96.0%), Remittance from relatives 17 (100.0%), Small scale trade 183 (96.3%), Wage earner 128 (98.4%) used water less than 60 lpcd. Those households who consumed water more than greater than 60 lpcd were; Aid/Cash transfer 0 (0.0%), Formal employment 2 (4.0%), Remittance from relatives 0 (0.0%), Small scale trade 7 (3.7%), Wage earner 2 (1.6%). Further, the study computed the chi-square for the two variables. A chi-square of ($\chi^2_{4,0.05}$=1.957, P>0.05) showing that there is no significant relationship between consumption and main source of income.

The findings of national water quantity standard versus main source of income have been summarized in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN

INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.17.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.17: National water quantity standard versus main source of household income

		Less than 60 lcpd		More than 60 lcpd		Total		
		F	%	F	%	F	%	X^2
Source of income	Aid/Cash transfer	1	100.0	0	0.0	1	100.0	
	Formal employment	48	96.0	2	4.0	50	100.0	
	Remittance from relatives	17	100.0	0	0.0	17	100.0	1.957 (0.744)
	Small scale trade	183	96.3	7	3.7	190	100.0	
	Wage earner	128	98.4	2	1.6	130	100.0	
	Total	**377**	**97.1**	**11**	**2.9**	**388**	**100.0**	

Source: Field data, 2023

4.6.6. National water quantity standard versus type of house

Another correlation that was conducted was the quantity of water and the type of house. The findings from Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.18, showed that those made from Sticks and Mud Walls 26 (92.9%), made of Timber with Iron-sheet cladding 128 (94.8%), made of sticks, cartons, and other assorted materials 3 (100.0%), made of Concrete walls 219 (99.1%) used water less than 60 lpcd. On the other hand, those made from Sticks and Mud Walls 2 (7.1%), Made of Timber with Iron-sheet cladding 7 (5.2%), Made of Concrete walls 2 (0.9%) used water more than 60 lpcd. A chi-square of ($\chi^2_{4,0.05}$=7.736, P>0.05) was computed and it was established that there was no significant association between water quantity and the type of house.

**Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.18: National water quantity standard versus type of house**

		Less than 60 lcpd		More than 60 lcpd		Total		
		F	**%**	**F**	**%**	**F**	**%**	**X^2**
Source of income	Made from Sticks and Mud Walls	26	92.9	2	7.1	28	100.0	
	Made of Timber with Iron-sheet cladding	128	94.8	7	5.2	135	100.0	
	Made of sticks, cartons, and other assorted materials	3	100.0	0	0.0	3	100.0	7.736 (0.102)
	Made of Concrete walls	219	99.1	2	0.9	221	100.0	
	Others	1	98.4	0	1.6	1	100.0	
	Total	**377**	**97.1**	**11**	**2.9**	**388**	**100.0**	

Source: Field data, 2023

From the study, it was clearly evident that the National water standard quantity as set by the Government of Kenya at 60lpcd, does not show any signifant relationship with all the household characteristics, i.e., location of stay in terms of subcounty, highest level of education attained by household head, employment status, household income, main source of income and type of house the household stayed in in terms of construction materials used. This is a glaring finding that may clearly be pointing to a unique behaviour of households living in INSEs in Nairobi County. It was indeed observed that, readily cooked cheap food was popular among many households. Equally, people used paid toilets (KSh. 5 per person per use), and bathrooms (also KSh. 5 per person per use). This was the case because many households didn't have these facilities and there was no privacy for people especially women to take bath in the house. This therefore means that, households used far more water than they reported in the interviews.

4.7. Sphere standard quantity versus standard cost per 20L container

The study conducted a cross tabulation between the quantity sphere compliance against the affordability of the 20 Litre jerry can. The findings are as shown in Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.19.

**Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.19: Sphere standard quantity versus standard cost per 20L container**

	Water Affordability (Based on Standard cost of KSh.2 per 20L						
	Households paying more than KSh. 2 per 20L container		**Households paying KSh. 2 per 20L container**		**Total**		**X^2**
	F	**%**	**F**	**%**	**F**	**%**	
Access to at least 15 lpcd (Sphere Non-Compliant)	104	35.4	24	25.5	128	33.0	
Access to at least 15 lpcd (Sphere Compliant)	190	64.6	70	74.5	260	67.0	8.565 **(0.003)**
Total	**294**	**100.0**	**94**	**100.0**	**388**	**100.0**	

Source: Field data, 2023

The study established that there is association between water quantity accessed by households and water affordability in households. Households who could afford water according to minimum cost per 20L jerry can (sphere standard of 15 lpcd) were found to comply with quantities. 70 (74.5%) of households which complied with the standard cost of 20L container also complied with the required SPHERE standard quantities of water of 15 lpcd. A chi-square value of ($\chi^2_{1,0.05}$=8.565, P< 0.05) showed a significant relationship between water quantity and water affordability.

4.7.1. Sphere standard quantity versus Sub-County

The study established the correlation between sphere standard quantity of water and the sub- counties in which the informal settlements are located. From the findings (), those households consuming greater than 15 lpcd were as follows; Dagoretti North 11 (64.7%), Dagoretti South 26 (86.7%), Embakasi South 42 (58.3%), Embakasi West 1 (100.0%), Kamukunji 12 (70.6%), Kasarani 49 (91.7%), Kibra 19 (70.4%), Langata 4 (44.4%), Makadara 10 (62.5%), Mathare 8 (42.1%), Ruaraka 50 (69.7%), Starehe 13 (68.4%), and Westlands 20 (69.0%). On the other hand, those households which consumed less than 15 lpcd were as follows; Dagoretti North 6 (35.3%), Dagoretti South 4 (13.3%), Embakasi South 30 (41.7%), Embakasi West 0 (0.0%), Kamukunji 5 (29.4%), Kasarani 9 (8.3%), Kibra 8 (29.6%), Langata 5 (55.6%), Makadara 6 (37.5%), Mathare 11 (57.9%), Ruaraka 24 (30.3%), Starehe 6 (31.6%), Westlands 9 (31.0%). A chi-square value of ($\chi^2_{12,0.05}$=29.767, P<0.05) shows that there is a significant relationship between SPHERE Standard Quantity versus Sub-County.

A summary of the findings on sphere standard quantity of 15lpcd and it relates with sub-county where the household resided are show in Figure CHAPTER FOUR

WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.38.

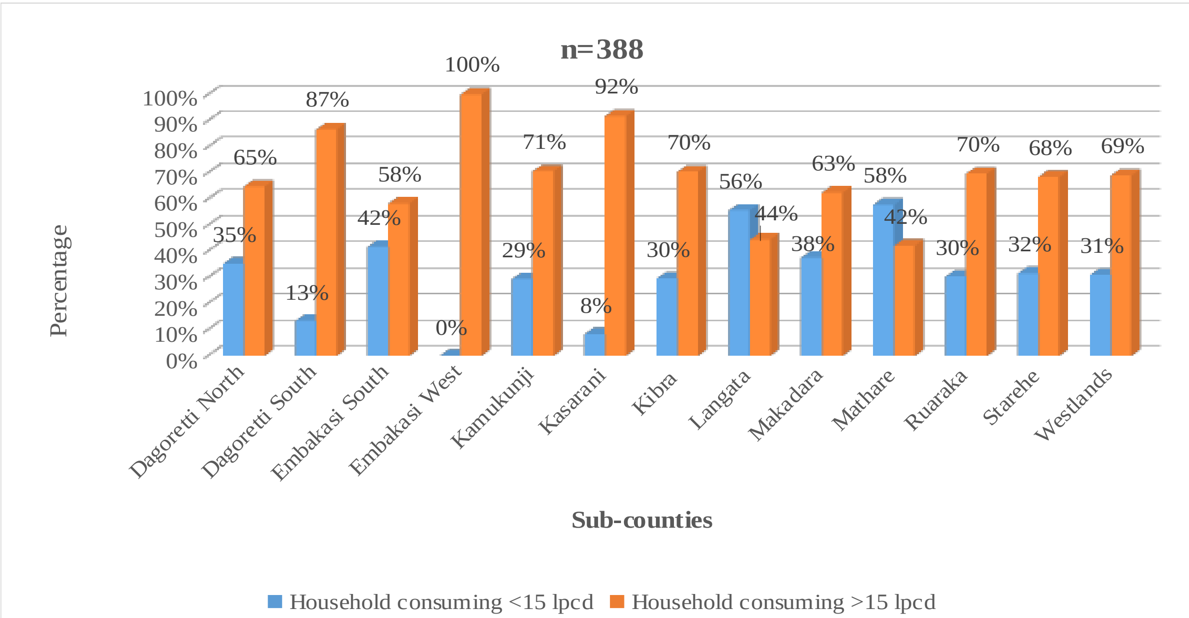

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.38: Sphere standard quantity versus Sub-County

Source: Field data, 2023

4.7.2. Sphere standard quantity versus highest level of education

The study established the relationship between sphere standard quantity and level of education. As summarised in Table CHAPTER FOUR

WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.20, it was observed that those households who consumed water less than 15 lpcd for the various categories of education includes; No Education 3 (42.9%), Primary complete 22 (27.2%), Secondary incomplete 13 (40.6%), Secondary complete 54 (36.2%), Tertiary (Certificate/Diploma) 12 (21.8%), University 16 (32.7%), Postgraduate 3 (21.4%). The households which consumed water more than 15 lpcd in the various education categories includes; No Education 4 (57.1%), Primary incomplete1 (100.0%), Primary complete 59 (72.8%), Secondary incomplete 19 (59.4%), Secondary complete 95 (63.7%), Tertiary (Certificate/Diploma) 43 (78.2%), University 33 (67.3%), Postgraduate 11 (78.6%). A chi- square value of ($\chi^2_{7,0.05}$=6.387, P>0.05) was computed indicating that there is no significant relationship between sphere standard quantity and level of education.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.20: Sphere standard quantity versus highest level of education attained

The highest level of education attained by the household head	Sphere Standard Quantity (Household consuming 15 lpcd - compliant SPHERE Standard water quantity)				Total		X^2
	Household consuming <15 lpcd		Household consuming ≥15 lpcd				
	F	%	F	%	F	%	
No Education	3	42.9	4	57.1	7	100.0	
Primary incomplete	0	0.0	1	100.0	1	100.0	
Primary complete	22	27.2	59	72.8	81	100.0	6.387
Secondary incomplete	13	40.6	19	59.4	32	100.0	(0.495)
Secondary complete	54	36.2	95	63.7	149	100.0	
Tertiary (Certificate/Diploma)	12	21.8	43	78.2	55	100.0	
University	16	32.7	33	67.3	49	100.0	
Postgraduate	3	21.4	11	78.6	14	100.0	
Total	**123**	**31.7**	**265**	**68.3**	**388**	**100.0**	

Source: Field data, 2023

4.7.3. Sphere standard quantity versus employment status

On the relationship between the sphere standard quantity and the employment status of the household head (Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.21), the study established that households which were consuming less than 15 lpcd of water for the various employment status was at follows; Not employed 33 (34.7%), Employed salaried 14 (25.9%), Employed casual labourer 30 (38.5%), Self-employed 46 (28.9%). The households that consumed more than 15 lpcd of water for the various employment status in the INSE included; Not employed 62 (65.3%), Employed salaried 40 (74.1%), Employed casual labourer 48 (61.5%), Self-employed 113 (71.1%), and Student 2 100.0%. Further, a chi-square was calculated between the two variables. A Chi- square of ($\chi^2_{4,0.05}$=5.705, P>0.05) was established indicating no significant relationship between the variables.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.21: Sphere standard quantity versus employment status of household head

The employment status of the household head	Sphere Standard Quantity (Household consuming 15 lpcd - compliant SPHERE Standard water quantity) Household consuming <15 lpcd		Household consuming ≥15 lpcd		Total		X^2
	F	%	F	%	F	%	
Not employed	33	34.7	62	65.3	95	100.0	

Employed salaried	14	25.9	40	74.1	54	100.0	5.705
Employed casual laborer	30	38.5	48	61.5	78	100.0	(0.222)
Self employed	46	28.9	113	71.1	159	100.0	
Student	0	0.0	2	100.0	2	100.0	
Total	**123**	**31.7**	**265**	**68.3**	**388**	**100.0**	

Source: Field data, 2023

4.7.4. Sphere standard quantity versus household income

As shown in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.22, the study sought to establish the relationship between the sphere standard quantity and household income for the various monthly income and the water consumption in the households, the results shows that those who used less than 15 lpcd of water were as follows in the various categories; Less than 23,670 were111 (33.9%) and between 23,671 to 119,999 were 14 (22.9%). However, those who consumed more than 15 lpcd of water in the different categories of income were; Less than 23,670 were 216 (66.1%) while those between 23,671 to 119,999 were 47 (77.1%). The Chi-Square analysis of ($\chi^2_{1,0.05}$=5.729, P<0.05) indicated that water quantity under sphere standards had a significant relationship with household income.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.22: Sphere standard quantity versus household income

The	Sphere Standard Quantity

approximate monthly income of the household in Kenya shilling	(Household consuming 15 lpcd - compliant SPHERE Standard water quantity)						
	Household consuming <15 lpcd		Household consuming ≥15 lpcd		Total		X^2
	F	%	F	%	F	%	
Less than 23,670	111	33.9	216	66.1	327	100.0	5.729
Between 23671 to 119,999	14	22.9	47	77.1	61	100.0	**(0.017)**
Total	**125**	**32.2**	**263**	**67.8**	**388**	**100.0**	

Source: Field data, 2023

4.7.5. Sphere standard quantity versus main source of income

The study also established the relationship between sphere standard quantity and the main source of income. From the results in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.23, the households which consumed less than 15 lpcd of water for the different main income sources included; Aid/Cash transfer 1 (100.0%), Formal employment 14 (28.0%), Remittance from relatives 6 (35.3%), Small scale trade 61 (32.2%), and Wage earner 49 (31.1%). On the flip coin, those who used water more than 15 lpcd for the various income sources were; Aid/Cash transfer 0 (0.0%), Formal employment 36 (72.0%), Remittance from relatives 11 (64.7%), Small scale trade 128 (68.9%), and Wage earner 94 (65.8%). A chi- square value of ($\chi^2_{4,0.05}$=2.581, P>0.05) was obtained indicating that there is no significant relationship between the sphere standard quantity of water and the main source of income in the study area.

Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.23: Sphere standard quantity versus main source of income

The current MAIN source of income of the household	Sphere Standard Quantity (Household consuming 15 lpcd - compliant SPHERE Standard water quantity) Household consuming <15 lpcd		Household consuming ≥15 lpcd		Total		X^2
	F	%	F	%	F	%	
Aid/Cash transfer	1	100.0	0	0.0	1	100.0	
Formal employment	14	28.0	36	72.0	50	100.0	2.581
Remittance from relatives	6	35.3	11	64.7	17	100.0	(0.630)
Small scale trade	61	32.2	128	67.8	189	100.0	
Wage earner	49	34.2	94	65.8	143	100.0	
Total	**125**	**32.2**	**263**	**67.8**	**388**	**100**	

Source: Field data, 2023

4.7.6. Sphere standard quantity versus type of house

The relationship between sphere standard and the different types of houses was established and summarised in Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.24.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.24: Sphere standard quantity versus type of house

Type of House in terms of materials used for construction	**Sphere Standard Quantity (Household consuming 15 lpcd - compliant SPHERE Standard water quantity)**				**Total**		**X^2**
	Household consuming <15 lpcd		**Household consuming ≥15 lpcd**				
	F	**%**	**F**	**%**	**F**	**%**	
Made from Sticks and Mud Walls	9	32.1	19	67.9	28	100.0	
Made of Timber with Iron-sheet cladding	36	27.0	97	73.0	133	100.0	2.021
Made of sticks, cartons, and other assorted materials	0	0.0	2	100.0	2	100.0	(0.732)
Made of Concrete walls	75	33.4	149	66.6	224	100.0	
Other: _(specify)	0	0.0	1	100.0	1	100.0	
Total	**120**	**30.9**	**268**	**69.1**	**388**	**100.0**	

Source: Field data, 2023

From the findings, the households which consumed less than 15 lpcd of water for the various house types were; Made from Sticks and Mud Walls 9 (32.1%), Made of Timber with Iron-sheet cladding 36 (28.3%), Made of sticks, cartons, and other assorted materials 0 (0.0%), Made of Concrete walls 75 (33.4%). Those that spend more than 15 lpcd for the different types of houses was as follows; Made from Sticks and Mud Walls 19 (67.9%), Made of Timber with Iron-sheet cladding 97 (73.0%), Made of sticks, cartons, and other assorted materials 2 (100.0%), Made of Concrete walls 149 (66.6%) (Table 4.16). A chi-square of ($\chi^2_{4,0.05}$=2.021, P>0.05) was obtained and it was established that there was no significant relationship between sphere standard quantity and the type of house that the respondent was residing in.

From the study, it was clearly evident that the Sphere standard quantity of 15lpcd, showed signifant relationship with only two of the household characteritics, i.e., location of stay in terms of subcounty and household income. It didn't show any significance with highest level of education attained by household head, employment status, main source of income and type of house the household stayed in in terms of construction materials used. This pointed to the fact that, despite the little amount set out at 15lpcd, the location of stay and household income played a major role in amount of water people accessed. Indeed, the household income also dictates the choice of location where a houseld stays.

4.7.7. Affordability of water based on cost of 20L container

The study undertook analysis of how affordable water was through crosstabulation with all the household characteristics to determine the level of significance of each variable. It is important to understand how affordable water is to customers because it is likely to affect the quantity of people access for domestic use and therefore have a bearing on the public health of the households living in informal settlements.

4.7.8. Affordability based on cost of 20L container versus Sub-County

The study established the relationship between water affordability of the 20L jerry can and the various sub-counties in Nairobi County. The results show those who are standard compliant and those that are non- compliant. The statistics of the various sub-counties which are standard compliant are; Dagoretti North 2 (11.1%), Dagoretti South 7 (24.1%), Embakasi South 17 (22.0%), Embakasi West 0 (0.0%), Kamukunji 12 (63.2%), Kasarani 5 (12.2%), Kibra 8 (30.8%), Langata1 (14.3%), Makadara 0 (0.0%), Mathare 3 (15.8%), Ruaraka 20 (22.2%), Starehe 7 (43.8%), and Westlands 6 (20.7%). On the other hand, those which are non- compliant in each sub-county are as follows; Dagoretti North 16 (88.9%), Dagoretti South 22 (75.9%), Embakasi South 60 (78.0%), Embakasi West 1 (100.0%), Kamukunji 7 (36.8%), Kasarani 36 (87.8%), Kibra 18 (69.2%), Langata 6 (85.7%), Makadara 16 (100.0%), Mathare 16 (84.2%), Ruaraka 70 (77.8%), Starehe 9 (56.3%), and Westlands 23 (79.3%) (Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.39). A chi- square value of ($\chi^2_{12,0.05}$=35.497, P<0.05) was obtained which indicates that there was a significant association between the water affordability and the sub-counties.

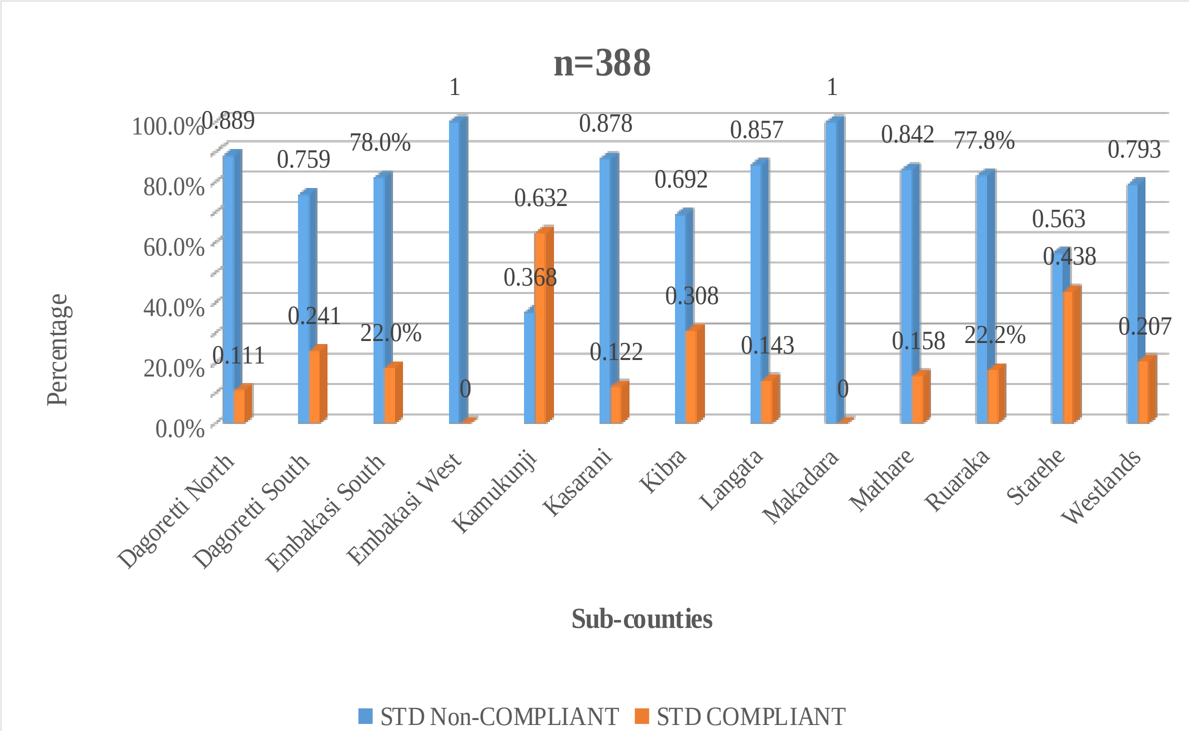

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.39: Affordability based on cost of 20L container versus Sub-County

Source: Field data, 2023.

4.7.9. Affordability based on cost of 20L container versus highest education

On the relationship between water affordability and the level of education, the study established that there was different compliance to affordability with the different education levels. The study established that those who were standard non-compliant for the different levels of education was; No Education 9 (90.0%), Primary incomplete 1 (100.0%), Primary complete 59 (76.6%), Secondary incomplete 24 (75.0%), Secondary complete 106 (74.6%), Tertiary (Certificate or Diploma) 47 (72.3%), University 41 (89.1%), and Postgraduate 12 (80.0%). On the flip coin, those who were standard compliant in the different education levels was as follows; No Education 1 (10.0%), Primary incomplete 0

(0.0%), Primary complete 18 (23.4%), Secondary incomplete 8 (25.0%), Secondary complete 36 (25.4%), Tertiary (Certificate or Diploma) 18 (27.7%), University 5 (10.9%), and Postgraduate 3 (20.0%). A chi- square computation of ($\chi^2_{7,0.05}$=5.519, P>0.05) showed that there was no significant association between affordability and education level of the household head.

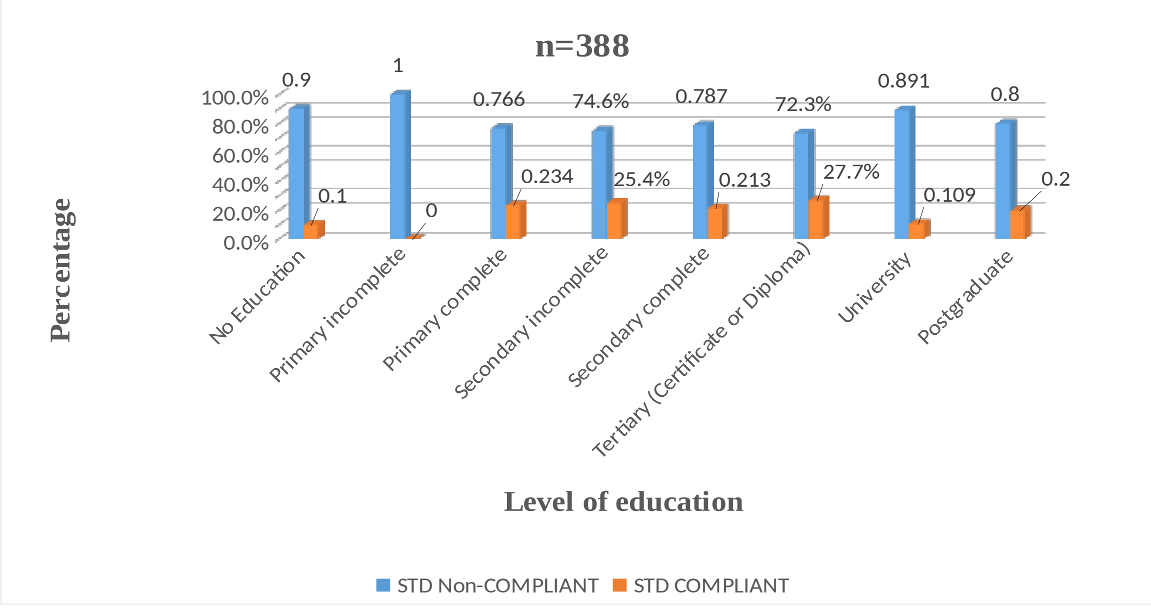

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.40: Affordability based on cost of 20L container versus highest level of education attained by household head

Source: Field data, 2023

4.7.10. Affordability based on cost of 20L container versus employment status

The study established the relationship between affordability of a 20L jerry can and employment status of the household head (Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN

INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.41). The study classified them into those who are standard compliant and non-compliant. The various categories of employment status of those who are standard compliant are as follows; Not employed 26 (21.3%), Employed salaried 12 (23.5%), Employed casual labourer 16 (22.5%), Self-employed 31 (21.6%), and Student 1 (100.0%). Those who were standard non-compliant includes; Not employed 96 (78.7%), Employed salaried 39 (76.5%), Employed casual labourer 55 (77.5%), Self-employed 112 (78.4%), and Student 0 (0.0%). A chi-square value of ($\chi^2_{4,0.05}$=6.121, P>0.05) was obtained which indicated that there was no significant relationship between the two variables.

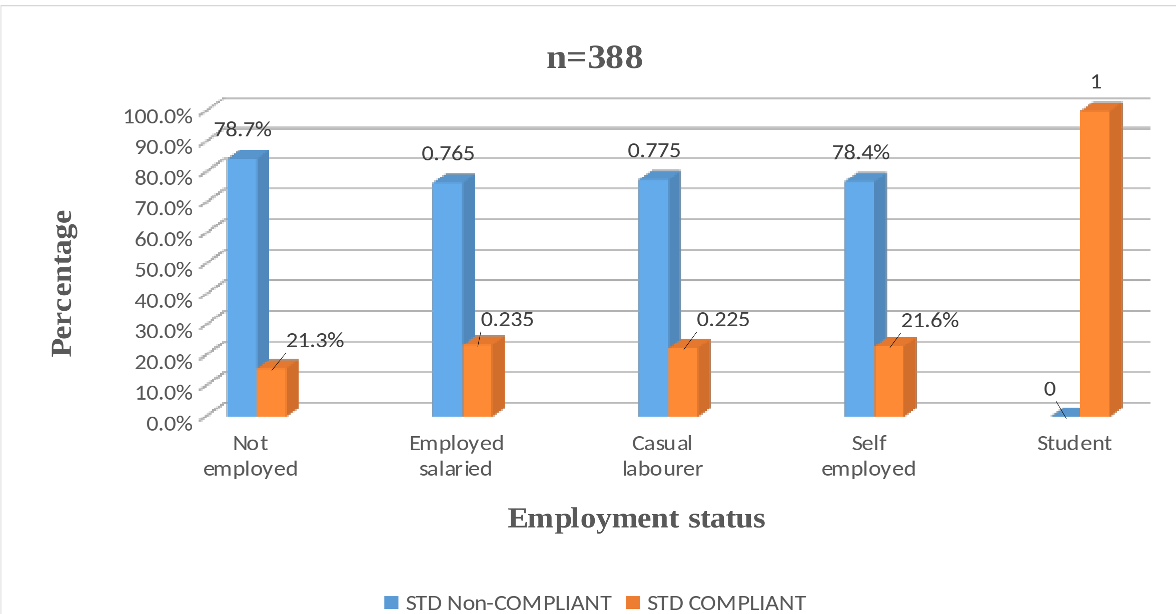

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.41: Affordability based on cost of 20L container versus employment status of the household head

Source: Field data, 2023

4.7.11. Affordability based on cost of 20L container versus household income

On the relationship between water affordability of 20L jerry can and household income, the study found out that those who were earning less than KSh. 23,670 were 253 (77.8%) while those earning between KSh. 23,671 to KSh. 119,999 were 44 (69.8%) who were non-compliant. Those who were compliant were; less than KSh. 23,670 were 72 (22.2%) and between KSh. 23,671 to KSh. 119,999 were 19 (30.2%) (Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.42). Chi- square value of ($\chi^2_{1,0.05}$=0.741, p>0.05) which showed that there was no significant relationship between the two.

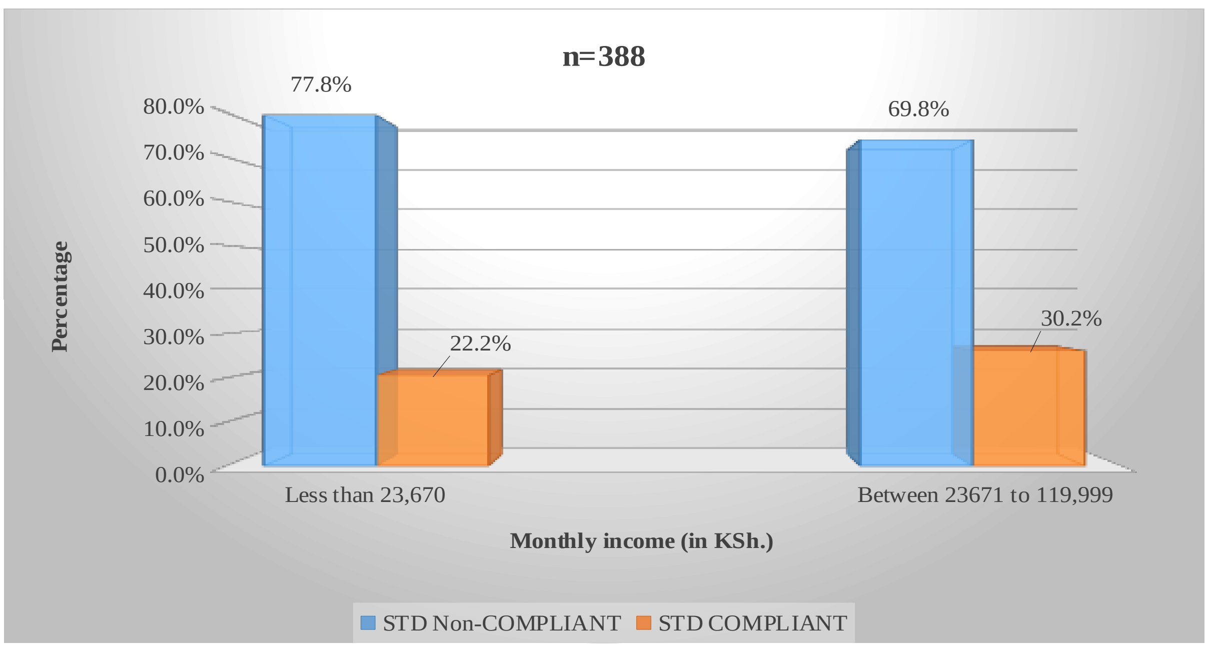

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.42: Affordability based on cost of 20L container versus household income

Source: Field data, 2023

4.7.12. Affordability based on cost of 20L Container versus main source of household income

Based on the relationship between the water affordability and the main source of income, the study classified them into standard compliant and non-compliant. As shown in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.43, those who were standard non- compliant for the different main source of income includes; Aid/Cash transfer 1 (50.0%), Formal employment 42 (72.4%), Remittance from relatives 17 (89.5%), Small scale trade 132 (75.0%), and Wage earner 106 (79.7%). On the other hand, those who were standard compliant for the various sources on income were; Aid/Cash transfer 1 (50.0%), Formal employment 16 (27.6%), Remittance from relatives 2 (10.5%), Small scale trade 44 (25.0%), and Wage earner 27 (20.3%).

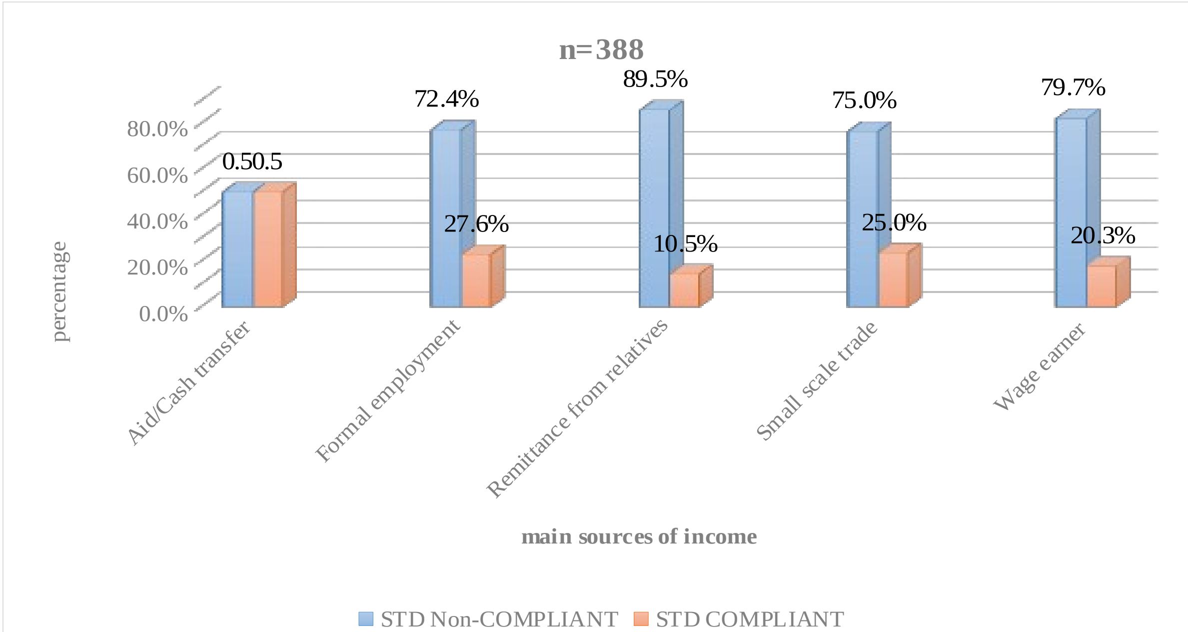

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.43: Affordability based on cost of 20L container versus source of household income

Source: Field data, 2023

From the chi- square of ($\chi^2_{4,0.05}$=0.2.805, P>0.05) was obtained which showed that there was determined no significant association between water affordability and the main source of income. Though other studies have compared affordability of water based on whether a household was getting their income from formal or informal sources, the specific income sources have not featured in previous studies. Households that depend on informal employment or casual labor are majorly affected, spending a higher percentage of their income on water compared to those with stable, formal employment. Gulyani et al. (2005) illustrate that these households face irregular income flows and thus, often resort to buying water from affordable informal vendors which may have serious water quality issues.

4.7.13. Affordability based on cost of 20L container versus Type of house

The study further established the relationship between affordability of 20L jerry can and the type of house that the household members were living in. The findings are summarized in Figure CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.44, from the findings, those who were standard non- compliant were; Made from Sticks and Mud Walls 20 (74.1%), Made of Timber with Iron-sheet cladding 92 (80.0%), Made of sticks, cartons, and other assorted materials 4 (100.0%), Made of Concrete walls 182 (75.8%). Those who were standard compliant were; Made from Sticks and Mud Walls 7 (25.9%), Made of Timber with Iron-sheet cladding 23 (20.0%), Made of sticks, cartons, and other assorted materials 0 (0.0%), Made of Concrete walls 58 (24.2%), and Others 2 (100.0%).

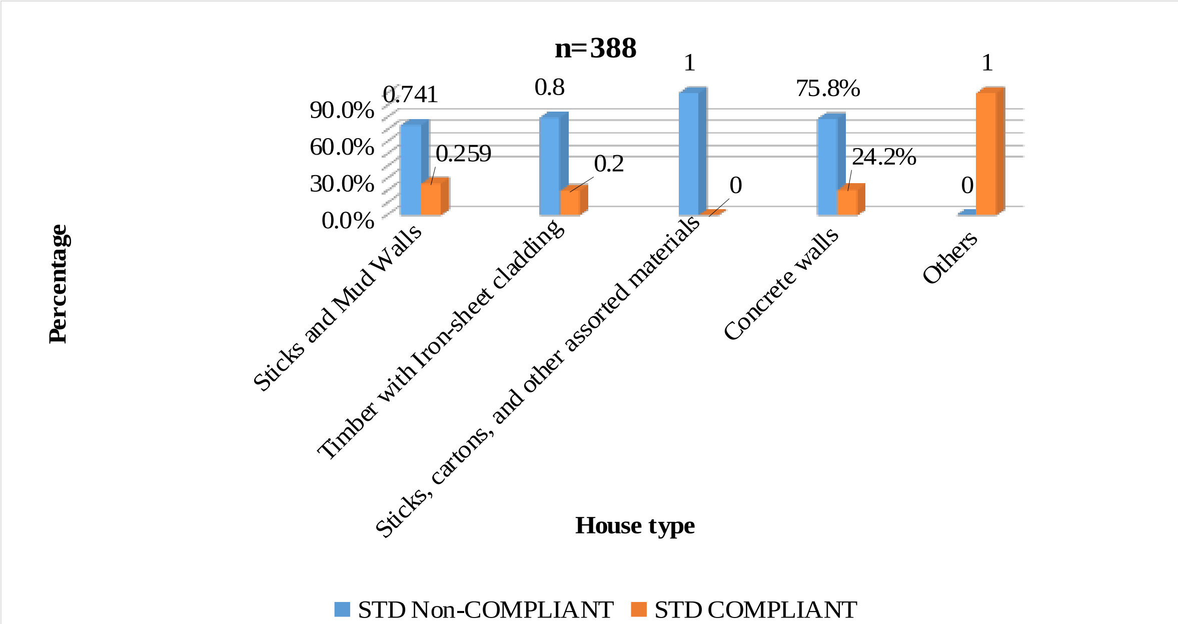

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.44: Affordability based on cost of 20L container versus type of house

Source: Field data, 2023

Chi-square value of ($\chi^2_{4,0.05}$=8.995, P>0.05) indicated there was no significant relationship between water affordability of the 20L container and the type of house (i.e., the materials making up the structure of the house) in which the household members were living in. However, in a study analysis by Fotso et al. (2011) in sub-Saharan Africa indicated that housing type was a strong determinant of water affordability, where informal housing were consistently observed to be facing higher per-liter water costs. As the study shows, in Nairobi, for people living within the INSEs, the house type doesn't matter since informality seems to place all people on an equal platform when it comes to the cost of water. It was also true that there were other factors that households considered on the type of house they chose to stay in, including the size of the house, security and proximity to their workplaces; and these factors were not really based on household income.

The other factor that played into easing the cost of water was technology. A prepaid meter technology was an automated teller machine (ATM) or Pre-Paid Dispenser (PPD) in which a chip was programmed to dispense a certain quantity of water per unit cost. This technology was part of an effort by NCWSC to control the price of water allowing for a Pay-As-You-Go (P.A.Y.G) model. The cost of water at the water ATM was reasonably cheap as reported by one of the FGD participants in Kamkunji area.

> "Nairobi water services through PPD self-service project provides fresh water to us at KSh. 1 per 20L jerrican. It has at least normalized water availability in the area and also improved water quality".

Indeed, despite the pro-poor strategy in Nairobi County which sets the standard water price of 20L container at KSh. 2, it was found that the price varied across the water kiosks, but largely people paid more than the set price. The situation is the same across many peri-urban settlements in African cities. For instance, in a study conducted by Bakker et al. (2008) in South African urban areas; found that households in informal setlements were disproportionately affected by water pricing policies, which did not account for the higher prices incurred by these households. Similarly, in peri-urban areas of Zimbabwe, Machethe et al. (2019) found that water scarcity and the high cost of water from vendors was a burden to households living in informal settlements. In Addis Ababa, Adane et al. (2017) highlighted that residents of informal settlements in Addis Ababa spent more than 10% of their household income purchasing water. Due to lack of municipal connection, households in informal settlements in East Africa spend up to 5% of the household income on water (Thompson et al. 2001). In Nairobi, this trend is evident as well, with informal settlement residents often paying more per liter for water compared to those in formal housing areas due to the lack of direct municipal water connections.

Generally, informal settlement residents across African cities continue to face significant challenges due to the lack of tailored water policies that address their unique needs and higher costs. It will be important to explore mechanisms to ensure that pro-poor water strategies are put in place to mitigate these inequities and therefore make water more affordable, either through household connection or from collection points such as water kiosks.

4.8. Water Quality

Water quality analysis looked at the sources which are classified as improved (safe) and un-improved (unsafe), and perceptions of the household respondents on water safety as suggested by Shaw (2014). The households' perception on water quality considers organoleptic characteristics of water such as colour or turbidity, taste and odour. Then analysis of households who treated water before use was computed with a focus on those with unsafe sources. Finally, analysis on the people who reported diarrheal cases in the household was analysed as an indication of water quality. The results are presented in the following sections.

