FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 1, February, 2024, pp 277 - 285
DOI: https://doi.org/10.33003/fjs-2024-0801-2225

DIGITAL CADASTRE FOR POTABLE WATER DISTRIBUTION NETWORK IN LOKOJA, KOGI STATE

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ABSTRACT

Water is one of the most important natural resources, and as a resource to any nation, it should be well-planned, developed, conserved, distributed, and managed. Its infrastructure should also be properly maintained to avoid future water problems. This project sought to evaluate the water infrastructure in Lokoja with a focus on identifying areas requiring improvement. The scope of the study encompassed mapping the primary water pipeline distribution network and gathering geometric and attribute data concerning storage tanks and reservoirs within the designated area. Employing a combination of remote sensing and ground survey techniques, data was collected and utilized to generate a detailed spatial distribution map illustrating the major water supply networks and reservoirs. ArcGIS 10.2 was utilized for data processing and analysis, with the 3D analyst tool utilized to generate an elevation map and ascertain optimal site selection for gravity reservoir placement. The outcomes of the analysis included a visual representation of major pipeline connections, the precise location of tanks and reservoirs, and a comprehensive database containing both location and attribute information for these structures within the study area. The study findings revealed a pressing need for enhancing maintenance practices for water reservoir tanks, as a significant portion were found to be in substandard condition. Additionally, the study highlighted the necessity for pipeline extension to incorporate newly developed suburban areas within the study vicinity. The collated data serves as a pivotal resource for informed decision-making regarding the establishment of new reservoirs and the expansion of existing pipeline networks. Overall, this study offers an exhaustive overview of the water infrastructure in Lokoja, positioning itself as a crucial asset for future research and developmental initiatives within the region.

Keywords: Digital Cadastre, Distribution, Network, Potable Water, DEM

INTRODUCTION

One of the things that lead to rural–urban migration is the presence of basic or essential amenities such as pipe-borne water, electricity, good road networks, quality of housing, etc. Under the most optimistic scenario, the world's population is expected to grow from more than six billion in 2000 to at least eight billion by 2025. This growth, 90 percent of which will occur in urban areas will intensify pressure on available resources, the demand for potable water and water of sufficient quality for use in the industry and waste treatment (Lacquemanne, 2000). Water is vital for man's existence and without it; there would be no life on Earth. Cities are growing very rapidly and water is required for cooking, washing, bathing, drinking, and industrial purposes. Demand for drinking water is continually increasing due to these various factors.

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 (Al-Layla et al, 1978; Audu and Anyata, 2010; Audu and Ehiorobo, 2010; Audu and Edokpia, 2010). Water is one of the most important natural resources, and as a resource to any nation, it should be well-planned, developed, conserved, distributed, and managed. Its infrastructure should also be properly maintained to avoid future water problems. To achieve that, up-to-date records of water infrastructure are needed, these can be done easily through Spatial Information Service. Spatial Information Service produces, manages, processes, and distributes location information on natural or artificial objects on plains including the earth's surface, underground, on water surface, and underwater.

A spatial database of the Water Distribution System (WDS) for the city should be created in a geospatial information system (GIS) environment. Although the size and complexity of water distribution systems (WDS) may vary dramatically, they all have the same basic purpose, to deliver water from the source (or treatment facility) to the consumer (Beecher, 2000). The source of water commonly determines the nature of collection, purification, transmission, and distribution works. Common sources are rainwater, surface water, and groundwater. A 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.

Water distribution systems account for 40-70% of the total cost of the water supply scheme, hence its proper planning, design, operation, and layout is of great importance. A water distribution network contains all the various components of a water system and defines how the components are interconnected. These components include water reservoirs, water pipes, water pumps, storage tanks, junctions, and valves. According to Lansey and Mays (2000), a water distribution system consists of three major components: distribution piping network, pumps, and distribution storage.

Regular inspections are imperative for ensuring the optimal performance of water pipeline systems. Studies indicate that a significant portion, over 80%, of information can be linked to geographic references (Dangermond, 1999). Parker (1996) further highlighted that approximately 85% of all information contains some spatial context.

The role of Geo-spatial analysis cannot be overemphasized, as a determining factor in today's policy-making for a better world; it must form the basis of any strategy for the economic development of a region (Haarsma, 2008). Geospatial information is the basic ingredient for the physical planning, design, and development of infrastructure. They are information that exists in the real world in terms of space (with location) and time and can be represented in the form of maps, databases, and statistical representation (Akinyede and Borroffice, 2004). Coordinates are geospatial information used to represent the location of natural or man-made features on the earth's surface. They are a set of values that define a position within a spatial reference (ESRI, 2000). Since Geospatial information plays a significant role in the planning, design, location, maintenance, and management of water distribution infrastructure (WDI), and most components of water infrastructure are referenced to the surface of the earth, therefore, they can be mapped.

