GEOSPATIAL MAPPING OF WATER DISTRIBUTION SYSTEM IN BAUCHI METROPOLIS

BY

ZAHARADDEEN MUHAMMAD BABA

DEPARTMENT OF GEOMATICS
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

JULY, 2018

GEOSPATIAL MAPPING OF WATER DISTRIBUTION SYSTEM IN BAUCHI METROPOLIS

BY

Zaharaddeen Muhammad BABA
P14EVGM8011

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN GEOMATICS

DEPARTMENT OF GEOMATICS
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

JULY, 2018

Declaration

I declare that the work in this thesis entitled **'**GEOSPATIAL MAPPING OF WATER DISTRIBUTION SYSTEM IN BAUCHI METROPOLIS' has been performed by me in the department of Geomatics, Ahmadu Bello University Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

ZAHARADDEEN MUHAMMAD BABA _____ _____
Name Signature Date

Certification

This thesis entitled **'**GEOSPATIAL MAPPING OF WATER DISTRIBUTION SYSTEM IN BAUCHI METROPOLIS' by Zaharaddeen Muhammad BABA meets the regulationsgoverning the award of Masters Degree in Geomatics of Ahmadu Bello University, and is approved for its' contribution to knowledge and literary presentation.

Dr. S.S. GARBA _____ _____ _____
Chairman, Supervisory CommitteeSignature Date

Dr. J.D. DODO _____ _____ _____
Member, Supervisory Committee Signature Date

Dr. O.A. ISIOYE _____ _____ _____
Head of Department SignatureDate

Prof. S.Z. ABUBAKAR _____ _____ _____
Dean, School of Postgraduate studiesSignature Date

Dedication

This work is dedicated to my belovedParents Alh.Muhammad Baba Shehu and Fatima Musa, together with mygrandmother lateZainabAbdullahi (Yayale)for theirimmeasurable Financial and moral contribution given to my life and academic pursuit.

Acknowledgements

All Praise is to Almighty Allah for granting me opportunity to complete thisM.Sc research successfully; this wasaccomplished by tremendous effort and academic guidance given by hard working supervisors, Dr. Samuel S.Garba and Dr.Joseph D.Dodo who supervised me tirelessly and friendly all over the period of my study, may God reward you abundantly.

My Profound gratitude goes toProf. L.M Ojigi, Prof. T.O Idowu, Prof. A.A.Musa, Dr. T.O Adewuyi,Dr.O.A Isioye and the remaining staff and lecturers of Geomatics department for their contributions towards my academic discipline and development which was achieved inAhmadu Bello University Zaria.

I wish to acknowledge the immense contribution given to me by Engr. Sagir of Abubakar TatariAli Polytechnic Bauchi, Adam B. Idris, Yusuf M. Inuwa, Hassan Musa, my colleguesand the staff of Bauchi State Water Board (BSWB) for giving me materials, time, and resources which led to the completion of this research, may allah bless you all.

My heartfelt gratitude goes toRukaiya M. Mai Auduga (Ruky),Jamal, Fatima, AdnanNasir, Nuru, Shehu (waleed), Musa (Abba),Amina (Umma) Zainab (Walida), Abubakar, Amina, Khadija, Aisha and Halima M. Baba together with all member of Late Alkali Shehu and Alh.MusaAbasayas' family for the prayers and concern expressed to my academic pursuit, may God bless the entire family.

Furthermore, I also wish to express my sincere appreciation to all success wishers,friends and working colleagues which time would not allow me to mentioned, may God bless our lives and upgrade our status to the peak position of success in all life endeavors.

Abstract

Mapping is a very important aspect that provides effective planning, operation and maintenance in water supply and distribution networks which is one of the most essential components of urban infrastructure. It helps in unlocking the information and identification of the actual location of points and features above and beneath the earth surface. Developing a functional system to manage water distribution assist government in water revenue collection and provide effective service delivery in water utility organizations. The main purpose of this study was to provide a comprehensive map of Bauchi Urban water distribution system using GIS technique with the objective of updating the existing water distribution map, creation of functional geo data base for water utility billing, analyzing the spatial accessibility to the pipelines and identifying the places that require theextension . This study identified the problem of inadequate water distribution and irregular accessibility in the study area due to increase in population, poor facility mapping and inadequate information. The primary data was collected from interview, questionnaire, and field survey using hand held G.P.S and DGPS. Secondary data collected include the analogue base map, Pleiades (50cm) satellite imagery and ward population data from the concern organizations. Queries overlay and proximity analyses have been carried out together with the statistical analysis of the questionnaire and compute the amount of water required by the population of the study. The results presented the updated map and developed a GIS based integrate water utility billing system. Also, it analyzed the water accessibility using international and Georgia accessibility standard, and finally, validation test was conducted to ensure the accuracy of the result.

TABLE OF CONTENTS

Title Page - - - - - - - - - - - i

Declaration - - - - - - - - - - - ii

Certification - - - - - - - - - - - iii

Dedication - - - - - - - - - - - iv

Acknowledgement - - - - - - - - - - v

Abstract - - - - - - - - - - - vi

Table of Content - - - - - - - - - - vii

List of Figures - - - - - - - - - - xii

List of Tables - - - - - - - - - - xiv

List of Appendices - - - - - - - - - xv

List of Plates - - - - - - - - - - xvi

1.0 INTRODUCTION - - - - - - - -1

1.1 Background to the Study - - - - - - - **1**

1.2 Statement of the Research Problem - - - - - **-3**

1.3 Research Questions - - - - - - - **-5**

1.4 Aim - - - - - - - - - **-5**

1.5 Objectives- - - - - - - - - **-5**

1.6 Justification of the Study- - - - - - - **5**

1.7 Scope of the Study - - - - - - - **-6**

1.8 Limitation of the Study - - - - - - - **-7**

1.9 The Study Area - - - - - - - - **-7**

1.9.1 Vegetation and climate - - - - - - - - 8

1.9.2 Rainfalls and rivers - - - - - - - - 8

1.9.3 Sources of water supply to Bauchi Metropolis - - - - 10

1.9.4 Pumping main from Gubi dam to Bauchi Metropolis - - - - 11

1.9.5 Water distribution systems into Bauchi Environs - - - -11

2.0 LITERATURE REVIEW - - - - - - **-12**

2.1 Geographic Information System and Remote Sensing - - - **12**

2.2 Components of Geographic Information System (GIS) - - **-12**

2.2.1 People - - - - - - - - - - 12

2.2.2 Data - - - - - - - - - -13

2.2.3 Hardware - - - - - - - - -13

2.2.4 GIS Software - - - - - - - - -13

2.2.5. Methods - - - - - - - - - 14

2.3 Application of Geographic Information System (GIS) in Water Utility Planning, Management and Maintainace - - - - - - - 14

2.4 Geographic Information System (GIS) Implementation Strategy for Water Utility - 16

2.4.1 Geographic Information System (GIS) planning and implementation - - 16

2.4.2 Elements of enterprise Geographic Information System (GIS) - - - 18

2.5 Related Literatures - - - - - - - -20

2.6 Research Gap - - - - - - - -- 28

3.0 METHODOLOGY - - - - - - - - 31

3.1 Methods - - - - - - - - - - 32

3.2 Materials - - - - - - - - - - 32

3.3 Data Collection - - - - - - - - -33

3.3.1 Hand held GPS House coordination survey - - - - -33

3.3.2 Differential Global Positioning System for Geo referencing - - -34

3.3.3 Interviews and questionnaires - - - - - - -36

3.3.4 Population data - - - - - - - - -37

3.3.5 Remotely sensed data - - - - - - - -37

3.3.6 Existing water distribution map (base map) - - - - -39

3.4 Updating the Bauchi Urban Water Distribution Map - - -40

3.4.1 Data processing - - - - - - - - -41

3.5 Building of Geodatabase - - - - - - -41

3.5.1 Procedure of building Geodatabase - - - - - -42

3.5.2 Rules of the Geodatabase - - - - - - -43

3.6 Procedure for Measuring the Proximity to the Pipelines - - -43

3.7 Criteria for Water Accessibility Assessment - - - - -44

3.8 Validation Test - - - - - - - - -44

4.0 RESULTS AND ANALYSIS - - - - - - - 45

4.1 Updating the Existing Water Distribution Map - - - - 45

4.2 Development of Geodatabase - - - - - - -50

4.2.1 The use of customer file Geodata base in facilitation of water utility billing system- - - - - - - - - - - 51

4.3 Water Accessibility Analysis - - - - - - - 55

4.3.1 Georgia standard criteria for water accessibility - - - - 55

4.4 Extension of Water Distribution Pipe Lines - - - - -59

4.5 Analysis of the Questionnaire - - - - - - -61

4.5.1 Management staff questionnaire - - - - - -61

4.5.2 Technical staff questionnaire - - - - - - -62

4.5.3 Questionnaire analysis results - - - - - - -63

4.5.4 Result of the interview - - - - - - - -68

4.6 Analysis of the Amount of Water Required by the Study Area. - -68

4.7 Overlay Analysis - - - - - - - - - -71

4.8 Results of Validation Test - - - - - - -74

4.8.1 Root Mean Square (RMS) error- - - - - - -74

4.8.2 Field validation - - - - - - - - -74

4.8.3 Data base validation - - - - - - - -75

5.0. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS - -76

5.1 Summary - - - - - - - - - -76

5.2 Conclusions - - - - - - - - -77

5.3 Recommendations - - - - - - - -78

5.4 Contribution to Knowledge - - - - - - -80

REFERENCES - - - - - - - - -81

APPENDICES - - - - - - - - -87

PLATES - - - - - - - - - -108

LIST OF FIGURES

Figure 1.1: The study area - - - - - - - - - - 9

Figure 3.1: Methodology flow chart - - - - - - -31

Figure 3.2: Ward distribution of the sample houses - - - - -33

Figure 3.3: Spatial representation of Ground Control points - - - -34

Figure 3.4: Bauchi Town Pleiades (50cm) Satellite Imagery (BAGIS, 2013) -38

Figure 3.5: Scanned Water distribution base map of Bauchi town - - - 39

Figure 4.1: Updated water distribution map (with dam) - - - -46

Figure 4.2: Updated water distribution map (without dam) - - - -47

Figure 4.3: A Map of Bauchi township pipelines - - - - - -48

Figure 4.4: Classification Map of the pipelines - - - - - 49

Figure 4.5: Customer File Geodatabase - - - - - - 50

Figure 4.6: A result of a query showing the customers that did not pay their utility bill - 51

Figure 4.7: A result of a query showing the customers that made the part payment -52

Figure 4.8: A result of a query showing the customers owing balance of #5,000 - 53

Figure 4.9: A result of a query showing the customers owing balance >#5,000 - 54

Figure 4.10: A service line buffered to 100 meter distance - - - - -56

Figure 4.11: Laterals buffered to 300 meter distance - - - - -57

Figure 4.12: A main line buffered to 1000 meter distance - - - - - -58

Figure 4.13: Existing and suggested pipelines buffered to 500 meter distance - - 59

Figure 4.14: Map of existing and suggested pipelines - - - - -60

Figure 4.15: A Pie-Chart showing the wards population distribution - - -70

Figure 4.16: A Histogram showing the average water requirement - - -71

Figure 4.17: An overlay of pipelines in Bauchi central wards. - - -72

Figure 4.18: An overlay of Pipelines in Miri and Dan iya wards - - - -73

LIST OF TABLES

Table 3.1: Control Points - - - - - - - - 35

Table 3.2:Logged Points - - - - - - - - - 35

Table 3.3: Pleiades Satellite Specification - - - - - - 38

Table 4.2: Managements Staff Questionnaire and Results - - - - - 64

Table 4.3: Technical Staff Questionnaire and Result - - - - - 64

Table 4.4:Customer Questionnaire Analysis - - - - - - 65

Table 4.5: Amount of Water Required by the Wards Population - - - 69

LIST OF APPENDICES

Appendix i: Management staff questionnaire - - - - -87

Appendix ii : Control points - - - --91

Appendix iii: Water utility shape files - - - - - 96

LIST OF PLATES

Plate i:Gubi dam water intake point - - - - - 108

Plate ii:The Gubi Dam - - - - - 108

Plate iii:View of some water treatment machineries at Gubi dam - -- 109

CHAPTER ONE

INTRODUCTION

1.1Background to the Study

Geospatial technology is a multidisciplinary field that includes disciplines such as Surveying, Remote sensing, Mapping, Geographic Information Systems (GIS) and Global Navigation Satellite System (GNSS) (Pun-Cheng, 2001). This technology is widely applied in the field of urban planning, facilities management, business, security and intelligence, automated mapping, real estate management, environmental management, land administration, telecommunication, civil engineering and so many professions that use the location base information (Klinkenberg, 2007).

Mapping is the graphic depiction on a flat surface of the physical features of the whole or part of the earth or other body, using shapes to represent objects and symbols, and labels to represent the feature properties or descriptions. The maps generally use a specified projection and indicate the direction of orientation, map elements include the title, north arrow, scale bar, descriptive text, symbol legend and map frame which provides the principal display of geographic information (Rauph, 2015).

An urban area is a place-based characteristic that incorporates elements of population density, social and economic organization and the transformation of the natural environment in to a built environment. Governments of many developing countries have promoted schemes to bring urban infrastructure to traditionally villages, in an attempt to keep migrants from overwhelming cities that are already crowded beyond the limits of infrastructure. (John,2010). The provision of water to urban areas requires major capital investment in storage, treatment, and supply networks. Furthermore the per capita

Consumption of waterhas generally tended to increase rather than decrease, although this can be expected to be largely a function of life style and population density (Jasen, 2002).

Water distribution system consists of a complex network of interconnected pipes, services, reservoirs, hydrants and other appurtenances including valves and flow meters which deliver water from the treatment Plant to the consumer (Walski*et al*, 2003).Water distribution systems have existed since the Minoans constructed system (Zhang, 2006).The distribution components form a large proportion of total investment in any water supply system (Rao, 2002).

Water distribution system account for 40-70% of the total cost of water supply scheme (Sarbu and Borza, 1997), hence itsProper planning, design, operation and layout is of great importance. Water distribution network contains all the various components of a water system and defines how the components are interconnected. These components include water reservoir, water pipes, water pumps, storage tanks, junctions and valves. Water distribution also includes water resources, pumps, treatment plants, reservoirs, pipes and their accessories (Babovic *et al*, 2002; Chin, 2006).

One of the major challenges in water supply is the provision and management of the pipe network and the associated assets. Effective functioning of these assets is necessary for distributing water continuously and efficiently, therefore effective asset management in the water supply sector is vital for providing uninterrupted services however, water supply assets are mostly buried underground and can only be accessed after excavation (Babovic*et al*., 2002).

The Institution of Civil Engineers (ICE) Geo-spatial Engineering Board, United Kingdom (UK), while examining "buried services in a conference, deliberated extensively on the problems of location, identification and geo-spatial positioning of a wide range of

buried services such as water, sewers, gas, electricity, etc, it buttresses the fact that the location and geospatial positioning of engineering infrastructure, which include water infrastructure, is not only a major problem in developing countries but also in industrialized nations of the world(Farrimond,2005). He also asked that "can we do something today to make these assets easier to find in a hundred years time?

1.2Statement of the Research Problem

Currently, more than two- third of African population are leaving their houses to seek water for drinking and other domestic use. In developing countries, particularly Nigeria, governments are facing problem in provision of social facilities especially the supply of sufficient water to citizens. About 800 million people worldwide have no access to water and almost 63 million Nigerians representing thirty nine percent (39%) of the estimated population lack access to drinking water despite the progress made by MDG project. Water coverage rate in Nigeria remain amongst the lowest in the world (WWD, 2016). Michael (2013) identified many reasons for not achieving the water supply and distribution equally in Nigeria. These challenges are associated with the following reasons; poor fund management, government in sincerity, in adequate information, maintenance and land issues.Bauchi state has a population of about 5.4 million of which approximately 30% live in urban areas. With this population only 36% have access to piped water with very poor service. The source of inadequate piped water coverage were great challenges in the urban water sector's institutional frame work and serious management problem within the Bauchi state water board (BSWB), the main service provider for Bauchi town water supply and distribution.

Urban water service delivery in Bauchi suffers many challenges, including lack of a clear policy, weak legal and institutional frame works; lack of financial management, old dilapidated

infrastructure. Bauchi state water revenue collection's efficiency was very low, billing and financial record keeping was carried out manually without appropriate accountable billing system, due to little information and lack of computerized data base management system for effective service delivery. Furthermore, the number of water connections was unknown and there was no customer metering, hence the board has no detailed and comprehensive customer information which result to improper record keeping and in adequate revenue generation (BSWB, 2015).

Water utilities are not effectively distributed due to government negligence and lack of comprehensive up to date map. The present water distribution map used by Bauchi State water Board (BSWB) was produced since year 2000 during Bauchi Township water supply project. It was sourced from the former 1995 water distribution map by scanning and overlaying on goggle earth imagery without proper geo-referencing, the auto CAD computer aided software was used to traced the pipelines and other point features, therefore, the existing map does not have any spatial reference, no defined coordinate; it lacks many map related features such as coordinate system grids, layout, scale and legend.(Mailafia, 2016).

Bauchi metropolis need 25,000,000 gallon because houses and population of Bauchi town has been drastically increased due to the migration of many people as a result of conflict and insurgency in the neighboring states. Before year 2010, the water was supplied and distributed to all part of the town 4 to 5 times in a week, but presently the urban Water supply has decreased to 2 or 3 times in a week because the demand is higher than the supply and the water has been distributed by load-shedding, (BSWB, 2015).

1.3Research Questions

(i) What is the status of the existing water distribution map of the study area?

(ii) How can a Geodatabase be used in facilitating the water distribution system?

(iii) What are the spatial distribution and the accessibility of water facilities in the study area?

(iv) Where are the places that require the extension of water facilities?

1.4Aim

The aim of this research is the Geospatial mapping of water distribution system in Bauchi metropolis with a view of identifying areas without such facilities in the study area.

1.5Objectives

The objectives of the study are to:

(i) Update the existing domestic water distribution map of the study area

(ii)Develop a functional Geo-data base that facilitate water distribution in the study area

(iii)Analysesthe spatial accessibility to the existing water facilities.

(iv) Identifyplaces that require the extension of water facilities.

1.6Justification of the Study

Effective water distribution requires efficient system of mapping and modern means of water utility record keeping. To improve the water distribution system, decision makers in

water sector need to embrace GIS technology to monitor the underground network of water utilities and manage the commercial activities between customers and the service provider.

Based on the various literature reviewed, many researchers have mapped and study the water distribution system in different part of the world using different data sources, methods and equipments. This study updated the water distribution map of Bauchi town due to the analogue map product used by the water board and provides accessible means of locating and expanding the utilities. It also advanced in to the development of a customer file Geo data base to integrate the system of water utility billing. When the used of this spatial data base was adapted by Bauchi State Water Board (BSWB), it enable the organization to have a functional Geo data base which identify the spatial distribution of the customers and their respective payment status using a dynamic map based query tool which extract information from the Geo data base. Therefore, it facilitates billing and provides a centralized Business system.

1.7Scope of the Study

This research focused on mapping of the water pipe network in eleven wards which cover the complete area designated as Bauchi town, other water facilities such as valves, chambers, nodes, hydrants, dam, roads and sample houses would also be shown on the map to ensure comprehensive coverage of features for updating the water distribution map, development of Geodatabase, water accessibility analysis and identify the extension of water facilities to the required places.

1.8Limitation of the Study

Any research has a given limitation; this study encountered a series of delay in data collection and release of information from the state water board as a result of strict administrative protocol. The material type data of pipelines was not able to acquire due to in adequate system of record keeping from Bauchi State Water Board (BSWB). Some pipelines were not connected after digitizing the water distribution base map and appeared not in the actual location because it shift a certain meters away due to lack of Georeferencing and coordinates. These problems were rectified by conducting a series of ground truthing and Georeferencing the base map using ten (10) ground control points.

1.9 The Study Area

Bauchi state lies between latitude $09^{o}30^{'}00''$N and $12^{0}30'00^{''}$North of the equatorand longitude $08^{o}45'00^{''}$E and 11^{o} 00' $00^{''}$East of the green which meridian. Within these coordinates, the state cover a total land mass of about 49,259 km^2, around 5.3% of the Nigerian land mass. It has a population of about 4,676,465 according to year 2006 population census.Bauchi state is watered by two major rivers; river Gongola and river Jama'are. A substantial part of Hadeja-Jama'are river basin lies in Bauchi State with various flood plain (Fadama) areas for agricultural activities, these are further supported by number of dams for irrigation and other purposes which include Gubi dam (the source of water to study area) and other water bodies.

Bauchi town is located at latitude 10^{o} $17^{'}$ 00''N and longitude 09^{o} $49^{'}$ $00^{''}$E, it has an area of about 1,662.118km^2 with a population of about 164,603 people. (Abubakar,2006).

1.9.1Vegetation and climate

Bauchi state span two distinct vegetation zones, namely; the Sudan savannah and the Sahel savannah, the Sudan savannah covers the southern part of the state especially along the water sources or rivers, while the Sahel savannah (semi desert) manifested from the middle of the state as one move from south to north part of the above influenced the climatic factor and the amount of rain fall received, therefore the weather of state.The vegetation types described north and southern part of the state varies considerably. While its humidity hot during the early part of the rainy season in the south, the hot dry and dusty weather lingers up north.

1.9.2 Rainfalls and rivers

The rainfall in Bauchi State ranges between 1300mm per annum in the south (the study area) and only 700mm per annum in the extreme north, this is because the rain started earlier in April in the southern part of the state where it is heaviest and last longer. On the other side, the northern part of the state receive the rainlate, usually around June or July and record the record the amount of 700mm per annum. Figure 1.1 below is the map showing the study area.

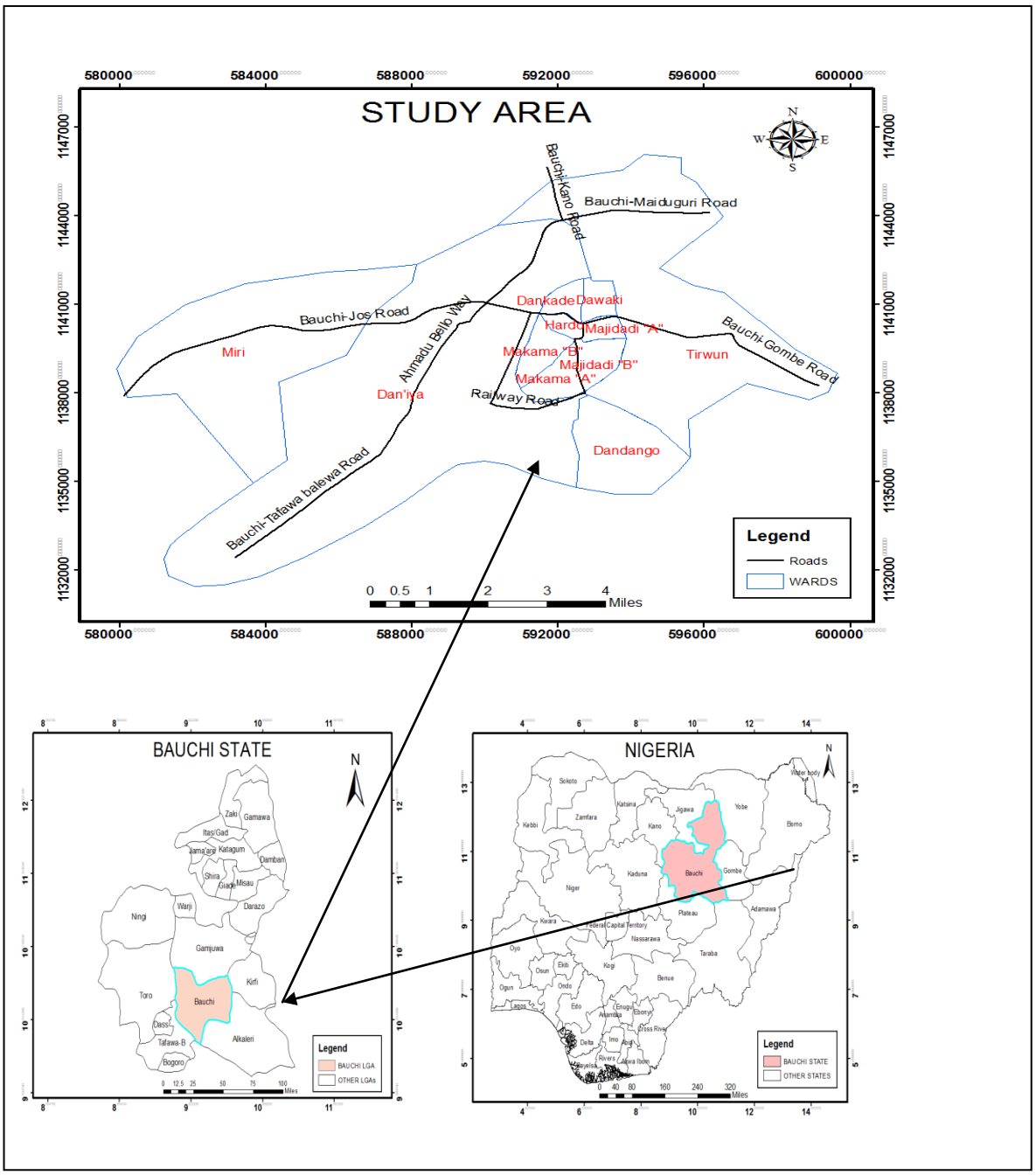


Figure 1.1: The study area

Bauchi State is watered by two major rivers; river Gongola and river Jama'are. River Gongola crosses the state through TafawaBalewa Local Government in the south, Kirfi and Alkaleri Local Government in the northern part of the state. River Jama'are cuts across a number of local government areas in the northern part of the state.

Moreover, a substantial part of Hadeja-Jama'are river basin lies in Bauchi State with various flood plain (Fadama) areas for agricultural activities, these are further supported by number of dams for irrigation and other purposes. These include Gubi dam (the source of water to study area) and Tilden Fulani dam; other water bodies include Mala dumba lake in Misau Local government area.

Bauchi town is located at latitude 10^{o} $17^{'}$ 00''N and longitude 09^{o} $49^{'}$ $00^{''}$N, it has an area of about 1,662.118km^2 with a population of about 164,603 people. (Abubakar,2006).

1.9.3 Sources of water supply to Bauchi Metropolis

Haladu*et al.*(2014), described the source of Gubi dam water as mainly coming from three tributaries, namely Gubi River, Tagwaye river link with Shadawanka and Ran River. The function of the dam is to supply the state capital and its environs with potable water and the dam was commissioned in 1981 with the embankments of 3.86km, bottom earth-fill of 2,315, 000m3 and the reservoir area of 590 hectares. The catchments area is 179km2 with total storage capacity of 38.4 x 106m3 and expected yield of 90,000m2/d. (Haladu*et al.*,2014).

1.9.4 Pumping main from Gubi dam to Bauchi Metropolis

The treated water from Gubi treatment plant is conveyed to warinje hill by the help of four pumps installed in the treatment plant at pumping station. Out of four pumps, only three are now in used while the other one is kept as standby, the types of pump used in Gubi treatment plant are centrifuged pumps. Known as weir pump manufactured. The pump has head of 152m or 15.2 bar and discharge (Q) = 1875m^3/h. the motor drive is 450 kW and 415 volt. From the pumping station the potable water is conveyed to two reservoirs at warinje hill through a steel pipe of 800 mm diameter of 12.004km length. (Haladu*et al.*,2014).

1.9.5 Water distribution systems into Bauchi Environs

The distribution of water in Bauchi environs start from warinje reservoir. There are two reservoirs at warinje hill, each reservoir have a capacity of 11000m^3 which is equivalent to 2.million gallons of water making total of 5 million gallons. The two reservoirs at warinje hill are connected with 800mm pipe diameter. The water distribution system in Bauchi town is classified into three zones which are lower north zone, lower south zone and upper south zone.

CHAPTER TWO

LITERATURE REVIEW

This chapter review the literature related to the research and described a detail frame work onGIS andremote sensing application in water utility mapping, GIS implementation strategy, water distribution mapping and Gubi dam water supply system.

2.1Geographic Information System and Remote Sensing

GIS is acronym for Geographic Information System. It is an organized collection of computer hardware, software, geographic data, procedures, and personnel designed to capture, store, analyze, query and display of all forms of geographic data.(Tomlinson, 2007).

Remote Sensing is the science and an art of acquiring spectral, spatial and temporal information of material objects, areas, or phenomena without coming into physical contact with the object, area, or phenomena under investigation (Jain, 2009). More commonly, the term remote sensing refers to imagery and image information derived by both airborne and satellite platforms that house sensor equipment.

2.2Components of Geographic Information System (GIS)

The components of GIS include: People, Data, Software, Hardware and Methods.

2.2.1 People

People are the most essential component of a GIS. They set the procedure and methods that are used by a GIS and carry out all operations such as ground truthing, data collection, data

storing, processing and analysis. People include surveyor, software user and GIS analyst. (Guanfu and Ershun, 1998).

2.2.2 Data

Data is the core of any GIS. The availability and accuracy of data will affect the results of any analysis. A GIS can integrate data from a number of different sources and store in a database management system. There are two types of data used in a GIS - spatial and Attribute data. (Phadke, 2006).

2.2.3 Hardware

The type of hardware determines, to an extent, the speed at which a GIS will operate. Additionally, it may influence the type of software used. To a small degree, it may influence the types and personalities of the people working with the GIS. Hardware types, range from desktop computers to large computer servers. Other hardware components include graphics devices, plotters, printers and scanners (Star and Estes, 1990).

2.2.4 GIS Software

Software tools provide the functions and tools required to store analyses and display the spatial data. This includes the GIS software, database and drawing software. It involve not only to the GIS package, but all the software used for databases, drawings, statistics, and imaging. (Tomlinson, 2007).

2.2.5. Methods

The procedures used to input, analyses, and query data determine the quality and validity of the final product. The procedures used are simple the steps taken in a well-defined and consistent method to produce correct and reproducible results from the GIS system (Tomlinson, 2007).

2.3 Application of Geographic Information System (GIS) in Water Utility Planning, Management and Maintainace

Geographical Information Systems (GIS) is an information system that integrate, store, edit, analyses, shares and display outputs of geographic information that can be used for decision making (GoodChild,2009).GIS applications provide industries the ability to save time and money along with integrating data and information into one manageable system (Shamsi 2005).

Customer billing and other information can be accessible in the GIS database for many applications, linking the customer information within the GIS is an important consideration, Customer information can be linked in four ways: by building, by parcel, by meter, and by address (Cannistra 1999).

