

**WATER DISTRIBUTION NETWORK ANALYSIS AND MANAGEMENT OF
UNIBEN UGBOWO CAMPUS USING GIS**



BY

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DEPARTMENT OF GEOMATICS

FACULTY OF ENVIRONMENTAL SCIENCE

UNIVERSITY OF BENIN

BENIN CITY

**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF GEOMATICS,
FACULTY OF ENVIRONMENTAL SCIENCE, IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF
SCIENCES (BSCGEM - B.SC. GEOMATICS) IN GEOMATICS.**

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CERTIFICATION

This is to certify that this project was carried out by OSARA ANOINTED IHINOSEN with matriculation number ENV2006565 in the Department of Geomatics, Faculty of Environmental Sciences, University of Benin.

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DEDICATION

This work is dedicated to God Almighty for His infinite mercies, grace and protection sustained me throughout my stay in University of Benin.

To my parents for their support and blessings.

ACKNOWLEDGEMENT

To God Almighty, I give all the glory for His unfailing love and support towards me throughout this work and always.

My profound gratitude goes to my project supervisor Surv. Dr. G.O. Nwodo, for his encouragement and support that aided this work, all lecturers and Staff of the Department of Geomatics for their commitment and support throughout my stay in the department.

From the depth of my heart, I sincerely wish to appreciate all my relatives and family members; Mr. and Mrs. Friday Ehi Osara, my siblings, Mr. and Mrs. Engr. S.I.O Osara, Mr. Olele Osara, Mr. Ebakole Osara for their support both prayerfully and financially which has been of immense help to me throughout my stay in school.

I also wish to appreciate my friends and loved ones Soroibe Chisom, Okoro Chris, Momodu Joel, Ichege Diamond, Joy Olla. And to everyone who contributed both directly and indirectly to my work, I see a very big thank you. To my wonderful course mates, you have all been awesome. May God richly bless you.

ABSTRACT

Water distribution plays a vital role in ensuring the sustainability and functionality of institutional environments. The University of Benin (UNIBEN), Ugbowo Campus, has experienced increasing water supply challenges over the years due to population growth, uneven distribution, leakages, and aging infrastructure. This project focused on the application of Geographic Information System (GIS) technology to analyze and manage the existing water distribution network of the campus with the aim of improving efficiency, monitoring, and future planning.

Both spatial and non-spatial data were obtained through field surveys, and records from the UNIBEN Works Department. The data were processed and integrated into a geospatial database using ArcGIS 10.8 and Google Earth. The study involved the generation of a Digital Elevation Model (DEM) and 3D terrain analysis to determine the relationship between topography and water flow. Population projection and water demand analysis were carried out using the compound growth rate method and standard per capita consumption rate of 150 litres per person per day.

The results showed that the campus terrain ranges from 74 to 121 metres above mean sea level, with the UNIBEN Water Scheme strategically located at the highest elevation to support a gravity-fed distribution system. The projected population increased from 40,320 in 2015 to 76,576 in 2040, representing an 89.9% rise over the 25-year design period. Consequently, the maximum daily water demand was estimated to increase from approximately 10.89 million litres in 2015 to 20.68 million litres in 2040. The pipeline network mapping revealed a well-structured system composed mainly of Asbestos Cement (AC) and PVC pipes, though aging sections require replacement.

In conclusion, the integration of GIS technology proved to be an effective tool for analyzing, managing, and visualizing water distribution systems. The study provides a comprehensive spatial database that can assist the University in maintenance planning, leak detection, infrastructure upgrading, and sustainable water management. It also demonstrates that GIS-based approaches can significantly improve decision-making in institutional water supply systems and serve as a model for similar environments across Nigeria.

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ACRONYMS

| | | |
|------|---|--|
| AC | - | Asbestos Cement |
| CAD | - | Computer-Aided Design |
| DEM | - | Digital Elevation Model |
| ESRI | - | Environmental Systems Research Institute |
| GCS | - | Geographic Coordinate System |
| GIS | - | Geographic Information System |
| GNSS | - | Global Navigation Satellite System |
| GPS | - | Global Positioning System |
| HDPE | - | High-Density Polyethylene |
| LGA | - | Local Government Area |
| LPCD | - | Litres Per Capita per Day |
| NPC | - | National Population Commission |
| PC | - | Personal Computer |
| PCS | - | Projected Coordinate System |
| PVC | - | Polyvinyl Chloride |
| UAV | - | Unmanned Aerial Vehicle |
| UTM | - | Universal Transverse Mercator |
| WHO | - | World Health Organization |
| WGS | - | World Geodetic System |
| 2D | - | Two Dimensional |
| 3D | - | Three Dimensional |
| GIS | - | Geographic Information System |

CHAPTER ONE

INTRODUCTION

1.1 GENERAL OVERVIEW OF THE STUDY

Water distribution is a critical aspect of infrastructure management in any urban or institutional setting. At the University of Benin (UNIBEN), Ugbowo Campus, the increasing demand for water due to population growth, coupled with aging infrastructure and poor documentation, has created challenges in ensuring efficient and consistent water supply. Common issues observed on the campus include frequent leakages, uneven distribution, low pressure in certain areas, and difficulties in tracking and maintaining underground pipelines.

Traditional methods of managing water infrastructure have proven insufficient in addressing these challenges due to their lack of spatial awareness and limited analytical capabilities. In contrast, Geographic Information Systems (GIS) offer a modern and efficient solution by allowing for the integration of spatial data with infrastructure attributes. GIS makes it possible to visualize the entire water network, analyze its components, identify weaknesses, and support effective decision-making.

This study focuses on the application of GIS technology to analyze and manage the water distribution network of UNIBEN Ugbowo Campus. The research involves data collection through GPS field surveys and existing campus utility maps, digitization of the network, and spatial analysis using GIS tools. The aim is to develop a comprehensive geospatial model of the water distribution system that can be used to monitor performance, detect issues such as leakages or low pressure zones, and support future planning for maintenance and expansion.

Overall, the study is geared toward enhancing water resource management within the campus by providing a structured, data-driven, and visual approach. It aligns with global best practices in smart infrastructure management and demonstrates how GIS can be harnessed to improve service delivery, reduce operational costs, and promote sustainability in institution.

1.2 STATEMENT OF THE PROBLEM

The University of Benin (UNIBEN), Ugbowo Campus, is a large and rapidly growing academic community with thousands of students, academic staff, and non-academic personnel who depend daily on a reliable water supply. Despite the importance of water to the campus community, the current water distribution system is plagued with numerous challenges that hinder efficient service delivery. Over the years, the campus has experienced frequent water shortages, unbalanced pressure across zones, and high incidences of leakage, all of which point to deep-rooted structural and management issues within the existing water distribution network.

One of the major problems is the lack of updated and accurate records of the water distribution infrastructure. Most pipeline layouts are either undocumented, outdated, or exist only in non-digital formats, making it extremely difficult for maintenance teams to locate faults or plan improvements. Additionally, the system lacks the technological capacity to monitor water flow in real time, detect leakage points promptly, or predict areas of potential failure, which leads to increased water loss and prolonged service downtime.

This study therefore seeks to address the gap by applying GIS to map, analyze, and manage the water distribution network of UNIBEN Ugbowo Campus, with the goal of enhancing efficiency, reducing losses, and enabling informed decision-making.

1.3 Aim and Objectives of the Study

The aim of this project is to analyze and manage the water distribution network of UNIBEN Ugbowo Campus using Geographic Information Systems (GIS) for improved efficiency and sustainability.

The objectives of the study are to;

1. Digitize and geo-reference pipelines, valves, tanks, and pump stations
2. Generate DEM maps for elevation-based planning of tanks and flow paths
3. Estimate future population growth and daily water demand (2015–2040)

1.4 Significance of the Study

Benefits gotten from this research are;

1. It will provide a comprehensive spatial database of the campus water infrastructure, which can be used for day-to-day operations, troubleshooting, and maintenance planning.
2. It also introduces a GIS-based management framework that promotes sustainable water resource use.
3. The study can serve as a model for other institutions facing similar water distribution challenges and can be adapted for broader municipal applications.

1.5 Scope of the Study

This study is focused on the UNIBEN Ugbowo Campus. It covers the acquisition and analysis of spatial data related to the water distribution system, including pipes, valves, tanks, and pumping stations. The study will utilize GIS tools for network modeling, performance analysis, and scenario simulation. However, it does not include the analysis of water quality or financial aspects of water supply.

CHAPTER TWO

LITERATURE REVIEW

Effective water distribution is a critical component of infrastructure management in both urban and institutional settings. A well-designed and efficiently managed water distribution network ensures that potable water is delivered reliably and equitably to various user points. In universities, where the population density and water demand fluctuate across hostels, academic buildings, laboratories, and staff quarters, managing the distribution system requires not only physical infrastructure but also robust spatial data and analytical tools (Akinbile & Ologunagba, 2012). Traditionally, water networks were managed using paper-based maps or basic schematic drawings, which often lack spatial accuracy and are vulnerable to loss, duplication, and degradation over time.

