

Analysis of Spatial Water Distribution Networks in Abuja Municipal Area Council, Federal Capital Territory, Abuja, Nigeria

Muhammad, S. A.¹, Sangari, D. U¹ and Adamu, T. O¹

¹Department of Geography, Nasarawa State University, Keffi, Nasarawa State.

Corresponding author's e-mail: muhd_alhassan2011@yahoo.com

ABSTRACT

Water infrastructure development is key to attaining sustainable development especially water supply, sanitation and health, agricultural development and energy production. Water supply and distribution system serves critical function and play large part in achieving human and economic health. Spatial distribution of water network in Abuja Municipal Area Council (AMAC) of the Federal Capital Territory, Abuja, Nigeria was assessed with the aim of analyzing the existing water distribution network. Four multi-date Landsat imageries; TM of 1990 and ETM+ of 2000, 2010 and OLI of 2020 at 30m resolution were utilized to identify the spatio-temporal changes. Baseline data on existing water distribution network was utilized to map water distribution network over the study period. Results indicated that there were dense and substantial existing spatial water distributing network in AMAC. This was attributed to the planned nature of the study area that takes cognizance of every needed resource and infrastructure. The water distribution network matched the land use changes over time and space because of the planned nature of the study area. The increasing failure of public water distribution (supply versus demand) necessitate greater percentage of the population to rely more on alternative water sources such as boreholes and water tanker vendors. Conclusively, urban water systems must include not only the reservoirs, groundwater wells, and aqueducts that are the sources of water supplies needed to meet the varied demands in an urban area, but also the water treatment plants, the water distribution systems that transport that water, together with the pressures required, to where the demands are located to ensure efficient water supply through the network. Continuous monitoring and evaluation of existing water networks is recommended and that planners and decision makers should take cognizance of future development pattern and make provisions for expansion.

Keywords: Water, Network, Pipeline, Distribution, Landsat

1. INTRODUCTION

Water is a finite resource and one of the most vital commodities for survival of all living things on earth, (Alkali et al, 2017). Water serves as a basic need with a wide range of valuable purposes that can never be substituted in domestic use, commercial, agriculture, navigation, recreation and construction amongst others. This precedes the notion of it being finite, as it varies spatially and greatly with time and quantity on the earth. The total

supplies of fresh water on earth far exceed human demand (Ortuña, 2010)

Water supply is largely dependent on demand by consumers (Bandyopadhyay, 2016). Thus, population projections are essential in determining how much water needs to be abstracted, treated and distributed for its different purposes in a given location (Berardi et al., 2015). However, the greatest paradox of all times in the establishment of efficient water supply system is the capacity failure to meet the

needs of the ever-growing population. Increase in population and industrialisation is directly proportional to the rise in potable water demand (Ahmadi *et al.*, 2020). For decision makers, it is very important to plan for effective and adequate delivery of potable water to cities. Whereas, network operators are very critical in managing and maintaining an efficient distribution system that will optimally supply water to populations with zero or less losses and malfunctions (Van den berg, 2015).

Water distribution system as one of those underground infrastructure systems is coexisting with human societies for around two millennia years, since the Minoans constructed the first piped water conveyance system. Today water distribution system is capable of serving communities and industry water consumption reliably, efficiently and safely. A water supply network is a system of engineered hydrologic and hydraulic components (Wallingford, 2003). They include water resources, pumps, treatment plants, tanks, water towers, pipes, fittings, fire hydrants, valves, and other equipments for management and maintenance. Undoubtedly components are different in every distribution system; meanwhile size and complexity of water distribution systems vary dramatically. However, all water distribution networks have a same basic purpose- to deliver water from sources to customers. In short, a water supply system has two primary requirements. Firstly, it needs to deliver adequate amounts of water to meet consumption requirements plus needed free flow requirements. Secondly, the water system needs to be reliable; the required amount of water needs to be available 24 hours a day.

Water is vital for man's existence and without it; there would be no life on earth. As a resource to any nation, it should be well planned, developed, conserved, distributed and managed. Its infrastructure should be properly maintained to avoid future water problems. While failure events are likely inevitable and often dramatic and costly, the day-to-day inefficient performance of a water distribution system (WDS) also entails great economic, social and environmental burdens.