Indeed, GIS applications have a variety of geometric system tools which allows a user to create a number of interactive queries using structured query languages (SQL), thereby analyzing spatial information, editing map data and caring up with an output that helps in making useful decision, (Rauph,2015). Therefore, GIS with extensive spatial analytical capabilities have become widely applied in the infrastructure sector; it is applied in four sections of the water infrastructure sector: asset management, distribution management, customer and outage management. It is ideal to manage infrastructure by integrating all the information systems within these sections. However, lack of data is often a serious

limitation. Consequently, a GIS application in the operations and maintenance section of water utilities is a first stage approach to integration and optimization of all sections of water supply systems (Brussels, 2005).

GIS further be applied in the entire process of water supply systems from planning to implementation, operation and maintenance to replacement, this is because GIS provides a variety of support in 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 closing valves to redirect water flow. Moreover, service continuity can be ensured by limiting repair and maintenance time through spatial scenario modeling, locating areas affected by particular problem and informing affected parties. Through GIS, the direction of flows can be established to find upstream and downstream of points to optimize water pressure so as to identify an isolated part of a network. (Brussels, 2005).

Geographic Information Systems (GIS) provides the tools for water utilities to efficiently map and manage their assets (Vega, 2009). GIS database maintenance was also listed as the first geospatial application in the water industry (Miner, 2005). Shamsi (2005) stated that GIS provides the ideal method of describing water infrastructure and means of identifying problems, recommending solutions, and scheduling the maintenance activities. A GIS stores both attributes and images of pipes, valves, meters, manholes, and numerous other objects with spatial locations (ESRI, 2007). GIS has therefore become a central tool used by water utilities not just for mapping, but for improved management of their assets (Baird, 2011). GIS can be used to more efficiently manage the distribution system during normal operation and emergency situations, it allows managers and operators the capability to efficiently manage their water distribution and give them the ability to maintain updated

maps. Lyon and Clifford (2008) noted that current and accurate maps are critical to water districts operations, not only for maintaining infrastructure and providing decision, but also ensuring compliance with government regulations. GIS provides a comprehensive asset inventory and accurate mapping system for utilities (Lyon and Clifford 2008).

2.4Geographic Information System (GIS) Implementation Strategy for Water Utility

This provides a starting point for water utilities that are interested in updating their current implementation of geographic information system technology or starting fresh with a new GIS project. Today, water utilities need a geospatial platform that is available across the utility to support business needs. The GIS platform provides easy access to maps and information on any device for everyone in the utility as well as others to collaborate and communicate with contractors and customers. Water utility organizations need the technology that can be configured to meet their foundational mapping and analysis. Accessing and managing work information from a map add a tremendous amount of value to a water utility because Staff members can locate their assets in the field.(ESRI,2014).

2.4.1Geographic Information System (GIS) planning and implementation

Consideration of organizational factors is important to successful GIS implementation and management because of the critical role that information plays in an organization's function. In most cases, the design and implementation of a GIS is a long-term effort. Experience has shown that, as important as technical issues of software, hardware, and database design are, it is the people problems arising from access to the information and its use that determine whether a GIS will succeed or fail (Aronoff, 1989).

Fellers (2013) stated that, during the planning of a major GIS acquisition or development, it is important to consider certain organizational attributes that will impact the chosen approach. These attributes, generally addressed in a needs assessment and should be evaluated in the broadest possible sense. In this way, the goals, equipments, costs, etc., of all impacted departments will be included in the implementation planning. Only after careful consideration of these attributes can the best possible implementation strategy is chosen.

The following are some attributes to consider for successful GIS implementation:

i. Overall organizational function and goals

ii. Sources of data available as input to the GIS system

iii. GIS hardware, software, databases and products that are currently and planned to be utilized

iv. Management approaches that will and have previously guided the GIS program

v. Costs of implementation, both historic and planned

vi. Benefits of implementation, both tangible and intangible

vii. Procedure to be used in evaluating and comparing the costs and benefits

viii. Generation procedures: review internal, external, current, and potential procedures

ix. Quality assurance, quality control, procedures and any applicable data standards

x. End-user interactions and training: consider how the GIS group will communicate with its "clients"

xi. Evaluation/assessment procedures to be used to review the GIS implementation

xii. Legal issues pertaining to data distribution and ownership

2.4.2 Elements of enterprise Geographic Information System (GIS)

ESRI (2014) have mentioned and explained the five (5) common solution patterns of GIS which form a framework to meet the need of water utility organizations with GIS based technology. Each pattern denotes a functional element of an enterprise GIS. These are asset management, planning and analysis, field mobility, operational awareness, and constituent engagement.

(i) Asset Management

GIS solutions for asset management include the process for storing, managing, and accessing spatial data. For water utilities, this is the authoritative repository for asset data such as pipes, valves, hydrants, meters, and other network features, as well as operational data such as pressure zones, work routes, main breaks, and inspection locations. Asset management leverages both GIS for Desktop and data persisting in the Geodatabase which requires workflow to keep data current and maintain data integrity.

(ii)Planning and Analysis

GIS solutions for planning and analysis involve the transforming of raw data into useful information through the application of analytical techniques. The GIS geoprocessing framework offers a complete set of spatial analytical functions and tools including feature overlays, selections, and modeling. Technically, there are many ways to use a geoprocessing function, but the two most common are through scripts and models. For example, the water main isolation tracing function is commonly used to help field crews identify which system valves to close to isolate a segment of the system in both emergency and maintenance scenarios. This network tracing leverages complex analysis through geoprocessing models. The GIS platform also allows the actionable intelligence to be shared, integrated, and visualized.

(iii)Field Mobility

Mobile GIS platforms enable the field personnel to view, capture, store, update, manipulate, and analyze their networks, facilities, and operational data (work order, customer complaints, and inspections). Field personnel require a simple solution for data visualization, exchange, collection, and updates. This GIS solution pattern is enabled by the availability of information that has been stored and optimized for the mobile environment.

(iv)Operational Awareness

Operational awareness applications are sometimes referred to as common operating pictures, operational dashboards, or executive dashboards, and they provide windows into relevant information supporting intelligent decision making. This information becomes obvious through proper planning and analysis techniques, collected in part from the field on mobile devices, created and stored in the Geodatabase. From the technological perspective, this pattern involves the combination of both data and analytical layers organized in a map and published over the network for application consumption.

(v)Constituent Engagement

Information harvested from constituents (citizens, potential/existing customers, stakeholders, etc.) can have a dramatic impact on operational activities, products offered, and services delivered. Constituent-generated data can be turned into valuable information through planning and analysis techniques and then be integrated into organizational workflows in support of smoother and more responsive operations. This solutions pattern promotes an ongoing connection between constituents and organizations that will help in promoting both internal and external transparency and accountability.

2.5Review of the Related Literatures

Water as a resource to any nation should be well planned, developed, conserved, distributed and managed. Its infrastructure should be properly maintained to avoid future water problems. The total water requirement is on the increase and the per capita water consumption is also on the increase due to the increase in population and civilization(Audu and Anyata, 2010; Audu and Ehiorobo, 2010; Audu and Edokpia, 2010). Under the most optimistic scenario, the world's population is expected to grow at least to eight billion by 2025. This growth, 90 percent of which will occur in urban areas will intensify the demand for potable water and water of sufficient quality for use in the industry and waste treatment (Lacquemanne, 2000).

According to the report of the WHO/UNICEF (2014) Joint Monitoring Program for Water Supply and Sanitation (JMP), more than 2 billion people have gained access to improved sources of drinking water since 1990, and 116 countries have met the MDG target on drinking water. More than half the world's population, almost 4 billion people, now has a piped water connection at their homes. With regard to sanitation, from 1990 to 2012, almost 2 billion people gained access to sanitation and 77 countries have met the MDG target on basic sanitation.

Water has always been a very important issue on the United Nations (UN) agenda. When defining the Millennium Development Goals, water was also taken into account as one of the aspects for ensuring environmental sustainability (Goal 7). The aim of the UN is to reduce by half the proportion of people without sustain able access to safe drinking water by 2015(MDGs, 2014).

World Health Organization (2011) specifies the minimum and maximum amount of water required per person per day as 40 liters ($0.04m^3$) to 80 liters ($0.08m^3$). In Nigeria, water

availability controls population distribution. 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 the country is from public water supplies, 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, this usually creates a great disparity in supply to different zones of the settlement. (Oyebande,2005).

Audu and Ehiorobo (2015) applied the geospatial technique to water distribution mapping and modeling in Warri port complex, Nigeria. The aims of their study were to examine the location of Nigerian Port Authority water distribution pipeline routes, determine geospatial information and produce a vector model. They used DGPS, Leveling machine, Total station and Google earth imagery. Control points were established by DGPS And used in running a secondary total station traverses through the proposed water distribution pipeline routes, the elevation data was generated from the topographic map and ground leveling and produce a contour map showing the terrain elevation. The water CAD and 3D civil CAD was used in design and network analysis. The output of the study was the water distribution network with the position of air valves, sluice valves, washout, end caps, fire hydrants etc. located. The interpretation of the geospatial database with analytical tools allowed the water distribution network to be planned more economically and effectively.

Pindiga, Sani, and Garba, (2015) presented a paper on mapping of water distribution network using GIS technology in Bauchi using metropolis, Nigeria. They scanned; geo referenced and digitized the old analogue water distribution base map, GPS instruments was used in locating the facilities such as pipes, nodes, valves, hydrants and buster. Queries

were made in Arc GIS to identify the location of nodes, hydrants and buster stations in the distribution network.

Eljamassi, and Rola (2013) conducted a research in A GIS –Based decision support system for management of water distribution networks in Rafah city.Their aim was to study and evaluate the existing water distribution network and prepare a GIS data base for the operation and management system. GIS technology was chosen as one the pool decision which deals with such quantity of data; it was looked with other software in accomplishing the aims of their study.These include Arc GIS 9.3 data sets and water CAD/water GEM hydraulic modeling the data was collected b conducting interview with the head manager and water network operators to clarify the existing water distribution system in the Rafah municipal area, they concluded that the study will assist the water networks department by providing data base and decisions support system for proper management and equal water distribution to the customers in all zones.

Mary (2008) examines the GIS representation and assessment of water distribution system for Mae la temporary shelter, Thailand. The purpose of the research is to assess and evaluate the predicted volume of water available to service houses within the area. Arc GIS software together with an EPANET water distribution model was used, the flow rate was predicted by the model using the point elevation of the distribution system infrastructure and checked the pipe line network specification data using a LASER range finder. Garmin e – Trex vista hand held 'GPS' device was used in data collection and super imposed the coordinates on Google earth imagery to locate the points, the imagery helps in estimating the number of available houses resident in the area, the result was represented in form of maps, graph and histograms, finally the research shows that majority of the residents in Mae la have adequate access to water.

Henry (2007) assessed the challenges of water supply in urban Ghana, his aim was to create awareness about the challenges and suggest the way to overcome some of the challenges. He used the method of structured questionnaire, interview and e-mail data collection. The statistical techniques were applied in data analysis and the result was presented in form of graphs and charts.

A water pump supplies water through primary, secondary and distributor water mains to the consumers, the smallest pipelines in the network should be 0.150m, smallest branching Pipelines with dead ends is 0.200m, the maximum space between the two is 200meters while the maximum space between main line and laterals in 1000meters and the maximum length of service line is 300 meters (Harry, 2008).

Tang and Gregory (2007) study the spatial analysis of house hold water supply and demand in a distributed Geographic network in the towns of Amherst and Clarence, New York, the objectives of the study was to analyze and visualized the impact of house hold water demand based on population distribution and apply spatial network modeling methodology in GIS. The spatial network models were constructed in GIS for simulations and the utility analyst extension was applied in Arc GIS to model and simulate both the demand accumulations and transportation capacity. The house hold water demand map layer was overlaid on the water supply capacity map layer to calculate the spatial patterns of the discrepancies. The results indicated that as a network extended eastward, south east part of the Amherst and three of the four sub - region in the town of clerenceencountered the discrepancy of supply capacity in meeting the accumulated house hold water demands rots.

Vida and Nandavdekar (2013) described the mapping of water distribution network through Geographical information system, they set out a research objective to design or

prepare Geographical layers for water distribution network. The methodology was explained through the process of data collection and GIS layer data presentation. They made a conclusion by describing the importance of GIS as a powerful analytical and decision making tool for management of water supply system.

Asajule, (2015) describe the measuring and mapping citizens' access to rural water supply in Tanzania, the aim was to examine the conceptual and practice of water access indicator in measuring citizens' access to water. A mixed method research approach was adapted by employing the both qualitative and qualitative method of data collection and analysis so as to enhance the validity and reliability of the results. 'GPS' was also used to field data collection while the spatial analysis and visualization was carried out in Arc GIS environment.

The statistical package for social science (SPSS) was used in the used in the statistical analysis. Water points mapping and spatial analysis of water coverage indicator practice was performed and the pockets of served and under underserved areas were highlighted. The findings show that the current practice of water access indicators assess the perform work of objective and quantitative access dimension which gives more focus on service providers and ignores citizens as service users value perception and their access strategies which significantly contribute to sector performance

Michael *etal.*,(2011) conducted a research on GIS water supply network maintenance in Tarkwa, South western Ghana, The objective was to create a geo-database that supports improved operations and performance to determine costs of asset replacement. They used Hand held G.P.S in data collection and ArcGIS software in the spatial analysis and attribute queries, Map layouts were generated from the spatial analysis and graph plotted using attribute data and developed a geo-database model. The analogue maps of the mains and

lateral pipelines were scanned and geo-referenced then the pipelines and valves were manually digitized. Finally the analysis indicated that more than half of the network was over-aged and also observed the consistent reduction in length of some pipes.

GIS databases incorporate two distinct branches, the spatial database and the associated attribute database. Many GIS software packages maintain this distinction. The spatial data are characterized as having a "vector" structure composed of features represented as points, lines, and polygons. Other GIS spatial data are handled as images, or "raster" having simple row-and column formats. Attribute data are handled in relational database software composed of records and fields, and the power of the relational model is applied to these data.

Baird (2011) mentioned that Geographical information system is needed for base maps, infrastructure and utility management, planning, demographic analysis, incident tracking and other uses. GIS allows utilities to maintain an up-to-date and accurate location of all assets while increasing operational efficiency and enhancing customer service. GIS enables water utilities to make better decisions, reduce response time, and realize cost savings.

Vega (2009) provided a critical analysis of the GIS plan for the City of Tampa, Florida, the first step was to explain to users the possibilities of GIS applications so users would have an understanding of information product that were needed for their job in managing the water distribution system.

Crawford (2012) documented the implementation of a water, sewer, and electric GIS for the City of Calhoun, during the needs assessment he interviewed the staff to establish an overall set of goals and objectives. His next step was to have a better understanding of their business processes through evaluating the existing data that was currently being used and identifying applications that the departments could benefit from. Lastly, he determined the

number of users that would be accessing the system from each of the departments. Crawford also gave insight on how data was created to populate the GIS. Features such as valves, hydrants, and water meters were located with handheld GPS in order to accurately place the lines. Crawford (2012) also implemented some web mapping applications to provide the utility with the ability to locate, query, and analyze different data sets so that people would have the ability to access data from tablets and smart phones in the field.

Omoniyi and Basorun (2013) Analyses the spatial distribution of Dam water supply at Ero region of Ekiti State, the questionnaire was distributed and analyzed the data by descriptive statistics, their result show that the water distribution covers almost all the region, but shortage of equipments and improper management affect the water reticulation in the region.

Fyassa (2009) mentioned some of the standard needed for laying water distribution pipelines, thestrip of land lying between the source of water supply and the distribution area should be surveyed to obtain the ground level for fixing up the alignment of the rising main. The distribution area should also be surveyed and prepared a detailed maps showing the positions of roads, houses, commercial and industrial areas etc. A topographical map of the area should be prepared to identify the high and low areas, the positionof existing underground service lines like electric and telephone lines, sewer lines, existing water supply lines and a tentative layout of the distribution line should be marked showing the location of the treatment plant(s), distribution mains, distribution and balancing reservoirs, valves, hydrants, etc. The fire hydrants should be placed at 50 to 100m intervals on straight runs, and on street junctions. The pipes should be designed for a discharge ranging from 2.25 to 3 times the average rate of supply. For populations over 50,000, the distribution mains should have a capacity of 225% of average rate of supply, while for population

below 5000; the distribution pipes should have a capacity of 300% for the average rate of supply.

New England civil Engineering corporation (2006) Executed the project on water distribution system GIS mapping for the district of Tops field, Gloucester and Grafton, the map comprises the water mains, valves, hydrants wells, tanks and pumps, it also incorporated the ortho photography, street lines, buildings property lines wetlands and other surface features. The record drawings were scanned and imported into the same coordinate system as the client GIS layers, water infrastructure was digitized over the record drawing information and hyper linked to the drawings for each pipe segment. All pipes and features were populated with age, condition and serviceability information.

Victor and Aline (2005) used remote sensing to map and monitor water resources in Arid and semi arid regions, they stated that a variety of passive and active remote sensors with visible and micro wave bands can be used to estimate and delineate water boundaries. Data from high resolution commercial satellite such as IKONOS and Quick Bird have been used to produce a more detailed map of the study regions. The Radar altimetry was used to obtain point measurement of water surface elevation in order to determine volumetric water storage. They have made a conclusion that mapping and monitoring of utilization and rational management

Welday(2005) conducted a research on water supply coverage and water loss in distribution systems, the case of Adisababa, Ethopia.The main objective of the research was to evaluate the supply coverage and explore the water loss in city water supply distribution and suggest a method to better identify and reduce the loss for the data collection, the cadastral information of Adisababaabout 10 years ago was used as a base, also the telephone communication was made with the water authority. Digital water pipe network for the

whole city comprising the attribute such as size, age and material of the pipes has been collected in Auto CAD formats, the network include the main pipes and secondary pies that cover the major part of the city, but the tertiary pipes were not available in the digital format. The contour of the city was used to define the elevation of the facilities. It is concluded that the intra city distribution of the water supply coverage was found to be positive and strong (+ 0.749), this shows the shortage of water in the city. The recommendation was made to update the network and introduced GIS to facilitate a timely network updates and support related spatial analysis.

Andrea (2002) study the water supply and sanitation in Govansolo, Mali.The main purpose of the study was to assess the situation of water supply and sanitation in the Govansolo, Mali, to identify the problems, potential water supply and sanitation improvement projects as solution. The study was conducted by observations, interviews and surveys. The result shows that almost all of the households have reasonable access to water source from an improved water source.

2.6Research Gap

Various research and relevant literatures have been consulted, among which are:

Pindiga, Sani, and Garba, (2015) who mapped the water distribution network in Bauchi using Geospatial technique. They scanned; geo referenced and digitized the old water distribution base map using G.P.S and Arc GIS software. Their study did not provide any information on pipelines which is the major facility in water distribution network,the main distribution pipelines that convey water from Gubi dam was not incorporated in the distribution network; they mapped the pipelines and made queries to identify the location of nodes hydrants and buster station on the map. The present research has tried to fill the

missing gap by developing a functional water utility geo data base and customer file geo data base to demonstrate the use of GIS in water utility billing. Furthermore, all pipelines in the distribution network were classified based on diameter. Queries overlay and the proximity analysis was conducted to explore information about these facilities.

Audu and Ehioribo (2015) applied geospatial technology for water distribution modeling in Warri port complex; they made use of Google earth imagery in their study. Marry (2008) also used the Google earth image to study the GIS representation and assessment of water distribution system in Thailand, This study used the Pleiadessatellite imagery with high resolution (50cm) to ensure effective and accurate representation of features on the map. In addition, it measures the containment of pipelines within the neighboring wards in the study.

In the research conducted by Michael, *etal* (2011) on GIS in water supply network and maintenance in Tarkwa, Ghana. Their objective was to build a Geodatabase that support the improved operation and determine the cost asset replacement of the over aged pipelines; the Geodatabase was restricted to cost asset replacement. Various studies were conducted by researchers such as Eljamasi,*etal.*,(2013), Crawford, D (2012), Baird (2011), Vega (2009) and many others, some of them identified the use of water utility Geodatabase and some have created the Geodatabase for water utility planning, but none of the geodatabase incorporated the customer based information which develop a dynamic map based query tool for extracting detailed information about the payment status of the customers for effective water billing system as provided by this study.

Based on the reviewed literatures, only Pindiga*etal* have mapped the water distribution in Bauchi town using GIS technology, their result was map of the pipelines and made queries

on nodes, fire hydrants and buster stations. They did not analyzed the spatial accessibility to these pipelines and provide no information on the pipeline feature. The method applied in Georeferencing (Transformation) and the type of 'GPS' instrument used was not mentioned. Finally, they recommended the use of GIS as decision making tool for municipal water Authorities to ensure strategic planning, effective resource and operation management so as to achieve the business objectives such as customer satisfaction, business growth and customer based expansion. From the aforementioned recommendation by Pindiga*etal,* to ensure a GIS based water planning and management system, a spatial data base need to be created. This study has createdan integrated GIS based customer file Geo data base for water utility billing in Bauchi town which incorporated the payment status of the customer and Geospatial data for easy house identification on the map to ensure the achievement of the business objectives.

CHAPTER THREE

METHODOLOGY

This chapter describes the type of method used, technique applied and the available tools used in data collection, processing and analysis to accomplish the objective of the research and ensure a reasonable conclusion.

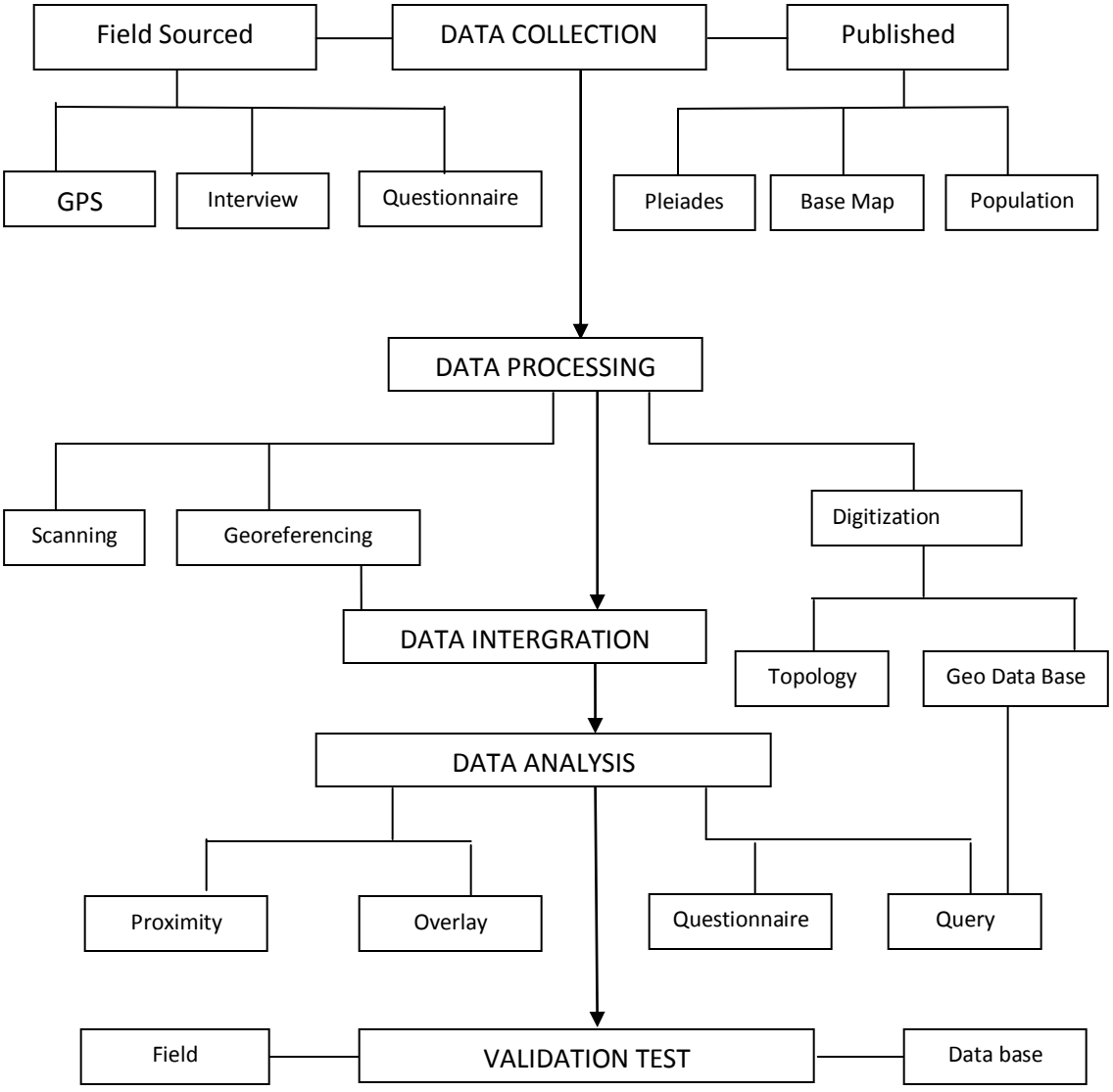


Figure 3.1: Methodology Flow Chart

3.1 Method

This section is about the technique used in data collection which helps to find solution to research problem.Data is among the component of GIS; therefore it is a raw fact which served as basic requirement for the research.The methodology flow chart in figure 3.1 above is a diagram showing a clear representation of the primary and secondary sources of data collection, method of data processing and analysis which finally leads to validation of results.

3.2 Materials

Materials involved GIS hardware such as HP 630 pavilion with 2G Ram capacity, AO Scanner HP designjet with optical scan resolution of 600 dpi, external storage device 250 Giga Bytes capacityfor backup and recovery, Garmin 76 hand held Global Positioning System (GPS) at ±3m accuracy and Hi-target GNSS Real time kinematic (RTK) dual frequency differential GPS with $\pm (10 + 1 \times 10^{-6})$mm and $\pm (20 + 1 \times 10^{-6})$mm horizontal and vertical accuracy respectively.

The software used in mapping and analysis includemap source software as a medium for receiving the hand held GPS field survey data and Spectrum survey office for DGPS raw data processing. Arc GIS 10.1 version was used as the major GIS software used in data processing and analysis; this was achieved by using different Arc GIS tools such as arc tool box, arc catalogue and geo-processing tool in accomplishing the task.

3.3Data Collection

3.3.1 Hand held GPS house coordination survey

The primary data collected comprises the field sourced data of the seven (7) sample houses coordinates (N,E)from each of the eleven (11) wards, making a total number of seventy seven (77) houses in the study area acquired during the field survey with Garmin 76 hand held GPS at an accuracy of ±3m.

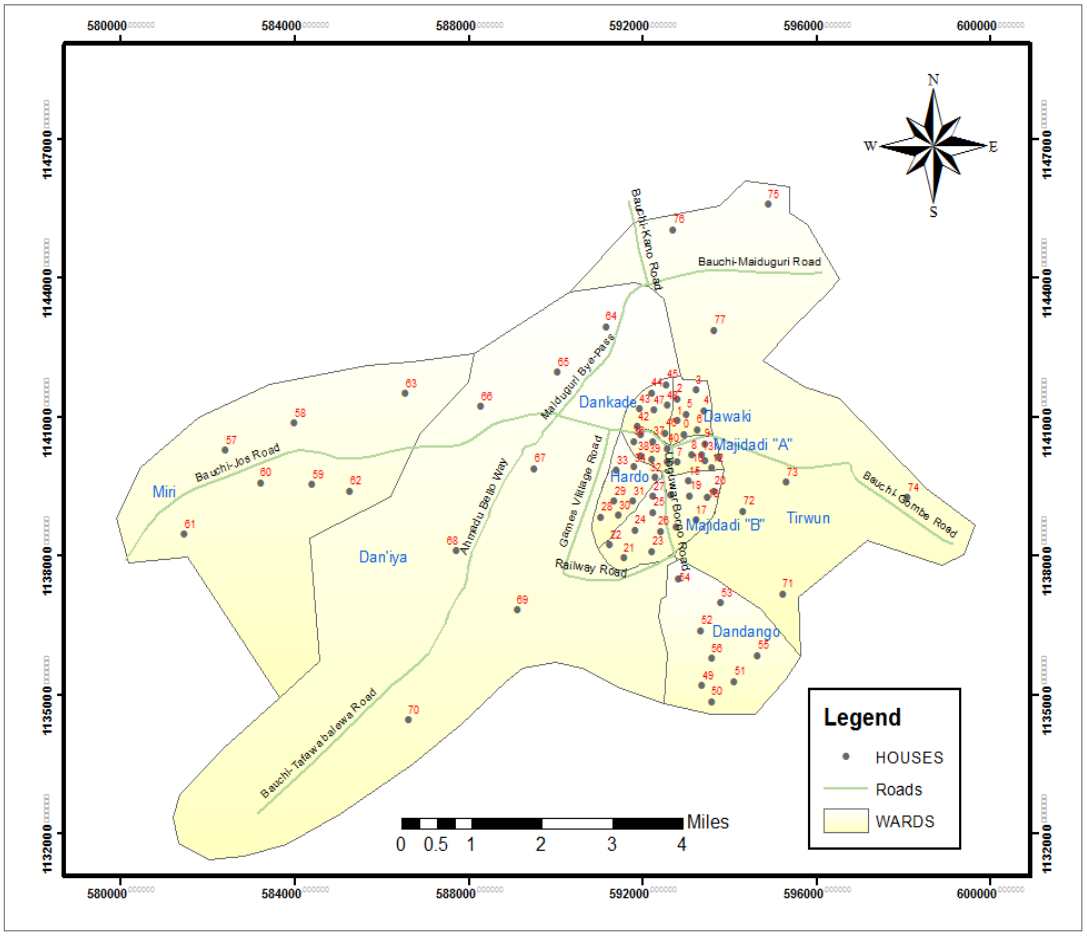


Figure 3.2: Ward distribution of the sample houses

3.3.2 Differential Global Positioning System for Georeferencing

The Bauchi state survey control point B1244A13 was used to feed the DGPS instrument mounted and set up at the center of Awalah round about along Bauchi - Maiduguri road as (CS05) survey base station; the master and rover were synchronized to enable the transmission of signal. Second ground control point (FG44) was captured at GidaDubu road junction, the third coordinate (CS07) was obtained at Inkil rail and road link junction, then central market round about (CS09), Railway roundabout (CS10), A.T.B.U junction (CS06), Wikki oil road junction (CS55), Eagle round about along Bauchi-Jos road (CS11), Zaranda Hotel road junction (CS08) and finally Bauchi state house of assembly road junction along Bauchi -Gombe Road (FG45) as the last control point.