GIS offers the ability to visualize, digitize, and analyze spatial features such as water pipelines, valves, tanks, and consumer nodes, enabling surveyors to better understand the spatial relationships, performance, and coverage of utility networks (Burrough & McDonnell, 1998; Longley et al., 2015). When combined with surveying instruments such as Global Navigation Satellite Systems (GNSS), total stations, and remote sensing data, GIS allows for the creation of precise, attribute-rich spatial databases that are essential for managing underground infrastructure like water distribution systems.

2.1 Water Distribution Systems

Water distribution systems are engineered networks that ensure the conveyance of potable water from a source or reservoir to end-users across various zones in a given area. These systems are critical in institutional environments like university campuses, where water demand is both dynamic and distributed across a wide variety of buildings and facilities

2.1.1 Concept of Water Distribution Networks

A water distribution network refers to an interconnected system of pipes, reservoirs, valves, and other control structures designed to transport potable water from a source or treatment plant to consumers (Mays, 2000). In the context of institutional settings such as university campuses, this network must be designed to meet the varying demands of residential halls, academic blocks, laboratories, recreational centres, and administrative buildings. The efficiency of a water distribution system is largely dependent on how well the network is designed, mapped, maintained, and updated over time. From a geospatial perspective, understanding the layout and extent of such networks is key to effective planning and management.

2.1.2 Importance of Water Distribution Networks

The importance of a functional water distribution system in any built environment cannot be overstated. It ensures reliable water supply, promotes hygiene and sanitation, and supports academic, residential, and industrial operations within campuses (World Health Organization, 2017). In university communities like UNIBEN Ugbowo Campus, where water demand varies by location and time, a well-monitored distribution system helps avoid shortages, pressure imbalances, and leakages. Moreover, an accurately mapped water network enhances operational efficiency, supports quick response to faults, and facilitates future system upgrades (Sule, 2000).

2.1.3 Basic Structure and Components

A water distribution system comprises several interconnected elements designed to transport water efficiently and reliably from a central source to various points of consumption. The structure of the system is not only functional but spatially defined,

making it crucial to map and manage using geospatial and surveying technologies. Each component plays a role in ensuring the system operates under the desired pressure and flow conditions while maintaining water quality. Below are the main components

1. Pipes

Pipes form the core of any water distribution system. They act as the physical channels that carry water from sources or reservoirs to the various outlets within a network. Pipes vary in material (e.g., PVC, ductile iron, steel, HDPE), diameter, and pressure rating depending on their role in the system. Pipes can be categorized as:

- i. **Main Pipes:** Primary conduits delivering water to large areas or zones.
- ii. **Sub-mains:** Intermediate lines branching off the mains.
- iii. **Service Lines:** Final connections to end-users or buildings.

2. Valves

Valves are mechanical devices used to control water flow within the system. They can:

- i. Start or stop flow (gate valves),
- ii. Control pressure and flow direction (check valves, pressure-reducing valves),
- iii. Isolate sections for maintenance (shutoff valves).

1. Junctions or Nodes

Nodes are the connection points where two or more pipes meet. In GIS and hydraulic modeling, nodes are used as key reference points for:

- i. Calculating pressure at various parts of the network,
- ii. Tracing flow paths,

- iii. Mapping water demand at endpoints.

2. Storage Facilities (Tanks and Reservoirs)

Storage facilities serve multiple roles including:

- i. Buffering against demand fluctuations,
- ii. Providing pressure through gravity (elevated tanks),
- iii. Storing emergency supply in case of pump failure.

3. Pumps

Pumps are used where gravity flow is insufficient, particularly when water needs to be moved uphill or across distant locations. Although less common in gravity-fed institutional systems, booster pumps may be found in hilly areas of campus layouts. GIS mapping helps determine pressure zones and energy usage for such installations.

3. Consumer Outlets (Taps, Standpipes, and Hydrants)

These are the end points where users access water. On campuses, they include:

- i. Public standpipes
- ii. Outdoor taps
- iii. Fire hydrants
- iv. Internal plumbing connections in buildings

2.1.4 Challenges in Mapping Institutional Water Infrastructure

Despite the importance of water networks, several challenges hinder their effective documentation and mapping, especially in developing regions, these challenges includes;

1. Many institutions lack original as-built plans or have outdated paper-based maps that are difficult to interpret or verify (Olawuni et al., 2018).
2. Underground pipes are often unmarked or poorly documented, making it hard to detect exact locations without advanced survey techniques.
3. Institutional inertia and lack of inter-departmental coordination often delay data collection and digital transition.

2.2 Geospatial Data in Utility Mapping

Geospatial data is at the core of modern utility mapping and management. In the context of water distribution systems, geospatial data enables the precise location, analysis, and monitoring of infrastructure such as pipelines, valves, tanks, and service connections. For academic institutions like the University of Benin (UNIBEN), efficient utility mapping using geospatial technologies offers a sustainable solution for planning, monitoring, and decision-making regarding campus infrastructure.

2.2.1 Types of Spatial Data Relevant to Water Networks

Spatial data refers to information about the physical location and shape of geographic features and their relationships on the Earth's surface. In the context of water distribution networks, spatial data is essential for modeling, analyzing, and managing infrastructure. The two primary categories of spatial data are **vector data** and **raster data**, both of which are critical in GIS-based utility mapping.

1. Vector Data

Vector data is composed of discrete geometric features represented as:

- i. **Points:** Used to map features such as hydrants, valves, meters, and pipe junctions.

- ii. **Lines:** Represent pipelines, service lines, and network flow paths. Line features are essential for modeling connectivity and flow in a water distribution system.
- iii. **Polygons:** Used to define zones such as service areas, buffer zones, or storage tank coverage areas.

Vector data is highly precise and suitable for mapping individual components of the network. It is especially valuable in surveying because it allows accurate distance and connectivity analyses within the network.

2. Raster Data

Raster data consists of grid cells or pixels, each with a value representing a specific attribute. Common raster datasets in utility mapping include:

- i. **Satellite Imagery:** Provides a visual base map for referencing utility features, identifying land use patterns, or assessing environmental factors.
- ii. **Digital Elevation Models (DEMs):** Represent terrain surfaces and are useful for analyzing slopes, watershed boundaries, and elevation profiles that affect water flow and pressure.
- iii. **Scanned Maps:** Historical or legacy maps that are digitized and georeferenced for use in modern GIS platforms.

Raster data is especially useful for background analysis and terrain modeling, supporting the interpretation of how topography influences water distribution.

2.2.2 Coordinate Systems and Map Projections

A coordinate system is fundamental in geospatial analysis because it allows features on the Earth's surface to be precisely located, measured, and mapped. In utility mapping, choosing

the correct coordinate system and map projection is essential for spatial accuracy, data integration, and analysis consistency.

1. **Geographic Coordinate Systems (GCS)**

A Geographic Coordinate System uses a three-dimensional spherical surface to define locations on the earth. It is based on a datum and uses angular units; latitude and longitude. A common GCS used globally is WGS 1984 (World Geodetic System 1984), which is the default for many GPS and GNSS devices.

2. **Projected Coordinate Systems (PCS)**

To perform accurate linear measurements (e.g., distances between pipes or pipe lengths), a Projected Coordinate System is used. A PCS converts the Earth's curved surface to a two-dimensional flat map using mathematical projections.

For Nigeria and the UNIBEN campus specifically, the commonly used PCS is:

Universal Transverse Mercator (UTM), Zone 31N

- i. Datum: WGS 1984
- ii. Unit: meters
- iii. Suitable for small-area, high-accuracy mapping
- iv. Minimizes distortion for east-west aligned regions

The UTM system divides the world into 60 longitudinal zones, each 6 degrees wide. Zone 31N covers southwestern Nigeria and is appropriate for mapping UNIBEN Ugbowo Campus due to its local scale and need for metric precision.

2.2.3 Methods of Spatial Data Acquisition

The accurate acquisition of spatial data is foundational to the successful development of a GIS-based water distribution network model. In surveying for utility mapping, various methods are used to capture both spatial and non-spatial information about existing infrastructure.

Several standard methods of spatial data acquisition used in utility surveys include:

2.2.3.1 GPS/GNSS Surveys

Global Positioning System (GPS) and the broader Global Navigation Satellite Systems (GNSS) represent fundamental technologies in modern surveying, offering efficient and precise means of acquiring spatial data.

GPS (Global Positioning System) is a satellite-based navigation system that allows users to determine their precise location (latitude, longitude, and altitude) anywhere on Earth. Developed by the United States Department of Defense and launched in the 1970s, GPS is the most widely used and well-known form of GNSS (Global Navigation Satellite System).

GNSS (Global Navigation Satellite System) refers to a constellation of satellites that transmit signals used for determining precise location, navigation, and timing information anywhere on Earth. These satellite systems work by providing signals to GNSS receivers on the ground, which can then calculate the receiver's position using triangulation methods. By measuring the time it takes for signals to travel from multiple satellites to the receiver, the system can determine the receiver's latitude, longitude, and altitude with high accuracy.

2.2.3.2 Total Station Measurements

A Total Station is an optical/electronic instrument used for surveying and building construction that integrates a theodolite (for measuring angles) with an electronic distance meter (EDM). It measures both horizontal and vertical angles and slope distances from the instrument to a particular point.

