SPATIAL ANALYSIS OF ACCESS TO DOMESTIC WATER SUPPLY IN GYEL DISTRICT, JOS SOUTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

BY

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DECLARATION

I declare that this dissertation titled **"Spatial Analysis of Access to Domestic Water Supply in Gyel District of Jos South Local Government Area, Plateau State, Nigeria"** has been performed by me in the Department of Geography under the supervision of Prof. E.O Iguisi and Dr. D. N. Jeb. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this project report was previously presented for another degree of any university.

______________________________ ____________________

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CERTIFICATION

This dissertation titled **“Spatial Analysis of Access to Domestic Water Supply in Gyel District of Jos south LGA, Plateau State, Nigeria”**by **Meshach Arome OMADA** meets the regulations governing the award of M.Sc Remote Sensing and Geographic Information System of Ahmadu Bello University Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to Almighty God for His Grace. Also to my beloved wife, parents, brothers, sisters, friends and colleagues whose love, support and encouragement have contributed to all that I have accomplished.

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ABBREVIATIONS	MEANING
WHO	World Health Organisation
UNICEF	United Nations Children's Fund
WDS	Water Distribution System
GIS	Geographic Information System
GPS	Global Positioning System
UNDP	United Nation Development Programmes
UTM	Universal Traverse Mercator
TIFF	Tagged Image File Format
NCRS	National Centre for Remote Sensing
PSWB	Plateau State Water Board
NPC	National Population Commission
ESRI	Environmental System Research Institute
RDBMS	Relative Database Management System
WELL	Water and Environmental health at London and Loughborough.
JMDB	Jos Metropolitan Development Board

ABSTRACT

In recent times, domestic water scarcity was severe in Gyel district area of Jos South Local Government in Plateau state, as the water supply from the source has not kept pace with the population increase, this existing problem has necessitated the study to examine the spatial analysis of access to domestic water supply in the area. The research involves the use of Satellite data, coordinates of various source of domestic water and their attributes, population data coupled with a structured questionnaire and photographs from field in achieving the objectives. Spatial analytical method such as; Density and Proximity analysis were used to examine the objectives with the aid of ArCGIS 10.3 tool in Mapping and Geo-processing, while SPSS and Microsoft software were used for computing the Statistical analysis. Thus, the result obtained was; Hand dug well has the highest frequency of coordinates among the public water source, supported with the 60% of the respondents who used it as their primary source of domestic water supply. The pattern of the distribution of water supply facilities were found clustered around the city centre and well planned cadastral area, this exert serious effect on access to the source especially on those within the unplanned and newly developed area as only 32% of the respondents has access to the public domestic water source. Most of the built-up area which constituted the households falls within the basic access and No-access level were the standards for domestic water usage are not met, 71% of the respondents asserted that there is a problem of water scarcity as a result of distance and time travelled, Inconsistency of supply and seasonal effect from the source. Therefore, the following recommendations were suggested, which are; Encouragement for the provision of more domestic water source by the Plateau State Water Board (PSWB), Private sectors and Individuals, The Jos metropolitan development board (JMDB) should ensure built-up area adopt town planning standard and the PSWB should ensure periodic extension service of water supply facilities in the area.

CHAPTER ONE
INTRODUCTION

1. 1 Background to the Study

Water as a vital resource in the environment, has unique characteristics which makes it a desirable resource, As a universal solvent, There is no life without it, no economic production, no environment. There is no human activity that does not depend on water. (Savenije and Vanderzaag, 2002*)*. About 97% of water on earth has high saline content while only 3% is assumed to be safe for human consumption (Oguntoyinbo 1983). Water makes life possible as without it; life and civilisation cannot develop or survive. As man's standard of living increases; so does his need for consumption of water. It is therefore not surprising that early civilisations flourished around river valleys such as those of the Nile in Egypt, Indus in India, Hwang Ho in China and Euphrates and Tigris in ancient Mesopotamia (Ayoade 1988).

Adequate and safe water supply is one of the basic services, which influences economic progress of human settlements and the health of the dwellers. Although household water demands constitute the least water use in the world, which is about 6% (Cunningham and Cunningham 2004), it is however, a use that has no clearly defined substitute. It is thus a critical demand that is not negotiable. This is because domestic water use, including drinking, cooking, washing and general sanitation which entails a number of health implications. In many parts of Africa, domestic water supply is mainly the function of different traditional water supply sources; which often poses challenges to Households as supply is affected by such factors like income, household size and distance. The impact of inadequacy, manifest strongly on households in terms of time and distance taken to obtain water.

In modern times, there is a close relationship between water availability and economic development, especially in the developing countries (Warner, 1995). According to World Health Organisation (WHO, 2003). domestic water is water used for all domestic purposes which include drinking, cooking and bathing. Therefore, when measuring adequacy of water in the household all such uses should be considered. Bustamante *et al.*,(2004) defined domestic water as the water needs of families for drinking, cooking, washing and sanitation/hygiene.

According to Robinson *et al*., (2004), it is not only water quality but also water quantity that is important in achieving health improvements, and quantity in turn is dependent on accessibility. The benefits of improved water supply and sanitation are many, including prevention of disease, improved basic health care, better nutrition, increased quantity and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing, and generally improved quality of life (Okun 1988).

According to Cairncross and Feachem (1993) the need for domestic water supplies for basic health protection exceeds the minimum required for consumption (drinking and cooking). Additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry. Poor hygiene may in part be caused by a lack of sufficient quantity of domestic water supply which depends on the level of accessibility and efficiency of the existing facilities, in this case accessibility plays key role in domestic water supply.

According to WHO (2004), access revolves around distance and time indices. These indicators show four (4) paramount levels of accessibility; No access, for the worst scenario; Basic access; Intermediate access and Optimal access all on the basis of time and distance. Adeyemo and Afolabi (2006), defined accessibility as the balance between the demand for and the supply of consumer services over a geographic space, and narrowing or bridging the gap between geographic spaces is all about the significance of transport. Spatial technology refers to technology used for estimation, measurement, analysis and visualization of features or phenomena that occur on the earth, this includes various technologies specially related to mapping features on the surface of the earth (Thakur *et al.*,2011). Integrating Geographic Information System database can provide utility managers reliable and scientific support decision making on water distribution network management and rehabilitation (Soakodan *et al*., 2011). Urban drinking water supply network is made of over ground and underground intake, pumping, improving the quality of the water, storage and transport to the user's connections in GIS environment (Pandure, 2006).

Population explosion and resulting demand of appropriate infrastructure facilities are posing serious challenges for administrators and planners. Technology has emerged with solution of sustaining data on existing utilities. Obviously, effective management and planning requires updated maps and information and recent developments in the area of science and technology like GIS, Global Positioning System and Remote Sensing have come up as powerful tools. These advanced technologies can effectively be used to handle the present complex problems related to optimum utilization of available resources and infrastructure. Today, it is possible to produce accurate mapping of the underground infrastructure facilities like electrical & telecommunication cables and water pipelines (Rana, 2011).GIS can be applied in the entire lifespan of water supply systems from planning to implementation, operation and maintenance to replacement for the prime reason that GIS provides a variety of support in asset inventory (keeping record of pipes, valves fittings, and meters together with their characteristics and status); determining and prioritizing repair and replacement works; and closing valves to redirect water flow (Soakodan *etal*., 2011). It has been proved that GIS is a competent and effective tool for managing networks (Zhang, 2006).

1.2 Statement of the Research Problem

In 1990,265 million lacked access to safe water out of the 500 million people living in sub-Saharan Africa, this situation is worse in some drought affected area (WHO and UNICEF1990), More than 1.1 billion people in low and middle-income countries (representing about one in every five people) lack access to clean, safe drinking water (Mercy Corps,2006). In Nigeria, water availability controls population distribution as settlements that are provided with modern water supply networks are usually those situated along the major trade and transportation networks and all improved water supply in Nigeria is from public water supplies (Oyebande, 2005). Though the pattern of water supply varies from one settlement to another, generally as the population of a settlement increases, the service efficiency to the expanding population decreases. 58% of Nigerians have access to safe water (WHO and UNICEF, 2012). Thus, most households have to source drinking water from wells and streams especially in the rural and suburban communities.

Hassan *et al.*,(2013) worked on groundwater supply in Jos-East Local Government Area of Plateau state, and found that; there was a significant relationship between distance to improved groundwater source and the time taken to collect water, while no significant relationship, statistically exist between frequencies of visits to improved groundwater supply source, quantity collected daily per household. Also Chia *et al.*, (2014) investigated the various sources of water available in Makurdi metropolis, the state capital of Benue State and its distribution across the various wards, its availability and frequency, and confirms that the problem of water supply in the area is affiliated to the increase in the demand for water against the inadequate supply of water due to insufficient power supply and problem of inadequate pumping infrastructure, in which area closer to the water board service have more water supply than areas far away.

According to (PSWB,2014) Report, 250 cubic metre of domestic water is demanded but only 90 could be supplied whereas the Shen dam as the major source of the water constructed since 1972 to serve 450,000 people is still the dam serving about 3.3 million people in Jos and environs, despite the effort of government in the construction of domestic water supply management schemes for both the state and the local levels for the benefit of the communities available record shows that less than 20% access to safe and adequate water supply source, this shows that the demand for domestic water is far greater than the supply which accessibility to the source is the key factor.The study area is experiencing increasing population resulting in increase in residential houses and urbanisation generally, but water supply pipelines exist only along the major road and do not extend to the new areas, most of the residents are faced with the problem of scarcity of water supply for domestic uses, also from the recent reconnaissance survey, it was noticed that there was problem of water scarcity as a result of increase in time to collect water because of the distance.

This research used spatial techniques in mapping, examined the source, the pattern and level of access to domestic water supply in the sampled communities of the study area as well as creating geo-database and the use GIS techniques such as density and proximity analytical techniques to analyse the pattern and level of accessibility to domestic water supply source, which assist the local community dwellers, planners and government in solving the complex issue in the study area. Despite the findings from the related studies, the methodology was not well utilized among the researcher, planner and local communities, as little attention has being given to the spatial analysis of access to domestic water supply in this study area, therefore the research also contribute to the knowledge of both researcher, planners and local community authority in the use of spatial analytical techniques through identifying, mapping, examining the pattern and assessing it's impact on accessibility to the source as well as the quantity of water used, this also provide idea for the policy makers in both the state and local level to improve their decision on domestic water supply service. Therefore, the study addressed the following research questions:

i. Where are the sources of domestic water supply?

ii. What is the pattern of domestic water supply?

iii. What is the level of accessibility of the domestic water supply in the study area?

1.3 Aim and Objectives

The aim is to examine the spatial analysis of access to domestic water supply source in Gyel, District area of Jos plateau state, Nigeria.

The aim of the study was achieved through the following objectives, which are to;

i. identify and map domestic water supply sources in the study area

ii. examine the existing pattern of domestic water supply source in the study area

iii. assess the level of accessibility to domestic water supply source in the study area

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1.4Scope of the Study

This research work analysed the spatial distribution and pattern of domestic water supply source and its level of accessibility within Gyel district of Jos South Local Government Area (LGA)in Plateau State using remote sensing, geographic information system, global positioning system and statistical techniques in analysing the data, the study also covered the total population size as well as land cover of the area, which is absolutely located between latitude 9° 46'0" N and 9° 54'0"N, north of the equator and longitude 8°48'0"E and 8°52'0"E and relatively bounded in the north by Tudun wada and Holwse in Jos north LGA, while in the south by vom district, west by Bassa LGA and in the east by Dadin kowa,Whytt and Rahol kanan respectively, and the field work was carried out within the period of January to November, 2016 covering both dry and wet season.

1.5 Justification of the Study

Many of the urban utilities like water mains, streets, sewer lines, were planned and constructed based on the population distribution and economic development at the time of establishment. Consequently, the infrastructures and utilities may encounter stress or potential stress as the impact of spatial patterns of population distribution and economic development change with time. There are diverse sources of supply of domestic water supply in rural and urban areas. These include; conventional communal sources and self-supply sources. The conventional communal sources are justified for improved water quality and use of high level technology like drilled boreholes equipped with hand pumps, collection tanks and protected springs as well as concrete lined wells (Carter *et al.,* 2005). However, the conventional communal facilities in most of the rural areas in the developing countries have been proved not to be sustainable because of their high rate of breakdown as a result of poor operation and maintenance, congestion, difficulty in operating the pumps and long distances because sources are too few and yet rural households are many and scattered (Brett *et al.,* 2007)

To ensure that rural households are water secure, it necessary to evaluate the number, geographic location, yield, dependability, season and quality of the water sources (Kahinda *et al.,* 2007). Besides, equipping people in rural communities with appropriate technologies and skills to enable them harvest rain water and excavate underground water together with effective management of these sources can provide sustainable solutions to the problems associated with the scarcity of domestic water supply in rural households (Malley *et al.,* 2008).

The study on spatial analysis of access to domestic water supply sources in the area has received little or no attention. Because, this research gives more insight on the use of spatial techniques in solving reality of complexities on access to domestic water source through mapping and creating of geo-database which assist to create awareness in both government and individual on proper distribution and management of this resource, thus, GIS can analyze possible planning alternatives more quickly, giving decision makers better choices (Kumar *et al.,*2002).

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter defines the conceptual framework and reviews relevant literatures related to Spatial Analysis of access to domestic water supply.

2.2 Theoretical framework

2.2.1 Domestic water

World Health Organization (WHO) defines domestic water as being 'water used for all usual domestic purposes including consumption, bathing and food preparation, It also defines domestic water as a residential water which is used for household purposes, such as drinking, food preparation, bathing, washing clothes, flushing toilets, watering lawns and gardens (WHO, 1993; 2002).

There are diverse sources of domestic water supply in rural and urban areas. These include; conventional communal sources and self-supply sources. The conventional communal sources are justified for improved water quality and use of high level technology like drilled boreholes equipped with hand pumps, collection tanks and protected springs as well as concrete lined wells (Carter, *et al.*, 2005). According to Felix and Olusola (2016), the possible sources of water for domestic consumption in any developing country such as Nigeria include: Surface flowing rivers and streams, lakes, shallow wells, deep wells or boreholes and pipe borne water.

White *et al.*, (1972) suggested that three types of use could be defined in relation to normal domestic supply which includes: consumption (drinking and cooking), hygiene (including basic needs for personal and domestic cleanliness) and amenity use (for instance car washing, lawn watering). Jiang (2004) indicated household water use was divided into six main categories: hygiene uses; include shower, washing (e.g. washing hand, face, brush teeth), drinking water, flushing toilet, washing machine, kitchen uses: include cooking, washing dishes and amenities: watering flowers. Thompson (2001) mentioned four main types of water use in a typical urban East African household: consumptive uses (i.e., drinking and cooking), hygiene uses (i.e., bathing, washing clothes, cleaning and toilet flushing), amenities use (watering lawns, car- washing, gardens-watering and other non- essential tasks) and productive uses (watering livestock, the construction of homes and beer-brewing).