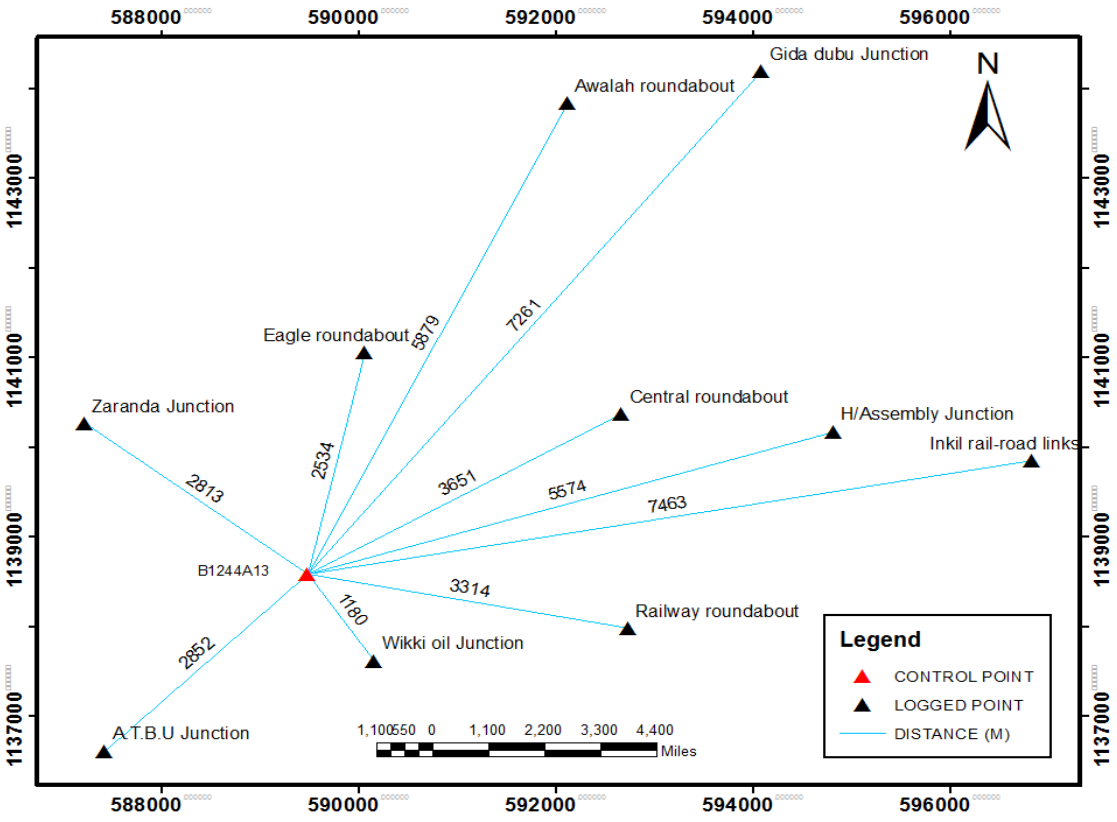


Figure 3.3: Spatial representation of Ground Control points

Table 3.1Control Points

Name	Components	95%Error	Status
B1244A13	Long 9° 49' 01.83000"E	0.000	FIXED
Lat 10° 17' 56.45750"N	0.000	FIXED	
Ellips height	628.418	0.000	FIXED

Table 3.2:Logged Points

Name	Components	95% Error	Status
CS05	Long 9° 50' 29.28889"E	0.013	Adjusted
Lat 10° 20' 47.15228"N	0.013	Adjusted	
Ellips height	624.769	0.019	Adjusted
	Description	*AWALA ROUDNABOUT*	
CS06	Long 9° 47' 54.10018"E	0.015	Adjusted
Lat 10° 16' 52.23602"N	0.015	Adjusted	
Ellips height	630.183	0.018	Adjusted
	Description	*A.T.B.U Junction*	
CS07	Long 9° 53' 3.7720314"E	0.018	Adjusted
Lat 10° 18' 36.85514"N	0.016	Adjusted	
Ellips height	622.510	0.021	Adjusted
	Description	*Inkil Rail-road Link*	
CS08	Long 9° 47' 47.77816"E	0.018	Adjusted
Lat 10° 18' 51.29963"N	0.020	Adjusted	
Ellips height	604.357	0.021	Adjusted
	Description	*Zaranda Junction*	
CS09	Long 9° 50' 46.76504"E	0.020	Adjusted
Lat 10° 18' 54.17086"N	0.020	Adjusted	
Ellips height	597.877	0.024	Adjusted
	Description	*Central round about*	
CS10	Long 9° 50' 48.87953"E	0.021	Adjusted
Lat 10° 17' 36.39754"N	0.021	Adjusted	
Ellips height	597.851	0.027	Adjusted
	Description	*Railway round about*	
CS11	Long 9° 49' 21.13513"E	0.087	Adjusted
Lat 10° 19' 16.70672"N	0.085	Adjusted	
Ellips height	591.061	0.117	Adjusted
	Description	*Eagle round about*	
CS55	Long 9° 49' 23.96941"E	0.008	Adjusted
Lat 10° 17' 24.92960"N	0.008	Adjusted	
Ellips height	629.972	0.012	Adjusted
	Description	*Wikki oil junction*	
FG44	Long 9° 51' 33.94973"E	0.096	Adjusted
Lat 10° 20' 58.65434"N	0.071	Adjusted	
Ellips height	628.098	0.101	Adjusted
	Description	*Gidadubu junction*	
FG45	Long 9° 51' 57.62722"E	0.066	Adjusted
Lat 10° 18' 47.72275"N	0.067	Adjusted	
Ellips height	626.238	0.085	Adjusted
	Description	*H/Assembly junction*	
TP02	Long 9° 49' 20.73397"E	0.006	Adjusted
Lat 10° 19' 14.60046"N	0.005	Adjusted	
Ellips height	639.761	0.008	Adjusted
	Description	*MAIDUGURI BYE PASS*	

3.3.3 Interviews and questionnaires

The interview was conducted and questionnaires were administrated purposely to reveal some silent issues concerning the water distribution system of the study area from the staff of the Bauchi State Water Board (B.S.W.B) and the sampled customers.The reliability of the questionnaire was determined by conducting a pre-test prior to the actual data collection to make sure that the questions is simple to understand by the respondents and fit the purpose of the research. Three different structured questionnaires was administered and distributed to three categories of respondents which are customers, management and technical staff of the State water board.

Interview was conducted in the month of December, 2016 with the objective of acquiring information about the status of the urban water utility and the method of upgrading the system. Two staff interviewed was the Assistant General Manager (AGM) operation and maintenance (O & M) representing the management staff and chief technical officer (CTO) represented the technical staff. Many questions that are relevant to the purpose of the research were asked,these includes the status of the existing map, pattern used in house numbering, relationship between the water board and their customers, system of record keeping, the correlation between water board and the state GIS office, any proposal on the ground to upgrade the system, what is the criteria used in the distribution and extension of water utilities, what are the achievement so far, and the present problems associated to urban water distribution system. This enable to the acquisition of reliable information to ensure the use of qualitative data in the research.

In the questionnaire aspect, 77 sampled customers were selected from the study area and they are to answer 13 questions. While two other structured were for the management and technical staff, eachhas 10 different questions. All the questions were asked based on

the research objectives. A total number of twenty (20) questionnaires were distributed to the staff of B.S.W.B. out of which seven (7) questionnaires were responded by the management staff which involves the General Manager/Managing Director (GM/MD), area manager, Assistant General Manager (AGM) for planning, AGM operation and maintenance, AGM commercial and AGM Administration. The remaining thirteen (13) questionnaires were for technical staff and responded by the area Engineer, project Engineer, and other technical officers from different departments and units.

3.3.4 Population data

The projected 2017 population data of all the wards in the study area was collected from National Population Commission (NPC) Bauchi.

3.3.5Remotely sensed data

Pleiades (50cm) 2012 satellite imagery covering the study area was acquired from Bauchi Geographic information system (BAGIS). This Imagery covers the total area of about 200km^2 of Bauchi local government which comprises the study area.

Pleiades 1B was the newest high resolution (50cm) satellite imagery operated by Astrium Geo information services, France. It has a maximum acquisition capacity of one million (1 million sq.km) square kilometer per day and exceptional agility to maximize the acquisitions of a specific area of interest using five (5) acquisition modes, these are: Target, Strip mapping, Tristereo, Corridor and persistent surveillance.(http/www.landinfo.com/Pleiades imagery.htm).

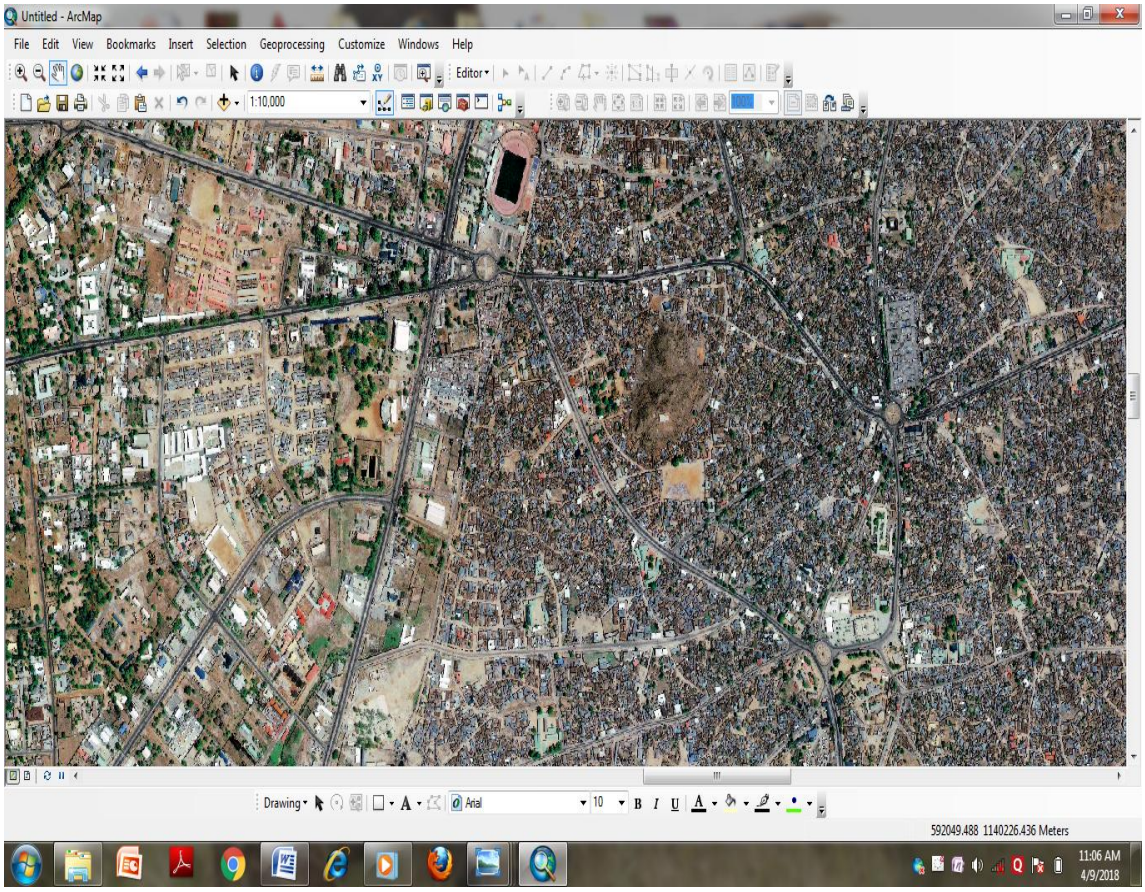


Figure 3.4: Bauchi Town Pleiades (50cm) Satellite Imagery (Source: BAGIS, 2013)

Table 3.3: Pleiades Satellite Specification

Spectral Range	Panchromatic 480 – 830nm
Product	Color: 50cm (Merge) Bundles: 50cm panchromatic 2m multispectral
Dynamic Range12 bit per pixel	
Revisit Rate	Daily
Swath width	20km (single pass mosaics up to 100km x 100km)
Altitude	694km
Accuracy	4.5m – 10m CE90 (Exclusive of terrain displacement)
with refine altitude data without Ground control points	
Stereo Capability	Pleiades – 1 is the first to commercially offer Tristerior

(Source: BAGIS, 2013)

3.3.6 Existing water distribution map (base map)

Other secondary data used in this research was the Bauchi Urban water distribution map acquired from Bauchi State water board (B.S.W.B), this map was collected in hard copyand converted into soft copy using AO Scanner, the scanned raster image was in TIFF format, the image has three (3) bands (Red, Green, and Blue), and its size was196.12MB and a pixel depth of 8 bit. Figure 3.5below show the scanned copy of the existing water distribution base map.

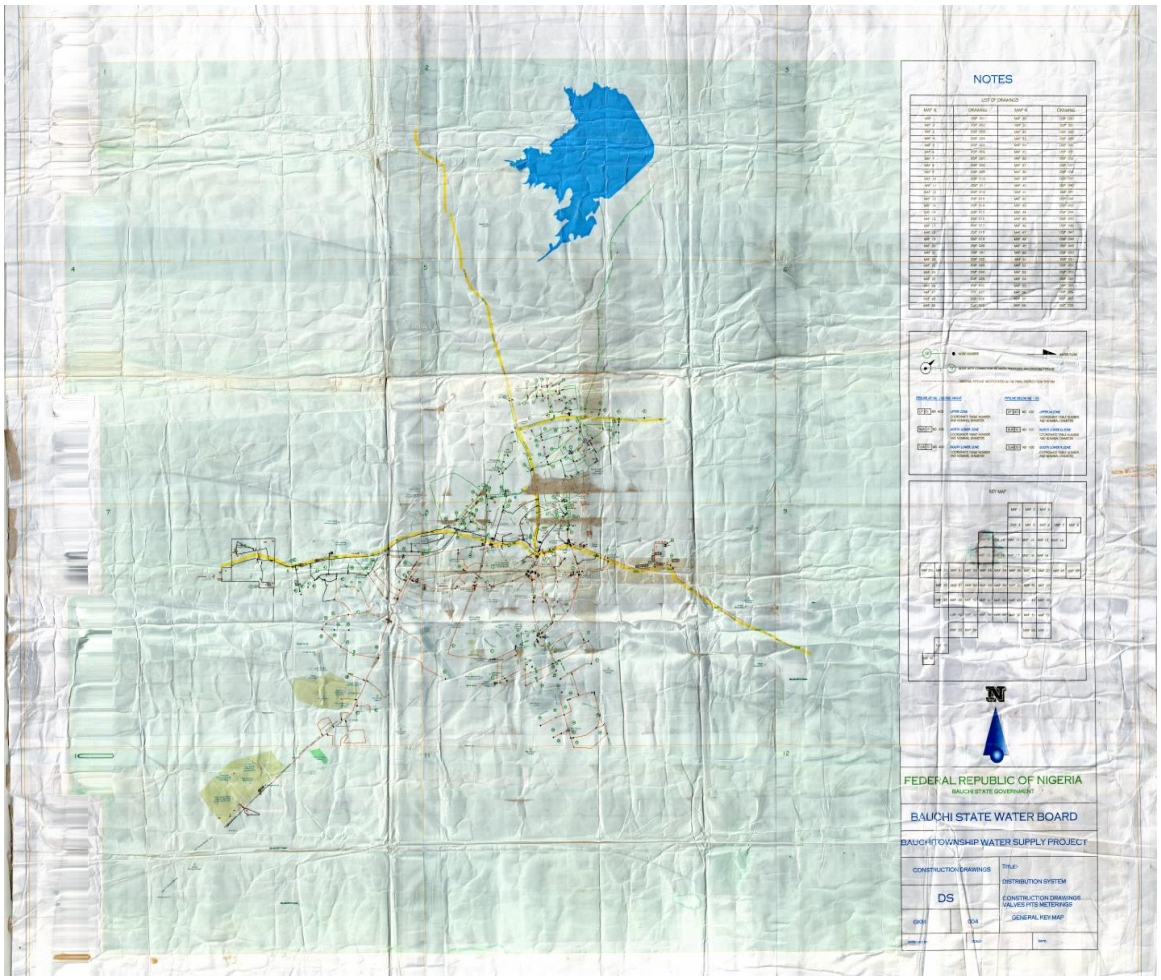


Figure 3.5: Scanned Water distribution base map of Bauchi town (Source: BSWB, 2015)

3.4 Updating the Bauchi Urban Water Distribution Map

Map updateshere involves the process of scanning the base map to convert it into raster image as shown above, Georeferencing the scanned base map to determine its positioning on the earth surface and digitization of features in Arc GIS environment. The deformation of the base map was handled by zoom in the scanned base map during digitization and overlaying the digitized pipelines on the Pleiades 50cm resolution satellite imagery to verify the position of the pipelines on both the imagery and ground.

The present water distribution map used by Bauchi State water Board (B.S.W.B) was produced in the year 2000 during Bauchi Township water supply project. It was sourced from the former 1995 water distribution map,the former 1995 map was scanned and overlaid on goggle earth imagery without proper geo-referencing, they used Auto CAD computer aided software to traced the pipelines and other point features (B.SWB, 2015).Based on the above information, the existing map was found to lack spatial reference, no definite coordinate; therefore it lacks many map related features such as coordinate system, georeference, grids, layout, scale and legend.

During the process of updating the existing map, the hard copy base map was scanned and converted to soft copy raster image using AOscannerwith optical scan resolution of 600 dpi. The raster image was imported into Arc GIS environment and created the spatial reference, built pyramid and calculated the statistics, the image was thengeo referenced with respect to the road network by making spatial reference from the known points on the roundabout and road junctions, the position of these ground control points were identified and the corresponding control points (for both ground and image) was added by inputting X and Y coordinates one after another and updated the geo-reference. Finally, Pleiades 50cm imagery was then added and overlaid on the geo-referenced water distribution raster

image. Different features were digitized from the base map and provide the spatial reference, coordinate system, grids, layout, scale and legend to the updated map.

3.4.1 Data processing

Data processing includes post-processing of captured data, changing data formats, applying the map projections andGeoreferencing the image data. The scanned water distribution map, and Satellite imagery was imported into Arc catalog work station and created the spatial reference for eachusing WGS84Universal Traverse Mercator (UTM) Zone 32. Both the image and the base map were added into Arc map workstation and geo-referenced using ten (10) ground control points. The position of pipelines, valves, chambers, nodes hydrants dam and wards weredigitized from both the imagery and the base map.

For map digitization, three (3) different vector layers were created in Arc Catalog; the features used are points, lines and polygons. The points were used to representvalves, hydrants, nodes, chambers and sample houses.The line was used to represent roads and pipelines while the polygon used representGubi dam and wards.

3.5Building of Geodatabase

Geodatabase is the physical store of geographic information using database management system (DBMS). It store the information in a single file which contains a multiple points, lines or polygon layers, these shape files are called “feature class” which perform the same function in arc GIS after adding as layer in the map.

The water distribution is among the sources of revenue generation in Bauchi state, the water board is charging the amount of #10,000 annually per registered house for water utility, therefore the Arc catalogue was used to develop schema and the geographic dataset

was queried using structured query language (SQL). Query was conducted with the purpose of getting information about the payment status of the customers. Hence, customers with the balance of #000 have paid their bills completely, those with balance of #10,000 did not pay and those customers with a balance >#000 <#10,000 have made the part payment. The customer occupation and payment status could help the water board to know the different classification of their customers based on employment status and level of income; these provide a scale and measure in increasing or decreasing the water charges. House I.D is the unique transaction identity that differentiates one house or subscriber to another. Wards and coordinates could enable the board to locate the unpaid houses on the map by querying the database; therefore take any necessary action such as sending the message for reminder or rather send an agent for disconnection.

3.5.1 Procedure of building Geodatabase

In this study, file Geodatabase was built from the Arc catalogue window and the feature class was imported, simple tables and well-defined attribute types were used to store the schemaand spatial attribute data for each geographic dataset. This approach provides a formal model for storing and working with data, the structured query language (SQL) a series of relational functions and operators was used to create, modify, and query tables and their data elements.

The Geodatabase was created by opening the Arc catalogue and connected to the location of the data, then right clickedfrom the Arc catalogue window and navigated to the new and file Geodatabase was selected because of its large storage capacity. The feature class (multiple) was imported and the feature was inputted, database was right clicked and imported the table (single).The same data table was selected from same folder of the

inputted table and used the same name for the output table. Information can be acquired from these files from the arc catalogue window.The table was made of up rows and columns; each row in the table represent one feature and the columns is comprised of the customer detail such as field I.D,house coordinates (E, N), name House I.D, address, occupation, mobile, payment status and balance. Hence the feature class is stored as a business table with a relational function and query capability.

3.5.2 Rules of the Geodatabase

The attribute rule was used in defining a specific rule on field in a specific feature class; a class can have a multiple attribute rule with a maximum of one rule per field, this rule was created by associating field to the domain.

3.6Procedure for Measuring the Proximity to the Pipelines

In the process of measuring the proximity to different classes of pipelines, three different buffer zoneswere created to the service line, laterals and main lines at several specified distance around the input features. This procedure involve setting the map projection in to UTM zone 32 projected coordinate system and select the buffer analyst tool from the Arc tool box and browsed the pipelines as the input features (features to be buffered), the output feature was set to locate the place to save the buffer. Distance and the linear unit was set for each class of the pipelines and select the “FLAT’ type of buffer which is for line features, finally the software processed the input data and provide the output as new vector layer.

3.7Criteria for Water Accessibility Assessment

Nigeria as a developing country has no standard criteria forthe spatial accessibility to water distribution pipelines. Therefore, the Georgia criteria were embraced in this research. According to Georgia standard, access to service line should not exceed 100 meters, laterals 300 meters and mainline with 1000 meter distance interval (Hassan andFuntua, 2014).

3.8 Validation Test

A test was carried out to check the consistency between the features on map and features on the ground. The field validation test was achieved by conducting a six days field operation in collaboration with B.S.W.B field officer from operation and maintenance department. It was achieved by using Pleiades imagery (50cm) and Six (6) ground control points along the major roads as reference. The position of some nearby facilities such as pipelines, valves and chambers were identified from the updated map and the corresponding ground surface. Some Buildings, roundabouts and road junctions were also identified from the Pleiades imagery (50cm resolution) and compared with the ground facilities around the vicinity.

The validity of the Geo data base was also tested. This was done in the office of the billing manager by making spatial and attributes queries in Arc GIS environment in order to display detail information about customers and their water utility payment Status.

CHAPTER FOUR

RESULTS AND ANALYSIS

This chapter describedthe outcome of the research which was accomplished as a result of data collection, processing and analysis. Analysis such as proximity overlay and statistical analysis was conducted in conformity withthe research objectives. Therefore, the results present the updatedwater distributionmap and the built Geodatabase;it also analysed the spatial accessibility and identify the places that require the extensionof water facilities in the town. Analysis was made on the administered questionnaire and computes the amount of water required by the population of the study. The research outcomewas tested in office and the field to ensure the validity of results.

4.1 Updating the Existing Water Distribution Map

The existing water distribution map was updated using GIS tools and techniques, therefore the updated map incorporate the map related features such as grids, layout, scale, legend, geo reference and coordinate system, which were not defined in the existing analogue base map, the resultdescribed the network of water facilities which comprises the pipelines, nodes, valves, chambers, reservoirs and hydrants. Geometric and attribute information of these facilities was accurately defined and identified on the map by allocating a unique identifier to each facility. The roundabout and major roads appeared on the map to provide a reference guide for locating some water facilities beside the road. Gubi dam is a source which supply waterthrough the connection of 800mm diameter pipelinefrom the treatment plant to the reservoirs at warinji hill and distributed to the town through the network of pipelines of different diameter as shown in figure 4.1.

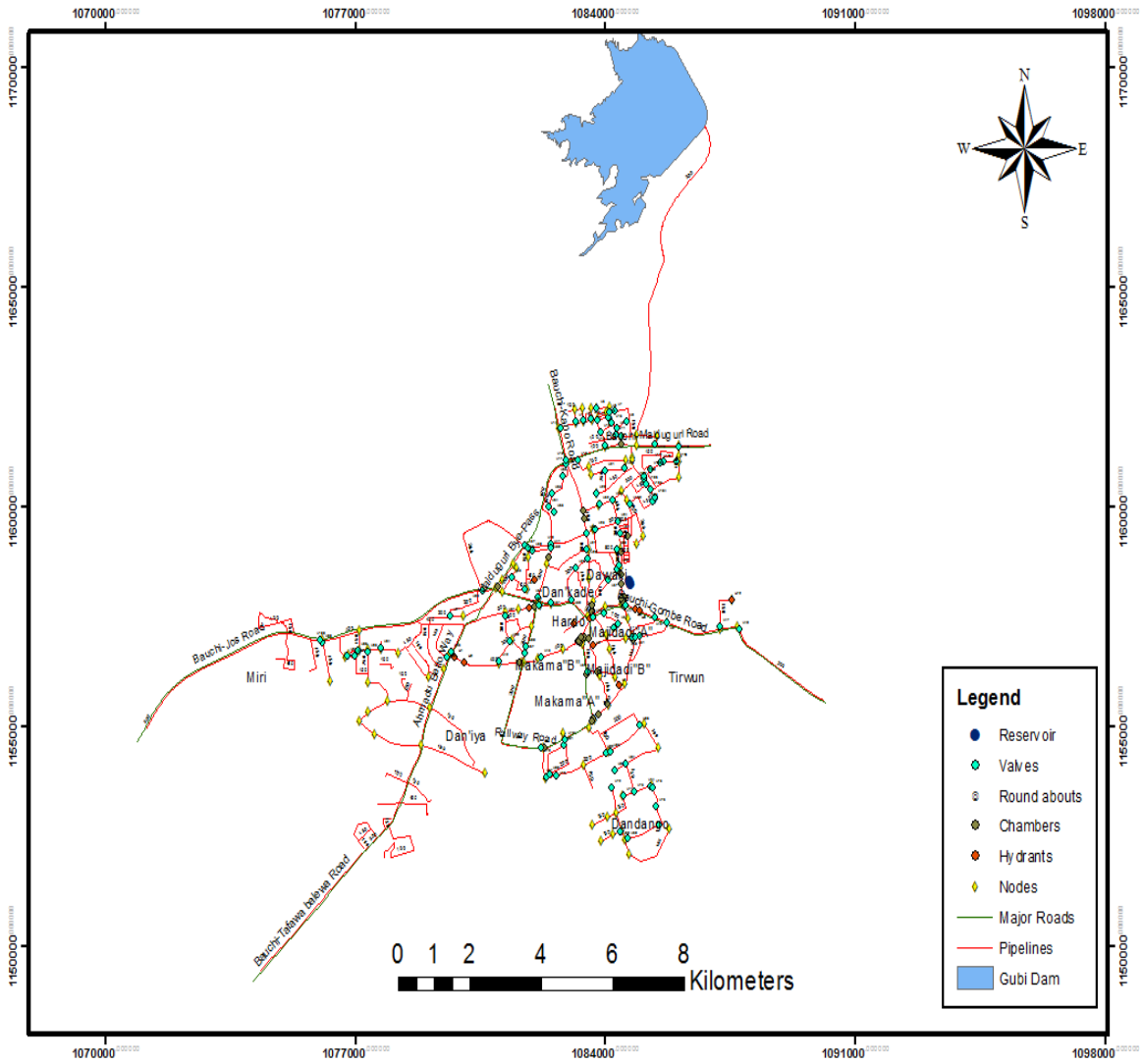


Figure 4.1: Updated water distribution map (with dam)

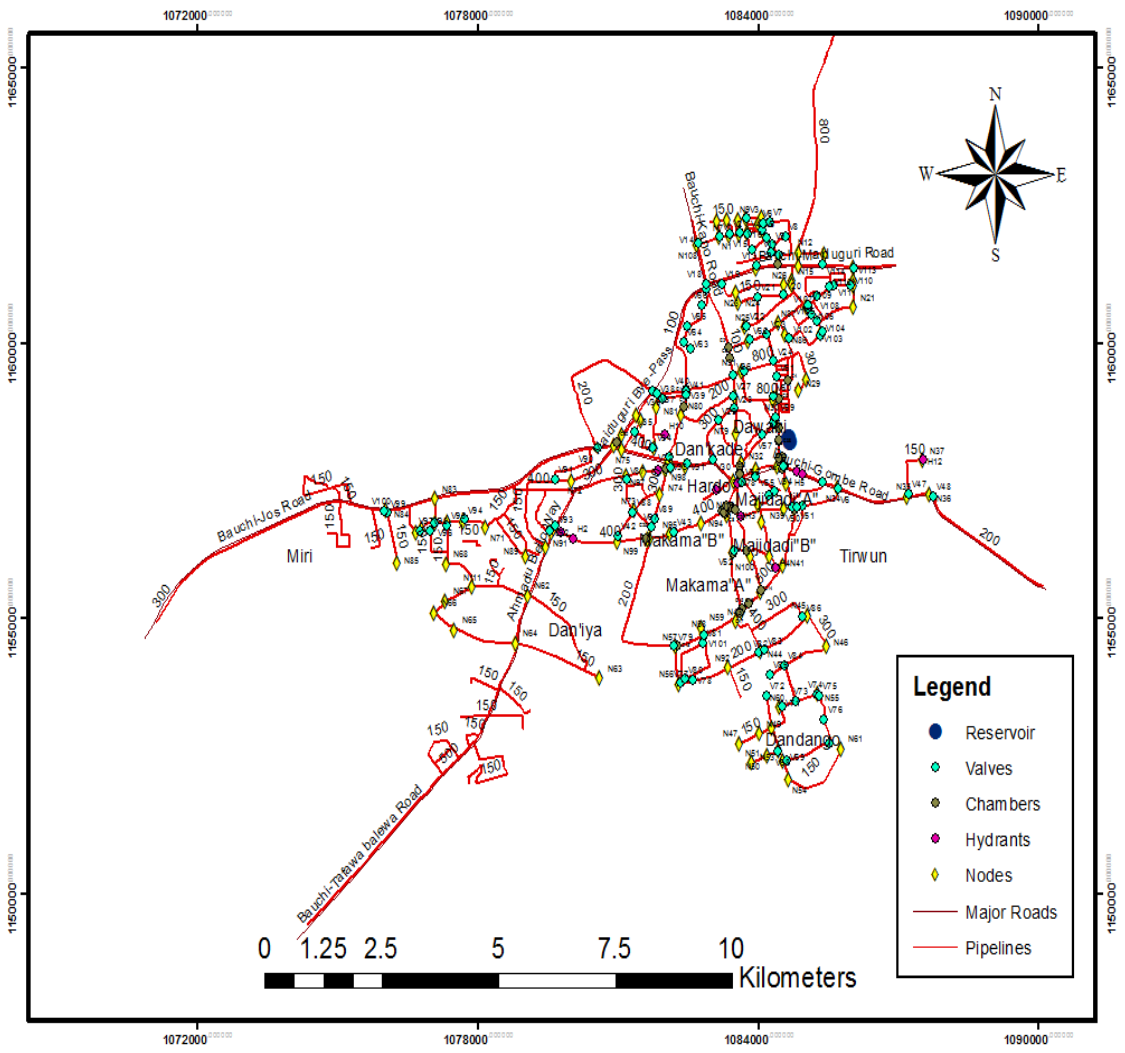


Figure 4.2: Updated water distribution map (without dam)

Figures 4.2 show the location of water facilities such as valve (V), hydrants (H), Chambers (C) and pipelines (P). Each facility was allocated a unique identifier (ID) and labeled with successive identification numbers after the first alphabets (i.e. V_n, H_n, C_n and P_n), these number were labeled on the maps for easy recognition of these facilities on earth surface.