Because of significant development of urbanized areas and construction of thousands of small and large-scale water supply and distribution systems in recent decades, many

people have access to clean water and adequate sanitation. However, the quality of service which is provided by water utilities is often questionable and the cost of new systems is still often prohibitive.

There are poor quality water distribution networks all over the world and the situation is becoming worse and worse due to inefficient design, poor construction work, improper or unqualified material, improper bedding, aged pipelines, poor network management and maintenance, surrounding environment and breaks from unexpected elements, for example damages from nearby underground constructions. Abuja being a growing city is not immune from these water distribution challenges and thus, this paper assesses the spatial distribution of water network in Federal Capital Territory, Abuja, Nigeria with a view to identify operational challenges and suggest appropriate measures.

2. MATERIALS AND METHODS

2.1 The Study Area

Abuja Municipal Area Council (AMAC) is the largest and most developed of the six area councils, while Kuje Area Council falls within the semi-urban settlement location of the Federal Capital Territory. The bulk of the built-up area of AMAC is made up of the Federal Capital City (FCC). The FCC has five main districts, namely Asokoro, Maitama, Garki, Wuse, and Central Area and other newly developed districts Apo, Gaduwa, Gudu, Lokugoma, Kaura, Durumi, Katampe, Gwarimpa, (Okobia, 2011), other districts such as Kagini, Karsana, Karmo, etc, has shown recent developmental growth in the FCC.

Figure 1 gives the boundary location of the study areas. AMAC is located between latitude 8° 40' 1" and 9° 20' 1" north of the equator and longitude 6° 40' 1" and 7° 40' 1" east of the Greenwich meridian. The Abuja FCT has a land mass of approximately 8000 sq km of which the FCC occupies about 250 sq km with population recent census at 778,567 for Abuja Municipal Area Council (Federal Republic of Nigeria Official Gazette, 2007).

Climate

The climate of the Abuja Municipal Area Council is quite similar to that of the Territory; it is the hot, humid, and tropical type. It is such that its major elements have regimes that are transitional from those of the Southern and the