2.2.2 Domestic water usage standard

Residential water use standards vary with climatic conditions, life style, culture, technology and economy. A water use standard was identified about thirty-nine years ago, the United Nations (1977), determined the concept of a water use standard to meet people’s basic need for water. This stated that all people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs. The UNDP (2008) stated that, the minimum absolute daily water need per person per day is 50liters which include: 5liters for drinking, 20liters for sanitation and hygiene, 15 liters for bathing and 10liters for preparing food.

2.2.3 Access to domestic water source

WHO (2000) defines the term reasonable access to a water source as the "availability of at least 20 liters per person per day (Liter/capita-day) from a source within one kilometer of the user's dwelling. Nigeria has high level of urbanisation and population growth in both the urban and rural areas. Water should be distributed in Water Distributed System (WDS) by the land used method, which is the most accurate method, which fixed appropriate way of fixing the desired demand to the nodes. The nodes that is sensitive to the land use categories to simulate accurate computer modelling of the water system. This method uses the areas of current land use categories, which are defined in the areas of master plan and average water demand coefficients.

Water supply assessment in urban and suburban regions is one of the key issues of sustainable economic development. Many of the urban utilities like water mains, streets, sewer lines, were planned and constructed based on the population distribution and economic development at the time of establishment. Consequently, the infrastructures and utilities may encounter stress or potential stress as the impact of spatial patterns of population distribution and economic development change with time (Goulter and Kettler 1985, Foxon*et al.,*2000). However, the conventional communal facilities in most of the rural areas in the developing countries have been proved not to be sustainable because of their high rate of breakdown as a result of poor operation and maintenance, congestion, difficulty in operating the pumps and long distances because sources are too few and yet rural households are many and scattered (Brett*et al.,* 2007, Singh *et al.,* 2004).

In ensuring that rural households are water secured, it is necessary to evaluate the number of geographic location, the yield, dependability, season and quality of the water sources (Kahinda, *et al.,*2007). Besides, equipping people in rural communities with appropriate technologies and skills to enable them harvest rain water and excavate underground water together with effective management of these sources can provide sustainable solutions to the problems associated with the scarcity of domestic water supply in rural households (Malley, *et al.,* 2008). Moreover, access to clean portable water has significant effect on sanitation and public health. Table 2.1 indicates the likely quantity of water that will be collected at different levels of service.

Table: 2.1.Service level descriptors defined by distance and time to water source.

Service level	Distance to source and collection time	Approximate total quantities collected
No Access	Less than 1000 m Less than 30 min total collection time	Very low, Less than 5 Litres
Basic Access	Between100 – 1000 m Between 5 – 30 min	Low, Unlikely to exceed 20 Litres
Intermediate Access	On-plot e.g. single standpipe on compound or in house	Medium, around 50 Litres
Optimal Access	Multiple taps in house	Varies likely to be 100 L/capita-day and possibly up to 300 Litres

Source: Taken from Howard and Bartram (2003).

2.2.4 Domestic water demand

Although household water demands constitute the least water use in the world, which is about 6% (Cunningham and Cunningham, 2004), it is however, a use that has no clearly defined substitute. It is thus a critical demand that is not negotiable. This is because domestic water use, including drinking, cooking, washing and general sanitation which entails a number of health implication. However, collection time and distance to the source are found to be significant driving force of household choice of water source (Mu, Whittington and Briscoe, 1990). Also, thechoice of water source is found to be driven by piped water pressure level (Madanat and Humplick, 1993) and by opinions about taste and reliability of water,if service from a piped connection is available for longer hours, water use by connected households increases (Nauges and Van den Berg,2009). However, the magnitude of the effect is found to be quite small, extra hour of piped water availability would increase per capita consumption of households.

2.2.5 The effect of access on domestic water quantity

Cairn cross (1987) provides an example from Mozambique that demonstrated that water consumption in a village with a standpipe within 15 minutes was 12.30 litres per capita per day compared 3.24 litres per capita per day in a village where it took over five hours to collect a bucket of water. However, the difference in time points to the influence of only gross differences in service level, in this case between effectively no access and a service level that can be described as basic access. Reviewing several studies on water use and collection behaviour, He suggests that there is a clearly defined general response of water volumes used by households to accessibility, shown in Figure 2.1.

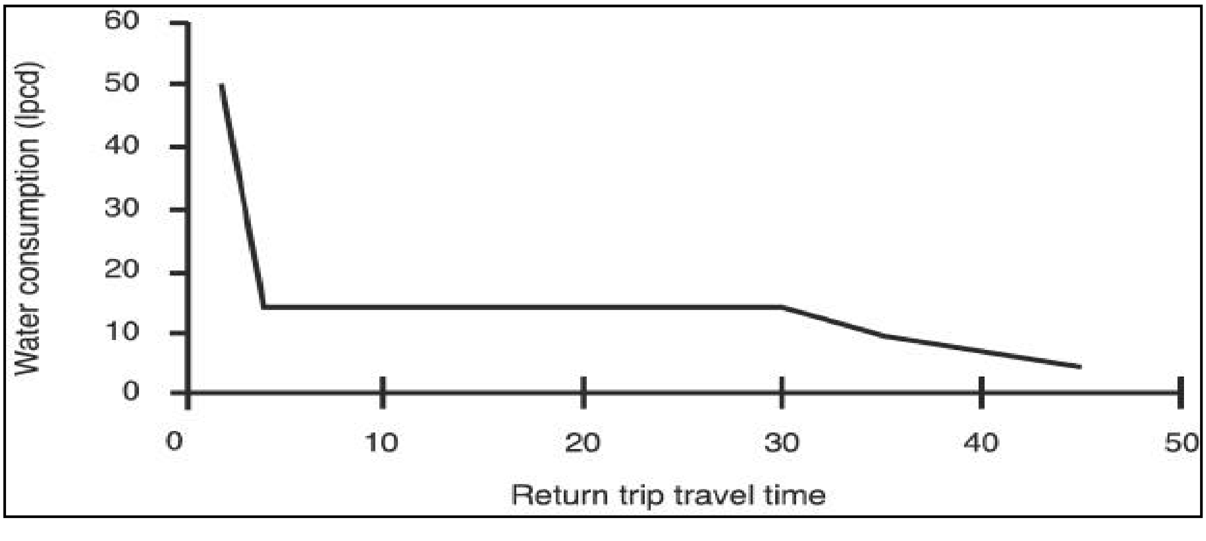

Figure 2.1: Graph of travel time (in minutes) versus consumption
Source: Adopted from WELL, (1998)

Figure 2.1 shows that, once the time taken to collect water source exceeds a few minutes (typically around 5 minutes or 100m from the house), the quantities of water collected decrease significantly. This graph contains a well-defined ‘plateau’ of consumption that appears to operate within boundaries defined by distances equivalent to around 100 to 1000m or 5 to 30 minutes collection time. Which indicated that there is little change in quantity of water collected within these boundaries according to Cairncross and Feachem, (1993) that is, beyond distance of one kilometer is more than 30 minutes total collection time, quantities of water will be expected to further decrease.

2.2.6 The use of spatial techniques in domestic water management

Extensive spatial analytical capabilities have become widely applied in the infrastructure sector since its introduction in the 1960s. Spatial technology refers to technology used for estimation, measurement, analysis and visualization of features or phenomena that occur on the earth, this includes various technologies specially related to mapping features on the surface of the earth (Thakur,*et al.*,2011).Groot and McLaughlin (2000) pointed out that geospatial data can be referred to data that identifies the geographic location of features and boundaries on earth, such as natural or constructed features, oceans, and more. It is usually stored as coordinates and topology, and is data that can be mapped. Geospatial data is often accessed, manipulated or analyzed through Geographic Information Systems. They linked geospatial data to geospatial data infrastructure, to encompass the networked geospatial databases and data handling facilities, institutional, organizational, technological, human and economic resources that interact with one another and underpins the design, implementation and maintenance mechanisms that facilitate the standardization, sharing, access to and responsible use off geospatial data at affordable costs for a specific application domain or enterprise.

Integrating GIS database can provide utility managers reliable and scientific support decision making on water distribution network management and rehabilitation (Soakodan,*et al.*, 2011), GIS is applied in four sections of the water infrastructure sector: asset management, distribution management, customer and outage management (Brussels, 2005). It is ideal to manage infrastructure by integrating all the information systems within a section. GIS is further applied in the entire lifespan of water supply systems from planning to implementation, operation and maintenance to replacement. This is because GIS provides a variety of support asset inventory (keeping record of pipes, valves, fittings, hydrants and meters together with their characteristics and status); determining and prioritizing repair and replacement works and to be able to excavate and replace a damaged pipe at the exact route and depths required. This has the advantage of preventing waste of resources when buried pipes can be traced, of which Geographical Information Systems(GIS) data can be used to solve it, Moreover, service continuity can be ensured by limiting repair and maintenance time through spatial scenario modeling, locating areas affected by particular problem and informing the affected area.

In summary spatial technology provides quick answers to many issues regarding domestic water distribution network such as: provision of service, planning and maintaining network infrastructure, managing existing customers, finding new customers and administering network coverage.

2.3 Review of Related Studies

MacDonald, Dochartaigh and Welle (2009) mapped water and sanitation in Ethiopia. ArcGIS was used to come up with spatial distribution of water location in the three Wards which are, Woredas, Benishangul and Gumuz in Ethiopia which was subsequently overlaid on vectorized hydro-geological map of the region. The results revealed that hand pumps failure in this region were that of the reduced yield of the aquifer and deep seated water level during the dry season. The study also informed the planners of the need to channel more funds for the maintenance of the schemes in the affected areas.

Matheaus *et al.,* (2017) assessed the challenges and opportunities of community water supply systems in Wote Town, Makueni County, Kenya. The study employed a Survey Research Design (SRD), primary and secondary data were collected by use of questionnaires, interviews, photography and use of GIS. On average it was found that it took 22 minutes to fetch water from the preferred source located at a mean distance of 0.94 kilometers. About (35.8%) of the respondents used head log and (32.2%) bicycles which were the most used modes of transport. Others include use of donkeys, water boozers and motorcycles. More than half of the residents who drew water from River Kaiti used it for selling. The price ranged from US$ 0.10 to US$ 0.26 per 20-liters Jerrican. The residents reported some cases of water borne diseases such as diarrhea (23.1%) and typhoid (15.4%). Most preferred water treatment methods were boiling (23%), use of water guard (13%), and chlorination (3.3%) while majority (76%) did not treat the water before drinking.

Tao and Gregory (2007) conducted a research on spatial analysis of household water supply and demand in a distributed geographic network in the towns of Amherst and Clarence, New York**.**

Spatial network models were constructed in Geography Information Systems environment for simulations. Baseline data of household water consumption per person per day, their population distribution and transportation capacity of water main utility lines was collected for the model simulation in ArcGIS environment. The results indicated that as the network extended eastward, southeast part of the Amherst and three of the four sub-regions in the Town of Clarence encountered the discrepancy of supply capacity in meeting the accumulated household water demand.

Wafula and Ngigi (2015) analyzed GIS based supply and forecasting piped water demand in Nairobi. The study uses GIS based regression model, that is geographically weighted regression(GWR) and ordinary least square (OLS) to forecast monthly water demand in the western region of Nairobi Water Supply System. Vector dataset (spatial) of the study region by itinerary levels and statistical data (non-spatial) on water consumption, household, building density, land value, connections and population data were used in this exploratory analysis. The result shows that GWR is a significant improvement on the Global model. Comparing both models it reveals that for the former, the value is reduced from 2801 (for OLS model) to 2694 (for GWR model). For the latter, OLS explained 83.46 percent while GWR explained 91.16 percent. The results of the study show that the GWR model is capable of predicting water demand more accurately than OLS regression model. This implies that local model's fitness is higher than global model.

George, George and Jacob (2010) assessed accessibility of water services in Kisumu municipality, Kenya. Based on cross sectional survey and purposive sampling of 367 households, they examine the level of accessibility to privatized water services in Kisumu

Municipality. The study shows that the proportion of households with access to piped water supply within a distance of 200 m is 77.1%, only 65.6% of the basic water requirements of the residents are met and that only 25% of the households access the minimum recommended 50 l/c/d. The low income households and low levels of investment in water infrastructure are related to reduced access to water services. The researches recommended that new water ethics and demand based service delivery should also be adopted for better management and services.

Atser and Udoh (2014) assessed dimensions in rural water coverage and access in Akwa-Ibom State, Nigeria. Four spatial factors of total length of road infrastructure in the local government area, total area in square kilometers, poverty index, and rural population were used to investigate their influence on the number of safe water points among the Local Government Areas. All the four independent variables were surrogate to rural development. However, the result showed that only the rural population factor was highly significant and correlated with the number of safe water points in the state ($r = 0.678$; $r^2 = 46\%$), implying that about 46% of variance in number of safe water points was explained by rural population.

Odafivwotu and Abel (2014) investigated access to potable water supply in Yenagoa Metropolis, Nigeria. In achieving the aim, 15 borehole water samples were collected from 15 neighborhoods, which the metropolis was structured. A total of 375 copies of questionnaires were randomly distributed in these neighborhoods using the systematic sampling technique. The analyses revealed that both the quality and quantity of water supply in Yenagoa were inadequate. The turbidity values (20.70-41.20 NTU) in all the sampled water were above the WHO 5 NTU threshold; while 7 (46.67%) samples had pH values below the WHO minimum value of 6.5, indicating acidity. Similarly, iron and lead also had 4 (26.67%) and 3 (20%) samples above the WHO thresholds of 0.3mg/l and 0.01mg/l respectively. It was also found that inspite of the proliferations of wells and boreholes, and the short distances to sources of major water supply, 29.28% of sampled respondents used below 20 litres of water per capita per day. This is mainly attributed to the high cost of water supply (average of N4, 500 per month) in relation to the monthly minimum national wage of N18, 000.

Enoch and Issaka (2015) conducted a situation analysis of access to household water supply in the Wa Municipality, Ghana. This study highlights several important issues on access to water supply focusing on availability, accessibility and cost. Clustered sample of residential areas of the municipality was employed and the study was able to examine spatial disparities in access to water supply. The results obtained shows that access to potable water supply in the municipality is generally high as only 13% of households depend on open wells as their main source. Also, the private sector is major driven factors in public water supply in the municipality. In spite of the progress made in access to potable water supply, distance and cost of water remain serious challenges confronting households. The study recognizes that private individuals create additional water facilities to augment public supplies in Wa Municipality.