Jaiswal et al. (2021), created a spatial database of the water distribution system (WDS) for Dehradun City in a geospatial information system (GIS) environment. From their study, it was revealed that more than three-quarters of the system has outdated water pipelines. Water supply-demand gap analysis confirmed that although Dehradun city has a surplus supply, it suffers from scarcity, mainly due to the unsatisfactory condition of the existing WDS. It was also discovered that twenty-seven percent of the existing pipes are smaller than the prescribed standards, there is an undesirable practice of direct pumping of water from tube wells into the network, and storage tanks are required for at least 29 locations in the network.

Lokoja is a fast-growing city, due to its position as the gateway to Northern and Eastern Nigeria, as well as its peaceful nature. This has led to continual emigration of people in search of greener pastures; this in turn has led to pressure on the existing utilities. The high influx of people into the city has also led to expansion of development at the fringes and these areas are yet to be captured by the water distribution authority. Water supply distribution is unequal in the city; the far-flung and newly added areas are mostly not covered under the water distribution system. In some areas, water supply pressure is shallow. Unequal distribution of drinking water in terms of quality and quantity leads to water stress. Therefore, the project aims to map the existing water infrastructure in the city to determine the extent of coverage, as well as the spatial distribution of overhead tanks and reservoir to enable an informed decision as to the location of gravity reservior.

MATERIALS AND METHODS

The Study Area

The Study Area is located within Lokoja Metropolis, it lies between Latitudes 7^0 45'N and 7^0 51'N and Longitudes 6^0 41'E and 6^0 45'E, within the lower Niger- Benue trough in Central Nigeria (see Figure 1). Lokoja is the capital city of Kogi State in North Central Nigeria, it was also the capital of the British Northern Nigeria Protectorate and remained a convenient administrative town for the British colonial government after the amalgamation of Northern and Southern Nigeria in 1914 (Kogi State Government, 2013). Lokoja is also the headquarters of a Local Government Area in Kogi State. Lokoja has an area of 63.82 km² (Adeoye, 2012) and a population of 195,261, (National Population Commission on the 2006 Census). It is a trade center for its agricultural produce such as rice because it sits at the confluence of the Niger and Benue Rivers. Some of the economic activities carried out by the inhabitants of Lokoja are fishing, farming, lumbering, trading, boat making, people working in the public sector, and civil servants. All of these result in an increase in pressure on wood for fuel and other basic amenities due to the population increase in the town.