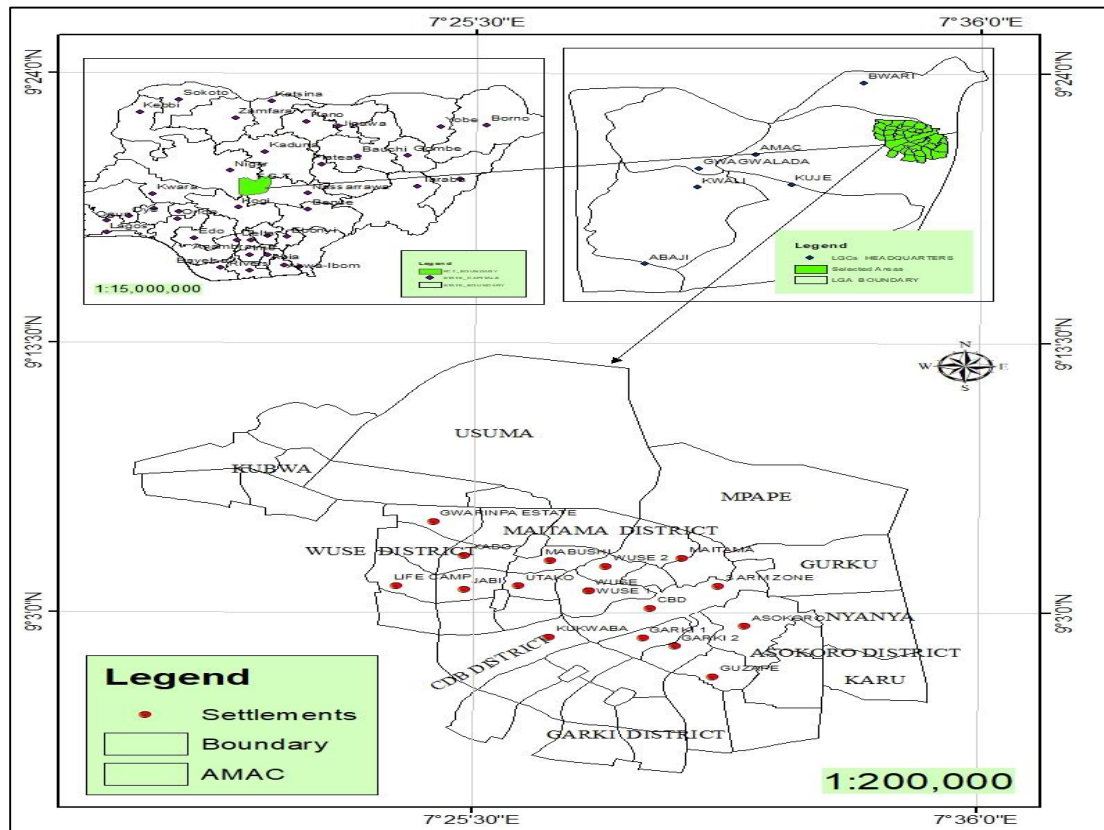


Figure 1: The Study Area - The Abuja Municipal Area Council (AMAC), Abuja, Nigeria

Northern parts of the country. It has temperatures ranging from 210C – 26.70C yearly and a total annual rainfall of approximately 1,650 mm. About 60% of the annual rains fall during the month of July, August and September, Nigeria Metrological Agency (NIMET, 2010). A crucial climatic characteristic of this area is the frequent occurrence of squall lines heralded by thunder storms, lightening, strong winds and rainfall of high intensity (Hassan, 2008).

2.2 Data used

Baseline data on existing water distribution network was utilized to map water distribution network in the districts of Maitama, Wuse, Garki, Central Business District and Asokoro. The water utility base maps of the study area were scanned and imported into ArcGIS environment for further processes.

ArcGIS 10.3 software was used to convert the scanned Water Utility Map (WUM) into vector entities by first geo-referencing the map with coordinates of points taken from the field with the GPS. In other words, the image was registered to Universal Traverse Mercator (UTM). ArcGIS software is preferred because it is embedded with image processing

extension, a module used in viewing and processing image stored in (tiff) format.

2.3 Data Analysis

All the water distribution features on the map such as pipelines, valves, reservoirs, etc. were digitized on screen. A geo-database file was created in ArcCatalog and the feature class (containing the features) was created. The pipes were represented as lines, the reservoirs as polygon while other features such as sluice valves, wash outs, water points, air valves, reducers etc. as points. The Markov-cellular Automata (CA) was used to project land use evolution from GIS/Remotely sensed data with respect to a transition probabilities matrix and a transition area matrix. Projections of land use were carried out up to the year 2040 using a short time (2010-2020) and long time (2020-2040) trajectory.

3.0. RESULTS AND DISCUSSION

The water distribution network map of each of the Five (5) districts that make up the Abuja Municipal Area Council (AMAC) were identified and presented. Figure 2 shows the Asokoro district in AMAC. It is one of the districts in phase one of the development phases of the Federal Capital City. It shows that there were six water pipe junctions, one booster

station and one pump station which supply water to the district. The Asokoro district is highbrow area in the Federal Capital City (FCC) and of low population density, however, because of its unique status of housing top echelon of the society, water distribution network in this district appear to be efficient and effective.

Figure 3 shows the water distribution network in the Central Business District. It indicates the existence of one booster station which enables the supply of water to the area. The area is transverse by the major water pipe which is the

main source of water to other minor distribution network.

Figure 4 shows the water distribution network for Garki district. The district has two booster stations and eight junctions which accelerate the distribution of water. The distribution channels are interconnected with one another and linked to the major water pipe. A pump station is to be found at the northern part of the district that supply water to the major water pipe for onward distribution to other channels.

Figure 5 shows the water distribution network in Maitama. The district has three junctions and