Figure 4.3 show the map of the pipelines in seven different wards, these pipelines were labeled with a diameter ranging from 100mm to 800mm. Seven houses were selected from each ward and displayed as sample on the map, these houses were shown concentrated in

Majidadi ‘A’ and ‘B’, Hardo, Dankade and Dawaki ward, these are area designated as the centre of the town characterized with small area and large population density.

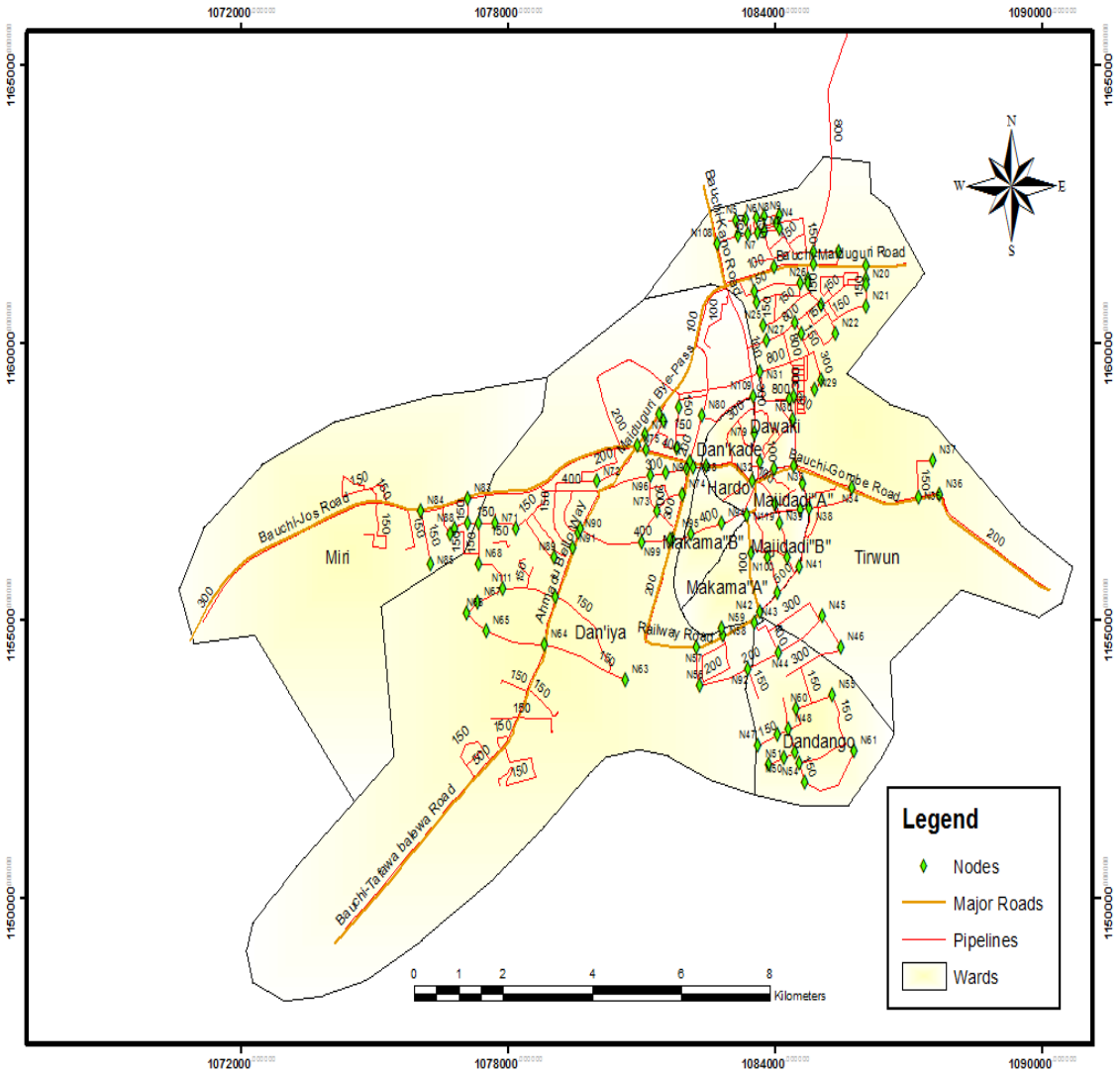


Figure 4.3: A Map of Bauchi township pipelines

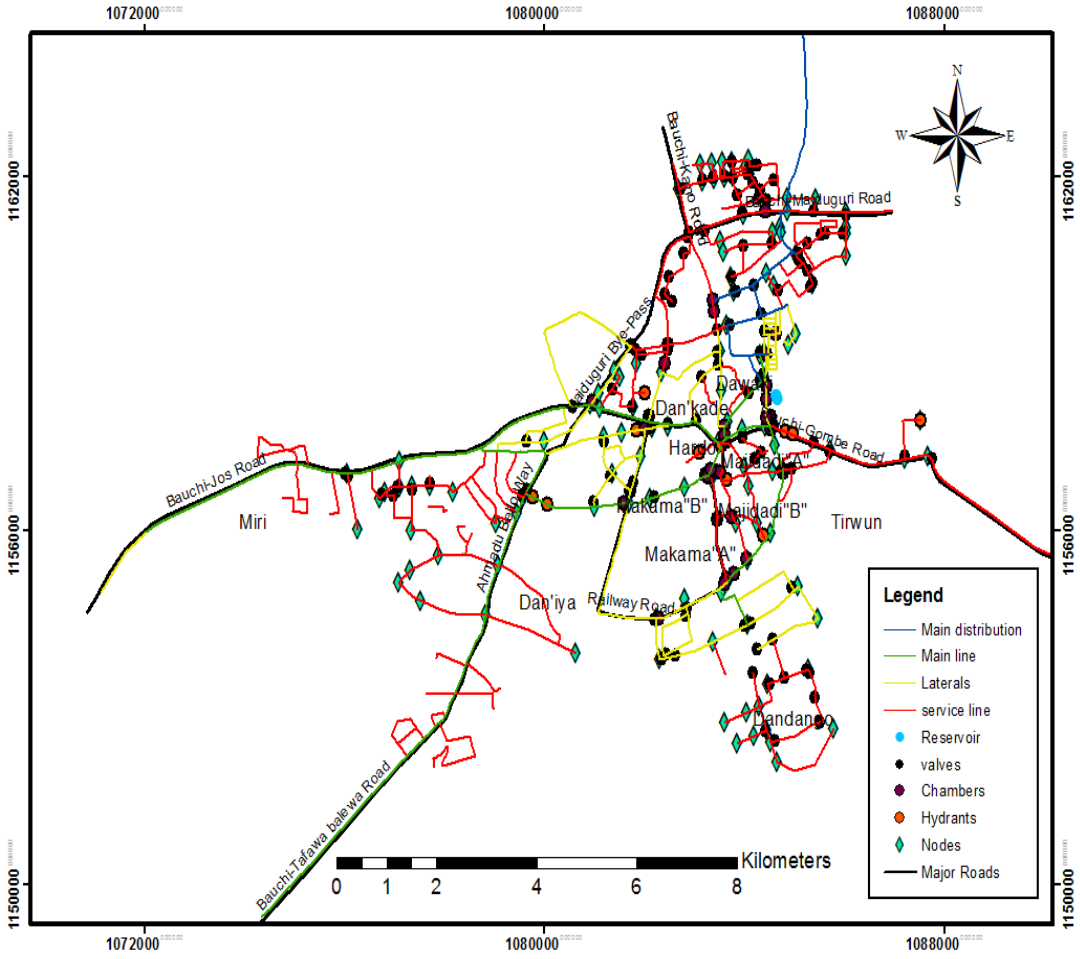


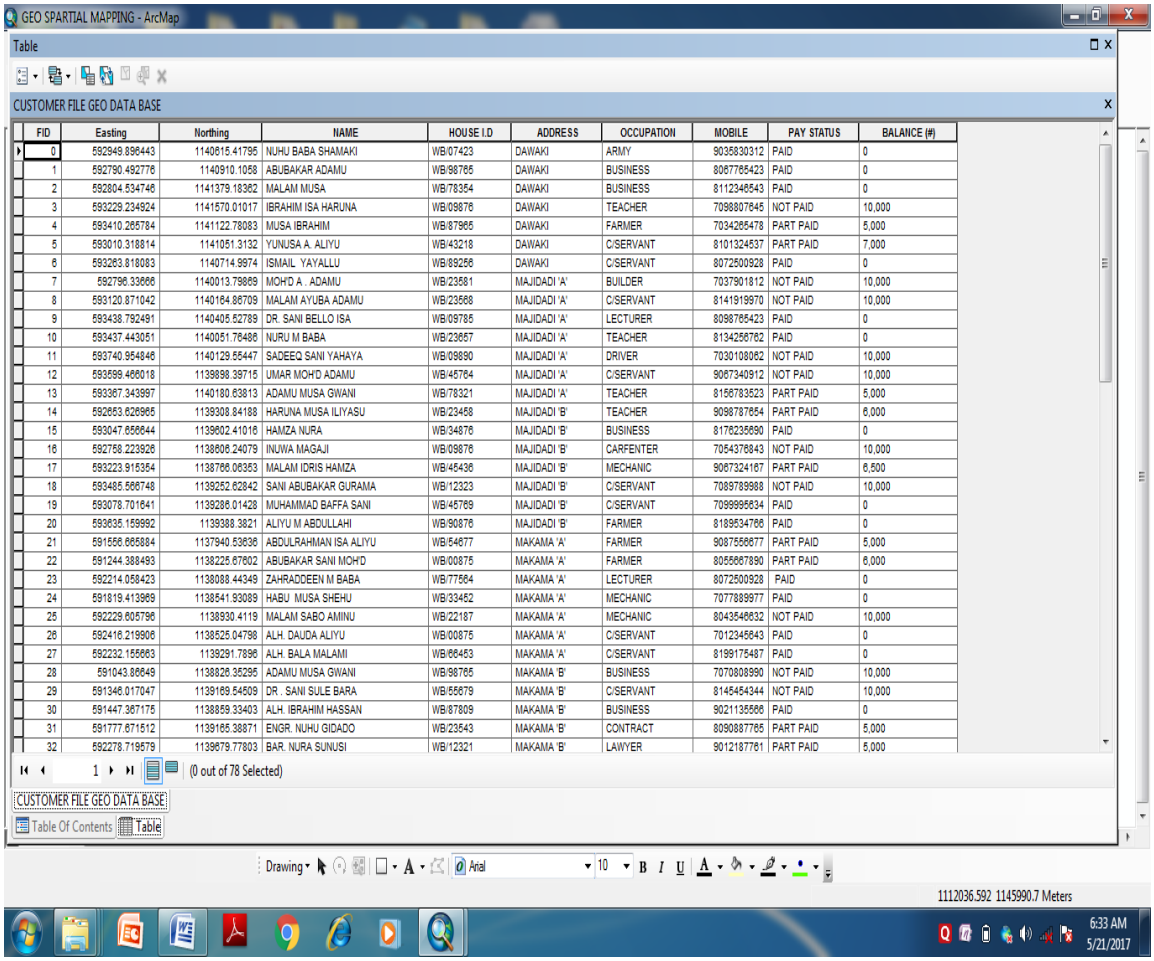
Figure 4.4: Classification Map of the pipelines

The water distribution pipelines were classified into four different classes based on diameter. Pipelines with 100mm to 150mm diameter was described as service lines and colored red, 200 to 300mm diameter pipelines was classified as laterals and allocated a yellow cartographic color, pipelines with 400 to 700mm was categorized as main lines and identified with green color, the main distribution is the blue colored pipeline with 800mm diameter, it is the major pipe line that convey water from the treatment plant to the town. It was shown from the map that the main lines are pipelines that convey water from the

reservoir to Dan dangoward,Miri and Dan iya ward along two major roads as described in figure 4.4

4.2Development of Geodatabase

Figure 4.5 described the created customer Geodatabase; it comprises the name, house coordinates, house ID, address, occupation, mobile number, payment statusand the remaining balance. The database was built and demonstrates the use of GIS based water utility billing system in facilitating water distribution in the study area.



FID	Easting	Northing	NAME	HOUSE I.D	ADDRESS	OCCUPATION	MOBILE	PAY STATUS	BALANCE (#)
0	592949.896443	1140615.41795	NUHU BABA SHAMAKI	WB/07423	DAWAKI	ARMY	9035830312	PAID	0
1	592790.492776	1140910.1058	ABUBAKAR ADAMU	WB/98765	DAWAKI	BUSINESS	8067765423	PAID	0
2	592804.534746	1141379.18362	MALAM MUSA	WB/78354	DAWAKI	BUSINESS	8112346543	PAID	0
3	593229.234924	1141570.01017	IBRAHIM ISA HARUNA	WB/09876	DAWAKI	TEACHER	7098807645	NOT PAID	10,000
4	593410.265784	1141122.78083	MUSA IBRAHIM	WB/87965	DAWAKI	FARMER	7034265478	PART PAID	5,000
5	593010.318814	1141051.3132	YUNUSA A. ALIYU	WB/43218	DAWAKI	C/SERVANT	8101324537	PART PAID	7,000
6	593263.818083	1140714.9974	ISMAIL YAYALLU	WB/89256	DAWAKI	C/SERVANT	8072500928	PAID	0
7	592796.33666	1140013.79869	MOH'D A . ADAMU	WB/23581	MAJIDADI 'A'	BUILDER	7037901812	NOT PAID	10,000
8	593120.871042	1140164.86709	MALAM AYUBA ADAMU	WB/23568	MAJIDADI 'A'	C/SERVANT	8141919970	NOT PAID	10,000
9	593438.792491	1140405.52789	DR. SANI BELLO ISA	WB/09785	MAJIDADI 'A'	LECTURER	8098765423	PAID	0
10	593437.443051	1140051.76486	NURU M BABA	WB/23657	MAJIDADI 'A'	TEACHER	8134256762	PAID	0
11	593740.954846	1140129.55447	SADEEQ SANI YAHAYA	WB/09890	MAJIDADI 'A'	DRIVER	7030108062	NOT PAID	10,000
12	593599.466018	1139898.39715	UMAR MOH'D ADAMU	WB/45764	MAJIDADI 'A'	C/SERVANT	9067340912	NOT PAID	10,000
13	593367.343997	1140180.63813	ADAMU MUSA GWANI	WB/78321	MAJIDADI 'A'	TEACHER	8156783523	PART PAID	5,000
14	592653.626965	1139308.84188	HARUNA MUSA ILIYASU	WB/23458	MAJIDADI 'B'	TEACHER	9098787654	PART PAID	6,000
15	593047.656644	1139602.41016	HAMZA NURA	WB/34876	MAJIDADI 'B'	BUSINESS	8176235690	PAID	0
16	592758.223926	1138608.24079	INUWA MAGAJI	WB/09876	MAJIDADI 'B'	CARFENTER	7054376843	NOT PAID	10,000
17	593223.916354	1138766.06353	MALAM IDRIS HAMZA	WB/45436	MAJIDADI 'B'	MECHANIC	9067324167	PART PAID	6,500
18	593485.566748	1139252.62842	SANI ABUBAKAR GURAMA	WB/12323	MAJIDADI 'B'	C/SERVANT	7089789988	NOT PAID	10,000
19	593078.701641	1139286.01428	MUHAMMAD BAFFA SANI	WB/45769	MAJIDADI 'B'	C/SERVANT	7099995634	PAID	0
20	593635.159992	1139388.3821	ALIYU M ABDULLAHI	WB/90876	MAJIDADI 'B'	FARMER	8189534766	PAID	0
21	591556.665584	1137940.53636	ABDULRAHMAN ISA ALIYU	WB/54677	MAKAMA 'A'	FARMER	9087556677	PART PAID	5,000
22	591244.388493	1138225.67602	ABUBAKAR SANI MOH'D	WB/00875	MAKAMA 'A'	FARMER	8055667890	PART PAID	6,000
23	592214.058423	1138088.44349	ZAHRADDEEN M BABA	WB/77564	MAKAMA 'A'	LECTURER	8072500928	PAID	0
24	591819.413969	1138541.93089	HABU MUSA SHEHU	WB/33452	MAKAMA 'A'	MECHANIC	7077889977	PAID	0
25	592229.605796	1138930.4119	MALAM SABO AMINU	WB/22187	MAKAMA 'A'	MECHANIC	8043546632	NOT PAID	10,000
26	592416.219906	1138525.04798	ALH. DAUDA ALIYU	WB/00875	MAKAMA 'A'	C/SERVANT	7012345643	PAID	0
27	592232.155663	1139291.7896	ALH. BALA MALAMI	WB/66453	MAKAMA 'A'	C/SERVANT	8199175487	PAID	0
28	591043.86649	1138826.35295	ADAMU MUSA GWANI	WB/98765	MAKAMA 'B'	BUSINESS	7070808990	NOT PAID	10,000
29	591346.017047	1139169.54509	DR. SANI SULE BARA	WB/55679	MAKAMA 'B'	C/SERVANT	8145454344	NOT PAID	10,000
30	591447.367175	1138859.33403	ALH. IBRAHIM HASSAN	WB/87809	MAKAMA 'B'	BUSINESS	9021135566	PAID	0
31	591777.671512	1139165.38871	ENGR. NUHU GIDADO	WB/23543	MAKAMA 'B'	CONTRACT	8090887765	PART PAID	5,000
32	592278.719579	1139679.77803	BAR. NURA SUNUSI	WB/12321	MAKAMA 'B'	LAWYER	9012187761	PART PAID	5,000

Figure 4.5: Customer File Geodatabase

4.2.1The use of customer fileGeodatabase in facilitation of water utility billing system

The geodatabase provide versatile means of communications including text messages to notify the customers; this method eliminates the cost of printing bills, mitigate thedifficulty in distribution and save time for easy delivery.

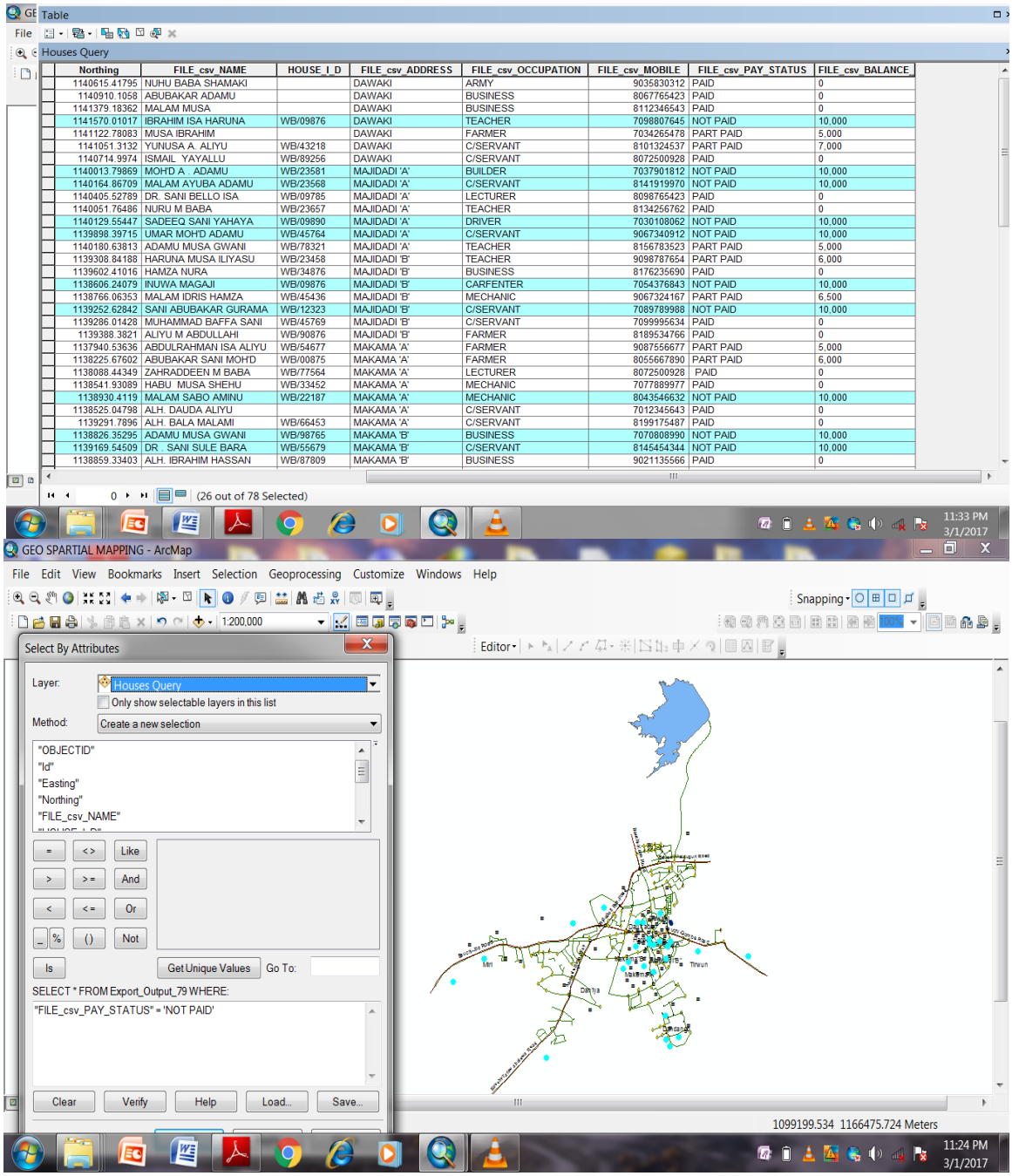
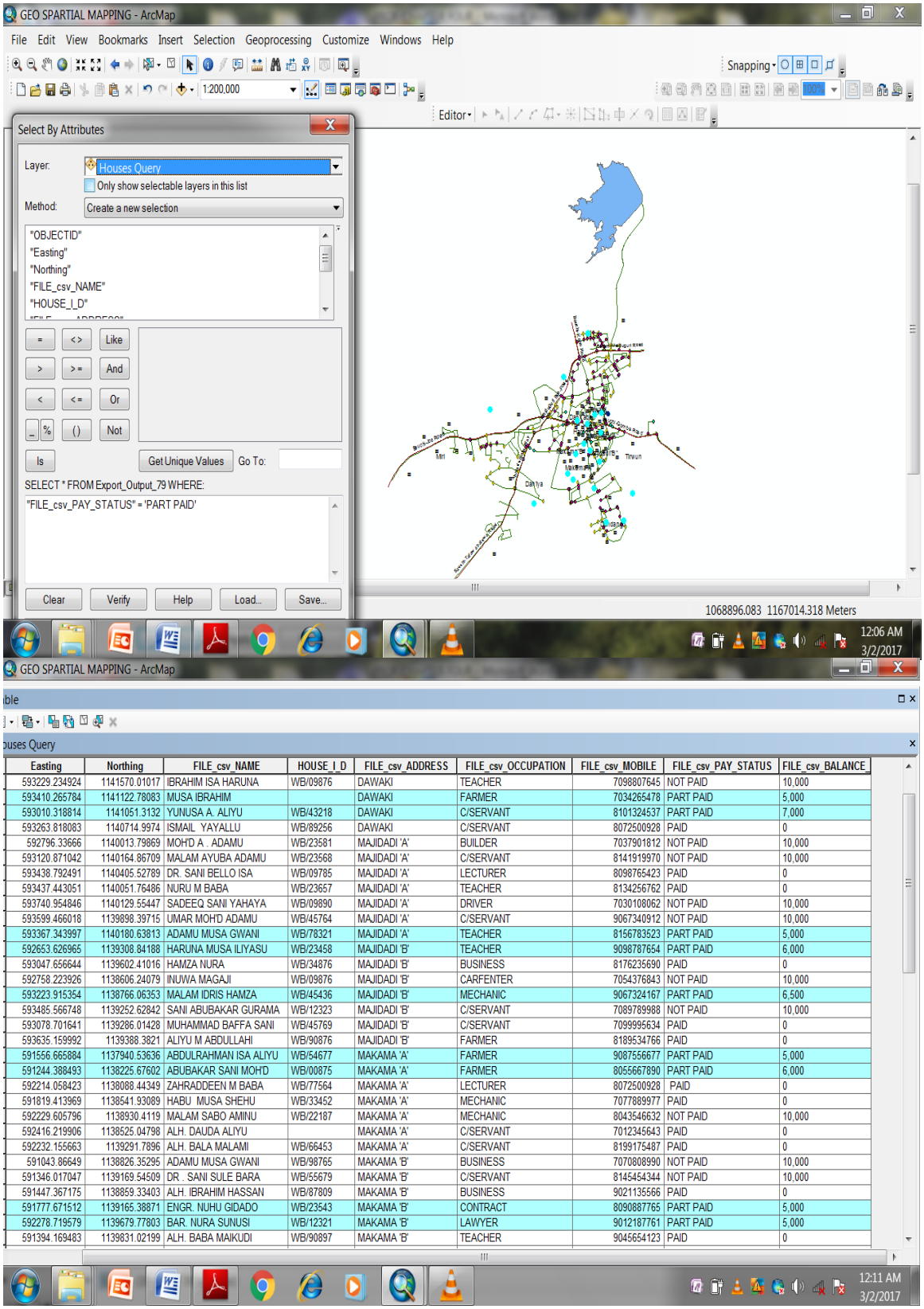
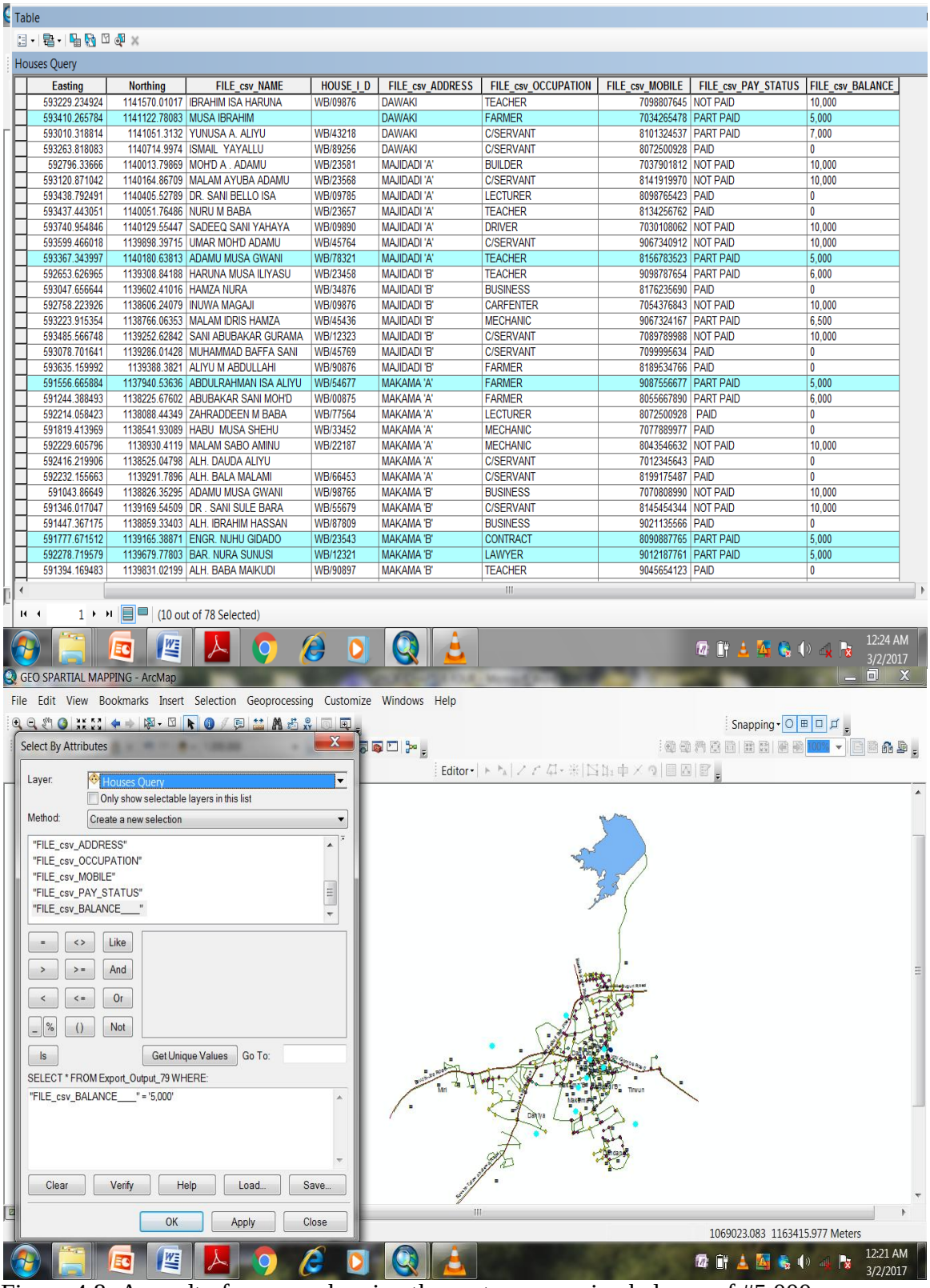


Figure 4.6: A result of a query showing customers that did not pay their utility bill