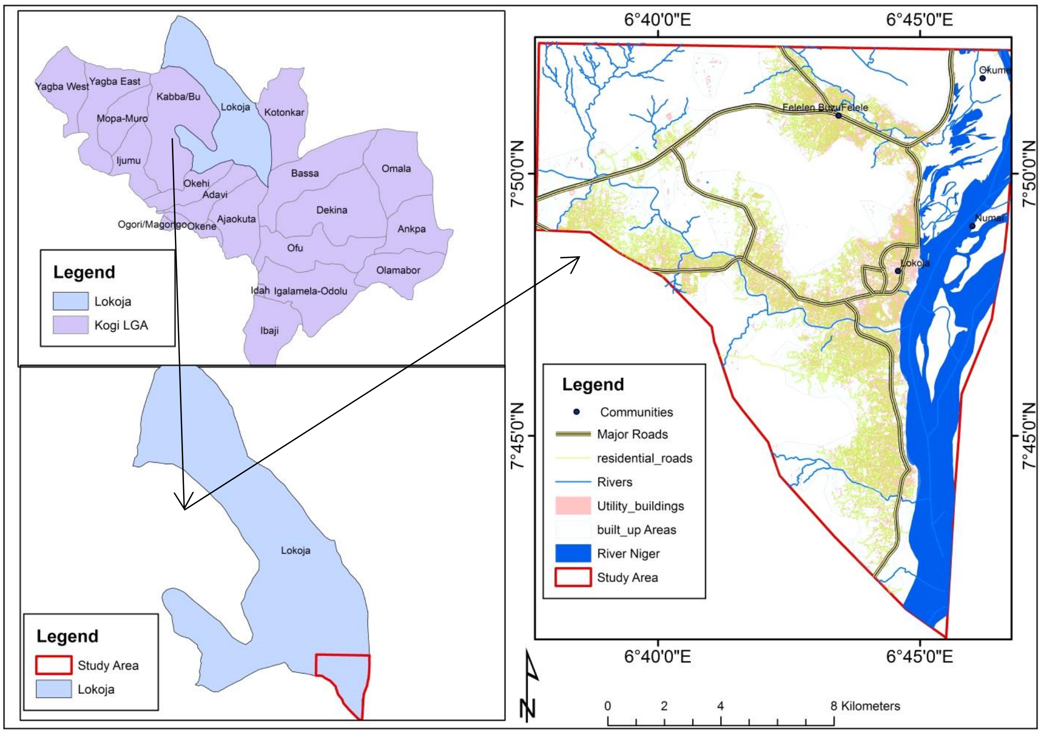

Figure 1: The study Area (Source: Author's lab work)

Data Needs and Acquisition

The 6m natural colour SPOT6 imagery and 30m Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) covering the area were acquired for this project. SRTM30 is a near-global digital elevation model (DEM) comprising a combination of data from the Shuttle Radar Topography Mission, flown in February 2000, and the U.S. Geological Survey's GTOPO30 data set. It can be considered to be either an SRTM data set enhanced with GTOPO30, or as an upgrade to GTOPO30. SPOT-6 is an optical imaging satellite capable of imaging the Earth with a resolution of 1.5 meters panchromatic and 6 meters multispectral (blue, green, red, and near-IR). Other data used include;

i. Lokoja Local Government Area Map, retrieved from Bureau of Lands, housing and urban development, Lokoja
ii. Vector Layers comprising road networks, buildings, and rivers, downloaded online from http://www.gofabrik.de site
iii. Ground coordinates showing the geometric position of overhead tanks, Reservoirs, and control points showing the Junctions of water pipe connection obtained using hand-held GPS(Nava Pro Handheld GPS)

Datum Harmonisation

The data sets employed in this study came from disparate sources based on different formats, coordinate systems, and projections. The datasets were harmonized under the Universal Transverse Mercator (UTM) coordinate system referenced to Minna Datum. The origin of the Minna datum is at the Minna base station L40. The harmonization under UTM also helps to overcome measurement difficulties and preserve the geometric properties of the features.

Map Extraction and Clipping

To get the desired extent of the project area, the area of interest was digitized from the Lokoja Local Government Area map in ArcGIS 10.2.as a polygon, the digitized area of interest was then used as a mask to extract the area of interest from the Spot 6 image, SRTM DEM, and also for clipping the vector layers (road network, rivers, buildings etc.) downloaded from geofabric website. Extract by the mask is a function in ArcGIS that extracts cells of the raster that correspond to the area defined by the mask. The vector data shapefiles downloaded from the geofabric website include; road networks, buildings, rivers, towns, and water bodies, since the shapefile covers the whole of Nigeria, the area of interest needed to be clipped out. The features that were clipped include the road networks, rivers, and buildings within the study area

RESULTS AND DISCUSSIONS

Extent of Water Distribution

A total of thirty-five (35) tanks were mapped across the study, the tanks were scattered in different locations (Ganaja village, House of Assembly Quarters, Old Poly Quarter, Wada Estate, Phase 1 and 2, Kabawa, Zone 8, etc.). In the course of the project work some of the residents were also interviewed to ascertain the status of the tanks, and whether the tanks were in good or bad condition, it was discovered that out of the thirty-five (35) tanks, eight (8) were bad and twenty (26) were good, as shown in table 1 and 2. Figure 2 shows the major water pipeline distribution network in red and reservoir locations in the study area.

The network of pipelines runs from Ganaja village through ganaja junction and extends to part of zone 8, Otokiti Housing Estate down to parts of Army barracks. It also extends upwards, from Ganaja junction through Old Market, Kabawa, and felele, and terminates at Kogi State Polytechnic, Lokoja. Some communities were not covered by the water project, these communities include; part of felele, Federal University, Lokoja, Felele Campus, Crusher, Shetimma, Zangodaji, and its environs. Figure 3 shows this the distribution of overhead tanks, manholes and reservoir locations across the study area.