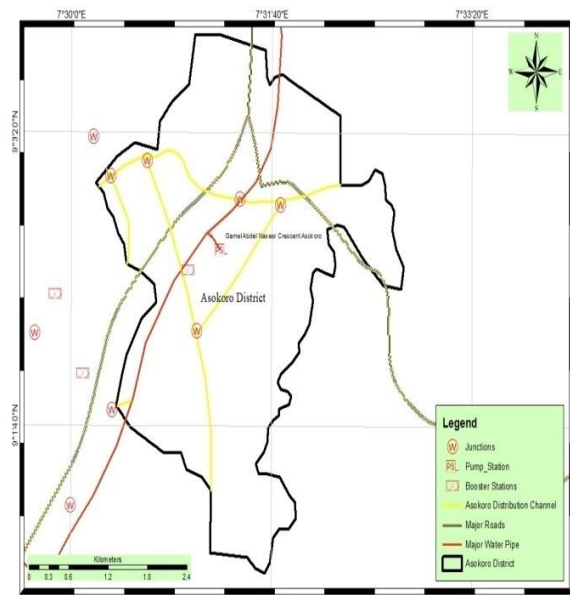


Figure 2: Water Distribution Network in Asokoro District

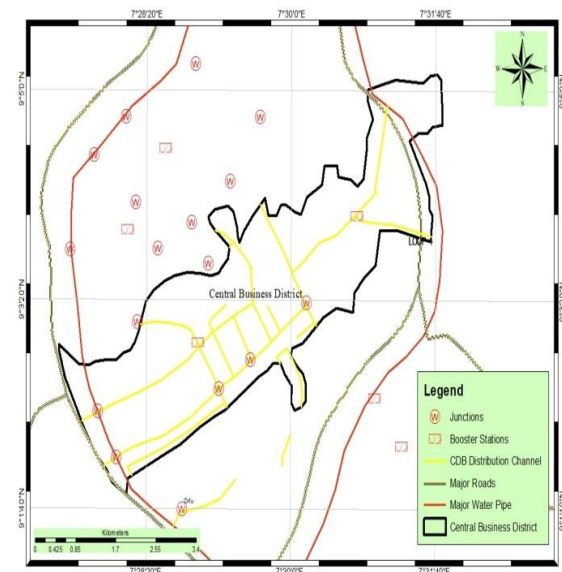


Figure 3: Water Distribution Network in Central Business District (CBD)

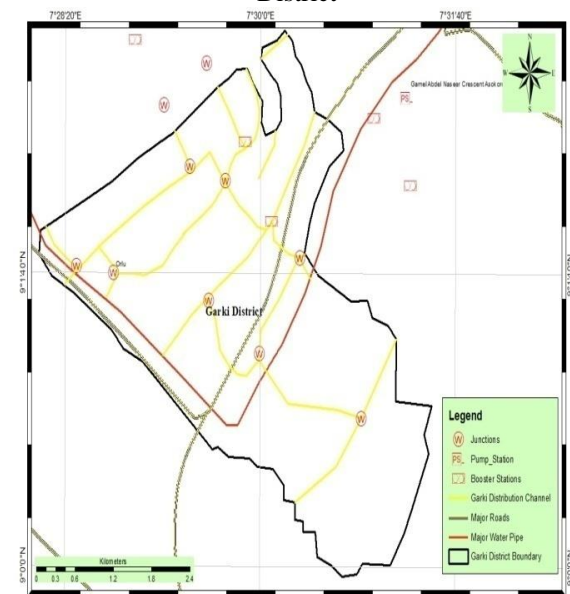


Figure 4: Water Distribution Network in Garki District

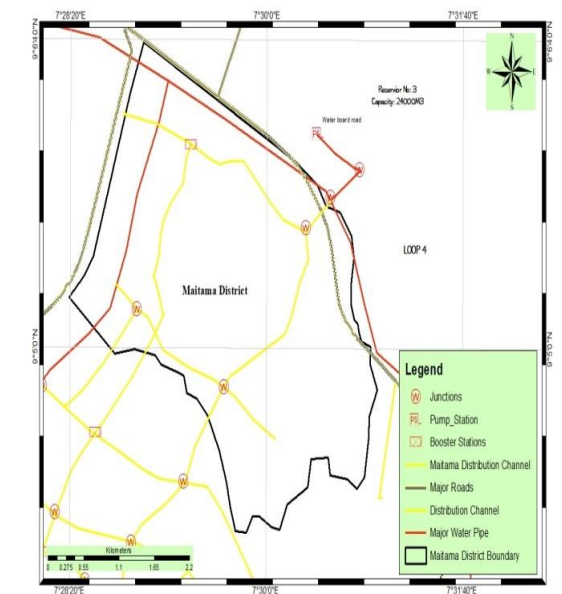


Figure 5: Water Distribution Network in Maitama District

one booster station that help in the distribution of water. There is a pump station outside the station that supplies water to the main water pipe which supplies water to Maitama water distribution channel.

