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GEOSPATIAL EVALUATION OF TOPOGRAPHIC CONDITIONS FOR WATER DISTRIBUTION NETWORK PLANNING AT THE FEDERAL POLYTECHNIC, OKO PERMANENT SITE, ANAMBRA STATE, NIGERIA.

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Abstract

Adequate water distribution remains one of the major infrastructural challenges in many educational institutions due to inadequate planning and insufficient consideration of terrain characteristics during network design. This study evaluated the Topographic Information System (TIS) of the Federal Polytechnic, Oko Permanent Site, Anambra State, Nigeria, with a view to developing an efficient and sustainable water distribution network. The acquired field observations were processed using Geographic Information System (GIS) techniques and Surfer 12 software to generate Digital Terrain Models (DTMs), spot height maps, contour maps, wireframe models, vector flow maps, and three-dimensional surface models of the study area. The generated topographic products were analyzed to determine terrain elevation, slope characteristics, drainage patterns, flow directions, and suitable reservoir locations for gravity-driven water supply. The analysis revealed significant elevation variations across the campus, with the highest elevations of approximately 200 m in Section A and 182 m in Section B. These elevations provide suitable locations for strategically positioning elevated storage reservoirs to maximize gravity-assisted water distribution while minimizing pumping requirements and operational costs. The vector flow and contour analyses further identified the most appropriate pipeline routes and drainage alignments capable of supporting efficient water conveyance throughout the campus. The study demonstrates that integrating GIS-based topographic information with terrain analysis provides a reliable decision-support framework for water distribution planning, infrastructure development, and campus utility management. The proposed water distribution network offers an economical and technically feasible solution capable of improving water accessibility, reducing energy consumption, and enhancing the long-term sustainability of water supply within the Federal Polytechnic, Oko Permanent Site. The methodology adopted in this study can also be applied to similar institutional and urban environments requiring terrain-based water distribution planning.

Keywords: Geographic Information System (GIS), Topographic Information System, Water Distribution System, Digital Terrain Model, Differential GPS, Topographic Survey, Terrain Analysis, Remote Sensing, Mapping, and Permanent Site

1. INTRODUCTION

Water was an important factor in the location of the earliest settled communities, and the evolution of public water supply systems is tied directly to the growth of cities. In the development of water resources beyond their natural condition in rivers, lakes, and springs, the digging of shallow wells was probably the earliest innovation(Adepoju, 2013). As the need for water increased and tools were developed, wells were made deeper. Brick-lined wells were built by city dwellers in the Indus River basin as early as 2500 BC and wells almost 500 metres deep are known to have been used in ancient China. The water distribution system transports water after purification to the end-user through a network of pipes, which is energy consuming process depending on the characteristic of an area's topographic features, management strategies, and amount of water demanded (Shakeel, 2020). Different types of approach such as quality indicator, energy comparison technique, water network energy efficiency, excess of supplied energy, optimal control and water supply energy were applied to assess the distribution system's energy efficiencies with different management strategies, layouts, and designs. Since water distribution networks mostly are on a large scale and complex, they cannot be evaluated easily

Topographic surveying can be define as the science of drawing maps and diagrams, which simply represent both natural and artificial features of the earth's surface. It is traditionally produced largely by conventional surveying method using analogue equipment. But recently the availability of fast computers and digital data acquisition technology has bought a revolution into map-making through the application of geographic information system (Banister and Raymond, 2020). Topographic surveys will be used to identify and map the contours of the ground and existing features on the surface of the earth or slightly above or below the catchment area of permanent site of Federal Polytechnic Oko (i.e. buildings, streets, walkways, manholes, utility poles, retaining walls, etc).Topographic information system has much application with the generation of Digital Terrain Model in order to serve the need for diverse users in a flexible manner. Where DTM is a digital description or representation of the real world based on observed, measured or computed coordinates in X, Y, Z of the terrain. In the DTM, the 3rd variable Z, can be any other parameter apart from height or quantity existing on the terrain e.g. temperature, rainfall, soil type, land cover type, land use type.This research is to create topographic information system of the permanent siteof Federal Polytechnic, Oko, Orumba North Local Government Area, Anambra State with a view of adequate water distribution system.