Total stations are essential for mapping water infrastructure with high precision. In the UNIBEN Ugbowo Campus project, they can be used to:

1. Determine the exact positions of above-ground fixtures such as manholes, hydrants, water tanks, and inspection chambers.
2. Collect elevation data, which is vital for understanding pipe gradients, flow direction, and drainage efficiency.
3. Establish control points and benchmarks to support GNSS and digitized datasets.
4. Survey hard-to-reach areas where GNSS signals are obstructed by buildings, trees, or underground settings.

2.2.3.3 Satellite and Aerial Imagery

Satellite and aerial imagery are crucial methods of acquiring spatial data, especially for large-scale mapping and environmental monitoring. These techniques allow surveyors to obtain high-resolution images of the terrain, which can then be analyzed to understand existing infrastructure, topography, and land use.

Satellite Imagery

Satellite imagery refers to images of the Earth's surface captured by satellites orbiting the planet. These images can be used to monitor changes in land cover, vegetation, and urbanization. Various types of satellites are;

- i. Landsat Satellites
- ii. Sentinel Satellites (Sentinel-2)
- iii. QuickBird and GeoIQ (Commercial Satellites)

Aerial Imagery

Aerial imagery is captured from aircraft or drones (Unmanned Aerial Vehicles, UAVs) that fly at lower altitudes compared to satellites. Aerial imagery offers higher resolution and can be obtained on-demand, making it a more flexible option for campus-level surveys. Types;

- i. Manned Aircraft
- ii. Drone (UAV) Imagery

2.2.3.4 Digitization of Existing Records

Digitization of existing records is a step in creating accurate, up-to-date geospatial datasets for utility infrastructure such as water distribution networks. It involves converting physical maps, drawings, and documents into digital formats, which can then be integrated into Geographic Information Systems (GIS) for analysis, management, and decision-making. For water distribution systems, these records often contain historical data about the layout, maintenance, and expansion of pipelines, manholes, water tanks, valves, and other infrastructure elements.

2.2.4 Importance of Attribute Data

While spatial data provides the "where" (location) of the features, attribute data provides the "what," "how," and "why" behind those features. For a comprehensive and effective analysis of a water distribution system, it is crucial to capture both spatial and attribute data in a GIS system.

The importance of attribute data includes;

1. Efficient System Operation and Monitoring:

Attribute data provides crucial insights into the operational behavior of the water distribution system. By integrating attribute data with GIS, water utilities can monitor the system in real-time, understand usage patterns, and track water distribution dynamics such as pressure, flow rates, and leaks.

2. Decision-Making and Planning:

Attribute data plays a significant role in strategic planning and decision-making. For instance, if certain water pipes have exceeded their expected lifespan, utilities can plan for their replacement based on material, installation date, and condition.

3. Leak Detection and Water Loss Management:

With the right attribute data, utilities can identify unusual pressure changes or flow patterns that may indicate a leak or a pipe burst. By monitoring the attributes of specific network sections, water utilities can reduce water loss, improve resource management, and maintain system integrity.

4. Regulatory Compliance and Reporting:

Water utilities must comply with regulatory standards for water quality, flow, pressure, and infrastructure maintenance. Attribute data provides a way to document and report compliance.

2.3 Definition and Capabilities of GIS

Geographic Information Systems (GIS) can be defined as a computer-based tool used for capturing, storing, manipulating, analyzing, managing, and presenting spatial or geographic data. In the context of surveying and water distribution network analysis, GIS serves as a bridge between the physical world and digital representation, allowing for the integration of location-based data with various types of descriptive information.

At its core, GIS operates on two fundamental data types: spatial data, which provides the geographic location and shape of features (e.g., points, lines, polygons), and attribute data, which describes the characteristics of those features (e.g., pipe diameter, material, installation year).

The capabilities of GIS in water distribution analysis include:

1. **Mapping and visualization** of underground and surface utilities for easy interpretation.
2. **Network modeling and analysis**, including flow direction, pressure simulation, and leak detection.
3. **Data integration**, allowing surveyors to combine GNSS coordinates, CAD designs, and attribute databases in one system.
4. **Spatial querying and decision support**, enabling users to answer location-based questions such as “Which pipes are older than 20 years?” or “Which valves control this section of the network?”
5. **Temporal analysis**, helping track infrastructure changes and maintenance history over time.

2.3.1 Role of GIS in Water Distribution Network Analysis

Geographic Information Systems (GIS) play a central role in the analysis, planning, management, and visualization of water distribution networks, especially within large and complex environments like a university campus. GIS enables the integration of spatial and non-spatial (attribute) data, supporting effective decision-making for water infrastructure maintenance, expansion, and management.

1. Spatial Visualization of Water Infrastructure

GIS provides a platform for visualizing all components of the water distribution network — such as pipelines, valves, reservoirs, meters, and control structures in their real-world spatial context.

2. Network Analysis and Modeling

GIS supports advanced network analysis to understand how water flows through the distribution system. With built-in tools or by integrating hydraulic models like EPANET, GIS can simulate flow direction, pressure zones, and identify potential issues like low pressure areas or isolated zones during maintenance. Survey-derived elevation data and accurate node placements are crucial inputs for such analyses.

3. Data Integration and Management

One of the core strengths of GIS is its ability to integrate multiple datasets. It links spatial data (from field surveys) with attribute data (such as pipe material, installation date, condition, and ownership).

4. Asset Inventory and Maintenance Planning

GIS enables the development of a comprehensive inventory of all water infrastructure components. Each asset can be assigned a unique ID and stored with its geographic location, physical properties, maintenance records, and inspection history. This makes it easier to monitor asset conditions, schedule preventive maintenance, and plan for timely replacements.

5. Planning and Decision Support

GIS aids utility managers and planners in making informed decisions about water network upgrades or expansions. By analyzing population density, building functions, and water demand zones, GIS can guide where to add new pipelines or increase capacity.

2.3.2 GIS Workflows in Utility Mapping

The GIS workflow in utility mapping involves a systematic process of collecting, organizing, and analyzing spatial and attribute data for infrastructure like water distribution systems. This process begins with field data acquisition using instruments such as GNSS receivers or total stations. The data is then imported into a GIS platform where it is structured into meaningful layers, analyzed spatially, and used for visualization and decision-making.

2.3.2.1 GIS Layers for Water Networks

GIS layers are the fundamental building blocks of spatial data representation in utility mapping. These layers allow for organized, scalable, and interpretable mapping of various components. Each layer in a GIS database represents a specific type of feature, such as

pipes, valves, nodes, reservoirs, or background reference information like roads and buildings.

The use of layered data organization provides flexibility in analysis. For instance, if only valve positions need to be checked, the valve layer can be isolated for focused examination.

In a typical water utility mapping project, the key GIS layers include:

1. **Pipe Layer:** Represents the linear alignment of underground or above-ground water pipelines. Attributes include diameter, material, installation date, and condition, it is represented using lines.
2. **Node Layer:** Shows the junction points where two or more pipes meet. Each node has elevation and pressure attributes crucial for hydraulic analysis, it is represented using points.
3. **Valve Layer:** Indicates locations of control valves, air-release valves, and isolation valves. These are critical for managing water flow and sectional shutdowns during maintenance, it is represented using points.
4. **Reservoir/Tank Layer:** Marks the locations and properties of water storage facilities, which influence pressure and supply continuity, it is represented using polygons and points.
5. **Building and Facility Layer:** Includes spatial footprints of structures that are served by the water network. This helps in demand estimation and service planning, it is represented using polygons.
6. **Road/Access Layer:** Provides road networks to help utility workers access components for maintenance and repair, it is represented using lines.

2.3.2.2 Base Map Layers

A base map typically contains a variety of spatial features that define the physical and administrative environment. These include roads, buildings, walkways, vegetation, boundaries, and natural features like rivers or elevation contours. While these features may not directly influence the hydraulic behavior of a water network, they are essential for situational awareness, accessibility planning, and spatial referencing.

2.3.2.3 Pipe Network Layer

The pipe network layer is the backbone of any water distribution mapping project within a Geographic Information System (GIS). It consists of linear features (polylines) that represent the physical layout and alignment of the water pipes supplying various sections of the study area.

This layer is crucial because it models the flow pathways of water from sources (e.g., reservoirs or boreholes) to consumption points (e.g., academic buildings, hostels, laboratories).

Role of the Pipe Network Layer in GIS Analysis:

1. **Hydraulic Modeling:** Used in simulation software like EPANET or integrated GIS tools to model water pressure, velocity, and distribution efficiency.
2. **Leak Detection and Maintenance:** Helps identify critical segments prone to failure based on age, material, or historical performance.
3. **Infrastructure Expansion:** Assists in planning new pipe layouts by analyzing existing network capacity and coverage gaps.

4. **Asset Management:** Provides a database of pipeline properties for inventory control, budgeting, and infrastructure audits.

2.3.2.4 Nodes, Valves, and Reservoirs

In the GIS-based mapping of a water distribution network, the nodes, valves, and reservoirs are critical point features that represent junctions, control elements, and storage systems within the hydraulic infrastructure. These elements are individually mapped as point layers in a GIS and hold both spatial and attribute data, making them integral to the understanding, analysis, and management of water flow across UNIBEN Ugbowo Campus.