Figure 6 shows the water distribution network in Wuse district. The district has nine junctions, two booster station and one loop that help in the distribution of water. Main water pipe cut-

across the district which supply water to Wuse water distribution channel. The district shows that the pipes are well interconnected to supply sufficient water to the area.

Figure 7 shows the combined water distribution network across the study area. Results indicate that there is a reservoir in Asokoro and beside Maitama District which are the main source of water supply to the district. There is also a loop

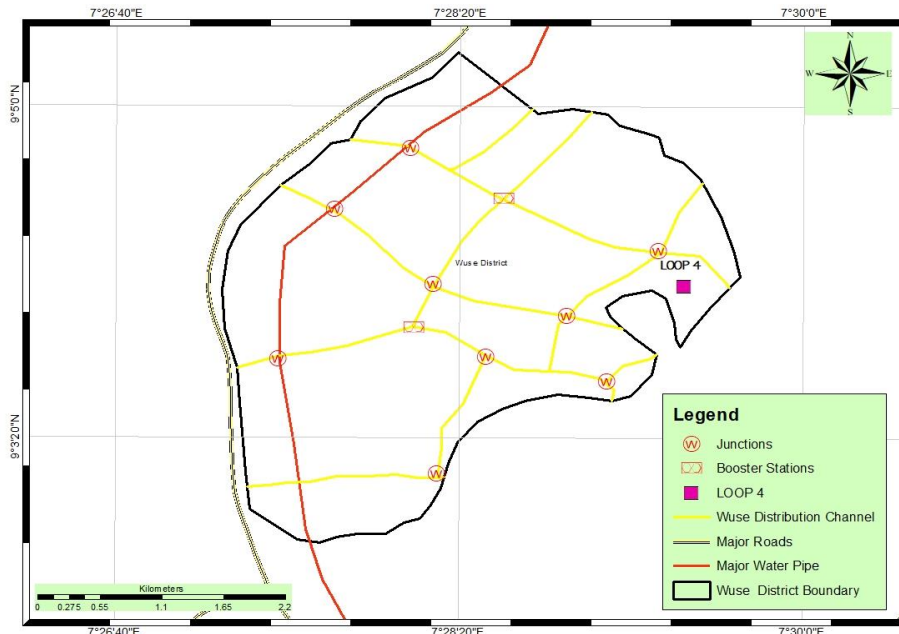


Figure 6: Water Distribution Network in Wuse District

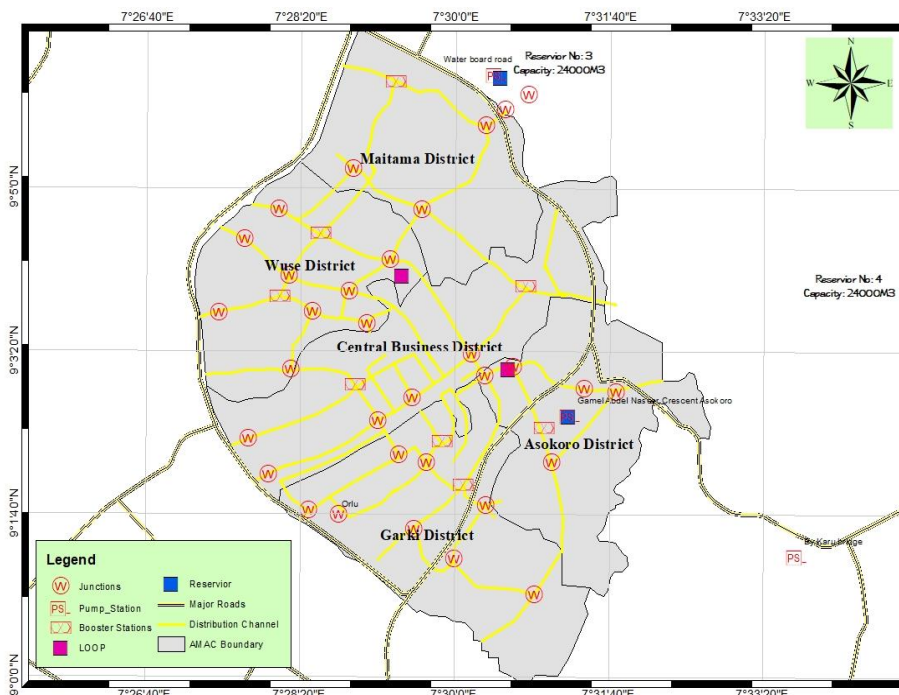


Figure 7: Existing Water distribution network in AMAC.

at Wuse and Asokoro respectively while there are several boosters, pump stations and junctions.