4.8.1. Water quality accessed by household versus Sub-County

The study sought to determine the water quality in the various sub-counties under study. The study classified the areas into those with no quality water source and those with at least one quality source. The findings were summarised in Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.45:

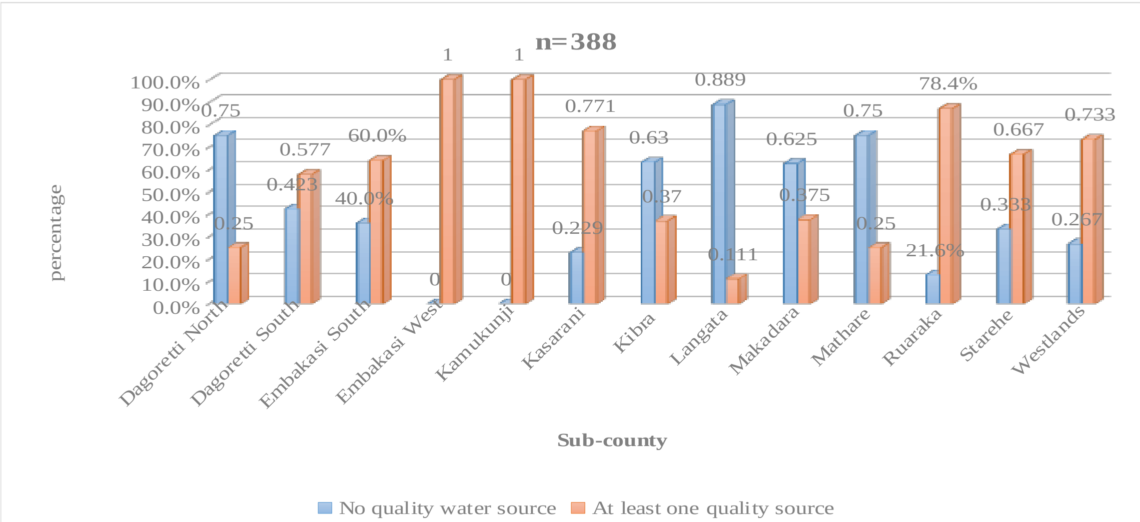

Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.45: Water quality accessed by household versus Sub-County

Source: Field data, 2023

From the analysis, the sub-counties with at least one quality source of water included; Dagoretti North 3 (25.0%), Dagoretti South 15 (57.7%), Embakasi South 51 (60.0%), Embakasi West 1 (100.0%), Kamukunji 14 (100.0%), Kasarani 27 (77.1%), Kibra10 (37.0%), Langata 1 (11.1%), Makadara 6 (37.5%), Mathare 4 (25.0%), Ruaraka 80 (78.4%), Starehe 10 (66.7%) Westlands 22 (73.3%). Those who had no any quality water source were; Dagoretti North 9 (75.0%), Dagoretti South 11 (42.3%), Embakasi South 34 (40.0%), Embakasi West 0 (0.0%), Kamukunji 0 (0.0%), Kasarani 8 (22.9%), Kibra 17 (63.0%), Langata 8 (88.9%), Makadara 10 (62.5%), Mathare 12 (75.0%), Ruaraka 22

(21.6%), Starehe 5 (33.3%) Westlands 8 (26.7%). A chi- square value of ($\chi^2_{12,0.05}$=73.695, p<0.05) showed there was a significant relationship between the two variables.

4.8.2. Water quality accessed by household versus highest level of education

The study also established the relationship between water quality and the highest level of education of the household head. The results are detailed in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.25.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.25: Water quality versus highest level of education attained by household head

The highest level of education attained by the household head	Water Quality (Household with at least one quality water source)						
	No quality water source		At least one quality source		Total		X^2
	F	%	F	%	F	%	
No Education	4	36.4	7	63.6	11	100.0	
Primary incomplete	0	0.0	1	100.0	1	100.0	
Primary complete	39	43.8	50	56.2	89	100.0	6.533
Secondary incomplete	7	29.2	17	70.8	24	100.0	(0.479)
Secondary complete	43	32.0	91	68.0	134	100.0	
Tertiary (Certificate/Diploma)	25	37.3	42	62.7	67	100.0	
University	20	39.2	31	60.8	51	100.0	
Postgraduate	3	27.3	8	72.7	11	100.0	
Total	**141**	**36.3**	**247**	**63.7**	**388**	**100.0**	

Source: Field data, 2023

As it can be seen from the results, the households with at least one quality source of water for the different education levels were; No Education 7 (63.6%), Primary incomplete 1 (100.0%), Primary complete 50 (56.2%), Secondary incomplete 17 (70.8%), Secondary complete 91 (68.0%), Tertiary (Certificate/Diploma) 42 (62.7%), University 31 (60.8%), Postgraduate 8 (72.7%). Those who had no quality water source included; No Education 4 (36.4%), Primary incomplete 0 (0.0%), Primary complete 39 (43.8%), Secondary incomplete 7 (29.2%), Secondary complete 43 (32.0%), Tertiary (Certificate/Diploma) 25 (37.3%), University 20 (39.2%), Postgraduate 3 (27.3%).

From the Chi- square value of ($\chi^2_{7,0.05}$=6.533, P>0.05), it was an indication that there was no significant relationship between water quality and level of education attained by household head. However, this was contrary to, Omondi & Jackson (2022), who from a study on households' heads characteristics and access to water carried out in Kenya, found out that households with education whether primary, secondary, or tertiary compared to households with no education, increased the probability of a household selecting clean source of water. This contrast could be as a result of the fact that, in informal settlements, the context under which people live does not act favourbly to anyone based on the level of education, that is, it doesn't matter whether you have knowledge of the need for accessing good water quality but rather, depend on the only sources available. In the Omondi & Jackson (2022), the study was country-wide drawing data from the 2015/2016 Kenya Integrated Household Budget Survey.

4.8.3. Water quality accessed by household versus employment status

On the relationship between water quality accessed by household and the employment status of the household head (Table CHAPTER FOUR

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.26), the study established that those who had no quality water source for the different categories included; Not employed 32 (34.0%), Employed salaried 20 (42.6%), Employed casual labourer 40 (43.4%), Self-employed 51 (33.3%), Student 1 (50.0%). Those who had at least one quality water source were; not employed 62 (66.0%), Employed salaried 27 (57.4%), Employed casual labourer 52 (56.6%), Self-employed 102 (66.7%), Student 1 (50.0%).

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.26: Water quality accessed by household versus employment status of household head

The employment status of the household head	Water Quality (Household with at least one quality water source)				Total		X^2
	No quality water source		At least one quality source				
	F	%	F	%	F	%	
Not employed	32	34.0	62	66.0	94	100.0	
Employed salaried	20	42.6	27	57.4	47	100.0	3.667
Employed casual labourer	40	43.4	52	56.6	92	100.0	(0.453)
Self employed	51	33.3	102	66.7	153	100.0	
Student	1	50.0	1	50.0	2	100.0	
Total	**144**	**37.1**	**244**	**62.9**	**388**	**100.0**	

Source: Field data, 2023

From the A chi- square analysis, ($\chi^2_{4,0.05}$=3.667, P>0.05), the study revealed that, there was no signifant relationship between water quality and employment status of the household head. This was in contrast to Omondi & Jackson (2022), who found out that, being employed as well as being male increased the probability of accessing clean water. The reason of this contrast could be as a result of the inherent water insecurity in the INSEs which may not depend on employment status. A majority of people living in the study area were found to be engaged in casual labour who were very much aware of water quality needs for their households. In our observation, people who had more than one source of water, used NCWSC sources or what they perceived as better quality for drinking and cooking purposes, while they used optional sources which they considered less quality for cleaning and sanitation purposes.

4.8.4. Water quality accessed by household versus household income

The study further established the relationship between water quality and household income, as summarised in Table CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.27.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.27: Water quality accessed by household versus household income

The approximate monthly income of the household in Kenya shillings	Water Quality (Household with at least one quality water source)						
	No quality water source		At least one quality source		Total		X^2
	F	%	F	%	F	%	
Less than 23,670	117	37.0	199	63.0	316	100.0	0.385
Between 23671 to 119,999	28	38.8	44	61.2	72	100.0	(0.535)
Total	**145**	**37.4**	**243**	**62.6**	**388**	**100.0**	

Source: Field data, 2023

The results show that, those who had no quality water source for the respective income were; less than KSh. 23,670 were 117 (37.0%) and between KSh. 23,671 to KSh. 119,999 were 28 (38.8%). A chi-square test was done and the value ($\chi^2_{1,0.05}$=0.385, P>0.05) revealed that there was no significant relationship between water quality and household income.

In the study it emerged that, level of household income did not have any influence on the water quality accessed by the household. While it could be apparent that, households with better income will choose a better source of quality water, the context in the INSEs in Nairobi made the choice a bit limited to the available sources. This again might not be the case if a similar study was carried out in an environment outside the INSEs as was the case of, Omondi & Jackson (2022), where in a cross-sectional study covering the whole country in Kenya found that, an increase in the income of the household head led to an increase in the household's access to clean water.

4.8.5. Water quality accessed by household versus main source of income

The research established the relationship between water quality and main source of income. The findings were as shown in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.28:

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.28: Water quality accessed by household versus source of income

Main source of income of the household	Water Quality (Household with at least one quality water source) No quality water source		At least one quality source		Total		X^2
	F	%	F	%	F	%	
Aid/Cash transfer	1	50.0	1	50.0	2	100.0	
Formal employment	17	37.0	29	63.0	46	100.0	0.488
Remittance from relatives	6	37.5	10	62.5	16	100.0	(0.975)
Small scale trade	68	37.7	112	62.3	180	100.0	
Wage earner	53	36.8	91	63.2	144	100.0	
Total	**145**	**37.4**	**243**	**62.6**	**388**	**100.0**	

Source: Field data, 2023

Results show that, those who were with no quality water source included; Aid/Cash transfer 1 (50.0%), formal employment 17 (37.0%), remittance from relatives 6 (37.5%), small scale trade 68 (37.7%), wage earner 53 (36.8%). On the other hand, those who had at least one quality water source included; Aid/Cash transfer 1 (50.0%), formal employment 29 (63.0%), remittance from relatives 10 (62.5%), small scale trader 112 (62.3%), wage earner 91 (63.2%). Chi-square value of ($\chi^2_{4,0.05}$=0.488, P>0.05) showed that there was no significant relationship between water quality and main source of income.

People living in INSEs in Nairobi are involved in various livelihood activities – from small trade, casual work, formal and informal employment etc. It is therefore expected that, some income sources are more stable than others and might have the households make differentiated decisions on water quality to access. However, the study has shown that, the source of income didn’t influence the water quality that the household accessed. It however, important to say that, while this finding was pointing to main source of water accessed by the household, they (households) also had other optional sources where they could source higher quality of low quality water depending on the use the household intended to use it for.

4.8.6. Water quality accessed by household versus type of house

The study established the relationship between water quality and type of house of the household head. The results are as shown in Table CHAPTER FOUR

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CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.29. From the analysis, those who had no quality water source for the various house type included; Made from Sticks and Mud Walls 12 (42.9%), Made of Timber with Iron-sheet cladding 42 (35.3%), Made of sticks, cartons, and other assorted materials 1 (50.0%) made of concrete walls 84 (35.4%). on the other hand, those with at least one quality source of water includes; made from sticks and mud walls 16 (57.1%), Made of Timber with Iron-sheet cladding 77 (64.7%), made of sticks, cartons, and other assorted materials 1 (50.0%), made of concrete walls were 153 (64.6%), others2 (100.0%). A chi- square value of ($\chi^2_{4,0.05}$=2.023, P>0.05) was obtained and it showed that there was no significant relationship between water quality and the type of house.

Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.29: Water quality accessed by household versus type of house

Type of House	Water Quality (Household with at least one quality water source)				Total		X^2
	No quality water source		At least one quality source				
	F	%	F	%	F	%	
Made from Sticks and Mud Walls	12	42.9	16	57.1	28	100.0	
Made of Timber with Iron-sheet cladding	42	35.3	77	64.7	119	100.0	2.023
Made of sticks, cartons, and other assorted materials	1	50.0	1	50.0	2	100.0	(0.732)
Made of Concrete walls	84	35.4	153	64.6	237	100.0	
Other: (specify)	0	0.0	2	0.0	2	100.0	
Total	**139**	**35.8**	**249**	**64.2**	**388**	**100.0**	

Source: Field data, 2023

4.9. Reliability of Water Service

The study sought to find out the reliability of water services in the area. The researcher established this through the number of days that stored water could last when there is no water supply. The results of this analysis are shown in Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.30.

From the table it can be observed that 107 (27.6%) could store for at least five days, 94 (24.2%) can store for more than five days, 90 (23.2%) could store for three days, 45(11.6%) for two days, 32 (8.2%) for one day and lastly 20 (5.2%) for four days.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.30: Number of days stored water can last when there is no water supply

Number of days stored water can last	Frequency	Percent
One day	32	8.2%
Two days	45	11.6%
Three days	90	23.2%
Four days	20	5.2%
Five days	107	27.6%
More than five days	94	24.2%
Total	**388**	**100.0**

Source: Field data, 2023

Ochungo et al. (2019) states that distributive efficiency is the determining factor in a water supply system's reliability. If a water distribution system can resist pressure surges and other types of failures up to a certain threshold, it is considered reliable. Three factors determine the reliability of a water works system: the amount of water provided at the correct pressure and time, the quality of that water, and whether or not all consumers can afford it fairly. Urban water supply unreliability is a prevalent concern, especially in developing nations, according to the study. The cost of coping is putting a significant strain on households in many regions (Ochungo et al., 2019).

4.9.1. Water service reliability versus Sub-County

The study determined the relationship between water service reliability and sub-county.

The various sub-counties were divided into those which are water unreliable and water reliable households, as shown in Figure CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.46.

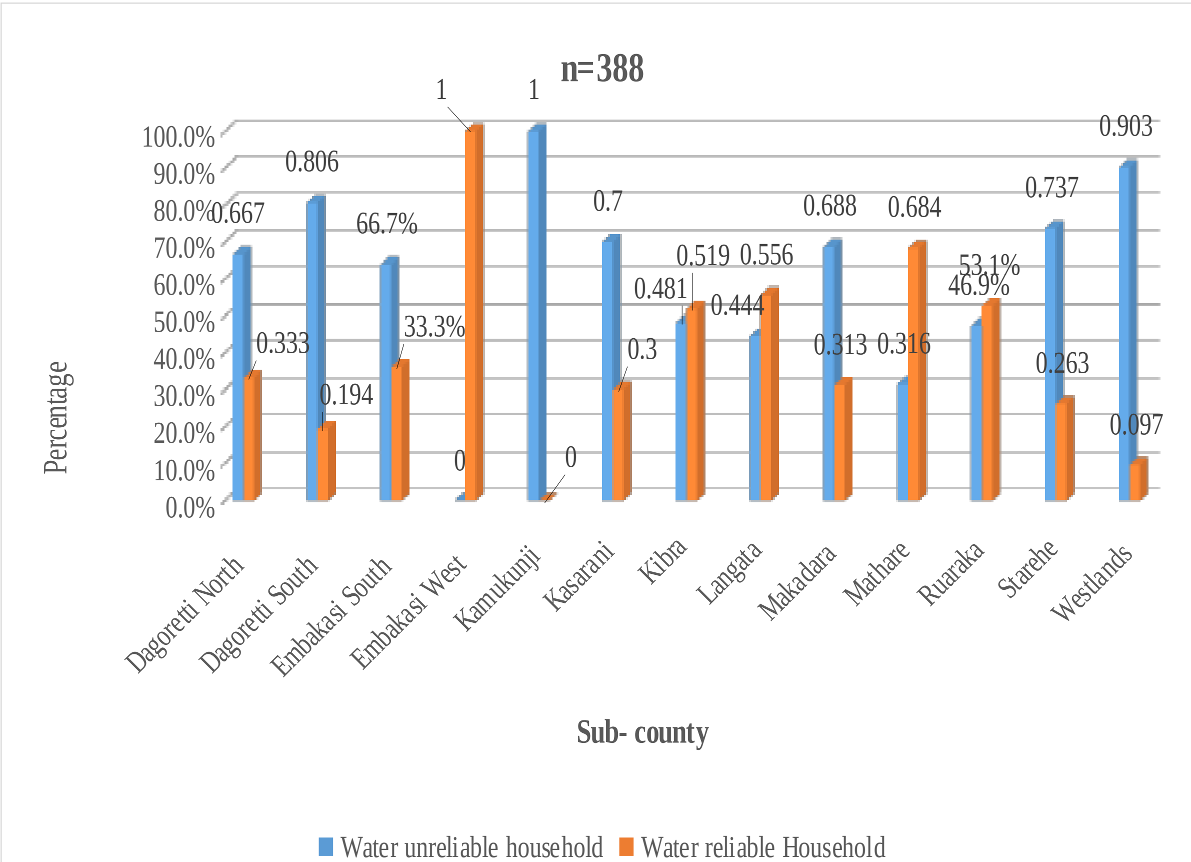


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.46: Water service reliability versus Sub-County

Source: Field data, 2023

From the analysis it was found that, those who were water reliable included; Dagoretti North 6 (33.3%), Dagoretti South 6 (19.4%), Embakasi South 20 (33.3%), Embakasi West

1(100.0%), Kamukunji 0 (0.0%), Kasarani 15 (30.0%), Kibra 14 (51.9%), Langata 5 (55.6%), Makadara 5 (31.3%), Mathare 13 (68.4%), Ruaraka 43 (53.1%), Starehe 5 (26.3%), Westlands 3 (9.7%). On the other hand, those who are water unreliable included; Dagoretti North 12 (66.7%), Dagoretti South 25 (80.6%), Embakasi South 40 (66.7%), Embakasi West 0 (0.0%), Kamukunji 26 (100.0%), Kasarani 35 (70.0%), Kibra 13 (48.1%), Langata 4 (44.4%), Makadara 11 (68.8%), Mathare 6 (31.6%), Ruaraka 38 (46.9%), Starehe14 (73.7%), Westlands 28 (90.3%).

A chi- square computed ($\chi^2_{12,0.05}$=55.620, P<0.005) was obtained which showed that there was a significant relationship between water service reliability and sub-county. This agreed with the findings of Sverdlik & Walnycki (2020) found that water service reliability varied significantly across the different sub-counties in Nairobi. That areas with better infrastructure and efficient local governance experienced experienced more reliable water services. This suggests that targeted investments and policy interventions in underdeveloped sub-counties are necessary to improve water service reliability (Sverdlik & Walnycki, 2020).

The spatial nature of reliability of services was also closely linked to the presence of water cartels. These cartels undertook illegal connections or even illegally took up ownership of government installed water points, denying locals a chance to access of water. For instance, in an FGD carried out in Kamkunji, one responded said,

> "There are too many illegal connections along the main pipeline and this has affected the pressure in the system, making the water supply un-reliable".

Other reasons given by the FGD respondents included corruption in which case, water kiosks that have been installed in chiefs' camps was actually being sold to people when it was supposed to be accessed for free.

4.9.2. Water service reliability versus highest level of education

The study established the relationship between water service reliability and the level of education. From the findings (Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.47), those who were water reliable for the different levels of education included; No Education 5 (45.5%), Primary incomplete 1 (100.0%), Primary complete 39 (41.9%), Secondary incomplete 10 (29.4%), Secondary complete 42 (35.0%), Tertiary (Certificate/Diploma) 15 (24.2%), University 19 (37.3%), Postgraduate 5 (31.3%). On the flip coin, those with unreliable water in the household were; No Education 6 (54.5%), Primary incomplete 0 (0.0%), Primary complete 54 (58.1%), Secondary incomplete 24 (70.6%), Secondary complete 78 (65.0%), Tertiary (Certificate/Diploma) 47 (75.8%), University 32 (62.7%), Postgraduate 11 (68.8%).

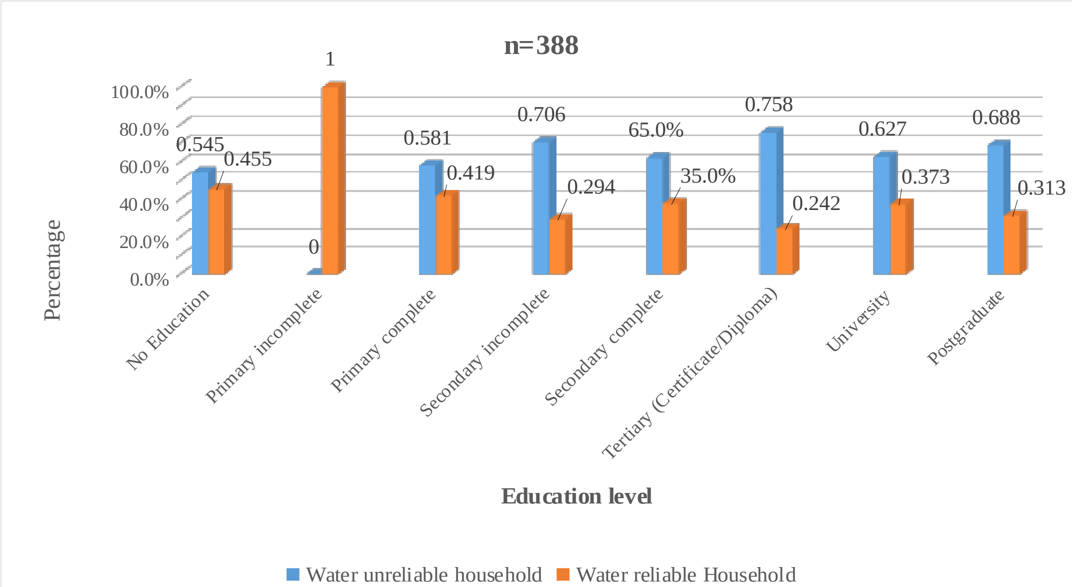


Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.47: Water service reliability versus highest level of education attained by household head

Source: Field data, 2023

From the Chi- square value of ($\chi^2_{7,0.05}$=8.401, P>0.05) it was evident that, there was no significant relationship between water service reliability and level of education of the household head. This was different from the results of McDonald et al., (2012), who found out that, higher levels of education in Nairobi's households are linked to improved reliability of water services. Two reasons given included the educated households capability to advocate for better services and the fact that they had communication skills that help them interact with water service providers. Secondly, that educated households often had higher incomes, enabling them to afford more reliable water sources (McDonald et al., 2012).

The reason for the difference in findings could be attributed to the context in which the two studies were conducted. The informal settlements present a totally different environment where water scarcity is prevalent and therefore education may not dictate the water service reliability experienced by a household on the basis of education.

4.9.3. Water service reliability versus employment status

The relationship between water service reliability and employment status of the various categories showed that those who were water unreliable were; Not employed 62 (62.0%) employed salaried 32 (64.0%), Employed casual labourer 43 (51.8%), Self-employed 111 (72.5%), Student 0 (0.0%). On the other side, those who had water reliable were; Not employed 38 (38.0%), Employed salaried 18 (36.0%), Employed casual labourer 40 (48.2%), Self-employed 42 (27.5%), Student 2 (100.0%).

The results of water service reliability versus employment status were as summarized in Figure CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.48.

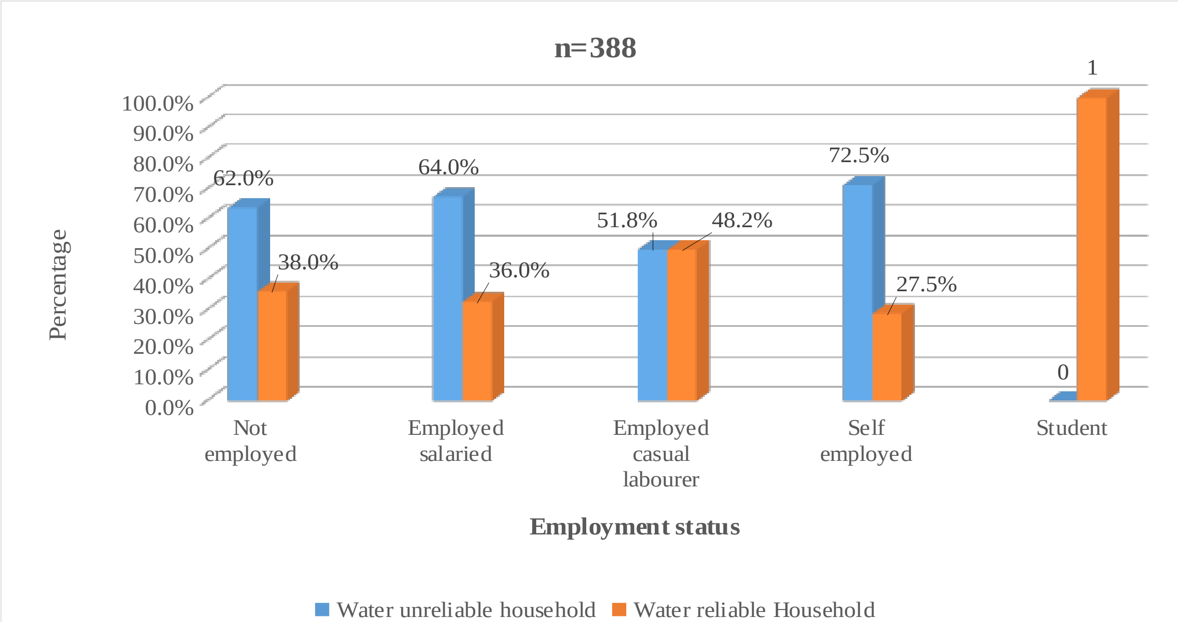


**Figure CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.48: Water service reliability versus employment status of household head**

Source: Field data, 2023

A chi-square value of ($\chi^2_{4,0.05}$=14.760, P<0.005) showed that there was a significant relationship between water service reliability and employment status of the household head. This is in agreement with K'Akumu & Appida (2006), who found that employment status significantly impacted water service reliability. Employed individuals typically have better financial stability, allowing them to invest in reliable water sources or pay for consistent water delivery services. Conversely, unemployed individuals or those dependent in casual jobs had unstable income and therefore struggled to secure reliable water, worsening their water insecurity situation, (K'Akumu & Appida, 2006).

4.9.4. Water service reliability versus household income

The study sought to determine the relationship between water service reliability and household income. From the findings, those with unreliable water were; less than 23,670 were 210 (62.1%) and those earning between 23,671 to 119,999 were 38 (76.0%). The ones with water reliable in the households were; less than 23,670 were 128 (37.9%), between 23,671 to 119,999 were 12 (24.0%). From the analysis, a chi- square value of ($\chi^2_{1,0.05}$=3.730, P>0.05) showed that there was no significant relationship between water service reliability and household income.

The results were summarized in Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.31:

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.31: Water service reliability versus household income

The approximate monthly income of the household in Kenya shillings	Reliability (Consolidated water reliability)						
	Water unreliable household		Water reliable Household		Total		X^2
	F	%	F	%	F	%	
Less than 23,670	210	62.1	128	37.9	338	100.0	
Between 23671 to 119,999	38	76.0	12	24.0	50	100.0	3.730 (0.053)
Total	**248**	**63.9**	**140**	**36.1**	**388**	**100.0**	

Source: Field data, 2023

The results contrast Kjellén & McGranahan (2006), who found that household income was a critical determinant of water service reliability in Nairobi. Specifically, Kjellén & McGranahan (2006), found that higher-income households could afford to invest in infrastructure such as water tanks and pumps, ensuring a consistent water supply. On the other hand, those from lower-income households often relied on less reliable sources, such as communal taps or water vendors, which were prone to disruptions (Kjellén & McGranahan, 2006).

The contrast in these findings could be due to the context in which the two studies were conducted. While this study focused on the informal settlements, Kjellén & McGranahan (2006) targeted the entire population of Nairobi City. The most accessed water services in the informal settlements were through the informal services which are inherently less reliable.

4.9.5. Water service reliability versus main source of household income

The relationship between water service reliability and main source of household income was established. The study classified them into households that were water unreliable and water reliable. From Table CHAPTER FOUR

WATER SECURITY

CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.32, those who were water reliable included; Aid/Cash transfer 2 (100.0%) Formal employment 12 (24.0%), Remittance from relatives 12 (70.6%), Small scale trade 65 (34.6%), Wage earner 49 (37.4%). On the other hand, those with water unreliable households were, Aid/Cash transfer 0 (0.0%) Formal employment 38 (76.0%), Remittance from relatives 5 (29.4%), Small scale trade 123 (65.4%), Wage earner 82 (62.6%). A chi- square value of ($\chi^2_{4,0.05}$=15.617, $P<0.005$) indicated a significant relationship between water service reliability and the main source of income for the household head.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.32: Water service reliability versus main source of household income

MAIN source of income of the household	Reliability (Consolidated water reliability) Water unreliable household		Water reliable Household		Total		X^2
	F	**%**	**F**	**%**	**F**	**%**	
Aid/Cash transfer	0	0.0	2	100.0	2	100.0	
Formal employment	38	76.0	12	24.0	50	100.0	15.617
Remittance from relatives	5	29.4	12	70.6	17	100.0	**(0.004)**
Small scale trade	123	65.4	65	34.6	188	100.0	
Wage earner	82	62.6	49	37.4	131	100.0	
Total	**248**	**63.9**	**140**	**36.1**	**388**	**100.0**	

Source: Field data, 2023

The findings are similar to the studie of Baker & Lettenmaier (2020) who found that the main source of household income affected water service reliability. It was found that, households who were in formal employment had stable income which made them to be more likely to experience reliable water services compared to the ones in informal jobs who faced greater challenges in maintaining a consistent water supply, and therefore experienced water security (Baker & Lettenmaier, 2020).

4.9.6. Water service reliability versus type of house

On the relationship between water service reliability and the type of house (Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.33), the study established that those who are water unreliable were; Made from Sticks and Mud Walls 22 (66.7%), Made of Timber with Iron-sheet cladding 90 (65.7%), Made of sticks, cartons, and other assorted materials 3 (75.0%), Made of Concrete walls 135 (63.7%). On the other hand, those who were water reliable were; Made from Sticks and Mud Walls 11 (33.3%), Made of Timber with Iron-sheet cladding 47 (34.3%), Made of sticks, cartons, and other assorted materials 1 (25.0%), Made of Concrete walls 77 (36.3%).

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.33: Water service reliability versus type of house

Type of house in terms of construction materials	Reliability (Consolidated water reliability) Water unreliable household		Water reliable Household		Total		X^2
	F	%	F	%	F	%	
Made from Sticks and Mud Walls	22	66.7	11	33.3	33	100.0	
Made of Timber with Iron-sheet cladding	90	65.7	47	34.3	137	100.0	1.908
Made of sticks, cartons, and other assorted materials	3	75.0	1	25.0	4	100.0	(0.753)
Made of Concrete walls	135	63.7	77	36.3	212	100.0	
Other materials	2	100.0	0	0.0	2	100.0	
Total	**252**	**64.9**	**136**	**35.1**	**388**	**100.0**	

Source: Field data, 2023

A chi- square value of ($\chi^2_{4,0.05}$=1.908, P>0.05) was obtained and it showed that there was no relationship between water service reliability and type of house. This indeed is the case for people living in informal settlements whose kind of makeshift houses or shunties. As confirmed by Thieme (2018), the type of housing influences water service reliability in Nairobi. Permanent and well-constructed houses typically have better access to reliable water services due to more robust infrastructure. In contrast, informal settlements and temporary structures often lack such infrastructure, leading to less reliable water supply and greater water insecurity (Thieme, 2018).

Overall, the study findings show that reliability depended on spatial factors (sub-county where the household was located), also showed significance to the main source of income and employment status of the household head. There was no signifance seen in terms of household income, type of house and level of education. Pointing to the fact that, attainment of reliability very much depended on the context.

This somehow agrees with Majuru et al. (2016), who in their systemic review, found that unreliable water supplies affected both households and institutions such as health care facilities, and schools, etc. They therefore recommended that urgent attention should be given to the coping strategies that households and institutions employ in such settings and how they can be optimized to address reliability issues.

4.10. Characteristics breakdown of household water security

From Table CHAPTER FOUR WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.34, it can be observed that in general, 210 (53.4%) of the households did not have readily available water in their households while 178 (46.6%) had water readily available overall from all sources. On households with acceptable water access 278 (71.7%) and those with unacceptable water access were 110 (28.3%). Households with sphere compliant were 294 (75.7%) while sphere non-compliant were 94 (24.3%). Households who were Non- Compliant with National Standard were 377 (97.1%) while those who were compliant with national standard were 11 (2.9%). On the other variable of water quality, the study found out that those who had at least one quality source were 250 (64.6%) while 138 (35.4%) did not have any quality water source.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.34: Overall status of household water security

Water security variable	Status	Frequency	Percent
Availability	Water not readily available	210	53.4%
(Household overall water availability)	Water readily available overall from all sources	178	46.6%
	N	**388**	**100.0%**
Access	Unacceptable access	110	28.3%
(Water service overall	Acceptable access	278	71.7%
access)	**N**	**388**	**100.0%**
Quantity Sphere Standard	Sphere Compliant	294	75.7%
(Sphere compliance of 15	Sphere non-compliant	94	24.3%
lpcd)	**N**	**388**	**100%**
Quantity National Standard	Non- Compliant with National Standard	377	97.1%
(Household compliant with	Compliant with National Standard	11	2.9%
National Standard water quantity of 60 lpcd)	**N**	**388**	**100.0%**
Quality	No quality water source	138	35.4%
(Household with at least one	At least one quality source	250	64.6%
water source with acceptable quality)	**N**	**388**	**100.0%**
Affordability	STD non-compliant	305	78.8%
(Standard cost per 20 litres at	STD compliant	83	21.2%
KSh. 2)	**N**	**388**	**100.0%**
Reliability	Water unreliable household	249	64.4%
(Consolidated water	Water reliable Household	139	35.6%
reliability)	**N**	**388**	**100.0%**

Source: Field data, 2023

On water affordability, 305 (78.8%) households were standard non- compliant while those who were standard compliant were 83 (21.2%). On water reliability, households with water unreliable were 249 (64.4%) households while those who had water reliable were 139 (35.6%) households.

People living in Nairobi's INSEs lived in very uncertain circumstances hence not being able to prepare well when water was not available. There also reported lack of communication from the part of NCWSC on water rationing. As one discussant reported in Kasarani,

> "I can say that we are not assured of receiving water since Nairobi water company do not give us any information on water rationing so that we can plan ourselves. Instead we are left alone to do guesswork on rationing"

4.11. Overall status of household water security

As detailed in Table CHAPTER FOUR

WATER SECURITY CHARACTERISTICS

OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.35, only one household of the sampled households met all the criteria of being water secure by meeting all the six parameters of water security representing only 0.4%. a majority of the households, 31.8% satisfied four parameters, 30% met three parameters, 20.8% met two parameters, 11.7% met 5 parameters and 5.3% met one parameter. This pointed to a situation where water security is a major concern in Nairobi's INSEs.

Table CHAPTER FOUR
WATER SECURITY CHARACTERISTICS OF EXISTING WATER SERVICE PROVISION SYSTEMS IN INFORMAL SETTLEMENTS WITHIN NAIROBI COUNTY.35: Overall score on water security characteristics

Number of water security characteristics met	Number of households	Percent
1	15	5.3
2	59	20.8

3	85	30.0
4	90	31.8
5	33	11.7
6	1	0.4
Total	**283**	**100.0**

Source: Field data

From the research findings, there was a correlation between the water security factors (availability, access, quantity, quality, affordability and reliability) with sub-counties, an indication that, spatial, socio-demographic and environmental factors palyed a major role in attainment of water security. This was also the case for a study in Benin which highlighted socio-demographic and environmental factors as important factors in water access, Gaffan, N., (2022).

CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA

5.1. Introduction

The findings in this chapter are in line with objective two of the study, which sought to examine the different existing structures (production, treatment, storage, and distribution) of water service provision systems and how they impact on the water security factors (availability, access, quantity, quality, affordability and reliability). Analysis was undertaken for the four major categories of structures: no structure (water delivered by hand carts, tankers or other means), basic structure (water fetched from source e.g., borehole or wells), intermediate structure (water accessed from kiosk) and full structure (water connected to house or from shared connections). This was then run against the water security variables.

5.2. Water service levels

Water service levels (WSL) were computed based on access levels classified as optimal, intermediate, basic and no service levels. From the findings in Table CHAPTER FIVE

THE EXISTING STRUCTURE OF

WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.36, 255 (65.7%) had intermediate access, 81 (20.9%) had basic access, 28 (7.1%) had no service while 24 (6.3%) had optimal access to water services.

Table CHAPTER FIVE
THE EXISTING
STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.36 : Water service levels

Ref.	Service Level Accessed by household	Frequency	Percentage
1	Optimal access	24	6.3
2	Intermediate access	255	65.7
3	Basic access	81	20.9
4	No service	28	7.1
	Total	**388**	**100.0**

Source: Field data, 2023

If acceptable and unacceptable access is classified based on intermediate and optimal access, then the Table CHAPTER FIVE

THE EXISTING

STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.37, gives a summary of the findings. It can be observed that 276 (71.2%) of the respondents had acceptable access to water while on the other hand, 112 (28.8%) had unacceptable access.

Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.37 : Water service overall access

Ref	Acceptability of access	Frequency	Percentage
1	Unacceptable access	112	28.8
2	Acceptable access	276	71.2
	Total	**388**	**100.0**

Source: Field data, 2023

5.3. Water service structures

Water service structures was classified based on 4 categories:

i. **No water service structure –** where water delivery to the household was either done by water tanker or boozer, water cart, rainwater harvesting and those with other sources.

ii. **Basic water service structure-** In this structure, there existed only production infrastructure and therefore it included sources where household picked water directly from the source. This included private and public boreholes.

iii. **Intermediate water service structure –** In this structure, it had production and storage but no pipeline to households but there existed access infrastructure in the neighbourhood. Water kiosks were classified as intermediate structures.

iv. **Full water service structure –** the one with production, storage and reticulation or pipeline. The following water sources were classified as ones with full structure: Piped connection, shared connection, shared plot connection, shared neighbour connection.

From the Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.38, 197 (51.0%) had no water service structure, 34 (8.7%) had basic structure, 11 (2.9%) had intermediate structure, and 146 (37.5%) of the respondents had full water service structure.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.38 : Water service structure

Ref	Water Service Structure available to household	Frequency	Percentage
1	Full structure	146	37.5
2	Intermediate structure	11	2.9
3	Basic structure	34	8.7
4	No structure	197	51.0
	Total	**388**	**100.0**

Source: Field data, 2023

5.3.1. Water Service Structure versus Sub-County

The study established the relationship between water service structure and the sub- counties in Nairobi County. Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL

SETTLEMENTS IN NAIROBI COUNTY, KENYA.39 summarizes the findings.

Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.39 : Water service structure versus Sub-County

Sub-County	Water service structure										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
Dagoretti North	12	66.7	1	5.6	0	0.0	5	27.8	18	100.0	
Dagoretti South	16	51.6	10	32.3	0	0.0	5	16.1	31	100.0	
Embakasi South	39	54.2	22	30.6	2	2.8	9	12.5	72	100.0	
Embakasi West	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	
Kamukunji	13	50.0	13	50.0	0	0.0	0	0.0	26	100.0	
Kasarani	25	50.0	14	28.0	2	4.0	9	18.0	50	100.0	144.55
Kibra	25	92.6	2	7.4	0	0.0	0	0.0	27	100.0	**(0.001)**
Langata	8	88.9	0	0.0	0	0.0	1	11.1	9	100.0	
Makadara	14	87.5	2	12.5	0	0.0	0	0.0	16	100.0	
Mathare	12	63.2	1	5,3	3	15.8	3	15.8	19	100.0	
Ruaraka	24	25.8	66	71.0	1	1.1	2	2.2	93	100.0	
Starehe	13	68.4	6	31.6	0	0,0	0	0.0	19	100.0	
Westlands	11	35.5	14	45.2	4	12.9	2	6.5	31	100.0	
Total	**197**	**51.0**	**146**	**37.5**	**11**	**2.9**	**34**	**8.7**	**388**	**100.0**	

Source: Field data, 2023

From the findings, those with full water structure for the various sub-counties were; Dagoretti North 1 (5.6%), Dagoretti South 10 (32.3%), Embakasi South 22 (30.6%), Embakasi West 1 (100.0%), Kamukunji 13 (50.0%), Kasarani 14 (28.0%), Kibra 2 (7.4%), Langata 0 (0.0%), Makadara 2 (12.5%), Mathare 1 (5.3%), Ruaraka 66 (71.0%), Starehe 6 (31.6%) and Westlands 14 (45.2%). A chi- square value of ($\chi^2_{12,0.05}$=144.554, P<0.05) showed a significant relationship between water service structures and sub- counties.