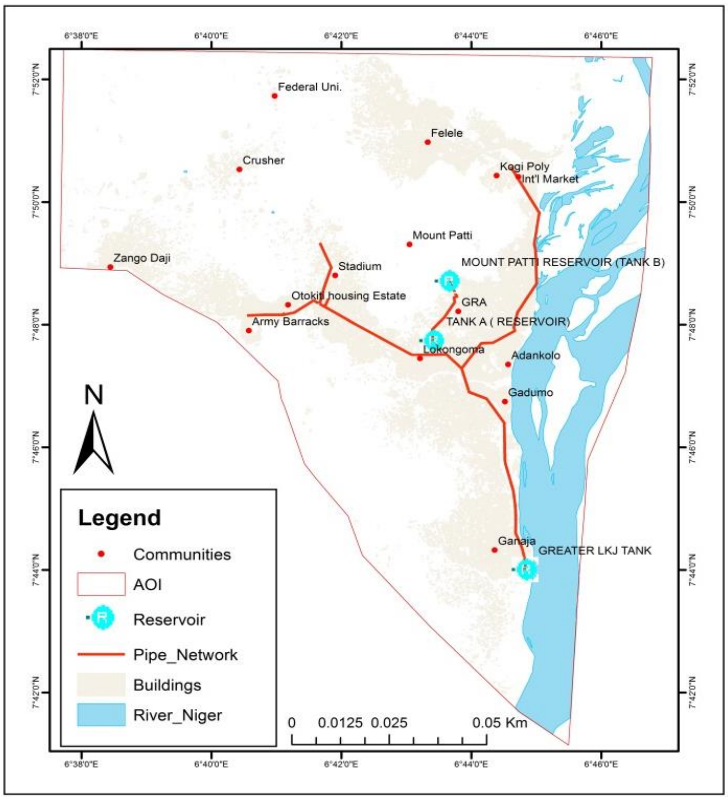

Figure 2: Major Water Pipeline and Tanks distribution Map

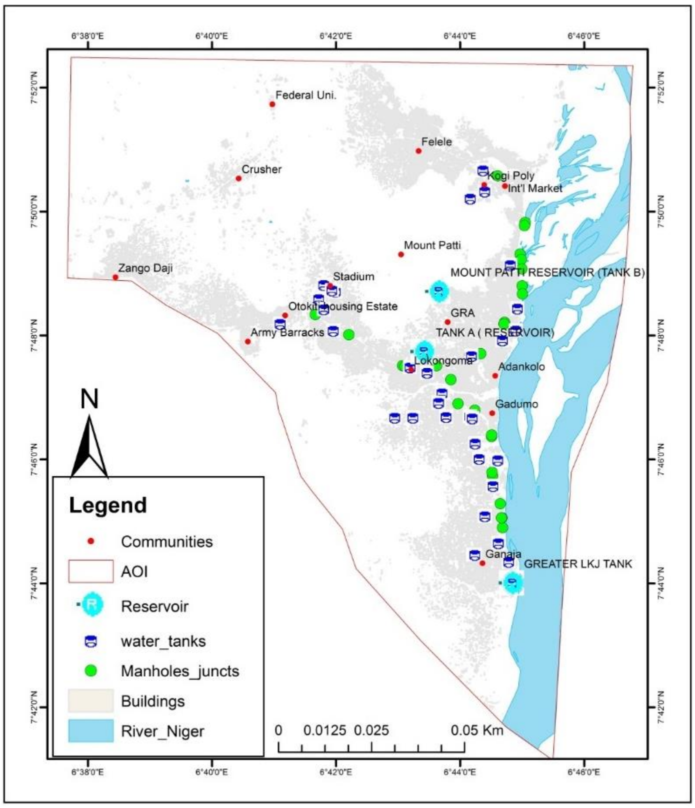

Figure 3: Tanks, Reservoirs and Manholes Locations

Table 1: Excerpts of selected water distribution Network and manholes

Point Id	Eastings	Northings	Description
AVDN50	251488	855380	Control
AVDN50	251490	855356	Control
AVDN50	251480	855341	Control
DN1	251253	857059	PIPELINE
DN2	251233	857350	500 Unit Junction
DN4	251187	857769	FED. MIN. OF Agriculture
DN5	250969	858595	
DN6	250952	858704	
DN7	250943	859770	
DN8	250944	859815	
DN9	250447	860551	Opposite200unit
DN10	249951	860752	Opposite 200 UNIT

Source: author's field work, 2023

Table 2: Excerpts of selected Reservoirs and Overhead tanks Coordinates

Point Id	EASTING	NORTHING	CONDITION	LOCATION
1	250306.7	860454.2	GOOD	200 UNITS
2	250375.4	860443.4	GOOD	200 UNITS
3	249600.5	860443.3	GOOD	200 UNITS
4	249485.6	861151	GOOD	OLD POLY QUARTERS
5	248617	860430.1	GOOD	OLD POLY QUARTERS
6	248075.3	859798.7	GOOD	WADA ESTATE
7	249382.9	860865.8	BAD	OLD POLY QUARTERS
8	250459.2	859650.5	BAD	COMMISSIONER'S QUARTERS
9	250735.1	857486.1	BAD	PEACE COMMUNITY
10	250735.2	857486.3	GOOD	500 UNITS
11	251131.7	856682.2	BAD	500 UNITS
12	250376.4	856335.4	GOOD	BEHIND GANAJA PRI. SCHOOL

Source: Author's field work, 2023

GIS Queries

Simple queries were run on the database using the Identify tool on the Tools toolbar in ArcMap. These queries helped to view attribute values for particular features. Here are the steps followed to achieve this; the Identify tool on the toolbar was selected, and then a location in the data frame was clicked on to identify the features at the location. The attributes were presented in the Identify window. The figures 4, 5 and 6 below shows some of the queries carried out on the database created.