Uwem, Jacob and Samuel (2015) analyzed and depicted accessibility levels of water schemes in rural areas of AkwaI-bom State, Nigeria. Data used were of rural water schemes, population data as well as community map of the study area. GIS technique was employed in creating a personal database of water schemes and the spatial distribution of the water schemes were displayed on the map. Based on the criteria stipulated in the National Water

Supply and Sanitation Policy for Nigeria, percentage rural water accessibility map was computed and analysed using ArcMap software extension. The findings revealed discrepancies in the sitting of water facilities and gradual phasing out of hand pump boreholes to mini water schemes. Lack of community boundary map is a setback to rural water scheme implementation. Percentage access to safe water supply was found to be very low.

2.4 Knowledge Gap Identified

The research aimed at using spatial analytical method which include; Global Positioning System (GPS), Density and Proximity analysis with the aid of Satellite data, Coordinates of various public domestic water source, Population data through structured questionnaire and photographs from the field in describing the pattern of water supply source distribution, levels of its accessibility and the effect on the quantity used. To the best of my knowledge this method has not been used to address the problem in this area as reviewed by the related literature in this work, and this will help the Plateau State Water Board and other related sectors in planning and decision making on how to solve the complex problem of domestic water supply in the area.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Introduction

This chapter deals with the study area, and methodology used in the research, the nature and type of data used in achieving the objectives.

3.2 The Study Area

3.2.1 Location and size

The study area (Gyel District) is absolutely located between latitude 9° 46'0" N and 9° 52'0"N, north of the equator and longitude 8°48'0"E and 8°52'0"Eand is relatively bounded in the north by Tudun wada and Holwse in Jos north LGA, while in the south by vom district, west by Bassa LGA and in the east by Dadin kowa,Whytt and Rahol kanan respectively**,** in Jos South Local Government Area of Plateau state which covers the total land area of 81.9km/sq approximately.

3.2.2 Climate

Ojo, Gbuyiro and okoloye (2004) asserted that the influence of the oscillation of the Inter Tropical Discontinuity (ITD) is completely modified by the high altitude of the Plateau. The area has more cold weather than most parts of Nigeria on the same latitude**,** It is characterised with an Average monthly temperatures range between 21–25 °C, these cooler temperatures have made it a semi-temperate like area. It receives about 1,400 millimetres rainfall annually between April and October with the precipitation arising from both conventional and orographic sources, owing to the location of the area.

3.2.3 Geological setting

Gyel district is an area of Younger Granite intruded into the older basement complex rocks which covers the entire locality and other neighboring localities. These younger granites are thought to be about 160 million years old. This creates unusual scenery of Jos. There are numerous hilly rocks with gentle slopes, characterized by a long period of weathering and erosion (Iloejo, 1981).

3.2.4 Soil

According to Iloejo (1981), two soil types can readily be identified at the superficial level. These are the sandy loam and grey loam soils. Most Soils are stony, fertile and hard to work on for the agriculturalist. This seems to result from the washing away of the top soil by denudation processes. The major soil is characterized by tropical ferruginous soils, which comprises of hills rock outcrops containing younger granite rocks extensively intruded into the older basement complex rocks characterized by a long period of weathering and erosion

3.2.5 Relief and Drainage

Omotosho (2007) asserted that the average elevation of the Jos Plateau is about 1150 meters above mean sea level and the highest peak on the Shere hills which is about 1777 meters above sea level. However, the area is dominated by relief average altitude of 1,217m, with depressions which pave way for drainages adjoining the plain area.

Also according to Adams (2000), the drainage pattern on the area is in a radial pattern where the many rivers and streams diverge from the top of the plateau and flow away to different directions, some of the streams drain into river Ganawuri and Kaduna

3.2.6 Vegetation

The dominant vegetation is the montane type due to the undulating terrain characterized by shrubs and tall grasses; there are varieties of economic trees, like mango, cacti, gmelina, eucalyptus which were artificially grown and also, cultivated land within the communities, (Iloejo, 1981).

3.2.8 People and socio-economic activities

The population of the area was 145,750 from 2006 population census conducted, it comprises 24communities mostly dominated by the Berom, Hausa, Yoruba, Ibo and other minor tribes from within and outside plateau state which most of them are Christians combined with the Muslims, The area is known for vegetable farming, animal grazing; Rock quarrying, Tin Mining activities and marketing, (Barbour, 1982).

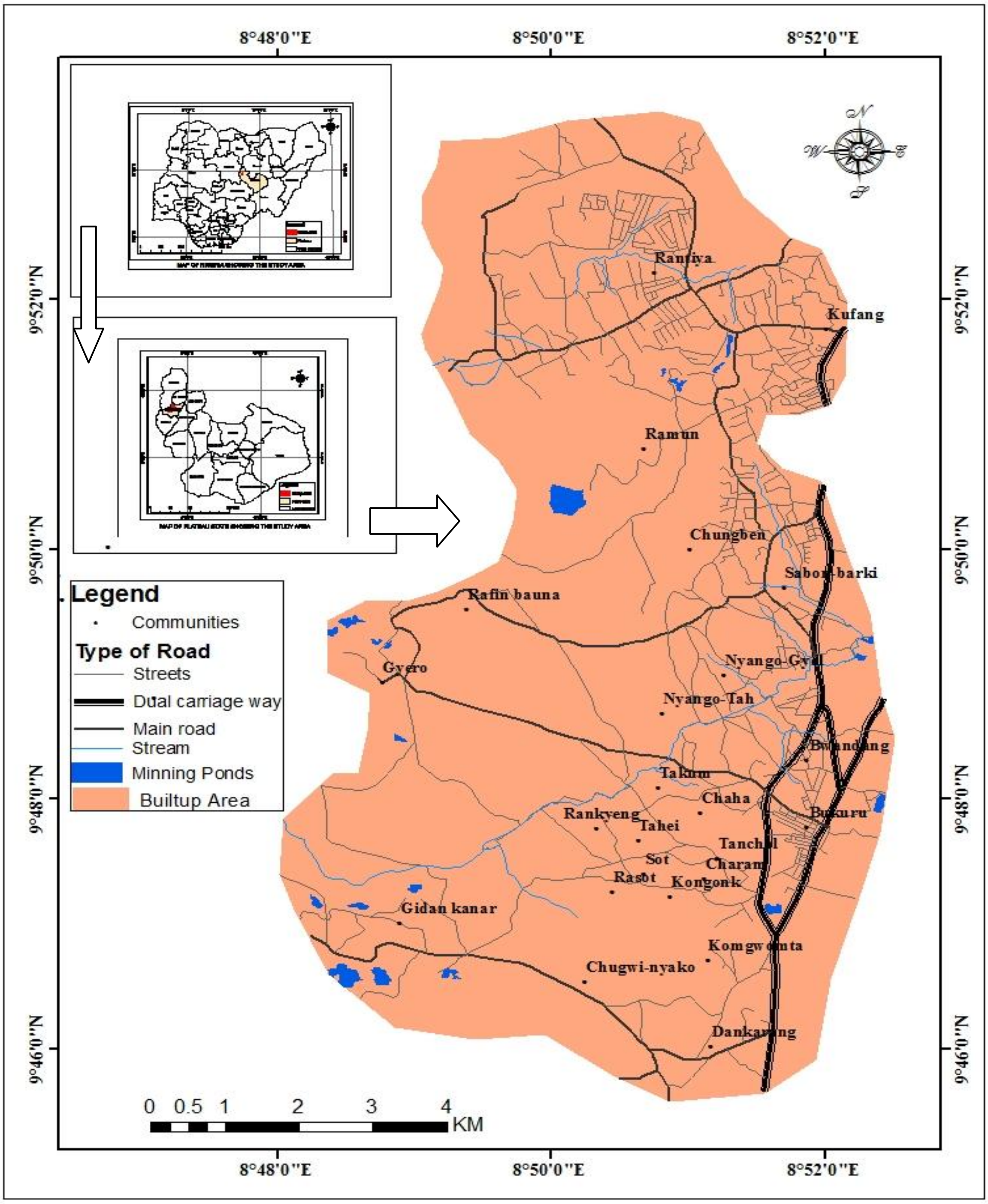

Figure 3.1: Study area

Source: Modified from Quickbird Satellite Image 2015

3.3 RESEARCH METHODOLOGY

The Figure 3.2 show flow chart for methodology used in achieving the objectives of this research work.

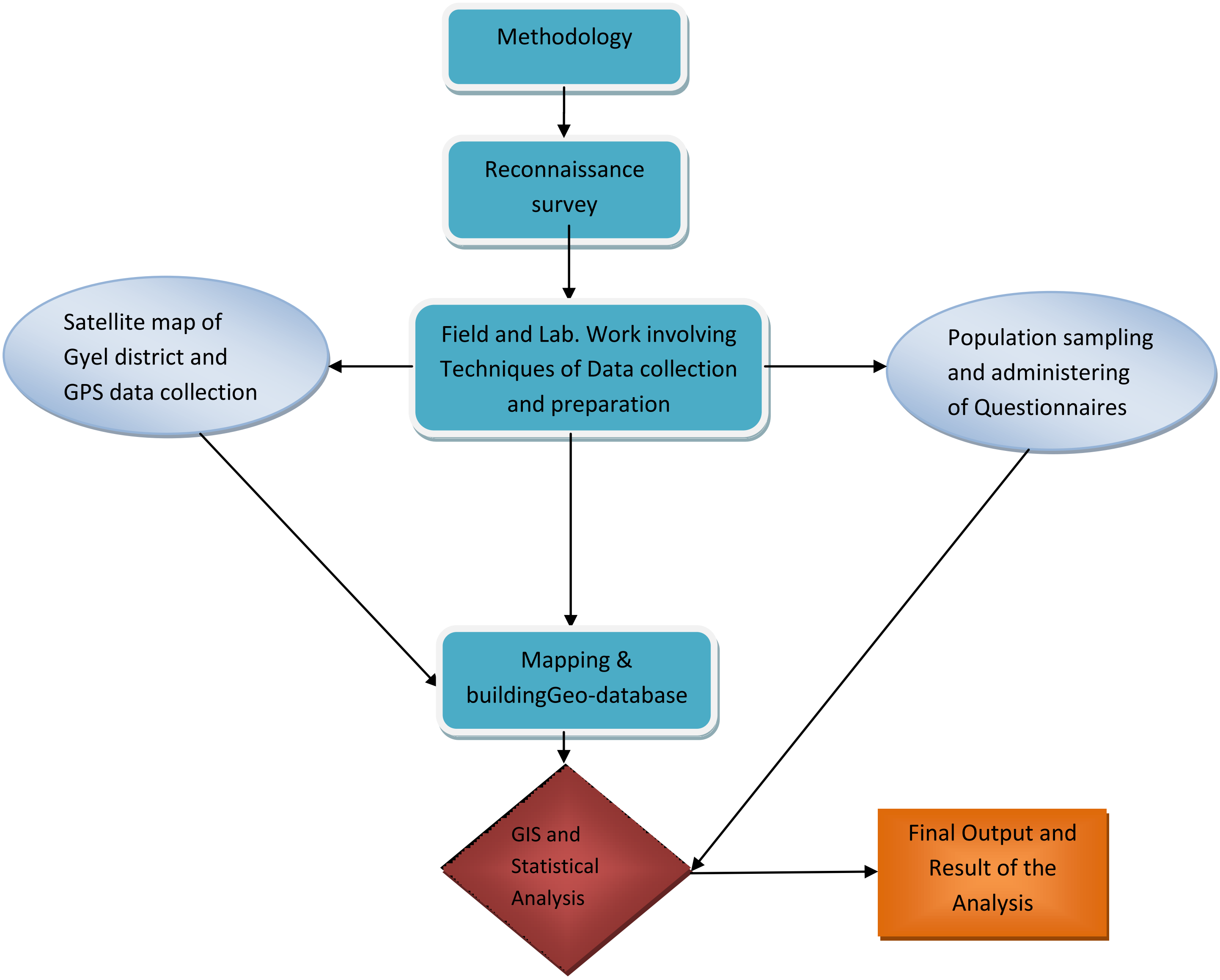

Figure 3.2: A Flow Chart for the Methodology
Source: Compiled by the Author (2014).

The procedure for achieving the research started from reconnaissance survey, then, the use of satellite image, GPS data and population sampled through the use of structured questionnaire, followed by mapping and building of geo-database used for GIS analysis coupled with the statistical analysis to yield the result.

3.3.1 Reconnaissance survey

A reconnaissance survey was carried out January,2016 to familiarized with the study area, followed by detailed field work which commenced February 2016,which include the collection of the necessary ancillary data like Satellite image, Population data, administering of questionnaires and acquaintance with the staffs of the plateau state water board, Tracing and collecting the GPS points of various domestic water source, retrieving of the questionnaires ,taking of photographs and observations which was rounded up by November,2016.

3.3.2 Data used and source

Data used in the research work and their source include;

Table 3.1: Data used

Data used	Data source
Coordinate of Public Reservoirs, hand dug well, water supplying pipes network, bore holes and water hydrants	Field work and plateau state water board, Jos
Quick bird satellite image (0.6 m resolution) of 2015	National centre for Remote sensing, Jos
Population data.	National population commission, Jos
Photographs of the current situation of water supply source	Field work
Statistical data	Questionnaires administered
Journals and other published documents on water supply	Library and Internet

3.3.4 Methodology and data pre-processing

This include geo-referencing, delineating the study area using the data collected to create of geo-database and feature classes which were digitized into map format used for the spatial analysis

3.3.4.1 Geo-referencing of all maps to common coordinates

All the maps acquired were properly geo-referenced in ArcGIS software and Geo-corrected to a common Projection System (UTM, Clarke 1880), and to a common Geo-TIFF data format. The maps were also geo-coded to a common resolution with the quick bird satellite image at a resolution of 0.6m to ensure both compatibility and data standard.

3.3.4.2 Shape-file for the digital map of the study area

A shape file was created in ArCGIS to delineate the boundary of the study area and to show the extent of features necessary for the research analysis.