5.3.2. Water service structure versus National quantity standard

The study established water service structure against national standard quantity. The respondents were classified into non-compliant with standard of 60 lpcd and those who are compliant. From the findings in Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.40, only 5 (45.5%) were compliant with the full structure. A chi- square computation of ($\chi^2_{4,0.05}$=2.676, P>0.05) showed that there was a significant relationship between water service structures and national standard quantity.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.40 : Water Service Structure versus National Standard Quantity

Compliance to National Quantity Standard of 60 lpcd	Water service structure coded										
	No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	%	F	%	F	%	F	%	F	%	
Non-Compliant with National Standard of 60 lpcd	207	54.9	118	31.4	16	4.2	36	9.5	377	100.0	2.676
Compliant with National Standard of 60 lpcd	4	36.4	5	45.4	0	0.0	2	18.2	11	100.0	(0.444)
Total	**211**	**54.4**	**123**	**31.7**	**16**	**4.1**	**38**	**9.8**	**388**	**100.0**	

Source: Field data, 2023

5.3.3. Water Service Structure versus Sphere Standard Quantity

On those who had water service structure and had a sphere standard quantity were classified in terms of the households able to access water of 15 lpcd. From the findings, 30 (26.3%) had full structure and were accessing less than 15 lpcd of water while 98 (35.7%) had full structure and could access more than 15 lpcd of water. A chi-square value of ($\chi^2_{3,0.05}$=3.478, P>0.05) showed that there was no significant relationship between the two variables (Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.41).

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.41 : Water Service Structure versus Sphere Standard Quantity

Households meeting SPHERE Standard Water Quantity	Water service structure coded										
	No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	%	F	%	F	%	F	%	F	%	
Households accessing <15 lpcd	66	57.9	30	26.3	5	4.4	13	11.4	114	100.0	
Households accessing ≥15 lpcd	148	54.0	98	35.7	7	2.6	21	7.7	274	100.0	3.478
Total	**214**	**55.2**	**128**	**32.9**	**12**	**3.1**	**34**	**8.8**	**388**	**100.0**	0.324

Source: Field data, 2023

5.3.4. Water Service Structure versus affordability

On the relationship between water service structure and affordability, the study established that 102 (32.7%) had full structure but were buying water at more than the set standard of KSh. 2/20L jerry can. Only 26 (30.3%) of the households had full structure and were buying water at or less than KSh. 2/20L container in the study area (Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.43). On whether there was relationship between water service structure and affordability, the Chi-square value ($\chi^2_{3,0.05}$=2.203, P>0.05) established that there was no significant relationship.

Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.42 : Water Service structure versus Affordability based on cost of 20L container

Compliance to standard cost of water based on 20L container	Water service structure coded										
	No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	%	F	%	F	%	F	%	F	%	
Households buying water at more than the set standard	158	50.6	102	32.7	16	5.1	36	11.6	312	100.0	2.203

KSh. 2/20L container.											
Households buying water at or less than the set standard KSh. 2/20L container.	46	60.5	23	30.3	2	2.6	5	6.6	76	100.0	0.531
Total	**204**	**52.6**	**125**	**32.2**	**18**	**4.6**	**41**	**10.6**	**388**	**100.0**	

Source: Field data, 2023

5.3.5. Water Service Structure versus consolidated reliability of services

A relationship between water service structure and water reliability was established. From the findings in Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.43, households with water unreliable and had full structure were 100 (39.4%) while those who were water reliable and full structure were 42 (31.3%). A chi- square value of ($\chi^2_{3,0.05}$=2.222, P>0.05) showed that there was no significant relationship between the water service structure and water reliability.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.43 : Water Service Structure versus Consolidated Reliability of Water Services

Househol	**Water service structure coded**

d reliability based on existing structure	No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	
Water unreliable household	126	49.6	100	39.4	7	2.7	21	8.3	254	100.0	2.222
Water reliable Household	72	53.7	42	31.3	5	3.8	15	11.2	134	100.0	0.528
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Source: Field data, 2023

5.3.6. Water Service Structure versus consolidated overall availability of services

The study established the water service structure and water availability of water (Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.44). From the findings, those who had full structure and water was readily available were 50 (28.0%). On the other hand, those who had full structure but water was not readily available was 92 (43.8%). A chi- square value of ($\chi^2_{3,0.05}$=11.170, P<0.05) showed that there was significant relationship between the water service structure and overall water availability.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.44 : Water Service Structure versus Consolidated Overall Availability of Water Services

Availability of water based on structure	Water service structure										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
Water not readily available	92	43.8	92	43.8	5	2.4	21	10.0	210	100.0	11.170
Water readily available overall from all sources	106	59.6	50	28.0	7	3.9	15	8.4	178	100.0	**(0.010)**
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Source: Field data, 2023

5.3.7. Water Service Structure versus household with at least one source with acceptable water quality

The study established water service structure against household with at least one source with acceptable water quality. From Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.45, it was observed that 98 (40.2%)

had a full structure and at least one quality source of water. Those who had full structure but had no quality water were 28 (19.4%). A chi- square value of ($\chi^2_{3,0.05}$=21.558, P<0.05) showed that there was a significant relationship between water service structure and at least one source with acceptable water quality.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.45 : Water Service Structure versus Household with At least One Source with Acceptable Water Quality

Household access to quality at least one acceptable quality water source	**Water service structure coded**										
	No structure		**Full structure**		**Intermediate structure**		**Basic structure**		**Total**		**X^2**
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	
No quality water source	85	59.0	28	19.4	10	6.9	21	14.7	144	100.0	21.558
At least one quality source	115	47.1	98	40.2	13	5.3	18	7.4	244	100.0	**(0.001)**
Total	**200**	**51.5**	**126**	**32.5**	**23**	**5.9**	**39**	**10.1**	**388**	**100.0**	

Source: Field data, 2023

5.3.8. Water Service Structure versus household overall water access

The study sought to determine the relationship between water service structure and household overall water access. The households with unacceptable access and had full structure were 34 (32.1%) while those who had an acceptable access and had a full structure were 108 (38.3%) as shown in Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.46.

Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.46 : Water Service Structure versus Household Overall Water Access

Water access	**Water service structure coded**										**X^2**
	No structure		**Full structure**		**Intermediate structure**		**Basic**		**Total**		
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	
Unacceptable access	43	40.6	34	32.1	8	7.5	21	19.8	106	100.0	26.972
Acceptable access	155	55.0	108	38.3	4	1.4	15	5.3	282	100.0	**(0.001)**
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Source: Field data, 2023

From the analysis of water service structure against water security variables the Chi-square value ($\chi^2_{3,0.05}$=26.558, P<0.05) that was computed showed that there was an association of water service structure and availability, access and quality. There was no association found between water service structure and quantity, affordability, and reliability.

The study showed that, various water security parameters in Nairobi's informal settlements significantly varied across different sub-counties, reflecting disparities in infrastructure, investment, and resource management. This was supported by K'Akumu and Appida (2006) who concluded that the political landscape in Nairobi influences water access, with sub-counties that have strong political representation and advocacy enjoying better water services. This was the case with Bartram & Cairncross (2010) who highlighted that areas with better-developed infrastructure had relatively higher water access, emphasizing the role of governmental and non-governmental investment in improving water services.

5.4. Binary Logistic Regression of water availability and household characteristics

The study conducted a binary logistic regression of water availability and the household characteristics of the respondents. The results are as summarized in Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.47.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.47 : Binary Logistic Regression: Household Characteristics and Water Availability

Sub-County	B	S.E.	Wald	Df	Sig.	Odds Ratio
Sub- County						
Dagoretti North (Ref)**			46.071	11	.000	
Dagoretti South	.984	.748	1.729	1	.189	2.675
Embakasi South	.950	.700	1.846	1	.174	2.587
Kamukunji	-.832	.867	.921	1	.337	.435
Kasarani	1.335	.704	3.592	1	.058	3.800
Kibra	.942	.827	1.298	1	.255	2.565
Langata	-1.073	1.081	.986	1	.321	.342
Makadara	1.386	.884	2.459	1	.117	3.998
Mathare	-1.985	1.012	3.850	1	.050	.137
Ruaraka	-.473	.697	.460	1	.498	.623
Starehe	1.426	.837	2.903	1	.088	4.164
Westlands	1.466	.785	3.487	1	.062	4.331
Level of Education						
No Education (Ref)**			20.224	6	.003	

Primary complete	-.160	.782	.042	1	.838	.852
Secondary incomplete	-1.909	.873	4.777	1	.029	.148
Secondary complete	-.913	.776	1.383	1	.240	.401
Tertiary	-.200	.801	.062	1	.803	.819
University	-1.592	.842	3.571	1	.059	.204
Postgraduate	-.854	1.008	.718	1	.397	.426
Employment Status						
Not employedd (Ref)**			6.387	4	.172	
Employed salaried	-.068	.425	.025	1	.874	.935
Employed casual labourer	-.785	.369	4.537	1	.033	.456
Self employed	.034	.310	.012	1	.913	1.035
Household income						
Less than 23,670 (Ref)**						
Above 23670	.024	.397	.004	1	.952	1.024

Housing type			.978	4	.913	
Sticks and Mud Walls						
Timber with Iron-sheet	.487	.539	.815	1	.367	1.627
Concrete walls	.367	.508	.522	1	.470	1.444
Other	1.063	1.700	.391	1	.532	2.894
Main Sources of water						
Piped water connection						
Shared water connection	.415	1.482	.079	1	.779	1.515
Hand Cart Water Vendors	.872	.432	4.074	1	.044	2.393
Private water tanker	-.596	.590	1.020	1	.312	.551
Public borehole or well	.341	.563	.366	1	.545	1.406
Private borehole or well	-.439	.793	.306	1	.580	.645
Private borehole or well in	.746	.908	.676	1	.411	2.109
Rain water Harvest	.750	.338	4.912	1	.027	2.117
Shared plot connection	.009	.579	.000	1	.988	1.009

Source: Field data, 2023

There is varied relationship between sub-counties and availability of water in households. Households in the informal settlements in Starehe and Westlands are up to more than 4 times likely to have water readily available compared to Dagoretti North. Households in Kamukunji, Mathare and Langata are less likely 0.43, 0.34 and 0.62 respectively to have water readily available. In term of education, households with more educated heads were found not to have water readily available compared to those that were not. Those with tertiary, university and post- graduate education were particularly found to have less likelihood of having water readily available.

Households with income of above KSh. 23, 670, were slightly more likely to have water readily than those that had less income. Equally, households with better living conditions with permanent dwelling are more likely to have water readily available.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.48 : Binary Logistic Regression: Household Characteristics and Water Access

Variable	B	S.E.	Wald	df	Sig.	Odds Ratio Exp(B)
Sub-County						
Dagoretti North (Ref)**						
Dagoretti South	1.490	1.041	2.049	1	.152	4.437
Embakasi South	.435	.818	.282	1	.595	1.545
Kamukunji	-1.771	.956	3.434	1	.064	.170
Kasarani	-1.238	.805	2.365	1	.124	.290
Kibra	-.299	.903	.109	1	.741	.742
Langata	.223	1.142	.038	1	.845	1.250
Makadara	1.453	1.308	1.233	1	.267	4.274
Mathare	-.350	.993	.124	1	.724	.704
Ruaraka	-.345	.814	.180	1	.671	.708
Starehe	-.041	.939	.002	1	.966	.960
Westlands	-1.079	.896	1.450	1	.229	.340
Level of Education						
No Education						
Primary complete	.113	.899	.016	1	.900	1.120
Secondary incomplete	.054	.964	.003	1	.955	1.056
Secondary complete	-.397	.885	.201	1	.654	.672
Tertiary (Certificate/Diploma)	.180	.918	.038	1	.845	1.197
University	.156	.961	.026	1	.871	1.169
Postgraduate	-.207	1.139	.033	1	.856	.813
Employment Status						
Not employed (Ref)**						
Employed salaried	-1.222	.521	5.508	1	.019	.295
Employed casual labourer	-1.294	.435	8.852	1	.003	.274
Self employed	-1.026	.395	6.736	1	.009	.359
Household Income						
Less than 23,670 (Ref)**						
Above 23670	.567	.508	1.244	1	.265	1.763

House Type (materials)						
Sticks and Mud Walls (Ref)**						
Timber with Iron-sheet cladding	-.330	.569	.337	1	.562	.719
Sticks, cartons, and other assorted materials	.333	1.308	.065	1	.799	1.396
Made of Concrete walls	.015	.541	.001	1	.978	1.015
Main Source of Water						
Piped water connection						
Shared water connection	-.842	1.844	.208	1	.648	.431
Water kiosk	-.404	1.521	.070	1	.791	.668
Hand Cart Water Vendors	1.917	.704	7.407	1	.006	6.800
Private water tanker	-.677	.643	1.109	1	.292	.508
Public borehole or well	-2.668	.642	17.281	1	.000	.069
Private borehole or well	-.383	.755	.258	1	.612	.682
Self-supply	-2.266	.916	6.120	1	.013	.104
Rain water Harvest	-.675	.373	3.280	1	.070	.509
Shared plot connection	.743	.827	.808	1	.369	2.103

Source: Field data, 2023

Compared to Dagoretti North, households in Dagoretti South 4.4, Makadara 4.2 and Embakasi South 1.5 are more likely to have appropriate water access. Other sub-counties are less likely to have recommended water access. Apart from households receiving water from vendors (6.8) and shared plot connection (1.7) other sources are less likely to meet accessibility needs. Households with unemployed heads are more likely to access to water compared to employed counterparts. Households with income above KSh. 23,670 are more likely to have reliable water access compared to those that have less.

A photo taken in Dagoretti South Kawangware slums (Plate 5.1), shows how water access in informal settlements, is not only a women affair but also men get involved in water fetching. The photo has people collecting water directly from a privately owned water kiosk and a hand cart which an intermediary vendor supplying water to households, institutions and small hotels.

Plate 5.1: Photo taken in Dagoretti South Kawangware Slums

Though from the study, there are inconsistencies on the level os education and attainment of water access, there were higher odds for households having better access to water. Other studies have shown that education impacts awareness, advocacy, and water management practices. For instance, Jagals & Mokoena (2010) found that higher educational levels improve water access, as educated individuals were more knowledgeable about their rights and better equipped to negotiate with providers. Seager et al., (2012) noted that higher education correlates with better water conservation and hygiene practices, reducing waterborne diseases. Mutisya & Yarime (2014) highlighted that educated community members in Kibera effectively lobby for improved water services, benefiting the entire community. Gulyani, Talukdar, & Kariuki (2005) emphasized that education enhances community development and informed decision-making on water resources. Hope (2006) argued that education bridges the gap between policy and practice, leading to more effective implementation of water programs. Bartram & Cairncross (2010) stressed that educational initiatives on water, sanitation, and hygiene are crucial for sustainable water access improvements in informal settlements. Lack of correlation of education and water access in informal settlements might be due to the fact that, the context doesn’t favour those with education to make better access choices given limited availability of water.

Monthly income is a direct determinant of water access in Nairobi's informal settlements. Higher-income households generally have better and more reliable water access. Agreeing with the findings of this study, Whittington et al., (2009) demonstrate that income levels significantly influence a household’s ability to maintain a stable water supply, as higher-income households can afford to pay for water services or invest in storage solutions. This financial capability is crucial in environments where water is often a commodity sold at high prices due to scarcity.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.49 : Binary Logistic Regression: Household Characteristics and Water Quantity - Sphere Standard

Variable	B	S.E.	Wald	df	Sig.	Odds Ratio Exp(B)
Sub- County						
Dagoretti North (Ref)**						
Dagoretti South	1.550	.890	3.035	1	.081	4.710
Embakasi South	-.233	.707	.108	1	.742	.792
Kamukunji	.059	.915	.004	1	.948	1.061
Kasarani	1.643	.822	3.994	1	.046	5.170
Kibra	.173	.835	.043	1	.836	1.189
Langata	-.949	.991	.917	1	.338	.387
Makadara	.367	.863	.180	1	.671	1.443
Mathare	-.705	.816	.745	1	.388	.494
Ruaraka	.179	.724	.061	1	.804	1.197
Starehe	.396	.838	.223	1	.637	1.486
Westlands	.034	.801	.002	1	.966	1.035
Level of Education						
No Education (Ref)**					.	
Primary complete	1.232	.956	1.661	1	.197	3.430
Secondary incomplete	.424	1.002	.179	1	.672	1.529
Secondary complete	.409	.938	.190	1	.663	1.505
Tertiary (Certificate/Diploma)	1.134	.974	1.354	1	.245	3.107
University	.491	.999	.242	1	.623	1.634
Postgraduate	.540	1.244	.188	1	.664	1.716
Employment Status						
Not employed (Ref)**						
Employed salaried	.553	.453	1.488	1	.222	1.739
Employed casual labourer	-.052	.381	.018	1	.892	.950
Self employed	.496	.335	2.189	1	.139	1.642
Household Income						
Less than 23,670 (Ref)**						
Above 23670	.641	.482	1.766	1	.184	1.898
Household Dwelling type						
Sticks and Mud Walls (Ref)**						
Timber with Iron-sheet cladding	-.381	.561	.461	1	.497	.683
Other	.030	.529	.003	1	.954	1.031

Main Source of water						
Piped water connection (Ref)**			8.474	9	.487	
Shared water connection	-1.318	1.519	.753	1	.386	.268
Hand Cart Water Vendors	.108	.485	.050	1	.823	1.114
Private water tanker	.011	.844	.000	1	.990	1.011
Public borehole or well	-1.009	.584	2.984	1	.084	.365
Private borehole or well	1.262	1.255	1.010	1	.315	3.532
Private borehole or well in our compound (self-supply)	-1.040	.834	1.553	1	.213	.354
Rain water Harvest	-.567	.370	2.354	1	.125	.567
Shared plot connection	-.058	.633	.008	1	.927	.943
Piped water connection	-.056	1.275	.002	1	.965	.945

Source: Field data, 2023

Apart from Langata and Mathare, households in all other sub-counties are more likely to meet the sphere recommended quantities of water. The highest odds of compliance were found on in Kasarani, 5.1 and Dagoretti South 4.7 respectively. Households whose head had some education, were found to be more likely to have the sphere recommended water quantities compare to those that had no education at all. However, the highest odds were among those with complete primary education (3.1) and tertiary education (3.4). Overall, households with self -employed heads and salaried heads were found to be more sphere quantity compliant with odds of 1.6 and 1.9 respectively. Households with income of above KSh. 23, 670 were also found to be more likely to meet the recommended sphere quantities.

Table CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.50 : Binary Logistic Regression: Household Characteristics and Water Quantity - Sphere Standard

Household Characteristics	B	S.E.	Wald	df	Sig.	Exp(B)
Sub-County						
Dagoretti North (Ref)**						
Dagoretti South	1.550	.890	3.035	1	.081	4.710
Embakasi South	-.233	.707	.108	1	.742	.792
Kamukunji	.059	.915	.004	1	.948	1.061
Kasarani	1.643	.822	3.994	1	.046	5.170
Kibra	.173	.835	.043	1	.836	1.189
Langata	-.949	.991	.917	1	.338	.387
Makadara	.367	.863	.180	1	.671	1.443
Mathare	-.705	.816	.745	1	.388	.494
Ruaraka	.179	.724	.061	1	.804	1.197
Starehe	.396	.838	.223	1	.637	1.486
Westlands	.034	.801	.002	1	.966	1.035
Level of Education						
No Education (Ref) **						
Primary complete	1.232	.956	1.661	1	.197	3.430
Secondary incomplete	.424	1.002	.179	1	.672	1.529
Secondary complete	.409	.938	.190	1	.663	1.505
Tertiary (Certificate/Diploma)	1.134	.974	1.354	1	.245	3.107
University	.491	.999	.242	1	.623	1.634
Postgraduate	.540	1.244	.188	1	.664	1.716
Employment Status						
Not employed (Ref)**						
Employed salaried	.553	.453	1.488	1	.222	1.739
Employed casual labourer	-.052	.381	.018	1	.892	.950
Self employed	.496	.335	2.189	1	.139	1.642
Household Income						
Less than 23,670 (Ref)**						
Above 23670	.641	.482	1.766	1	.184	1.898
Main Source of Water						
Piped water connection (Ref)**						
Shared water connection	-1.318	1.519	.753	1	.386	.268
Hand Cart Water Vendors	.108	.485	.050	1	.823	1.114
Private water tanker	.011	.844	.000	1	.990	1.011
Public borehole or well	-1.009	.584	2.984	1	.084	.365
Private borehole or well	1.262	1.255	1.010	1	.315	3.532

Private borehole or well in compound	-1.040	.834	1.553	1	.213	.354
Rain water Harvest	-.567	.370	2.354	1	.125	.567
Shared plot connection	-.058	.633	.008	1	.927	.943

Source: Field data, 2023

The analysis household water characteristics and likelihood of meeting sphere recommended quantities was undertaken. Results show that recommended quantities of water are found in Kasarani, Dagoretti South, Makadara South and Westlands compared to Dagoretti North. Langata, Embakasi South and Westlands households in informal settlements. Mathare, Langata and Embakasi South households were found to be comparatively non-compliant to sphere recommended water quantities. Households with an educated head at any level are more likely to attain the sphere recommended quantities of water. Households whose heads have some primary education or tertiary education. Households with individual piped connection are likely to attain sphere recommended quantities of water compared to other main sources. The only variation was found in households accessing water from rainwater harvesting, private/ public borehole and water kiosk.

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.51 : Binary Logistic Regression: Household Characteristics and Water Reliability

Household Characteristics	B	S.E.	Wald	df	Sig.	Exp(B)
Subcounty						
Dagoretti North (Ref)**						
Dagoretti South	-.197	.820	.058	1	.810	.821
Embakasi South	.058	.716	.006	1	.936	1.059
Kasarani	.715	.737	.942	1	.332	2.044
Kibra	.649	.829	.613	1	.434	1.914
Langata	.823	1.025	.645	1	.422	2.277
Makadara	-.704	.891	.623	1	.430	.495
Mathare	2.244	.899	6.231	1	.013	9.430
Ruaraka	1.456	.724	4.048	1	.044	4.289
Starehe	-.573	.874	.429	1	.512	.564
Westlands	-1.563	.999	2.447	1	.118	.209
Level of Education						

No Education (Ref) **						
Primary complete	-.084	.737	.013	1	.909	.919
Secondary incomplete	-.842	.847	.988	1	.320	.431
Secondary complete	.027	.728	.001	1	.970	1.028
Tertiary (Certificate/Diploma)	-1.087	.772	1.982	1	.159	.337
University	.175	.803	.047	1	.828	1.191
Postgraduate	-.577	1.055	.299	1	.584	.561

Employment Status						
Not employed (Ref)**			9.700	4	.046	
Employed salaried	-.013	.461	.001	1	.978	.988
Employed casual labourer	.791	.366	4.669	1	.031	2.206
Self employed	-.281	.324	.757	1	.384	.755
Household Income						
Less than 23,670 (Ref)**						
Above 23670	-.057	.477	.014	1	.906	.945
Main Sources of Water						
Own piped water connection						
Water kiosk	1.027	1.492	.473	1	.492	2.791
Hand Cart Water Vendors	-.422	.561	.565	1	.452	.656
Private water tanker	-.247	.677	.133	1	.716	.782
Public borehole or well	1.140	.577	3.897	1	.048	3.127
Private borehole or well	-.968	.885	1.196	1	.274	.380
Private borehole or well in our compound (self-supply)	-.201	.961	.044	1	.835	.818
Rain water harvesting	1.131	.368	9.457	1	.002	3.099
Shared plot connection	.255	.558	.208	1	.648	1.290

Source: Field data, 2023

There are notable differences in household water reliability by sub-counties. Compared to Dagoretti, households in Kasarani, Ruaraka, Starehe, Kibra and Langata have better odds of having reliable water (odds ratio ≥ 1.1). Apart from households, headed by university graduates, the odds of household water reliability do vary by education level of the household head. Households with casual employment as the main source of income have higher likelihood of having reliable water source compared to those without source of income (odds ratio ≥ 2.2).

Table CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.52 : Binary Logistic Regression: Household Characteristics and Water Affordability

Household Characteristics	B	S.E.	Wald	df	Sig.	Exp(B)
Dagoretti North (Ref)**						
Dagoretti South	.649	1.000	.421	1	.516	1.913
Embakasi South	.500	.938	.284	1	.594	1.648
Kamukunji	2.760	1.091	6.395	1	.011	15.799
Kasarani	-.105	.984	.011	1	.915	.900

Kibra	1.102	1.045	1.113	1	.291	3.010
Langata	.341	1.439	.056	1	.813	1.407
Makadara	-19.124	9563.053	.000	1	.998	.000
Mathare	.353	1.086	.105	1	.745	1.423
Ruaraka	.660	.948	.485	1	.486	1.935
Starehe	1.718	1.035	2.758	1	.097	5.574
Westlands	.716	1.021	.491	1	.483	2.046
Level of Education						
No Education (Ref)**						
Primary incomplete	1.092	1.140	.919	1	.338	2.981
Primary complete	.692	1.202	.332	1	.565	1.998
Secondary incomplete	.600	1.142	.276	1	.600	1.822
Secondary complete	.673	1.156	.339	1	.561	1.959
Tertiary (Certificate/Diploma)	-.657	1.265	.270	1	.604	.518
University	-.436	1.454	.090	1	.764	.647
Employment Status						
Not employed (Ref)**						
Employed salaried	.702	.536	1.712	1	.191	2.017
Employed casual labourer	.754	.481	2.460	1	.117	2.126
Self employed	.242	.407	.353	1	.552	1.274
Household Income						
Less than 23,670 (Ref)**						
Above 23670	.591	.526	1.261	1	.261	1.805
Main Source of Water						
piped water connection (Ref)**						
A shared water connection next to your dwelling	-20.125	40192.970	.000	1	1.000	.000
Water kiosk	-19.302	28355.720	.000	1	.999	.000
Hand Cart Water Vendors	1.050	.496	4.490	1	.034	2.859
Private water tanker	-.271	.921	.086	1	.769	.763
Public borehole or well	-.414	.764	.293	1	.588	.661
Private borehole or well	1.114	.992	1.260	1	.262	3.046
Private borehole or well	-.554	1.151	.232	1	.630	.575
Rain water harvesting	.312	.432	.521	1	.471	1.366
Shared plot connection	-.727	1.100	.436	1	.509	.483

Source: Field data, 2023

The odds of affording water are high in Ruaraka, Westlands, Kibra, Kamukunji and Starehe compared to Dagoretti North. Households in Kasarani and Makadara have lower odds of affording water compare to their Dagoretti North counterparts. Households with income above 23,670 are up to 1.8 times more likely to afford water compared to those that are below. Similarly, households whose heads are in employment are more likely to afford water than those that are not. Compared to piped individual connection, households sourcing water from hand-carts vendors, private borehole and rain water reported better affordability. This could have been due to the fact that, for households with individual connections and those with shared connections, they still had to get water from carts and kiosks when they did not have a reliable supply.

5.5. Quantity sphere compliance and household overall water availability

The study established the quantity sphere compliance (i.e., household consuming at least 15 lpcd) and household overall water availability of the households. The findings in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.49 shows that 81 (65.9%) were sphere non-compliant and had no water readily available while 42 (34.1%) had water readily available but were not sphere compliant. Those who were sphere compliant and had water readily available were 115 (43.5%) while 149 (56.5%) were sphere compliant but had no water readily available. A chi- square value of ($\chi^2_{1,0.05}$=10.493, $p<0.05$) showed a significant relationship between quantity sphere compliance and water availability.

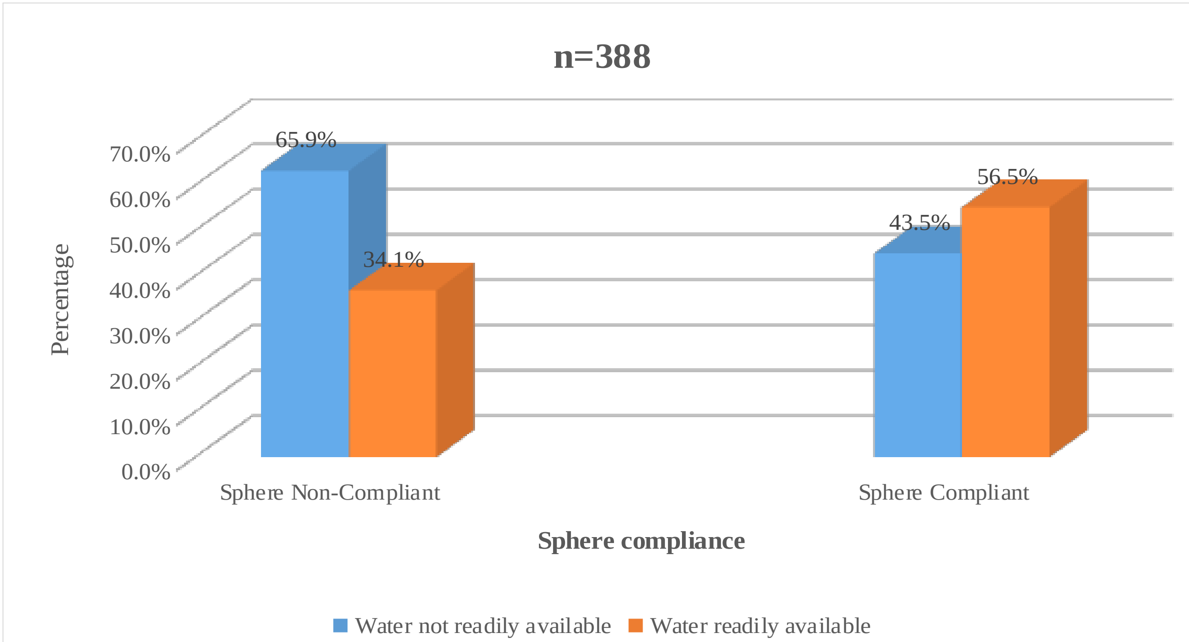


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.49 : Compliance to Sphere quantity versus household overall water availability

Source: Field data, 2023

5.6. Household with access to at least one quality water source and overall water availability

The study also did a relationship between quality of water and water availability in the households. From Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.50, the results shows that 82 (56.9%) had both no quality water source and water not readily available while 62 (43.1%) had no quality water source but had water readily available. On the other hand, 92 (37.7%) had at least one source but water was not readily available while 152 (62.3%) of the respondents had at least one quality source with water readily available. A chi- square of ($\chi^2_{1,0.05}$=0.939, $p<0.05$) showed a significant relationship between quality and water availability.

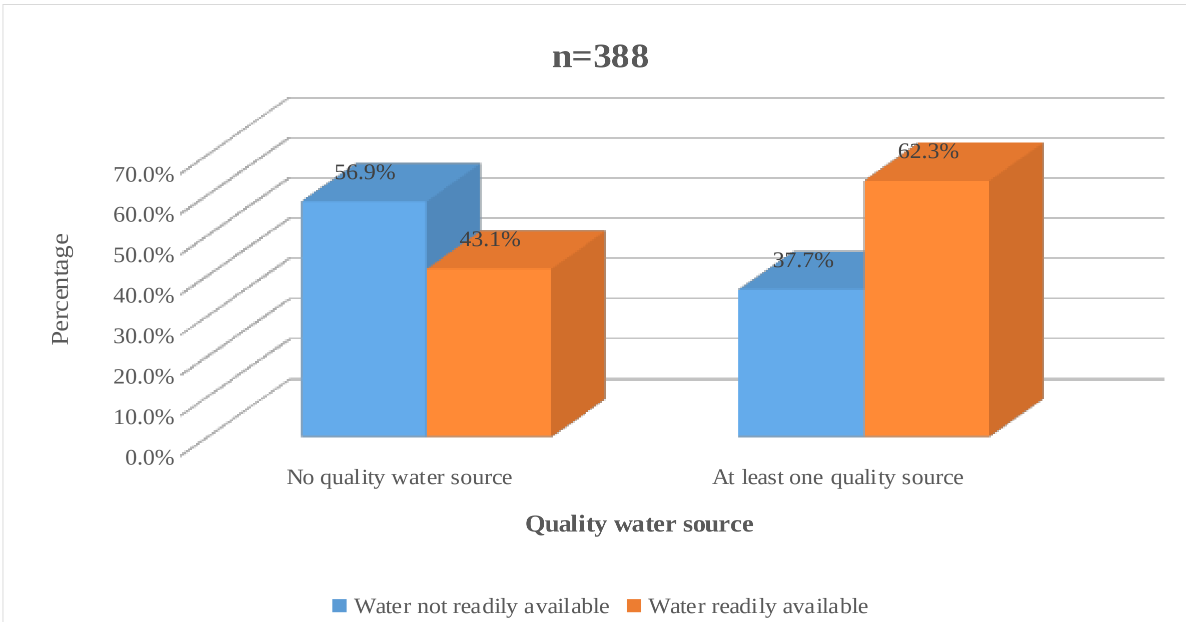


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.50 : Household with at least one quality water source and overall water availability

Source: Field data, 2023

5.7. Access water service overall access and overall water availability

The study correlated between water access and availability among the household heads. From Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.51, the results indicates that 76

(56.7%) had unacceptable access with water nor readily available while 162 (52.3%) had no water readily available but had acceptable access. On the other hand, 58 (43.3%) had unacceptable access but water was readily available while 148 (47.7%) had acceptable water access and water was readily available. A chi-square value of ($\chi^2_{3,0.05}$=0.906, p<0.05) showed that there was a significant relationship between water access and availability.

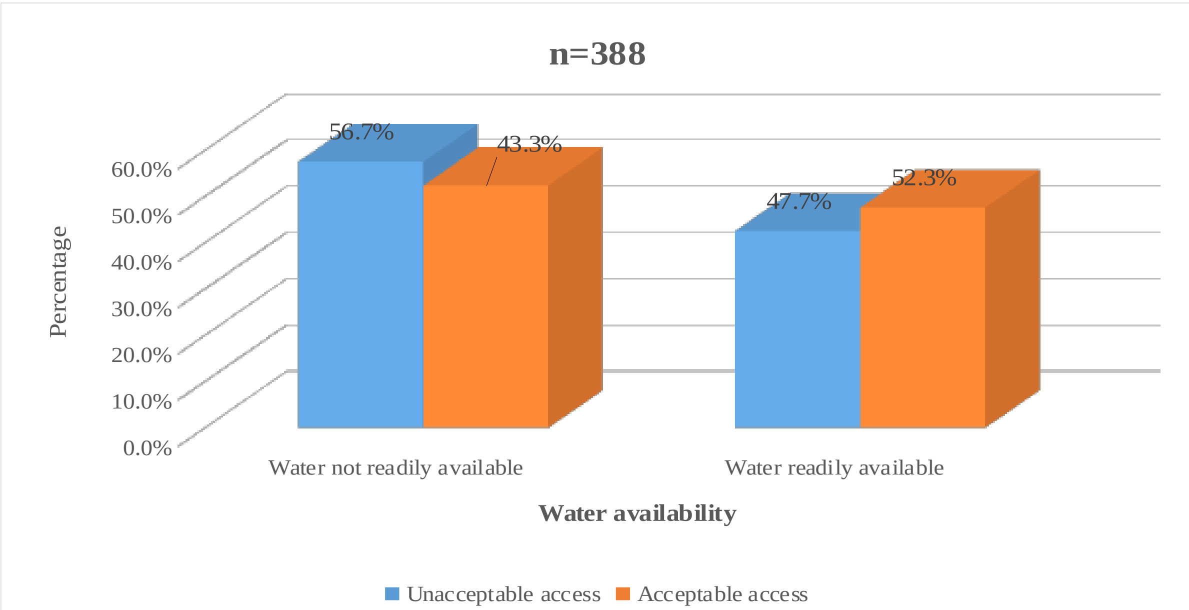


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.51 : Overall water service access versus overall water availability of the household

Source: Field data, 2023

5.8. Standard cost per 20 litres against overall water availability

The study established between water affordability based on standard cost of a 20-litre container and water availability among the household heads. The findings are as shown in Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.52. The findings shows that only 44 (48.7%) were standard compliant with water readily available from all sources. A chi-square value of ($\chi^2_{3,0.05}$=0.004, p>0.05) showed that there was no significant relationship between water affordability and availability in the study area.

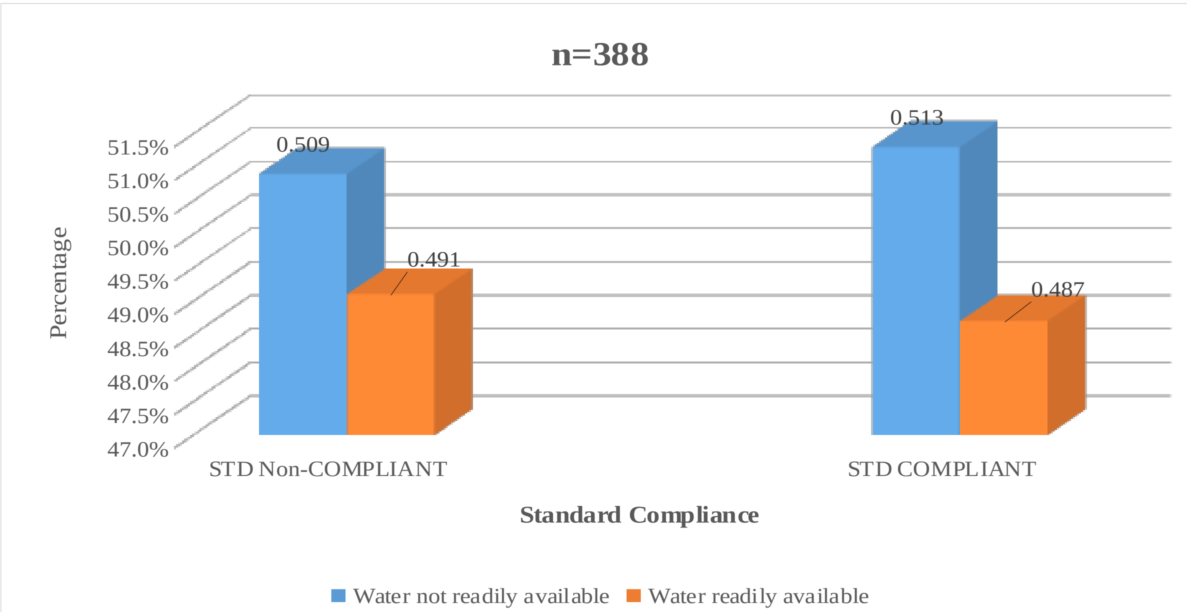


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.52 : Standard cost of 20L container (Affordability) versus overall water availability of the household

Source: Field data, 2023

5.9. Consolidated water reliability and overall water availability

On the relationship between reliability and availability, the results are presented in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER

SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.53. The findings shows that 50 (33.8%) had water reliable and water was readily available. On the other hand, 98 (66.2%) of the households had water reliable but water was not readily available. A chi- square value ($\chi^2_{3,0.05}$=14.145, p<0.05) showed a significant relationship between water reliability and water availability.

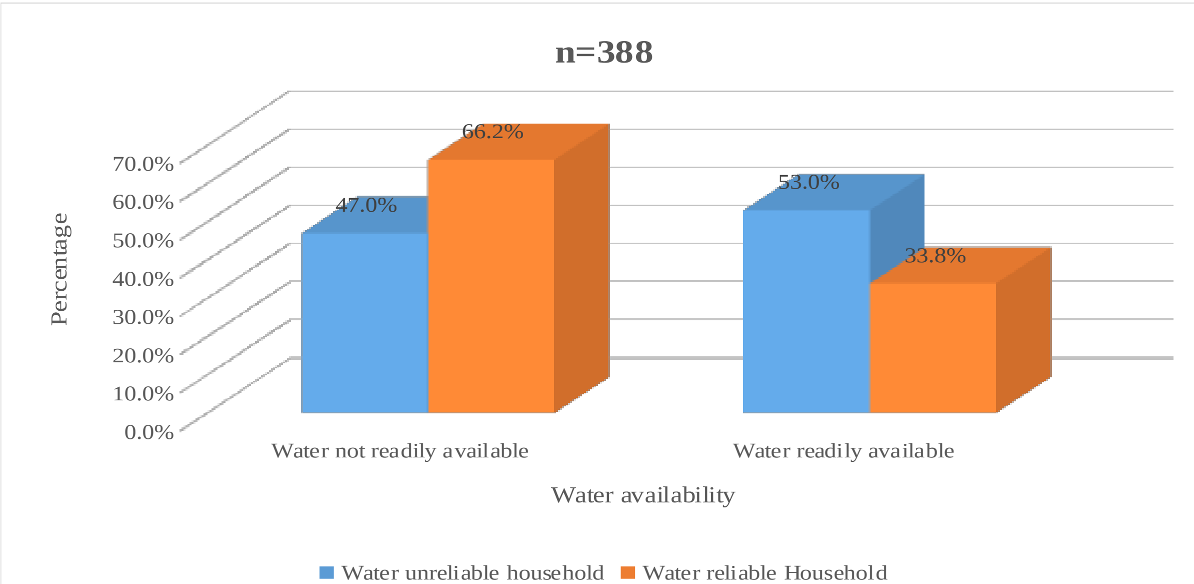


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.53 : Consolidated water reliability versus overall water availability to the household

Source: Field data, 2023

5.10. Sphere quantity compliance versus overall access to water service

The study established the relationship between quantity sphere compliance and water access. From the findings in Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL

SETTLEMENTS IN NAIROBI COUNTY, KENYA.54, 191 (74.6%) were sphere compliant and had acceptable access. On the other hand, 35 (30.7%) of the respondents were sphere non- compliant and had unacceptable access. A chi- square value of ($\chi^2_{3,0.05}$= 1.128, p>0.05) showed that there was no significant relationship between quantity sphere and water access.