Easting	Northing	FILE_csv_NAME	HOUSE_I_D	FILE_csv_ADDRESS	FILE_csv_OCCUPATION	FILE_csv_MOBILE	FILE_csv_PAY_STATUS	FILE_csv_BALANCE_
593229.234924	1141570.01017	IBRAHIM ISA HARUNA	WB/09876	DAWAKI	TEACHER	7098807645	NOT PAID	10,000
593410.265784	1141122.78083	MUSA IBRAHIM		DAWAKI	FARMER	7034265478	PART PAID	5,000
593010.318814	1141051.3132	YUNUSA A. ALIYU	WB/43218	DAWAKI	C/SERVANT	8101324537	PART PAID	7,000
593263.818083	1140714.9974	ISMAIL YAYALLU	WB/89256	DAWAKI	C/SERVANT	8072500928	PAID	0
592796.33666	1140013.79869	MOH'D A . ADAMU	WB/23581	MAJIDADI 'A'	BUILDER	7037901812	NOT PAID	10,000
593120.871042	1140164.86709	MALAM AYUBA ADAMU	WB/23568	MAJIDADI 'A'	C/SERVANT	8141919970	NOT PAID	10,000
593438.792491	1140405.52789	DR. SANI BELLO ISA	WB/09785	MAJIDADI 'A'	LECTURER	8098765423	PAID	0
593437.443051	1140051.76486	NURU M BABA	WB/23657	MAJIDADI 'A'	TEACHER	8134256762	PAID	0
593740.954846	1140129.55447	SADEEQ SANI YAHAYA	WB/09890	MAJIDADI 'A'	DRIVER	7030108062	NOT PAID	10,000
593599.466018	1139898.39715	UMAR MOH'D ADAMU	WB/45764	MAJIDADI 'A'	C/SERVANT	9067340912	NOT PAID	10,000
593367.343997	1140180.63813	ADAMU MUSA GWANI	WB/78321	MAJIDADI 'A'	TEACHER	8156783523	PART PAID	5,000
592653.626965	1139308.84188	HARUNA MUSA ILIYASU	WB/23458	MAJIDADI 'B'	TEACHER	9098787654	PART PAID	6,000
593047.656644	1139602.41016	HAMZA NURA	WB/34876	MAJIDADI 'B'	BUSINESS	8176235690	PAID	0
592758.223926	1138606.24079	INUWA MAGAJI	WB/09876	MAJIDADI 'B'	CARFENTER	7054376843	NOT PAID	10,000
593223.915354	1138766.06353	MALAM IDRIS HAMZA	WB/45436	MAJIDADI 'B'	MECHANIC	9067324167	PART PAID	6,500
593485.566748	1139252.62842	SANI ABUBAKAR GURAMA	WB/12323	MAJIDADI 'B'	C/SERVANT	7089789988	NOT PAID	10,000
593078.701641	1139286.01428	MUHAMMAD BAFFA SANI	WB/45769	MAJIDADI 'B'	C/SERVANT	7099995634	PAID	0
593635.159992	1139388.3821	ALIYU M ABDULLAHI	WB/90876	MAJIDADI 'B'	FARMER	8189534766	PAID	0
591556.665884	1137940.53636	ABDULRAHMAN ISA ALIYU	WB/54677	MAKAMA 'A'	FARMER	9087556677	PART PAID	5,000
591244.388493	1138225.67602	ABUBAKAR SANI MOH'D	WB/00875	MAKAMA 'A'	FARMER	8055667890	PART PAID	6,000
592214.058423	1138088.44349	ZAHRADDEEN M BABA	WB/77564	MAKAMA 'A'	LECTURER	8072500928	PAID	0
591819.413969	1138541.93089	HABU MUSA SHEHU	WB/33452	MAKAMA 'A'	MECHANIC	7077889977	PAID	0
592229.605796	1138930.4119	MALAM SABO AMINU	WB/22187	MAKAMA 'A'	MECHANIC	8043546632	NOT PAID	10,000
592416.219906	1138525.04798	ALH. DAUDA ALIYU		MAKAMA 'A'	C/SERVANT	7012345643	PAID	0
592232.155663	1139291.7896	ALH. BALA MALAMI	WB/66453	MAKAMA 'A'	C/SERVANT	8199175487	PAID	0
591043.86649	1138826.35295	ADAMU MUSA GWANI	WB/98765	MAKAMA 'B'	BUSINESS	7070808990	NOT PAID	10,000
591346.017047	1139169.54509	DR . SANI SULE BARA	WB/55679	MAKAMA 'B'	C/SERVANT	8145454344	NOT PAID	10,000
591447.367175	1138859.33403	ALH. IBRAHIM HASSAN	WB/87809	MAKAMA 'B'	BUSINESS	9021135566	PAID	0
591777.671512	1139165.38871	ENGR. NUHU GIDADO	WB/23543	MAKAMA 'B'	CONTRACT	8090887765	PART PAID	5,000
592278.719579	1139679.77803	BAR. NURA SUNUSI	WB/12321	MAKAMA 'B'	LAWYER	9012187761	PART PAID	5,000
591394.169483	1139831.02199	ALH. BABA MAIKUDI	WB/90897	MAKAMA 'B'	TEACHER	9045654123	PAID	0

Figure 4.7: A result of a query showing the customers that made the part payment



Easting	Northing	FILE_csv_NAME	HOUSE_I_D	FILE_csv_ADDRESS	FILE_csv_OCCUPATION	FILE_csv_MOBILE	FILE_csv_PAY_STATUS	FILE_csv_BALANCE_
593229.234924	1141570.01017	IBRAHIM ISA HARUNA	WB/09876	DAWAKI	TEACHER	7098807645	NOT PAID	10,000
593410.265784	1141122.78083	MUSA IBRAHIM		DAWAKI	FARMER	7034265478	PART PAID	5,000
593010.318814	1141051.3132	YUNUSA A. ALIYU	WB/43218	DAWAKI	C/SERVANT	8101324537	PART PAID	7,000
593263.818083	1140714.9974	ISMAIL YAYALLU	WB/89256	DAWAKI	C/SERVANT	8072500928	PAID	0
592796.33666	1140013.79869	MOH'D A . ADAMU	WB/23581	MAJIDADI 'A'	BUILDER	7037901812	NOT PAID	10,000
593120.871042	1140164.86709	MALAM AYUBA ADAMU	WB/23568	MAJIDADI 'A'	C/SERVANT	8141919970	NOT PAID	10,000
593438.792491	1140405.52789	DR. SANI BELLO ISA	WB/09785	MAJIDADI 'A'	LECTURER	8098765423	PAID	0
593437.443051	1140051.76486	NURU M BABA	WB/23657	MAJIDADI 'A'	TEACHER	8134256762	PAID	0
593740.954846	1140129.55447	SADEEQ SANI YAHAYA	WB/09890	MAJIDADI 'A'	DRIVER	7030108062	NOT PAID	10,000
593599.466018	1139898.39715	UMAR MOH'D ADAMU	WB/45764	MAJIDADI 'A'	C/SERVANT	9067340912	NOT PAID	10,000
593367.343997	1140180.63813	ADAMU MUSA GWANI	WB/78321	MAJIDADI 'A'	TEACHER	8156783523	PART PAID	5,000
592653.626965	1139308.84188	HARUNA MUSA ILIYASU	WB/23458	MAJIDADI 'B'	TEACHER	9098787654	PART PAID	6,000
593047.656644	1139602.41016	HAMZA NURA	WB/34876	MAJIDADI 'B'	BUSINESS	8176235690	PAID	0
592758.223926	1138606.24079	INUWA MAGAJI	WB/09876	MAJIDADI 'B'	CARFENTER	7054376843	NOT PAID	10,000
593223.915354	1138766.06353	MALAM IDRIS HAMZA	WB/45436	MAJIDADI 'B'	MECHANIC	9067324167	PART PAID	6,500
593485.566748	1139252.62842	SANI ABUBAKAR GURAMA	WB/12323	MAJIDADI 'B'	C/SERVANT	7089789988	NOT PAID	10,000
593078.701641	1139286.01428	MUHAMMAD BAFFA SANI	WB/45769	MAJIDADI 'B'	C/SERVANT	7099995634	PAID	0
593635.159992	1139388.3821	ALIYU M ABDULLAHI	WB/90876	MAJIDADI 'B'	FARMER	8189534766	PAID	0
591556.665884	1137940.53636	ABDULRAHMAN ISA ALIYU	WB/54677	MAKAMA 'A'	FARMER	9087556677	PART PAID	5,000
591244.388493	1138225.67602	ABUBAKAR SANI MOH'D	WB/00875	MAKAMA 'A'	FARMER	8055667890	PART PAID	6,000
592214.058423	1138088.44349	ZAHRADDEEN M BABA	WB/77564	MAKAMA 'A'	LECTURER	8072500928	PAID	0
591819.413969	1138541.93089	HABU MUSA SHEHU	WB/33452	MAKAMA 'A'	MECHANIC	7077889977	PAID	0
592229.605796	1138930.4119	MALAM SABO AMINU	WB/22187	MAKAMA 'A'	MECHANIC	8043546632	NOT PAID	10,000
592416.219906	1138525.04798	ALH. DAUDA ALIYU		MAKAMA 'A'	C/SERVANT	7012345643	PAID	0
592232.155663	1139291.7896	ALH. BALA MALAMI	WB/66453	MAKAMA 'A'	C/SERVANT	8199175487	PAID	0
591043.86649	1138826.35295	ADAMU MUSA GWANI	WB/98765	MAKAMA 'B'	BUSINESS	7070808990	NOT PAID	10,000
591346.017047	1139169.54509	DR. SANI SULE BARA	WB/55679	MAKAMA 'B'	C/SERVANT	8145454344	NOT PAID	10,000
591447.367175	1138859.33403	ALH. IBRAHIM HASSAN	WB/87809	MAKAMA 'B'	BUSINESS	9021135566	PAID	0
591777.671512	1139165.38871	ENGR. NUHU GIDADO	WB/23543	MAKAMA 'B'	CONTRACT	8090887765	PART PAID	5,000
592278.719579	1139679.77803	BAR. NURA SUNUSI	WB/12321	MAKAMA 'B'	LAWYER	9012187761	PART PAID	5,000
591394.169483	1139831.02199	ALH. BABA MAIKUDI	WB/90897	MAKAMA 'B'	TEACHER	9045654123	PAID	0

Figure 4.8: A result of a query showing the customers owing balance of #5,000

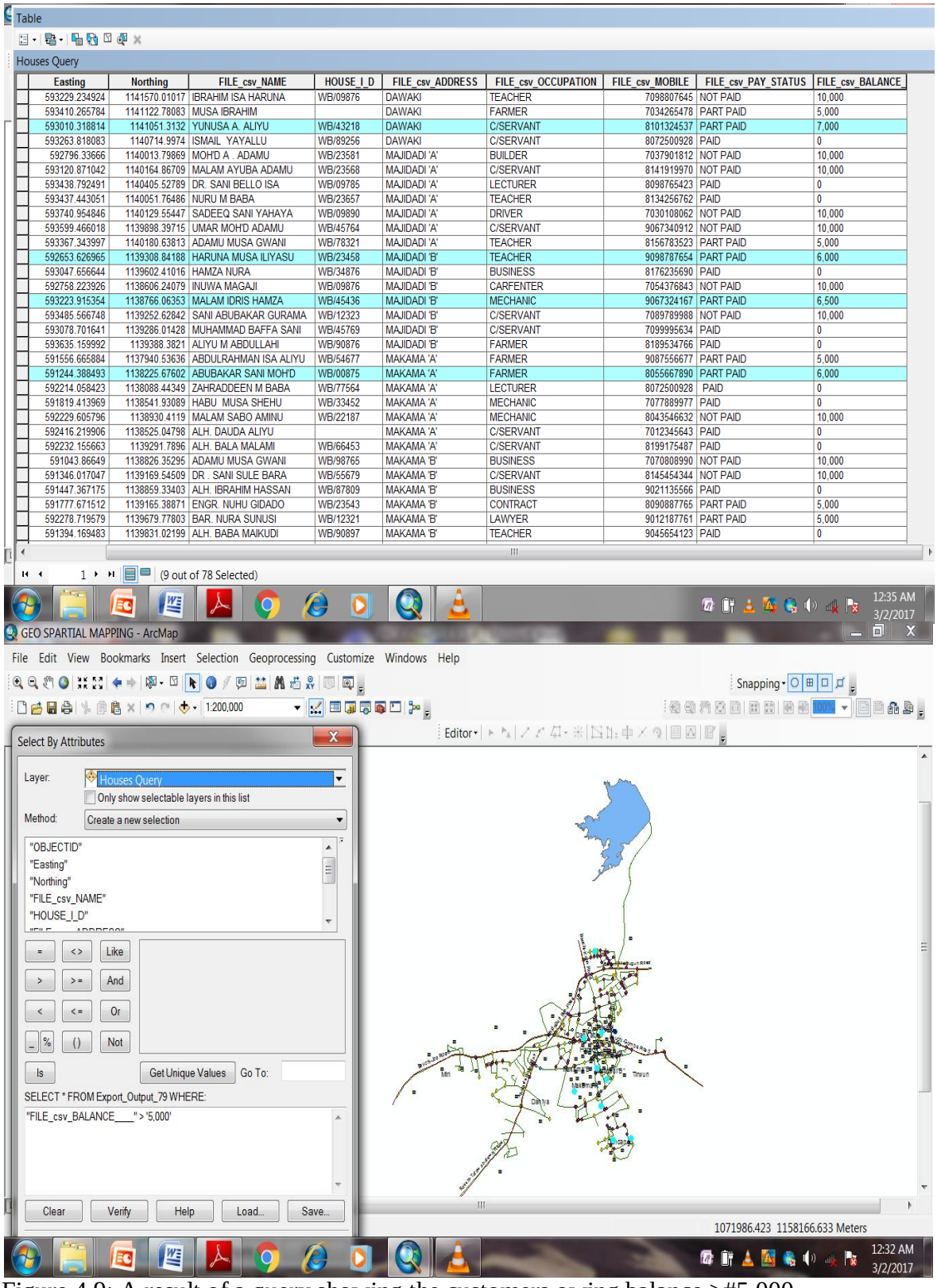


Figure 4.9: A result of a query showing the customers owing balance >#5,000

From the data base query of the result in figure 4.6, the highlighted rows in the database table represents details and the payment status of the unpaid customers with their names and other information, the location of the Houses was shown on the above map figure for easy identification. The remaining figures show the data base query result of the partly paid customers,with a balance >#000 <#10,000. Therefore the state water board should notify them to make sure they clear the outstanding balance.

4.3 Water Accessibility Analysis

According to Georgia criteria, access to service line should not exceed 100meters, while lateral lines 300 meters and main line with 1000 meter intervals (Hassan, 2014). Therefore this standard criterion was considered in this research to assess the spatial accessibility because it classified the pipelines in to different classes and measure the accessibility at different distance interval.

4.3.1Georgia standard criteria for water accessibility

The standard criteria for accessing the service line (100mm to 150mm) is defined in the country of Georgia as 100 meter, the serviceline are pipe lines that transport water from laterals to neighboring community. The result from figures 4.10shows that, almost two-third of the network are service line, these pipe lines have a very low water discharge capacity to meet the requirement particularly in densely populated area which lead toin adequate distribution in such areas.

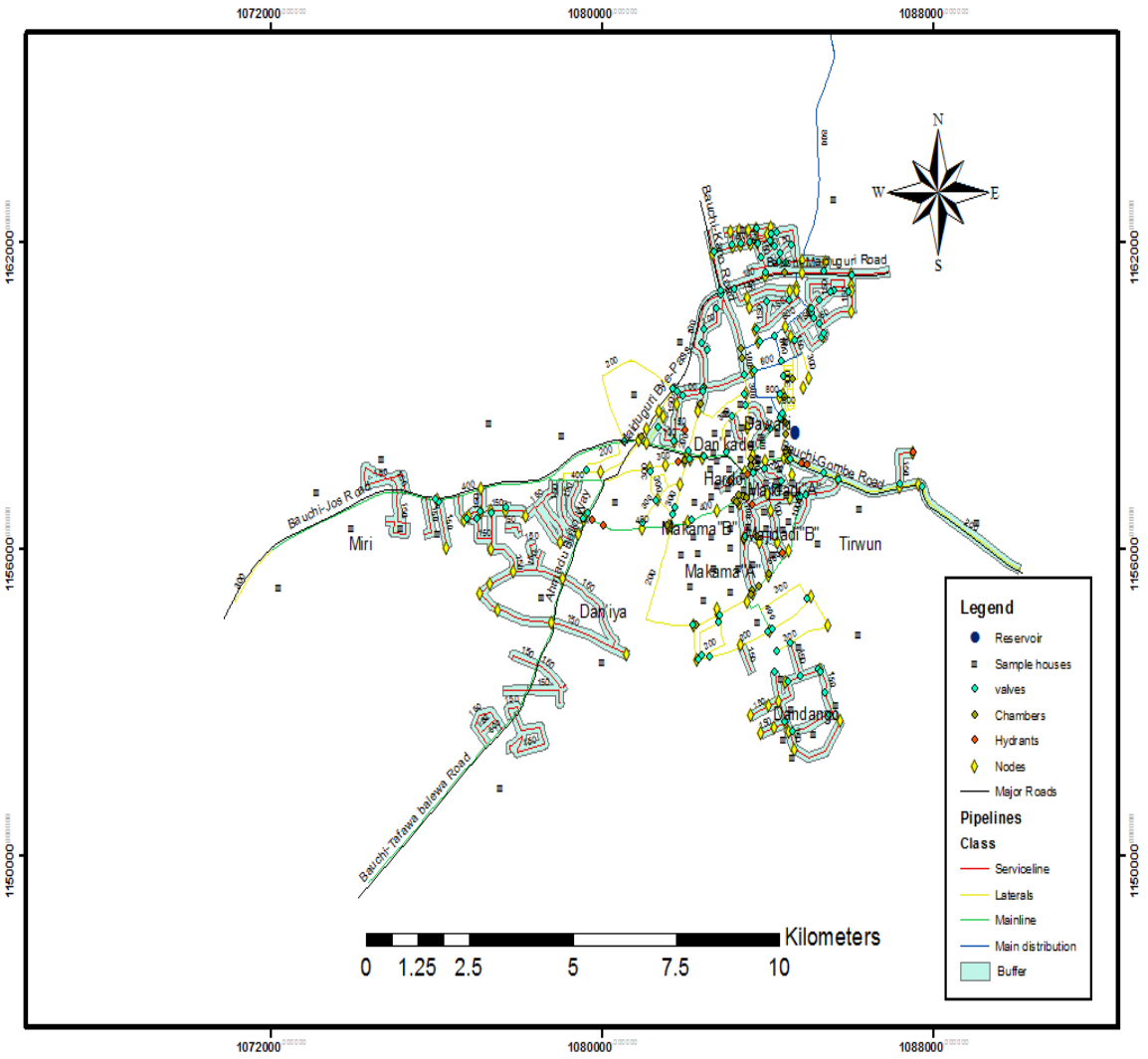


Figure 4.10: A service line buffered to 100 meter distance

The service lines are connected to laterals or mainline in the distribution network. The result show the in accessibility of service line inMakamaAand B wards which are also densely populated.

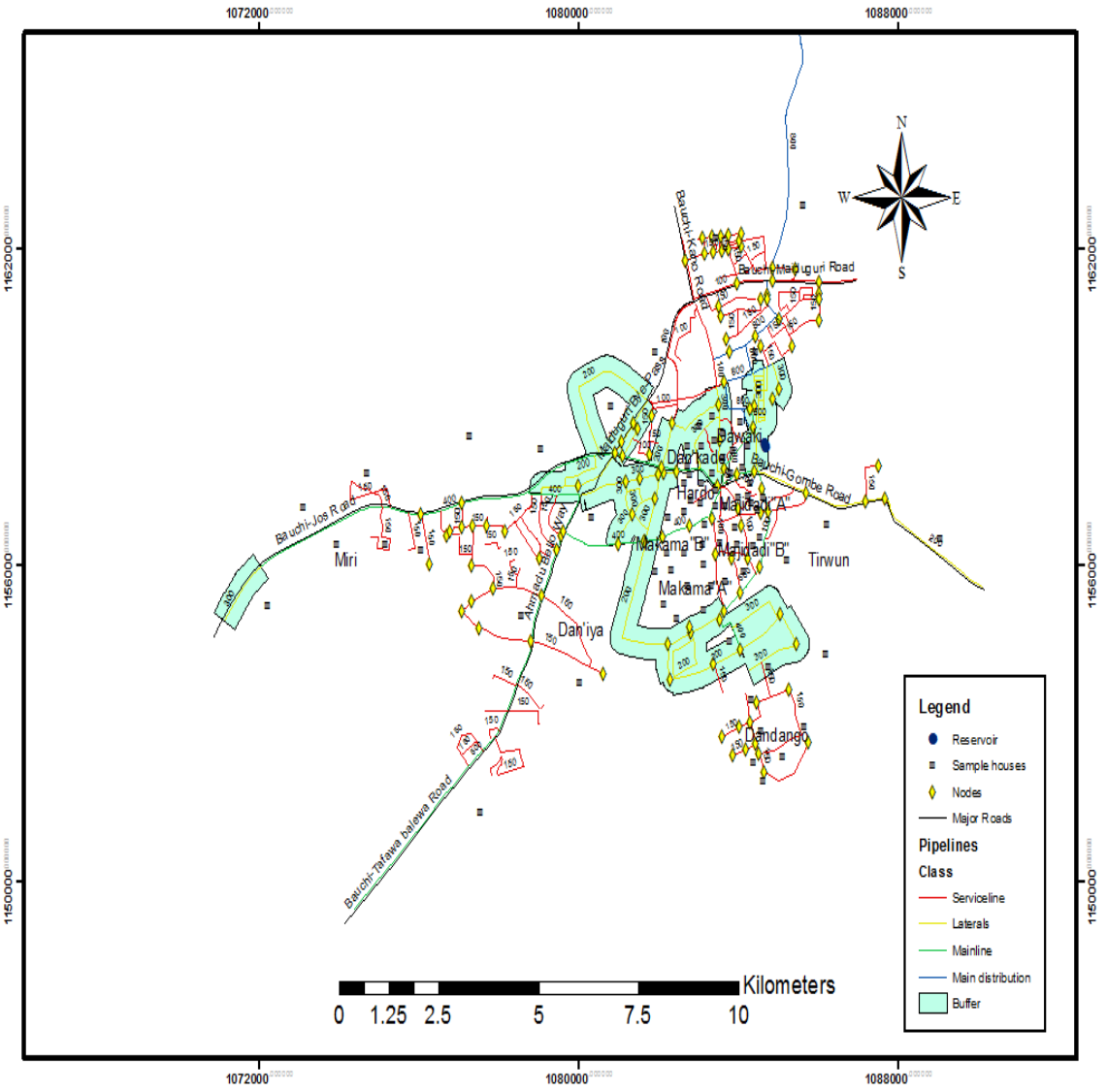


Figure 4.11: Laterals buffered to 300 meter distance

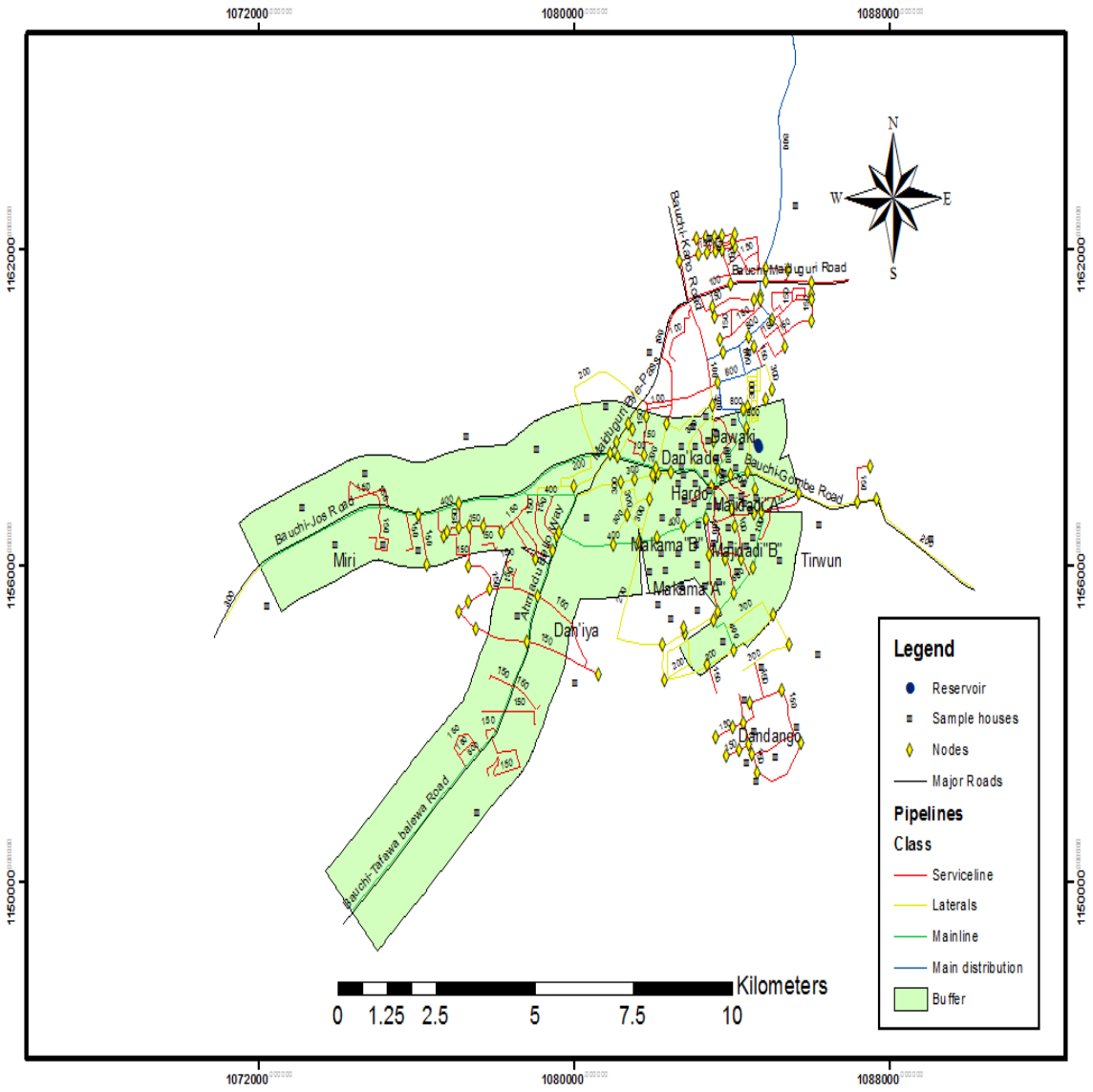


Figure 4.12: A main line buffered to 1000 meter distance

From figure 4.11 and 4.12, the result show the laterals convey water to Dan dango, Dankade and Dawaki ward, mainlines convey water from the main reservoir to different part of the town. Hence the laterals along Gombe road need to be upgraded to improve the situation due to urbanization along the axis.

4.4Extension of Water Distribution Pipe Lines

The world health organization (2011) described the maximum distance to reach the nearest water facility as 500 meters, in this regard, the existing and suggested pipelines was buffered to such distance. Figure 4.13 show the result of buffering existing and suggested pipelines while figure 4.14 is the map of existing and suggested pipelines which provide bases for decision making in the study area.

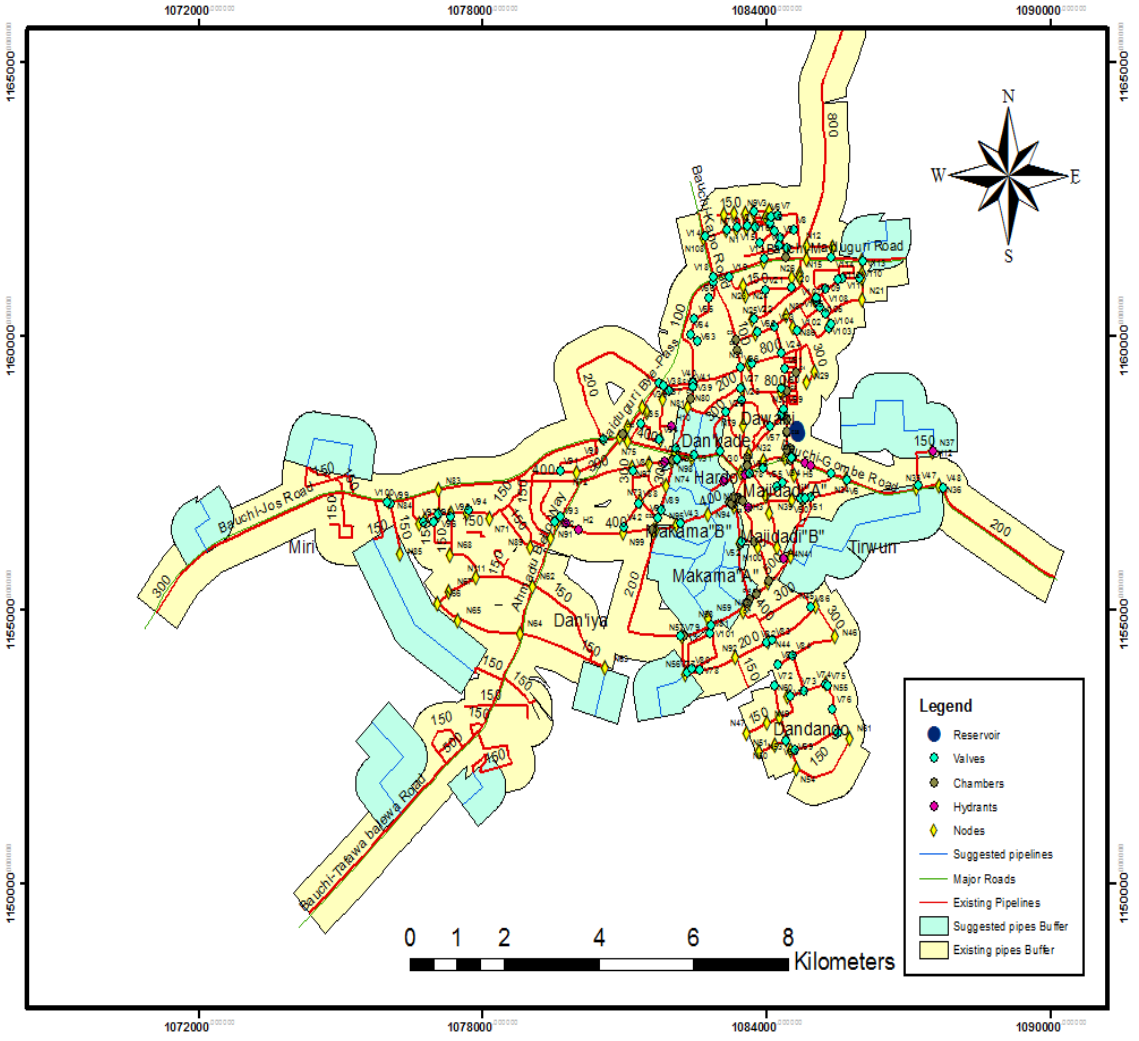


Figure 4.13: Existing and suggested pipelines buffered to 500 meter distance

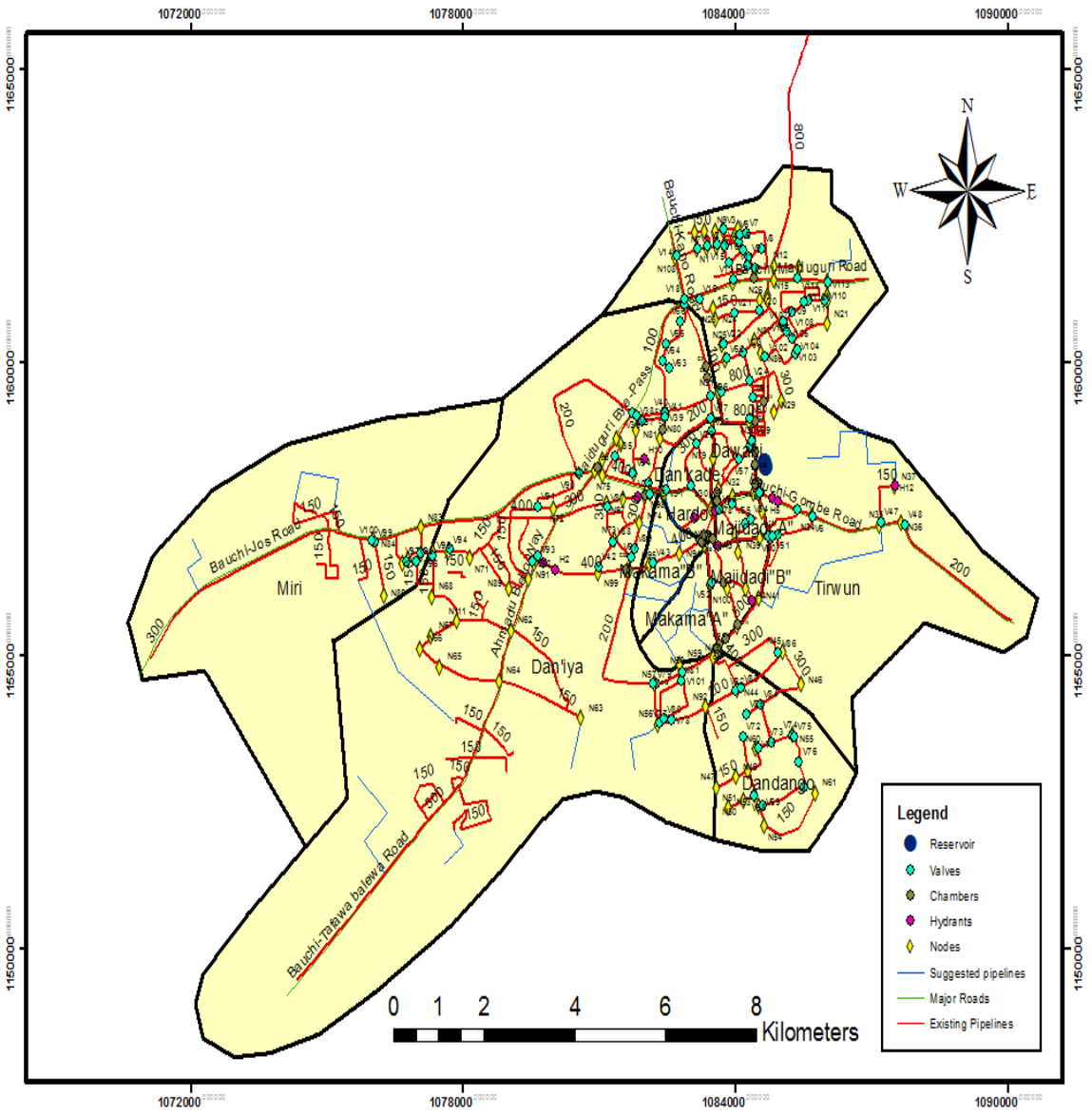


Figure 4.14: Map of existing and suggested pipelines

From figures 4.13 and 4.14, manypipelines were identified to be extended in Makama “A”, Makama “B”, Hardo and little portion of Dankade ward, these wards are high density residential area in Bauchi town. Pipelines were also suggested in Miri, Tirwun and Dan Iya ward as shown in the above figure. These extensions were suggested based on the result of analyzing the spatial accessibility to the pipe lines from the water distribution network.