3.3.5 Sampling technique and size determination

Stratified random sampling techniques was adopted for the administering of the questionnaire for the study, A total number of three hundred and eighty four (384) questionnaires were distributed, in which the entire 24 communities within the study area covering both the urban and rural area were randomly and proportionally represented with the total population of 145,750, using the formula by Krejcie and Morgan (1970);

$$n^1/n \quad x \quad N \quad = \quad N^1/N \quad x \quad Q \qquad (1)$$

Where n^1: Sampled population for individual community

n :Sum total for the population of the whole sampled communities

N^1: Sampled proportion for individual community

N: Proportion of the sample size which is 100%

Q: Total Questionnaire Administered 384

Table 3.3 List of Sampled Communities in Gyel District and Number of Questionnaires Allocated

S/N	Sampled Communities	Population Size	Population Proportion (%)	Numbers of Questionnaires Allocated
1	Bukuru	95535	65.5	252
2	Rantiya	6103	4.2	16
3	Rankyang	5166	3.5	14
4	SabonBarki	3548	2.4	9
5	Gyero	3283	2.3	9
6	Gidankanar	3037	2.1	8
7	Kufang	3216	2.2	9
8	Tanchol	3436	2.4	9
9	Sot	2447	1.7	7
10	Rasot	2080	1.4	5
11	Nyangogyel	2755	1.9	7
12	Ramun	2381	1.6	6
13	Dan karang	2276	1.6	6
14	RafinBauna	1316	0.9	4
15	Chugwi-nyako	1476	1.0	4
16	Gwandam	1158	0.8	3
17	Chaha	802	0.6	2
18	Kongonk	992	0.7	3
19	Takum	939	0.6	2
20	Chunben	883	0.6	2
21	Kogwomta	875	0.6	2
22	Chararam	802	0.6	2
23	Tahei	434	0.3	1
24	Nyango-tah	620	0.4	2
Total	24	145,750	100	384

Source: NPC Office Jos, 2006 National Population Census

3.3.6 Data collection

This involve reconnaissance survey, the use of questionnaire, during the field work, in which 384 questionnaires were distributed to households and 263 retrieved back, Oral interview were conducted couple with personal observation to gain more insight on domestic water supply in the study area also the use of GPS receiver to collect the coordinates of various water facilities and digital camera for photographs. The coordinates of the following public water supply source were collected from the field, which include; pipe-borne taps, hand dug wells, boreholes, reservoirs and water supplying pipes which were transformed in excel sheet and imported to ArCGIS 10.3 environment to create the geo-database.

3.3.7 Creation of Geo-database

ArCGIS 10.3 version was used to create a file geo-database for this research work, which consist of Built-up area, Road network, water supplying pipe network, public reservoir, taps, boreholes, hand dug well, water hydrant, stream and ponds feature classes within Gyel district area and their necessary attributes such as location, diameter, condition, function and distance covered which was conceptually organized.

3.3.8 Data analysis

Integrated approach was used to achieve the objectives which includes both the GIS and Statistical analysis, thus;

3.3.8.1 GIS Analysis

The GIS analytical techniques involve the use of ArcGIS 10.3 in achieving the research objectives includes; A handheld GPS receiver (Garmin CX 76) was used to collect coordinate points of the public domestic water source such as pipe-borne taps, boreholes, hand dug well, water hydrants, reservoirs, traced water supply pipes and their attributes and was transformed into ArcGIS environment using Microsoft excel which was used to create a file geo-database containing the feature classes which were digitized and compiled into a digital map which form the basis for the analysis.

Density analysis, which include; kernel density for the pattern of distribution of public hand dug well and boreholes and line density for the distribution of water supplying pipes were used respectively to described the pattern of domestic water source distribution and concentration depicting the area of high, moderate and low concentration within the study area. Proximity analysis using multiple ring buffering of distance in metres to standard was adopted, this depicts four level of accessibility which includes; optimum, intermediate, basic and no-access levels were used with the following distance interval which were; 1-30m, 30-100m, 100-1000m and 1000m above to analyse the level of accessibility to domestic water source within the study area.

3.3.8.2 Statistical Analysis

The statistical analysis includes the use of results from a structured questionnaire administered on the field with the use of statistical packages for social science (SPSS) in computing simple percentage and statistical diagram for the following variables which are the source, pattern and level of accessibility to domestic water supply source in the study area.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion on the sources of domestic water supply, the pattern of it's distribution and it's levels of accessibility in the study area

4.2 Results

4.2.1.1 Sources of domestic water supply

Table 4.1 shows the various sources of domestic water supply in Gyel district area, which were the public water supply source that the coordinate points were taken on the field to create geo-database for the spatial analysis.

Table 4.1 Sources of domestic water

Sources of domestic water	Number of respondents	Percentage
Pipe borne	73	28
Hand dug Well	157	60
Borehole	11	4
Stream and ponds	22	8
Total	**263**	**100**

Source: Field survey (2016)

From table 4.1, hand dug well was the dominant domestic water source which was 60% of the source of water for the respondent followed by pipe borne water which was just 28%, borehole 11% and stream 8%, which indicated, that hand dug wells are the primary source domestic water supply in this area, while from figure 4.1 and plate 4.1, the source of domestic water supply in this area includes Hand dug well, Boreholes, and water supplying pipes, Stream and ponds**.**

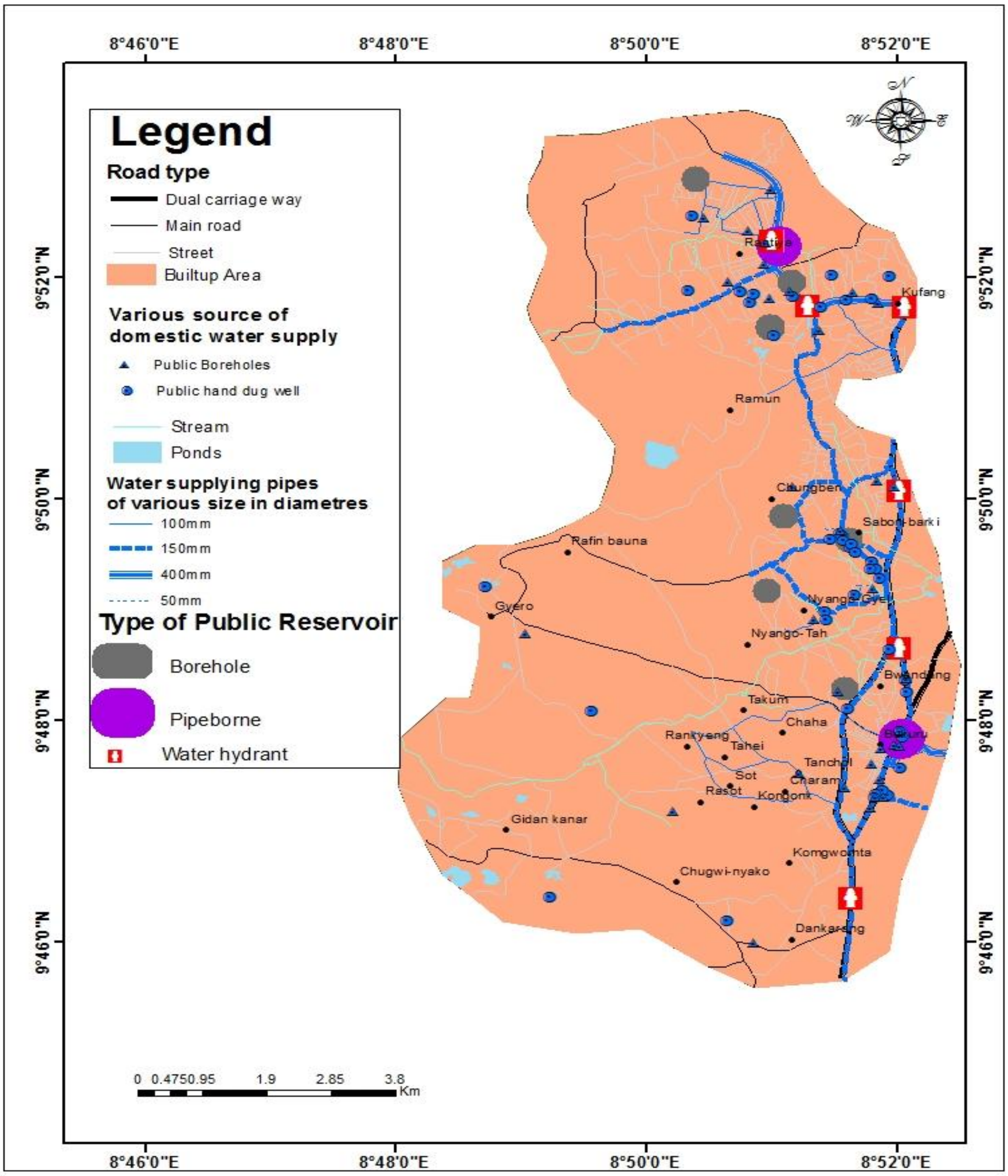

Figure 4.1 Map showing various source of public domestic water supply

Figure 4.1 shows the map compiled from the geo-database created from the coordinates of public water supply source in the study area, while plate 4.1 show the types of water source in the area.

Plate 4.1(A – D): Various sources of Public domestic water supply in the area

Source: Field survey (2016)

4.2.1.2 Uses of domestic water

Domestic water supplied is mostly used for the various purposes which includes; drinking, cooking, bathing, washing and general sanitation. Table 4.2 shows the uses of domestic water.

Table 4.2 Uses of domestic water

Uses of the water supply	Number of respondents	Percentage
Drinking	36	14
Cooking	52	20
Bathing	61	23
Washing and sanitation	48	18
All of the above	66	25
Total	**263**	**100**

Source: Field survey (2016)

Table 4.2 shows that the water supply in this area is being used for all the domestic purpose, as indicated the highest percentage of the respondents from the households used water for various domestic purpose such as drinking, cooking, bathing, washing and general sanitation which proved the necessity of domestic water supply to the area.

4.2.2 The pattern of domestic water supply source

4.2.2.1 Public water source pattern based on density analysis

The density analysis used for public water facility indicated that most of the facilities were found along the major road and well planned cadastral layout area which are the public service offices, commercial centres and low-cost area, This was in support of Oyebande (2005) that found that settlements that are provided with modern water supply networks are usually those situated along the major transportation networks and all improved water supply in Nigeria is from public water supplies , The public water source used in the analysis include pipe-borne network, boreholes ,hand dug wells and streams as depicted in figure 4.2,4.3,4.4,4.5.

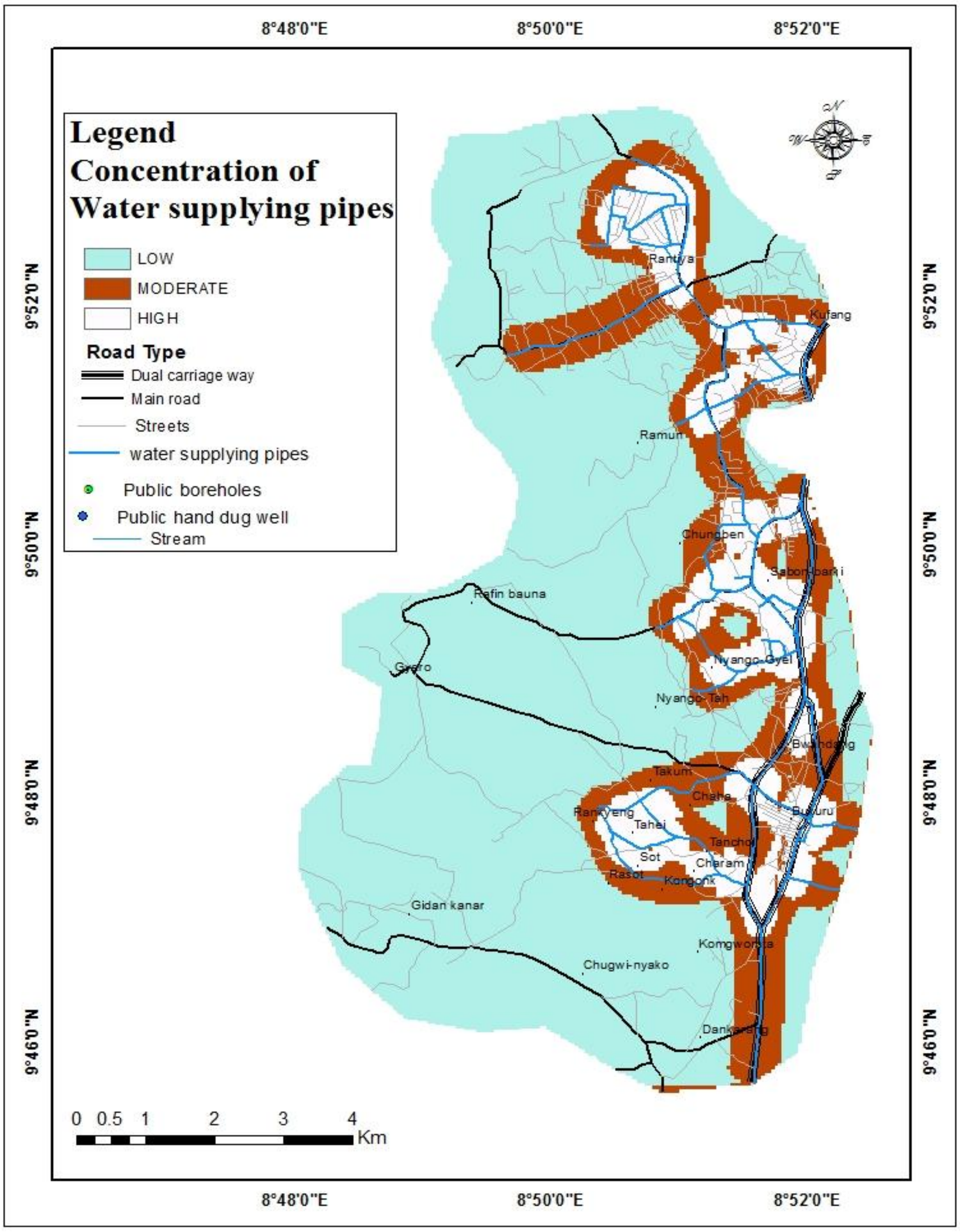

Figure 4.2 Density map of public water supplying pipes concentration

The density analysis for pipe-borne water supply source as shown in figure 4.2, indicated that most of the pipe-borne water supply network are found clustered around the major roads in the centre of the town where the cadastre is well planned, which proof that area that are not planned and the newly extended area which are outskirt of the town has the problem of access to domestic water supply source.