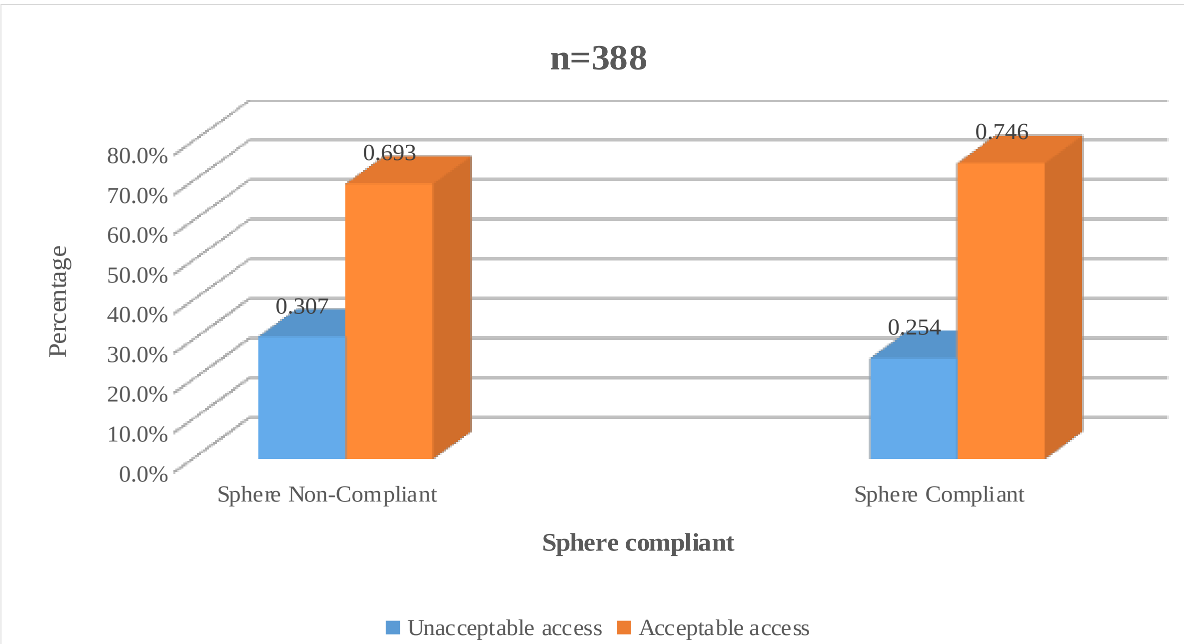


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.54 : Sphere quantity compliance versus overall access to water service

Source: Field data, 2023

5.11. Sphere quantity compliance versus overall water quality

The study established the relationship between water quality and access. The findings are as shown in Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF

WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.55, it was observed that 171 (78.1%) had water access and at least one water quality. A chi- square value of ($\chi^2_{3,0.05}$=5.256, P<0.05) showed that there was a significant relationship between sphere quantity compliance and overall water quality.

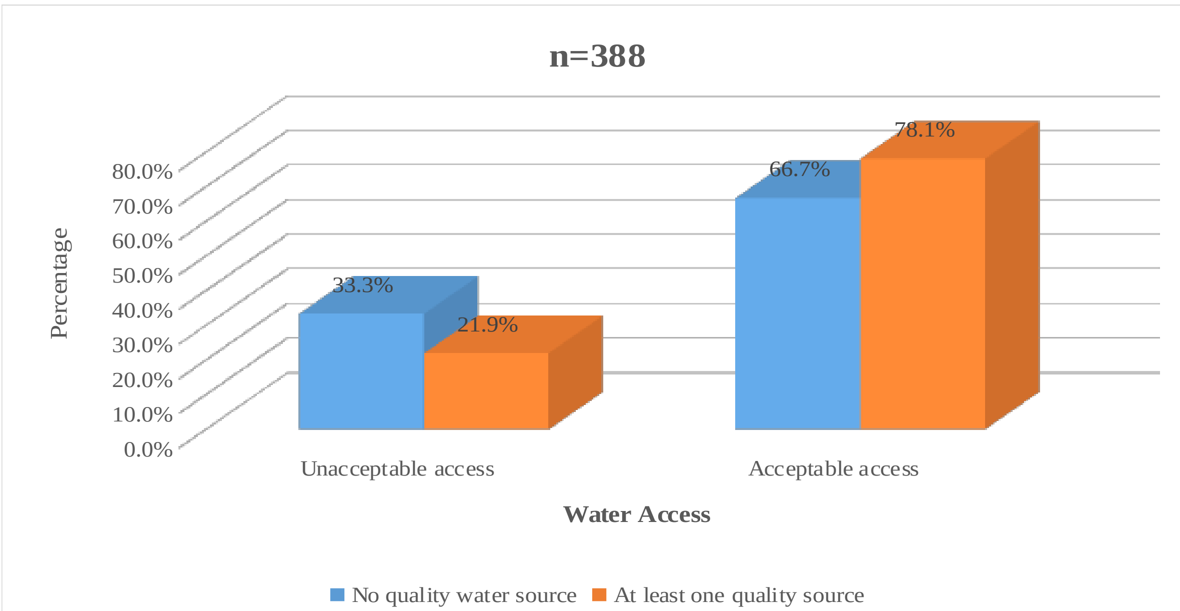


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.55 : Quality based on household with at least one quality water source versus overall access to water services

Source: Field data, 2023

5.12. Affordability based on 20L container versus overall water access

On the relationship between water affordability and access, the study found out that 60 (65.9%) had acceptable access and were standard compliant while 215 (72.4%) had acceptable access but were standard non- compliant. Those who had unacceptable access and were standard non-compliant were 82 (27.6%) while 31 (34.1%) had unacceptable access and but standard compliant. A Chi-square value of ($\chi^2_{3,0.05}$=0.427, p>0.05) indicated that there was no significant relationship between water affordability and access.

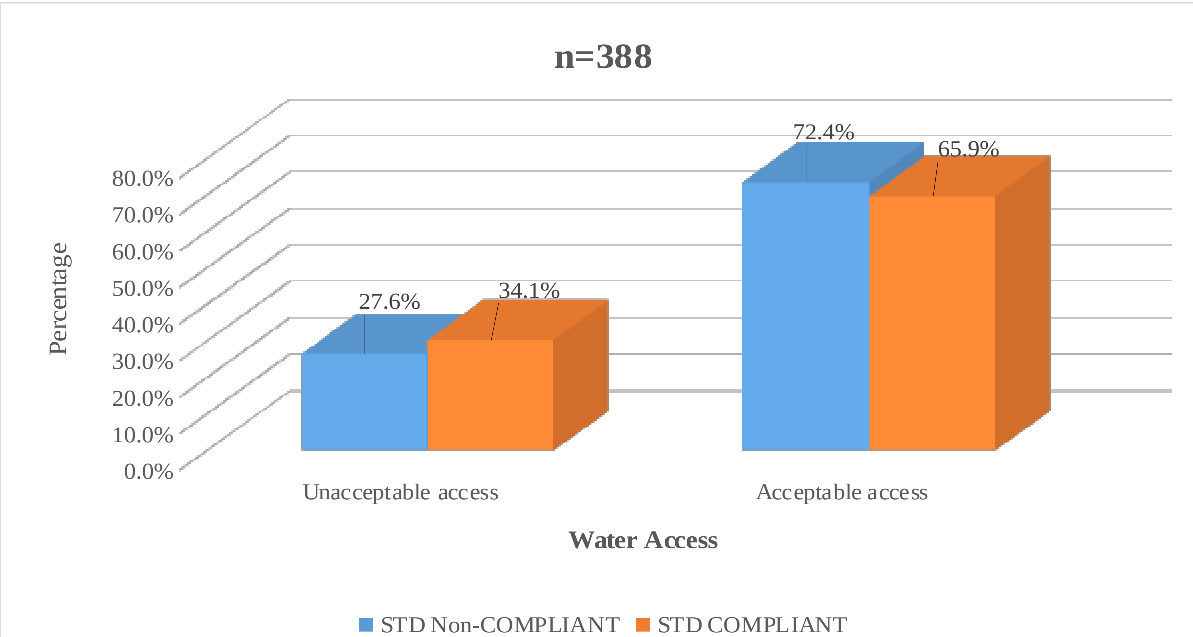


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.56 : Affordability based on standard cost of 20L container versus overall water access

Source: Field data, 2023

5.13. Consolidated water reliability versus overall access to water services

The study established the relationship between reliability and water access. From the findings in Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.57, 87 (64.9%) had acceptable access and water was reliable while 47 (35.1%) were water reliable but had unacceptable access. Only 59 (23.2%) had unacceptable access and water was not reliable. 195 (76.8%) had acceptable access with water being unreliable. A chi-square value of ($\chi^2_{3,0.05}$= 6.534, $p<0.05$) showed that there was a significant relationship between water reliability and access.

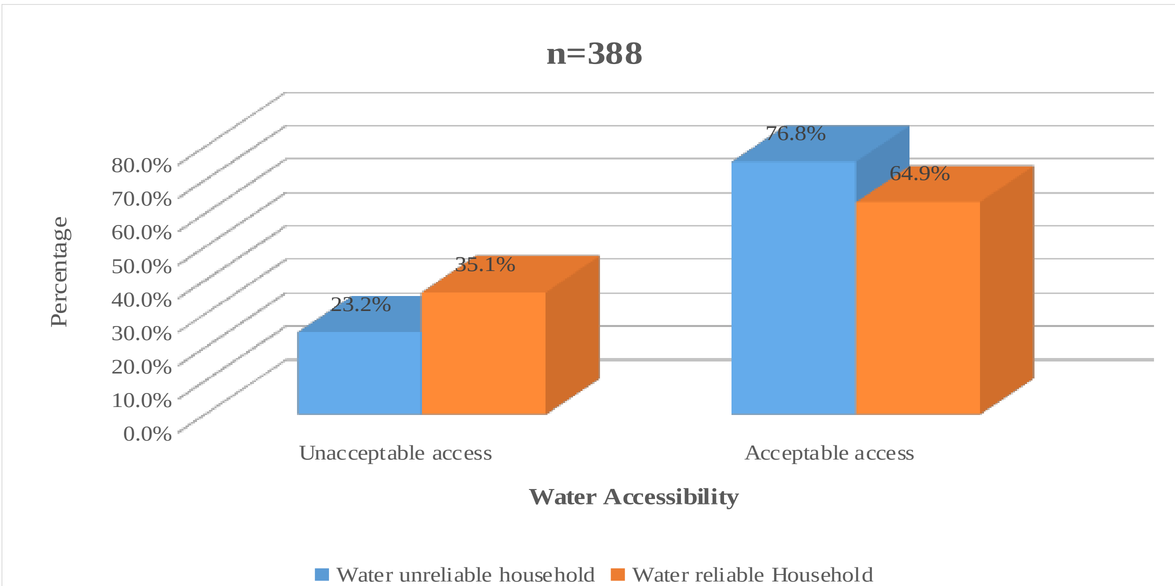


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.57 : Consolidated water reliability versus overall access to water services

Source: Field data, 2023

5.14. Quality based on household with at least one quality water source and Sphere quantity compliance

The study established the relationship between water quality and quantity. From the findings in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF

WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.58, 164 (69.5%) of the respondents were sphere compliant with at least one quality source of water while 88 (57.9%) were sphere compliant but had no quality water source. On the flip coin, 30.5% (72) were sphere non- compliant but with at least one quality source and 64 (42.1%) were sphere non-compliant and had no quality water source. A chi- square value of ($\chi^2_{3,0.05}$=5.287, P<0.05) showed a significant relationship between water quality and quantity.

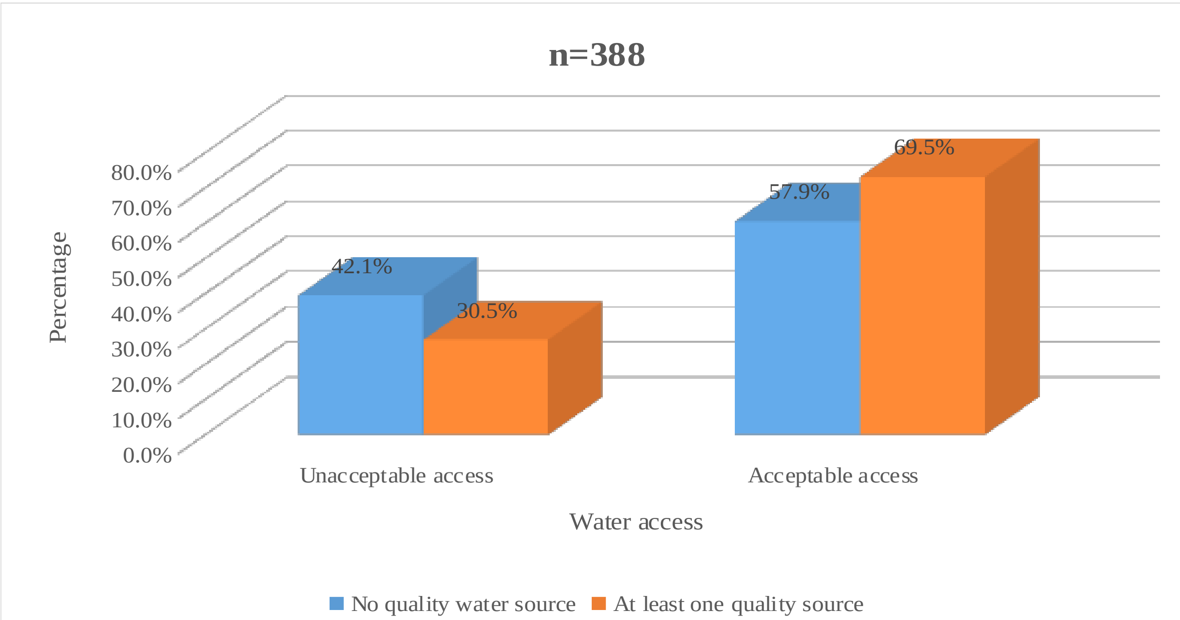


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.58 : Quality based on household with at least one quality water source versus Sphere quantity compliance

Source: Field data, 2023

5.15. Affordability based on standard cost per 20 litres versus Sphere quantity compliance

The relationship between water affordability and quantity showed that 72 (75.0%) were both sphere and standard compliant while 24 (25.0%) were sphere non- compliant but standard compliant. 189 (64.7%) of the respondents were sphere compliant but standard non- compliant. On the other side, 103 (35.3%) were both sphere and standard non-compliant. A chi- square value of ($\chi^2_{3,0.05}$=8.565, P<0.05) showed a significant relationship between water affordability and water quantity.

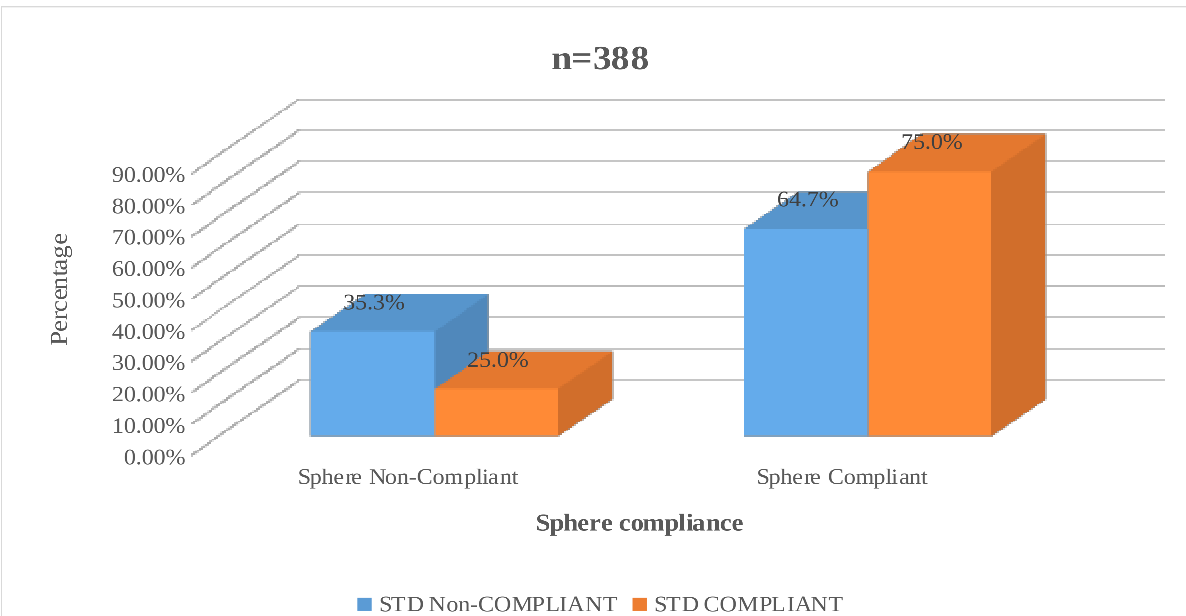


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.59 : Affordability based on standard cost of 20L container versus Sphere quantity compliance

Source: Field data, 2023

5.16. Consolidated water reliability versus Sphere quantity compliance

From the findings, 85 (62.0%) were sphere compliant having reliable water while 180 (71.7%) were sphere compliant but had unreliable water in the households. On the other side, 52 (38.0%) were sphere non- compliant but had reliable water while 71 (28.3%) were both sphere non- compliant and had unreliable water. A chi-square value of ($\chi^2_{3,0.05}$=3.804, $p<0.05$) showed that there was a significant relationship between water reliability and water quantity.

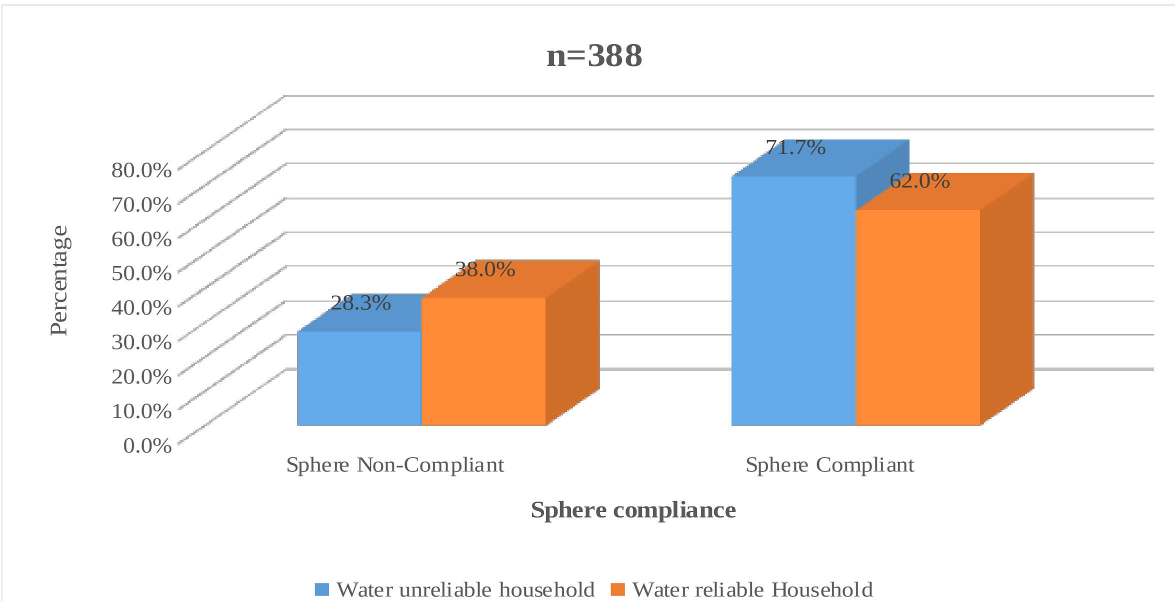


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.60 : Consolidated water service reliability versus Sphere quantity compliance

Source: Field data, 2023

5.17. Affordability based on standard cost per 20L versus quality as per household with access to at least one quality water source

The nexus between water affordability and water quality was established in this study. The findings are presented in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.61. From the findings, 70 (67.2%) of the respondents had at least one quality source of water and were standard compliant while 34 (32.8%) had no quality water source but were standard compliant. On the other hand, 179 (63.2%) were standard non- compliant and had at least one quality source of water while 104 (36.8%) had no quality water source and were not standard compliant. A chi-square value of ($\chi^2_{3,0.05}$=0.345, p>0.05) showed that there was no significant relationship between water affordability and water quality.

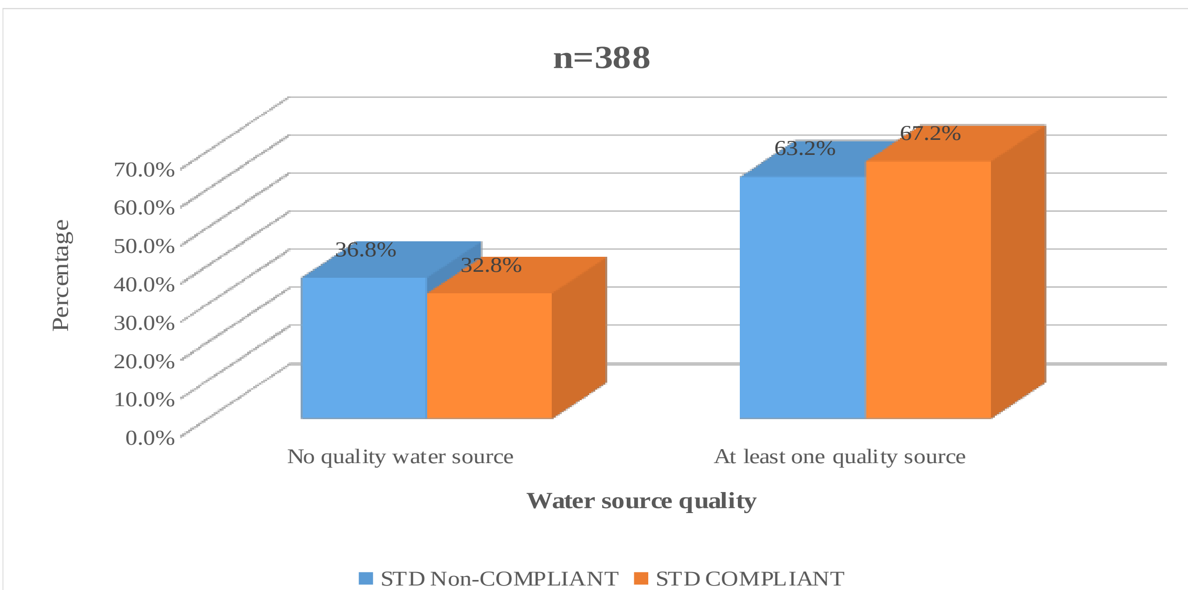


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.61 : Affordability based on standard cost of 20L container versus quality based on household with access to at least one quality water source

Source: Field data, 2023

5.18. Consolidated water reliability versus quality based on household with access to at least one quality water source

The study established the relationship between water reliability and water quality. The findings are summarized in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.62. From the findings, 87 (50.7%) of the households had at least one quality source and water was reliable while 163 (75.4%) had at least one quality source but water was unreliable. On the flip coin, 85 (49.3%) of them had no quality source but were water reliable while 53 (24.6%) had no quality water source and were water unreliable households. A chi- square of ($\chi^2_{3,0.05}$=22.277, $p<0.05$) showed a significant relationship between water reliability and water quality.

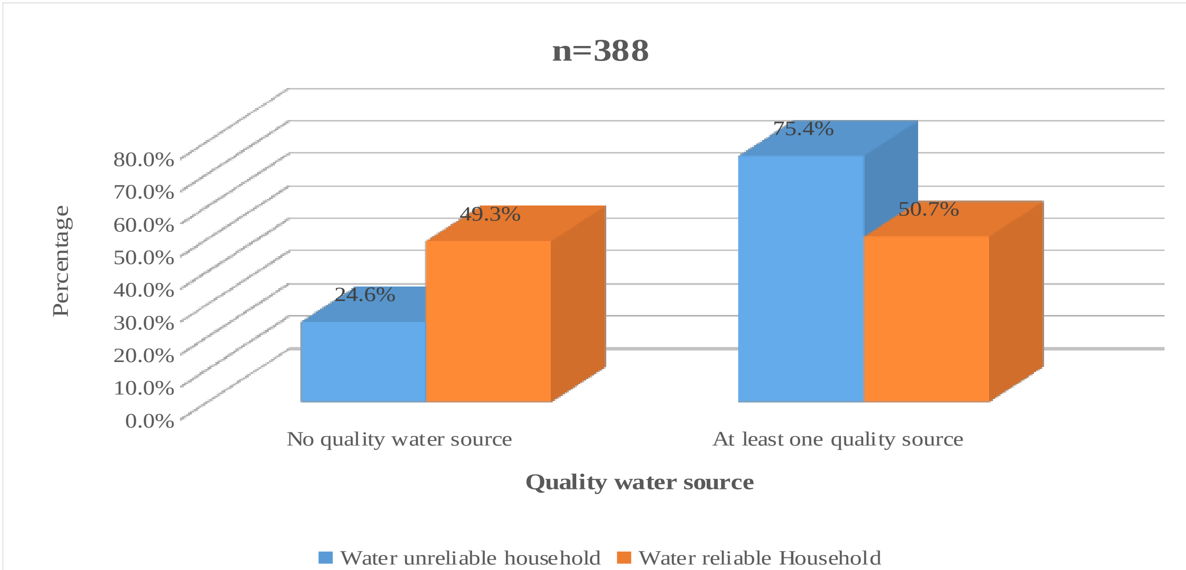


Figure CHAPTER FIVE

THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.62 : Consolidated water reliability versus household with at least one quality water source

Source: Field data, 2023

5.19. Water affordability based on standard cost per 20 litres versus reliability

Consolidated Water reliability Cross tabulation was established and the findings are as presented in Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.63. From the findings, 28 (31.6%) of the respondents were water reliable and standard compliant while 111 (37.1%) of them were water reliable but standard non- compliant. On the other hand, 62 (68.4%) were water unreliable but standard compliant while 187 (62.9%) were water unreliable and standard non- compliant. A chi- square of ($\chi^2_{3,0.05}$=0.794, p>0.05) showed that there was no significant relationship between water affordability and water reliability.

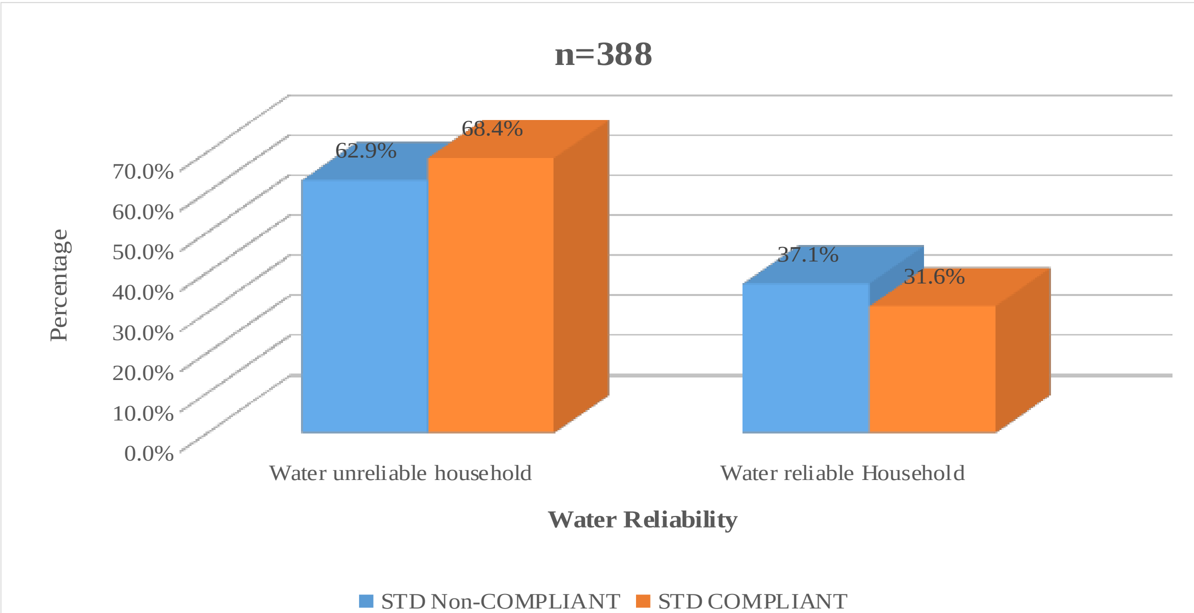


Figure CHAPTER FIVE THE EXISTING STRUCTURE OF WATER SERVICE PROVISION SYSTEM AND WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA.63 : Standard cost per 20L container versus consolidated water reliability

Source: Field data, 2023

The findings of this research found that, some of the water security parameters impacted each other in a way that was complex. For instance, the study found that there was significant relationships between affordability and quantity; reliability and quantity; reliability and quality. However, there was no significant relationship between affordability and quality and affordability and reliability. It is important to point here that households coping mechanisms played an important role in ensuring that they had access to water. From observation, many people picked already cooked food from the street food vendors hence reducing the direct burden of having to use water for cooking cook. Street foods are reasobaly cheap in the informal settlements with a cup (300 ml) of *Githeri* (a mix of boiled beans and maize) costing as low as KSh. 30 (US $0.23), which can feed a family of two members.

Other observations made include the fact that, there were ablution blocks next to the water kiosks and many people took their bath and nature call from here at a fee (KSh. 5 per person). The quantity of water used here and the cost incurred by household members may not be reflected in the relationship between water affordability and quantity.

In a study conducted by Purshouse et al., (2017), in eastern part of Nairobi County, they found that average per capita water consumption had a correlation with the water source choice. The findings also demonstrated that, household wealth, education, and cost of water, did not have significant effects on per capita water consumption. This is contrary to the study by Joshi et al., (2023) who found a strong influence of socioeconomic status on both availability and cost of piped water. There was a glaring contrast in water access based on monthly income; with high and middle income households enjoying more reliable water supply through in-house connections, while lower-income individuals faced higher costs and limited access.

CHAPTER SIX

WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY

6.1. Introduction

The findings in this chapter are in line with objective three of the study, which sought to evaluate water service provision system integration approaches on water security in informal settlements within Nairobi County, Kenya.

6.2. Combinations of water accessed by household

The study undertook analysis to identify households that accessed water services from a mix of providers to find out if that made the household more water secure. The study found out that, a number households used one single source of water (60%) while the rest used a multiple of sources (40%), evident of a demand-driven integration of services or otherwise known as coping strategies.

Table CHAPTER SIX WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.53, shows various combinations of water sources households in informal settlements used to ensure they had water in their households.

**Table CHAPTER SIX
WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.53: Water source combinations**

Water source(s) accessed by households	Number of households (Frequency)	Percent

Piped Water connection only	7	1.9
Shared Connection only	91	23.4
Water Kiosk only	103	26.6
Piped Water Connection + Kiosk	2	.5
Water kiosk + Shared connection	24	6.3
Hand cart only	9	2.2
Piped connection + Hand cart	2	.5
Shared connection + Hand cart	7	1.6
Piped connection + Shared connection, + Hand cart	1	.3
Hand cart + Water kiosk	5	1.1
Shared connection + Water kiosk + Hand cart	4	.8
Water Tanker/Boozer only	1	.3
Shared connection + Water tanker	1	.3
Hand cart + Water tanker	2	.5
Public borehole only	7	1.6
Piped connection + Public borehole	4	.8
Shared connection + Public borehole	11	2.7
Water Kiosk + Public borehole	22	5.7
Hand cart + Public borehole	7	1.6
Private Borehole only	14	3.8
Shared connection + Private Borehole	9	2.4
Water Kiosk + Private Borehole	2	.5
Handcart + Private Borehole	4	1.1
Shared connection + Public borehole + Private borehole	1	.3
Shared connection + Self-supply	1	.3
Water Tanker/Boozer + Self-supply	1	.3
Rain water harvesting only	1	.3
Piped connection + Rainwater harvesting	2	.5
Shared connection + Rainwater harvesting	5	1.4
Piped connection + Shared connection + Rainwater Harvesting	1	.3
Water Kiosk + Rainwater Harvesting	17	4.3
Piped connection + Water kiosk + Rainwater Harvesting	2	.5
Shared connection +Water kiosk + Rainwater Harvesting	3	1.1
Shared connection + Water kiosk + Hand cart + Rainwater Harvesting	1	.3
Shared connection + Public borehole + Rainwater Harvesting	2	.5
Private Borehole + Rainwater Harvesting	7	1.9
Shared connection + Other sources	2	.5
Water Kiosk + Other sources	1	.3
Water Tanker/Boozer + Other sources	2	.5
Total	**388**	**100.0**

Source: Field data, 2023

6.3. Existing water service integration

The analysis of water service integration focused on three parameters, that is, who was producing the water? How the household accessed water? And finally, what level of service the household was experiencing? The study also assessed the context under which the producers engaged, the integration efforts made by the producers and the existing opportunities for more integration.

6.3.1. Integration in water production

There were four producers of water identified – self-supply, not-for-profit organizations (NGOs, CBOs and FBOs), private water source developers, and lastly, the public water developers (government institutions). Arbitrary scores were assigned to producers as 0, 1, 2, and 3 respectively to show the level water development in an area, as shown in Figure CHAPTER ONE

INTRODUCTION.64 . Of course, in many instances, an area had one or more than one producer which led to competition.

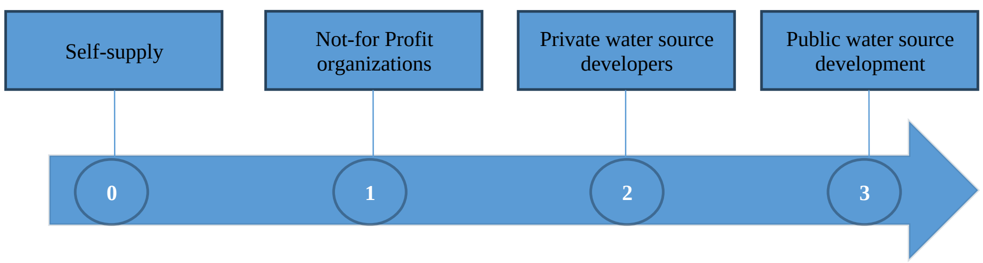


Figure CHAPTER ONE
INTRODUCTION.64: Scales of water production
Source: Author 2023

The results of analysis of each producer were summarised in Table CHAPTER SIX

WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.54, based on contextual issues, forms of integration happening and opportunities for possible integration. The contextual issues were the conditions in the INSEs that led the developer to install the source. Ongoing integration was identified from

FGD and KII interviews conducted and the recommendations deduced for opportunities for integration.

Private water source developers undertook connections to households at a fee which in most instances was quite high. One private borehole owner charged KSh. 60,000 connection fee which did not include pipes and labour cost for connection. The private company did not take responsibility for any water losses through leakages or illegal connection coming up with an innovative mechanism where they installed water meter at the source. The household took responsibility of guarding their pipeline from illegal connection and / or leakage. The household or business connected paid as per meter reading at the source. Key integration existed with the NCWSC where their laboratory was used in water quality analysis providing information required to compute the quantities and therefore dosage of purification chemicals for the borehole owner.

Not-for Profit organizations also ventured into water supply because of scarcity of water in the INSEs. Though their primary intention was to get water for their own use, the neighbouring community were also in need forming a business case as potential customers. Like the private entities, they supplied water to households, water kiosks, tankers and water carts.

Table CHAPTER SIX
WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.54: Water Production Integration

	Self-supply producers	Not-for Profit producers	Private water source producers	Public water source producers
Contextual	• Water	• Water	• Water	• Slum

issues	scarcity in area • Secure water source for tenants • Water treatment done • Issues of trust and therefore limited extension of services • Rampant illegal connections. • Existing public sources/kiosk which is unreliable • Sells to food joints and households. • Doesn't sale to onward resellers such as carts.	scarcity in area • They were actually selling water	scarcity in the INSEs • Water treatment done with automated dossiers • Sells water to households, food joints, cart and truck owners, water kiosks. • Rampant illegal connections. • Purely competition-based.	upgrading • Boreholes sunk in schools, hospitals, police stations • Electrical blackouts lead to no water • Free water • No treatment
Integration happening	• Extension of water to service through kiosks for neighbours. •		• Connection to households at a fee (some fees were very high, KSh. 60,000 or US $500) non-refundable not including pipes and labour charges.	• Public owned • Community-managed • NWSC maintained • Use of existing government institutions such as chief's office. • Cart owners fetch for free

				and sale. • NGOs supporting with household water treatment (HWT) through supply of aqua tabs.
Opportunities for integration	• Possibility to extend services by supplying to neighbouring property owners with a bulky metered connection.	• Partner with vendors to install kiosks for on-selling • Partner with property owners/land lords/ladies to pipe water to their property.	• More partnerships with other private vendors to install water kiosks and extend services • Partnership with technology companies in installation of ATM machines • Partnership with technology companies for installation of solar/hybrid power system.	• Allow private, NGOs and CBOs to drill boreholes, treat and install storage facilities in existing government institutions through public-private partnership (PPP) or build operate transfer (BOT) concessions. •

Source: Field data, 2023

6.3.2. Integration in service provision infrastructure

The access points of water by household were classified as – direct from source, water delivered through kiosk of vendors, a shared household connection (water yard in a plot), and finally individual household connection. The level of infrastructure development was determined by investiment from the service provider or through integration of providers. Arbitrary scores were assigned to service provision infrastructure as 0, 1, 2, and 3 respectively to show the level of development of service infrastructure, Figure CHAPTER ONE INTRODUCTION.65.

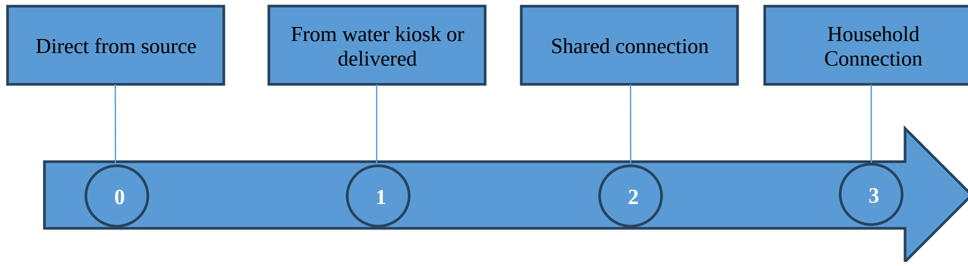


Figure CHAPTER ONE INTRODUCTION.65: House water access points from source to household connection

Source: Author, 2023

The levels of water access were an indication of both availability of water within the vicinity of the household and accessibility of water. Households that accessed water directly from the source (mostly boreholes), were within a distance of 100 m and if they stayed far, they got it through the services of the water carts. The households that accessed water directly from source in most cases water was provided at no cost. When they sought the services of the water carts, the water costed the households KSh. 10.00 (US $0.083) per 20-liter container delivered.

According to KIIs and FGD findings, most of the shared connections were initiated by landlords of Plot 10 housing arrangements. These Plot 10 property owners, have installed one pipeline connection from NWSC or a private borehole source to a common water yard within the plot which is accessed by all tenants in the property. Households living here accessed all their water needs (drinking, cooking, washing and other sanitation services such as flushing toilets) from this single point. The households here also stored water in various containers to cater for periods when the water was not flowing or periods of scarcity.

This level of the water supply system (delivery infrastructure) showed a lot of opportunity for integration. Already, some level of integration was happening where various arrangements existed by the water producers. For instance, for community managed water kiosks, O+M was done by the NCWSC and in some instances, they hired local plumbers to fix any leakages when it happened. From kiosks, shared connections and household connections, most households depended on a number of sources. There were instances where there were household – to – household connections (H2HC), and cases where a connected household was selling water from their tap just like water vendors.

This findings are similar to what Angueletou-Marteau A., (2007), study in Peri-urban areas of Mumbai, India. They found that households unofficially sold water from the utility connection to other un-connected houselds. This was a lucrative business as they were making some very good profits if they sold to several households.

In one informal settlement, there were more than 100 water kiosks and yards, not counting the water carts and other on-sellers, depicting water as a commodity in a pure market of demand and supply whose price varied from source to final consumer/household.

Table CHAPTER SIX WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.55 is a summary of the delivery service infrastructure with details on how various households accessed water. It gives the prevailing INSE context, integration already happening in water service provision and existing opportunity for providers to integrate.