4.5Analysis of the Questionnaire

Three different questionnaires were administered and distributed of which two were for the technical and management staff and distributedon 20th of January 2017 for the purpose of acquiring the research data from the Bauchi State Water Board (BSWB) to transform Bauchi urban water distribution map and create a water utility Geodatabase. The other questionnaire was distributed to the 77 sampled customer houses.

4.5.1 Management staff questionnaire

There are seven (7) management staff in B.S.W.B of which all are males. These included the managing Director/General Manager (MD/GM) and his four assistants (AGMs) heading other departments whilethe remaining two are billing and area managers.

All of the above management staff responded that there was a proposal for updating the existing water distribution map, and they presently operate in analogue system of mapping. Five out of seven responded that the state GIS (BAGIS) could help in the development of Bauchi water information system (BAWIS). The General Manager (GM) and four other expressed that they never used high resolution satellite imagery for mapping, and all agreed that the board does not have any modern tool o assess the spatial accessibility of the utilities to the consumers. All the seven management staff agreed that the house I.D number had been allocated in the newly built settlements and also the implementation of Geospatial water information system would improve the state revenue generation. Finally, all responded (Yes) to shows that the present mode of record keeping in B.S.W.B is both manual and computerized and all the respondent responded (yes) to advice the state

government in the implementation of water Geographic Information System (GIS) for proper planning, management and maintenance of water utilities.

4.5.2 Technical staff questionnaire

A total number of thirteen (13) questionnaires were distributed to the technical staff of BSWB of which all are males, Ten out of Thirteen responded (yes) that they refer to the map in locating the water utilities. Nine out of Thirteen expressed that they have encountered problem in locating the underground utilities more than Four times (4 and above) and Four staff expressed that they have encountered two to three (2 – 3) times problem in locating the underground water utilities. This problem in locating the network of underground water utility is associated with the lack of map update by Six out of Thirteen respondents, Four out of Thirteen relate it with inadequate tools and three respondents associated it with changes in neighborhood. All the responses show (No) that the current map does not cover the urban settlement and the water distribution is inadequate to serve the population. Eleven out of Thirteen respondents expressed that they received public complain verbally, while Two of Thirteen said they received it by messages, Five out of Thirteen responded that (yes) they refer to the map when there is complain, and such map defined the location to meet the complain. Finally all the responses shows that a consumer is determined only by house ID number, and Eleven out of Thirteen responded (No) that the board does not have any system of retrieving the water utility information.

4.5.3 Questionnaireanalysis results

The management staff questionnaire queries on the current system of mapping and any proposal to update the existing map, it also asked on whether they have used any high resolution satellite imagery before and their relationship to the state GIS for the development of water information system. Other questions enquire on modern water accessibility tools (software), allocation of house identifier, mode of record keeping and of the benefit of GIS implementation in improving the system of revenue generation. The result shows that all the principal management staff of BSWB are males and the board are proposing to update the current analogue system in to a digital, the management have embraced the idea of collaborating with Bauchi state Geographic Information System (BAGIS) for the establishments of Geospatial water information system to facilitate planning and improve the state revenue generation.

The technical staff questionnaire made inquiry on referral to map in locating the underground facilities, problems encountered and causes. It also queries on whether the current map cover the newly built settlement and the adequacy of water to the population. Other questions asked on the method of receiving public complain, mode of identification of the customers and the system of retrieving the utility information. The result shows that, majority of the technical staff are male with the qualification of certificates, national Diploma and H.N.D with grade level ranges from level six to fourteen (6-14), these staff expressed the problems such as lack of map updates, in adequate tools and changes in neighborhood. They further indicate that the map does not cover the new settlement therefore the water distribution is inadequate to serve the urban population.

Table 4.1: Managements Staff Questionnaire and Results

S/n	Question	Response		
		(a) Yes	(b) No	(c)
(i)	Does the board have any proposal for Updating the existing map?	7	0	_
(ii)	What is your current system of mapping?	(Analogue)	(Digital)	_
			70	_
(iii)	Modern water corporations operates in digital System, do you have such plan?	7	0	_
(iv)	Does the state GIS relates to the development of Water information system?	5	2	_
(v)	Have you ever used high resolution satellite to Map out the facilitie	5	2	_
(vi)	Does the board have any modern tool to assess the accessibility to the pipelines?	0	7	_
(vii)	Did you know that the implementation of GIS would improve the state revenue ?	7	0	_
(viii)	Does the B.S.W.B house I.D Number being Allocated in the new settlements?	7	0	_
(ix)	What is the present mode of record keeping?	(Manual)	(Digital)	(Both)
			0	7
(x)	Could you advice government to implement Water GIS?	7	0	_

Table 4.2: Technical Staff Questionnaire and Result

S/n	Question	Response		
		(a) Yes	(b) No	(c)
(i)	Did you refer to map in locating the underground Water utilities?	10	3	_
(ii)	How many times have you encountered problem in locating the utilities?	(0 – 1) 0	(2 – 3) 4	(4 & above) 9
(iii)	What is the cause of the problem?	(Map) 6	(Tool) 4	(Changes) 3
(iv)	Did the current map cover the newly extended settlements?	0	13	_
(v)	Is the water distribution adequate to serve the urban population?	0	13	_
(vi)	How do you received public complain?	(Verbal) 11	(Phone) 0	(Message) 2
(vii)	Do you refer to the map when there are complain?	5	8	_
(viii)	Did your map defined the accurate location to meet the complain?	5	8	_
(ix)	How do you determine a consumer?	(I.D Number) 13	(Data base) 0	(Maps) 0
(x)	Did you have any system of retrieving the utility information?	0	13	_

Table 4.3:Customer Questionnaire Analysis

Title: How customers observed the water distribution network

Response	Frequency	Percentages
Good	21	27.3
Fair	13	16.9
Poor	43	55.8
TOTAL	77	100

The result shows that the more than have observed it as poor distribution network.

Title: Knowing the location of closest public utility pipeline

Response	Frequency	Percentages
Yes	32	41.6
No	45	58.4
TOTAL	77	100

These show that many people are not are not aware of the location of the nearest public utility pipeline from their houses.

Title: Connections to the public utility pipeline

Response	Frequency	Percentages
Direct	32	41.6
Indirect	40	51.9
None	5	6.5
TOTAL	77	100

The result shows that approximately half of the customers have direct pipeline connection .

Title: Registration with Bauchi State Water board

Response	Frequency	Percentages
Yes	36	48.6
No	41	53.2
TOTAL	77	100

It is clearly shown that almost half of the customers are not registered with the water board.

Title: Mode of receiving water bill by registered customers

Response	Frequency	Percentages
Printed paper	17	42.7
Electronic SMS	0	0
Board agents	19	52.8
TOTAL	36	100

These show that the bills are distributed using papers and agents without SMS.

Title: Perception to service delivery

Response	Frequency	Percentages
Good	22	28.6
Fair	18	23.4
Poor	37	48.0
TOTAL	77	100

The result shows that almost half of the response to service delivery is poor.

Title:Causes of the poorness

Response	Frequency	Percentages
Over population	18	48.6
Lack of maintenance	12	32.4
Low funding	7	19
TOTAL	37	100

Most of the causes of poor service delivery were associated with over population.

Title: Houses with pipe born water

Response	Frequency	Percentages
Yes	41	53.2
No	36	46.8
TOTAL	77	100

From the above result, 36 respondents do not have pipe borne water in their houses; therefore they are those 36 people in the above table which are not registered with the state water board. They are also those 36 to 37 respondents who have poor perception to service delivery and water accessibility.

Title: Availability of water supply

Response	Frequency	Percentages
Good	10	24.4
Fair	12	29.3
Poor	19	46.3
TOTAL	41	100

The water supply was assessed to be poor by majority of the respondents

Title:Travel distance to the nearest pipe born water point

Response	Frequency	Percentages
< 50 meters	39	50.6
> 100 meters	15	19.5
200 meters & above	23	29.9
TOTAL	77	100

The above result shows that half of the respondents are closer to the water point at a distance less than 50 meters, hence their percentages is closer to those houses with the connection to pipe born water in table above, therefore, the remaining 38 houses are closer to those 36 houses without connection to water supply.

Title: Need for Facility extension

Response	Frequency	Percentages
Yes	48	62.3
No	29	37.7
TOTAL	77	100

Finally, many respondents suggested the extension of water facilities to the community; these show the scarcity of water supply and distribution in Bauchi urban area.

4.5.4 Result of the interview

The result of the interview conducted with some of the B.S.W.B staff described that the map does not cover the complete town and the water distribution is inadequate to serve the urban population because the population is drastically increased and the water is not discharged daily. The pressure is very low in Yelwa (Dan iya ward) along BauchiTafawaBalewa road, therefore they expressed need to install a booster station to enhance the water distribution in the area.

Furthermore, buildings were erected on some pipelines due to the negligence of the concerning authority, therefore compensation has to be made to demolish some buildings and demarcate the actual right of way or redirection of some pipelines.

4.6 Analysis of the Amount of Water Required by the Study Area

The projected population of Bauchi town is about 464, 948 people (NPC, 2017).

World Health Organization has described the minimum and maximum amount of water required by one person per day as 40 – 80 liters (WHO 2011).

Therefore the amount of water required per day in the study area = population x volume required.

Therefore, Minimum = 464, 948 x 40

= 18 ,597,920 liters/day

Maximum = 464, 948 x 80

= 37, 195, 840 liter/day

The average requirement = $\frac{\text{Min. + Max.}}{2}$

= $\frac{18, 597, 920 + 37, 195, 840}{2}$

= 27, 896, 880 liters/day

Table 4.4: Amount of Water Required by the Wards Population

S/n	Ward	Population	Min (Lit)	Average (Lit)	Max (LIt)
(i)	Majidadi 'A & B'	93,917	3756680	5635020	7513360
(ii)	Makama "A & B"	114,281	4571240	6856860	9142480
(iii)	Hardo	8,004	320160	480240	640320
(iv)	Dankade	41,485	1659400	2489100	3318800
(v)	Dan'iya	53,494	2139760	3209640	4279520
(vi)	Dawaki	51,889	2075560	3113340	4151120
(vii)	Dan dango	20,103	804120	1206180	1608240
(viii)	Miri	32,453	1298120	1947180	2596240
(ix)	Tirwun	49,322	1972880	2959320	3945760

The volume of water discharged by the treatment plant is 5,000,000 gallons per day.

1 gallon = 4.54609 liters

Therefore 5,000,000 gallons = 22,730,450 liters/day

This does not meet the average requirement and also the water is not discharged daily, it is discharged in the average of 3 -4 days.

Therefore, the average volume increment required per day

= average requirement – volume discharged

= 27, 896,880 – 22,730, 450

= 5,166, 430 liters/day

That is almost 18.5% of the average requirement, it is important to note that the water has being discharged 3 -4 times in a week, the average discharge per week = 3.5 days which is the half of a week, therefore the average volume requirement per week would be doubled to satisfy the requirement.

= daily requirement x 2

= 5,166,430 x 2

= 10, 332, 860 liters/week.

These occupy 37% of the average requirement.

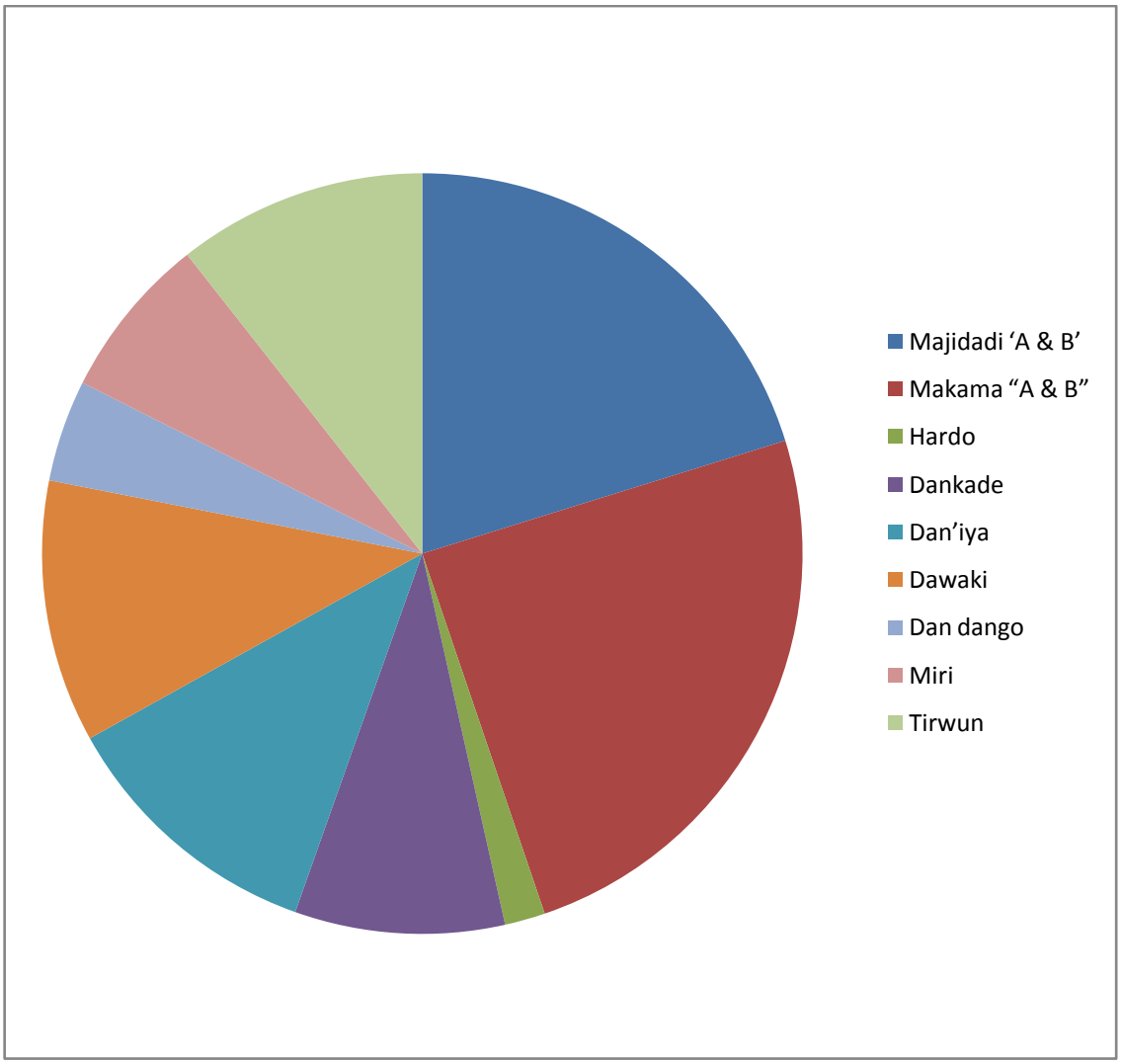


Figure 4.15: A Pie-Chart showing the wards population distribution

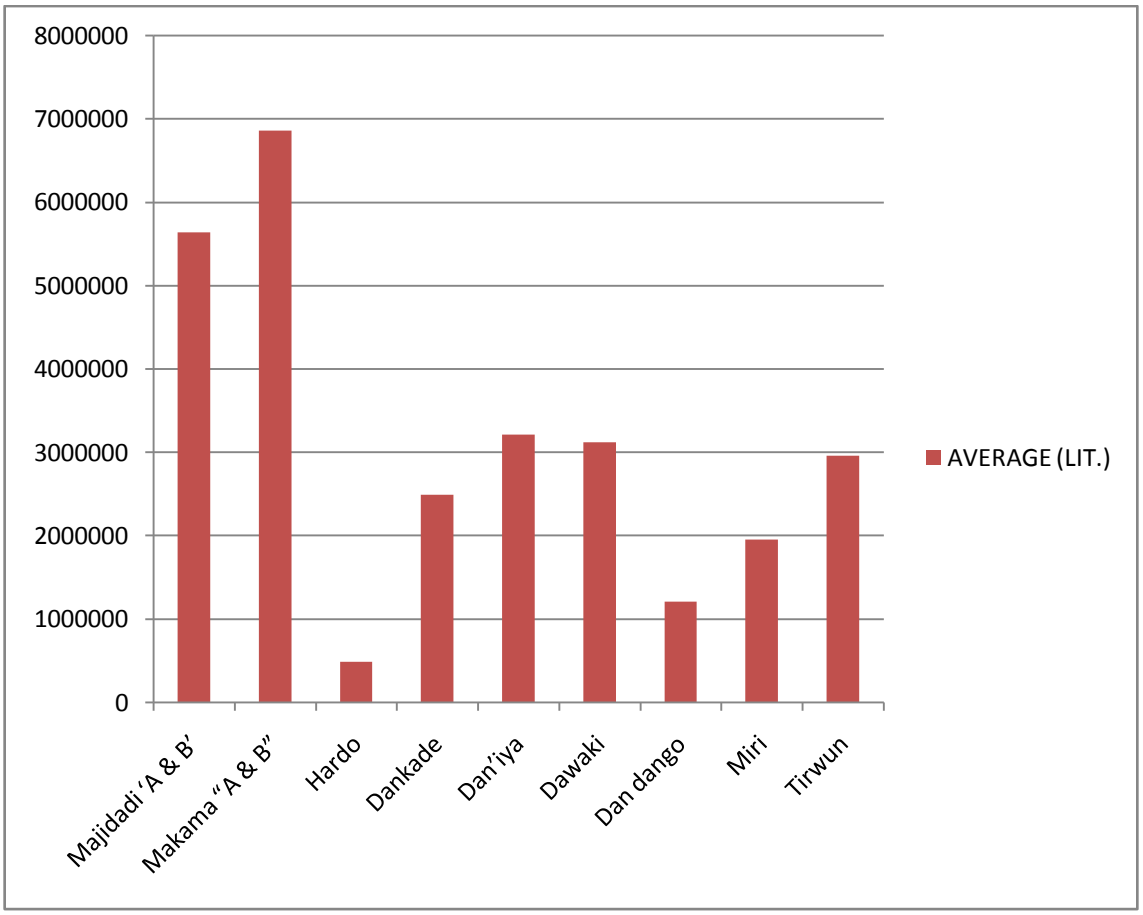


Figure 4.16: A Histogram showing the average water requirement

4.7Overlay Analysis

This analysis was conductedto show the availablepipelines that falls within a neighboring ward therefore, provide usefulinformation in locating the network of pipelines available in a particular area during operation and maintenance of water infrastructures. Figure 4.17 and 4.18show the containment of pipe lines within two or more neighboring wards of the study.

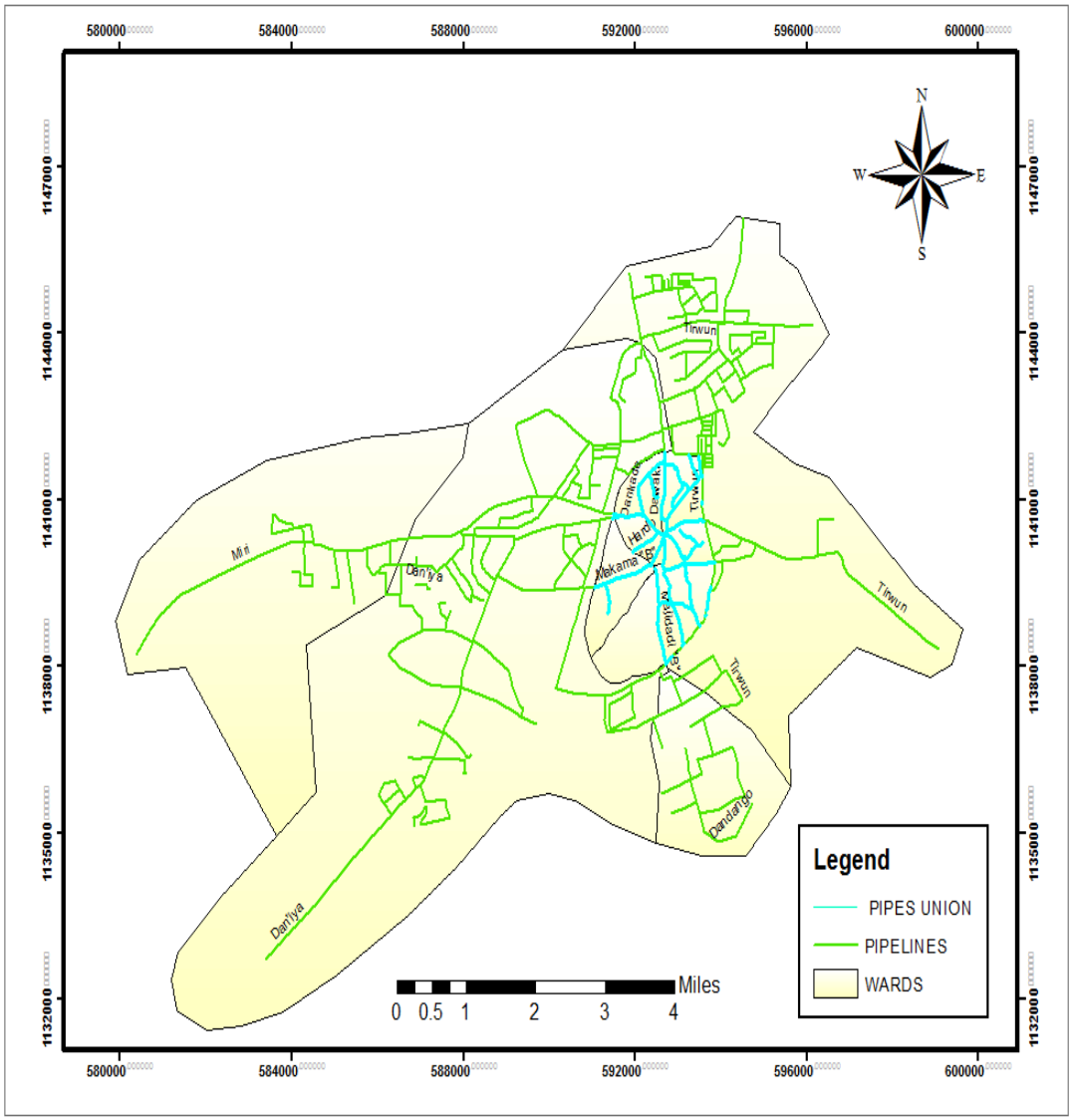


Figure 4.17: An overlay of pipelines in Bauchi central wards.

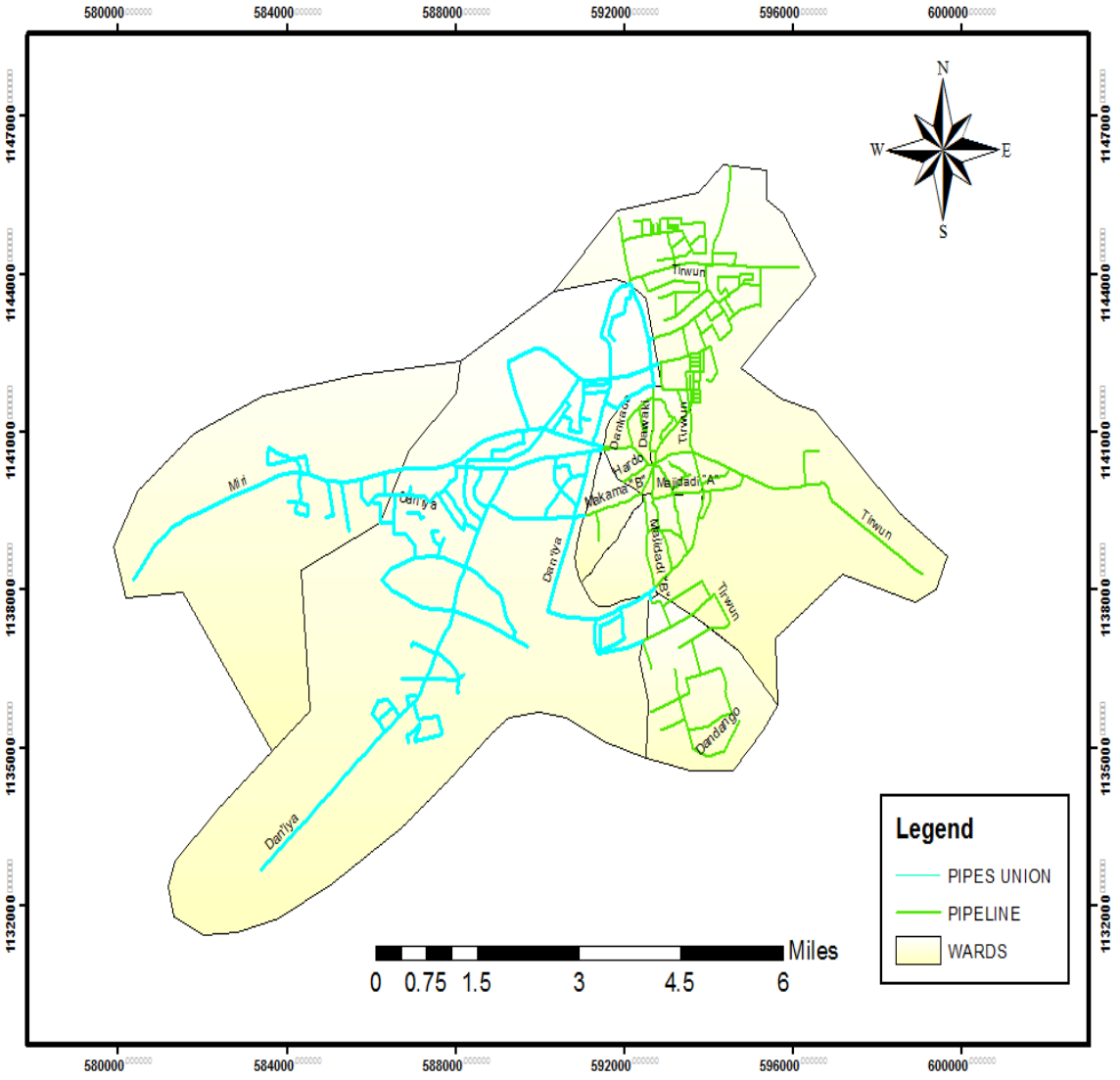


Figure 4.18: An overlay of Pipelines in Miri and Dan iya wards

Figure 4.17 show the unions of pipelines in seven different wards, these wards are within the historical city wall of Bauchi town formally known as the central wards. Figure4.18 show the union of pipelines within two different neighboring wards,, these layers are the input features, therefore all features and their attributes was displayed in the output feature class.

4.8Resultsof Validation Test

4.8.1 Root Mean Square Error (RMSE)

RMS error in this case is the distance between the input (source) location of a ground control point (GCP)and the retransformed location for the same GCP. In other words, it is the difference betweenthe desired output coordinate for a GCP and the actual output coordinate for the same point,when the point is transformed with the geometric transformation (Mathew, 2007).

The 3rd order transformation method was applied and obtained a RMS error of 0.136m during the process of Georeferencingthe water distribution base map using ten (10) ground control points.

4.8.2Field validation

The validity of the updated water distribution map was tested in the field using the existing map, the result shows that many facilities in the map were in their corresponding position on the ground, but some facilities have been relocated by changing their orientation due to construction and dualization of road in some part of the town, these changes were successful effected on the updated map. Furthermore, buildings were erected on some service lines due to the negligence of the concerning authority, therefore, compensation has to be made to demolished some buildings and demarcate the actual right of way or otherwise change the orientation of some pipelines.

4.8.3 Data base validation

The data base was approved to be tested by General Manager Commercial through the billing Manager, the built customer file geo data base incorporating the detail information of their houses coordinates, house identifier, Address, occupation, mobile number and their respective payment status was used for spatial and attribute queries in GIS environment, the result shows the house location and the attached attribute information of the sampled customers that did not pay their water utility bill for year 2016. These operations provide the simple means of customer notification through his mobile number from the data base, to save time and eliminate the cost of printing bills.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The aim of this study was to provide a digital map ofwater distribution system in Bauchi town using GIS technique. Therefore, it has the objective of updating the existing map, creation of functional geo data baseto facilitate the distribution system, analyzing the spatial accessibility to the pipelines and identifying places that requirethe extension of water facilities. The research identified the problem of inadequate water distribution and irregular accessibility in the study area due to increase in population, poor facility mapping and inadequate information.