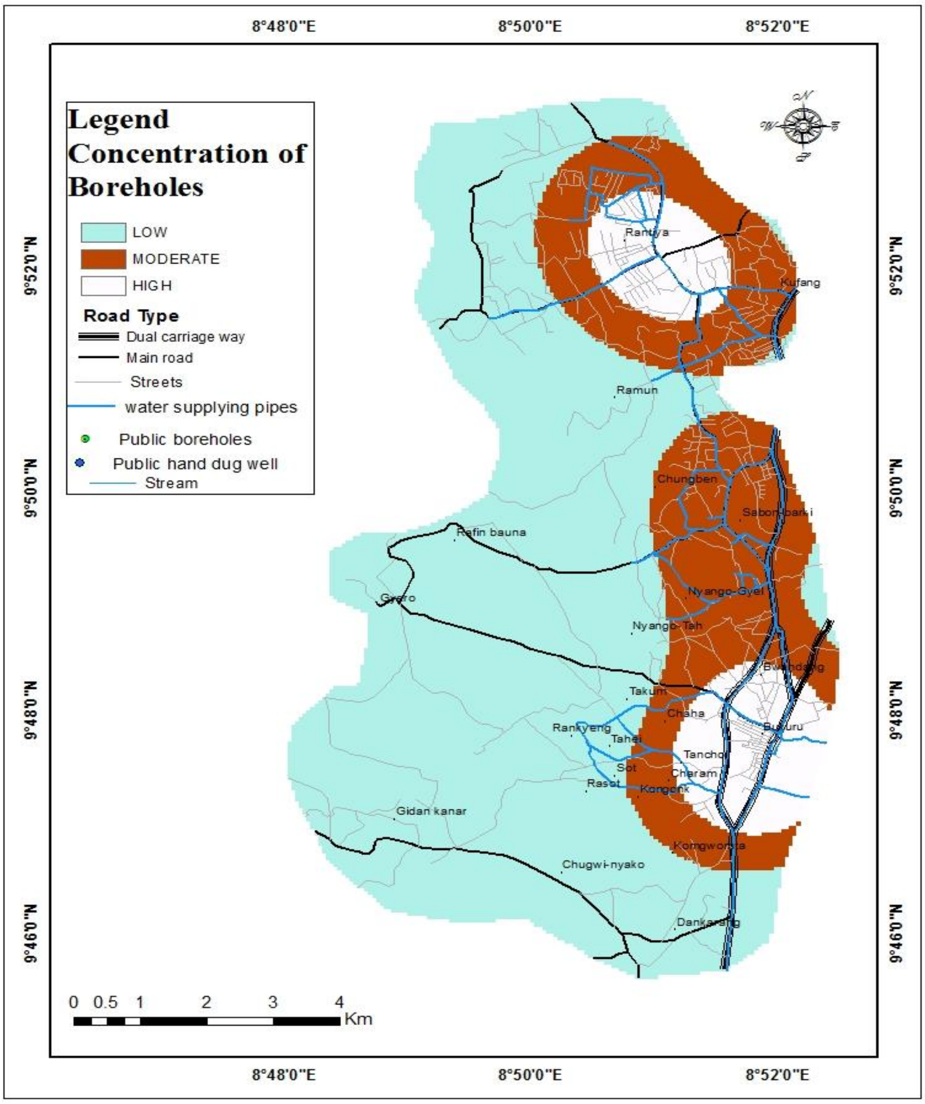

Figure 4.3 Density map of concentration of public borehole

Also the boreholes concentration are found clustered along the major road and city centre which exert effect on access to water source.

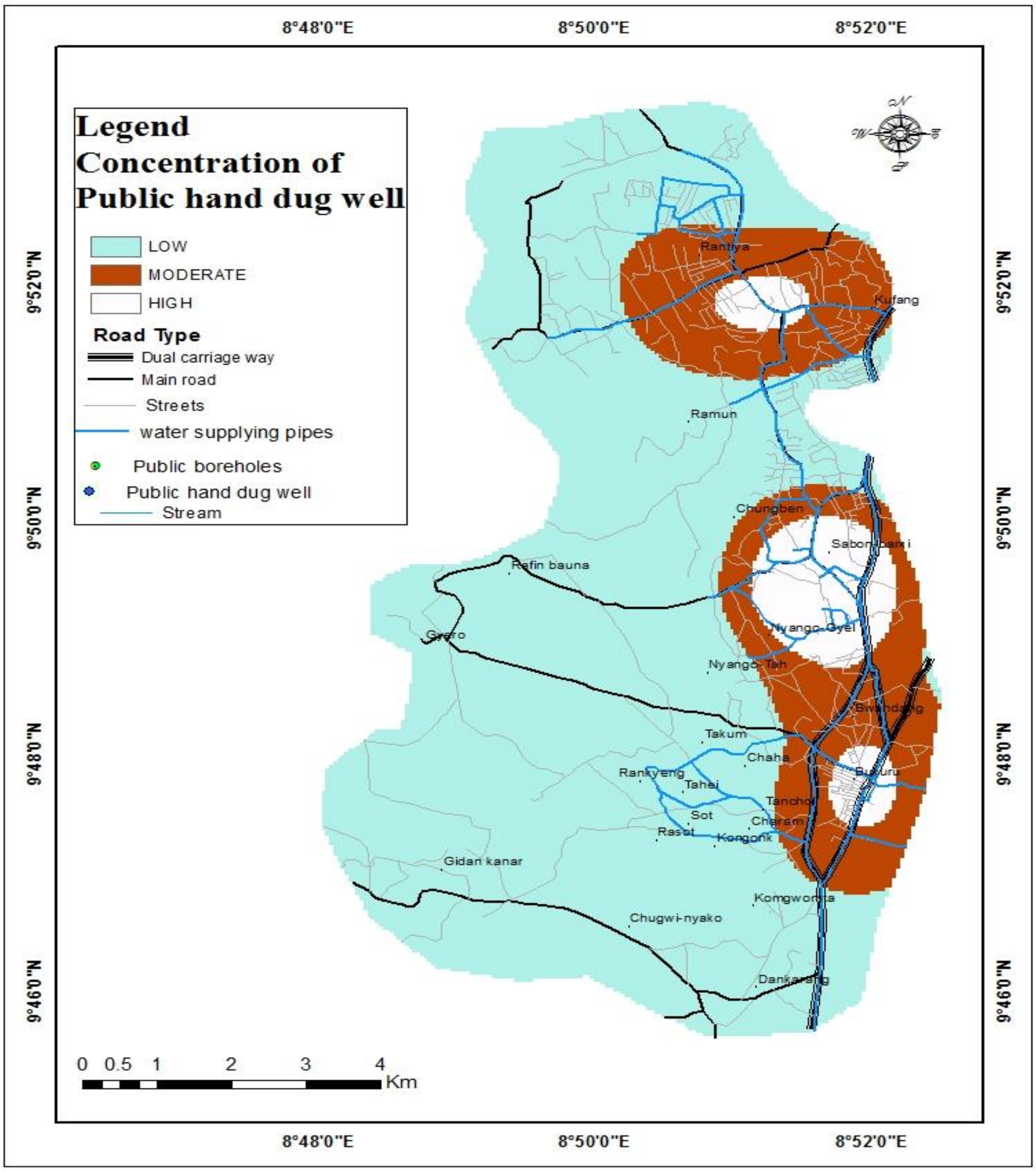

Figure 4.4 Density map of concentration of public hand dug well

Figure 4.4 shows the distribution of public hand dug wells with high concentration along the well planned area in the city centre and low concentration in the outskirt which includes the newly extended area**.**

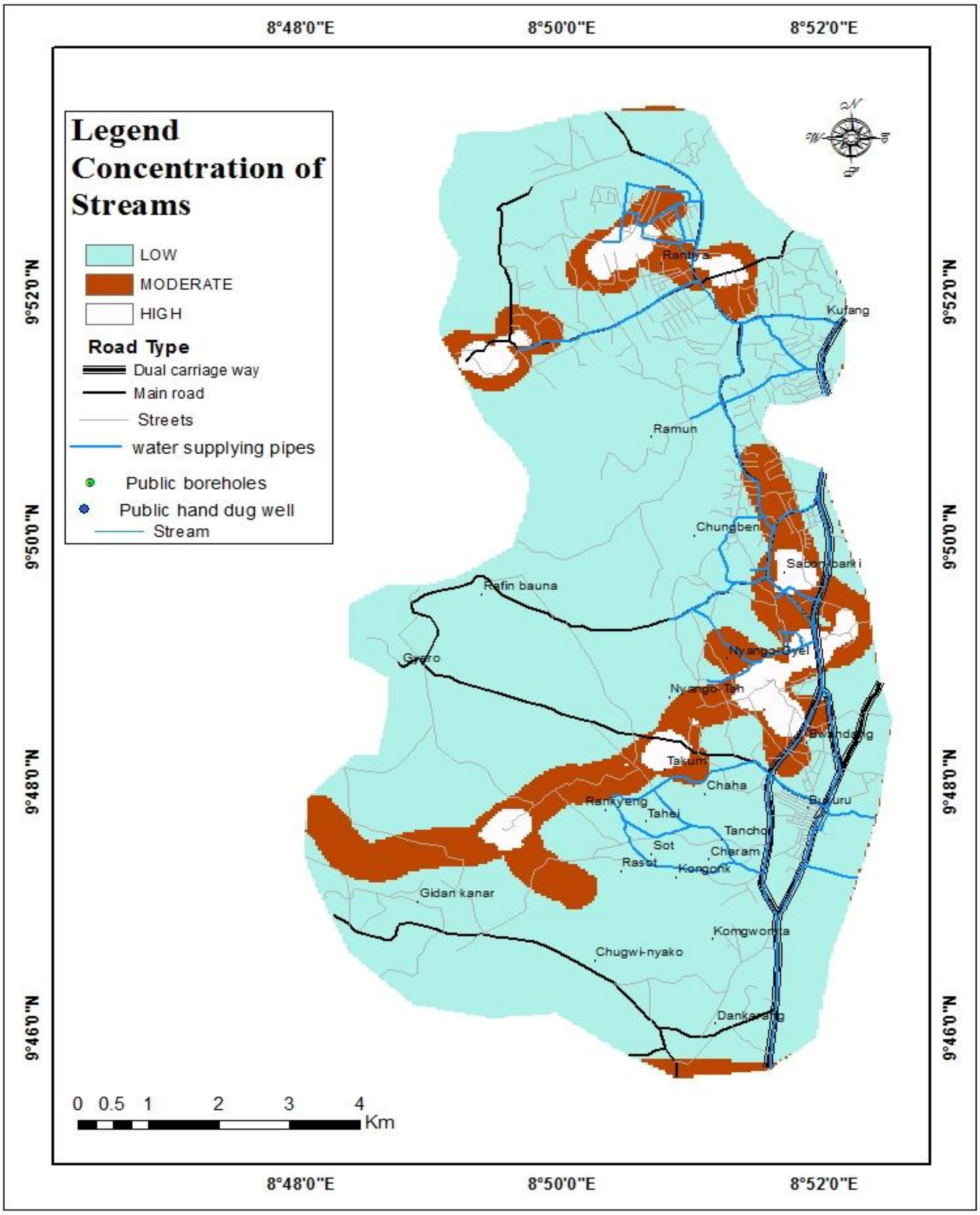

Figure 4.5 Density map of concentration of streams

Figure 4.5 shows the distribution of the streams as they also affect source of domestic water supply in this area, because they are unevenly distributed and are seasonal.

4.2.2.2 Reasons for Inaccessible to domestic water Source and solution

The analyses were also supported statistically based on the sampled questionnaire as Figure 4.6 shows the result for the reasons of not been close to the water source.

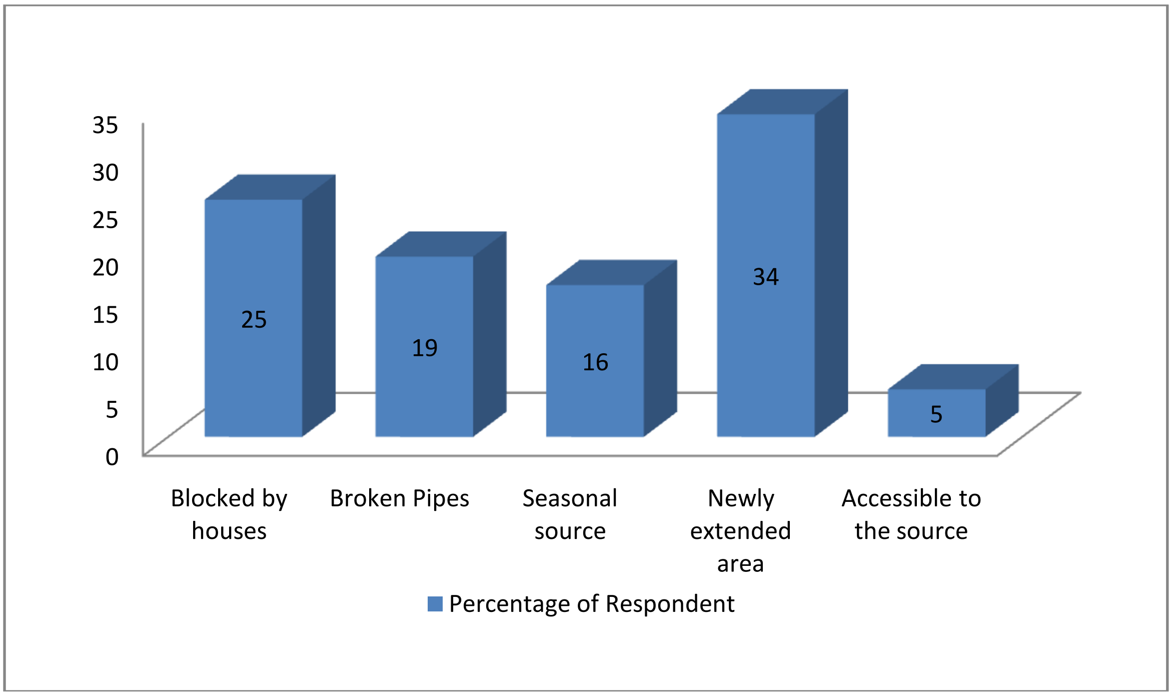

Figure 4.6 Reasons for inaccessible to water supply source
Source: Field survey (2016)

Figure 4.6 shows the reasons why access to water supply was far to the respondents, which include blockages of public water source by houses as a result of unplanned cadastral layout, broken water supply pipes which were not notice to be replaced by water board management, seasonal effect on the water source most especially the well, boreholes and stream during dry season and newly extended built-up area, also plate 4.2 show domestic water users clustered along the road with water supply source around Bukuru low-cost and Kufang area, this finding is similar to that of MacDonald, Dochartaigh and Welle (2009) who mapped water and sanitation in Ethiopia and found that water supply failures in this region were that of the reduced yield of the aquifer and deep seated water level during the dry season. Also similar to the findings by George, George and Jacob (2010) in accessibility of water services in Kisumu municipality which revealed that the proportion of households with access to piped water supply within a distance of 200m is 77.1%, only 65.6% of the basic water requirements of the residents are met and that only 25% of the households access the minimum recommended 50 l/c/d, which the possible solution were shown in table 4.3

Table 4.3 Possible solution to the reasons

Solution to the reasons	**Number of respondents**	**Percentage**
Sinking Boreholes	60	23
Laying of water supply pipes	103	39
Digging wells	88	33
Buying from water supply vendors	12	5
Total	**263**	**100**

Source: Field survey (2016)

Table 4.5 shows the possible solution suggested by the respondents to solve the problem of domestic water supply in the area, in which extension of water supply pipes will widely solve this problem especially for the newly extended area, followed by digging wells and others.

Plate 4.2(A-B): Domestic water users on the street with public water supply source around Nyango-Gyel Low-cost Area(A) and Kufang(B).Source: Field survey (2016).

4.2.3 Accessibility to domestic water supply source

4.2.3.1 Access to domestic water source

The proximity analysis techniques used include the multiple ring buffer, with the standard of distance 1-30,31-100,100-1000 and 1000 meters above, depicting the four level of accessibility which are; optimum, intermediate, basic and no-access, which were used on the various public water supply sources in the study area, as shown in figure 4.7,4.8,4.9,4.10,4.11, shows the following results respectively.