Table CHAPTER SIX
WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.55: Integration approaches of household water access points from source to household connection

	Direct from source	From water kiosk or delivered by vendor	Through a shared connection of yard	Household connection
Contextual issues	• Government drilled boreholes (NMS) • Happens where free water is available • Practiced by households that are 50-100 m from source • Some sources have extensions and collection happens at kiosks.	• Most kiosks are owned by CBOs where source is public • All kiosks are privately owned where source is private. • Tankers are owned by a mixture of businesses (youth CBOs, individuals) • Operates where majority of households are not connected • Most water kiosks and vendors are supplied by boreholes • Customers include households, food joints, schools, churches, mosques, big	• This was reported in Plot where there were rental properties mostly known as Plot 10 • It was initiated by property developer/land lord or lady • Tenants did not pay for water separately from rental fee. • In some cases, the households also had a household connection. In such cases, the landlord disconnected the household if they have not paid rent as a first step to push the household to	• A few households had multiple taps (kitchen, water closet and sinks). • Most households had a door-step tap connection especially for Plot 10. • Most sources were publicly owned systems. • Water for drinking was bought bottled water from shops.

		flats and estates, construction sites	pay. • Many of these properties also depended on illegal connections from water cartels.	
Integration happening	• Community – managed sources and collection points • O+M by NCWSC for publicly owned supply systems.	• Kiosks sell to cart owners • Operation and maintenance work through local plumbers engaged at a fee	• Some properties use multiple sources including direct from source/kiosk, delivered from source/kiosk by vendor, sometimes from other households. • Land lords/ladies' installation of storage tanks in their properties. • Land lords/ladies incurring connection fee expenses and installing a common water point.	• The households also accessed water from multiple sources and delivery mechanisms including kiosks, vendor delivery and used of shared connection in plot.
Opportunities for integration	• Both public and private source owners extending services through	• Both public and private source owners extending services through	• Door-step household connections by land lords/ladies leading to optimal	• Connection to multiple sources to cover for periods of main source

	kiosks to under-covered areas – leading to basic service • Both public and private source owners undertaking household connections – leading to optimal service • Community management of illegal connections. • Extend services to public facilities such as schools, health centers, chiefs camps etc to reduce distance to collection points.	kiosks to under-covered areas – leading to BS • Both public and private source owners undertaking household connections – leading to optimal service • Community management of illegal connections. • Extend services to public facilities such as schools, health centers, chiefs camps etc to reduce distance to collection points.	service. • Land lords/ladies install storage tanks that can serve all households with water flow of up to 24 hours to lead to optimal service.	breakdown. • Meter all household connections and have them pay for water services to allow for ring-fencing. • The water lord model seems to be a workable model.

Source: Field data (2023)

The four access typologies of how households access water from direct from source, those that receive water from kiosks and is delivered by water vendors, to shared household connection and finally individual household connections. It was observed that several households used multiple access points indicating a continuum of service provision.

6.3.3. Service levels

This classification was generated by analysing the distance of the water service accessed by and how water reached the household. On the supply side, the service levels experienced by a household was dependent on water production and level of development of delivery infrastructure.

No service was an indication that, there existed minimal water production infrastructure and therefore households received water either by directly fetching from the source, or by a water vendor delivering the water to them. This category of households could easily be advanced to basic services by extending water service infrastructure such as water kiosks or yards, to minimize distance travelled and time taken to fetch water. However, the was unwillingness from water producers and service providers to extend services to household because of rampant illegal connections. It was also mentioned that, the cost of connection was prohibiting those willing since it ranged between KSh. 30,000 to KSh. 60,000, without including the cost of pipes and labour which had to be borne by the household seeking connection.

Basic water service (getting water from water kiosk), was the most popular mechanism of accessing water in the INSEs of Nairobi. According to the kiosk operators and owners, the cost was reasonable and controlled by NWSC. However, for kiosks depending on private and not-for profit water sources, the price of water at kiosk was set by the owner of the kiosk. The cost of water for publicly owned water kiosk was set at KSh. 2 while at the privately owned kiosk, the price was between KSh. 5 and KSh. 10. It was also evident that, there were several water kiosks in any given area leading to competition and most of the time, several vendors dropped out of business because of what they termed as low profits. The presence of free water and low-priced water from water ATMs or token system, contributed to some private kiosks closing their water vending business.

Due to reliability of service, even those households thought to be having access to intermediate and optimal services, did experience scarcity and therefore relied on other water service providers. This evidently was a demand-driven effort that led households to cope with the water scarcity situation in INSEs. Arbitrary scores were assigned to service levels as 0, 1, 2, and 3 respectively to show the incremental level of water access by households and therefore level infrastructure development, Figure CHAPTER ONE INTRODUCTION.66 and Table CHAPTER SIX WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.56.

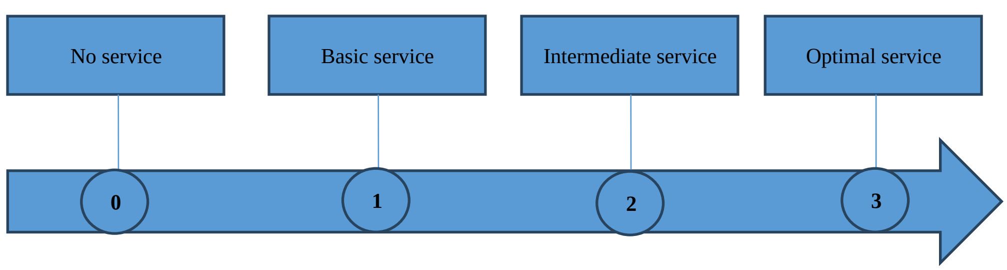


Figure CHAPTER ONE INTRODUCTION.66: Incremental water service levels experienced by households

Table CHAPTER SIX
WATER SERVICE PROVISION INTEGRATION APPROACHES IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY.56: Integration results of incremental water service levels

	No service	Basic service	Intermediate service	Optimal service
Contextual issues	• No infrastructure except the source development.	• Little or no service delivery infrastructure. • Depend on water kiosks or yards near the household. • Both public and private systems may end up providing basic service.	• Some reasonable service delivery infrastructure such as pipeline and storage. • Several neighbouring households accessed water from a single collection point within one rental property. • Some instances, a connected household did a connection to another household to supply them with water (H2HC).	• Household was connected and metered • Since most of the houses were single or double rooms, a single tap was used by the household members and therefore water for all domestic use was collected from that single tap.
Integration happening	• No integration was reported in this service level.	• During water scarcity, other *ad hoc* vendors provided services.		• Only form of integration was where some water kiosks were installed in the

				neighbourhood which served the connected households during times of scarcity. • Other vendors also delivered water to the households during scarcity. • Vendors/ cartels were blamed for illegal connection so that they could create false scarcity for them to remain in business.
Opportunities for integration	• Possibility existed for partnerships with land owners to extend services through water kiosks. • Possibility existed for government institutions such as schools and chief camps to develop sources and/or provide	• Possibility existed of the kiosk operators extending pipeline to neighbouring households. • Possibility existed for other institutions to support with amortisation enabling households to pay for connection over a reasonable	• Possibility existed for extending connection from single collection point to individual households.	• The problem in this instance was seen as that of type of houses and house designs installed by developers targeting low-income earners. This in most cases had one or two rooms occupied by household. • No kitchen, no WC or separate wet areas for

	space for construction of storage facilities and delivery infrastructure such as kiosks.	time.	laundry. • Common places installed such as pour and flush toilets which were also being used for laundry. •

Source: Field data (2023)

6.4. Outcomes of water production, service infrastructure and service levels

The complexity of water service system integration was deduced from the production, service provision infrastructure and the service levels experienced by various households depending on existing supply system. Depending of the level of infrastructure development, various water service levels were experienced by the households in the INSEs.

Equally, the study found four (4) water service providers arrangements which included self-supply, not-for profit providers, private water service providers and publicly owned water service providers. These fell into the two broad categories – formal and informal services. Further, the informal water services operational in Nairobi's informal settlements included water tankers, water carts, private boreholes, water kiosks, resellers of public and private sources and other sources such as rainwater and open surface water. Angueletou-Marteau, A. (2007), found similar informal water operators in Mumbai, India including private tankers, owner of wells/borewells, resellers of municipal network water, and free open sources of water.

In peri-urban Maputo, Matsinhe (2008), found that household water resellers and small-scale independent provides were covering 21% of unconnected households, therefore making an important and indispensable source of access to water. This was also the case for the case of Malawi. Findings in Lilongwe, indicated that, a majority of people depend on water kiosks constructed in the 1980s (Adams, 2017). Just like in the case of Nairobi, the informal settlements have access to multiple water service providers and have developed coping strategies where they purchase less quality water for non-potable uses like sanitation (Adams, 2017).

6.4.1. Self-supply system

A self-supply system, Figure CHAPTER ONE INTRODUCTION.67 , was deduced from the KII and FGDs conducted. This system exhibited a fully developed infrastructure though small scale water service provider model. Water was produced from ground sources, had pumping into an overhead storage tank with an inflow treatment system (chlorination), then it was supplied to tenants who lived within the owner of the borehole's property. An additional pipeline was installed to a water yard accessed by tenants in case of system related issues. Another line of pipeline was extended to a water kiosk which was accessed by neighbouring households and water cart vendors. The neighbouring households purchased water directly from the water kiosk. On the other hand, the water cart operaators sold water to other neighbouring households and small food joints who sought their services.

The self-supply system did show potential in meeting needs of the people living near the property of the owner. It also provided for a water market system where vendors buying at a lower price (at KSh. 2) sold the water at prices 5 to 10 times higher depending on how far their customers stayed from the source.

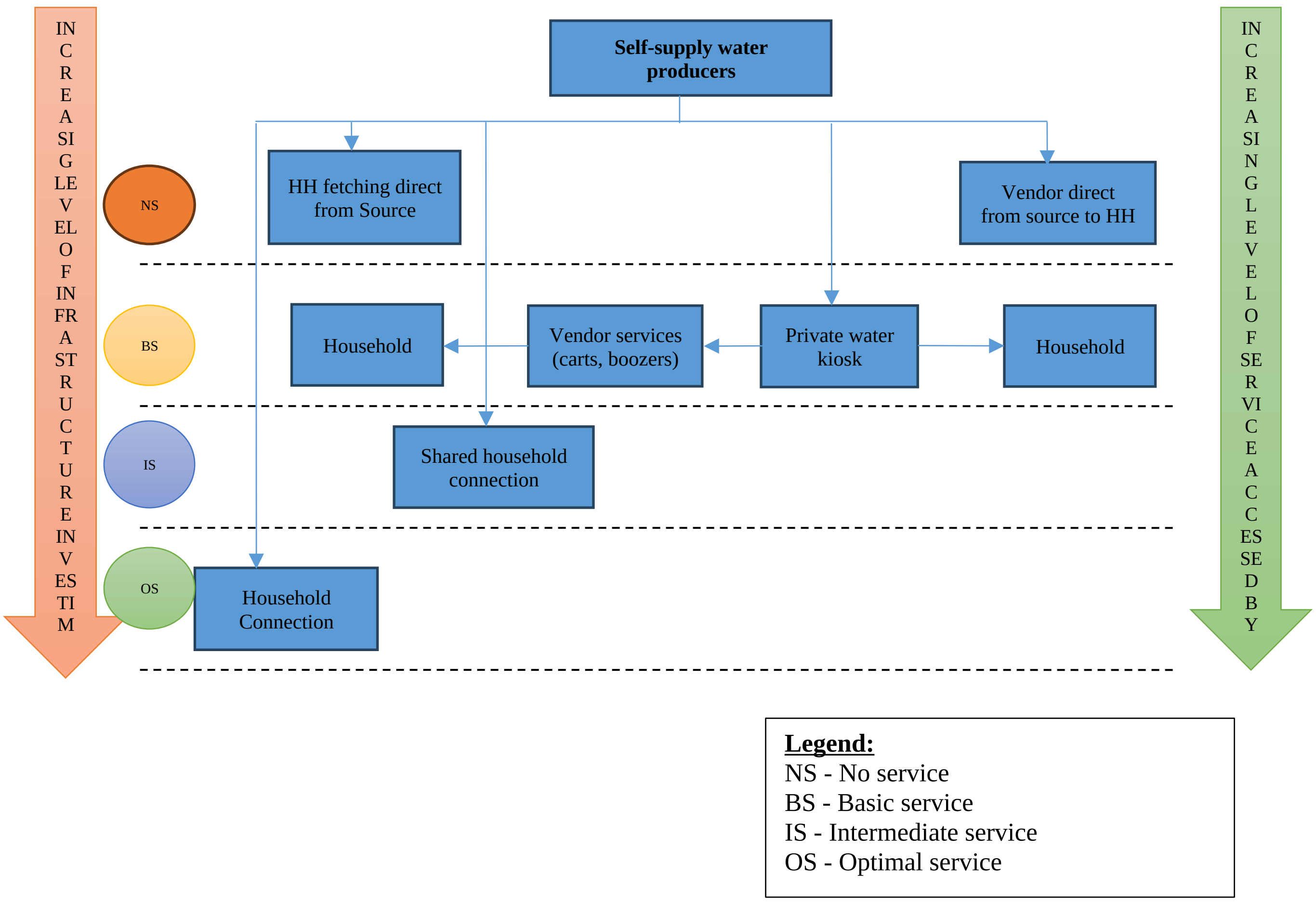


Figure CHAPTER ONE INTRODUCTION.67: Water supply system for a self-supply water development
Source: Author, 2003

Challenges of such system was the financial breakthrough since a major breakdown of the submersible pump or even electrical malfunction could put the system out of operation for almost three months. The cost of replacing a submersible pump was born by the owner of the borehole alone despite the fact that he had other neighbouring community members connected. The expectation of the borehole owner was that, the neighbouring community supported him during such a period and when this didn't happen, he decided to disconnect external customers and only supplied to his tenants and dispensed to neighbours through a water kiosk which was constructed within his property.

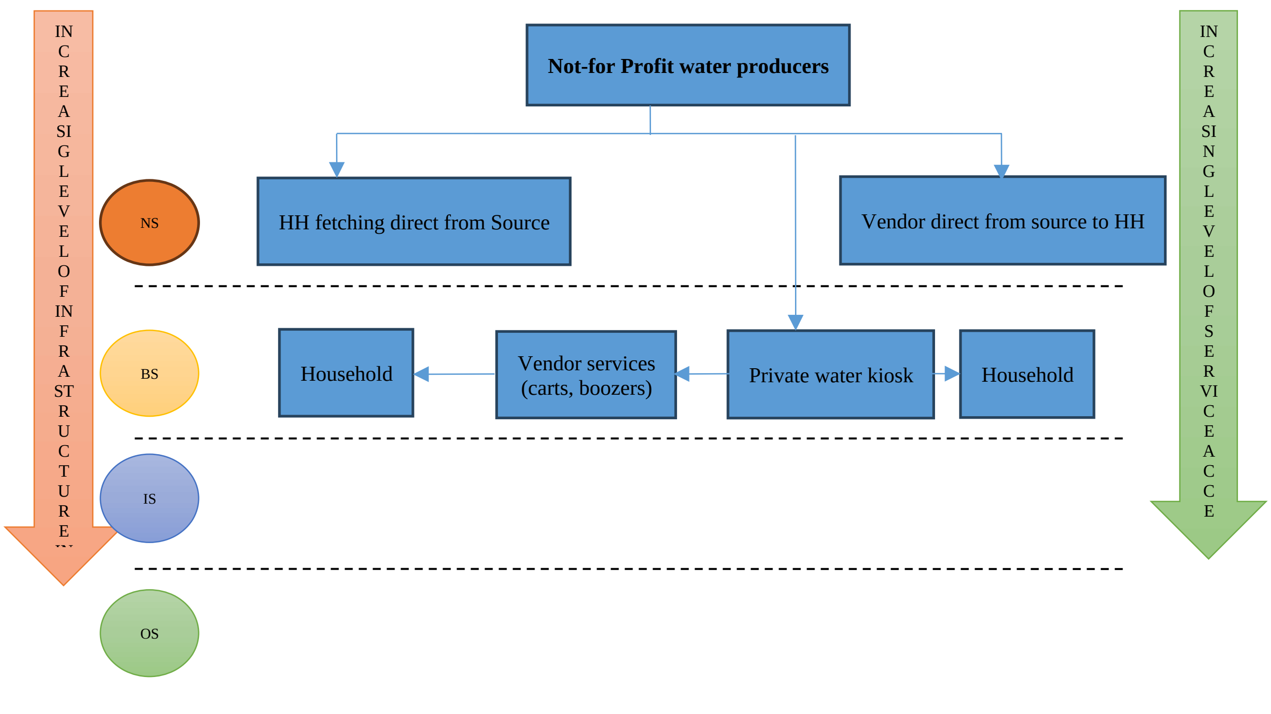
There were issues of mistrust given the rampant illegal water connection in the neighbourhood. This was said to be the main reason why the private borehole owner had not developed any delivery infrastructure and pipeline to serve the neighbouring community. Beyond the water kiosk which was owned and managed by the private water developer, there was not opportunity for integration of this service.

In Ethiopia, Butterworth et al., (2013), found that self-supply wells performed better in terms of adequacy, i.e., water supply sufficiency to user needs. Oluwasanya et al. (2012) recommends that, mainstreaming self-supply systems into an urban water supply scheme could lead into ensuring the appropriateness of the water source while also ensuring that safety regulations are adhered to.

6.4.2. Not-for profit supply system

This system developed by not-for profit organisations, that include CBOs, NGOs, FBOs etc. While for NGOs, the objective was to provide free water to people with access problems, the main objective for CBOs and FBOs was to have water available in their facilities for their use. However, the demand from neighbouring community, lead the not-for profit organizations to supply to them. These organizations did not invest in pipelines to households but rather, people accessed water either directly from the source point or through water kiosks.

Figure CHAPTER ONE INTRODUCTION.68, shows the not-for profit water producer system with level of infrastructure development and the water service level experienced by households.



Legend:
NS - No service
BS - Basic service
IS - Intermediate service
OS - Optimal service

Figure CHAPTER ONE INTRODUCTION.68: Water supply system for not-for profit water developer

Source: Author, 2023

A discussion with the these service providers identified two opportunities that can enable them reach more households with water. The first opportunity is whereby they sale to water tankers who can transport to other areas where there is no infrastructure or where there are no reliable sources. The second one is to undertake household connections to nearby places and water kiosks to supply to those who are not connected. The other facilities that can be connected to the supply system, includes places of worship, schools and health facilities that do not have any supply or their own water source.

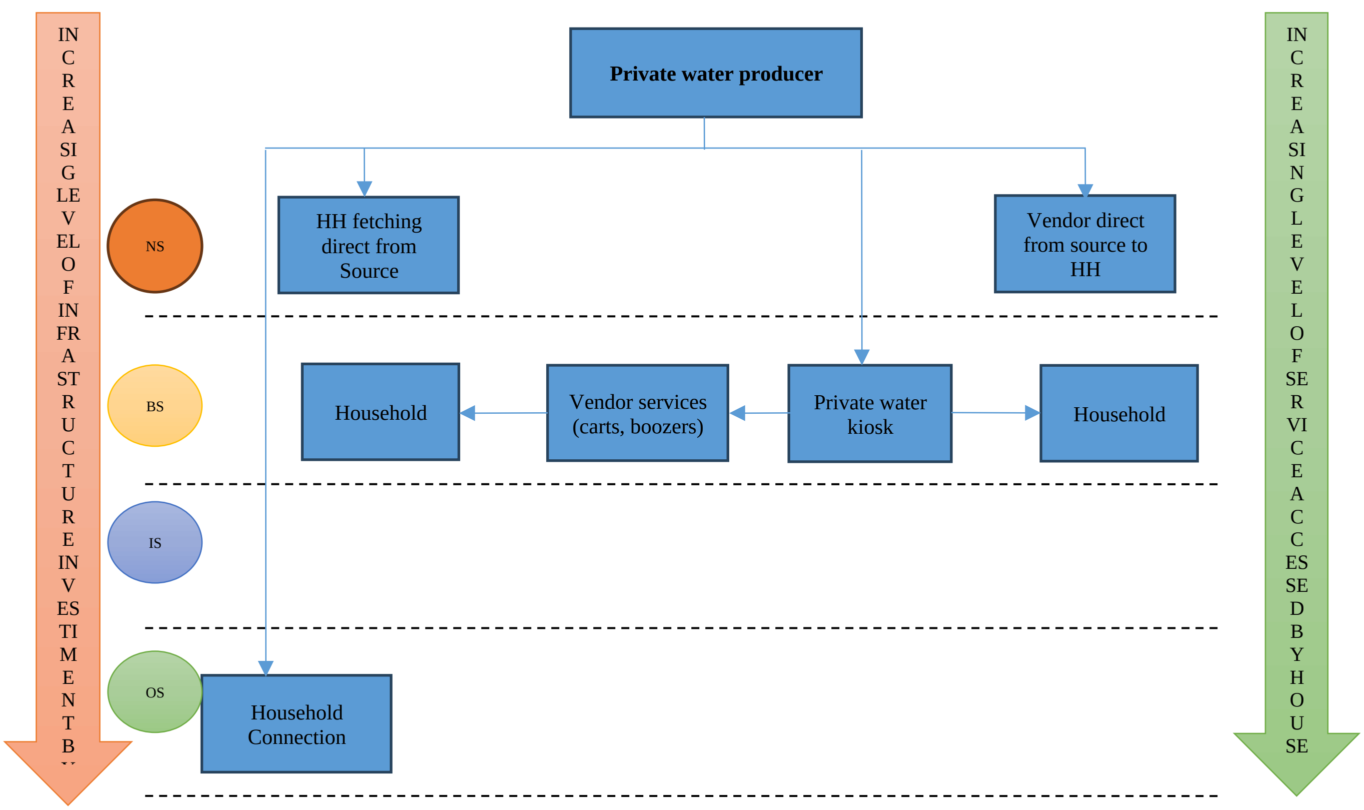
It was also observed that NGOs operating in the informal settlements have direct intervention in water services, through they may not be recognised as formal service providers. In Bangladesh, the role of NGOs and CBOs was recognized by Dhaka Water Supply Authority (DWASA) to work as mediators to improve water-supply systems in the slum settlements and also in creating awareness and advocacy on water scarcity (Habib, 2009). Equally, in Indonesia, NGOs' role was crucial in mobilizing resources targeting improved access to water services for the urban poor communities in Jarkata (Winayanti & Lang 2004).

6.4.3. Private supply system

This system is motivated by business with the main objective of producing water and offering related supply services. In all cases, water was only treated with chlorine, stored with overhead tanks and supplied directly from the borehole source, through private water kiosks, water tankers, and household connection.

The connection fee was a one-off amount paid to the private borehole owner that varied between KSh. 30,000 to KSh. 60,000. The cost of pipes and labour charges were born by the household seeking the service. Equally, the household negotiates for wayleave which most of the time meant that the pipes are laid near neighours doors. This also meant that, illegal connections could easily be done by cartels without the owner of the borehole or the customer seeking connection.

Figure CHAPTER ONE INTRODUCTION.69 , shows the private water producer system with level of infrastructure development and the water service level experienced by households.



Legend:
NS - No service
BS - Basic service
IS - Intermediate service
OS - Optimal service

Figure CHAPTER ONE INTRODUCTION.69: Water supply system for a private developer

Source: Author, 2023

Key innovations were noted in this type of system whereby, the owner of the borehole installed meters at the borehole source, leaving the responsibility of monitoring illegal connections to the connected households. In one particular borehole, each pipeline was installed with two meters, one at the borehole source and the other at the customer's compound. This provided a counterchecking mechanism since both the borehole owner and the user could monitor water consumption real time and if there was any deviation in both meter readings, they were able to diagnose the reason for loss which could be due to leakage of illegal connection.

6.4.4. Public supply system

This system was developed by government driven objectives, which was to supply water to under-covered areas. A number of government entities were involved, both National and County Government of Nairobi. A majority of the boreholes were drilled by an outfit of the NCC dubbed, the Nairobi Metropolitan Services (NMS), which was led by an Army General.

As shown in Figure CHAPTER ONE INTRODUCTION.70 , the system included, a drilled borehole equipped with a submersible pump, elevated water storage tanks, and several water kiosks connected to the borehole. The supply system here showed a complex relationship among the developer, private water kiosk owners, water tankers, cart owners and connected households. For instance, there were cases where one legally connected household also connected a neighbouring household. There were cases where a connected household also sold water from their tap to other who were not connected. It was also observed that, some private water kiosks, also did household connection and collected fee.

The system was managed through the Chiefs (which falls under the office of the president) through the ministry of interior. The communities managed the water kiosk in their neighbourhood through the community elders or a selected individuals. However, operation and maintenance costs were born by the NCWSC. This meant that, whenever there was a breakdown, the NCWSC [illegible] directly using their technical teams or by engaging local plumbers on a casual basis.

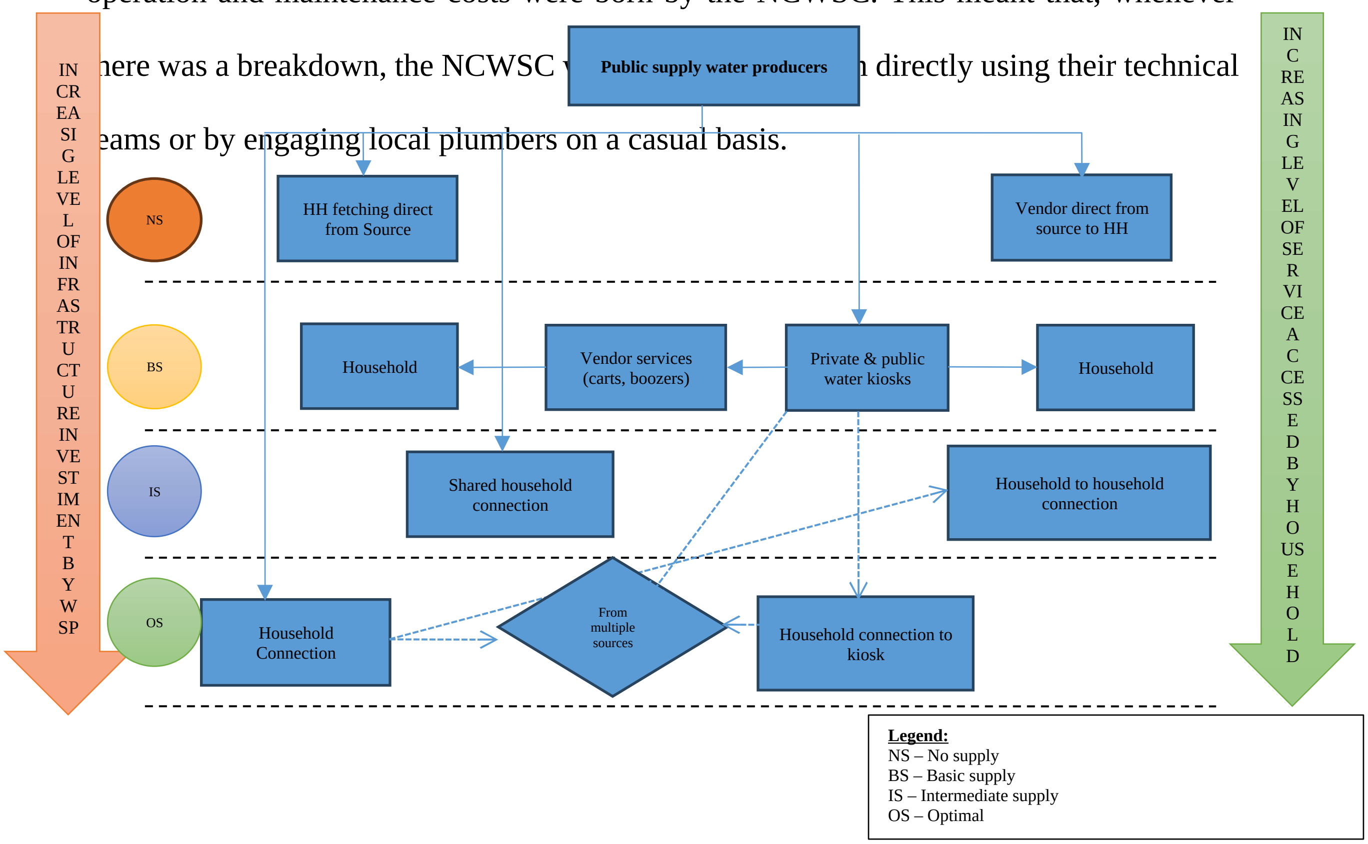


Figure CHAPTER ONE INTRODUCTION.70: Water supply system for public water developer

Source: Author, 2023

This exhibited a very complex system of water service supply in Nairobi's INSEs. From one source, a household could receive water by more than one mechanism, either directly connected to source, through the kiosk, from a cart vendor or from a neighbouring household, demonstrating existing opportunities for water service integration.

From observation, it was found out that, both NCWSC water kiosk run by private individuals and the borehole water from either private or by government, operated in proximity to each other. There were instances when water from borehole was accessed for free if it was a government drilled borehole and where it was paid for, when it was a private borehole.

While the study found that, willingness to connect to existing system was limited by the the rampant illegal connections, willingness to pay (WTP), and reliability of service, it was observed that, the cost of connection was prohibitingly high, a majority of households were poor and could not afford the one-off connection fee. This begged for the need to regulate the cost of water service connection fee and/or institutionalization of the pro-poor approaches such as amortization of connection fee.

This agreed with the study carried out by Abualtayef, M., et al (2019), in Khan Younis City in Palestine, who found out that household income, water quality, water distribution schedule, water quantity, municipality services, marital status, reliability of service of water continuity, and general customer satisfaction were determinants for household customer's willingness to pay.

In Tanzania, it was found that, since none of the water supply systems was reliable and therefore was unable to satisfy the informal households with water consumption needs, people sought to use multiple sources (Dakyaga et al. 2018). Due to the inherent competition between the publicly owned but vendor run water kiosks, and the private kiosks whose sources were groundwater, the price of water reduced significantly. It was stated by an FGD discussant in Kibera slums that,

> “If the borehole was not there, the NCWSC could be selling water at KSh. 20 against what the current price of KSh. 10”.

In this area in Kibra, it was absorved that, the water kiosk sourcing water from a borehole, was selling a 20L container at KSh. 5. This borehole had solar pannels installed making cost of water production much lower compared to an electricity grid or diesel generator pumped system.

Intergration of various service providers could help address insecurity by filling the gap that might be existing due to scarcity from the utility company. This is also supported by the World Bank (2012) who underscore the fact that, addressing water access disparities across Nairobi’s sub-counties requires integrated urban planning and substantial investment in water infrastructure. It is therefore important to advocate for a more equitable distribution of resources and targeted interventions in informal settlements to bridge the gap between different regions. Equally, contextual factors have to be taken into account while planning for service provision in the INSEs.

CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION

7.1. Introduction

System dynamics is a modelling approach that falls under operations research. Its purpose is to help decision makers make more informed or data-driven decisions. Though it is closely linked to statistics and econometrics, SD is different in that, it makes different assumptions to econometrics, combining elements of quantitative modelling with expert judgement to help decision makers deal with dynamic complexity. This dynamic complexity is captured through the feedback loop. The presence of a feedback loop is an indication of dynamic complexity.

The findings in this chapter are in line with objective four of the study, which sought to develop a system dynamics model for integrating water service provision that addresses water security in the informal settlements within Nairobi County, Kenya. The chapter discusses the overview of the model starting with reference mode forming the causal theory which helps in defining causal loop diagram (CLD), then the data inventory based on secondary and primary data. Further, the chapter deduces a stock and flow diagram (SFD) to enable undertake model simulation, then model calibration, and finally policy testing based on two policy undertakings.

The model synthesized the Nairobi County's urban informal settlement representing an average informal or slum settlement in a developing country.

7.1.1. Dynamic hypothesis reference mode

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .71, the population of Nairobi County grows, there is increasing pressure on available water supply and therefore the gap between supply and demand widens (Mafuta et al., 2010). This has been explained as the reason to why there are mushrooming small scale water service providers (SSIPs) who view this as a business opportunity to fill the supply gap (refer to Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .73).

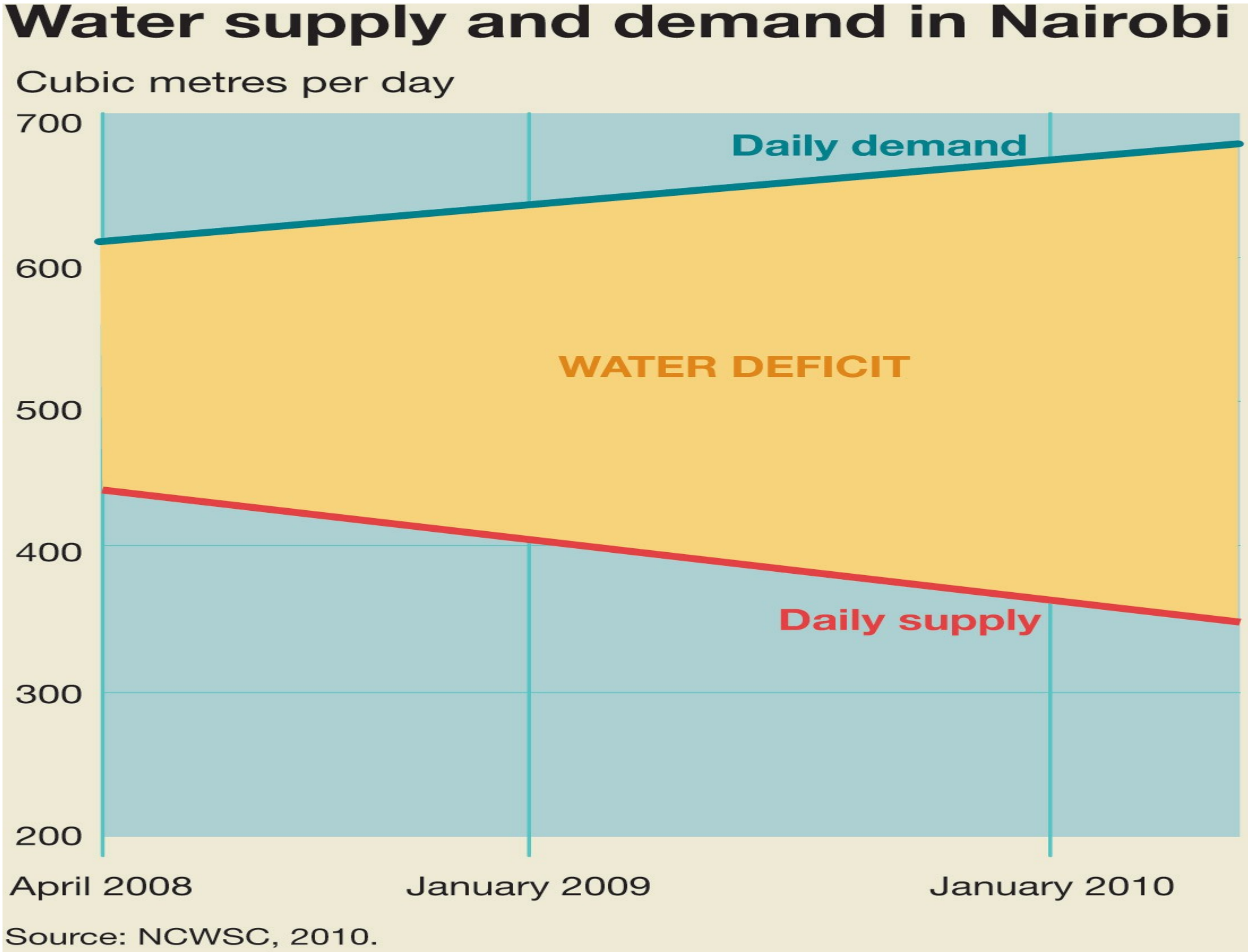


Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 71: The reference mode of the system dynamics model

Source: NCWSC (2010)

7.2. Model overview

The model was built around a household living in an informal settlement. Either the household was living in their own house or in a rented house. On average, INSEs are marginal land parcels in riparian sections of urban settlements, or that the land is occupied illegally. Therefore, provision of services especially household water connection is perceived as illegal given the conditions of ownership that can guarantee households attain access to water. Accordingly, people here struggle with access to basic services always exposed to recurrent water security.

The inherent water stress in these settlements has led to different models of water service provision with many players emerging to provide this scarce resource. The emergence of these players is either driven by self-suppliers, not-for profit organizations, private developers with interest in water business or by government due to their mandate to provide water to her citizens.

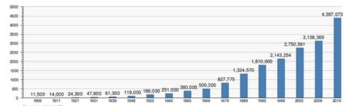
Generally, people living in INSEs are sensitive to water security (its availability, access, quantity, quality, affordability and reliability). With many players trying to address either one or most of these issues, investments to develop water infrastructure has happened in a siloed manner and therefore lacking synergies to fill the water security gap. Some of the questions policy makers have include: is drilling of boreholes and provision of free water going to solve the problem of water security? Are the small-scale independent providers (through self-supply, not-for profit organisations, or private developers) addressing the water stress issues?

To address these questions, a System Dynamics Model was developed composed of three components (Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .72). Component one was a qualitative model which has a high-level system description, including the most important mechanisms that affect households in INSEs during water scarcity/stress. The second component was a data model that includes all the numerical assumptions that were made and included or incorporated into the analysis. And it had all the checks that made sure the data was internally consistent, because data was collected from multiple sources. Therefore, these checks were made to make sure that all of these data from different sources was consistent. Then, in between those two components, was the simulation model, which drew its numerical assumptions from the data model and the feedback loops from the qualitative model, and enabled the undertaking of the scenario analyses and to test different policies.

Therefore, in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .72, the left-hand side of the integrated water service provision model, is the raw data, and on the right-hand side is the qualitative system description which doesn't have any numbers. The simulation model is in between, combining elements of both data and qualitative model.

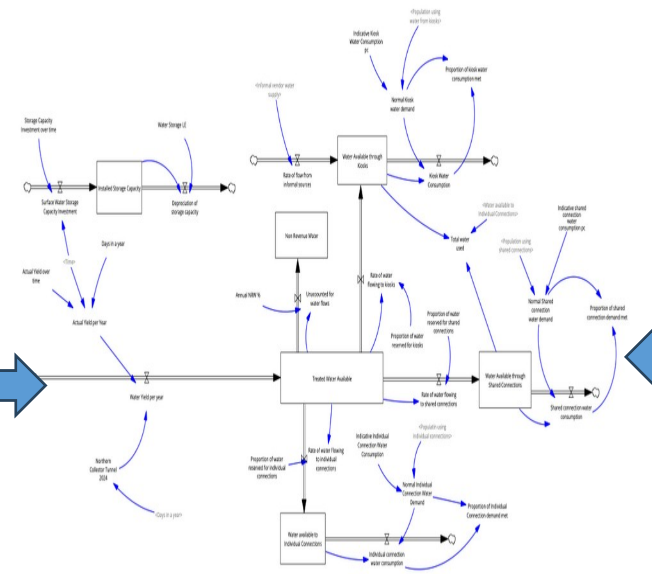
The integrated water service provision model (IWSPM), was presented in Figure CHAPTER SEVEN

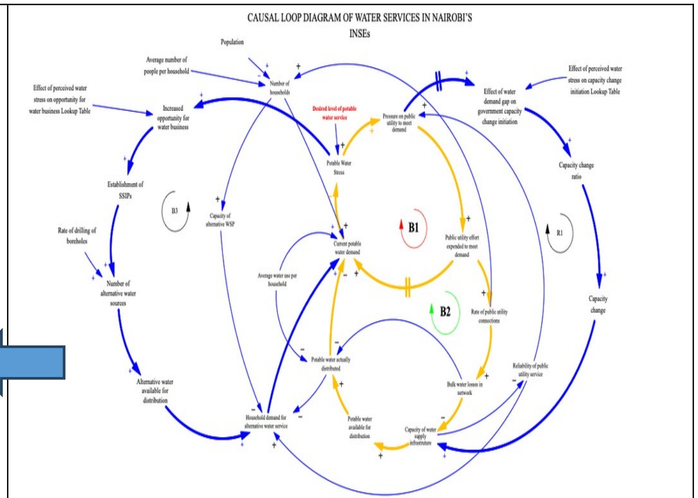
with data model, CLD and the SFD.



Year	Number of drilled boreholes	Cumulative drilled borehole
1900s	1	1
1920s	0	1
1930 – 1939	14	14
1940 – 1949	91	105
1950 – 1959	141	246
1960 – 1969	12	258
1970 – 1979	78	336
1980 – 1989	133	469
1990 – 1999	239	708
2000 – 2009	432	1,140
2010 – 2019	1,414	2,554

Year	Source	Storage capacity *10^6	Design yield (m^3/day)	Current yield (m^3/day)	Cumulative yield (m^3/day)
1906	Kikuyu Springs	0	4,000	4,000	4000
1950	Ruiru River - Dam	2.9x10^6 m^3	22,000	22,800	26,800
1955 1968	Sasumua River	15.9 x10^6 m3	59,000	52,800	79,600
1974	Chania River		37,000	37,000	116,600
1984	Chania River		127,000	127,000	243,600
1994	Chania River	77x10^6 m^3	0	0	
1995	Chania River		220,000	220,000	463,600
Current total		95.8x10^6 m^3	469,000	463,600	463,600
2020/22	NCT		140,000	140,000	603,600
Total		95.8x10^6 m^3	469,000	463,600	603,600





Data model | **Simulation model/SFD** | **Qualitative model/CLD**

Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .72: The Integrated Water Service Provision Model (IWSPM)

7.3. Water service integration model boundary

The model for water service integration in Nairobi County Informal Settlements seeks to produce an endogenous explanation of the problem of water security. To do so, and based on the literature review and empirical study conducted, various variables shown in Table

CHAPTER SEVEN A

SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE

PROVISION .57, were considered as endogenous, exogenous and those excluded from the model.