Many relevant literatures were consulted before this task was accomplished; materials used include hand held GPS, DGPS, HP A0 Scanner and Arc GIS computer software. The data was collected from different organizations, field survey, interview and administration of structured questionnaires, GIS technique was used in data processing and analysis. Data processing involved scanning the base map, Georeferencing using ten (10) ground control points and finally digitization using Arc GIS 10.1version software. Queries overlay and proximity analyses have been carried out together with the statistical analysis of questionnaire. The Average, minimum and maximum amount of water required by the population of the study areawas computed. The results presented the updated water distribution map and developed a functional customer file geo data base that facilitates water utility billing. Also, itanalyzed the water accessibility using international standard and Georgia accessibility standard. These criteria were applied in identifying the extension of water facilities to the required places, and finally validation test was conducted to ensure the accuracy of the result.

5.2 Conclusions

The mapping of Bauchi township water distribution system was successfully achieved using GIS technology. GIS components such as hardware, software, data man power and method were utilized in updating the existing water distribution map and development of customer file geo data base which facilitate water utility billing system and provide means of improving the state water revenue generation. Thisstudy measure the water accessibility and identified places that need extension of water facilities based on the area coverage of the created buffer. The results show the updated water distribution map and answer the research questions in accordance with designed objectives.

(i) The updated map was adequately enriched and varies obviously from the existing map because it incorporate additional map features such as grids, layout, scale, legends and coordinate system which were not defined in the existing maps, furthermore, each facility was labeled and allocated a unique identification number.

(ii) The developed geo data base could be used in improving water distribution system by generating tangible water revenue which may be used in the utility maintenance and effective service delivery.

(iii) The updated map was used to determine the places that need extension of water facilities in the study area.

The Georgia standard criteria was used in assessing the spatial accessibility to water facilities, therefore the service line cover almost two third of the distribution network and clustered around the densely populated area which lead to in adequate distribution due to low water discharge capacity, therefore some service lines need to be upgraded to laterals to improve the situation. The laterals along Gombe road were also need to be upgraded due to urbanization along the axis. Furthermore, it was suggested to increase the pipelines in

Makama A' and 'B' Hardo and little portion of Dankade wardbecause these wards are high density residential area in Bauchi town. Pipelines were also identified to be extended in Miri, Tirwun and Dan iya ward.

Finally the questionnaire was analyzed and the amount of water required by the population of the study was computed, the result gives 37, 195, 840 liters per day as maximum requirement, 18, 597, 920 liters per day as minimum and 27, 896, 880 liters per day as average water requirement which is closer to 25 million gallons required by the state in last year. The water distribution problem was associated with the increase in population which exceeds the present discharge of 15 million gallon per day; moreover the unstable power supply reduces the daily water pumping requirement to Bauchi town and the cost of running on generation was very high due to improper revenue generation by the water board and inadequate funding from government.

5.3 Recommendations

The water supply and distribution sector need to be given more priority than other sectors as it helps to prevent prevalence of diseases to ensure environmental health and sustainability. Governments are spending considerable amount of money every year and allocated intangible percentage for water sector despite the increase in people without access to water. Many international organizations are donating huge amount of money to improve the situation but our government divert it and spend a little amount due to corruption, lack of clear water policy, financial management and accountability.

Underground utilities need to be accurately mapped to enabled government know the network coverage and quantify the amount required, it also helps during the operation, utility maintenance, replacement and extension. The implementation of Geographical

information system (GIS) for water utilities would provide accurate tools for mapping, analysis and processing of spatial and non spatial data, hence features and information can be regularly updated, therefore this study is quite different with the previous literatures as it applied GIS technology in mapping of underground water utilities in Bauchi town and developed a functional Geodatabase which provide an integrated customer based water information system for tangible revenue generation in the state.

To upgrade the system and improve the situation, this studymade the following recommendations.

(i) Due to the rapid development and environmental changes, a longitudinal study on water utility mapping should be carried out after the specific period of time to ensure good and proper decision making in water sector.

(ii) The state water board has to standardize the criteria in the installation of water utilities to ensure the accessible and even water distribution particularly in Bauchi urban area.

(iii) To facilitate the development of GIS based water billing system, therecord keeping should be absolutely computerized.

(iv) The customer data should be coordinated and incorporate the Geodatabase for easy identification on the map.

(v) Water utility extension should be carried out in conformity with the GIS based water utility map to meet the demand and ensure proper service coverage in all part of the town.

This study developed a functional customer file Geodata base which will help the utility service providers such as water, sewer, electricity distribution companies, oil and

Gas Company as well as other utility organizations to have a reasonable benchmark for developing a contemporary Geospatial information system for effective business operation. Therefore, it is going to be working document to policy makers for the appraisal of Internal Generated Revenue (IGR) on water sector and many other utility service providers. It would serve as useful academic research material for further investigation and relevant literature to the existing knowledge.

Finally,the future research is recommended to add on classification of pipelines based on the material type, network analysis and correlate the pipeline network withstreets and the terrain.

5.4 Contribution to Knowledge

This study contributes to the body of the existing knowledge by providing the integrated geospatial based water utility information system for proper decision making in water sector by tagging entities with locations which has not been done before in the study area. Therefore, the contributions are as follows:

(i) The study developed a functional Geodatabase for water distribution in Bauchi metropolis which helps the utility service providers to use a contemporary Geospatial information system for effective business operation.

(ii) Identified areas within the study area without water supply network and provided the effective means of covering these areas.

(iii) Established the spatial accessibility of residents of Bauchi metropolis to the existing water facilities which help to identify the places that require extension of such facilities.

REFERENCES

Abubakar, M.C. (2006).Historical Perspective of Bauchi State, NigeriaFirst Published 2006, p. 3.

Andrea, C.T .(2002). *Water supply and sanitation study of GouansoloVillage,Mali,West Africa*, (Master of Science thesis in Environmental Engineering,MichiganTechnologhical University. Retrieved from https://m.mtu.edu> programs> civil >pdfs

Asajile, A.M. (2015).*Measuring and mapping citizens access to rural water supply in Tanzania*,(Master of Science thesis in Geo-information Science and Earth observation, Enschede, Neitherland). Available onhttps://itc.nl>msc>upm>mwamaso.

Aronoff .S . (1989).*GeographicInformation Systems: A Management/Perspective*WDLPublications, Ottawa, Canada. Retrieved from https://www.tandfonline.com

Audu, H.A.P. and Ehiorobo, J. O. (2010).“Location and Geospatial Positioning ofWaterdistribution Infrastructure in GIS Environment”, Technical Transaction, *Journal ofNigerian Institution of Production Engineers*, Benin City,12: 65-79.

Audu, H.A.P. and Anyata, B.U. (2010).“Water QualitySurveillance in Niger Delta Region of Nigeria”, Technical Transaction, *Journal of the Nigerian Institution of Production Engineers*, Benin City, 12: 80 – 90.

Audu, H.A.P. and Edokpia, R.O. (2010).“Planning andMaintenance Management of Water Distribution System with Geo-spatial Information System”*Journal of Engineering for Development*, Benin City. 9: 142-154

Audu, H.A.P. and Ukeme, U. (2013).“Geospatial informationfor the locationandmaintenance Management ofwaterservice pipelines”, *Journal ofadvanced Materials Research, Zurich*, Switzerland, 824: 634-642.

Audu, H.A.P. and Ehiorobo, J. O. (2015). Geospatial technique in water distribution network Mapping andmodeling in Warri port complex, Nigeria.7663,Federation of International Surveyors, FIG working week, 2015.Retrieved from https://www.fig.net

Babovic,V.J.Drescourt, M. K, and Hansen, P.F.(2002).A dataminingapproachto modeling of waterSupply assets, Urban Water, 4: 401-414.

Baird,G.(2011).Heating the spot GIS helps improve U.S. water infrastructure.*Water and Waste WaterInternational*,26(5) available on.http://www.waterworld.com/articles/print/26

Brussels, M.J.G.(2005).Asset Managementand GIS, unpublished lecturenotes,ITC PGMDepartment, p. 14.

BSWB,(2015).Reviewing the water supply and distribution system of Bauchi town for the proposed World Bank Project in Bauchi state, Nigeria.(Unpublished office document)

Cannistra, J. R.(1999).Converting utility datafor a GIS, *American WaterWorks Association Journal*, 91(2):55-64.

Chin, D.A. (2006). *Water-Resources Engineering*,2nd editionPearson/PrenticeHall, New Jersey, pp: 774-865. Available on https://www.abebooks.com

Cullen, T. (2005).“Geomatics World” Contribution of the expert to the one-day Event organizedby the Institution of Civil Engineers, Geo-spatialEngineering Board, London,13: 21-23.

Crawford, D. (2012). *Implementing a Utility Geographic Information System for Water, Sewer, andElectric*. (Master’s thesis, Northwest Missouri state University). Available on htpps://www.nwmissouri.edu >CrowfordDavie.

EljamassiR, and Rola A.A. (2013). A GIS based DSS for management ofwater distributionNetworkin Rafah city, *Journal of geographic information system*, 5: 281 – 291

ESRI,(2014).*Implementing ArcGISfor water utility*, an Environmental System ResearchInstitute white paper.Available on https://www.esri.com> whitepapers >pdfs.ESRI, (2007).*GIS Technology for water, waste water, and Storm Water Utilities*,[Online]Available from: http://www.esri.com/library/brochures/pdfs/water-wastewater.pdf [Accessed 1 April 2011]

Farrimond, M. (2005). “Geomatics world” Contribution of the expert to the one-Day eventOrganized by the Institution of Civil Engineers, Geo-spatial Engineering Board United Kingdom, UK, July/August 2005.

Fellers, J.(2013). Implementing a Geographic information system for rural water and sewer Company Newberry water and sewer authority.Retrieved from https://www.nwmissouri.edu> 2013 >FellersJeff.

Fyassa (2009),Technical guidelines for the construction and management of drinking water Distributionnetworks,a manualforfieldstaff and practitioners developed in Partnership with UNICEF April 2009.Available on https://www.sswm.info.

Goodchild, M. F (2009). Geographic information system(GIS)and science, today andtomorrow. Retrieved from https://www.tandfonline.com

Guanfu, S. and Ershun, Z.(1998). ResearchandDevelopment of Components Geographic Information Systems [J], *Journal of Image and Graphics.*Available on https://shodhganga.inflibnet.ac.in>bitstream.

Haladu, S.,Abdullahi, I., Bayang, F., Garba, H., Ndububa, O.I, and Tshoho, U.(2014). GubiWater TreatmentPlant as A Source Of Water Supply In Bauchi TownshipAmerican Journal of Engineering Research (AJER)e-ISSN: 2320-0847 ISSN: 2320-0936, 3:119.

Harry, E.H. (2008). Watersupplysystem and evaluation107methods, United State of America fire administration. Available on https://www.usfa.fema.gov

Hassan, M. and Funtua, A.I.(2014).Assessment of the spatial dimension of the water distributionSystem of Jibia dam, North West Nigeria using GIS technique, *International Journal ofEnvironmental andConstruction Management, Cambridge research and publication International.*

Henry, A.A and Jacob,O.E.(2015).*Geospatial technique inwaterdistribution Network andModeling in Warri port complex, Nigeria,* Federation of International Surveyors (FIG)Working week, 2015. Retrieved from https://www.fig.net

Henry, W.D.(2007).Assessing the challenges of water supply in urban Ghana,University of Benin. Available on https://www.ircwash.org

Jain M. (2009).GIS and Remote Sensing Techniques- a case study of a developing urban centre.HimanshuPublication, NewDelhi,India. Available on https://www.himanshupublications.com

Jason, B. (2013).Implementingand using GIS in water distribution system, water department Of Madison country. Retrieved from https://www.derectiosnmag.com

Jasen, M.A (2002). Water consumptionevaluation in Kuwait,*Journalof Water supplyresearch and technology,* 51: 8. Practice & Research 16:281-292.

John,R.W(2010). Defining urban areas, department of Geography, San Diego state university, U.S.A, 3:34.

Klinkenberg, B. (2007).GeospatialTechnologies andthe Geographies of hope and fear*Annals of the Association of American Geographers*, 97: 350-360.

Lacquemanne, O. (2000). "Integrated approach key to ground water management" Water and Waste water International magazine. 16: 10-15.

Lyon,T.and Clifford, D. (2008).From deficient to efficient many benefits flow from waterDistrict's GIS[Online].*ArcUserOnline*,Spring.Availablefrom: http://www.esri.com

Mailafia, M.(2016). Appraisal of Bauchi township water utility map, (Bauchi State Water BoardUnpublished office document, 2016).

Mary, P.H (2008).GIS Representation and Assessment of Water DistributionSystem for Mae La Temporary Shelter, Thailand. Master's thesis in Civil and environmental Engineering,Massachusetts Institute of Technology.Available on https://web.mit.ed

Mathew O.A (2007). *Land use land cover change detection with remote sensing and GIS at metropolitan Lagos, Nigeria.*,(Doctoral thesis,University of Leicester) Retrieved from Pro Quest LLC, 2013 published.

Michael,S.A.,Naa, D.T, and Saviour, M.(2011).GIS water supply network maintenance in Tarkwa GhanaResearch*Journal of Environmental and Earth Sciences* 3(6): 737-744

Michael, O.(2013), Challengesofwatersupply schemes in Nigerian context.Retrieved from https://www.hydratelife.org

MDGs (2014).Millennium Development Goal (MDGs) in Nigeria: Issues and ProblemsGlobal Journal of human and social sciences. Available onhttps://www.socialsciencesresearch.org

Miner, M , (2005).Water industry realizing benefits from GIS Applications. *American Water Works Association Journal*, 97(11): 56-59.

NECE.(2006). WaterdistributionsystemGIS Mapping, New England Civil Engineering Corporation,Tops field, Gloucester and Grafton District. Available onhttps://www.engineeringcorporation.com

NPC. (2017). Wards projectedpopulation data of Bauchi metropolis, National PopulationCommission Bauchi, Bauchi State (Unpublished office documents)

Omoniyi, O.J. and Basorun, J.O.(2013).Spatial Analysisof Dam Water Distribution inEro Region,Department of Urban and Regional Planning, Federal University of Technology Akure,Nigeria.*European International Journal of Science and Technology,2:5*

Oyebande, L.(2005)."Water Resources"Adalemo, I.A. and Baba, J.M. (editors)Giant in theTropics, A Compendium, Gabumo Publication Company Limited.

Phadke,D. N.(2006). *GeographicalInformation Systems (GIS) in library and information Services*, Concept Publishing Company. Available on https://www.abebooks.com

Pindiga, A.M, Sani, M.J and Garba, T. (2015).Mapping ofWaterDistribution NetworkusingGIS TechnologyinBauchiMetropolis, Nigeria,Journal*of Environment and Earth Science. ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online).*Available on https://www.ijircce.com.

Pun-Cheng, L.S.C.(2001),knowingourcustomers: A quantitative analysis of GeomaticsStudents,*InternationalResearch in Geographical and Environmental Education*,10: 322-341, ISSN 1038-2046.

Rao, V. P. (2002).“Environmental Engineering”, Firstedition,New Delhi, India, Published byPrentice hall Limited.

Rauph, O.A.(2015), *Introduction topractical Geographical InformationSystem(GIS)using Arc Geographical Information System 10*(Arc GIS 10 version).

Sarbu, I. and Borza, I. (1997),“Optimal design ofwater distribution networks”,*JournalofHydraulic research*,35:63-69.Available on https://www.tandfonline.com

Shamsi,U. (2005). GIS Applications for Water, Wastewater and Stormwater Systems,BocaRaton Florida: CRC Press. Retrieved from https;//www.crcpress.com

Star, J. and Estes, J.(1990).*Geographic Information System. An Introduction*, Englewood Cliffs,New Jersey, United State of America.

Tang, T.and Gregory, K. (2007). Spatialanalysis of house hold water supply and demand in a distributed Geographic network in the towns of Amherst and Clarence,New York,middle States Geographer, 2007, 40:133-141.

Tomlinson, R. (2007). Thinking about GIS: Geographic Information SystemPlanning for Managers, ESRI Press, New York. Middle states Geographic, 2007 40:133 – 141.

Ufoegbune, G.C., Oyedepo, J. A., and Awomeso, A.O. (2010).Spatialanalysis of watersupply in Abeokuta Metropolis. Southwest, Nigeria, University ofAgriculture.Real Corp 2010 proceedings. Available on http//www.corp.at.com

Ukaejiofo, A. N. (2009).*Identifying appropriate tools for land governance in Nigeria*,A PaperPresented at the 7th Federation of International Surveyors (FIG) Regional Conference on ‘Land Governance and the Environment – Building the Capacity’ held inHanoi, Vietnam, 19-22 October2009.Retrieved from https://www.fig.net

Umar, D. (2017). Bauchi residents decry poorwater supply.*Daily streamnews paper*.Available on https://www.dailystream.com.ng

UNICEF.(2014). Joint MonitoringProgram for Water supply and sanitation.Retrieved from http://www.sphereproject.org

URT. (2006). National watersectordevelopment strategy, ministryof Waterand livestockdevelopment,United Republicof Tanzania Dares Salam, Tanzania, p.109

Vega, R.(2009). Managing Water Utilities With Geographic Information Systems: The Case of The city of Tampa Florida.Master Thesis. NorthwestMissouriState University

Victor, K .and Aline P.(2015). Using Remote Sensing to Map and Monitor Water Resources in Arid and Semi-arid Regions. Available on https://www.link.springer.com

Vidya S. G and Nandavdekar,V.D. (2013).Mapping ofwater distribution networkthrough Geographical information system,*International Journal of Civil Engineering (IJCE)ISSN(P): 2278-9987; ISSN(E): 2278-9995, 2: 33-44*

Warner, D.B.(1995).Water Needs and Demands: Trends and Opportunities from a domesticWater Supply, Sanitation and Health Perspective. (A workshop onscenarios and WaterFutures, Stockholm Environment Institute, Boston, Massachusetts, 28-30 September 1995.

Walski, T.M, Donald, V.C, Dragon, A.C and Walter, G.(2003). *Advanced Water Distribution Modelling and Management" First Edition,*CT, United State of America, 2003.

WaterAccessibility (2017).*International Journalof water resource development.*Retrieved from https://tandfonline.com

Welday, B.D.(2005). Water supply coverage and water loss in distribution system, Adisababa.(Master of Science thesis in Geo-Information Science and Earth Observation) International Institute for Geo-information Science and Earth Observation, Enschede, Neitherland.

W H O.(2011).WorldHealthOrganizationguidelinesfordrinkingwater.Fourth edition, Available on https://www.who.int>2011 > dwq-guidelines.

World Bank Regional Reports. (2001). World Bank Regional Reports – AfricaRegion. Rretrieved from http://urbanupgradingOctober 8 2006.

World Water Day.(2016).DailyTrustNigerianews paper. Available on https;//www.dailytrust.com.ng

Zhang, T.(2006).Application ofGIS and CARE-W Systems on Water Distribution networksin Skärholmen,Stockholm, Sweden, unpublished M. ScThesis, RetrievedFrom:http://www.infra.kth.se/geopublication.

APPENDIX I

MANAGEMENT STAFF QUESTIONNAIRE

● SEX (a) Male (b) Female

● RANK_____● DEPARTMENT_____

1. Does the board (B.S.W.B) have any proposal for updating the existing water distribution map?

(a) Yes (b) NO

2. What is your current system of mapping?

(a) Analogue (b) Digital

3. Modern water corporations operate in digital system; do you have such plan in Bauchi state water board (B.S.W.B)? (a) Yes (b) NO

4. The state Government has implemented Geographic Information System (BAGIS) for the

Ministry of Lands and Housings; does it relate to the development of Bauchi Water Information System (BAWIS)? (a)Yes (b) NO

5. Have you ever used a high resolution satellite image to map out the water facilities?

(a)Yes (b) NO

6. Does the B.S.W.B have any modern tool (Software) to assess the proximity of the pipeline to the consumers? (a) Yes (b) NO

7. Did you know that the implementation of Geospatial Water Information System would improve the state revenue system? (a) Yes (b) NO

8. Does the B.S.W.B house identification number being allocated in the newly built settlements?

(a)Yes (b) NO

9. What is the present mode of record keeping? (a) Manual file (b) Computerized (c) Both

10.Could you advice government to implement Water Geographic Information system for planning, management and maintenance of the utilities? (a) Yes (b) NO

TECHNICAL STAFF QUESTIONNAIRE

● SEX (a) Male (b) Female

● LEVEL_____ ●QUALIFICATION_____

● DEPARTMENT/ UNIT _____

1. Did you refer to the map in locating the underground network of water facilities?

(a) Yes (b) NO

2. How many times have you encountered problem in locating the underground water facilities?

(a) 0-1 (b) 2-3 (c) 4 and above

3. What is the cause of the problem?

(a) Lack of map update (b) In adequate tools (c) Changes in neighborhood

4. Did the current water distribution map cover the newly extended settlements?

(a)Yes (b) NO

5. Is the water distribution adequate to serve the urban population? (a) Yes (b) NO

6. How do you received public complain? (a) Verbal report (b) Phone (c) Messages

7. Do you refer to the map when there are complain?

(a) Yes (b) NO

8. Did your maps defined the accurate location to meet the complain?

(a) Yes (b) NO

9. How do you determine a particular consumer?

(a) House ID number (b) Database (c) Maps

10. Did you have any system of retrieving the water utility information? (a) Yes (b) NO

CUSTOMER QUESTIONNAIRE

- Sex (a) Male (b) Female
- Age (a) 20-30 (b) 31-40 (c) 41and above
- Marital status (a) Single (b) Married (c) Separated
- Occupation (a) Civil servant (b) Business (c) Others

1. How do you describe the network of Bauchi urban water facilities?

(a) Good (b) Fair (c) Poor

2. Do you know the location of your closest public utility pipeline?

(a) Yes (b) No

3. From where have you connected to the public utility pipeline?

(a) Direct (b) Indirect (c) None

4. Have you register with the State Water board?

(a) Yes (c) No

5. If registered, how do you receive bills and notifications?

(a) Printed papers (b) Electronic SMS (c) Board agent

6. How do you rate the service delivery?

(a) Good (b) Fair (c) Poor

7. If poor, what is the cause?

(a) Over population (b) Lack of maintenance (c) Low funding

8. How do you assess the water accessibility?

(a) Good (b) Fair (c) Poor

9. If poor, what is the cause?

(a) Long distance (b) I n adequacy (c) Long queue

10. Do you have pipe born water in your house?

(a) Yes (b) No

11. If yes, how do you assess the availability of water supply?

(a) Good (b) Fair (c) Poor

12. If no, how long have you walk to reach the nearest pipe born water facility?

(a) < 50 meters (b) >100 meters (c) 200 meters and above

13. Do you suggest the extension of water facilities to your community?

(a) Yes (b) No

APPENDIX II

CONTROL POINTS

Land Survey Overview

GNSS Solutions, Copyright (C) 2010 Ashtech. 6/15/2016 8:51:45 PM
www.ashtech.com

Project Name : BAUCHI CONTROL POINTS
Spatial Reference System : WGS 84
Time Zone : (GMT+01:00) West Central Africa
Linear Units : Meters

Coordinate System Summary

Coordinate system

Name :	WGS 84
Type :	Geographic
Unit name :	Radians
Radians per unit :	1
Vertical datum :	Ellipsoid
Vertical unit :	Meters
Meters per unit :	1

Datum

Name :	WGS 84
Ellipsoid Name :	WGS 84
Semi-major Axis :	6378137.000 m
Inverse Flattening :	298.257223563
DX to WGS84 :	0.0000 m
DY to WGS84 :	0.0000 m
DY to WGS84 :	0.0000 m
RX to WGS84 :	0.000000 "
RY to WGS84 :	0.000000 "
RZ to WGS84 :	0.000000 "
ppm to WGS84 :	0.000000000000

Control Points	:	1
Reference Points	:	0
Logged Points	:	11
Target Points	:	0
Intermediate Points	:	0

Control Points

Name		Components	95% Error	Status
B1244A13	Long	9° 49' 01.83000"E	0.000	FIXED
Lat 10° 17' 56.45750"N	0.000	FIXED		
Ellips height	628.418	0.000	FIXED	

Logged Points

Name	Components	95% Error	Status
CS05	Long 9° 50' 29.28889"E	0.013	Adjusted
Lat 10° 20' 47.15228"N	0.013 Adjusted		
Ellips height	624.769 0.019	Adjusted	
Description	*AWALA ROUDNABOUT*		
CS06	Long 9° 47' 54.10018"E	0.015	Adjusted
Lat 10° 16' 52.23602"N	0.015 Adjusted		
Ellips height	630.183 0.018	Adjusted	
Description	*A.T.B.U Junction*		
CS07	Long 9° 53' 3.7720314"E	0.018	Adjusted
Lat 10° 18' 36.85514"N	0.016 Adjusted		
Ellips height	622.510 0.021	Adjusted	
Description	*Inkil Rail-road Link*		
CS08	Long 9° 47' 47.77816"E	0.018	Adjusted
Lat 10° 18' 51.29963"N	0.020 Adjusted		
Ellips height	604.357 0.021	Adjusted	
Description	*Zaranda Junction*		
CS09	Long 9° 50' 46.76504"E	0.020	Adjusted
Lat 10° 18' 54.17086"N	0.020 Adjusted		
Ellips height	597.877 0.024	Adjusted	
Description	*Central round about*		
CS10	Long 9° 50' 48.87953"E	0.021	Adjusted
Lat 10° 17' 36.39754"N	0.021 Adjusted		
Ellips height	597.851 0.027	Adjusted	
Description	*Railway round about*		
CS11	Long 9° 49' 21.13513"E	0.087	Adjusted
Lat 10° 19' 16.70672"N	0.085 Adjusted		
Ellips height	591.061 0.117	Adjusted	
Description	*Eagle round about*		
CS55	Long 9° 49' 23.96941"E	0.008	Adjusted
Lat 10° 17' 24.92960"N	0.008 Adjusted		
Ellips height	629.972 0.012	Adjusted	
Description	*Wikki oil junction*		
FG44	Long 9° 51' 33.94973"E	0.096	Adjusted
Lat 10° 20' 58.65434"N	0.071 Adjusted		
Ellips height	628.098 0.101	Adjusted	
Description	*Gidadubu junction*		
FG45	Long 9° 51' 57.62722"E	0.066	Adjusted
Lat 10° 18' 47.72275"N	0.067 Adjusted		
Ellips height	626.238 0.085	Adjusted	
Description	*H/Assembly junction*		
TP02	Long 9° 49' 20.73397"E	0.006	Adjusted
Lat 10° 19' 14.60046"N	0.005 Adjusted		
Ellips height	639.761 0.008	Adjusted	
Description	*MAIDUGURI BYE PASS*		

Files

Name	Start Time	Sampling	Epochs	Size (Kb)	Type	
B1234A13.165	16/06/16	11:14	15	44	20	L1 GPS/WAAS
B1234B13.165	16/06/16	11:37	15	40	19	L1 GPS/WAAS
B1234C13.165	16/06/16	11:56	15	40	21	L1 GPS/WAAS
B1234D13.165	16/06/16	12:15	15	40	21	L1 GPS/WAAS
B1234E13.165	16/06/16	12:34	15	40	22	L1 GPS/WAAS
B1234F13.165	16/06/16	13:45	15	40	18	L1 GPS/WAAS
B1234G13.165	16/06/16	14:07	15	40	18	L1 GPS/WAAS
B1234H13.165	16/06/16	14:26	15	40	20	L1 GPS/WAAS
B1234I13.165	16/06/16	14:48	15	40	18	L1 GPS/WAAS
B1234J13.165	16/06/16	15:10	15	40	18	L1 GPS/WAAS
B1234K13.165	16/06/16	15:29	15	40	18	L1 GPS/WAAS
B1244A13.165	16/06/16	09:35	15	1492	730	L1 GPS/WAAS

Occupations

Site	Start Time	Timespan	TypeFile	
CS11	June 14 2016 11:14:15.00	00:12:15.00	Static	B1234A13.165
CS10	June 14 2016 11:37:00.00	00:09:45.00	Static	B1234B13.165
CS09	June 14 2016 11:56:00.00	00:09:45.00	Static	B1234C13.165
CS08	June 14 0216 12:15:45.00	00:09:45.00	Static	B1234D13.165
CS07	June 14 2016 12:34:45.00	00:09:45.00	Static	B1234E13.165
CS06	June 14 2016 13:45:30.00	00:09:45.00	Static	B1234F13.165
CS05	June 14 2016 14:07:30.00	00:09:45.00	Static	B1234G13.165
FG45	June 14 2016 14:26:15.00	00:09:45.00	Static	B1234H13.165
FG44	June 14 2016 14:48:15.00	00:09:45.00	Static	B1234I13.165
CS55	June 14 2016 15:10:00.00	00:09:45.00	Static	B1234J13.165
TP02	June 14 2016 15:29:30.00	00:09:45.00	Static	B1234K13.165
DN01	June 14 2016 09:35:15.00	01:39:00.00	Static	B1244A13.165
CS11~1	June 14 2016 11:14:15.00	00:22:45.00	Dynamic	B1244A13.165
CS10~1	June 14 2016 11:37:00.00	00:18:45.00	Dynamic	B1244A13.165
CS09~1	June 14 2016 11:55:45.00	00:20:00.00	Dynamic	B1244A13.165
CS08~1	June 14 2016 12:15:45.00	00:19:00.00	Dynamic	B1244A13.165
CS07~1	June 14 2016 12:34:45.00	01:10:45.00	Dynamic	B1244A13.165
CS06~1	June 14 2016 13:45:30.00	00:22:00.00	Dynamic	B1244A13.165

```
       CS05~1             June 14 2016 14:07:30.00    00:18:30.00  Dynamic
B1244A13.165
       FG45~1             June 14 2016 14:26:00.00    00:22:15.00  Dynamic
B1244A13.165
       FG44~1             June 14 2016 14:48:15.00    00:20:45.00  Dynamic
B1244A13.165
       CS55~1             June 14 2013 15:09:00.00    00:20:30.00  Dynamic
B1244A13.165
       TP02~1             June 14 2013 15:29:30.00    00:25:30.00  Dynamic
B1244A13.165
```

Processes

Reference	Reference File	Rover	Rover File	Mode	Num
B1244A13	B1244A13.165	TP02	B1234K13.165	Static	1
B1244A13	B1244A13.165	CS10	B1234B13.165	Static	2
B1244A13	B1244A13.165	CS09	B1234C13.165	Static	3
B1244A13	B1244A13.165	CS08	B1234D13.165	Static	4
B1244A13	B1244A13.165	CS07	B1234E13.165	Static	5
B1244A13	B1244A13.165	CS06	B1234F13.165	Static	6
B1244A13	B1244A13.165	CS05	B1234G13.165	Static	7
B1244A13	B1244A13.165	FG45	B1234H13.165	Static	8
B1244A13	B1244A13.165	FG44	B1234I13.165	Static	9
B1244A13	B1244A13.165	CS11	B1234A13.165	Static	10
B1244A13	B1244A13.165	CS55	B1234J13.165	Static	11