Nodes

Nodes are the junction points where two or more pipes connect. In a GIS, these are mapped as point features and are fundamental for defining network topology. Each node determines how water moves through the system and is essential for hydraulic modeling and flow simulation.

Typical node attributes include:

1. Node ID
2. Elevation (used to calculate pressure head)
3. Junction type (e.g., tee, cross)
4. Connected pipe IDs

Valves

Valves serve as control mechanisms within the distribution network. Their placement and function determine how water flow is managed, redirected, or shut off in specific sections.

In a campus environment, they are particularly important for:

1. Isolating leaks or bursts without affecting the entire network
2. Conducting maintenance on specific buildings or blocks
3. Managing pressure zones

Reservoirs and Storage Tanks

Reservoirs or overhead tanks provide storage and head pressure for the entire distribution system. Their placement and elevation are critical in determining the gravitational flow of water across different campus zones.

Typical reservoir attributes include:

1. Reservoir/tank ID
2. Storage capacity (liters or cubic meters)
3. Elevation or tank height
4. Supply source (e.g., borehole, municipal main)
5. Service area or zone
6. Overflow and outlet pipe details

These storage units play a major role in regulating pressure, balancing peak demand, and ensuring water availability during supply shortages.

Importance of Mapping These Features in GIS

1. **Network Connectivity:** Accurate placement of nodes ensures the pipe network behaves correctly in models and simulations.
2. **Operational Control:** Valve mapping supports section-based maintenance, reducing disruption to campus water supply.
3. **Hydraulic Analysis:** Elevation and capacity data from reservoirs feed into models to determine pressure distribution and system efficiency.
4. **Asset Management:** Tracking the age, type, and status of each point feature supports proactive maintenance and system upgrades.

2.3.4 Use of GIS for Utility Management and Decision Support

Geographic Information Systems (GIS) are not just mapping tools; they serve as powerful platforms for **utility management** and **strategic decision support**. In the context of water distribution networks such as that of the University of Benin (UNIBEN) Ugbowo Campus, GIS enables administrators, engineers, and surveyors to visualize infrastructure, assess operational efficiency, predict future needs, and make informed decisions.

Utility Management with GIS

GIS supports the **systematic monitoring and control** of utility assets such as pipes, valves, tanks, and meters. Each element is linked to a spatial location and a set of attribute data, allowing for dynamic updates and effective tracking.

Key utility management tasks supported by GIS include;

1. **Asset Inventory:** All water infrastructure components (e.g., pipe materials, installation dates, diameters) are cataloged and georeferenced. This allows for fast retrieval of data during repairs or upgrades.
2. **Inspection and Maintenance Scheduling:** GIS can be programmed to flag pipes or valves due for inspection based on age or usage patterns. It allows staff to visualize which assets require maintenance and plan routes accordingly.
3. **Leak Detection and Response:** When a leak is reported, GIS helps identify the nearest valve to isolate the flow. This reduces service disruption and prevents unnecessary shutdowns of unaffected areas.
4. **Work Order Management:** GIS-based systems allow for the integration of maintenance requests and work orders, helping to manage tasks spatially and prioritize interventions by severity or location.

Role of the Surveyor

For GIS to be effective in utility management, accurate spatial data is essential. Surveyors ensure that all water infrastructure components are precisely located, up-to-date, and well-documented. They collect and update the GIS database using tools such as GNSS receivers, total stations, and field data collection apps. Their role is foundational to the reliability of any decision made using GIS.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

This study was carried out within the University of Benin (UNIBEN), Ugbowo Campus, situated in Benin City, the capital of Edo State, Southern Nigeria. The campus lies within the administrative boundaries of Egor Local Government Area (LGA) and serves as a major academic, residential, and administrative hub. It plays a crucial role in the socio-economic landscape of the state.

Geographically, the campus is located between latitude 6°24'N and 6°26'N, and longitude 5°36'E and 5°38'E. It is bordered by the Lagos–Benin Expressway and shares proximity with adjoining communities such as Ekosodin, Uselu, and Isihor. The Ugbowo Campus occupies an estimated land area of 6.5 square kilometres (650 hectares).

According to the National Population Commission (NPC, 2006), Egor LGA had a recorded population of 339,899 during the 2006 national census. With an assumed annual growth rate of 2.6%, the projected population of Egor LGA by 2025 is over 500,000. The university community constitutes a significant portion of this population. Current estimates suggest that the Ugbowo Campus accommodates approximately 55,000 to 60,000 individuals daily, including students, academic and non-academic staff, and visitors. Specifically, there are about 45,000 enrolled students, with an estimated 4,000 university personnel, and several thousand daily visitors including vendors, contractors, and temporary workers.

The campus terrain is gently undulating, and the environment is characteristic of the tropical rainforest climate, with a distinct wet season (April–October) and dry season

(November–March). These environmental conditions influence both surface water flow and underground infrastructure design, necessitating efficient planning and monitoring of utility systems.

Despite having a network of boreholes, pumping stations, overhead tanks, and buried pipelines, the campus water distribution system suffers from a lack of comprehensive geospatial data and regular infrastructure audits. This has led to challenges in maintenance, service delivery, and planning.

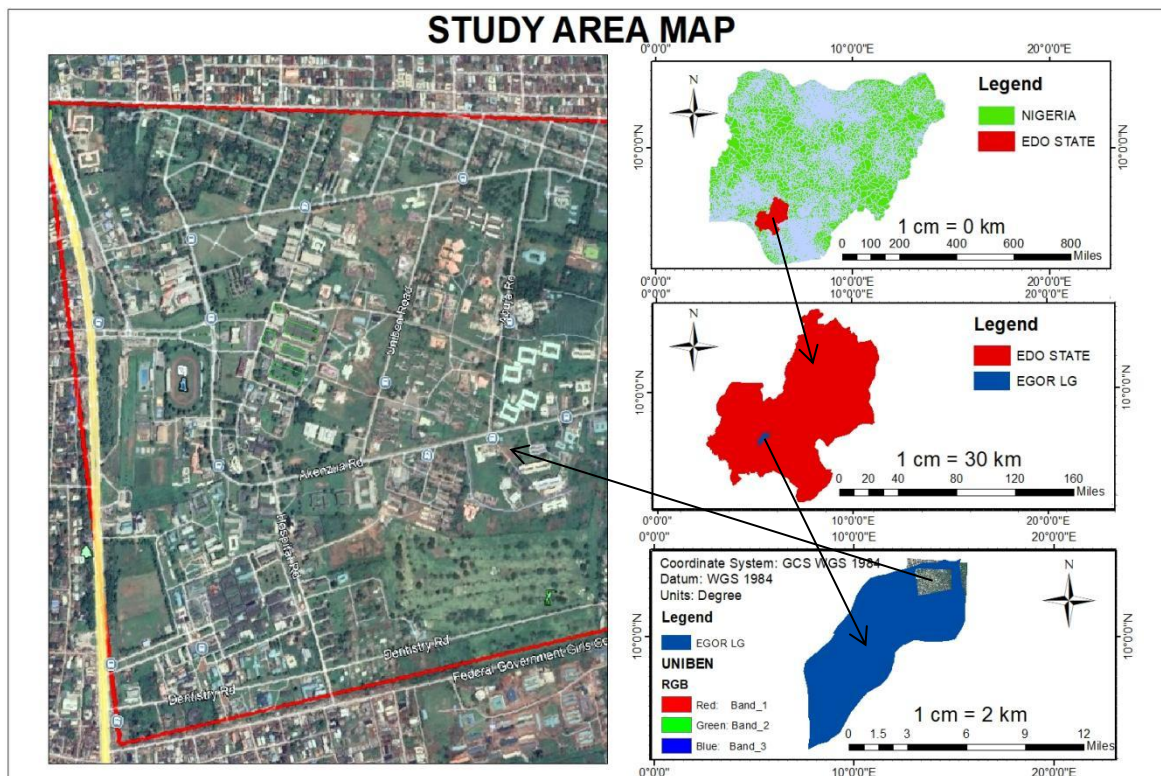


Figure 3.1: Study Area Map

3.2 Sources of Data Collection

Sources of data refer to the key areas where information about a research is derived. In this study, data collection involves the systematic gathering of both spatial and non-spatial information required to analyze and manage the water distribution network of the University of Benin, Ugbowo Campus. Data is collected from both primary and secondary

sources to ensure a comprehensive understanding of the existing infrastructure and support the development of a GIS-based management system.

Primary data were obtained directly from the field through the use of geospatial surveying tools and direct observations. Measurements were taken to capture the coordinates of water infrastructure components such as pipelines, boreholes, overhead tanks, and control valves. The physical layout of the water network were verified on site to validate existing documentation and detect undocumented or outdated installations. In addition, interviews were conducted with relevant university staff to obtain operational information that is not available in mapped form. Observations during field visits also provided insights into the functional condition of the infrastructure.

Secondary data was sourced from institutional records, existing layout plans, and published population data. These materials were used to support spatial referencing, demographic estimation, and infrastructure modeling. Existing maps and drawings obtained from the university's works and physical planning departments guided me in the digitization process. Satellite imagery and campus base maps aided in georeferencing and served as contextual backdrops for mapping the water infrastructure. Supporting literature and previous studies was also consulted to strengthen the methodological framework and ensure best practices are applied during data processing and analysis.