Table CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 57: Model Boundary

Endogenous Variables	Exogenous Variables	Excluded Variables
Households and population.	Household size	Sex composition of household members
Water demand (lpcd)	Household type	Day and night population changes
Water Consumption (lpcd)	Volume of water available	Economic or physical water availability
Service levels (no service, basic service, intermediate service, full service).	Amount of water consumed by household by virtue of the service experienced	Land tenure system

Formal water supply (NWSC).	Water sources	Water production cost
Informal water supply (ISSP).	Government regulations	Specificity of the government regulations
Water losses from public utility system (NRW).	Capacity of delivery infrastructure	Age of delivery infrastructure

Source: Author, 2024

7.4. Creating Causal Theories

7.4.1. Linear versus systems view

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .73, the model development started with two linear views. The first view was that of the government-affiliated water utility – they claim that people living in informal settlements are not willing to pay for services, therefore will undertake illegal connections and most of them are squatters since they do not own the land. They therefore do not quality for water connection, otherwise it will lead to loss of revenue. They connect these people through bulky meters managed by middle-men who would then sale the water to people in INSEs and from the sales, pay the utility based on meter reading on an agreed rate.

The second linear view is that of water entrepreunuers. These are private people, CBOs, and in some cases, NGOs who see a business opportunity based on existing water supply gap. They, without much delay, identify the opportunity to supply water to people in these settlements, will drill boreholes and supply water making them private water service providers. In most cases, the supply is done informally.

The last view is the systems approach. It is based on identification of the water supply problem, mapping behaviour over time and then developing the causal theories. From the two linear views, the systems approach is developed by linking ‘no pipeline connection except through kiosk’ to the ‘gap in water service in INSEs’ and closes it with ‘private water service provider’ to ‘people settling in INSEs demand for water services’. This results into a rloop – systems view.

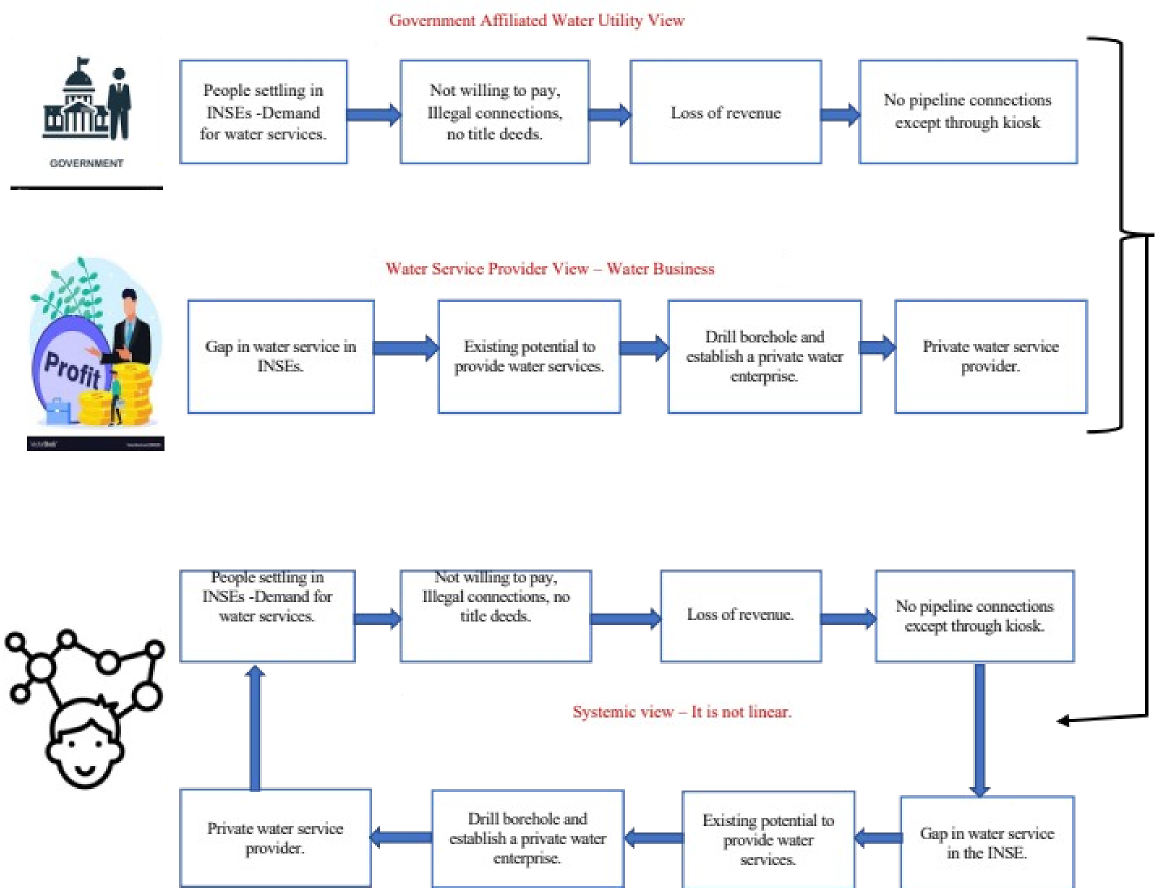


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 73: Creating causal theories

Source: Author, 2024

7.4.2. Causal loop diagram

The factors that may influence water security at household level were identified with causal relationships described through a Causal Loop Diagrams (CLDs). The key variables identified include population, households' service levels, formal and informal services. The main endogenous variables are linked through causal relations through causal loops. The endogenous variables are the primary driving forces of the system, and therefore the feedbacks between these variables should be included within the model. On the other hand, exogenous variables are those that affect the system, but are not affected by the system. These too are included in the model. Since a model is a simplification of the real world, but to serve as a fair representation and therefore explanation of the system, some variables are treated as less important and are accordingly excluded from analysis.

The study developed causal loop diagram as shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .78, in which the main endogenous factors are linked through causal relations. There are four main causal loops that include, Public Utility Potable Water Services Demand Loop (R1), the public utility household water connection loop (R2), the alternative water service loop (B1), and the public utility infrastructure development loop (R2).

The Public Utility Potable Water Services Demand Loop (R1) in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .74, shows that, when population increases, the number of households increases (number of households is computed from population divided by average number of household members which has been averaged at 3.4) driving demand for potable water high. This drives the water stress high, putting pressure on public utility to meet demand. Further, this leads to public utility effort to extend services which leads to more demand for services.

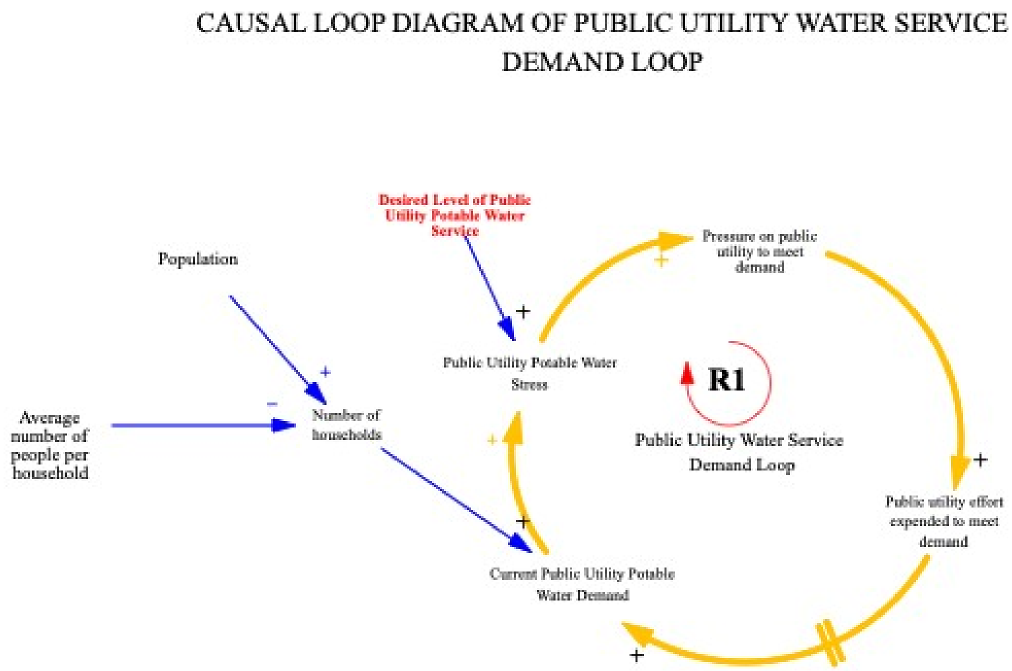


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 74: Causal Loop Diagram of Public Utility Water Service Demand Loop

Source: Author (2023)

The other response from public utility management is that of initiating new household connections (R2). This loop in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .75, shows that, when population increases, the number of households increases driving demand for potable water high. This drives the water stress high, putting pressure on public utility to meet demand. Further, this leads to public utility effort to extend services and therefore the need for new household connections in the INSEs. This leads to water losses in reticulation related with illegal connections or just technical losses related to leakage. Therefore, the more the water losses, the less the capacity of water supply infrastructure. The higher the capacity of the infrastructure, the higher the amount of potable water available for distribution which also means that the actual volume of water distributed increases. This further spike the current potable water demand.

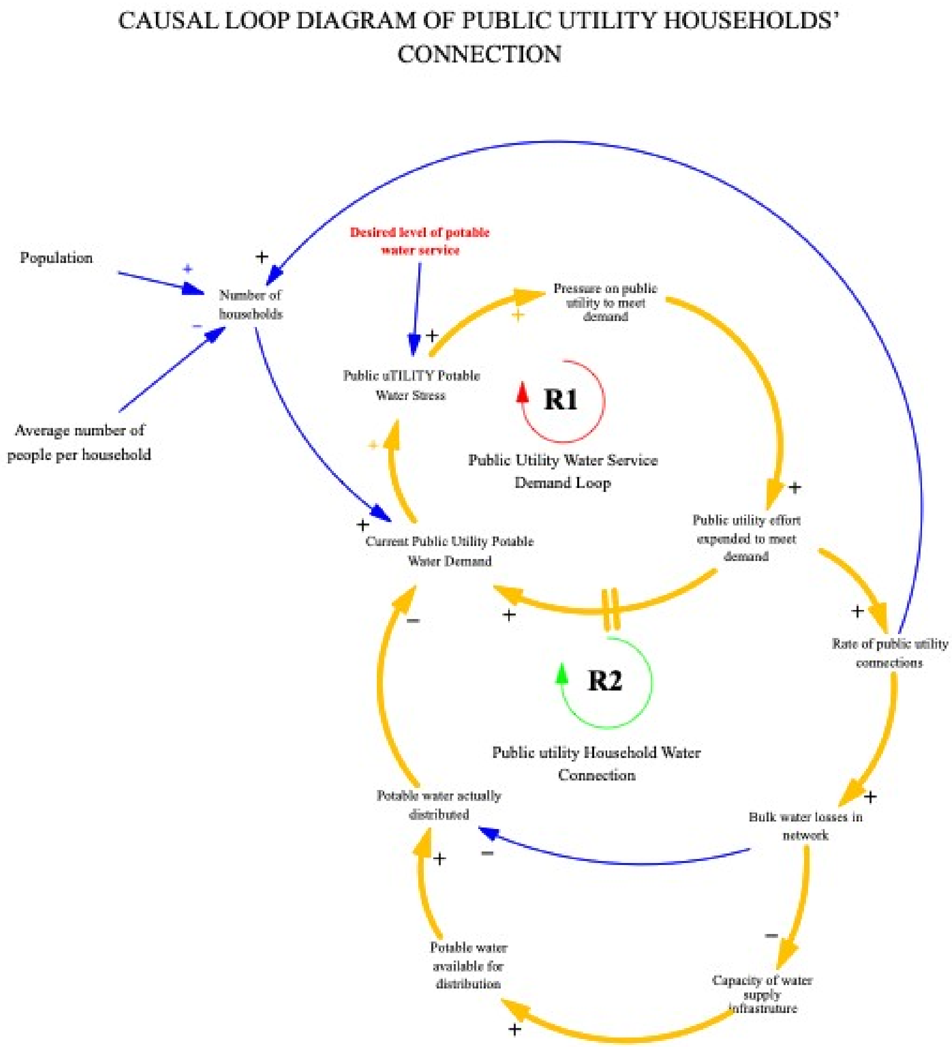


Figure CHAPTER SEVEN

A SYSTEM

DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 75: Causal Loop Diagram of Public Water Utility Households' Connection

Source: Author (2023)

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .76, the alternate water service loop (B1) is generated because, the formal (public) utility potable water stress increases the opportunity for water business, which leads to establishment of informal or small-scale independent water service providers (SSIPs). This leads to an increase in alternative water sources (which depends on rate of borehole drilling), further increasing the volume of alternative water available for distribution. This pushes the households' demand for alternative water service higher, easing (reducing) the demand on public utility potable water. Such a feedback mechanism is known as a goal-seeking loop which leads to system equilibrium.

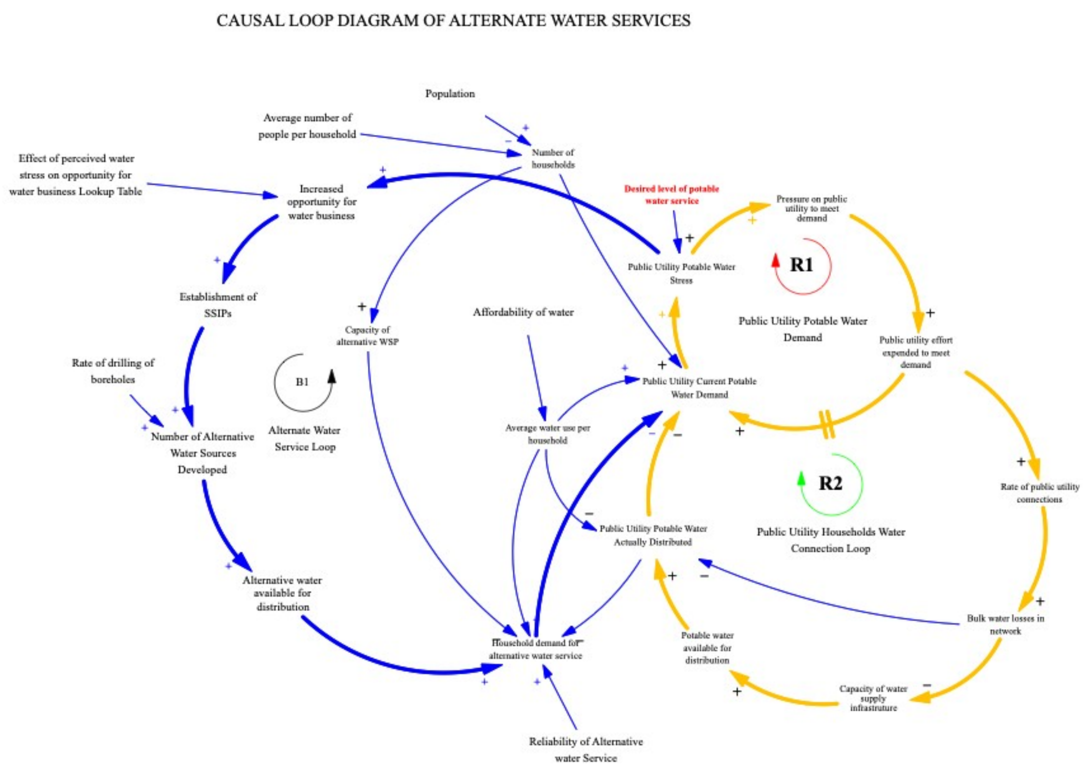


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .76: Causal Loop of Alternate Water Service

Source: Author (2023)

Further, as shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .77, the formal utility infrastructure development loop (B2) is generated because, with pressure on public water utility to meet demand (with a delay), leads to government management to initiate a production capacity change exploring and developing new water sources and storage and reticulation. The increase in capacity is positive (a constant computed from a ratio of new production capacity divided by existing production capacity; >1.0). This further increases the capacity of the water supply infrastructure leading to more public utility potable water available for distribution and increase in water actually distributed. This drives the demand for public utility potable water high which leads to more potable water stress. This is true because of the long delays that accompany government response to increasing demand and water stress thereof. This is evident from data models (Table CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL

FOR INTEGRATION OF WATER SERVICE PROVISION .58) which shows that, production of water has not been at par with demand, always leading to a gap (potable water stress).

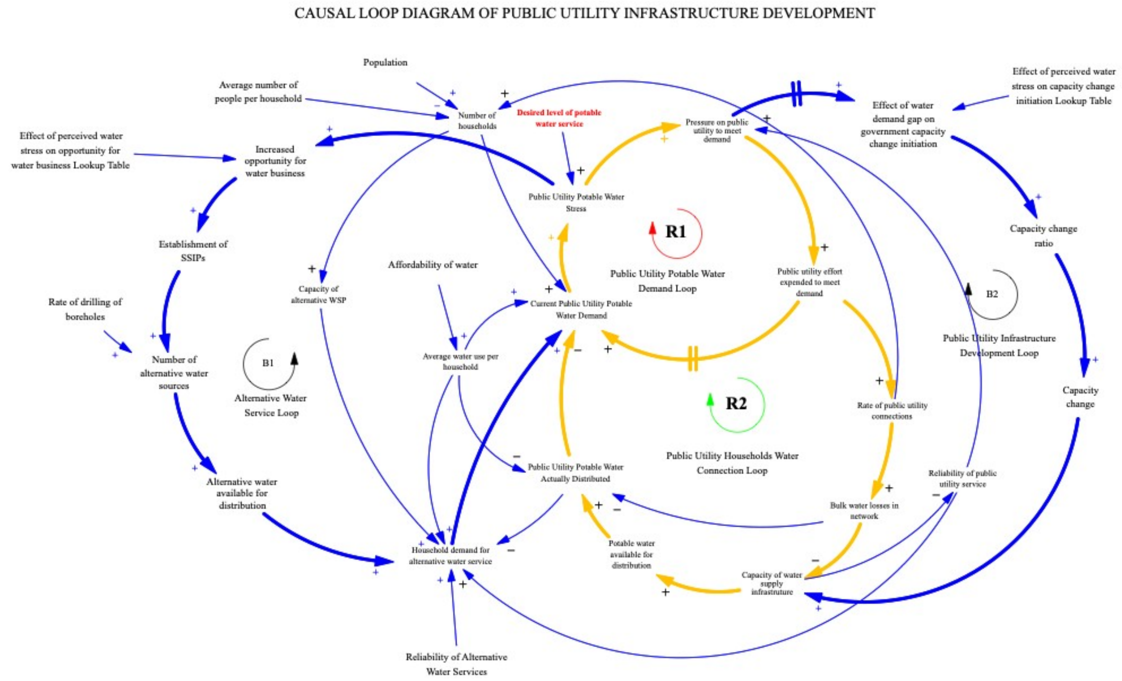


Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .77: Causal Loop Diagram of Public Utility Infrastructure Development

Source: Author (2023)

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .79, the water utility management loop is driven by potable water stress, which increases through increasing potable water demand. The potable water demand varies with population and average water use per household. The average water use per household is computed from average per capita use and the household size.

The driver of the system is the ‘water stress’ which is the gap between current and the desired levels of potable water services in Nairobi’s informal settlements. If public utility water stress is one (1), in which case, the demand is equal to consumption, then there is no need for alternative water services. For the formal water utility (the NCWSC), to ensure they are the sole water service providers for Nairobi residents, they should aspire to meet the demand of residents in the INSEs. This is a very elusive target since from history, there is no time, when NCWSC has ever met the demand of Nairobi residents.

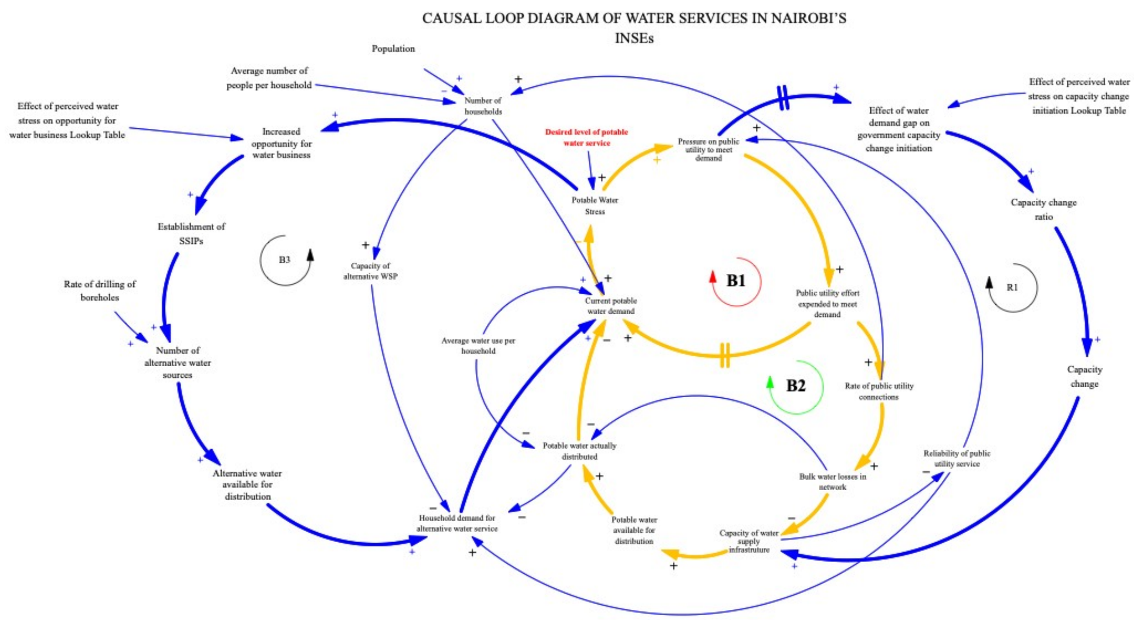


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 78: Causal loop diagram depicting the main endogenous factors

Source: Author (2023)

The research identifies, that possible technical and policy intervention 'nodes' through the quantitative data analysis and the CLD model that would provide integral advantage to meet water security in Nairobi's INSEs.

Since availability, access, quantity, quality, affordability and reliability of water services have to be met to attain water security, integration of formal and informal water service providers could happen when the total volume of water available for distribution from both service providers meets demand and therefore, no water stress is experienced. This can be an optimal result such that policy makers should seek to attain this scenario.

The integral nodes have been identified in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .79 as, 'alternative water available for distribution' which is basically the informal water supply and 'potable water available for distribution', which is the formal water supply from public utility.

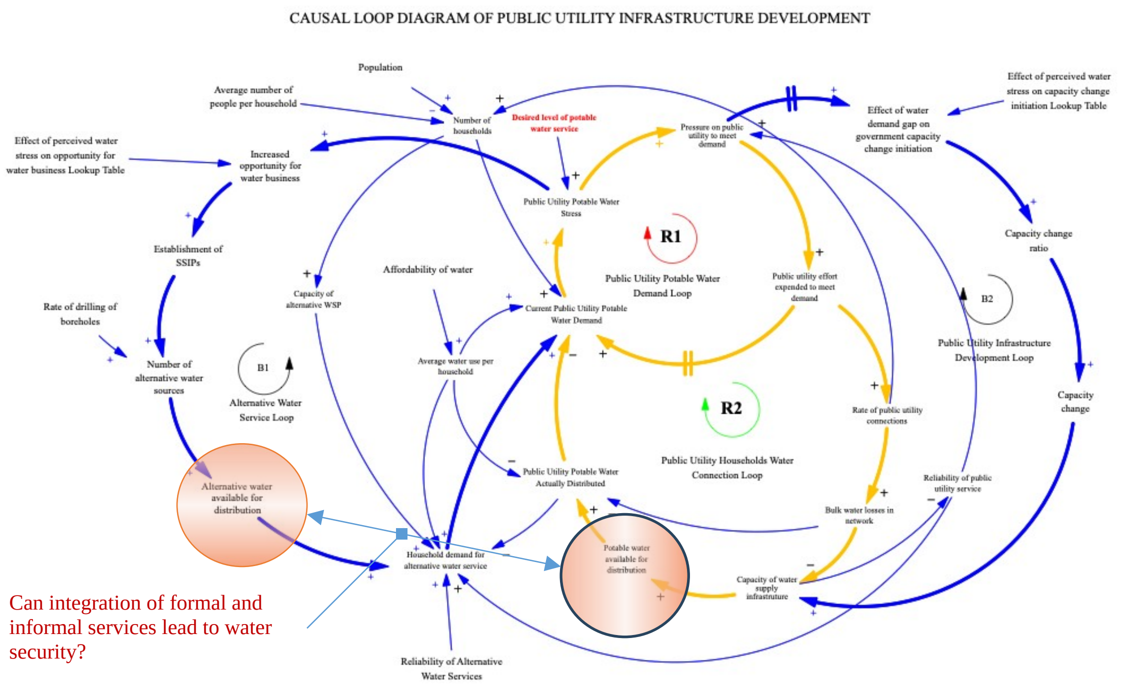


Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 79: Integral 'nodes' for attainment of water security in INSEs

Source: Author (2023)

7.5. Data model

The role of the data model is to provide for reference of the model based on mental and historical data (Albin S., 1997). The data model was created from the data inventory that includes all the numerical assumptions that were input into the model. The inventory was stored in an excel file making it easier to explore and update if any of the numerical assumptions was deemed insufficient or if better data was sourced. The data model composed of both primary data analysis results of selected variables and secondary data sets.

7.5.1. Population of Nairobi

The population of Nairobi has grown significantly from 11,500 people in 1906 to 4,397,073 people according to the 2019 national census as shown in Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL

FOR INTEGRATION OF WATER SERVICE PROVISION .80.

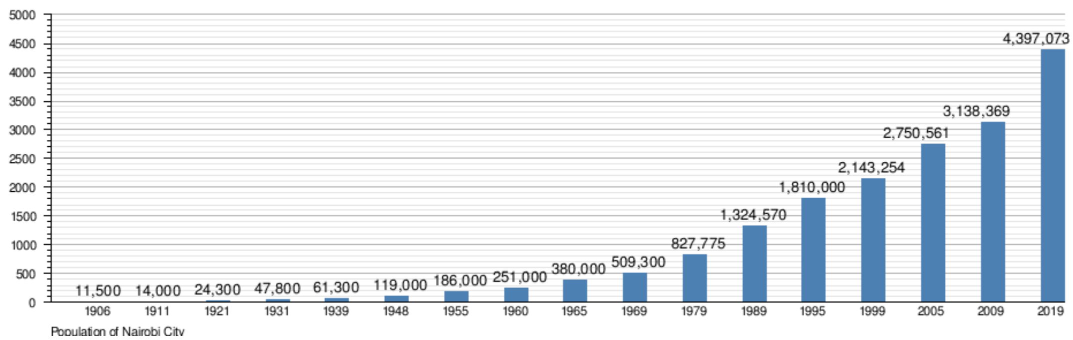


Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 80: Population growth of Nairobi since 1906

Source: Anonymous (2023)

7.5.2. Nairobi water resource development since 1900

Since its founding as a rail outpost in 1899, Nairobi's water supply has largely consisted of drawing water from ever-more-distanced sources to keep up with the city's fast expansion. While deep wells within the city provide 2% of Nairobi's water, 98% of the city's water comes from surface sources. The three dams—Thika, Sasumua, and Ruiru—contribute most of the surface water. While 482 940 m3/day is the present production, the current expected demand for water in Nairobi is 650 000 m3/day (WRMA 2010). Population increase, inadequate distribution network carrying capacity, and climate shocks have all contributed to an increasing gap between supply and demand.

The Kikuyu springs and the Kabete treatment facility, which was established in 1906, were the sources of Nairobi's initial piped water delivery system, as summarized in Table CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .58.

Table CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 58: Water source development for Nairobi over the period 1906 to 2018

Year	Source	Storage capacity *10^6	Design yield (m^3/day)	Current yield (m^3/day)	Cumulative yield (m^3/day)	Pipeline length to Nairobi in KM
1906	Kikuyu Springs	0	4,000	4,000	4000	10
1950	Ruiru River -Dam	2.9x10^6 m^3	22,000	22,800	26,800	25
1955 1968	Sasumua River (water from Kiburu and Chania Rivers)	15.9 x10^6 m3	59,000	52,800	79,600	60
1974	Chania River		37,000	37,000	116,600	
1984	Chania River		127,000	127,000	243,600	
1994	Chania River	77x10^6 m^3	0	0		
1995	Chania River		220,000	220,000	463,600	36
Current total		95.8x10^6 m^3	469,000	463,600	463,600	
2020/22	NCT (Maragua, Gikige and Irati Rivers)		140,000	140,000	603,600	
Total		95.8x10^6 m^3	469,000	463,600	603,600	

Water demand: 760,000 m^3/day (WASREB Impact 10 Report, 2018)
NrW = 38% - keeps changing (WASREB Impact 10 Report, 2018)
Source: multiple sources

Afterwards, in 1935, the Aberdare Range north of Nairobi was home to the Ruiru dam, and in 1945, the Sasumua Dam on the Chania River. Deep wells in the area were also utilized. In the 1970s, when these sources were no longer enough to meet the needs of the expanding population during the dry season, plans were made to build a bigger dam, the Thika Dam, to ease the increasing water scarcity. Financing for the dam, pipeline, and water treatment facility came from the World Bank, the African Development Bank, the European Investment Bank, and the Japanese OECF. From 1976 to 1995, the gross water availability grew from 165 to 200 liters per capita and day. With the completion of the Thika dam, the city's last wellfield for piped water supply was shut down, forcing the city to depend solely on surface water.

Other data sources, indicate water production for Nairobi County from 1906 show some inconsistencies. A source from Nyanchaga, E.N. (2016) is summarised in Table

CHAPTER SEVEN A

SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE

PROVISION .59.

Table CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 59: Summary of Nairobi Water Supplies by 2005

Supply	**Year established**	**Total output (m^3/day)**
Kikuyu springs	1906	273
Ruiru dam	1938	909
Nairobi dam	1946	1137
Chania/Sasumua	1952	4546
Chania/Ngethu	1974	440,000

Source: Nyanchaga, E.N. (2016)

Groundwater exploration though an expensive option, has remained as an alternative source of water for Nairobi County over the years. The historical groundwater exploration and number of boreholes drilled summarised in Table CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL

FOR INTEGRATION OF WATER SERVICE PROVISION .60.

Table CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 60: Borehole drilling and development between 1900 to 2019

Year	**Number of drilled boreholes**	**Cumulative drilled borehole**
1900s	1	1
1920s	0	1
1930 – 1939	14	14
1940 – 1949	91	105
1950 – 1959	141	246
1960 – 1969	12	258
1970 – 1979	78	336
1980 – 1989	133	469
1990 – 1999	239	708
2000 – 2009	432	1,140
2010 – 2019	1,414	2,554

Source: Nyanchaga, E.N. (2016)

7.6. Stock and Flow Diagram

From the literature review, secondary and primary data analysis, key variables that emerged as endogenous to the water service integration were modelled into a quantitative Stock and Flow Diagram (SFD) simulation model. Then from a data inventory was created together with all the numerical assumptions, making it easier to input into the model and easier to maintain and update. For simulation to be undertaken, the model variables had equations input.

Further, synthesis of Nairobi Informal Settlement representing an average unplanned settlement in a developing country was used. The flow equations used to compute variables within the integrated water service provision model were generated based on mathematical equations and parameter estimates.

Stock is an integral of inflow and outflow and is therefore represented in system dynamics in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .81 and by Equation 2 and Equation 3:

Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 81: Stock flow representation

Equation 2: General stock equation

OR

Equation 3: General stock equation, simplified

The main stock flow model is composed of Eight main stock variables; population in informal settlements, the households with basic services, households with intermediate services, households with optimal services, the volume of water produced from surface sources by NCWSC, the volume of surface water supplied by NCWSC, the number of boreholes drilled as alternative water sources, and last but not least, the volume of water supplied from alternative sources, Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .82.

The Eight stock variables were grouped into Four sub-models that formed the main and simulation model. These were, the population, the household, formal service and informal service sub-models. The sub-models had their own boundaries which through integration were used to assess how integration happened intra and inter-sub-models to form the integrated water service provision model.

7.6.1. The population sub-model

The population sub-model comprised of one stock (P), which represented the population in INSEs within Nairobi which varied over time as a fraction of total population of Nairobi (taken as 60% in this model). The population increased by births (r_b) and decreased by deaths (r_d). while in-migration and outmigration are factors that affect population in Nairobi's INSEs, this were assumed as negligible and excluded from the model.

Equation 4: Population sub-model equation

7.6.2. The household sub-model

First, the total number of households were estimated from the population sub-model using the equation,

Equation 5: Household sub-model equation

The average household size was assumed to be = 3.4 persons per household

The household sub-model had three stocks, the first stock was the household with basic service (HBS) was influenced by the net growth of INSEs households with basic services (r_{bs}) and the rate of growth of households with shared connections (r_{sc}).

The second stock, the household with intermediate service (HIS) is influenced by the net growth of households with shared connections (r_{sc}) and the rate growth of households with individual connections (r_{ic}).

The third stock, in this sub-model is the households with optimal services (HOS) which is influenced by the net growth of households with individual connections (r_{ic}). While it was also determined that, some connected households get disconnected (r_{id}) or water supply service gets dysfunctional over time and they return to either no, basic or intermediate service, this was insignificant and therefore excluded from the model.

7.6.3. Formal service provider sub-model

The formal water service provider sub-model has two stocks, that is, the volume of water produced from surface sources (VSS_P) by NCWSC and the volume of surface water supplied (VSS_S) by NCWSC. The first stock, volume of water produced from service sources (VSS_P) increases with rate of capacity increase from new sources developed which is also influenced by the level of water stress experienced; but reduces with the capacity of delivery infrastructure to informal settlements. Delivery infrastructure is also controlled by rate of connection of households in informal households or access through kiosks and other delivery mechanisms.

The second stock, the volume of surface water supplied (VSS_S) by NCWSC increases with improved capacity of delivery infrastructure (CDI), which include, pipelines and storage facilities along the supply lines, and decreases with increase in consumption of formal water services and water losses (termed as non-revenue water or NrW) which in turn is a function of delivery infrastructure capacity (old or poor pipe materials and uncontrolled pressure may lead to leakage). Further, the consumption of formal water services is driven by water demand from people living in INSEs. Important to note that, the volume of surface water supplied by NCWSC to INSEs is a fraction of the total amount of water supplied by NCWSC. Other factors influencing borehole drilling include, the cost of drilling, the increased probability of striking a productive aquifer and the availability of financing. A majority of the private boreholes were funded from family financial resources.

7.6.4. Informal water service provider sub-model

The informal water service provider sub-model has two stocks, that is, the number of boreholes drilled as alternative water sources ($NBHS_D$) and the volume of water produced from boreholes as alternative water sources ($VBHS_P$). The first stock, number of boreholes drilled ($NBHS_D$) increases with the level of water stress experienced (i.e., the gap between demand and water available from NCWSC) and rate of borehole drilling; and decreases with the yield of, and rate of pumping from borehole sources. The government regulations on drilling, production and supply of water also influences the rate of borehole drilling.

The second stock, the volume of water produced and supplied from boreholes as alternative sources ($VBHS_P$), increases with borehole yield and decreases with alternative water consumption which is driven by water demand. This is also influenced by the total available supply since there more water available for supply, the less the demand and therefore consumption of alternative water sources.

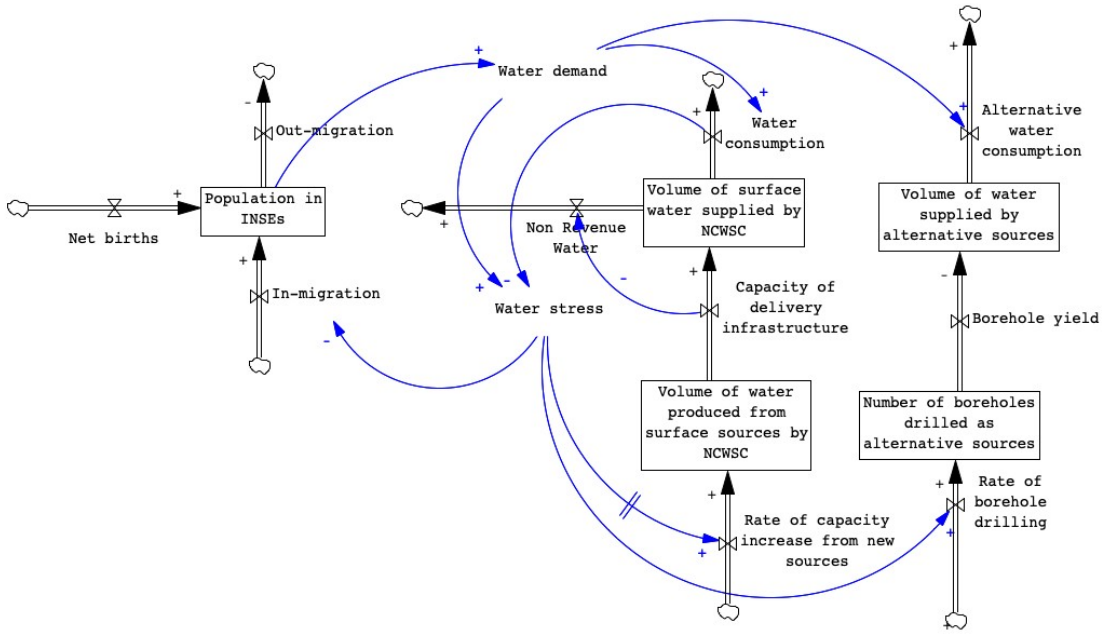


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .82: The main stock flow model

Source: Author (2023)

As per the study findings, informal water service providers have been operation in Nairobi's INSEs since before independence. They were mostly established by private individuals as a business to fill the water supply gap. Lack of reliability of public utilities have been said to be the reason why some households are not connected to public utilities. For instance in Mumbai, India, informal water operators are supplying water in all peri-urban territories of the city, and have been in operation for more than 20 years (Angueletou-Marteau, 2007).

7.6.5. Stock and Flow Structure of the Simulation Model

The Stock and Flow Diagram (SFD) is the complete System Dynamics Model (SDM) that allows for quantitative analysis of the model otherwise known as simulation. This has been refined from the main stock flow model to pick the most important variables and also to allow for measurement. The integrated water service provision (IWSP) model (Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .85), is a combination of the three sub-models of population, formal and informal water service provision.

The most important variable in the system is the total household domestic water demand which links all the four sub-models. The causal-effect of the model stems from this variable upon which, the endogenous reactions either cause self-seeking (balancing) or violent reaction (reinforcing).

The Population sub-model has only one stock, Population; which increases with births and decreases with deaths. This sub-model represents the demand side of the Integrated Water Service Model and therefore two important auxiliary variables, that of total water demand and actual total water consumption that interact to give an indication of water stress experienced by the population.

The sub-model is connected to the formal water supply system sub-model through four shadow variables – indicative kiosk water consumption per capita, individual water connection consumption, shared water connection consumption, and kiosk water consumption. This connection allows for simulation of the entire model irrespective of which sub-model is active in Vensim PLE.

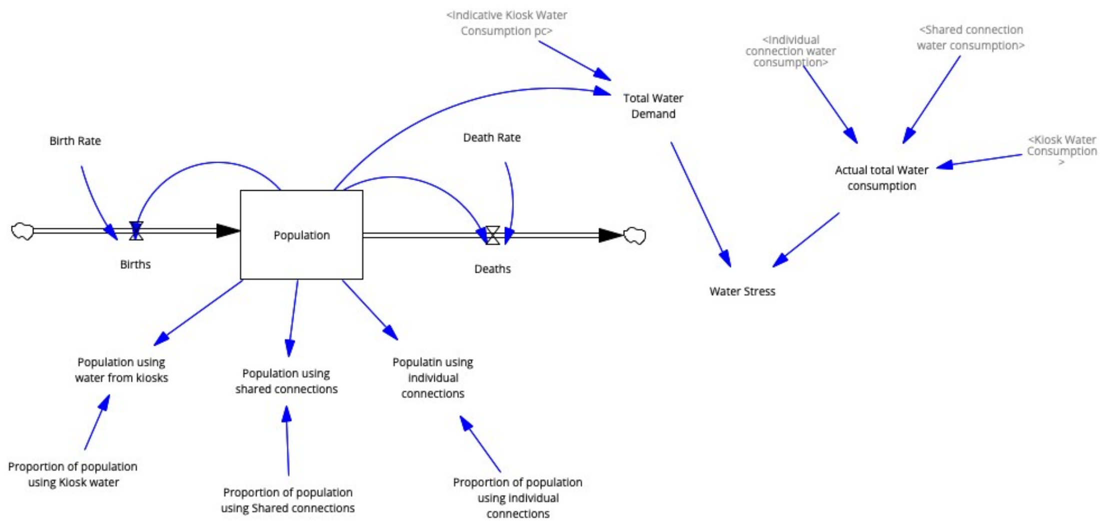


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .83: Population sub-model

Source: Author (2023)

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .84, the informal water system sub-model had two stocks, the functional boreholes which had new boreholes drilled as inflow and borehole decay as an outflow. The second stock was the alternative water available stock which had borehole yield as an inflow and informal water vendor supply as an outflow. The informal water system sub-model is connected to the formal water supply system through the rate of flow from informal services which feeds into the water available through kiosk stock.