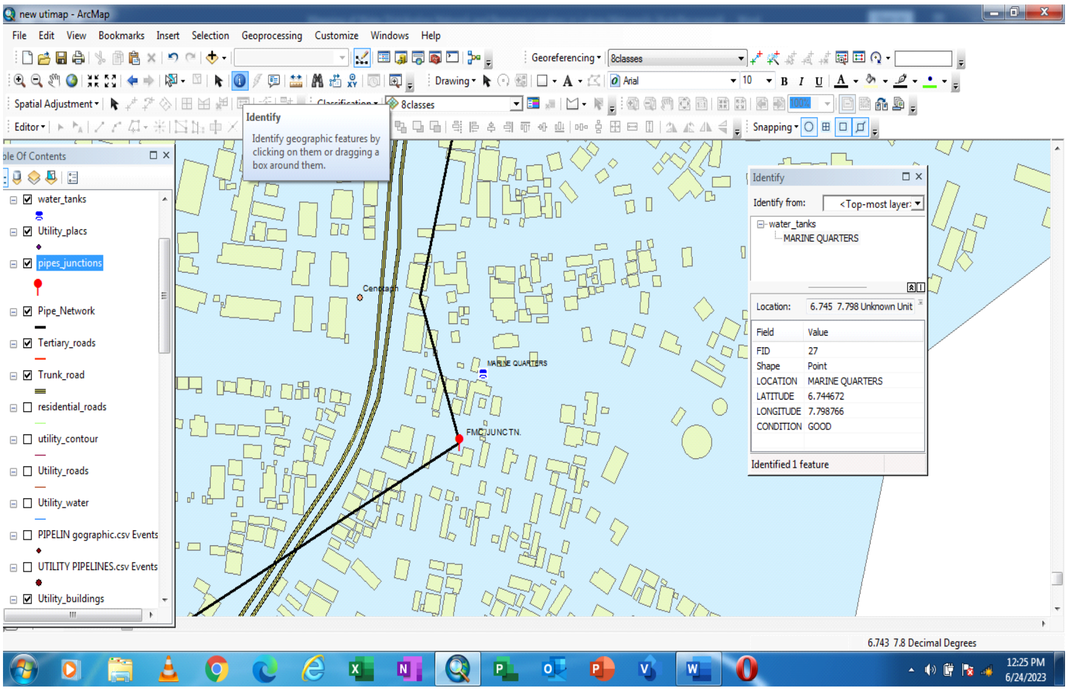

Figure 4: Shows a pipe junction located at Marine Quarters

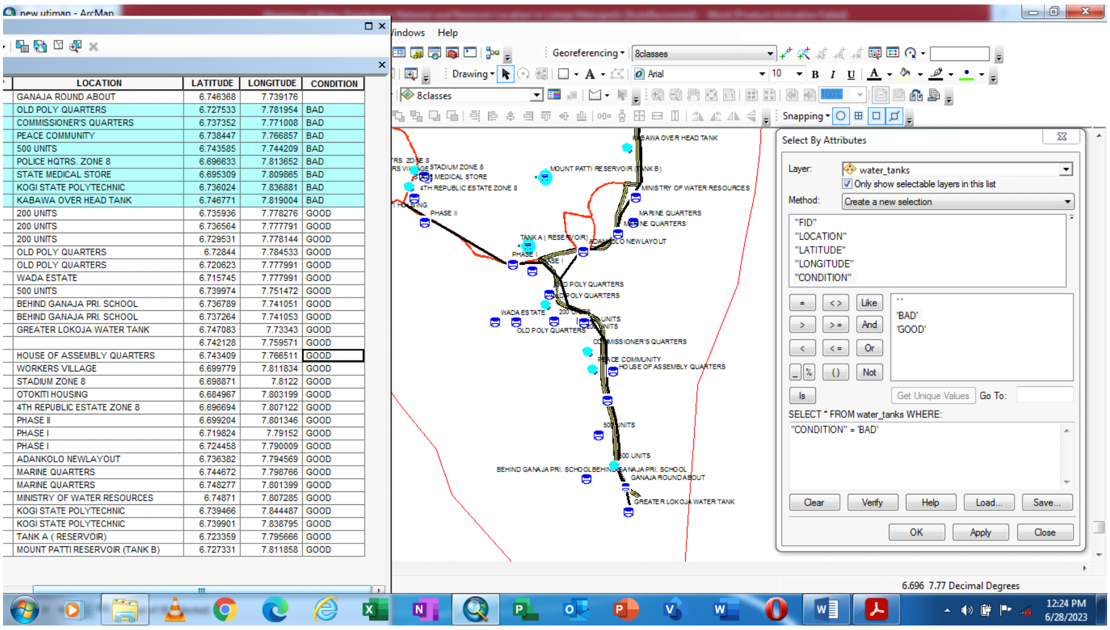

Figure 5: Shows query by attribute, showing location of bad overhead tanks on the map

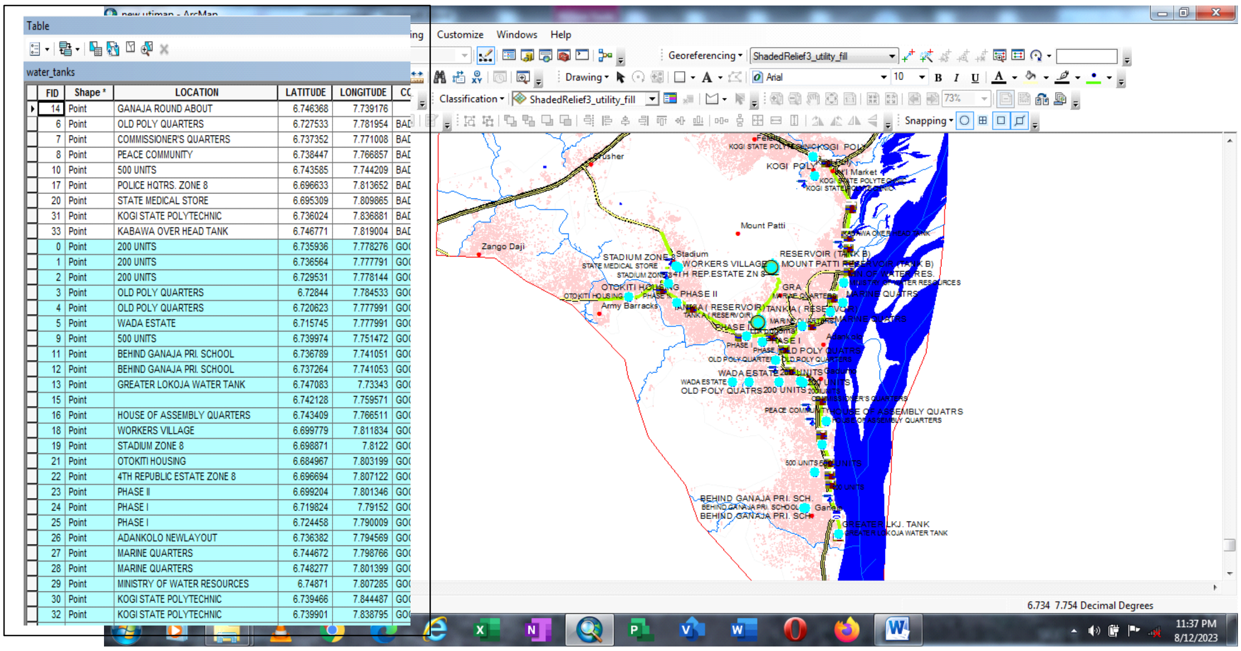

Figure 6: Shows query by attribute, showing location of good overhead tanks on the map.

Best Site Selection for Gravity Distribution Water Reservoirs

Lokoja, despite its location at the confluence of Niger and Benue and being surrounded by water still lacks potable water, this problem has driven so many researchers to investigate the status of the water supply in lokoja. Abenu, et al. (2016), investigated domestic water supply patterns in Lokoja town, the study revealed that despite the Greater Lokoja Water Supply Scheme which was developed to increase domestic water supply in the town in 2011, access to the potable water supply was inequitable, with planned neighborhoods having greater access than unplanned neighborhoods. According to their study, to meet water needs in households, inhabitants also depend on several sources of domestic water like groundwater sources, rainwater harvesting, water vending, and river or stream water.