2. LITERATURE REVIEW

Adequate water supply and distribution remain a significant challenge in many developing countries, including Nigeria, despite considerable government investment. The problems are multifaceted, including a lack of sufficient data for planning, rapid urbanization, inadequate infrastructure, and inefficient management practices (Amoo*et al.,* 2025). A critical factor often underplayed or ignored is the influence of terrain and topography on the design and efficiency of water distribution networks. The advent of Geographic Information Systems (GIS) and remote sensing technologies offers robust tools to address these challenges by enabling the creation of detailed topographic information systems (TIS) for informed decision-making in water management (Patel &Nihalani, 2023).

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Key Challenges in Developing Countries and Nigeria

Rapid urbanization exacerbates these issues by increasing water demand while straining existing systems. In sub-Saharan Africa, including Nigeria, many urban areas face chronic shortages, with water supply often meeting only a fraction of demand. Factors such as poor institutional frameworks, aging infrastructure, high non-revenue water losses, intermittent supply, and limited integration of spatial data contribute to inefficiencies (Weston, *et al*., 2024). Terrain and topography play a critical but frequently overlooked role. Undulating or hilly landscapes lead to pressure variations, higher pumping costs, increased leakage in steep areas, and inequitable distribution, with higher elevations often experiencing lower pressures and service reliability. In Enugu, Nigeria, for instance, topographic irregularities have aggravated pipe-borne water challenges, with existing networks failing to align with elevation contours, resulting in suboptimal gravity flow and reliance on energy-intensive pumping. Similar patterns appear in other contexts, such as Taiz City, Yemen, where rugged mountainous terrain causes significant head losses (30–40m in high areas), pressure surges in lowlands, and elevated production costs.

Role of GIS, Remote Sensing, and Topographic Data

The advent of Geographic Information Systems (GIS), remote sensing (including LiDAR and SRTM-derived Digital Elevation Models/DEMs), and related geospatial technologies offers powerful tools to address these challenges. These enable the creation of detailed topographic information systems (TIS) for informed decision-making in water management (Patel &Nihalani, 2023). GIS integration supports, terrain analysis for optimal siting of reservoirs at higher elevations to facilitate gravity-fed distribution; network redesign using radial or combined radial/dead-end systems, and hydraulic modeling with tools like EPANET to simulate pressures, flows, and performance (Patel &Nihalani, 2023). In Enugu Urban, South-Eastern Nigeria, Ugwuoti et al. (2023) demonstrated this by using LiDAR-derived spot heights to restructure the WDN. They subdivided the area into 12 zones with reservoirs at elevated points, integrating topography with standard distribution patterns. The redesigned network was validated with EPANET and showed improved efficiency by leveraging gravity flow.

Comparable applications exist elsewhere in Nigeria and in hill areas globally, where GIS-based multi-criteria analysis, DEMs, and route optimization minimize costs, earthworks, and environmental impact while ensuring adequate pressure. Broader literature highlights GIS-remote sensing-EPANET coupling for sustainable WDN management, supporting pressure-dependent demand analysis, leak detection, future demand forecasting, and alignment with SDG (Patel &Nihalani, 2023).

Benefits and Recommendations

Topographic Information Systems (TIS) extend traditional GIS by emphasizing high-resolution elevation data for 3D modeling, slope/aspect analysis, and infrastructure planning. They facilitate better data-driven decisions, future-proofing against urbanization and climate variability. These steps can mitigate terrain effects, reduce energy costs, minimize losses, and improve equity in water access.

3. MATERIAL AND METHODOLOGY

This study adopted a survey and geospatial (GIS-based) research design. According to Creswell and Creswell (2018), a survey research design is appropriate for collecting, analyzing, and interpreting data systematically to address specific research problems. The geospatial component of the design enables the acquisition, processing, and analysis of spatial information required to evaluate the suitability of the existing terrain and water distribution system at the Permanent Site

of Federal Polytechnic, Oko. The design incorporates field observations, topographic surveying, Geographic Information System (GIS) analysis, and hydraulic evaluation to assess how topographic characteristics influence the efficiency and adequacy of water distribution across the study area.

3.1. Source of Data

Both primary and secondary datawere used to assess the importance of topographic surveying in water distribution in the area of study at permanent site of Federal Polytechnic Oko, Orumba North Local Government Area. The primary sources were collected by using Differential Global Positioning System receiver (UNISTRONG G970II PRO DGPS) to gather data from the study area while the secondary data were collected from different related sources, internet, journals, paper works and lecture notes.