3.2.1 Softwares

The Arc GIS 10.8 software was employed for the statistical processing of spatial digital data, specifically with the bi-variate statistical model.

Google Earth Pro was also used for extracting and interpreting satellite imagery, obtaining geographic context, and validating field-collected data.

3.2.2 Equipments

GPS Receiver was used to capture accurate coordinates (latitude, longitude, and elevation) of boreholes, pipelines, tanks, and other water infrastructure features.

Digital Camera or Smartphone was also utilized for taking geotagged photographs of utility features and field conditions to support visual verification during data processing.

Computer/Laptop with GIS and CAD Software was also useful for analysis of data.

3.3 Method of Data Analysis

The method of data analysis in this study involved the application of both geospatial and statistical tools to evaluate and optimize the water distribution network of the UNIBEN Ugbowo Campus. The analysis focuses on integrating spatial and non-spatial data to provide a comprehensive understanding of the current infrastructure, future water demand, and the overall functionality of the distribution system.

To begin with, data collected from field surveys and secondary sources such as existing maps, demographic reports, and remote sensing images was processed, structured, and analyzed using ArcGIS 10.8 and Google Earth. These software platforms served as the primary environments for spatial data visualization, integration, and analysis, offering the capabilities necessary to build, manipulate, and interpret the geospatial components of the water distribution system.

The first step in the analysis involved the integration of field data with the spatial base maps of the UNIBEN campus. These base maps, which represent the foundational geographic framework, were imported into ArcGIS and georeferenced to ensure consistency across all spatial layers. This georeferencing process aligned the dataset within

a common coordinate system, facilitating accurate spatial analysis and overlay of information.

Following georeferencing, the physical components of the existing water distribution system such as pipelines, valves, storage tanks, boreholes, and distribution nodes are digitized. This digitization process resulted in the creation of multiple thematic GIS layers, each representing a specific aspect of the infrastructure. These layers collectively formed a geospatial database that provides a digital representation of the entire water supply system across the study area.

To further improve the integrity and usefulness of the spatial data, topological analysis was conducted within ArcGIS. This step involved verifying the connectivity, direction of flow, and spatial relationships among the various features in the distribution network. By analyzing topology, the presence of spatial errors such as dangling lines, gaps, overlaps, or disconnected segments was identified and corrected. This process is essential for ensuring that the spatial network model can support accurate flow simulations and decision-making regarding infrastructure planning.

A Digital Elevation Model (DEM) was also generated for the UNIBEN Ugbowo campus to provide detailed terrain and elevation data. Elevation values extracted from the DEM will be analyzed to identify high and low points within the study area. This terrain analysis informed decisions regarding the placement and design of infrastructure such as elevated storage tanks, booster pumps, and boreholes, as water pressure and flow within a gravity-fed system are largely influenced by elevation differences.

In parallel with the spatial analysis, population projection was carried out to estimate the campus population from 2015 to 2040. The base year population figure, which comprises

the estimated number of students, academic staff, non-academic staff, and other residents, served as the input for this analysis. The compound growth formula was applied using a predefined growth rate to forecast population changes over the 25-year design period. This projected population data was critical for estimating future water demand.

The per capita daily water consumption was assumed to be a standard value for institutional and academic environments. To accommodate potential system inefficiencies, losses due to pipe damage, leakages, and overflow from tanks, a safety factor was introduced into the demand calculation. Using these figures, the average daily water demand and maximum water demand for the projected population was calculated. These values represents the total volume of water that must be delivered to the campus each day to meet the needs of its population.

The final stage of analysis focuses on the generation of thematic maps to visually represent the outcomes of the study. These maps includes representations of demand zones, elevation contours, network infrastructure, and service coverage areas. By presenting complex data in a visual format, these outputs facilitated interpretation, highlight infrastructure deficiencies, and support informed decision-making regarding system upgrades or new installations.

3.3.1 Field Work

The field work included visits to the study area to verify the existing water distribution infrastructure identified through remote sensing and preliminary mapping. This involved obtaining the geographical coordinates of key components such as pipelines, valves, reservoirs, and overhead tanks. The field visit also encompassed the verification of mapped features that were digitally extracted, ensuring that the spatial representations of the water network accurately reflected on-ground conditions.

3.3.2 Visit to the UNIBEN Water Scheme

As part of the data collection process for this project, a field visit was carried out to the University of Benin (UNIBEN) Water Scheme. The objective of the visit was to understand the existing water distribution infrastructure, gather technical insights on its components, and validate spatial data collected through remote sensing and secondary sources.

The water scheme is strategically located at the highest elevation point on the UNIBEN Ugbowo campus, which facilitates gravitational water distribution across the campus. This elevation advantage eliminates the need for booster pumps in the primary water transmission process, making the system more energy-efficient.

Water is sourced entirely from underground boreholes, with major pumping operations centered at three locations: the UNIBEN Water Scheme (main station), Basement, and Hall 1 pumping station. Additionally, some locations such as faculty buildings and residential zones are equipped with their own local boreholes and smaller storage reservoirs to serve as backup sources in the event of a mainline failure.



Figure 3.2: pump at the Uniben Water Scheme

The storage infrastructure includes overhead and surface metal/concrete tanks positioned strategically at the uniben water scheme. These tanks ensure a stable supply by maintaining pressure and serving as buffers during high-demand periods.



Figure 3.3: Overhead Steel Tank at the Uniben Water Scheme



Figure 3.4: Concrete Overhead Tank at the Uniben Water Scheme

The distribution process is automated, with water pumped continuously 24 hours a day. However, water distribution across the campus is carried out in scheduled intervals, totaling approximately 13 hours daily, broken down as follows:

1. 3:00 AM – 10:00 AM for Mornings
2. 12:00 PM – 2:30 PM
3. 4:00 PM – 8:00 PM

The distribution network is composed of different pipe categories:

1. **Main Pipes:** Combination of Asbestos Cement (AC) and PVC, typically 8 inches in diameter.
2. **Service Pipes:** Mostly AC pipes, with diameters ranging from 3 to 4 inches.
3. **Household/Hostel Connections:** PVC pipes, typically 1.5 inches.
4. **Internal Room/Unit Connections:** PVC pipes, 0.5 to 0.75 inches in diameter.

The system is divided into two major distribution zones managed by automated control valves:

Valve A (also called *Student Valve*): Serves student hostels, administrative offices, and parts of the Junior Staff Quarters (JSQ).

Valve B: Primarily supplies water to residential quarters and some office buildings.



Figure 3.5: Valve at the Uniben Water Scheme

Routine weekly inspections are conducted on the distribution pipelines to detect and address any signs of leakage or faults. These maintenance practices help ensure reliability and reduce water loss across the network.

While the water is sourced from boreholes, the specific treatment method used before distribution was not disclosed during the visit. However, it was confirmed that routine maintenance and system flushing are carried out annually to prevent the build-up of sediments and contaminants in the system.

A schematic sketch of the pipeline network was provided during the visit, which served to clarify the layout and operational zones within the campus water supply system.