Musilimu and John-Nwagwu (2022) assessed household accessibility to domestic water supply in Lokoja, Nigeria. According to their study, more than 70% of households residing at Zango Daji and Army Barracks areas rely on boreholes for their regular water supply. Well water and water from vendors are the principal sources of water for residents of Felele area and these constituted of 48.1% and 25.9%, respectively. Approximately, 100%, 57.7%, and 34.6% of urban households that reside at Old Poly Quarters, Lokogoma Phase 1 and 11, and Kabawa areas respectively, indicated that they rely on irregular and unpredictable public tap water supply provided by the Kogi State Water Management Board. The conclusion drawn from their study shows that the urban households perceived and rated the availability and quality of domestic water supply as dissatisfied. A study by Folorunsho and Umar (2023) on the assessment of inadequate domestic water supply on human health in selected neighbourhoods of Lokoja Metropolis reveals that there is a strong relationship and connection between potable water supply and health status among households.

In Lokoja, some communities are dispersed and hard to reach, and their access to water is threatened by many factors, including terrain and exclusion because of age, disability, social status, or political affiliation (Abenu, et al. 2016; Musilimu & John-Nwagwu, 2022). GIS tools and techniques can be applied to find the best site that can be used for the construction of a water reservoir that distributes water using gravity in Lokoja. Good quality gravity-flow water systems will increase communities' resilience to climate variability and water scarcity, as well as reduce the time and effort spent on water collection, **(**Water Aid, 2021).

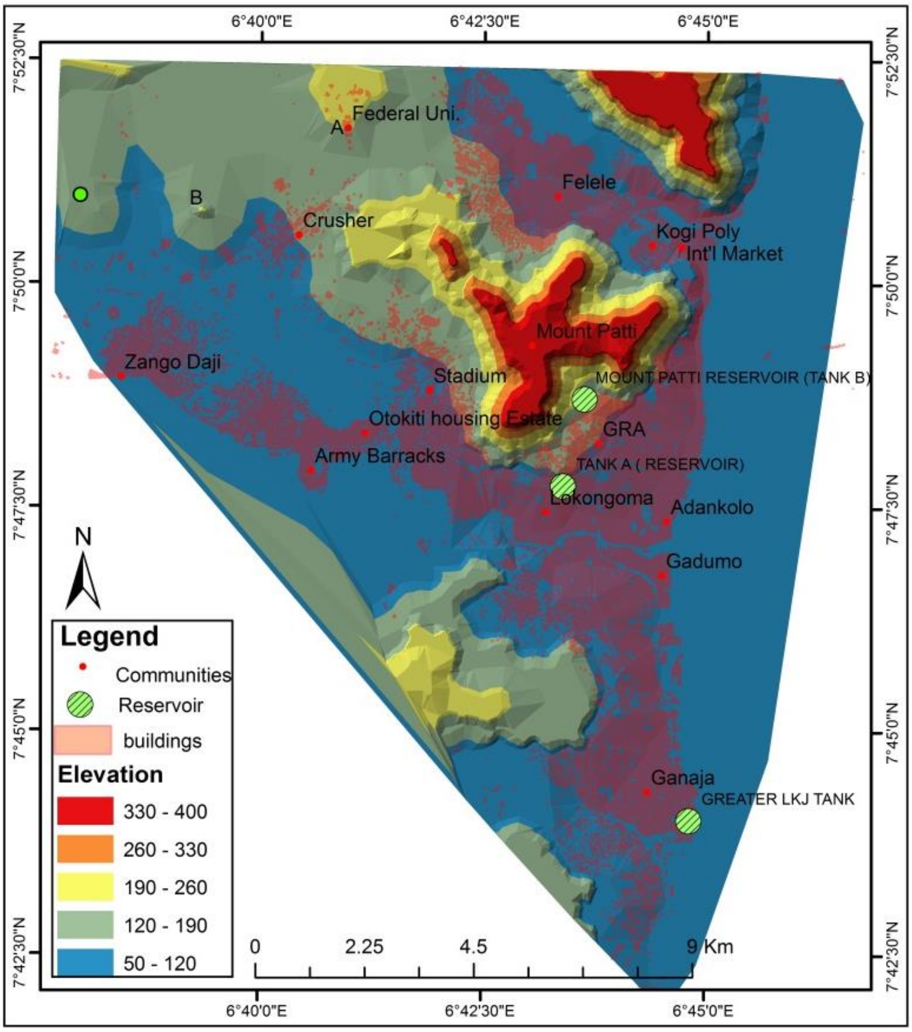

Figure 7: Digital Elevation Model of Lokoja Draped with built-up Areas

The analysis used the contour data to extract the terrain of the study area, the existing built-ups to see the settlements that can benefit, and an existing water reservoir to compare with the resulting site of the analysis (Figure 7). 3D Analyst extension of the ArcGIS desktop was used to generate the terrain model of the study area which was further re-classified into height (elevation) categories to find the best location of the reservoir.