3.2. Data Acquisition

Reconnaissance survey is the process of taking a general view of the area given, to know if there is any existing data on ground that can help in execution of the study or any obstruction that can delay the progress of the study and will invariably help in planning on how the project can be successfully executed and at the end of reconnaissance exercise.Based on this fact, site visitation was done to acclimatize with the area using some instrument like tapes, cutlass and writing materials and found out that there were some survey beacons welldensified round the area which were used as reference points for the field work. The information on the beacons were written down and obtain their coordinate details and datum values (reduced level) from the authority in charge of those beacons in the school as shown on Table 1.The artificial features in that area were checked, for instance the road networking of the catchment area in conjunction with drainages and the road networking and drainage facilities were well planned. Also, the width of all the drainages were checked ranging from 0.6m to 1.0m. and as well checked for the depth of the drainage networks in the area with very good gradient at average depth of 0.7 – 1.2m which can aid ease installation of pipes and ease flow of water though the pipes if it would be used as the pipe carriage. In addition, the building structures of different heights, sizes and shapes were checked if they were well situated at different locations round the area and as well other utilities (e.g. electric poles, mast, etc) and were all in strategic places round the campus area.

Table 1 Control Points at Permanent Site

STN ID	EASTING	NORTHINGS	ORTHOMETRIC HEIGHT
GPS005	516116.507	227575.401	185.399
GPS006	516100.517	227763.769	182.551
GPS007	516373.709	227777.523	178.743

4. RESULTS AND DISCUSSION

This operation was performed from digital elevation model generation using Surfer 12 version. The earth is 3-dimensional, most GIS application includes some element of 3-dimenstional analysis of which topographic operations and analysis of surface terrain becomes paramount. Contour, Slope, Aspect and Digital Terrain Model (DTM) generations are considered as the most common uses in application of terrain model use in GIS. The analyses were performed using Surfer 12 version and products generated were: -

Spot height map of the study area
Contour map of the study area
Vector map of the study area
3D surface of the study area