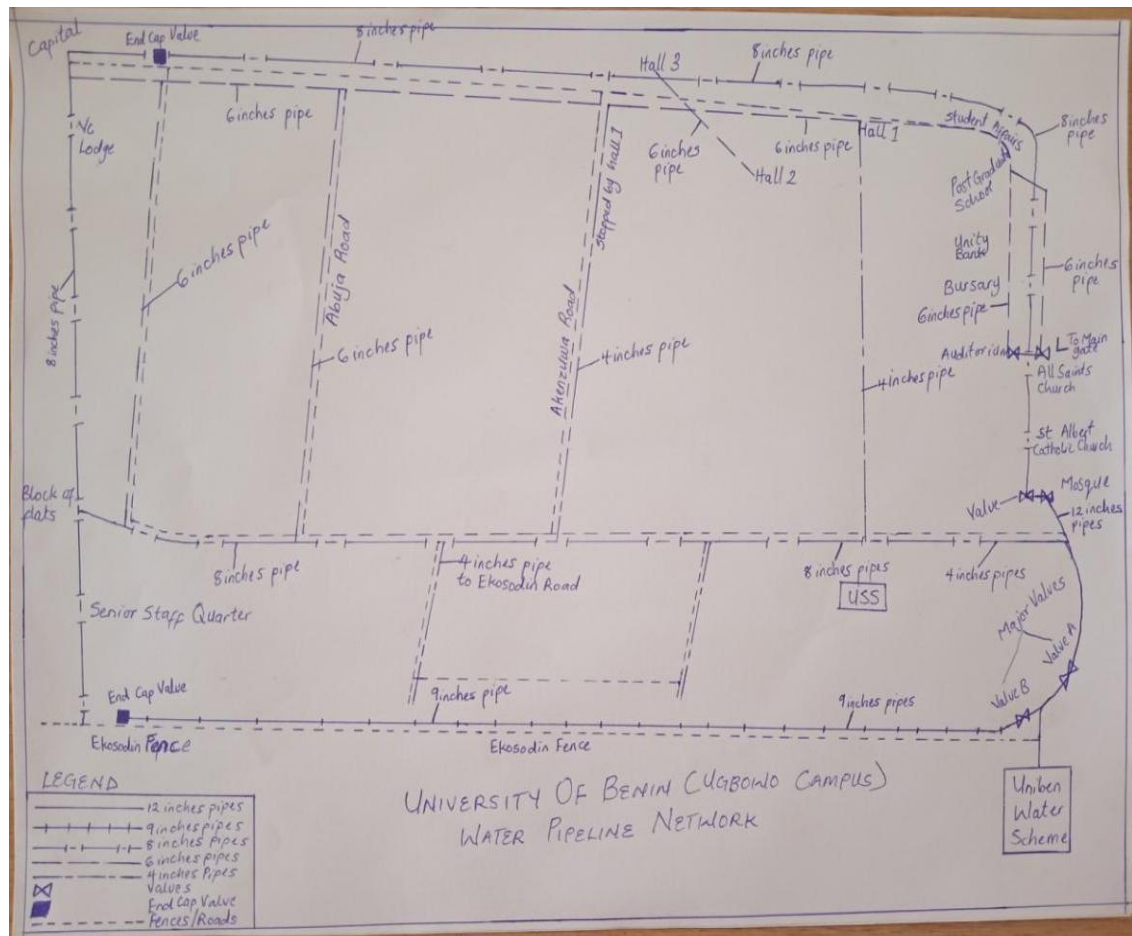


Figure 3.6: Sketch of the UNIBEN Water Pipeline Network

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the results obtained from the GIS-based analysis and field investigation of the University of Benin (Ugbowo Campus) water distribution network. The results are based on the integration of field data, spatial analysis, population estimation, and water demand projections. The analysis also includes the development and assessment of the Digital Elevation Model (DEM), 3D terrain visualization, and pipeline network mapping, which together form the basis for understanding the topography and flow dynamics within the study area. The discussions that follow are based on actual findings derived from the data collection, processing, and analysis stages of the project.

All maps produced are in WGS84 UTM Zone 31 N coordinate system.

4.1 Digitization and Georeferencing of Pipelines, Valves, Tanks, and Pump Stations

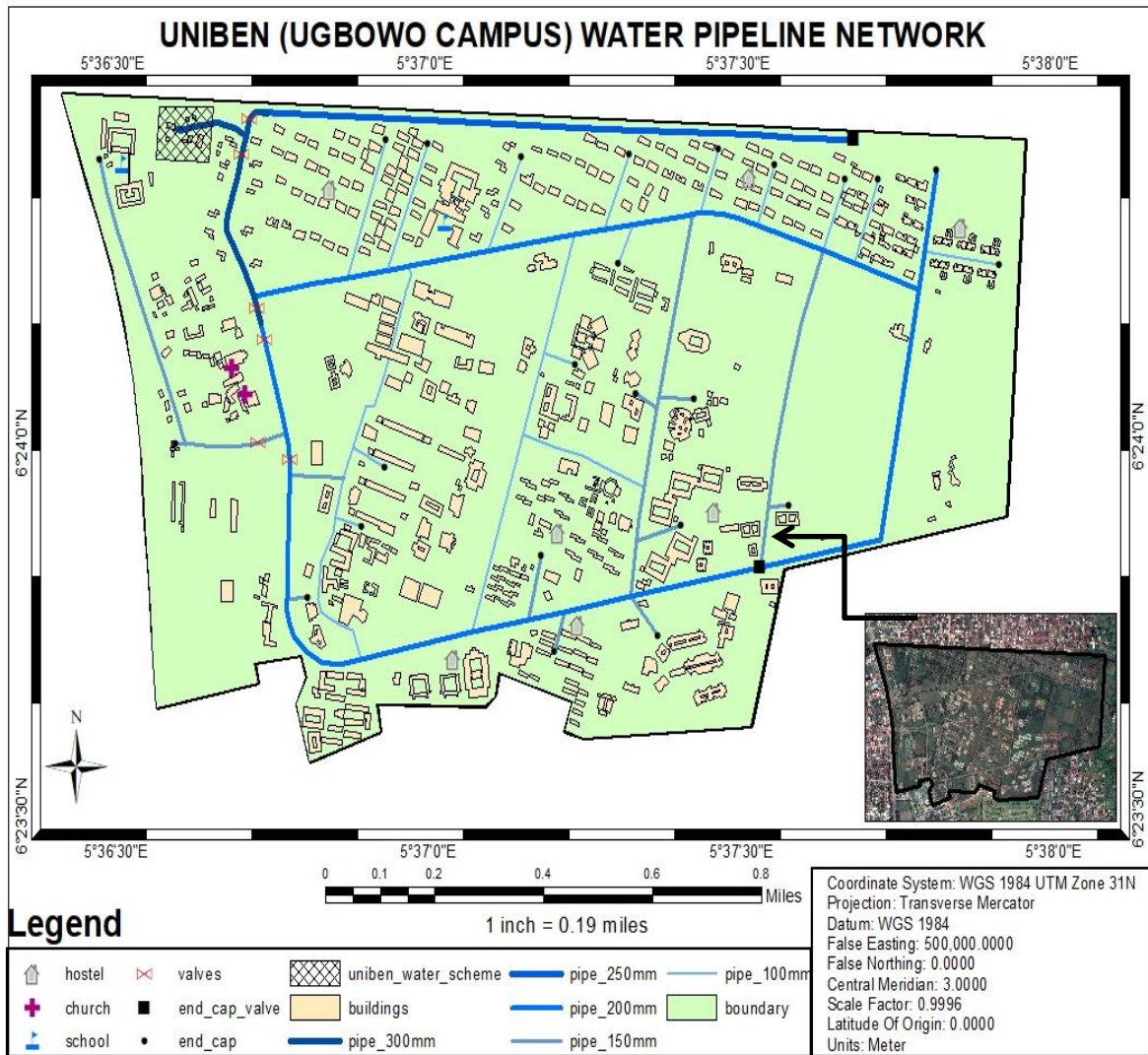


Figure 4.1: uniben water pipeline network

The UNIBEN water pipeline network was mapped and digitized from the coordinates collected during fieldwork. The network is well-structured, consisting of main, distribution, and service pipelines, each serving specific purposes in conveying water from the main source to different parts of the campus.

Table 4.1: Pipe categories and their functions

| Pipe Category | Material Type | Diameter | Function |
|--------------------|----------------------------|-------------|--|
| Main Pipes | Asbestos Cement (AC) & PVC | 9-12 inches | Convey water from the water scheme to major distribution zones |
| Distribution Pipes | AC & PVC | 6-8 inches | Supply water from main lines to service lines |
| Service Pipes | AC | 4-6 inches | Deliver water directly to buildings and end users |

The main transmission lines originate from the UNIBEN water scheme near the works department and run through the central parts of the campus, connecting major academic and residential zones. I identified several control valves and end caps that help regulate flow and isolate sections during maintenance. The presence of these control points shows that the system was designed with operational flexibility in mind.

During my field visits, I observed that water distribution occurs in intervals, usually between 3:00–10:00 a.m., 12:00–2:30 p.m., and 4:00–8:00 p.m. This schedule ensures fair distribution across all zones while maintaining pressure balance in the network. Maintenance is carried out weekly by the Works Department to identify and fix leakages.

However, one major challenge I noticed is the age and condition of some of the Asbestos Cement (AC) pipes. These pipes are old, brittle, and prone to leakage, especially under fluctuating pressure. Replacing these sections with PVC or HDPE pipes would greatly improve efficiency and reduce water loss.

The GIS mapping also showed that the pipeline layout is quite extensive and covers most developed parts of the campus, including academic buildings, staff quarters, hostels, and

administrative offices. The ability to visualize all pipelines on a single map made it easier to analyze connectivity and identify areas that might require expansion.