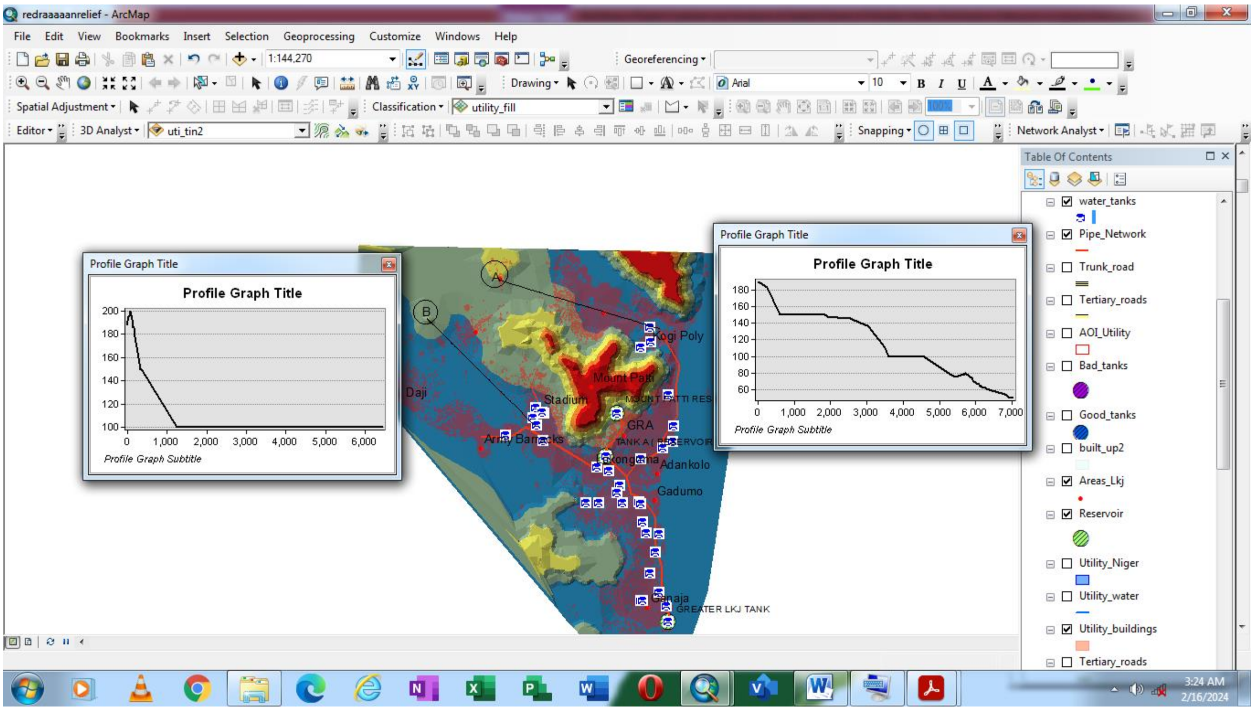

Figure 8: Shows point A and B, with the profile graph as best sites for Location of Gravity Tanks

Two points A and B at elevations 190.50m and 200m respectively above sea level, were selected as sites for siting of gravity reservoirs(figure 8). The existing reservoir Tank A and Tank B are sited at altitudes 100m and 168.5m respectively above sea level. Therefore, the selected site for the proposed Reservoir is higher confirming gravity-based water destitution system is in its appropriate site as one component to ensure fair water distribution.

CONCLUSION

The results of this study clearly show the relevance of GIS in utility mapping and planning. The final map clearly shows the extent of the major distribution of pipes across the study area, which also implies that some communities are yet to be connected to the greater Lokoja water project for potable water distribution and supply. A total number of thirty-five (35) tanks were mapped across the study area, these also include two reservoirs tank A and tank B located at the foot of Mt. Patti. Eight (8) out of the thirty-five (35) were bad and could not retain water, while twenty-six (26) were good. The map can be used as a guide to ensure that these communities are captured in the future extension and expansion of the water project. More so, incorporating elevation data enabled us to create more comprehensive and strategic plans for the siting of the gravity reservoirs and overhead tanks for future extension. It is recommended that all utility information in the State and across the nation should be digitized as these will serve as a useful tool for future development and expansion as the case may be. It is also recommended that the bad tanks be repaired for effective discharge of water and that network extension be carried out to felele, Zangodaji, Crusher, and Shettima areas of the Metropolis.

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