Analysis One: Spot height of the study area

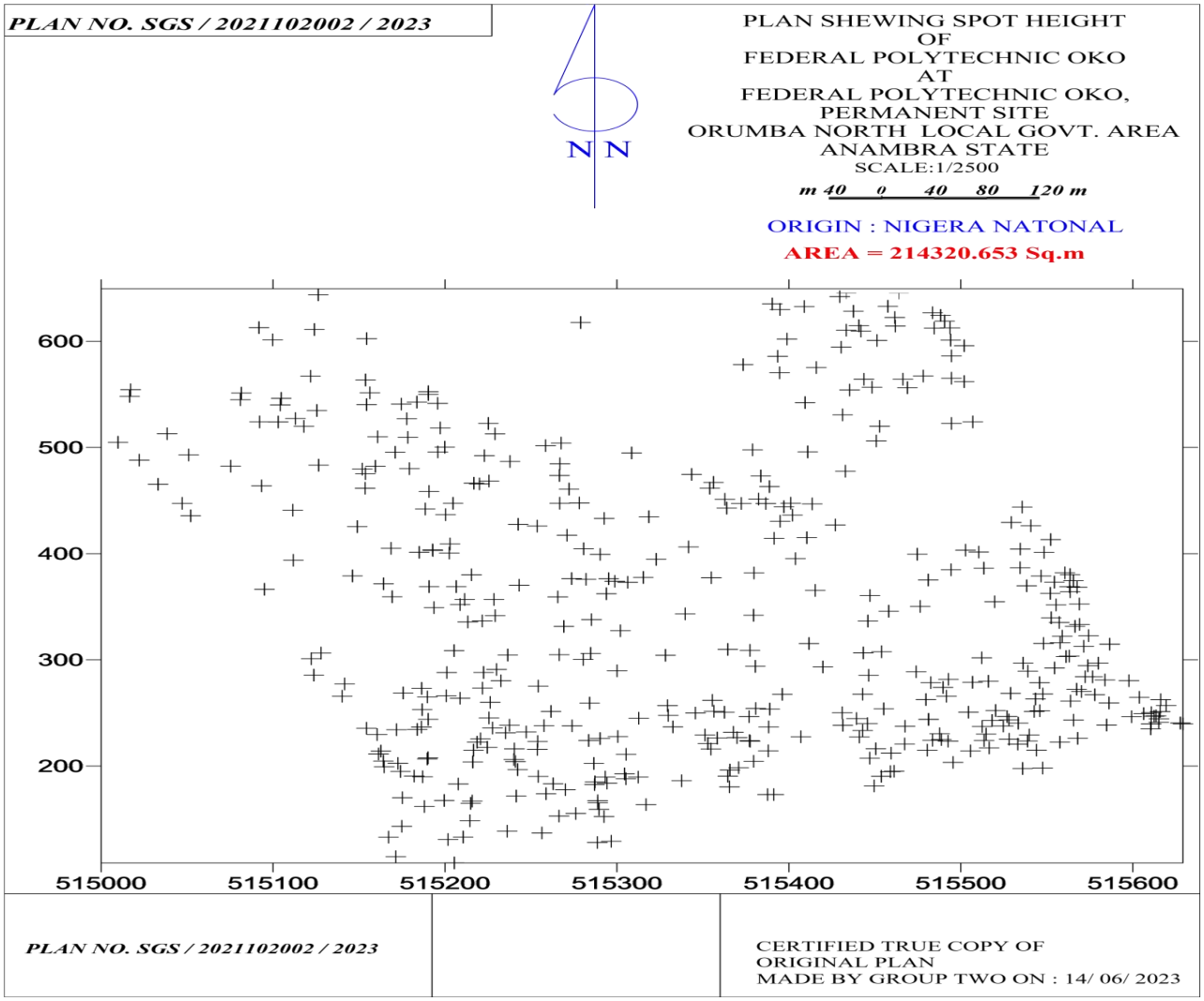
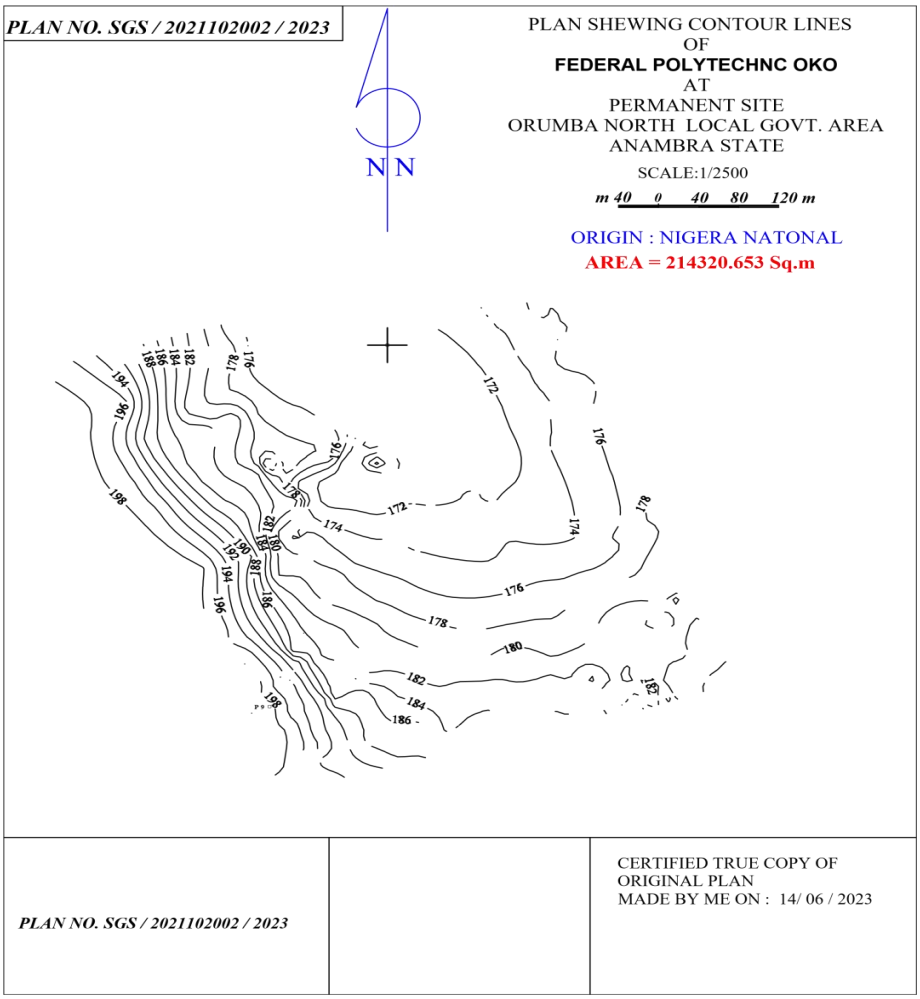


Fig. 1: Spot heights

Query: To determine the elevated points that made up the terrain model of the study area.