4.2 Generate DEM maps for elevation-based planning of tanks and flow paths

4.2.1 2D DEM Map Interpretation

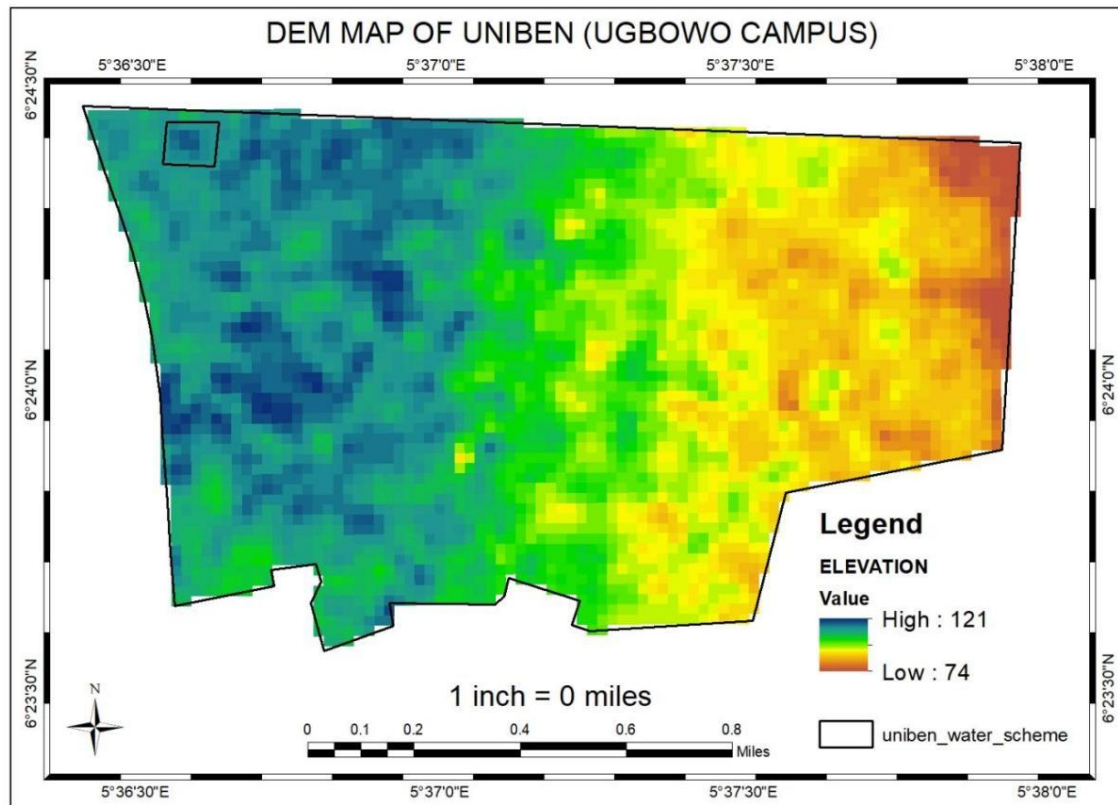


Figure 4.2: DEM map of uniben

The DEM of UNIBEN Ugbowo Campus was generated from elevation data obtained during the survey and supplemented with SRTM data to fill gaps. The map clearly shows the elevation variation across the entire campus, with values ranging from approximately 74 m to 121 m above mean sea level.

From the 2D DEM map, it is evident that the eastern and northeastern parts of the campus are located on higher grounds, while the western and southwestern sections are lower in

elevation. The central areas around the lecture complexes and the main administrative block fall within mid-range elevations.

This topographic variation plays a major role in how water moves through the network. The higher areas tend to have relatively lower water pressure, especially during periods of high consumption, while the lower areas experience higher pressures due to gravitational flow. The DEM helped me identify natural flow directions and potential pressure zones, which can influence where additional storage tanks or control valves may be required in the future.

Another key observation from the DEM map is that most of the existing water pipelines were laid in a way that aligns with the natural slope, indicating that the design originally took gravity-fed flow into consideration. This confirms the practicality of the layout and supports the use of the terrain for efficient distribution without depending heavily on pumping systems.

4.2.2 3D DEM Analysis

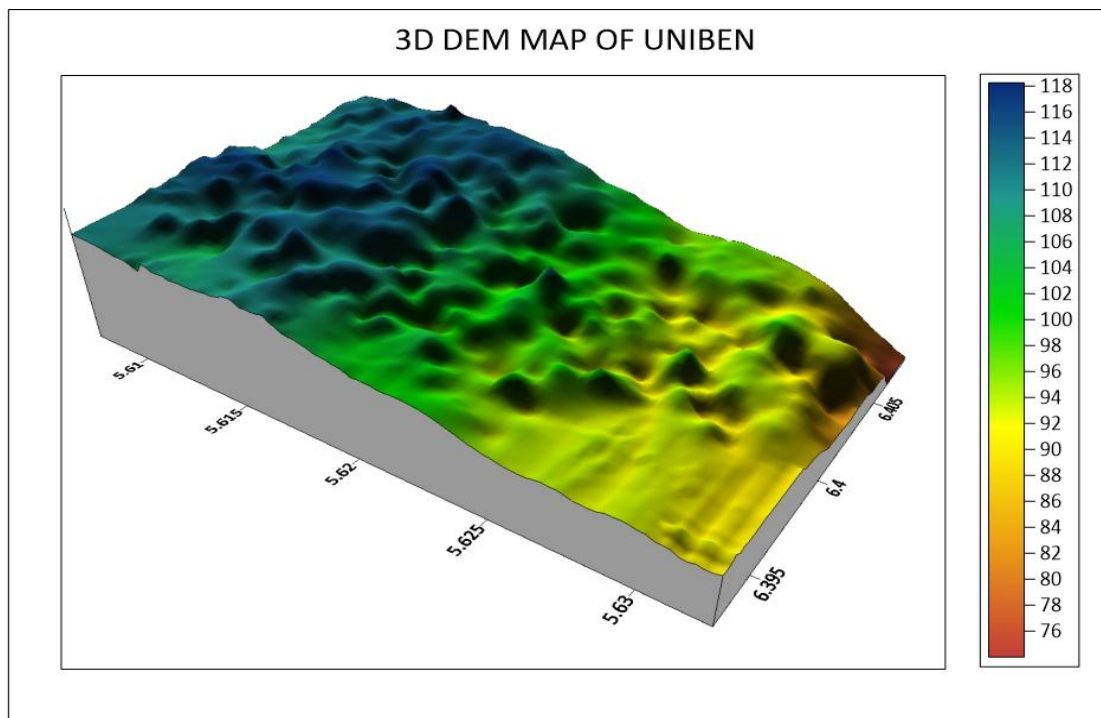


Figure 4.3: 3D terrain map of uniben

The 3D DEM visualization provided a more realistic and detailed understanding of the terrain. It highlights the undulating nature of the campus and shows how elevation differences are distributed spatially.

From the 3D map, I observed that the UNIBEN Water Scheme is strategically located in one of the highest elevation zones. This positioning is deliberate and ideal because it allows gravity to assist in distributing water to the rest of the campus. The 3D DEM also revealed that the terrain gently slopes toward the southwestern boundary, which aligns with the direction of the main pipelines leading toward the student hostels and residential quarters.

This terrain orientation confirms that the water distribution system was designed to take advantage of natural elevation, minimizing the need for additional pumping. It also means that most of the flow pressure generated from the water scheme can be sustained across the network with minimal energy input.

During the 3D analysis, I was able to rotate and view the surface from different perspectives, which provided insight into areas where water might accumulate or where drainage might be problematic. Such areas can experience reduced flow or leakage if the pipes are not properly aligned with the slope.

The 3D DEM model gave me a better sense of the campus's topographical pattern, which was very useful in validating the physical layout of the pipeline network obtained during the field survey.

4.3 Estimate future population growth and daily water demand (2015–2040)

4.3.1 Population Estimation

In this study, a design period of 25 years was assumed, with the base year set as 2015 and the design horizon extending to 2040. A daily water consumption rate of 150 litres per capita per day (LPCD) was assumed, in accordance with institutional planning standards for academic environments. The total volume of water required was calculated based on the projected population of the University of Benin (UNIBEN), Ugbowo Campus, using a compound growth rate model derived from the base population in 2006.

The standard population projection formula is:

$$P_n = P_o \times (1 + r/100)^n \quad (4.1)$$

Where:

P_n = Projected population after *n* years

P_o = Initial population in 2006

r = Annual growth rate (2.6 % according to NPC, 2006)

n = Number of years from 2006

The population of University of Benin, Ugbowo Campus as at 2006 was estimated to be about 32,000.

Population Estimation in 2015 (*n* = 9 years):

$$P_n = 32,000 \times (1 + 2.6/100)^9$$

$$P_n = 32,000 \times (1.026)^9$$

$$P_n \approx 32,000 \times 1.260$$

$$P_n \approx 40,320$$

Population Estimation in 2040 (n = 34 years):

$$P_n = 32,000 \times (1.026)^{34}$$

$$P_n \approx 32,000 \times 2.393$$

$$P_n \approx 76,576$$

Percentage Increase in Population (2015–2040):

$$= [(76,576 - 40,320) / 40,320] \times 100$$

$$\approx (36,256 / 40,320) \times 100$$

$$\approx 89.9\%$$

The population analysis was carried out using the compound growth rate model based on a 2006 baseline population of 32,000 and an annual growth rate of 2.6%. The projection shows a consistent increase over time, reaching 40,320 in 2015 and 76,576 in 2040.

Table 4.2: Population projection

| Year | Population |
|------|------------|
| 2006 | 32,000 |
| 2015 | 40,320 |
| 2040 | 76,576 |

The results indicate a significant population increase of about 89.9% between 2015 and 2040. This clearly shows that the demand for water will continue to rise in the coming years as student and staff populations grow.

This projection was essential because it provided a foundation for estimating future water demand and assessing whether the existing infrastructure can meet the expected load. From this analysis, it is clear that the water distribution network must be expanded and reinforced to accommodate future needs.

4.3.2 Water Demand Estimation

In estimating the water demand for the University of Benin Ugbowo Campus, a per capita daily water consumption of 80 litres was assumed as stated above. A safety factor of 1.5 was applied to account for losses due to leakage, pipe bursts, and reservoir overflows.