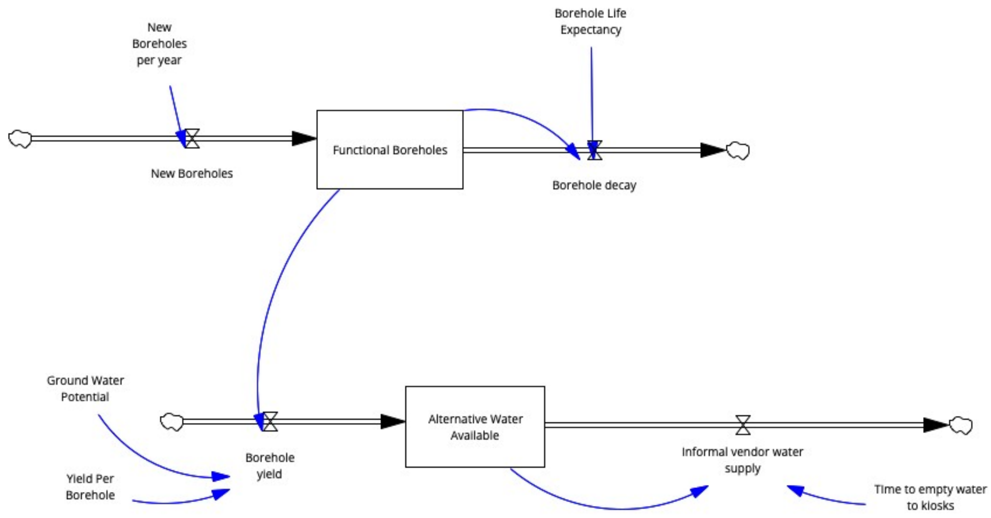


Figure CHAPTER SEVEN
A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 84: Informal water supply system sub-model

Source: Author (2023)

As shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .85, the formal water system sub-model composed of six stocks – initial storage capacity, treated water available, non-revenue water, water available through water kiosks, water available to individual connections, and water available through shared connections.

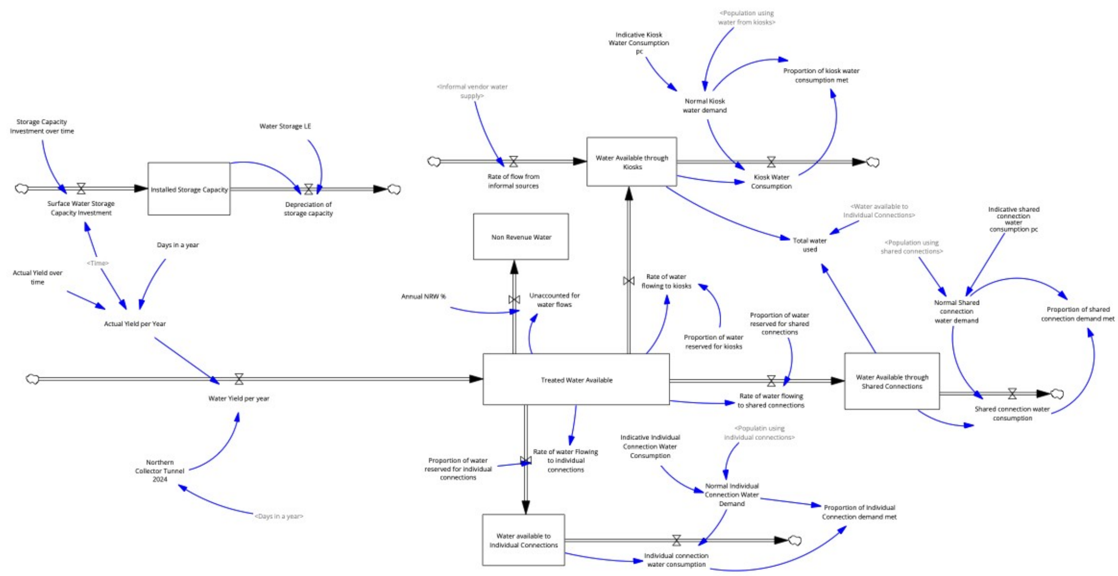


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .85: Formal water supply system sub-model

Source: Author (2023)

All the three submodels (population, formal water service and informal water service) are combined through shadow variables which were captured in both the population and formal water supply sub-models. This was done to ensure there is a clarity in terms of presentation and to allow for easy of documentation.

The IWSP-M is similar to Holmes, J. K. C. et al. (2014), which investigated the water supply and demand issues of a small South African municipality using System Dynamics. The South African Local Government's decentralization experiment was the inspiration for the model's development. Therefore, the "Kirkwood water demand system dynamics model," or K-DEM for short, was a simulation model that investigated the difficulties encountered by a small town in meeting the increasing demand for water services.

The model was built out of four (4) sub-models: population, household, potable water, rainwater. One key conclusion from this model was that municipality should institute programmes that can help address bulk water losses.

7.6.6. Initial values and parameter estimation of the stock variables

The initial values (base values) and parameter estimates for the stock variables was estimated from primary and secondary data. The variables and the estimates are as detailed in (01) to (66).

(01) Actual total Water consumption = Individual connection water consumption+Kiosk Water Consumption+Shared connection water consumption

Units: M^3/Person/Year

(02) Actual Yield over time(

[(0,0)-(2040,700000)],(1990,300000),(1995,463000),(2000,490000),(2005,520000),(2010,550000),(2015,575000),(2020,603000),(2040,603000),(2063,603000))

Units: Dmnl

(03) Actual Yield per Year=

Actual Yield over time(Time)*Days in a year

Units: M^3/Year

(04) Alternative Water Available= Integ (

Borehole yield-Informal vendor water supply,

1.4e+07)

Units: M^3

(05) "Annual NRW %"=

0.4+STEP(-0.2 , 2030)

Units: Dmnl

Base scenario: 0.4 as non-revenue water Vision 2030 scenario:

0.4+Step(0.2 ,2030), non-revenue water reduced to 20% of water distributed

(06) Birth Rate = 0.032

Units: 1/Year

(07) Births=

Population*Birth Rate

Units: Person/Year

(08) Borehole decay=

Functional Boreholes/Borehole Life Expectancy

Units: Borehole/Year

(09) Borehole Life Expectancy=10

Units: Year

Average life expectancy is 8-10 years. An interview with a groundwater expert stated this as 25 years depending on conditions such as design, building, O+M etc.

(10) Borehole yield = Yield Per Borehole*Ground Water Potential*Functional Boreholes

Units: M^3/Year

(11) Days in a year = 365

Units: Days

(12) Death Rate = 0.01

Units: 1/Year

(13) Deaths = Population*Death Rate

Units: Person/Year

(14) Depreciation of storage capacity = Installed Storage Capacity*Water Storage LE

Units: M3/Year

(15) Final Time = 2063

Units: Year

The final time for the simulation.

(16) Functional Boreholes= Integ. (New Boreholes-Borehole decay, 708)

Units: Borehole

(17) Ground Water Potential = 0.7

Units: Dmnl

This is the amount of water that can be pumped from a productive borehole. It is normally estimated at 70% of the established yield of the borehole, allowing 30% for what is termed as environmental flows.

(18) Indicative Individual Connection Water Consumption = 74.46

Units: M^3/Year

(19) Indicative Kiosk Water Consumption pc = 74.46

Units: M^3/Year

(20) Indicative shared connection water consumption pc = 74.46

Units: M^3/Year

(21) Individual connection water consumption = Min(Normal Individual Connection Water Demand , Water available to Individual Connections)

Units: M^3/Person/Year

(22) Informal vendor water supply = Alternative Water Available/TIme to empty water to kiosks

Units: M^3/Year

(23) Initial Time = 1999

Units: Year

The initial time for the simulation.

(24) Installed Storage Capacity= INTEG (Surface Water Storage Capacity Investment-Depreciation of storage capacity, 9.58e+07)

Units: M3

(25) Kiosk Water Consumption = MIN(Normal Kiosk water demand , Water Available through Kiosks)

Units: M^3/Year

Kiosk Water Consumption PC*Population using water from kiosks

(26) New Boreholes = New Boreholes per year

Units: Borehole/Year

(27) New Boreholes per year = 200+Step(500 , 2030)

Units: Borehole/Year

Base case: Continue to drill boreholes to supplement water

supply Vision 2030 case scenario: 200+Step(-200 , 2030)

(28) Non Revenue Water= INTEG (Unaccounted for water flows, 8e+08)

Units: M^3

(29) Normal Individual Connection Water Demand = Indicative Individual Connection Water Consumption*Populatin using individual connections

Units: M^3/Person/Year

(30) Normal Kiosk water demand = Indicative Kiosk Water Consumption pc*Population using water from kiosks

Units: M^3/Person/Year

(31) Normal Shared connection water demand = Indicative shared connection water consumption pc*Population using shared connections

Units: M^3/Person/Year

(32) Northern Collector Tunnel 2024 = 140000*Days in a year

Units: M^3/Year

(33) Populatin using individual connections = Population*Proportion of population using individual connections

Units: Person

(34) Population= Integ. (Births-Deaths, 2.17e+06)

Units: Person

Assumption is that migration to and from Nairobi is in

equilibrium and therefore not considered in this model.

(35) Population using shared connections = Population*Proportion of population using Shared connections

Units: Person

(36) Population using water from kiosks = Population*Proportion of population using Kiosk water

Units: Person

(37) Proportion of Individual Connection demand met = Individual connection water consumption/Normal Individual Connection Water Demand

Units: 1/Year

(38) Proportion of kiosk water consumption met = Kiosk Water Consumption/Normal Kiosk water demand

Units: 1/Year

(39) Proportion of population using individual connections = 0.063

Units: Dmnl

(40) Proportion of population using Kiosk water = 0.28

Units: Dmnl

(41) Proportion of population using Shared connections = 0.657

Units: Dmnl

(42) Proportion of shared connection demand met = Shared connection water consumption/Normal Shared connection water demand

Units: Dmnl

(43) Proportion of water reserved for individual connections = 0.4

Units: 1/Year

(44) Proportion of water reserved for kiosks = 0.05

Units: 1/Year

(45) Proportion of water reserved for shared connections = 0.1

Units: 1/Year

(46) Rate of flow from informal sources = Informal vendor water supply

Units: M3/Year

It Aasumed that informal water supply only kicks in in 2010 -

this can be changed to start at any year in the simulation period

(47) Rate of water Flowing to individual connections = Treated Water Available*Proportion of water reserved for individual connections

Units: M3/Person/Year

(48) Rate of water flowing to kiosks = Treated Water Available*Proportion of water reserved for kiosks

Units: M3/Year

(49) Rate of water flowing to shared connections = Treated Water Available*Proportion of water reserved for shared connections

Units: M3/Person/Year

(50) SAVEPER = TIME STEP

Units: Year [0,?]

The frequency with which output is stored.

(51) Shared connection water consumption = MIN(Normal Shared connection water demand , Water Available through Shared Connections)

Units: M3/Person/Year

(52) Storage Capacity Investment over time(

[(0,0)-(2040,10)],(1990,0),(1995,5),(2000,5),(2005,5),(2010,5),(2015,5),(2020,5),(2025,5),(2030,5),(2035,5),(2040,5),(2063,5))

Units: **undefined**

(53) Surface Water Storage Capacity Investment=

Storage Capacity Investment over time(Time)

Units: M3/Year

(54) TIME STEP = 0.125

Units: Year [0,?]

The time step for the simulation.

(55) TIme to empty water to kiosks = 1

Units: 1/Year

(56) Total Water Demand = Population*Indicative Kiosk Water Consumption pc

Units: M^3/Person/Year

(57) Total water used=

Water Available through Kiosks+Water Available through Shared Connections

+Water available to Individual Connections

Units: M^3

(58) Treated Water Available= INTEG (Water Yield per year-Rate of water Flowing to individual connections-Rate of water flowing to kiosks -Rate of water flowing to shared connections-Unaccounted for water flows, 2e+08)

Units: M3

Initiatized it at $50m^3$ in 1990

(59) Unaccounted for water flows=

Treated Water Available*"Annual NRW %"

Units: M^3

(60) Water Available through Kiosks= INTEG (Rate of flow from informal sources+Rate of water flowing to kiosks-Kiosk Water Consumption, 2.1e+07)

Units: M3

1.25e+08

(61) Water Available through Shared Connections= INTEG (Rate of water flowing to shared connections-Shared connection water consumption, 1.5e+07)

Units: M3

(62) Water available to Individual Connections= INTEG (Rate of water Flowing to individual connections-Individual connection water consumption, 6e+07)

Units: M3

(63) Water Storage LE = 0.005

Units: Year

(64) Water Stress = (Total Water Demand/Actual total Water consumption)/10

Units: Dmnl

(65) Water Yield per year = Actual Yield per Year+STEP(Northern Collector Tunnel 2024 , 2024)

Units: M3/Year

(66) Yield Per Borehole = 28640

Units: M3/Year

Yield per borehole is averaged at 10m3/hour pumping 8 hours per day and functional for 358 days in a year. This allows for up to 7 days of downtime per year.

7.7. Scenario and Policy testing

There are two policies that the model tested – If government banned new borehole development from the year 2030 to have 100% dependency on surface sources, that is a fully formal water supply system. Two, if government through NCWSC, implemented the commitment to reduce NrW down to only 20%, as per the Water Master Plan. The two strategies were tested under various approaches – extreme condition test, parameter sensitivity test, phase relationship test, and behaviour test. The model outputs under various tests were documented in the sections 7.7.1 through to 7.7.4.

7.7.1. Extreme condition test

Two extreme condition tests were undertaken to test the model's behaviour. One was to ban all informal water supply leaving only NCWSC to supply the entire population. The second test was where all treated water/supplied by NCWSC ended up as NrW. Of course these extreme conditions are not a reality, and therefore hypothetical and only meant to test the model behaviour.

i. Zero borehole supply

The extreme test condition undertook a simulation and analysis whereby the regulator banned all alternative water source operation leaving all population in INSEs in Nairobi to depend on NCWSC. This is based on the water master plan for Kenya (GoK, 2012), that by the year 2030, Nairobi County shall only depend on surface sources. With this policy implementation, it means that the number of functional boreholes will drop significantly as we move towards the end of the simulation period (2063). Equally, the water available to kiosk supply will also drop significantly in the year 2030, though it does not reach zero because there is still a small fraction of water going to the water kiosk from the NCWSC supply system, and there will still be boreholes supplying the kiosks until they complete their lifespan of 25 years.

From the model output, it can be confirmed that, from the reference mode both functional boreholes and water available through kiosks depict the expected behaviour, as shown in Figure CHAPTER SEVEN

A SYSTEM

DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .86.

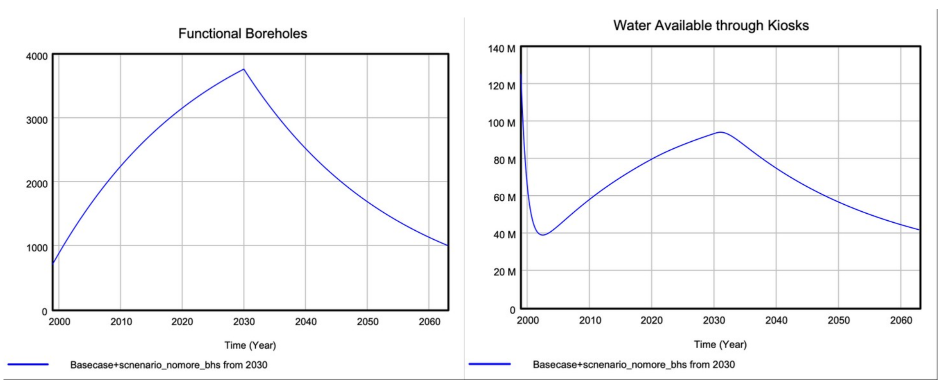


Figure CHAPTER SEVEN

A SYSTEM

DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .
86: Extreme condition test: no more borehole drilling from year 2030

ii. NrW is turned to 100%

Extreme condition test on if from the beginning of simulation, all produced water ended up as non-revenue water, in which case there was no NCWSC supply to shared connections and individual connections. A check on water available through kiosks dropped initially and started to pick since boreholes will still continue to supply kiosks. Indeed, the water kiosks are mainly supplied by boreholes sources with only 10% of NCWSC supplying them. On the other hand, water stress goes up significantly, then starts to drop especially for population using water kiosks.

The Figure CHAPTER SEVEN
A SYSTEM DYNAMICS MODEL
FOR INTEGRATION OF WATER SERVICE PROVISION .87, shows the results of the extreme condition test where all water produced by NCWSC ended up as NrW.

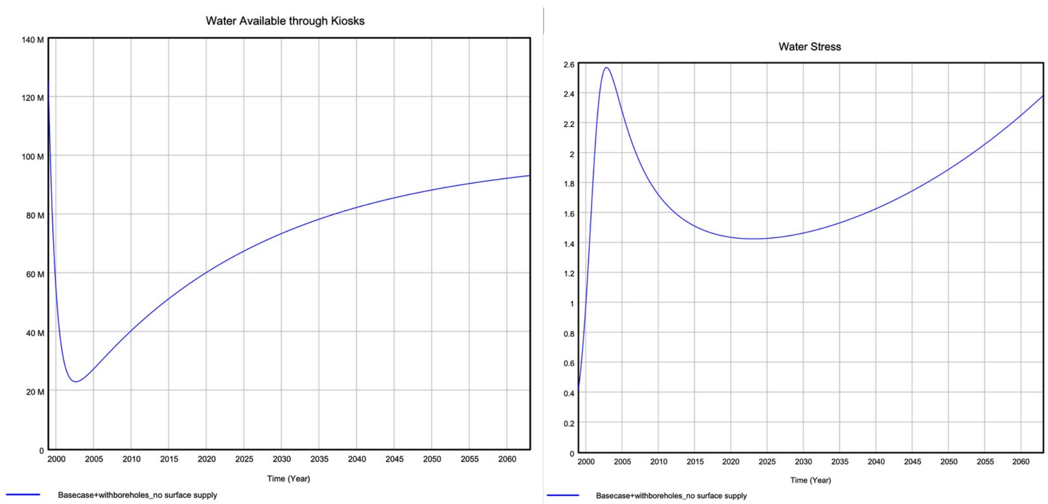


Figure CHAPTER SEVEN
A SYSTEM
DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 87: All NrW at 100%

7.7.2. Phase relationship test

Two phase relationship tests were undertaken to view how the model responded when two strategies were implemented; the additional water through the NCT in 2024 and the reduction of NrW to 20% by the year 2030. The NCT shall bring an additional 140,000 m3/day to augument NCWSC water supply in Nairobi. Due to the large losses experienced in the system, government strategy is to reduce NrW from the staggering 40% of the treated water down to 20%. This will see more water available for dirtibution hence increasing the water available through individual connections, shared connections and kiosks, proportionately.

i. Phase relationship with water available, water through individual connections, shared connections and through water kiosks

In the phase relationship, Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .88 it was seen that the treated water available for distribution increased with respective increase in water available through individual connections, shared connections and water accessed through water kiosks.

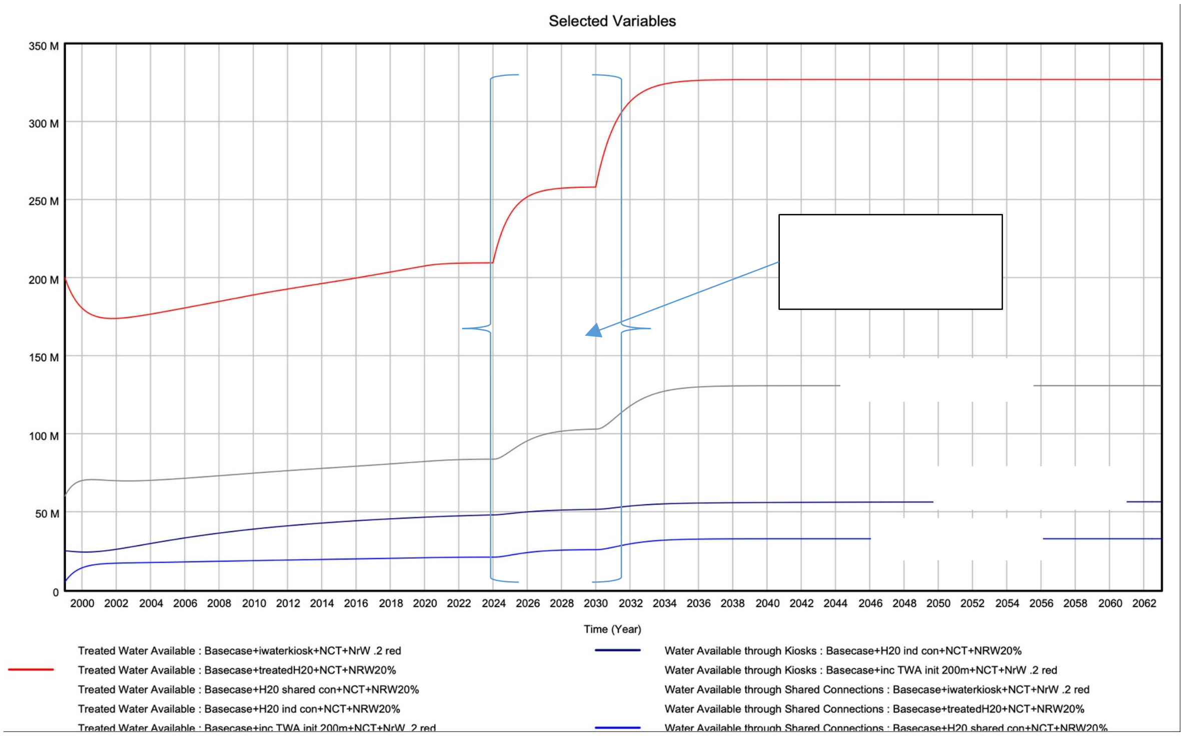


Figure CHAPTER SEVEN

A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 88: Phase relationship test on water availability based on service levels

ii. Phase relationship with water demand, consumption and stress

In the phase relationship, Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .89 demand will continue to increase all through the simulation period while consumption will slightly increase in 2024 due to additional NCT water and later in 2030 due to reduced NrW. This is because this means that more water is available in the system for people of various service levels to access. On the other hand, stress reduces in 2024 and later in 2030 because consumption increases in both instances. It is important to note that, while the two actions (NCT and NrW reduction) are implemented, water stress remains very high in Nairobi.

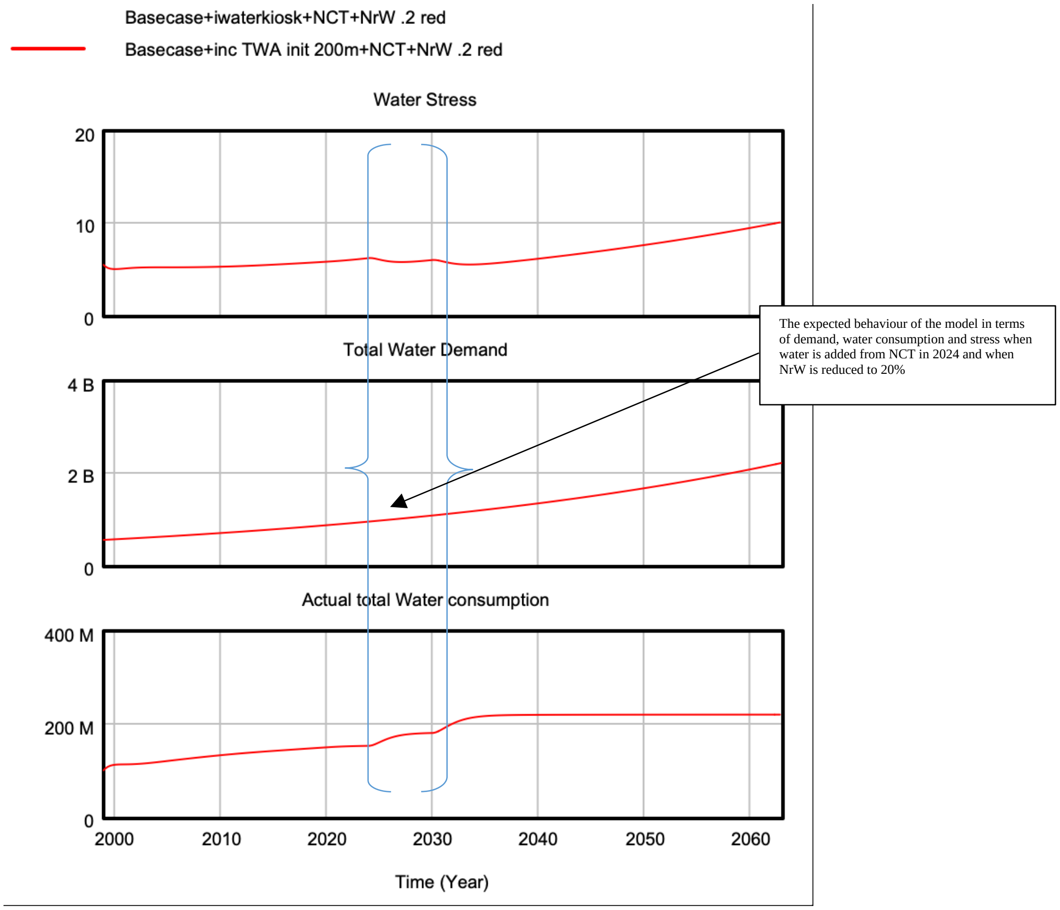


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 89: Phase relationship on demand, consumption and stress

7.7.3. Behaviour test

i. <u>**Behaviour of population and water demand**</u>

Behaviour of population and water demand over time as compared with other models. The behaviour pattern for population in Nairobi County and water demand was expected to increase exponentially. From the model output, it can be confirmed that, from the reference mode both population and water demand are following this behaviour, as shown in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .90.

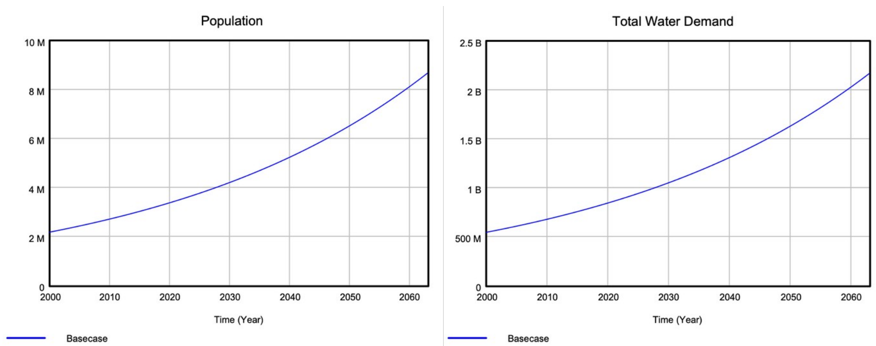


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 90: Expected and model behavior of population and water demand in Nairobi's INSEs

ii. Behavior of water available to the various service levels

Water available was simulated for various water service levels (those with individual connections, shared connections and those accessing water through kiosks). The base scenario was where the current treated/distributed water did not change over the simulation period. In Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .91, it is was seen that, water available (green) increased up to 2024 after which it remained constant until 2063. Due to additional water from the Northern Collector Tunnel (140,000 m^3), the water available shot up until 2030 after which it again remained constant until 2063. Finally, the government strategy of reducing Non-Revenue Water from the current staggering 40% down to 20% was simulated. This saw more water being available through the various service levels.

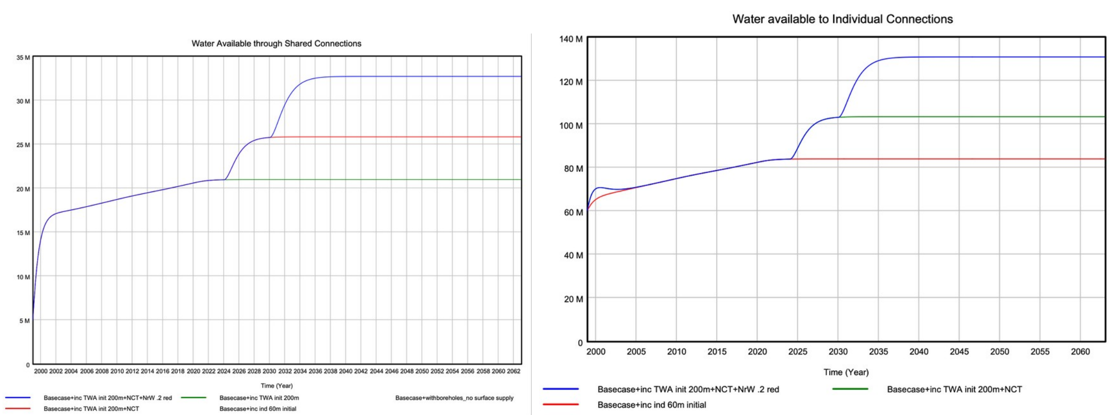


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION . 91: Water available through shared connections given three scenarios

7.7.4. Parameter sensitivity test

For the parameter sensitivity test, the simulation targeted water accessed through kiosks. This is because kiosks received water from both NCWSC and informal suppliers through groundwater development. To understand what the impact of putting in more water to supply the water kiosks would look like in the year 2030, the simulation added an average of 500 boreholes per year over and above the original 200 boreholes per year (making average boreholes drilled per year, 700). This showed that, the proportion of kiosk water consumption grew rapidly attaining equilibrium (whereby demand/consumption = 1), at year 2040 and maintaining this equilibrium for 15 years until 2055 when it again starts to fall down.

Comparing with the base scenario where an average of 200 boreholes are drilled over the simulation period, there is a decline of the proportion of kiosk water met. This decline is due to increasing demand for water from kiosks which is as a result of the natural population growth.

The results of the parameter sensitivity test are show in Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .92.

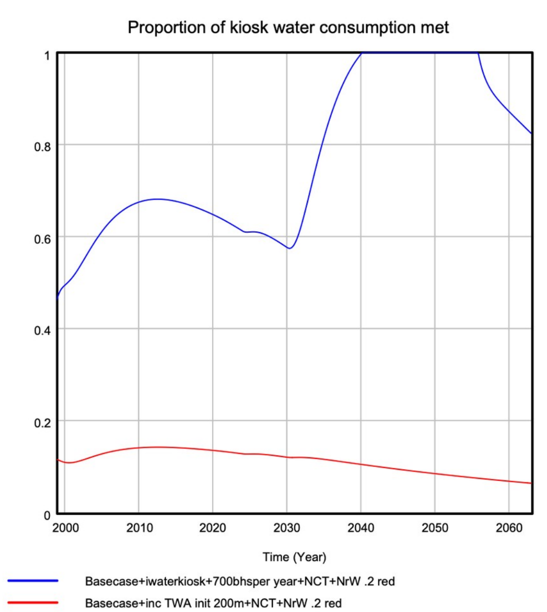


Figure CHAPTER SEVEN A SYSTEM DYNAMICS MODEL FOR INTEGRATION OF WATER SERVICE PROVISION .92: Parameter sensitivity test increased rate of borehole drilling to supply kiosks

Overall, the integrated water service provision (IWSP) model reveals that, to attain optimal water security, both NCWSC and the other service providers (Self-Supply, non-profit and private developers) need to collaborate in development of water sources and delivery infrastructure. In order to do so, exploration of groundwater resources and harvesting of surface sources need to happen concurrently by both government and other service providers. Therefore policies contained in the Governemnt Water Master Plan (GoK, 2012), may need to be re-evaluated to ensure that they consider this model outputs.

Other studies that have applied system dynamics modelling approach have made major contributions to shape policy in urban water management. For instance, Zarghami & Akbariyeh (2012) modelled the Tabriz's urban water system using a system dynamics approach in Iran. The model revealed that, by varying the price of domestic water, it was possible to determine its effect on the water shortage in Tabriz. The model proved useful with simulations showing that both inter-basin water transfer and demand management strategies reduced the water shortage up to 45% (Zarghami & Akbariyeh, 2012).

Another study focusing on the global south by Adams & Vásquez (2022) concluded that integrating of the community, government, and other relevant stakeholders into the process of water supply systems development and implementation will be essential to respond to local context and therefore sustainability. Sun et al. (2017), in their study in China concluded that, bridging the demand–supply gap will require improvement of water supply and not controlling demand.

One of the key insights derived from the study of Holmes et al., (2014) in a South African municipality, was that, it might be impossible for the the municipality to constrain the rate of connection, but it could be possible for them to counter the impacts of rapid expansion by investing in programmes that can address bulk water losses and to campaign for household-level water conservation.

CHAPTER EIGHT

SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1. Introduction

This chapter presents the summary of the study findings, the conclusions that were drawn based on the results, recommendations based on the conclusions and suggestions made for further research.

8.2. Summary of findings

It is apparent that there is a huge problem surrounding domestic water security for people living in informal settlements in Nairobi County, Kenya. The study assessed the water security characteristics of existing water service provision systems (availability, access, quantity based on national and sphere standards, affordability, quality and reliability) on the household characteristics (sub-county, level of education, employment status, monthly income, source of income and type of house they resided in). The study found significant relationships among the following: water availability and sub-county and main source of household income; water access and subcounty, employment status and main source of income; no significance was found between the national water quantity standard of 60lcpd and any household characteristics. However, the study found significance between Sphere standard of 15lcpd and subcounty raising questions as to whether attainment of the standard water quantity proposed by government is attainable. There was significance between water affordability based on cost of 20L container that is set at KSh. 2 (US $0.015) and sub-county; there was also significant relationship between water quality and sub-county.

Equally, the study also found significant relationship between reliability and sub-county, employment status and main source of income. It is therefore important to take into consideration these factors when designing water supply systems for people living in the INSEs within Nairobi County in order to attain desired water security.

Only 0.4% households met all the six parameters (availability, access, quantity, quality, affordability and reliability) of water security. A majority of the households, 31.8% satisfied four parameters, 30% met three parameters, 20.8% met two parameters, 11.7% met 5 parameters and 5.3% met one parameter. This pointed to a situation where water security is a major concern in Nairobi's INSEs.

The study also examined the different existing structures (production, treatment, storage, and distribution) of water service provision systems against water security in informal settlements within Nairobi County. It was found that, water structure had a significant relationship with availability, access and quality. Examined, against sub-counties, there was a significant influence between water structure and the sub-counties. Further, upon undertaking a logistic regression, it was found that some counties had a higher likelihood of having water that was more available, accessible, enough quantity, acceptable quality, affordable and that had a reliable service. Significant structural differences (i.e., level of infrastructure development from production, treatment, storage and distribution) existed among the sub-counties, pointing towards, political factors that could be playing a role in water security.

The study also evaluated water service provision system integration approaches on water security in informal settlements. The study analysed of water service integration with a focus on three parameters, that is, who was producing the water (self-supply, not-for-profit organizations (NGOs, CBOs and FBOs)? Private water source developers, and lastly, the public water developers (government institutions)? How the household accessed water (direct from source, water delivered through kiosk of vendors, a shared household connection (water yard in a plot), and finally individual household connection)? And finally, what level of service the household was experiencing (No service, basic service, intermediate service and optimal service)? The study also evaluated the context under which the producers engaged, the integration efforts made by the producers and the existing opportunities for more integration. It was found that, producers could integrate by allowing private developers and not-for profit organisations to drill and develop boreholes in water scarce areas especially in government institutions such as schools, health facilities and chiefs' camps. Equally, the household access to water, could be improved, if service providers increased access points either through plot connections or installation of water kiosks where access was low or missing. On water access levels, basic water service (getting water from water kiosk), was the most popular mechanism of accessing water in the INSEs of Nairobi. This pointed to the fact that, to be able to improve access at least to basic level, was easily attainable that intermediate and optimal service level, and this could be achieved through collaborative efforts of extending water services to under-covered areas through water kiosks.

The study also developed a system dynamics model for integrating water service provision that addresses water security in the informal settlements within Nairobi County. The causal loop model depicted a clear relationship between demand and supply of water in Nairobi's informal settlements. Population increase in Nairobi without requisite development in the water supply system will continue to drive water stress high and therefore lead to water insecurity over the period up to 2063.

From the longitudinal data of water development by Government of Kenya (GoK) to supply Nairobi County dating back to 1906, show a steady increase in borehole drilling moreso from the 1980s, an indication that, groundwater provided the much needed source to supplement the surface sources managed by NCWSC.

The model simulated various scenarios to test if the outputs resonated with what could be a real world behavior. These tests were compared with the cause-effect loop diagram to analyse behavior due to endogeneous and exogenous changes. The tests confirmed that the model was able to represent the dynamism of water service provision in an urban informal settlement setting, and could therefore give insights on policy/strategic interventions that could address water insecurity.

8.3. Conclusion

Overall, water insecurity in informal settlements in the informal settlements in Nairobi County can be concluded to be rampant. The several water service providers, Nairobi Water and Sewerage Company (NCWSC), the FBOs/CBOs, self-suppliers, private borehole developers, and the intermediaries with hand carts, water kiosks, and on-sellers, are not coordinated or collaborating leading to household water insecurity. Therefore, there is need for an integrated response of the service providers to advance water security among those living in informal settlement in Nairobi County.

Based on the research findings, the study made the following specific conclusions:

i. The findings of this study show that almost all households in Nairobi's informal settlements experience water insecurity. With only 0.4% of the households attaining water security, it is pointing towards an hazardous situation that may easily be disastrous if not addressed.

ii. For the informal settlements in Nairobi County, the existing water structures of water service provision system influenced only three of the six water security factors, and that is, availability, access and quality. The level of structure did not have any impact on quantity of water accessed by household, the affordability of the water, and how reliable the water service was. This pointed to households' coping strategies where there was dependency on multiple water sources in order to improve household water security. The study therefore concludes that, provision of infrastructure alone may not lead to household water security.

iii. The research findings show that, integration is possible along the three levels, water production, water delivery infrastructure, and service levels experienced by the households. In water production, integration happened where private borehole owners collaborated with NCWSC to undertake water quality analysis to aid them in chlorine dose calculation. Collaboration was also seen where government owned infrastructure but community managed the system. During water treatment, NGOs also collaborated with household water treatment (HHWT) by supplying them with chlorine aqua tabs. In water delivery infrastructure, integration happened where Plot 10 property owners connected water to public or private sources and tenants were then able to access water from a shared tap. Another system was a government-owned delivery infrastructure such as water kiosk, community managed but NCWSC operated and maintained. A unique integration in delivery of service was where a utility-connected household did connect another non-utility connected household in what was seen as household-to-household connection (H2HC). In water service levels, there were rare cases and even opportunities for integration. It was however noticed that, one household could depend on multiple sources and therefore experiencing various levels of service.

iv. The study findings reveal that, the gap between demand and supply, “stress” is the driver of the integrated water service provision model (IWSPM). This gap leads to two broad responses, one where entrepreneurs see it as a business opportunity who without delay drill new boreholes to sale services. On the other hand, government and public utility respond with new connections and exploration and development (with long delays) of new sources. This generates three (3) interlinked system loops: one is the public utility water service demand loop; two is the public utility household connection loop; third is the alternative water service loop; and fourth is the public utility infrastructure development loop. The simulation model revealed that, it will be difficult to resolve water security in Nairobi’s informal settlements with reliance on NCWSC and /or without the continued role of the small scale water service providers. Therefore, it might be important to explore more groundwater and drill high-yielding boreholes to supplement water supply in Nairobi’s INSEs.

8.4. Recommendations

The study recommends that there is need for formal and informal water service providers to collaborate in order to achieve water security in informal settlements. Based on the findings of each of the four specific objectives of the study, and conclusions made thereof, the study makes the following specific recommendations:

i. The National, County Government and stakeholders in water sector, while planning water service provision and infrastructure development, should ensure that efforts towards attaining universal access to water through availability, access, quantity, quality, affordability and reliability should have a targeted approach to reach those who are most water insecure.
ii. While planning the development of a water supply system structures (production, treatment, storage and distribution), the decision should be based on whether the investment will improve availability, access, quantity, quality, affordability and reliability of service. Accordingly, this decision should help inform the investment by policy makers to ensure water security.
iii. The Nairobi County Government, the National institutions involved in water resource and service provision, should identify areas of collaboration at production, service infrastructure, and the status of various zones of households in the INSEs. This will help policy makers to come up with clear guidelines on how services can be integrated leading to water security.
iv. The national, county government and the investors in water supply systems should recognize the informal water service providers and come up with clear guidelines on the production and supply of water services defined by quality, cost, and reliability of services and also clear strategies in improving availability, quantity and access to water in service provision areas (SPA).

8.5. Suggestions for further research

Based on the findings, the limitations of this research and the context in which the research was undertaken, the study recommends further research in the following areas;

i. We found significant difference in water security among households in the sub-counties in Nairobi County. Since sub-counties are political units that have both National and County Government influence, we suggest further research on the role of politics in influencing water security (availability, access, quantity, quality, affordability and reliability) in informal settlements in Nairobi County.

ii. Affordability of water had a significant impact on water access among people living in informal settlements in Nairobi. Further, it was found that, the cost of water increased significantly from source to final user; pointing towards commodification of water. It could be important to undertake a water value chain analysis in the informal settlements in Nairobi County.

iii. This study applied system dynamics methodology to measure how water service integration could address water insecurity in informal settlements in Nairobi County, Kenya. It could be important if the same methodology could be used to address the problem experienced at water catchment level where Nairobi County sources her water from.

iv.