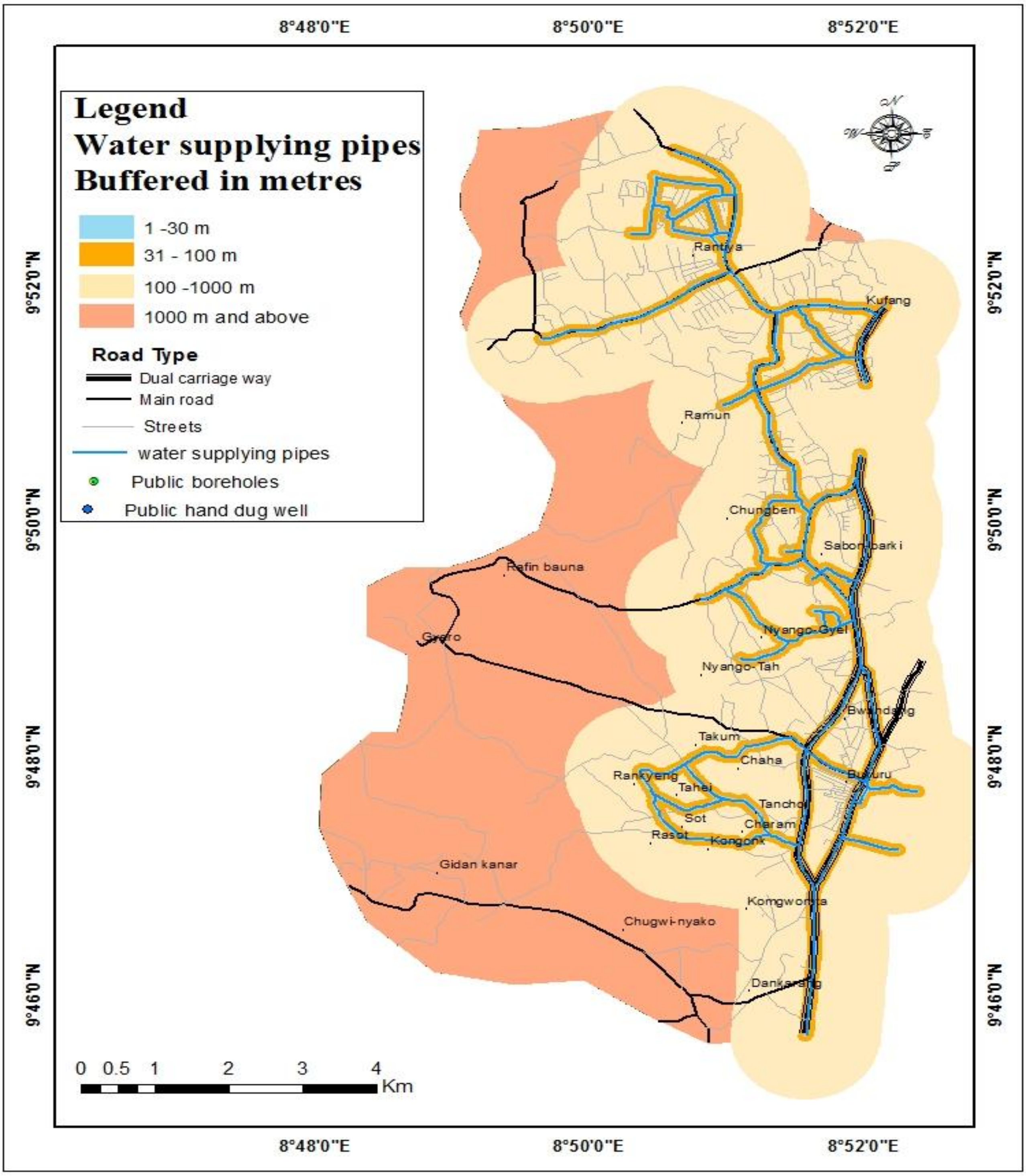

Figure 4.7: Multiple ring buffer map of public water supplying pipe

4.2.3.2 Regularity of pipe-borne water supply from the source

The regularity of pipe-borne water supply also affects access to domestic water supply in the study area as shown in figure 4.7 and table 4.4

Table 4.4 Regularity of pipe-borne water

Regularity of pipe-borne water source	Number of respondents	Percentage
Everyday	3	17
Once in three days	5	28
Once in a week	6	33
Once a month and beyound	4	22
Total	**18**	**100**

Source: Field survey (2016)

Table 4.4 shows that of 18 respondents that had access to pipe-borne water supply it were only 17% of the sampled households have access to domestic water supply on daily, This was as a result of irregular supply from the stations coupled with the problem of pipe damaged due to construction activities especially road construction and illegal connections and natural factor such as weakening and rusting of pipe material which were not replaced in time by the water board service.

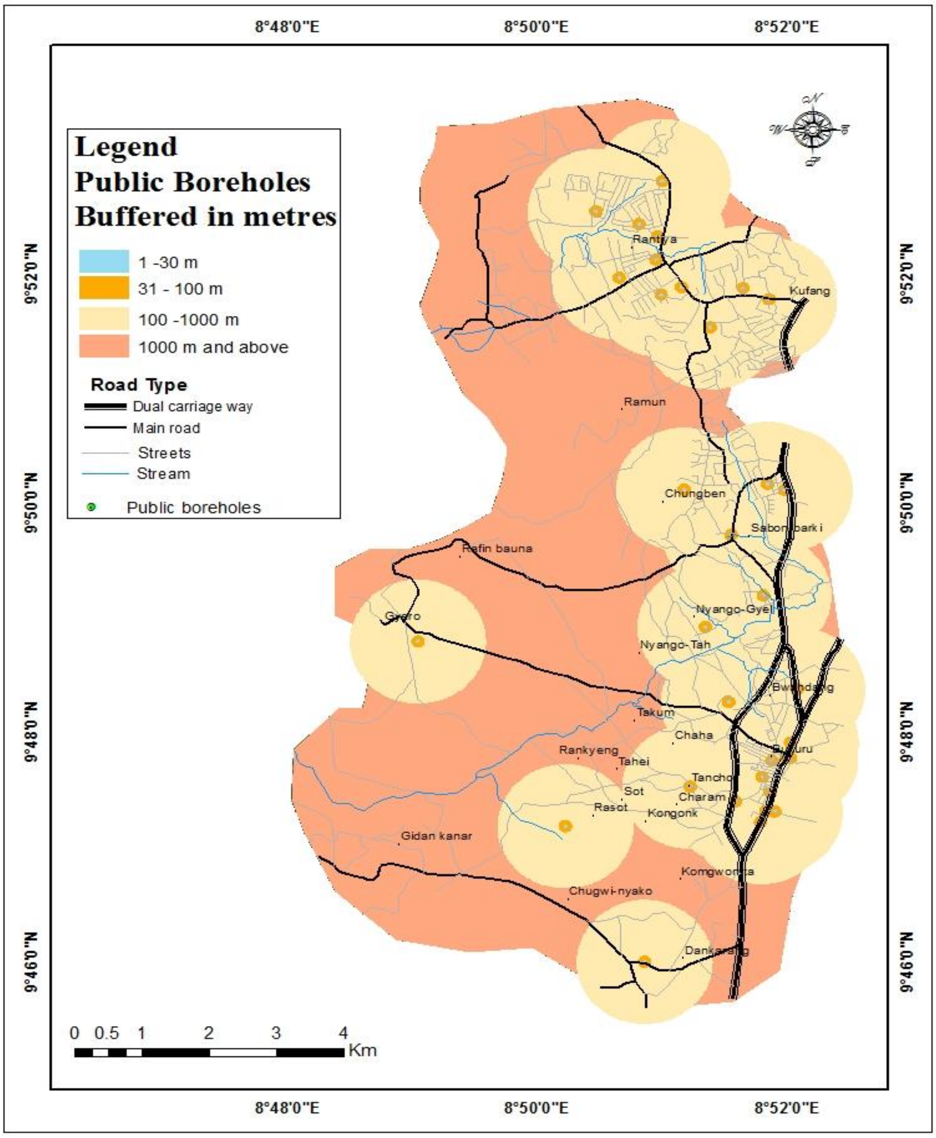

Figure 4.8: Multiple ring buffer map of public boreholes

Figure 4.8 shows the spatial distribution of drilled boreholes and its level of accessibility to the built-up area, large area falls within the level of no-access which takes them more than 1000 metres to reach the source, likewise the hand dug wells, streams and ponds from figure 4.9,10 and 11.

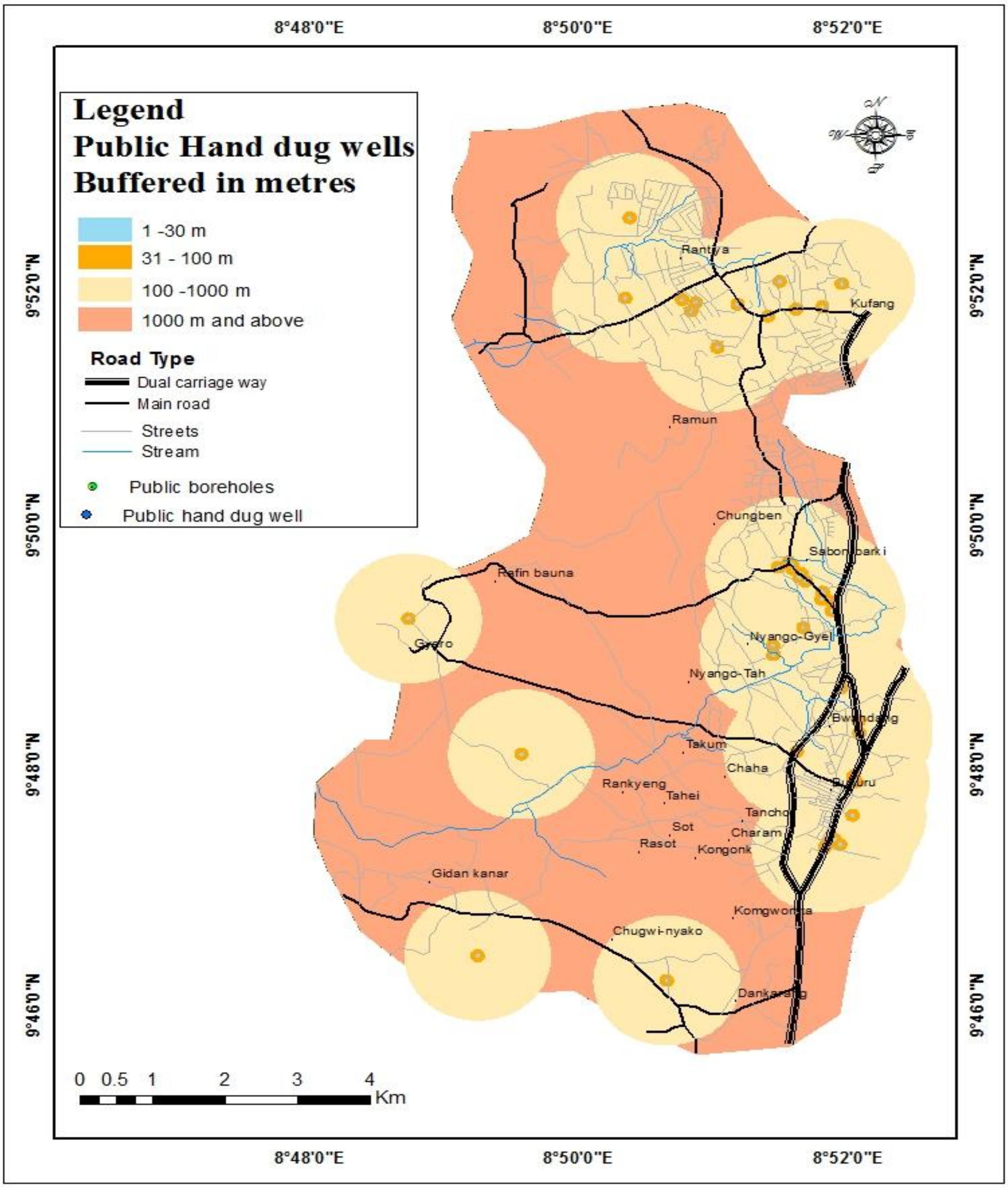

Figure 4.9: Multiple ring buffer map of public hand dug well

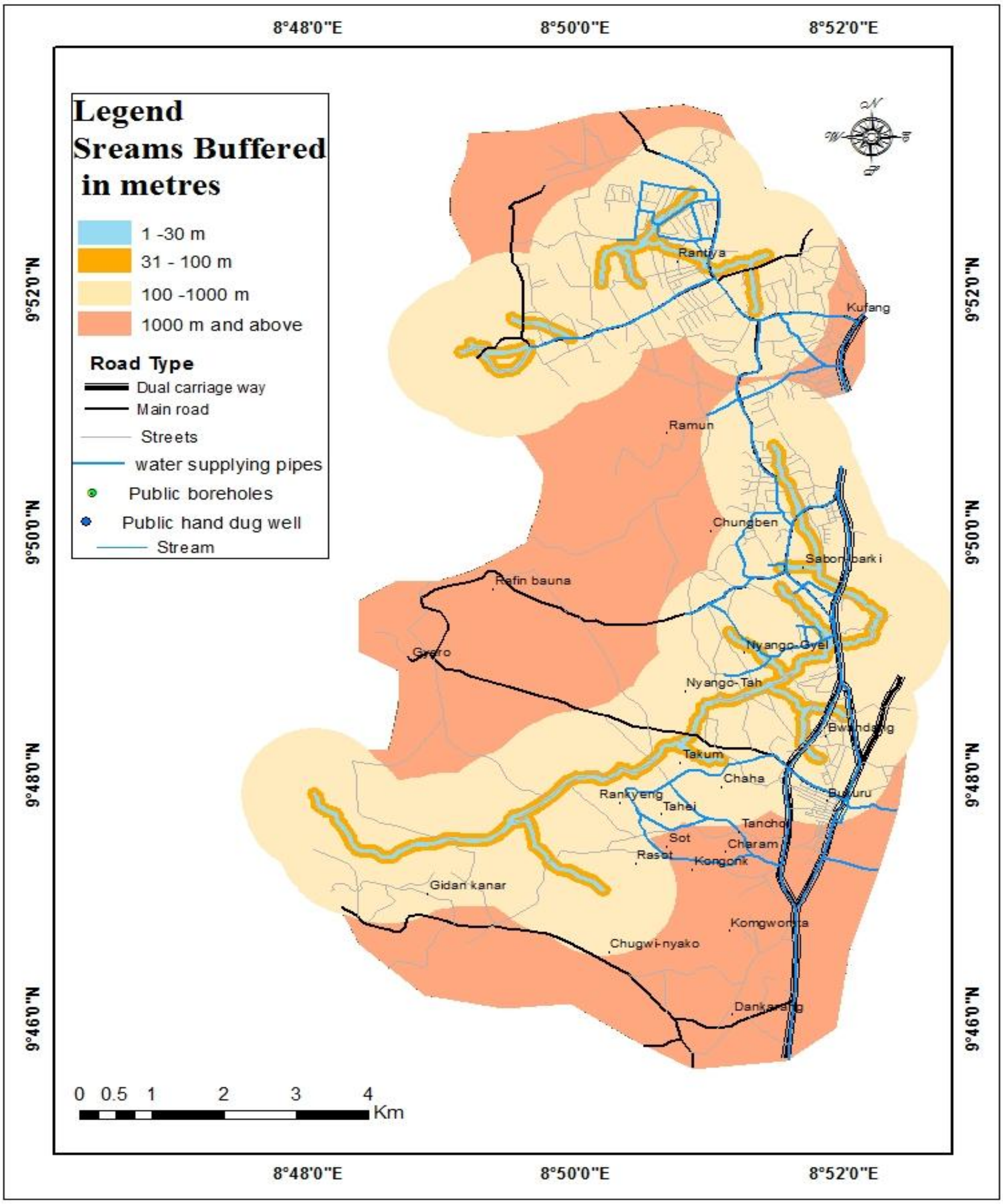

Figure 4.10: Multiple ring buffer map of streams in the area

4.2.3.3 Availability of Well, Borehole, Stream

Availability of ground water such as well, boreholes and stream sometimes were affected by seasonal variation as the aquifer goes down in the dry season and also no runoffs from rainfall this can be seen in table 4.5

Table 4.5 Availability of well, borehole, stream.