The average daily water demand was calculated using the formula:

$$\text{Average Daily Demand} = \text{Population} \times \text{Per Capita Consumption} \times \text{Safety Factor} \quad (4.2)$$

To account for peak usage, the maximum daily demand was obtained by multiplying the average daily demand by 1.2, as follows:

$$\text{Maximum Water Demand} = 1.2 \times \text{Average Daily Demand} \quad (4.3)$$

For the Year 2015:

$$\text{Population (2015)} = 40,320$$

$$\text{Maximum Demand (2015)} = 40,320 \times 150 \times 1.5 \times 1.2$$

$$\text{Result} = 10,886,400 \text{ litres/day}$$

For the Year 2040:

$$\text{Population (2040)} = 76,576$$

$$\text{Maximum Demand (2040)} = 76,576 \times 150 \times 1.5 \times 1.2$$

Result = 20,675,520 litres/day

The total daily water demand was estimated using a per capita consumption rate of 150 litres per person per day and applying a safety factor of 1.5 with a peak factor of 1.2. The maximum daily demand for 2015 was 10,886,400 litres/day, while for 2040, it was 20,675,520 litres/day.

Table 4.3: Water demand estimation

| Year | Population | Max. Water Demand (L/day) |
|-------------|-------------------|----------------------------------|
| 2015 | 40,320 | 10,886,400 |
| 2040 | 76,576 | 20,675,520 |

The results show that by 2040, the campus will require nearly double the current volume of water. This indicates the need for additional water sources or increased pumping capacity in the long term.

From my observations at the water scheme, the current pumping system can handle the present demand, but with the projected growth rate, there will be a need for either more boreholes, larger storage tanks, or a reinforced supply system to maintain reliability. The GIS database created from this project will serve as a useful tool for future planning and optimization of the network.

4.4 Discussion of Findings

From the overall analysis, several key points emerged. The DEM analysis confirmed that topography plays a significant role in determining the flow pattern and pressure distribution across the campus. The 3D model made it easier to visualize how elevation differences affect supply. The positioning of the UNIBEN water scheme at a high elevation is a major advantage because it allows water to flow naturally by gravity to lower areas, reducing energy costs.

The pipeline mapping revealed that while the existing network is well distributed, some of the materials are outdated. The reliance on AC pipes poses maintenance and efficiency challenges. During field inspections, some sections were found to be leaking or heavily corroded. Upgrading these sections with PVC or HDPE would improve flow efficiency and reduce maintenance costs.

The population and water demand projections clearly show that the current infrastructure, although functional, may not be adequate in the long term. Without capacity expansion, the system could experience pressure drops and inconsistent supply, especially in higher zones.

The integration of GIS into this project made it easier for me to analyze, visualize, and interpret the data in ways that would not have been possible using manual methods. It allowed me to understand spatial relationships between elevation, pipeline routes, and service coverage. The analysis also supports decision-making for infrastructure improvement, pipe replacement, and long-term system management.

Table 4.4: Findings

| Parameter | Findings | Implications |
|--------------------------------|--------------------------------|---|
| Elevation Range | 74–121 m | Clear elevation gradient, suitable for gravity-fed distribution |
| Water Scheme Location | High elevation zone | Ideal for gravity flow across campus |
| Pipeline Materials | AC and PVC | Some sections need replacement |
| Water Distribution Duration | 13 hours/day | Controlled intervals maintain pressure |
| Population Growth | 32,000 → 76,576 | Nearly 90% increase by 2040 |
| Water Demand Growth | 10.89 → 20.68 million L/day | Future infrastructure expansion required |

Overall, the results confirm that GIS is a powerful tool for improving water supply efficiency, supporting maintenance operations, and ensuring sustainable management of institutional water resources.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The successful completion of this project titled “*Water Distribution Network Analysis and Management of UNIBEN Ugbowo Campus Using GIS*” has clearly demonstrated the effectiveness of Geographic Information Systems (GIS) as a valuable analytical and management tool in utility infrastructure studies.

From the results and analysis presented, it is evident that GIS provided a platform to integrate spatial and non-spatial data, enabling a comprehensive understanding of the UNIBEN water distribution network. Through data acquisition, digitization, georeferencing, and analysis, a spatially referenced geodatabase was successfully developed, reflecting the true structure of the campus water infrastructure.

The Digital Elevation Model (DEM) and its 3D visualization revealed the influence of terrain on water flow and pressure distribution across the campus. The higher elevation zones were confirmed to experience reduced water pressure, while the lower areas received more consistent supply, validating the functionality of the gravity-fed system. The strategic siting of the UNIBEN Water Scheme at the highest elevation further enhances the efficiency of distribution with minimal pumping energy.

The population projection results, based on the compound growth rate model, indicated a substantial increase in population from approximately 40,320 in 2015 to about 76,576 by 2040—representing an 89.9% growth rate. Correspondingly, water demand projections showed that daily consumption will nearly double from about 10.9 million litres per day in

2015 to over 20.6 million litres per day by 2040. This demonstrates the urgent need for infrastructural expansion and modernization to meet future water requirements.

The pipeline analysis revealed a well-established but aging network composed mainly of Asbestos Cement (AC) and PVC pipes. While the existing design supports the current demand, the aging AC sections present potential risks of leakage, pressure loss, and contamination. Replacing these with modern materials like HDPE would ensure durability and improve hydraulic performance.

In conclusion, the GIS-based approach provided not only an analytical framework but also a visual decision-support system that can be used by the University's Works and Physical Planning Department for continuous monitoring, maintenance scheduling, and infrastructure planning. The integration of geospatial technology into campus water management will enhance operational efficiency, minimize losses, and promote sustainable water resource management.

5.2 Recommendations

1. The existing Asbestos Cement (AC) pipes should be replaced with High-Density Polyethylene (HDPE) or Ductile Iron pipes to reduce leakages, improve pressure maintenance, and enhance water quality.
2. The University should adopt a centralized GIS water management system to continuously monitor the network, update records, and support decision-making for maintenance and expansion.
3. Installing pressure sensors and flow meters at critical points would provide real-time data on flow rates, leak detection, and pressure variations across different zones.

Considering the projected population and water demand increase, additional overhead

tanks and boreholes should be constructed to supplement the existing system, especially in high-demand zones.

4. Regular data collection and geospatial updates should be institutionalized to ensure that the GIS database remains accurate and reflective of ongoing infrastructure changes.
5. Using GIS analysis, areas prone to leakage or failure should be identified proactively, allowing maintenance teams to prevent breakdowns before they occur.

References

- Akinbile, C. O., & Ologunagba, I. B. (2012). *Assessment of water supply and sanitation in a Nigerian university community*. *International Journal of Environmental Science and Development*, 3(2), 97–101.
- Burrough, P. A., & McDonnell, R. A. (1998). *Principles of Geographical Information Systems*. Oxford University Press.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic Information Systems and Science*. John Wiley & Sons.
- Mays, L. W. (2000). *Water Distribution Systems Handbook*. McGraw-Hill Professional.
- World Health Organization (WHO). (2017). *Guidelines for Drinking-water Quality* (4th ed.). Geneva: WHO Press.
- Sule, B. F. (2000). *Water Supply Engineering*. Ilorin: University of Ilorin Press.
- Olawuni, P. O., Adebayo, A. A., & Adeleye, M. I. (2018). *Challenges in utility mapping for institutional water infrastructure in Nigeria*. *Journal of Environmental Studies*, 12(4), 221–229.
- ESRI. (2011). *Understanding GIS: An ArcGIS Project Workbook* (2nd ed.). Redlands, CA: ESRI Press.
- Federal Ministry of Water Resources (Nigeria). (2020). *National Water Resources Master Plan*. Abuja, Nigeria.

Kansal, M. L., & Kumari, R. (2014). *GIS-Based Water Distribution Network Analysis and Planning*. *Journal of Water Resources Planning and Management*, 140(2), 196–206.

Shamsi, U. M. (2005). *GIS Applications for Water, Wastewater, and Stormwater Systems*. CRC Press.

University of Benin Physical Planning Unit. (2024). *Water Distribution Layout and Infrastructure Records [Unpublished internal documentation]*.

Google Earth. (2024). *Imagery of UNIBEN Ugbowo Campus*.

ArcGIS 10.8 Software Documentation. (2020). Environmental Systems Research Institute (ESRI). <https://desktop.arcgis.com/>

Olanrewaju, O. S., & Adewumi, J. R. (2017). *GIS-based pipe network modeling and analysis for water distribution systems*. *Procedia Engineering*, 186, 436–443.

Kumar, M., & Reddy, M. J. (2015). *Urban water supply system planning using GIS and remote sensing*. *Water Resources Management*, 29(3), 913–927.

UN-Habitat. (2020). *The Strategic Role of Water in Sustainable Development*. United Nations Human Settlements Programme.

Singh, V. P., & Woolhiser, D. A. (2002). *Mathematical modeling of watershed hydrology*. *Journal of Hydrologic Engineering*, 7(4), 270–292.

Mogaji, K. A., & Fagbohun, A. O. (2018). *Groundwater potential and aquifer vulnerability assessment in the University of Ibadan using GIS-based DRASTIC model*. *Environmental Earth Sciences*, 77(17), 633.

Olaleye, A. O., & Ogedengbe, K. (2017). GIS modeling and analysis of water supply coverage in Akure, Nigeria. Nigerian Journal of Environmental Sciences and Technology, 1(1), 79–93.

Walski, T. M., et al. (2003). Advanced Water Distribution Modeling and Management. Haestad Press.

U.S. Environmental Protection Agency (EPA). (2002). The Clean Water and Drinking Water Infrastructure Gap Analysis.