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APPENDICES

APPENDIX I: WATER AND SANITATION HOUSEHOLD SURVEY

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

General details about where you live: (Tick the appropriate box)

a. Part of the city
   - Korogocho
   - Viwandani/Kaloleni
   - Kibera
   - Kawangware/Gatina
   - Majengo/
   - Kiambiu
   - Mathare
   - Gitare Marigu/
   - Njiru
   - Mukuru/
   - Kayole Soweto
   - Gitogoro

b. Local name of the area ______________________________

Section 1: Demographics section of HH questionnaire

1. Sex of the respondent
    A. Male
    B. Female
2. Relationship of the respondent to the Household Head?
    A. Self
    B. Spouse
    C. Child (*if 18 years old, otherwise with permission of guardian*)
    D. Relative
    E. Other, explain ______________
3. How many people slept at your household last night? ___________

4. Who is the head of this household?
    A. Father
    B. Mother
    C. No parent/Child-headed
    D. Other, please specify ___________________________

5. How old is the household head? _________________

6. What is the highest level of education of the household head?
    A. No Education
    B. Primary incomplete
    C. Primary complete
    D. Secondary incomplete
    E. Secondary complete
    F. Tertiary (Certificate/Diploma)
    G. University
    H. Postgraduate

7. What is the employment status of the household head?
    A. Not employed
    B. Employed salaried
    C. Employed casual laborer
    D. Self employed
    E. Student

8. What is the approximate monthly income of the household in Kenya shillings?

9. What is the current MAIN source of income of the household?
    A. Small scale trade
    B. Large scale trade
    C. Aid/Cash transfer
    D. Wage earner
    E. Formal employment
    F. Remittance from relatives

10. What is the approximate amount of money you spend per month on water?

11. How long have you been living in the current location?
    A. ≤3 months
    B. ≥3 to ≤6 months
    C. >6 to ≤12 months
    D. >1 to ≤2 years
    E. >2 years

12. Where did you come from?
    A. Another INSE
    B. From an urban area other than Nairobi
    C. From a rural area
    D. Other, please specify ___________________

13. What made you move to this area?
    A. Better condition
    B. Affordable houses
    C. Search for a job
    D. Transfer by employer
    E. Business opportunity
    F. Availability of social amenities
    G. Other, please specify _________________

14. Type of house
    A. Made from sticks and mad walls
    B. Made of timber with iron sheet cladding
    C. Made of sticks, cartons, and other assorted materials
    D. Made of concrete walls
    E. Other ___________________________ (specify)

Section 2: Your current water supplies (for all water users)

2a) Where do you and other members of your household obtain water? (Please tick all water sources that you use)

A. Your own (individual) piped water connection
B. A shared water connection next to your dwelling
C. We obtain water from the water kiosk
D. We obtain water from the Hand Cart Water Vendors
E. We obtain water from the private water tanker
F. We obtain water from a public borehole or well
G. We obtain water from a private borehole or well
H. We have our own private borehole or well in our compound

2b) Water is your **MAIN** source of water supply?

A. Your own (individual) piped water connection
B. A shared water connection next to your dwelling
C. We obtain water from the water kiosk
D. We obtain water from the Hand Cart Water Vendors
E. We obtain water from the private water tanker
F. We obtain water from a public borehole or well
G. We obtain water from a private borehole or well
H. We have our own private borehole or well in our compound

2c) What quantity does your household need __________ (litres) and what quantity do you actually access or afford ______________ (litres)? NEW QUESTION

2c) Who is your water service provider? Edited…delete the previous 2c

A) Nairobi Water and Sewerage Company (NWSC).
B) Small Scale Independent Provider (SSIP).
C) I don't know.

2d) **Water storage:** What methods of water storage do your household use? – options added

A. Roof tank
B. Underground or ground level water tank outside the house
C. Overhead tank inside or outside the house
D. Water tank in the house
E. Small containers & Jerricans

2e) How many days can your water storage last when there is no water supply? – options added

A. Less than a day
B. One day

C. Two days
D. Three days
E. Four days
F. Five days
G. More than five days (Specify _________________ days)

2f) **Pipe connections:** Which of the following statements best describes your household situation with regard to piped water connections?

A. We have our own individual connection
B. We have shared piped connection
C. We do not have any piped connection.

2g) Have you applied to NCWSC for a water connection?

A) Yes
B) No

2h) To whom do you pay for water? (More than one box can be ticked if applicable)

A. Water utility (NCWSC)
B. Water kiosk operator
C. Hand cart water vendors
D. Private water tanker
E. Landlord
F. Buy from borehole or well
G. We have our own borehole
H. We obtain free water from borehole or well
I. We do not pay for water

Section 3: Piped water received directly from NCWSC's pipeline:
If your household obtains water from NCWSC through taps in the house or from a yard tap (shared water connection) – please answer the following questions from 3.1 to 3.3.

NOTE FOR ENUMERATOR: IF THE RESPONDENT DOES NOT RECEIVE NCWSC PIPED WATER, PLEASE MOVE TO SECTION 4.

3.1 Water service levels provided by NCWSC.

a) Availability: As we speak now, is water flowing in your supply system?

A. Yes
B. No
C. Maybe (Can we check?)

b) Supply frequency: On average how frequently do you receive piped water from NCWSC?

A. Once a day

B. Twice a day
C. Once in 2 or 3 days
D. Once a week
E. Continuous
F. Other _________ (please specify)

c) Reliability: Does the water supply reliably arrive at the frequency you have stated?
A. Yes
B. No
C. Sometimes

d) Supply duration: How many hours of water supply do you usually receive on average from NCWSC each time the piped water arrives?
A. Less than 2 hours
B. 2 to 4 hours
C. More than 4 hours each time

e) Timing: At what times of the day do you usually receive piped water from NCWSC?
A. Morning only
B. Evening only
C. Both Mornings and Evenings
D. All day
E. All night
F. Aal day and night

f) Are these times convenient for you?
A. Yes
B. No

g) If NCWSC has to ration water to customers and supply water only once in a day for a few hours, at which of the following times would you wish to receive water?
A. Morning only
B. Evening only
C. Other ________ (Please specify)

h) **Water pressure:** Does the water you receive from NCWSC's connection have enough pressure to reach and enter a roof tank or elevated tank?
A. Yes
B. No
C. Sometimes
D. I am not sure

i) **Quantity:** Do you receive enough (sufficient) piped water from the water utility (NCWSC) for your use?
A. Yes

B. No
C. Do not receive piped water from utility (NCWSC) directly

j) Quality: How would you generally rate the appearance of water supplied by NCWSC?
A. Good quality water (clear and colourless) most of the time
B. Poor quality (muddy/brown) most of the time

k) Water treatment: What type of water treatment do you carry out on the water from NCWSC?
A. Do not treat
B. Boil drinking water
C. Use water filter or purifier
D. Other ____________ (Please specify)

l) Overall are you satisfied with the piped water supply from NCWSC?
A. Yes
B. No

m) If the answer above is no, Why? Indicate below
A. Inadequate quantity or pressure
B. Costly (too expensive)
C. Low quality (colour/turbidity etc.)

n) Does the household depend on other sources?

3.2 Billing and payment of water charges (for NCWSC customers)

a) Do you receive a water bill from NCWSC?
A. Yes
B. No
b) Do you have a water meter?
A. Yes
B. No
c) How are you billed for water charges?
A. By flat rate charge because I have no water meter
B. Based on meter readings since I have a meter and it is read regularly
C. By meter reading estimate (because my meter is not read)
D. By meter reading estimate (because my meter does not work)
E. I do not know

d) How much do you pay NCWSC for water on average each month? ____________

e) How much did you pay for the piped connection charges? ________________

f) How often do you receive a water bill from the utility (NCWSC)?
A. Every month
B. Once in 2 or 3 months or even more
C. I never receive water bills from NCWSC
D. Other ___________ (Please specify)

g) How often do NCWSC meter readers read your meter?
A. Every month
B. Once in 2 months
C. Once in 3 months
D. Once in 4 to 6 months
E. Once a year
F. Never read

h) How do you pay for your water bills?
A. Cash or cheque to NCWSC's cashier's office
B. Cheque by post
C. NCWSC officers collect the cheque
D. I pay the meter reader
E. I do not pay
F. I pay the landlord

i) Do you understand the water bills that are sent to you?
A. Yes
B. No

j) Is the water bill that you receive reasonable
A. Yes
B. No

k) How often do you pay the water bills for your household?
A. Every month
B. Whenever I receive the bills
C. Once in 2 or 3 months
D. Other _____________(specify)

l) Do you have any complaints about the present billing system?
A. Yes
B. No

m) With the current price of the water bills from NCWSC, can you afford to pay for the minimum amount of water your family needs?
A. Yes, always
B. Yes, most of the time

C. Usually not

n) If the water was cheaper, would you buy more of it?
YES
NO

3.3 Customer services provided by NCWSC

a) When you find a problem with your water services do you make a complaint to NCWSC?
A. Yes
B. No

b) When you have a problem with your water supply or billing etc., who do you complain to?
A. The local NCWSC area office
B. The regional NCWSC office
C. Other, ______________________________ (Please specify)

c) When you have a complaint or query with your water supply or billing etc., how do you contact NCWSC?
A. Visit in person
B. By post (letter)
C. By telephone

d) How many times have you or a member of your household visited the NCWSC offices to make a request or complaint over the last year? __________

e) Do you consider the NCWSC offices to be accessible (distance, opening times, friendly etc.,) to you?
A. Yes
B. No

f) How would you rate the customer services provided by NCWSC for the following aspects:

		Good	Average	Poor
i)	Process for obtaining a new water connection			
ii)	Complaints on over billing			
iii)	Complaints on irregular delivery of bills			

iv)	Complaints for service interruptions such as lack of water			

g) Overall, how would you rate the general customer service that the NCWSC representatives give you?

A. Good
B. Average
C. Poor

Section 4: Alternative Water Sources

4.1 CUSTOMERS WHO OBTAIN WATER DIRECTLY FROM WATER KIOSKS (either always or sometimes)

If you use water directly from Water Kiosks, please answer the following questions:

a) Are the water kiosks, that you use, managed by

A. A private vendor
B. The NCWSC
C. A community group

b) Do you or members of your household collect water from the kiosk(s), or do you have it delivered to your house?

A. Collected by a member of your household
B. Delivered to your house
C. Some delivered and some collected

If you ticked boxes A) or C) please answer questions c) and d) below

c) How far is the water kiosk (that you use) from your house?

A. Less than 100m
B. Between 100 – 200m
C. More than 200m

d) How long does it usually take to collect water from the kiosk each time (one round trip)?

______

e) **Timing:** In general, can you obtain water from the kiosk at convenient times of the day?

A. Yes
B. No

f) **Supply frequency:** If you wanted, are you able to obtain water from this water kiosk?

A. Continuous (all the time)

B. Once a day
C. Twice a day
D. Once in 2 or 3 days
E. Once a week

g). **Reliability:** Does this water kiosk reliably provide water at the frequency you have stated?
A. Yes
B. No

h) **Quantity:** Do you receive enough (sufficient) water from the water kiosk for your use?
A. Yes
B. No

i) How many (20-litre) containers does your household usually use from kiosks in a day? _____

j) **Quality:** How would you generally rate the appearance of water you obtain from the water kiosk?
A. Good quality water (clear and colourless) most of the time
B. Poor quality water (muddy/brown) most of the time

k) **Water treatment:** What type of water treatment do you carry out on the kiosk water?
A. Do not treat
B. Boil drinking water
C. Use water filter/purifier

l) **Costs:** How much do you pay for a 20-litre container of water obtained from the kiosk?
A. During normal time when there are no water shortages? _______________
B. When there are water shortages? __________________

m) With the current price of the water sold at [the water kiosk], can you afford to purchase the minimum amount of water your family needs?
A. Yes, always
B. Yes, most of the time
C. Usually not

n) If the water was cheaper, would you buy more of it?
YES
NO

m) Overall, are you satisfied with the water supply from the kiosk?
A. Yes
B. No

n) If not satisfied; why?

A. Inadequate quantity or pressure
B. Costly (too expensive)
C. Low in quality (colour/turbidity etc.)

o) Do you think NWSC should provide more water kiosks in your area?
A. Yes
B. No

4.2 Alternative Water Sources: If you use water from other sources (other than NCWSC water and kiosks) such as boreholes, open wells or from water vendors, please answer the following questions:

a) Water alternative water sources do you use?
A. Boreholes
B. Open well
C. Rainwater
D. Hand cart water vendors
E. Water tankers
F. River
G. Other _____________ (Please specify)

b) Is this water source that you use, managed by:-
A. A private vendor
B. The NCWSC
C. A community group
D. Your household
E. Other _________ (Please specify)

c) Do you or members of your household collect water from this source, or do you have it delivered to your house?
A. Collected by a member of household
B. Delivered to your house
C. Some delivered and some collected

If you ticked boxes A) or C) please answer questions d) and e) below

d) How far is the water source (that you use) from your house?
A. Less than 100m
B. Between 100 – 200m
C. More than 200m

e) How long does it take to collect water from this source each time (round trip)? __________

f) **Timing:** In general, can you obtain water from this source at convenient times of the day?

A. Yes
B. No

g) **Supply frequency:** If you wanted, are you able to obtain water from this source?

A. Continuous (all the time)
B. Once a day
C. Twice a day
D. Once in 2 or 3 days
E. Once a week
F. Other ____________ (Please specify)

h) **Reliability:** Does this water source reliably provide water at the frequency you have stated?

A. Yes
B. No

i) **Quantity:** Do you receive enough (sufficient) water from the water kiosk for your use?

C. Yes
D. No

j) How many (20-litre) containers does your household usually use from kiosks in a day? _____

k) **Quality:** How would you generally rate the appearance of water you obtain from the water kiosk?

C. Good quality water (clear and colourless) most of the time
D. Poor quality water (muddy/brown) most of the time

l) **Water treatment:** What type of water treatment do you carry out on the kiosk water?

D. Do not treat
E. Boil drinking water
F. Use water filter/purifier
G. Other _______________ (Please specify)

m) **Costs:** How much do you pay for a 20-litre container of water obtained from the kiosk during normal time when there are no water shortages? ______________

n) **Costs:** How much do you pay for a 20-litre container of water obtained from the kiosk when there are water shortages? _________________

o) With the current price of the water sold at [specify the water source], can you afford to purchase the minimum amount of water your family needs?

A. Yes, always

B. Yes, most of the time
C. Usually not

p) If the water was cheaper, would you buy more of it?
YES
NO

o) Overall, are you satisfied with the water supply from the kiosk?
  A. Yes
  B. No

p) If not satisfied, why?
  A. Inadequate quantity or pressure
  B. Costly (too expensive)
  C. Low in quality (colour/turbidity etc.,)
  D. Opening times
  E. Long queues
  F. Other ____________________ (Please specify)

q) If NCWSC could provide more water kiosks near where you live, would you buy water from the NCWSC water kiosk instead of obtaining water from this source (source indicated in question "a" above)
  A. Yes
  B. No

4.3 Water from vendors: If you use water supplied by vendors (either sometimes or always), please answer the following questions:

a) Do you know the sources from which Hand-cart vendors obtain water?
  A. Yes
  B. No

b) If you know, where does the water vendors who supply your household obtain water from?
  A. Borehole
  B. Open well
  C. NCWSC water kiosk
  D. Rainwater
  E. Streams/springs
  F. NCWSC individual connection
  G. A combination of sources _________________ (Please specify)

c) How much do you pay for a 20-litre container of water brought to you by the Hand-cart water vendor during normal times when there are no water shortages? ______________________

d) How much do you pay for a 20-litre container of water brought to you by the Hand-cart water vendor during times when there are water shortages? ________________________

e) With the current price of the water sold at [specify the water source], can you afford to purchase the minimum amount of water your family needs?
A. Yes, always
B. Yes, most of the time
C. Usually not

f) If the water was cheaper, would you buy more of it?
YES
NO

e) Why do you prefer to buy water from a water vendor instead of collecting the water directly from the sources where the vendor obtain water?
f) Why do you obtain water from other sources instead of using NCWSC water?

A. I do not have a water connection
B. I have a connection, but NCWSC water is not enough
C. NCWSC water is costly (too expensive) compared with other sources
D. Other reasons ___________________ (Please Specify)

g) If NCWSC could provide more water kiosks near where you live with water available most of the time, would you buy water from the NCWSC water kiosk instead of buying water from vendors?

A. Yes
B. No

APPENDIX II: KII QUESTIONNAIRE FOR NCWSC-INSE MANAGER

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

Name of Water Utility serving City:

Address:

Head of Water Utility

Name:

Title:

Contact Telephone Number(s):

Contact:

Contact Email:

Year Utility was formed:

I. GENERAL UTILITY OVERVIEW

a) Is the Water Utility
   i) Part of Government Department
   ii) Government Corporation/Enterprise
   iii) Other, please explain

b) Is the water utility?
   i) Regulator
   ii) Operator
   iii) Regulator and operator

c) Is there a private sector involvement in the Water Utility?

YES

NO

IF yes, in what aspect(s)?

i) Source Development
ii) Production
iii) Distribution
iv) Management
v) Billing and Collection
vi) Leak repair
vii) Other, please explain.

d) Water utility responsibility?
   i) For city alone
   ii) City and other towns/cities
   iii) State/Region
   iv) National Authority

e) Utility is responsible for?
   i) Production
   ii) Distribution
   iii) Source Development

f) Number of water utility staff:
   i) Operations: _______
   ii) Development: _______
   iii) Total: ___________

g) Staff classification

h) Does the water utility have a specific policy for providing water supply to the urban poor?

i) Management Information System

j) Is there a development plan?

II. WATER SERVICES INFORMATION

Area covered by service network

Year 2000

Year 2001

Year 2002…

Year 2020

Number of connections (please separate by type of connection for the year 2000 o year 2020)

Type of	Total number	House connecti	Public	Industri al	Comme rcial	Bulky supply	Fire	Other:

connection	of connections	ons	Taps/ Standpipes	connections	connections	connections	hydrants	
2000								
2001								
2002								
…2020								

Proportion of total connections that are metered - ______%

Population served _______

Type of connection	Population
2000	
2001	
2002	
…2020	

Percentage of people dwelling in the jurisdiction of the utility with access to water within a radius of 1km

Type of connection	%
2000	
2001	
2002	
…2020	

Percentage of people dwelling in the jurisdiction of the utility with access to improved sanitation in immediate vicinity

Type of connection	%
2000	
2001	
2002	
…2020	

Estimated total water production: ___ m^3/day

Proportion of water production from: -

Surface water %

Ground water %

Other sources %

Number of treatment plants managed by the utility

Total capacity of water production treatment plant(s) ____ m^3/day

Proportion of water production receiving full treatment _ %

Proportion of water production receiving chlorination only _ %

Proportion of water production receiving NO treatment _ %

III. FINANCIAL AND ECONOMIC DATA

Annual O+M, Annual Billing, Annual Collections (in KSh.)

Year	Annual Operations and Maintenance Costs	Annual Billings	Annual Collections
2000			
2001			
2002…2020			

Tariff structure for households and industries:

When were the last 2 increases made (years)?

Briefly describe current tariff structure for,

Households –

Industries –

Other –

Total investments in the last 5 years: ___________ KSh.

Investments in the following fields:

Field of investment	%

Service extension	
Modernization of distribution network	
Water production treatment	
Management system	
Staff development	
Other	

Estimated unaccounted for water ________ % of water supplied

Estimated non-revenue water ____________%

Are subsidies provided to install new connections? YES NO

If yes, briefly explain ---

This questionnaire was completed by:

Name:

Designation:

Address:

Tel:

Email: Please return the filled questionnaire by email to lugardogaro@gmail.com by May 30, 2022.

APPENDIX III: KII WITH NAIROBI COUNTY, DEPARTMENT OF WATER

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

Ref.	Question	**Response**
1	Briefly explain the role of the County Government in Water Service Provision in Nairobi.	
2	How different is this role when it comes to informal settlements?	
3	What challenges does the County Government face in the supply of water to informal settlements? What challenges do exist in informal settlements that hinder water supply for the County Government of NCWSC? Probe for: i) Illegal connections	

	ii) Loss of revenue iii) Not willing to pay iv) Illegality of settlement v) Connection requirements by NCWSC vi) Physical/environmental challenges - sewer	
4	How many water vendors supply water to informal settlements in Nairobi?	
5	How many of these are licensed?	
6	What are the requirements for licensing of the following water businesses? i. Borehole development and supply ii) Water kiosk operation iii) Water truck delivery iv) Water carts v) On-sellers (connected HHs selling to others)	
7	Is the Water Utility Part of Government Department Government Corporation/Enterprise Other, please explain	
8	Is the water utility i) Regulator ii) Operator iii) Regulator and operator	
9	Is there a private sector involvement in the Water Utility? i) YES ii) NO	

10	IF yes, in what aspect(s)? i) Source Development ii) Production iii) Distribution iv) Management v) Billing and Collection vi) Leak repair vii) Other, please explain.	
11	Water utility responsibility? i) For city alone ii) City and other towns/cities iii) High potential areas only in city iv) Other, please explain	
12	Utility is responsible for? i) Production ii) Distribution iii) Source Development	
13	What are the minimum requirements set by the county of the following water security parameters? i) Water availability (24 hours) ii) Water quantity per person per day iii) Water quality iv) Water access (distance to source/point)	

	v) Reliability (dependability) vi) Safety measures (transportation/pipeline)	
14	What is the structure of water service regulation in the county? (Probe for – WASREB, WSB, WSP, SSIPs, Consumers)	
15	Does the county have any instruments for regulating water service provision? (If yes, can you share them?)	

APPENDIX IV: KII QUESTIONNAIRE FOR BOREHOLE OWNERS

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

INTEGRATION QUESTIONS

Ref.	Question	Response
1	Who owns this borehole? i) One individual/family, ii) SHG, iii) CBO, iv) FBO v) Government (Athi Water) vi) School vii) Church	
2	How long has this system been operational?	
3	Please describe this water system: i) Production ii) Storage	

	iii) Treatment iv) Supply network (pipeline) – (size and length of pipeline)	
4	Have you undertaken any joint commissioning of water schemes/supply systems? (Collaboration in production, storage, treatment, supply network)	
5	Do you see a possibility of pooling resources/funds together (collaboration) to increase access to water to under-covered areas?	
6	Do you see a possibility of partnership with community for them to provide services on a voluntary basis in? (Probe for the items below) i) Reporting of illegal connections ii) Reporting of leakages iii) Allowing for wayleave for pipe network iv) Cooperating in not damping solid waste into systems – valve chambers etc. v) Others	
7	Are there redesign pathways that can be considered to improve access to safe water? – aerial pipes in Kibera.	
8	Are there new delivery models that can be explored to improve on reliability of services? [*Probe for - such as having household connection at the same time installing water kiosks nearby to supply water when pressures are low. Increasing storage facilities…*]	
9	Are there any community/public assets	

	that can be used to deliver water near to households? – such as schools, health facilities, chief's camps, places of worship etc?	
10	How far are the community/public assets - such as schools, health facilities, chief's camps, places of worship etc?	
11	Are there skilled people such as plumbers and pump mechanics who live within the informal settlements?	
12	If yes, have they been engaged by NCWSC/WASH enterprise to undertake any repair or water related works?	
	Collaboration and integration of services	
13	**Production:** Have you gone into any agreement with any party in order to develop a water supply system? How much water do you produce per day? [M^3/day]	
14	**Treatment:** Do you have any agreement with any company/individual for the purpose of water treatment?	
15	**Storage:** Have you gone into any agreement with any company/individual for the purpose of improving storage of water which is meant for distribution?	
16	**Distribution:** Do you have any agreement with any company/individual for the purpose of distributing "your" water?	
17	**Main customers:** Who are your customers? i) Institutions – schools, health facilities, hotels, churches/mosques etc. ii) Water kiosk owners iii) Companies iv) Household connections v) Water truck owners vi) Cart owners vii) Any other?	
17	**Availability:** Do you have any agreement with any of your customers to ensure that water is available at all times? Or at	

	specified times as per schedule?	
18	**Quantity:** How much water do you sell per day (Volume)? (Do you have enough **quantity** of water to meet the demands)?	
19	**Quality:** Do you treat the water you produce in any way? Do people directly drink the water you produce without having to treat it?	
20	**Cost:** How much do you sell water in the following categories: i) Water to institutions KSh./CM ii) Water to companies KSh./CM iii) Water supply to water kiosk owner KSh./CM iv) Household connected KSh./CM v) Bulk water through lorry KSh./CM vi) Small quantities – cart buyers KSh./20L vii) Small quantities – others KSh./20L How do you ensure that your customers are paying the right tariff or price of water without any extortion?	
21	Is there any water tariff arrangement you have with your water vendors? (example where water cart owner buys water at reducing prices per an extra trip)	
21	**Reliable:** Do you have any agreement with any of your customers to ensure that water is available at all specified times as per schedule? Has your system failed to supply water for whatever reason during the last 30 days? If yes, for how long?	

	On an annual basis, can you say if your system has had a breakdown of more than 30 days cumulatively (out of the 365 days in a year?)	
22	**Safety:** What mechanisms have you put in place to ensure that water is delivered in a safe manner to the final user without any contamination during transportation/pipeline?	

APPENDIX V: KII QUESTIONNAIRE FOR WATER TRUCK OPERATORS

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

Ref.	Question	Response
1	Type of ownership i) One individual/family, ii) SHG, iii) CBO, iv) FBO v) Government (Athi Water) vi) School vii) Church viii) Co-owned - explain	
2	How long have you been in this business of selling water (using the truck)?	
3	How many trucks do you or your company own? What is their capacity?	
4	Do you use them all year round?	
5	How much water do you sell daily?	

	(Does this amount change)	
6	Who are your customers? i) Institutions – schools, health facilities, hotels etc. ii) Household iii) Other, please specify	
7	How many customers do you have?	Normal calendar season:- _______________ During water scarcity/drought season: _____________
8	Where do you get your water from? (On what basis?)	
9	Who are the customers that buy big volumes and how much do you sell?	
10	Who are the customers that buy small volumes and how much do you sell?	
11	Who are your competitors? i) NGOs, ii) CBOs iii) FBOs iv) Other traders, v) Individuals vi) Government etc.	
12	Are you willing to collaborate with other service providers to get paid? **(Who do you see in the system that you can collaborate with and how?)**	
13	What types of risks affects your business and what are their implications? (Costs, volumes, losses, etc.)	
14	Main concern you face in your business?	

15	What is the capacity/scale of the commercial water market (water availability, number and nature of players, pricing)?	
16	What is the willingness and capacity of players in the market to engage with NCWSC, NGOs/CBOs in market water access systems?	
17	What are the main challenges/bottlenecks for different players in the market?	
18	How responsive is water supply to increases in incomes/demand for water?	
19	What times are you available to provide water to your customers? i) How many orders do you receive in a day? ii) How many orders are you able to deliver? iii) What happens with the orders that you are not able to deliver?	
20	**Quality and safety:** i) How do you ensure that the water you supply is of acceptable quality? ii) What safety measures do you put in place to reduce contamination by the truck you are using?	

APPENDIX VI: KII QUESTIONNAIRE FOR WATER KIOSK OPERATORS

A Model for Integrating Water Service Provision Towards Addressing Water Security Challenges in Informal Settlements in Nairobi City County, Kenya

Introduction

My name is____, I am a research assistant undertaking a study on behalf of Lugard Kaunda Ogaro, for his PhD in Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology. We are conducting an important study on water security in Nairobi's informal settlements. The study is looking into developing a model for integrating water service provision towards addressing water security challenges. The purpose of talking with you today is to learn more about your thoughts, feelings, and experiences on household water security. Anything you tell me will not be personally attributed to you in any report that results from this study. The report will be written in a manner that no individual comments can be attributed to a particular person. Your participation is purely voluntary.

The interview will take about 30 minutes.

Ref.	Questions	Response
1	Type of ownership i) One individual/family, ii) SHG, iii) CBO, iv) FBO v) Government (Athi Water) vi) School vii) Church viii) Co-owned - explain	**Year started:**
2	How long have you been running this business (Water Kiosk)? State year	
3	How much water do you sell daily? (Does this amount change)	
4	Who are your customers? i) Institutions – schools, health facilities, hotels etc.	

	ii) Companies iii) Another water kiosk (Kiosk to Kiosk – K2K) iv) Ablution blocks v) Household connections vi) Lorries vii) Cart owners viii) Other, please specify	
5	How many customers are you providing services to?	Normal calendar season:- ___________________ During water scarcity/drought season: _______
6	In what quantities do you sell your water? i) 20L jerricans ii) 100L drums iii) 200L drums iv) Water boozers, 10,000L v) Water booze, 6,000L vi) Connections to households, institutions, companies vii) Other quantities, please specify	Quantity: Price:
	In what other quantities and arrangements do your sale your water?	
7	Is it the same price all year long? (Yes or no and ask the respondent to explain)	
8	Please describe the water system: i) Production (where do you get water from) ii) Storage	

	iii) Treatment iv) Supply / distribution v) Other?	
9	If you are not the owner of the source (borehole/other source), what kind of agreement do you have with your supplier?	
10	How much water do you sell per day (Volume)? (Do you have enough **quantity** of water to meet the demand)?	
11	What are the requirements of water to informal settlements? (permit, quality, metering, tariff/price, safety of supply, distance of pump from chamber, etc)	
12	What is the cost of setting up a water kiosk?	
13	What are the requirements for setting up and operating a water kiosk?	
14	Are you licensed to supply water in this area? If so, by who?	
15	Do you know of any vendors operating in this area? (How many are they?)	
16	Do these water vendors operate all year long; does this change at any point in the year?	
17	What challenges are you facing in the supply of water to people here?	
18	It is possible that some people started	

	a water kiosk but later dropped out of business. What do you think are some the reasons for this? (tick and explain) i) Regulations ii) Lack of customers iii) Competition iv) Lack of water v) Low profits vi) Because of the location they chose vii) Other?	
18	During periods of scarcity do you continue to provide water to people living here? (Where do you source your water from during this time)?	
19	What is the source of water provision during prolonged scarcity?	
20	Do you ensure any water quality testing; Can you provide details on the water quality testing that your company does?	
21	Who are your competitors? i) NGOs, ii) CBOs iii) FBOs iv) Companies through CSR v) Companies producing mineral water vi) Institutions vii) Other traders, viii) Individuals ix) NCWSC x) Government etc.	
22	Are you willing to collaborate with other service providers to be in the water business? – YES or NO	

	(i) Who do you see in the system that you can collaborate with? **(ii) How can you collaborate?**	
23	What types of risks affects your business and what are their implications? (Legal issues, costs, volumes, losses, etc.)	
24	Main concern you face in your business?	
25	What is the capacity/scale of the commercial water market (water availability, number and nature of players, pricing)?	
27	What is the willingness and capacity of players in the market to engage with NCWSC, NGOs/CBOs in market water access systems?	
28	What are the main challenges/bottlenecks for different players in the market?	
29	Do you have any additional comments which you could share?	

APPENDIX VII: FGD GUIDE FOR PRIVATE OPERATORS

Ref.	Questions	Response
1	Who are the majority owners of the water enterprises? ix) One individual/family, x) SHG, xi) CBO, xii) FBO xiii) Co-owned - explain	**Year started:**
2	Who are your main customers? ix) Institutions – schools, health facilities, hotels etc. x) Households xi) Other, please specify	
3	Is the price of water same all year long? (Yes or no and ask the respondent to explain)	
4	How does water quality change over the year based on scarcity and seasonal variations?	
5	If you are not the owner of the source (borehole/other source), what kind of agreement do you have with your supplier?	
5	What are the requirements of water to informal settlements?	
6	How many of you are licensed to supply water in the informal settlements? **Who has licensed you?**	

7	Are there some vendors who operate seasonally? And why?	
8	What challenges are you facing in the supply of water to people here?	
9	It is possible that some people started a water business and soon dropped out. What do you think are some the reasons for this? viii) Regulations ix) Lack of customers x) Competition xi) Lack of water xii) Low profits xiii) Because of the location they chose	
10	During periods of scarcity what other sources do you rely on?	
11	Who are your competitors? xi) NGOs, xii) CBOs xiii) FBOs xiv) Other traders, xv) Individuals xvi) Government etc.	
12	Are you willing to collaborate with other service providers to get paid? **(Who do you see in the system that you can collaborate with and how?)**	
13	What types of risks affects your business and what are their implications? (Costs, volumes, losses, etc.)	
14	Main concern you face in your business?	

15	What is the willingness and capacity of players in the market to engage with NCWSC, NGOs/CBOs in market water access systems?	
15	What are the main challenges/bottlenecks for different players in the market?	

APPENDIX VIII: FGD GUIDE FOR WATER USERS

Design a questionnaire that answers questions on water security issues – availability, access, quantity, quality, affordability, and reliability.

Have 3 questions per variable

Ref.	Questions	Response
1	How is the water situation in this area? How has it changed over the last 3 years?	
1	Who are the majority owners of the water enterprises? xiv) One individual/family, xv) SHG, xvi) CBO, xvii) FBO xviii) Co-owned - explain	**Year started:**
2	Who are your main customers? xii) Institutions – schools, health facilities, hotels etc. xiii) Households xiv) Other, please specify	
3	Is the price of water same all year long? (Yes or no and ask the respondent to explain)	
4	How does water quality change over the year based on scarcity and seasonal variations?	
5	If you are not the owner of the source (borehole/other source), what kind of agreement do you have with your supplier?	

5	What are the requirements of water to informal settlements?	
6	How many of you are licensed to supply water in the informal settlements? **Who has licensed you?**	
7	Are there some vendors who operate seasonally? And why?	
8	What challenges are you facing in the supply of water to people here?	
9	It is possible that some people started a water business and soon dropped out. What do you think are some the reasons for this? xiv) Regulations xv) Lack of customers xvi) Competition xvii) Lack of water xviii) Low profits xix) Because of the location they chose	
10	During periods of scarcity what other sources do you rely on?	
11	Who are your competitors? i. NGOs, ii. CBOs iii. FBOs iv. Other traders, v. Individuals vi. Government etc.	
12	Are you willing to collaborate with other service providers to get paid? **(Who do you identify in the system that you can collaborate with and how?)**	
13	What types of risks affects your	

	business and what are their implications? (Costs, volumes, losses, etc.)	
14	Main concern you face in your business?	
15	What is the willingness and capacity of players in the market to engage with NCWSC, NGOs/CBOs in market water access systems?	
15	What are the main challenges/bottlenecks for different players in the market?	
16	What are your recommendations to improve water security in this area?	

APPENDIX IX: KII GUIDE FOR CART OWNERS/OPERATORS

Ref.	Questions	Response
1	Who is the owner of the cart you are using to supply water? i) Self (he is the owner) ii) One individual/family, iii) SHG, iv) CBO, v) FBO vi) Co-owned – explain	
2	Are there vendors who hire or are employed by someone to carry the water? If so, please explain how this works.	
3	How long have you been in this business of water vending?	
4	How much water do you sell daily? (Does this amount change)	
5	Who are your customers? i) Schools, ii) Health facilities, iii) Hotels etc. iv) Households v) Other, please explain.	
6	How many customers are you providing services to?	Normal calendar season:- ____________________ During water scarcity/drought season: ________
7	In what quantities do you sell your water? viii) 20L jerricans	Quantity: Price:

	ix) 100L drums x) 200L drums xi) Other quantities, please specify.	
8	Is it the same price all year long?	
9	Where do you get your water from? (On what basis?)	
10	How much water do you sell per day (Volume)? (Do you have enough water to meet the demands)?	
11	What times are you available to provide water to your customers? i) How many orders do you receive in a day? ii) How many orders are you able to deliver? iii) What happens with the orders that you are not able to deliver?	
12	What are the requirements for you to own a cart to supply water? **Any need for licensing?**	
13	What is the cost of buying a water	

	cart?	
14	Do these water vendors operate all year long; does this change at any point in the year?	
15	What challenges are you facing in the supply of water to people here?	
16	During periods of scarcity do you continue to provide water to people living here? (Where do you source your water from during this time)?	
17	**Quality and safety:** i) How do you ensure that the water you supply is of acceptable quality? ii) What safety measures do you put in place to reduce contamination by the truck you are using?	
18	Who are your competitors? i) NGOs, ii) CBOs, iii) FBOs, iv) Other traders, v) Individuals vi) Government etc.?)	
19	Are you willing to collaborate with other service providers to get paid? **(Who do you see in the system that you can collaborate with and how?)**	
20	What types of risks affects your business and what are their implications? (Costs, volumes, losses, etc.)	
21	Main concern you face in your business?	
22	What is the willingness and capacity	

	of players in the market to engage with NCWSC, NGOs/CBOs in market water access systems?	
23	What are the main challenges/bottlenecks for different players in the market?	
24	Are there households that receive water or are connected to NCWSC, but they still ask you to supply them? And if so, why?	

APPENDIX X: OBSERVATION CHECKLIST

Ref	Observation	Response
1	Water materials are majority of houses made of?	
2	Do you see both men and women involved in water collection/activities?	
3	What water sources have you observed in the area?	
4	What water related technologies can you observe in the location?	
5	Do you observe any water treatment at source or in the households?	
6	Do you observe any storage facilities in the house or at the source?	
7	Do you observe any pipe network in the area and / or households?	
8	Do you observe water handling as safe?	
9	Do you observe one water service provider buying water from another service provider to sale it to households/small businesses?	
10	Do you observe any means used to pay for water services – mobile or cash?	
11	Do you observe any water meters in the area or household?	
12	What measure/size of container is used in selling water?	
13	Do you observe any water re-use by households in the area?	
14	Do you observe any water wastage in the area?	
15	Do you observe any illegal connections in the area?	
16	Do you observe any branded water point/source in the area? What is the name/brand?	
17	Do you observe any household selling or sharing water with another household?	
18	Do you observe any institution(s) in the area?	
19	Do you observe any shop selling water related items? What are they?	
20	Do you observe any water vendors/water points very close to each other? How close? Which ones are they (boreholes, kiosk, carts, trucks)?	

APPENDIX XI: UNIVERSITY RESEARCH PROPOSAL APPROVAL

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

Tel: 056-30870
Fax: 056-30153
E-mail: directordps@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

Directorate of Postgraduate Studies

Ref: MMU/COR: 509099

20th March 2023

Ogaro Lugard Kaunda
CDS/H/207/12
P.O. Box 190-50100
KAKAMEGA

Dear Mr. Ogaro,

RE: APPROVAL OF PROPOSAL

I am pleased to inform you that the Directorate of Postgraduate Studies has considered and approved your PhD proposal entitled: "***Design and application of System Dynamics Model for Water Security in Informal Settlements in Nairobi County, Kenya***" and appointed the following as supervisors:

1. Prof. Stanely Omuterema - SDMHA - MMUST
2. Prof. Edward Neyole - SDMHA - MMUST

You are required to submit through your supervisor(s) progress reports every three months to the Director of Postgraduate Studies. Such reports should be copied to the following: Chairman, School of Disaster Management and Humanitarian Assistance Graduate Studies Committee and Chairman, Department of Disaster Management and Sustainable Development. Kindly adhere to research ethics consideration in conducting research.

It is the policy and regulations of the University that you observe a deadline of two years from the date of registration to complete your PhD thesis. Do not hesitate to consult this office in case of any problem encountered in the course of your work.

We wish you the best in your research and hope the study will make original contribution to knowledge.

Yours Sincerely,

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY
DIRECTORATE OF POSTGRADUATE STUDIES
P.O. Box 190-50100, KAKAMEGA (K)
Date:............ Sign:............

Prof. Stephen O. Odebero, PhD, FIEEP
DIRECTOR, DIRECTORATE OF POSTGRADUATE STUDIES

APPENDIX XII: NACOSTE RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **486767**

Date of Issue: **13/April/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Lugard Kaunda Ogaro of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: DESIGN AND APPLICATION OF SYSTEM DYNAMICS MODEL FOR WATER SECURITY IN INFORMAL SETTLEMENTS IN NAIROBI COUNTY, KENYA for the period ending : 13/April/2024.

License No: **NACOSTI/P/23/25075**

486767

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

APPENDIX XIII: RESEARCH AUTHORIZATION, CC, NAIROBI

OFFICE OF THE PRESIDENT

MINISTRY OF INTERIOR AND NATIONAL ADMINISTRATION

STATE DEPARTMENT OF INTERNAL SECURITY AND NATIONAL ADMINISTRATION

Telegrams..........................
Telephone: Nairobi 316845, 341656
When replying please quote

COUNTY COMMISSIONER
NAIROBI COUNTY
P.O. BOX 30124-00100
NAIROBI

REF NO. ED 10/6 VOL. XXVI (146)

17th April, 2023

Lugard Kaunda Ogaro
P.O.BOX 968
KEROKA

RE: RESEARCH AUTHORIZATION

Your letter dated 13th April, 2023 refers.

This office has no objection and authority is hereby granted to conduct a research on **"Design and Application of System Dynamics Model for Water Security in Informal Settlements,"** in Ruaraka, Makadara, Langata, Dagoretti, Kamukunji, Starehe, Kasarani, Embakasi and Westlands Sub Counties for a period of ending 13th April, 2024.

JOSEPH K. MBITHI
FOR: COUNTY COMMISSIONER

CC: DEPUTY COUNTY COMMISSIONER – RUARAKA SUB COUNTY
- MAKADARA SUB COUNTY
- LANGATA SUB COUNTY
- DAGORETTI SUB COUNTY
- KAMUKUNJI SUB COUNTY
- STAREHE SUB COUNTY
- KASARANI SUB COUNTY
- EMBAKASI SUB COUNTY
- WESTLANDS SUB COUNTY