Processed vectors

Vector Identifier	Vector Length	95% Error		Vector Components	95% Error	SV	PDOP	QA	Solution
B1244A13 - CS55	7260.948431	0.023	X	-863.632	0.010	8	1.9		Fixed
13/06/14 15:10			Y	1396.359	0.009				
			Z	3375.380	0.009				
B1244A13 - CS11	5879.179355	0.240	X	-3224.982	0.106	10	1.6	**No**	Fixed
13/06/14 11:14			Y	9989.049	0.093				
			Z	7830.553	0.093				
B1244A13 - FG44	5574.117672	0.223	X	-1075.849	0.099	7	2.5	**No**	Fixed
13/06/14 14:48			Y	1819.705	0.100				
			Z	4115.209	0.069				
B1244A13 - FG45	7463.202475	0.181	X	-1372.099	0.076	8	1.8	**No**	Fixed
13/06/14 14:26			Y	2457.498	0.073				
			Z	5107.242	0.071				
B1244A13 - CS05	2812.708276	0.037	X	-1660.543	0.016	9	1.7		Fixed
13/06/14 14:07			Y	3725.457	0.015				
			Z	5467.890	0.014				
B1244A13 - CS06	2852.493354	0.039	X	-1806.148	0.017	9	1.8		Fixed
13/06/14 13:45			Y	4648.558	0.016				
			Z	5418.192	0.014				
B1244A13 - CS07	1179.513615	0.045	X	-2013.734	0.021	11	1.4		Fixed
13/06/14 12:34			Y	5838.564	0.018				
			Z	5378.700	0.016				
B1244A13 - CS08	2533.710272	0.048	X	-2253.354	0.020	9	1.7		Fixed
13/06/14 12:15			Y	7028.302	0.019				
			Z	5452.656	0.019				
B1244A13 - CS09	3650.778633	0.053	X	-2414.201	0.023	9	1.7		Fixed
13/06/14 11:56			Y	7664.172	0.021				
			Z	5686.400	0.019				
B1244A13 - CS10	3313.886837	0.057	X	-2706.403	0.024	9	1.7		Fixed
13/06/14 11:37			Y	8536.774	0.023				
			Z	6441.076	0.023				

B1244A13 - TP02	2469.146	0.016	X	-510.556	0.008	8	1.9
Fixed							
13/06/14 15:29			Y	495.414	0.006		
			Z	2364.441	0.005		

Adjusted vectors

Vector Identifier	Vector Length	Length Resid.	Components	Vector Resid.	Test	QA	Tau
B1244A13 - CS55	7260.948431	0.000	X	-863.632	0.000		
13/06/14 15:10			Y	1396.359	0.000		
			Z	3375.380	0.000		
B1244A13 - CS11	5879.179355	0.000	X	-3224.982	0.000		**No**
13/06/14 11:14			Y	9989.049	0.000		
			Z	7830.553	0.000		
B1244A13 - FG44	5574.117672	0.000	X	-1075.849	0.000		**No**
13/06/14 14:48			Y	1819.705	0.000		
			Z	4115.209	0.000		
B1244A13 - FG45	7463.202475	0.000	X	-1372.099	0.000		**No**
13/06/14 14:26			Y	2457.498	0.000		
			Z	5107.242	0.000		
B1244A13 - CS05	2812.708276	0.000	X	-1660.543	0.000		
13/06/14 14:07			Y	3725.457	0.000		
			Z	5467.890	0.000		
B1244A13 - CS06	2852.493354	0.000	X	-1806.148	0.000		
13/06/14 13:45			Y	4648.558	0.000		
			Z	5418.192	0.000		
B1244A13 - CS07	1179.513615	0.000	X	-2013.734	0.000		
13/06/14 12:34			Y	5838.564	0.000		
			Z	5378.700	0.000		
B1244A13 - CS08	2533.71027	0.000	X	-2253.354	0.000		
13/06/14 12:15			Y	7028.302	0.000		
			Z	5452.656	0.000		
B1244A13 - CS09	3650.77863	0.000	X	-2414.201	0.000		
13/06/14 11:56			Y	7664.172	0.000		
			Z	5686.400	0.000		
B1244A13 - CS10	3313.886837	0.000	X	-2706.403	0.000		
13/06/14 11:37			Y	8536.774	0.000		
			Z	6441.076	0.000		
B1244A13 - TP02	2469.146	0.000	X	-510.556	0.000		
13/06/14 15:29			Y	495.414	0.000		
			Z	2364.441	0.000		

APPENDIX III

WATER UTILITY SHAPE FILES

PIPELINES

FID	Shape *	Length(m)	Diameter(mm)	Pipe num	Class
0	Polyline	1737	150	P1	0
1	Polyline	207	150	P2	0
2	Polyline	2878	150	P3	0
3	Polyline	324	150	P4	0
4	Polyline	173	150	P5	0
5	Polyline	396	150	P6	0
6	Polyline	869	150	P7	0
7	Polyline	520	150	P8	0
8	Polyline	420	150	P9	0
9	Polyline	389	150	P10	0
10	Polyline	311	150	P11	0
11	Polyline	239	150	P12	0
12	Polyline	2915	800	P13	3
13	Polyline	516	800	P14	3
14	Polyline	2081	100	P15	0
15	Polyline	515	800	P16	3
16	Polyline	1117	150	P17	0
17	Polyline	768	150	P18	0
18	Polyline	393	150	P19	0
19	Polyline	387	150	P20	0
20	Polyline	2083	150	P21	0
21	Polyline	855	100	P22	0
22	Polyline	2034	100	P23	0
23	Polyline	1815	800	P24	3
24	Polyline	1253	800	P25	3
25	Polyline	776	300	P26	1
26	Polyline	760	300	P27	1
27	Polyline	1714	500	P28	2
28	Polyline	981	500	P30	2
29	Polyline	801	500	P31	2
30	Polyline	6295	200	P32	1
31	Polyline	851	300	P33	1
32	Polyline	321	300	P34	1
33	Polyline	403	300	P35	1
34	Polyline	323	300	P36	1
35	Polyline	113	300	P37	1
36	Polyline	440	300	P38	1
37	Polyline	96	300	P39	1
38	Polyline	1244	100	P40	0
39	Polyline	936	100	P41	0

40	Polyline	1666	100	P42	0
41	Polyline	1421	150	P43	0
42	Polyline	1214	150	P44	0
43	Polyline	634	150	P45	0
44	Polyline	655	150	P46	0
45	Polyline	557	800	P47	3
46	Polyline	1323	150	P48	0
47	Polyline	480	150	P49	0
48	Polyline	691	200	P50	1
49	Polyline	1857	200	P51	1
50	Polyline	1213	300	P52	1
51	Polyline	2046	300	P53	1
52	Polyline	1330	150	P54	0
53	Polyline	551	150	P55	0
54	Polyline	2916	150	P56	0
55	Polyline	1015	150	P57	0
56	Polyline	632	150	P58	0
57	Polyline	1507	150	P59	0
58	Polyline	479	100	P60	0
59	Polyline	883	200	P61	1
60	Polyline	1512	500	P62	2
61	Polyline	1055	400	P63	2
62	Polyline	1386	300	P64	1
63	Polyline	976	150	P65	0
64	Polyline	540	150	P66	0
65	Polyline	1841	150	P67	0
66	Polyline	963	150	P68	0
67	Polyline	971	150	P69	0
68	Polyline	2084	200	P70	1
69	Polyline	1252	150	P72	0
70	Polyline	121	150	P73	0
71	Polyline	579	400	P74	2
72	Polyline	2085	400	P75	2
73	Polyline	4680	200	P76	1
74	Polyline	2293	200	P77	1
75	Polyline	915	400	P78	2
76	Polyline	1437	300	P79	1
77	Polyline	687	150	P80	0
78	Polyline	594	150	P82	0
79	Polyline	1653	400	P84	2
80	Polyline	1789	100	P85	0
81	Polyline	1130	150	P86	0
82	Polyline	630	100	P88	0
83	Polyline	645	100	P89	0
84	Polyline	3311	200	P90	1
85	Polyline	1298	200	P91	1
86	Polyline	718	100	P92	0
87	Polyline	811	200	P93	1

88	Polyline	1297	400	P94	2
89	Polyline	2401	300	P95	1
90	Polyline	749	150	P96	0
91	Polyline	981	150	P97	0
92	Polyline	782	400	P98	2
93	Polyline	104	300	P99	1
94	Polyline	682	300	P100	1
95	Polyline	106	300	P101	1
96	Polyline	1319	300	P102	1
97	Polyline	972	300	P103	1
98	Polyline	1366	300	P104	1
99	Polyline	1579	100	P105	0
100	Polyline	2296	500	P106	2
101	Polyline	1183	100	P108	0
102	Polyline	1809	100	P109	0
103	Polyline	665	100	P110	0
104	Polyline	504	100	P111	0
105	Polyline	882	100	P112	0
106	Polyline	1254	800	P113	3
107	Polyline	389	300	P115	1
108	Polyline	380	300	P116	1
109	Polyline	337	300	P117	1
110	Polyline	249	300	P118	1
111	Polyline	231	300	P119	1
112	Polyline	230	300	P120	1
113	Polyline	238	300	P121	1
114	Polyline	156	300	P123	1
115	Polyline	248	300	P124	1
116	Polyline	498	800	P125	3
117	Polyline	1770	300	P128	1
118	Polyline	1215	100	P132	0
119	Polyline	175	100	P133	0
120	Polyline	1321	200	P134	1
121	Polyline	1335	300	P135	1
122	Polyline	545	100	P136	0
123	Polyline	800	100	P137	0
124	Polyline	659	100	P138	0
125	Polyline	710	150	P139	0
126	Polyline	666	100	P140	0
127	Polyline	583	500	P141	2
128	Polyline	802	100	P142	0
129	Polyline	575	100	P143	0
130	Polyline	484	100	P144	0
131	Polyline	672	100	P145	0
132	Polyline	8484	500	P146	2
133	Polyline	1413	150	P147	0
134	Polyline	460	150	P148	0
135	Polyline	493	150	P149	0

136	Polyline	2714	150	P150	0
137	Polyline	1044	150	P151	0
138	Polyline	589	150	P153	0
139	Polyline	782	150	P154	0
140	Polyline	103	150	P155	0
141	Polyline	682	150	P156	0
142	Polyline	1924	150	P157	0
143	Polyline	1961	150	P158	0
144	Polyline	2150	150	P159	0
145	Polyline	1575	150	P160	0
146	Polyline	443	150	P161	0
147	Polyline	172	150	P162	0
148	Polyline	701	150	P163	0
149	Polyline	234	150	P164	0
150	Polyline	395	150	P165	0
151	Polyline	512	150	P166	0
152	Polyline	470	150	P167	0
153	Polyline	297	150	P168	0
154	Polyline	803	150	P169	0
155	Polyline	2226	150	P170	0
156	Polyline	358	150	P171	0
157	Polyline	871	150	P172	0
158	Polyline	947	150	P173	0
159	Polyline	91	200	P175	1
160	Polyline	239	150	P176	0
161	Polyline	100	200	P177	1
162	Polyline	177	200	P178	1
163	Polyline	1044	200	P179	1
164	Polyline	1306	100	P180	0
165	Polyline	5036	800	P181	3
166	Polyline	1009	150	P182	0
167	Polyline	1871	150	P183	0
168	Polyline	1380	150	P184	0
169	Polyline	819	150	P185	0
170	Polyline	1192	100	P186	0
171	Polyline	186	100	P187	0

HYDRANTS

FID	Shape *	Id	Hydrant num	Eastings	Northings
0	Point	0	H1	1079768	1156574
1	Point	0	H2	1080043	1156451
2	Point	0	H3	1083630	1156863
3	Point	0	H4	1084371	1155931
4	Point	0	H5	1084813	1157680
5	Point	0	H6	1084951	1157635
6	Point	0	H7	1083540	1157456
7	Point	0	H8	1083104	1157328
8	Point	0	H9	1081844	1157705
9	Point	0	H10	1082003	1158333
10	Point	0	H11	1081740	1159133
11	Point	0	H12	1087529	1157883

CHAMBERS

FID	Shape *	Id	Chamber num	Eastings	Northings
0	Point	0	C1	1082459	1159160
1	Point	0	C2	1083359	1159913
2	Point	0	C3	1083391	1159724
3	Point	0	C4	1084621	1159332
4	Point	0	C5	1084426	1158979
5	Point	0	C6	1084335	1158544
6	Point	0	C7	1084764	1156983
7	Point	0	C8	1083286	1156902
8	Point	0	C9	1083209	1156945
9	Point	0	C10	1083412	1157020
10	Point	0	C11	1083601	1157642
11	Point	0	C12	1082395	1158840
12	Point	0	C13	1083444	1156187
13	Point	0	C14	1084047	1155520
14	Point	0	C15	1083790	1155279
15	Point	0	C16	1083639	1155189
16	Point	0	C17	1083603	1155108
17	Point	0	C18	1082270	1154509
18	Point	0	C19	1084436	1158232
19	Point	0	C20	1084512	1157926
20	Point	0	C21	1083753	1156246

21	Point	0	C22	1084556	1157765
22	Point	0	C23	1084434	1158460
23	Point	0	C24	1084418	1161418
24	Point	0	C25	1081719	1156669
25	Point	0	C26	1083504	1156989
26	Point	0	C27	1083256	1156932
27	Point	0	C28	1083316	1157042
28	Point	0	C29	1081585	1156461
29	Point	0	C30	1080956	1158196
30	Point	0	C31	1082093	1157931
31	Point	0	C32	1082013	1157727
32	Point	0	C33	1083602	1157768
33	Point	0	C34	1083600	1157622
34	Point	0	C35	1084463	1157849
35	Point	0	C36	1084436	1158239
36	Point	0	C37	1084439	1157917
37	Point	0	C38	1084436	1158239
38	Point	0	C39	1084511	1157723

NODES

FID	Shape *	Id	Node num	Eastings	Northings
0	Point	0	N1	1083377	1161958
1	Point	0	N2	1083759	1162006
2	Point	0	N3	1084095	1162045
3	Point	0	N4	1084017	1162163
4	Point	0	N5	1083117	1162211
5	Point	0	N6	1083342	1162237
6	Point	0	N7	1083162	1161926
7	Point	0	N8	1083565	1162254
8	Point	0	N9	1083745	1162266
9	Point	0	N10	1084082	1162290
10	Point	0	N11	1083597	1161985
11	Point	0	N12	1084858	1161646
12	Point	0	N13	1085424	1161627
13	Point	0	N14	1084864	1161413
14	Point	0	N15	1084718	1161142
15	Point	0	N16	1084724	1161066
16	Point	0	N17	1085028	1160675
17	Point	0	N18	1086033	1161391
18	Point	0	N19	1086031	1161154
19	Point	0	N20	1086031	1161049
20	Point	0	N21	1086037	1160660

21	Point	0	N22	1085356	1160175
22	Point	0	N23	1083520	1160919
23	Point	0	N24	1083578	1160735
24	Point	0	N25	1083716	1160301
25	Point	0	N26	1084561	1161060
26	Point	0	N27	1083787	1160047
27	Point	0	N28	1085025	1159339
28	Point	0	N29	1084867	1159150
29	Point	0	N30	1084400	1159022
30	Point	0	N31	1083649	1159484
31	Point	0	N32	1083652	1157851
32	Point	0	N33	1084419	1157778
33	Point	0	N34	1085708	1157378
34	Point	0	N35	1087200	1157218
35	Point	0	N36	1087672	1157271
36	Point	0	N37	1087522	1157882
37	Point	0	N38	1084764	1157027
38	Point	0	N39	1084088	1156757
39	Point	0	N40	1084256	1156131
40	Point	0	N41	1084530	1155965
41	Point	0	N42	1083658	1155147
42	Point	0	N43	1083532	1154966
43	Point	0	N44	1084056	1154409
44	Point	0	N45	1085061	1155073
45	Point	0	N46	1085470	1154514
46	Point	0	N47	1083608	1152749
47	Point	0	N48	1084287	1153032
48	Point	0	N49	1084035	1152932
49	Point	0	N50	1084189	1152524
50	Point	0	N51	1083855	1152396
51	Point	0	N52	1084443	1152626
52	Point	0	N53	1084524	1152420
53	Point	0	N54	1084650	1152084
54	Point	0	N55	1085277	1153655
55	Point	0	N56	1082301	1153829
56	Point	0	N57	1082236	1154509
57	Point	0	N58	1082823	1154732
58	Point	0	N59	1082797	1154849
59	Point	0	N60	1084453	1153404
60	Point	0	N61	1085772	1152648
61	Point	0	N62	1079068	1155424
62	Point	0	N63	1080619	1153936
63	Point	0	N64	1078807	1154572

64	Point	0	N65	1077508	1154804
65	Point	0	N66	1077072	1155123
66	Point	0	N67	1077314	1155334
67	Point	0	N68	1077331	1156000
68	Point	0	N69	1076690	1156561
69	Point	0	N70	1077088	1156742
70	Point	0	N71	1078170	1156656
71	Point	0	N72	1079997	1157511
72	Point	0	N73	1081351	1156978
73	Point	0	N74	1081912	1157265
74	Point	0	N75	1081094	1158077
75	Point	0	N76	1081388	1158710
76	Point	0	N77	1081080	1158343
77	Point	0	N78	1083474	1157506
78	Point	0	N79	1083531	1158368
79	Point	0	N80	1082348	1158697
80	Point	0	N81	1081830	1158844
81	Point	0	N82	1081780	1158109
82	Point	0	N83	1077087	1157186
83	Point	0	N84	1076047	1156970
84	Point	0	N85	1076266	1156019
85	Point	0	N86	1084580	1160152
86	Point	0	N87	1084440	1160365
87	Point	0	N88	1076794	1156649
88	Point	0	N89	1079023	1156132
89	Point	0	N90	1079572	1156571
90	Point	0	N91	1079450	1156303
91	Point	0	N92	1083368	1154123
92	Point	0	N93	1081684	1156460
93	Point	0	N94	1082791	1156747
94	Point	0	N95	1082107	1156542
95	Point	0	N96	1081186	1157603
96	Point	0	N97	1081541	1157661
97	Point	0	N98	1082145	1157756
98	Point	0	N99	1080992	1156410
99	Point	0	N100	1083829	1156141
100	Point	0	N101	1084053	1155498
101	Point	0	N102	1083446	1156219
102	Point	0	N103	1084559	1157005
103	Point	0	N104	1084001	1157083
104	Point	0	N105	1084607	1157449
105	Point	0	N106	1084309	1158977
106	Point	0	N107	1083966	1161363

107	Point	0	N108	1082681	1161794
108	Point	0	N109	1083504	1159045
109	Point	0	N110	1083962	1157723
110	Point	0	N111	1077868	1155579
111	Point	0	N112	1077341	1156754
112	Point	0	N113	1077697	1156761
113	Point	0	N114	1082458	1157775
114	Point	0	N115	1081494	1158602
115	Point	0	N116	1082084	1157857
116	Point	0	N117	1082013	1157727
117	Point	0	N118	1084384	1158612
118	Point	0	N119	1083345	1156888
119	Point	0	N120	1080909	1158140
120	Point	0	N121	1081644	1156464
121	Point	0	N122	1079615	1156644

VALVES

FID	Shape *	Id	Valve num	Eastings	Northings
0	Point	0	V1	1083161	1161938
1	Point	0	V2	1083374	1161983
2	Point	0	V3	1083746	1162258
3	Point	0	V4	1083765	1161983
4	Point	0	V5	1084068	1162041
5	Point	0	V6	1084092	1162175
6	Point	0	V7	1084238	1162194
7	Point	0	V8	1084577	1161940
8	Point	0	V9	1084300	1161783
9	Point	0	V10	1084435	1161601
10	Point	0	V11	1084273	1161636
11	Point	0	V12	1083854	1161698
12	Point	0	V13	1083964	1161403
13	Point	0	V14	1082721	1161802
14	Point	0	V15	1083594	1162010
15	Point	0	V16	1084171	1161908
16	Point	0	V17	1082872	1160975
17	Point	0	V18	1082874	1161068
18	Point	0	V19	1083206	1161081
19	Point	0	V20	1084533	1160872
20	Point	0	V21	1083983	1160840
21	Point	0	V22	1083736	1160305

22	Point	0	V23	1084182	1160160
23	Point	0	V24	1084326	1159674
24	Point	0	V25	1083700	1159489
25	Point	0	V26	1083450	1159412
26	Point	0	V27	1083453	1159034
27	Point	0	V28	1083482	1158813
28	Point	0	V29	1083140	1158599
29	Point	0	V30	1083021	1157881
30	Point	0	V31	1082465	1157819
31	Point	0	V32	1082124	1157751
32	Point	0	V33	1082093	1157931
33	Point	0	V34	1081742	1158111
34	Point	0	V35	1081354	1158392
35	Point	0	V36	1081722	1159137
36	Point	0	V37	1081816	1159078
37	Point	0	V38	1081947	1158993
38	Point	0	V39	1082456	1159104
39	Point	0	V40	1082458	1159144
40	Point	0	V41	1082456	1159068
41	Point	0	V42	1080986	1156499
42	Point	0	V43	1082186	1156569
43	Point	0	V44	1084544	1157769
44	Point	0	V45	1085378	1157492
45	Point	0	V6	1085704	1157359
46	Point	0	V47	1087201	1157263
47	Point	0	V48	1087744	1157218
48	Point	0	V49	1084940	1157050
49	Point	0	V50	1084733	1157023
50	Point	0	V51	1084810	1157032
51	Point	0	V52	1083475	1156242
52	Point	0	V53	1084215	1157232
53	Point	0	V54	1084330	1157322
54	Point	0	V55	1083944	1157570
55	Point	0	V56	1083649	1157491
56	Point	0	V57	1084077	1158339
57	Point	0	V58	1084317	1158570
58	Point	0	V59	1084375	1158655
59	Point	0	V60	1084306	1159026
60	Point	0	V61	1084388	1159387
61	Point	0	V62	1083818	1160055
62	Point	0	V63	1082545	1159897
63	Point	0	V64	1082405	1160016
64	Point	0	V65	1082483	1160308

65	Point	0	V66	1082781	1160696
66	Point	0	V67	1081719	1156669
67	Point	0	V68	1084407	1152606
68	Point	0	V69	1084609	1152433
69	Point	0	V70	1085504	1152753
70	Point	0	V71	1084497	1153413
71	Point	0	V72	1084165	1153604
72	Point	0	V73	1084796	1153509
73	Point	0	V74	1085241	1153639
74	Point	0	V75	1085297	1153600
75	Point	0	V76	1085402	1153176
76	Point	0	V77	1082340	1153834
77	Point	0	V78	1082605	1153882
78	Point	0	V79	1082193	1154505
79	Point	0	V80	1082420	1153909
80	Point	0	V81	1082816	1154565
81	Point	0	V82	1084005	1154387
82	Point	0	V83	1084125	1154433
83	Point	0	V84	1084556	1154159
84	Point	0	V85	1084241	1153990
85	Point	0	V86	1084948	1155034
86	Point	0	V87	1081182	1157522
87	Point	0	V88	1081312	1156932
88	Point	0	V89	1081769	1156815
89	Point	0	V90	1080552	1158103
90	Point	0	V91	1079643	1157527
91	Point	0	V92	1079542	1156584
92	Point	0	V93	1079652	1156696
93	Point	0	V94	1077700	1156802
94	Point	0	V95	1077340	1156690
95	Point	0	V96	1077058	1156741
96	Point	0	V97	1076742	1156605
97	Point	0	V98	1076973	1156591
98	Point	0	V99	1076062	1156920
99	Point	0	V100	1075996	1156966
100	Point	0	V101	1082842	1154694
101	Point	0	V102	1084661	1160080
102	Point	0	V103	1085319	1160139
103	Point	0	V104	1085364	1160209
104	Point	0	V105	1085249	1160401
105	Point	0	V106	1085132	1160527
106	Point	0	V107	1085066	1160629
107	Point	0	V108	1085255	1160866

108	Point	0	V109	1085070	1160697
109	Point	0	V110	1085969	1161041
110	Point	0	V111	1085620	1161048
111	Point	0	V112	1085519	1161020
112	Point	0	V113	1086036	1161357
113	Point	0	V114	1085378	1161421

PLATES



Plate I: Gubi dam water intake point

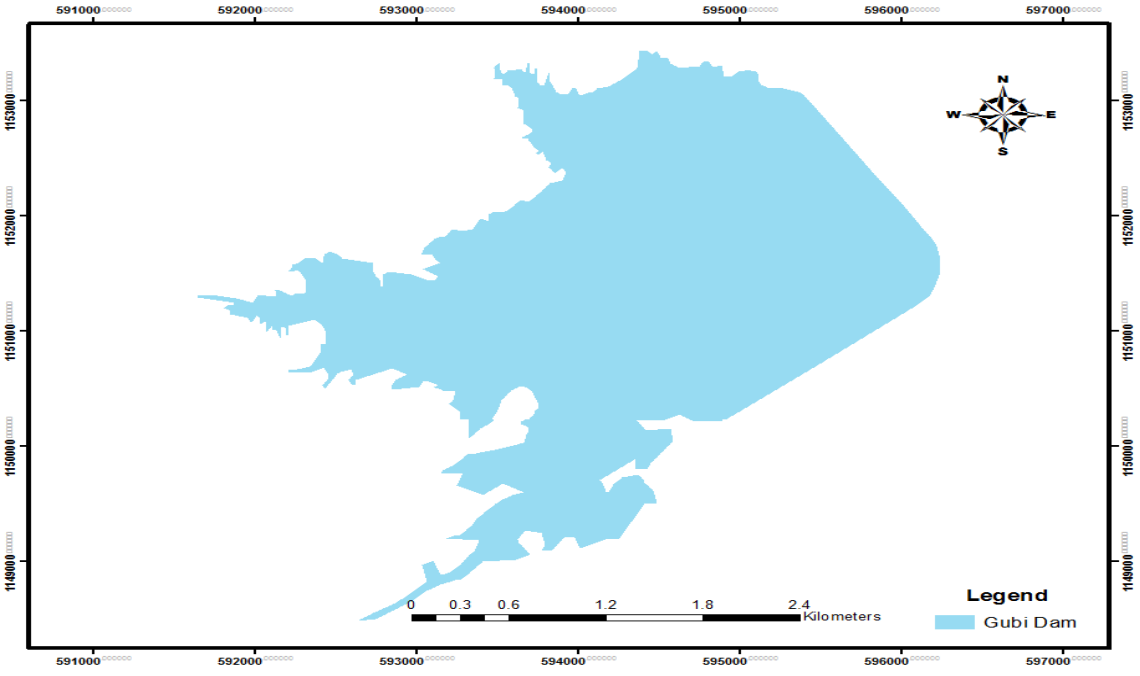


Plate II: The Gubi Dam

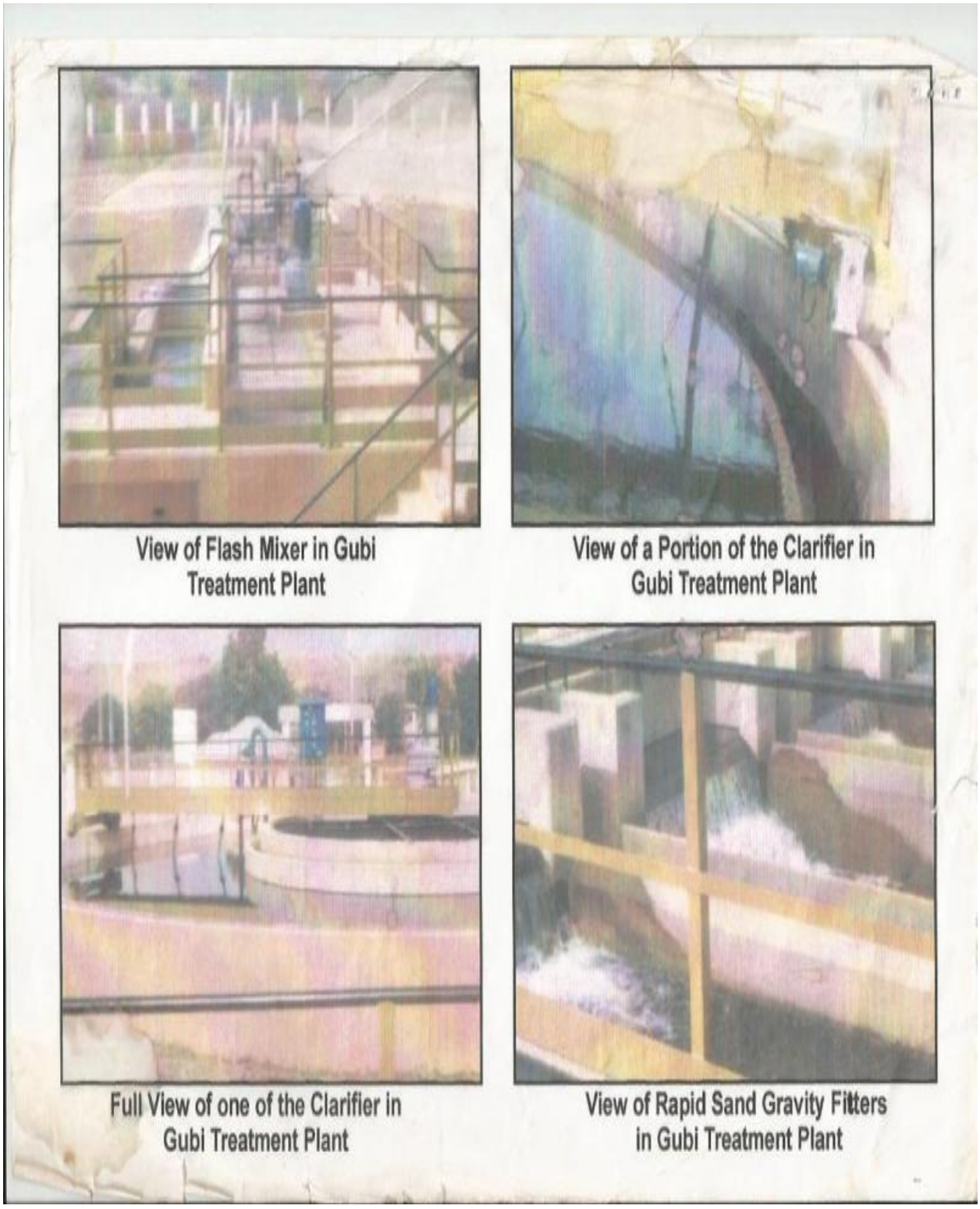


Plate III: View of some water treatment machineries at Gubi dam