Water availability	**Number of respondents**	**Percentage**
Throughout the year	135	55
Seasonal	106	43
Not at all	4	2
Total	**245**	**100**

Source: Field survey (2016)

Seasonal influence is a treat on domestic water source in this study area as the quantity reduce during the dry season thereby leading domestic water scarcity in the area and this supported that of Odafivwotu and Abel (2014) whose findings revealed that the quantity of water supply was inadequate and the distances to sources of major water supply reduces during dry season. this has been revealed earlier by MacDonald, Dochartaigh and Welle (2009) which mapped water and sanitation in Ethiopia and found that water supply reduced deep seated water level during the dry season, In addition to the streams figure 4.11 shows the distribution of mining ponds as they are also useful in domestic water supply.

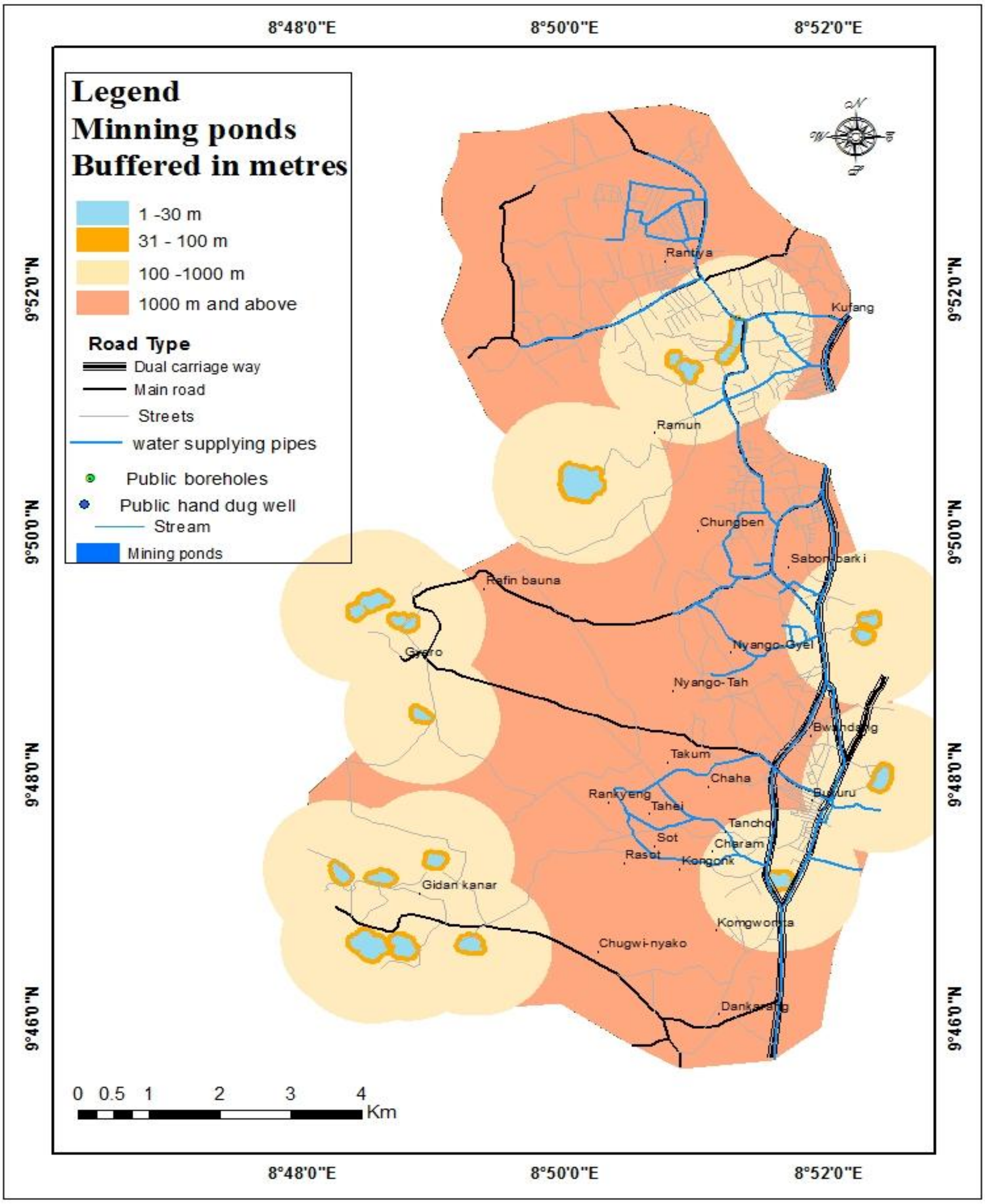

Figure 4.11: Multiple ring buffer map of ponds in the study area

Using multiple ring buffer analysis of the location of various source of domestic water supply from Figure 4.7, 4.8, 4.9, 4.10 and 4.11, has shown that most percentage of the households were within distance of basic access and no-access level of accessibility. This is similar to the findings by George and Jacob (2010) in accessibility of water services in Kisumu municipality which revealed that the proportion of households with access to piped water supply within a distance of 200m was 77.1%, Only 65.6% of the basic water requirements of the residents were met and that only 25% of the households access the minimum recommended 50 l/c/d. Also MacDonald, Dochartaigh and Welle (2009) mapped water and sanitation in Ethiopia and found that low income households and low levels of investment in water infrastructure are related to reduce access to water services.

4.2.3.4 Access to public domestic water supply

The result of access to public water source in the study area is show in Figure 4.12.

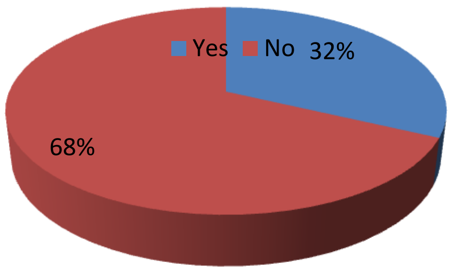

Figure 4.12 Access to public water supply
Source: Field survey (2016)

In the area only few people had access to the public water source which is just 32% of the population in the area.

4.2.3.5 Distance and time taken to obtain water from the Source

Table 4.6 shows the distance of the households from the water source and only 27% out of the respondents were closed to domestic water supply source in the area,

Table 4.6: Distance of households from water source

Distance of households from water source	Number of respondents	Percentage

1-30 metres	72	27
30-100 metres	55	21
100 – 1000 metres	103	39
More than 1000 metres	33	13
Total	**263**	**100**

Source: Field Survey (2016)

It was found from table 4.6 that the distance of households from water source 100-1000 meters based on the 39% of the respondents which constitutes the highest percentages of the respondents in the study area.

Table 4.7 Time taken to reach water source

Time taken to reach the source	Number of respondents	Percentage
1-15 minutes	51	19
16- 30 minutes	69	26
31-45 minutes	86	33
46-60 minutes	35	13
60 minutes and above	22	8
Total	**263**	**100**

Source: Field Survey (2016)

The time spent in collecting water from the source is very important in regard to the physical aspect of domestic water accessibility, In this area 19% out the respondents spent less than 15 minutes to access water from the source as seen from Plate 4.2. It was also found that it took most of the respondents used 31-45 minutes and above to reach the water sources in the study area and this was as a result of the distances of the residential areas to the water source as well as the nature of the topography which were mostly highlands area.

4.2.3.6 Quantity of water used daily

The result for the quantity of water supply in the study area is presented in Figure 4.13

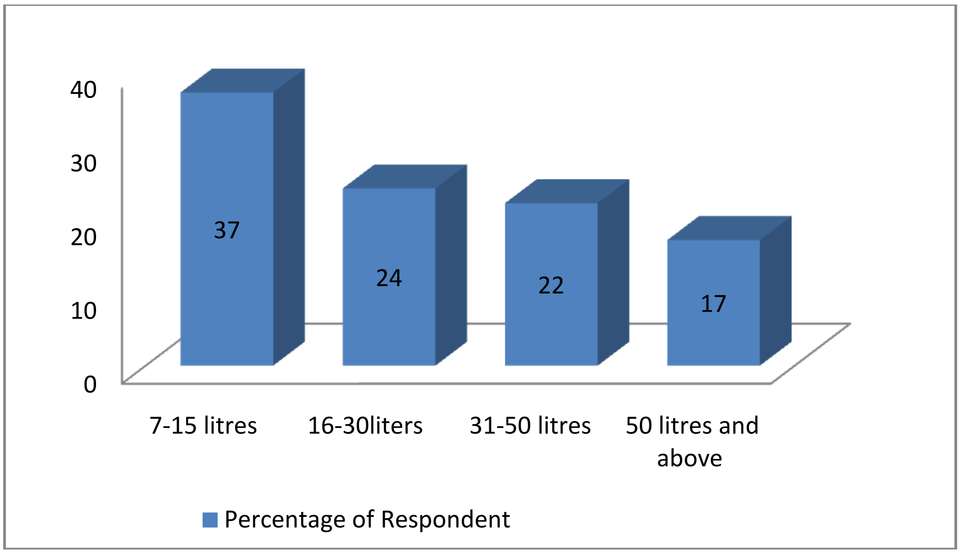

Figure 4.13: Quantity of water used daily
Source; Field survey

Figure 4.13 shows that the least quantity of domestic water, which is between 7-15 litres is used by most of the respondents (37%), this is as a result of distance travel and time taken to access water from a reasonable source, also supported by plate 4.3 showing the various means of accessing the source through the use of water supply tankers, head loading and the use of water vendors which are stressful and expensive.

4.2.3.7 Domestic water scarcity and period

Domestic water scarcity is severe as it is periodical, this is shown on table 4.8 and 9

Table 4.8 Problem of water scarcity

Water scarcity	Number of respondents	Percentage
Yes	188	71
No	75	29
Total	**263**	**100**

Source: Field survey (2016)

Majority of the people indicate that there is problem of domestic water scarcity in the area as seen in Table 4.8, where 71% experienced water scarcity. The importance of water to human lives requires every day access in desirable quantities (Human Right Council, 2007). The minimum absolute daily water need per person per day is 50liter (13.2gallons) which include: 5liters for drinking, 20liters for sanitation and hygiene, 15 liters for bathing and 10liters for preparing food is inadequate in the study area, hence the needs as supported by The UNDP (2008), In this area most of the respondents used below 15 litres per day which is below standard for usage as stated above, Indeed there is problem of water scarcity ,as can be seen in Figure 4.13, the highest percentage of the respondent used little quantity of water daily as most could not met the required quantity, This situation is severe in the dry season period as shown in Table 4.9.

Table 4.9 Period of water scarcity

Period of water scarcity	Number of respondents	Percentage
January to march	223	85
April to June	18	7
July to September	2	1
October to December	20	8
Total	**263**	**100**

Source: Field survey (2016)

Table 4.9 expressed in addition to the dominating water scarcity problem, there is also seasonal influence as the scarcity is more severe during dry season period especially during the month of January to march, when there is reduced yield of the aquifer as supported by MacDonald, Dochartaigh and Welle (2009).

Plate 4.3(A-C): Various means of accessing domestic water during scarcity and were the source is far in Sabon barki(A), Rantiya (B) and Kufang area(C).

Source: Field survey (2016)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter gives summary of the results and discussion with regard to the objectives and answer to the research questions, it also presents the possible solutions to the findings

5.2Summary of the Findings

Spatial analysis of access to domestic water supply in Gyel district is a research achieved through; identification and mapping, examining the pattern and assessing the level of accessibility to domestic water supply source within the study area. The primary dominating source of domestic water in this area is a hand dug wells as common to every households based on the record taken using a handheld GPS and Sampled questionnaire which include 41 points as the highest coordinate frequency of the public source as shown on page 66– 67, and 60% respondents depend on hand dug wells, other additional reliable water source to boost water supply is still the hand dug well, because other sources like pipe borne, Bore holes, Stream and ponds are not reliable as a result of irregularities in supply, damages to the pipes during construction , difficulty in extension through an unplanned area and inaccessibility to extend to the newly developed area.

Based on the Density analysis; The pattern of the distribution of water supply facilities were found clustered around the city centre and well planned cadastral area, this exert serious effect on access to the source especially on those within the unplanned and newly developed area as only 32% of the respondents has access to the public domestic water source.

It was observed from the Proximity analysis, that most of the households fall within the basic and no-access level, this has serious effect on distance travel, time taken to reach the source and the quantity of water used daily, as 52% of the respondents travel the distance of 100 to 1000 metres and above and 54% used the time frame of 30 to 60 minutes and above to reach the source, in which just 17% of the population could met the required standard. Besides, the situation is severe during the dry season period as 71% respondents asserted that there is problem of domestic water scarcity in the area.

5.3Conclusion

The application of Spatial analytical tool such as; Density and Proximity analysis using ArCGIS with the aid of Satellite, Global Positioning and Population data has been proved important in Spatial analysis of access to domestic water supply source in identification and mapping the pattern of it distribution and examining the effect on the accessibility in terms of distance and time travelled in related to the quantity of water used in the area. This gives the Planners and decision makers from both The Plateau State Water Board, Private sectors and Individual households, Idea on how to solve the complex problem of domestic water supply in the study area.