Table 1 shows Water Supply to Areas by Existing Pipe Water supply system. It indicates the supply on Phase by Phase basis in the Federal Capital City. FCT Water Board do supply treated bulk water from Lower Usman Dam water treatment plants through four transmission mains to major tanks covering water supply areas (approx. 44km). Four bulk meters enabling FCTWB to measure inflow volume to the whole piped water supply system were installed along these transmission mains at the outlet from the dam. There are major 16 concrete tanks in existing piped water supply system to which water is supplied by gravity and partially pump up. Reservoir Unit is in charge of these activities.

could be “lost” through unauthorized consumption (theft), administrative errors, data handling errors, and metering inaccuracies or failure; and this is referred to as apparent loss. All these come to play on water distribution network in Abuja.

Also water distribution network issues in Abuja include irregular supply which the study identified as caused by settlement problems. Some streets did not have pipe – borne water because settlements and estates popped up along those roads and into areas which are not covered in any of the phases of development planned for the Federal Capital City (FCC) water distribution. At present, the water network is incomplete as the settlements keep expanding yet already the facilities which were in use are degrading and sooner or later operating it would be a challenge.

Table 1: Water Supply Areas by Existing Piped Water Supply System

Development Areas	Water Supply Areas by existing Piped System
Phase 1	Maitama, Wuse I, Wuse II, Central Area, Asokoro, Garki I, Garki II *Development is almost completed.
Phase 2	Jabi, Katampe, Katampe Ext., Kado, Mabushi, Jabi, Utako, Dakibiyu, Wuye, Durumi, Gudu, Duboyi, Gaduwa, Apo, Dutse, Kaura *Development is partially completed.
Phase 3	Gwarinpa I, Gwarinpa II, Karmo *Development is a bit completed; currently distribution mains and networks have been constructed in the area.
Phase 4	None
Outskirts	Bwari, Ushafa, Kubwa, Gwagwalada, Karu, Nyanya
Others	Airport, Abuja University, KCK School, Barracks

Source: Federal Capital Territory Water Board, 2021

The water distribution system of the study area consists of reservoir, several boosters, loop, pump stations and junctions. Distribution mains are the pipelines from reservoirs (tanks) to water supply areas, sometimes as a part of distribution network in FCTWB (approx. 296 km) and pipeline unit for D300 mm or more. There are 16 major concrete tanks in existing piped water supply system to which water is supplied by gravity and partially pumping up.

Most drinking water infrastructure in Abuja, Nigeria has been in service for many years and this could be a significant source of water loss through leaks. The pipelines got weak and usually burst if there is any pressure variation. Since pipelines were not properly marked, a lot of them could also be destroyed during road and construction of other infrastructure amenities. This type of water loss is referred to as Real/Physical loss. In addition to leaks, water

4.0. CONCLUSION

Urban water systems must include not only the reservoirs, groundwater wells, and aqueducts that are the sources of water supplies needed to meet the varied demands in an urban area, but also the water treatment plants, the water distribution systems that transport that water, together with the pressures required, to where the demands are located. In most urban areas in developed regions, government regulations require designers and operators of urban water systems to meet three sets of standards. Pressures must be adequate for fire protection, water quality must be adequate to protect public health, and urban drainage of waste and storm waters must meet effluent and receiving water body quality standards. This requires monitoring as well as the use of various models for detecting leaks and for predicting the impacts of alternative urban water treatment,

distribution, and collection system designs and operating, maintenance and repair policies.

It is therefore recommended that; valve location and reservoir optimization; thorough research should be done in these areas to further reduce water losses and inefficiency in water distribution systems, the water distribution network should match the land use changes over time and space because of the planned nature of the study area. Due to the increasing failure of public water distribution (supply versus demand) to meet the increasing population, planners and decision makers should take cognisance of future development pattern and make provision for expansion.

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