5.4 Recommendations

The following recommendations were forwarded for consideration which include;

i. Encouraging the provision of more domestic water source by the Plateau State Water Board, Private Sectors and Individual household as this will boost water supply, also creating awareness on the importance of various source of domestic water supply as they complement each other's especially during dry season in the area.

ii. The Jos Metropolitan Development board should ensure that built-up area adopt town planning standard rules to ease laying of water supplying pipes and other public water supply facility extensions, especially in the newly developing built-up area.

iii. Plateau State water board should engage in periodic pipeline extension services to be able to cover the newly developed area, regular replacement of damaged facilities to enhance the supply of water in the area.

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APPENDIX 1

QUESTIONNAIRE

Department of Geography
Faculty of Science
Ahmadu Bello University,
Zaria, Kaduna State.

Dear Respondent,

This questionnaire is designed purposely for an M.Sc. Research thesis, titled on the topic, "SPATIAL ANALYSIS OF ACCESS TO DOMESTIC WATER SUPPLY IN GYEL DISTRICT, PLATEAU STATE". This exercise is purely on academic research and so any information supplied will be strictly used for this purpose and will be treated with the strictest confidence.

Thanks you for your anticipated cooperation

Omada Meshach Arome

SECTION A

HOUSE HOLD HEAD

1. Sex: Male [ ], Female [ ]

2. Age: 15-25 years [ ], 26-35 year [ ], 36-45 years, 46 and above [ ]

3. Marital status: Single [ ], Married [ ]

4. Occupation: Public servant [ ], Trader [ ], Farmer [ ], Student [ ]

SECTION B

SOURCES OF DOMESTIC WATER SUPPLY

1. Where is the primary source of your water supply? (a) Pipe borne [ ], (b) Hand dug Well [ ],

(c) Borehole [ ], (d) Stream, ponds and others [ ]

2. How will you rate the quality of the water? (a)Very good [ ], (b) Good [ ], (c) Poor [ ], (d) Very Poor [ ]

3. Do have any additional source to your main source of water supply? Yes [ ] or No [ ]

4. If yes, what are those sources? (a) Hand dug well [ ], (b) Pipe-borne tap [ ], (c) Borehole [ ], (d) Stream, ponds and others [ ]

5. What do you use the water for? (a) Drinking [ ], (b) Cooking [ ], (c) Bathing [ ], (d) Washing and general sanitation [ ] (e) All of the above [ ]

SECTION C

PATTERN OF DOMESTIC WATER SOURCE DISTRIBUTION

1. How close is your house to the nearest water supply source? (a) Very close [ ], (b) close [ ]

, (c) Far [ ] , (d)Very far [ ]

2. If so, what are the reasons? (a) Blocked by houses [ ], (b) Broken pipes [ ],(c) Seasonal source [ ] ,(d) newly extended area[ ], (e) Accessible to the source

3. What do you think should be the solution? (a) Sinking Boreholes [ ], (b) Laying water supplying pipes[ ],(c) Digging wells [ ] ,(d) Buying from water supply vendor[ ]

SECTION D

ACCESS TO DOMESTIC WATER SUPPLY

1. Do you have access to any public water supply source in your area? Yes [ ] or No [ ]

2. How accessible are you to the source? (a) Very accessible [ ], (b) Accessible [ ], (c) Not accessible [ ]

3. How far do you travel to get water from the source? (a) 1-30metres [ ],(b) 30-100metres[ ],

(c) 100-1000metres [ ], (d) more than 1000metres

4. How much time does it take you to get water from the source? (a) 1-15 minutes [ ],(b) 16-30 minutes[ ], (c) 31-45 minutes[ ],(d) 46-60 minutes[ ],(e) 60minutes and above.

5. What is the common source of your water supply in your area? (a) Pipe borne tap [ ],(b) Well [ ], (c) Borehole [ ], (d) Water supply vendor (e) Stream, ponds and others [ ]

6. If pipe-borne tap, how regular is the supply? (a) Everyday [ ], (b) Once in three days [ ], (c) Once in a week [ ], (d) Once a month [ ]

7. If well, boreholes, stream, ponds and others, how often is the availability for use? (a) Throughout the year [ ],(b)Seasonal [ ], (c) Not at all [ ],

8. Do you experience water scarcity in your area? Yes [ ] or No [ ]

9. Which period of the year do you experience water supply scarcity? (a) January to march [ ], (b) April to June [ ], (c) July to September [ ], (d) October to December [ ]

10. How much water do you use daily? (a) 7-15 litres [ ], (b) 16-30liters [ ], (c) 31-50 litres [ ],(d) 50 litres and above[ ]

APPENDIX 2

COORDINATES OF SOURCES OF DOMESTIC WATER SUPPLY SOURCE USED FOR THE CREATION OF GEO-DATABASE

The Coordinates of the traced water supplying pipes and their attributes

LATITUDE	LONGITUDE	LOCATIONS	PIPE SIZE(inches)	MATERIAL
9◦47'16.8"	8◦51'58.2"	Kuggiya Mkt.	4	Cast Iron
9◦47'26.8"	8◦51'52.6"	Bukuru	6	Cast Iron
9◦47'47.1"	8◦52'00.9"	Eco.Bk.Area	6	Cast Iron
9◦47'49.7"	8◦52'02.6"	Overhead Tank	12	Cast Iron
9◦48'12.8"	8◦52'05.1"	Bukuru Road	6	Cast Iron
9◦48'38.9"	8◦52'01.5"	Water Hydrant	6	Cast Iron
9◦49'03.4"	8◦51'56.9"	Bridge	6	Cast Iron
9◦49'08.8"	8◦51'55.2"	Nyango Gyel	6	Cast Iron
9◦49'04.0"	8◦51'43.5"		4	Ductile
9◦49'05.5"	8◦51'43.1"		4	Ductile
9◦48'58.6"	8◦51'26.5"		4	Ductile
9◦49'24.5"	8◦50'58.5"		2	Ductile
9◦49'37.4"	8◦51'18.6"	Sabon Barki	4 by 2 by 4	Ductile
9◦50'05.4"	8◦51'17.6"		4	Ductile
9◦50'03.0"	8◦51'36.0"		6 by 4	Cast Iron
9◦49'43.9"	8◦51'33.7"		6 by 4	Cast Iron
9◦49'32.9"	8◦51'40.5"		4 by 4	Ductile
9◦49'32.6"	8◦51'41.7"		4	Ductile
9◦48'00.9"	8◦51'33.8"		4	Ductile
9◦47'14.9"	8◦51'31.0"	Gyel	6 by 6	Cast Iron
9◦47'20.9"	8◦51'17.6"		6 by 6	Cast Iron
9◦47'21.2"	8◦50'38.1"		4 by 4	Ductile
9◦47'40.9"	8◦50'27.3"		4	Ductile
9◦47'56.0"	8◦50'41.2"		4	Ductile
9◦48'03.2"	8◦51'34.3"		6 by 6	Cast Iron
9◦51'46.2"	8◦52'00.4"	Miango Junct	16	Cast Iron
9◦51'46.9"	8◦51'28.2"	Kufang	16	Cast Iron
9◦51'27.2"	8◦51'20.2"	Kufang-Ramun	4	Ductile
9◦51'56.9"	8◦50'44.8"	Rantiya	6	Cast Iron
9◦52'24.5"	8◦50'55.7"	Fed.Lowcost	4	Ductile

Number of Public Wells and their coordinates

S/N	Latitude	Longitude	Location	Condition
1	9°52′33.602″	8°50′21.883″	Kufang	Not seasonal
2	9°51′53.718″	8°50′20.234″		Not seasonal
3	9°51′52.729″	8°50′45.615″		Not seasonal
4	9°51′51.081″	8°50′51.218″		Not seasonal
5	9°51′46.796″	8°50′49.900″	Rantiya	Not seasonal
6	9°51′28.338″	8°51′01.437″		Not seasonal
7	9°51′50.422″	8°51′10.336″		Not seasonal
8	9°51′44.159″	8°51′23.850″		Not seasonal
9	9°52′01.299″	8°51′29.124″		Not seasonal
10	9°50′47.785″	8°51′36.046″		Not seasonal
11	9°51′48.444″	8°51′56.812″		Not seasonal
12	9°52′00.970″	8°51′56.812″		Not seasonal
13	9°49′41.542″	8°51′33.409″	Sabon barki	Seasonal
14	9°49′40.223″	8°51′34.728″		Not seasonal
15	9°49′37.586″	8°51′35.387″		Not seasonal
16	9°49′39.235″	8°51′27.806″	Nyango-gyel	Not seasonal
17	9°49′35.279″	8°51′39.342″		Not seasonal
18	9°49′33.631″	8°51′37.694″		Seasonal
19	9°49′30.005″	8°51′40.661″		Seasonal
20	9°49′26.050″	8°51′48.572″		Seasonal
21	9°49′22.424″	8°51′47.583″	Tanchol	Not seasonal
22	9°49′21.765″	8°51′50.879″		Not seasonal
23	9°49′17.150″	8°51′52.197″		Not seasonal
24	9°49′08.251″	8°51′40.002″		Not seasonal
25	9°48′59.351″	8°51′25.828″	Bwandang	Not seasonal
26	9°48′54.407″	8°512′5.828″		Not seasonal
27	9°48′38.585″	8°51′57.142″	Bukuru	Seasonal
28	9°48′21.115″	8°52′04.723″		Not seasonal
29	9°48′15.842″	8°52′04.393″		Seasonal
30	9°48′06.283″	8°51′36.046″	Bwandang	Seasonal
31	9°47′53.757″	8°50′02.086″	Bukuru	Seasonal
32	9°47′50.791″	8°52′04.064″		Seasonal
33	9°47′33.980″	8°52′01.756″		Seasonal
34	9°47′22.444″	8°51′53.186″		Not seasonal
35	9°47′19.148″	8°515′6.153″		Not seasonal
36	9°47′21.125″	8°51′49.890″		Not seasonal
37	9°47′18.488″	8°51′49.890″		Seasonal
38	9°49′12.865″	8°48′43.327″	Gyero	Not seasonal
39	9°48′04.635″	8°49′34.088″	Gidan kanar	Not seasonal

40	9°46′24.102″	8°49′13.982″		Not seasonal
41	9°46′11.247″	8°50′38.693″	Dankarang	Not seasonal

Number of Water Hydrants and their coordinates

S/N	Latitude	Longitude	Location	Condition
1	9°52′20.115	8°50′59.862	Rantiya	Functioning
2	9°51′44.394	8°51′18.108	Kufang	Functioning
3	9°51′44.651	8°52′03.850		Functioning
4	9°50′04.685	8°52′01.280	Sabon barki	Functioning
5	9°48′38.853	8°52′01.537	Bwandang	Functioning

Number of public boreholes and their coordinates

S/N	Latitude	Longitude	Location	Condition
1	9°52′48.985″	8°50′57.589″	Rantiya	Functioning
2	9°52′26.016″	8°50′46.105″		Functioning
3	9°52′20.716″	8°50′56.706″	Kufang	Functioning
4	9°52′04.814″	8°50′55.822″		Functioning
5	9°51′58.631″	8°50′38.154″		Functioning
6	9°51′52.447″	8°51′08.190″		Functioning
7	9°51′49.796″	8°50′57.089″		Functioning
8	9°51′51.563″	8°51′36.459″		Functioning
9	9°51′47.146″	8°51′49.710″		Functioning
10	9°51′30.362″	8°51′20.558″		Functioning
11	9°50′10.855″	8°51′48.827″	Chungben	Functioning
12	9°50′06.438″	8°51′56.777″		Functioning
13	9°50′07.321″	8°51′09.073″		Functioning
14	9°49′43.469″	8°51′31.159″	Sabon barki	Functioning
15	9°49′11.667″	8°51′47.060″	Nyango gyel	Functioning
16	9°48′56.649″	8°51′19.674″		Not functioning
17	9°48′48.698″	8°49′00.096″	Gyero	Functioning
18	9°48′23.963″	8°52′02.078″	Bwandang	Functioning
19	9°48′15.129″	8°51′30.275″		Functioning
20	9°47′53.927″	8°51′00.311″	Bukuru	Not functioning
21	9°47′45.976″	8°51′59.428″		Not functioning
22	9°47′44.572″	8°51′57.889″		Functioning
23	9°47′46.285″	8°52′00.973″		Not functioning
24	9°47′44.572″	8°51′52.064″		Functioning

25	9º47′36.348″	8º51′46.925″		Functioning
26	9º47′28.467″	8º51′51.036″		Functioning
27	9º47′23.670″	8º51′34.247″		Functioning
28	9º47′17.846″	8º51′53.435″		Functioning
29	9º47′18.188″	8º51′49.323″		Functioning
30	9º47′12.363″	8º51′46.239″		Functioning
31	9º47′22.985″	8º51′34.590″		Functioning
32	9º47′31.209″	8º51′12.123″		Not functioning
33	9º47′10.650″	8º50′12.698″	Rasot	Functioning
34	9º45′59.723″	8º50′50.731″	Dankarang	Functioning
35	9º48′16.437″	8º51′31.163″	Bwandang	Functioning

Number of water supplying pipes

Number of pipes	Material used	Condition	Diameter	Function	Length in meters
1	Cast iron	Functioning	150mm	Service	1132.326094
2	Cast iron	Functioning	150mm	Service	1306.379297
3	Cast iron	Functioning	150mm	Service	71.65548874
4	Ductile	Functioning	100mm	Service	742.3806331
5	Ductile	Functioning	50mm	Service	63.29385871
6	Ductile	Functioning	50mm	Service	10.72278771
7	Ductile	Functioning	50mm	Service	23.9328508
8	Cast iron	Functioning	400mm	Main	425.3764532
9	Ductile	Functioning	100mm	Service	490.3843581
10	Cast iron	Functioning	150mm	Service	254.6020263
11	Ductile	Functioning	100mm	Service	111.5196158
12	Ductile	Functioning	100mm	Service	165.4405924
13	Ductile	Functioning	100mm	Service	84.41770679
14	Cast iron	Functioning	400mm	Main	118.0467738
15	Ductile	Functioning	100mm	Service	68.77533874

Number of Public Reservoirs and their coordinates

S/N	Latitude	Longitude	Location	Type	Condition

1	$9^o52'18.582$	$8^o51'02.815$	Rantiya	Pipe-borne	Functioning
2	$9^o47'50.354$	$8^o52'02.788$	Bukuru	Pipe-borne	Functioning
3	$9^o52'53.511$	$8^o50'23.273$	Rantiya	Bore-hole	Functioning
4	$9^o51'56.834$	$8^o51'10.724$	Kufang	Bore-hole	Functioning
5	$9^o51'33.767$	$8^o50'59.520$	Rantiya	Bore-hole	Functioning
6	$9^o49'50.299$	$8^o51'05.451$	Chungben	Bore-hole	Functioning
7	$9^o49'37.777$	$8^o51'36.426$	Sabon barki	Bore-hole	Functioning
8	$9^o49'10.097$	$8^o50'57.543$	Bukuru	Bore-hole	Functioning
9	$9^o48'16.056$	$8^o51'34.499$	Tanchol	Bore-hole	Functioning