Discussion: This map shows the different height of points on the terrain which can be used for interpolation and depicts the hills, valley and mountainous area within the study area. It is also the by-product of contour, TIN, Aspect, Slope, etc of the study area.



Analysis Two: Contour map

Fig. 2 Contour map of the study area

Discussion: Contour lines drawn on a map connecting point of equal elevation. The contour map of the study area is shown in map number SGS/2023/04. This map assists in planning and control of erosion and also water collection point of the study area.

Analysis Three: Wire Frame plan

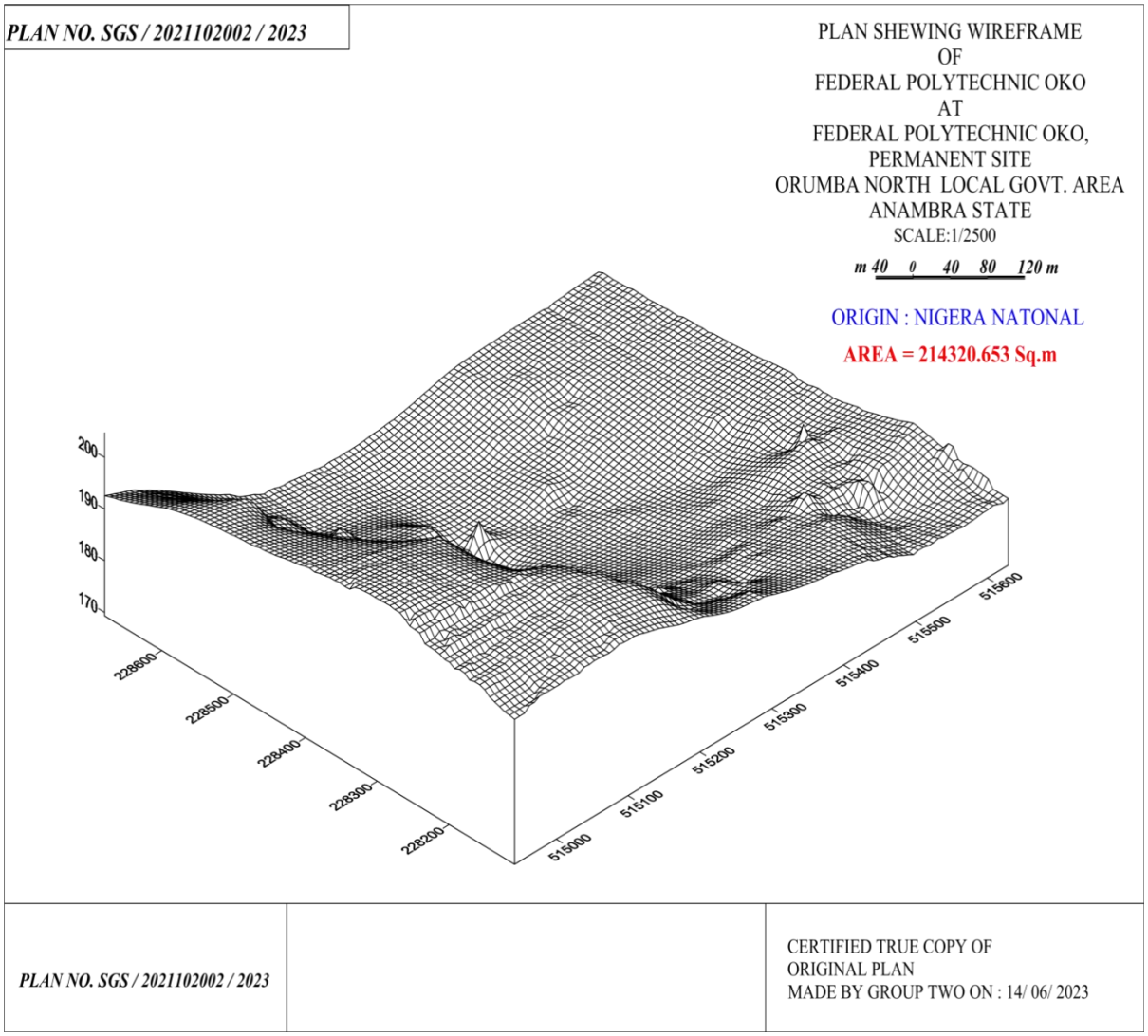
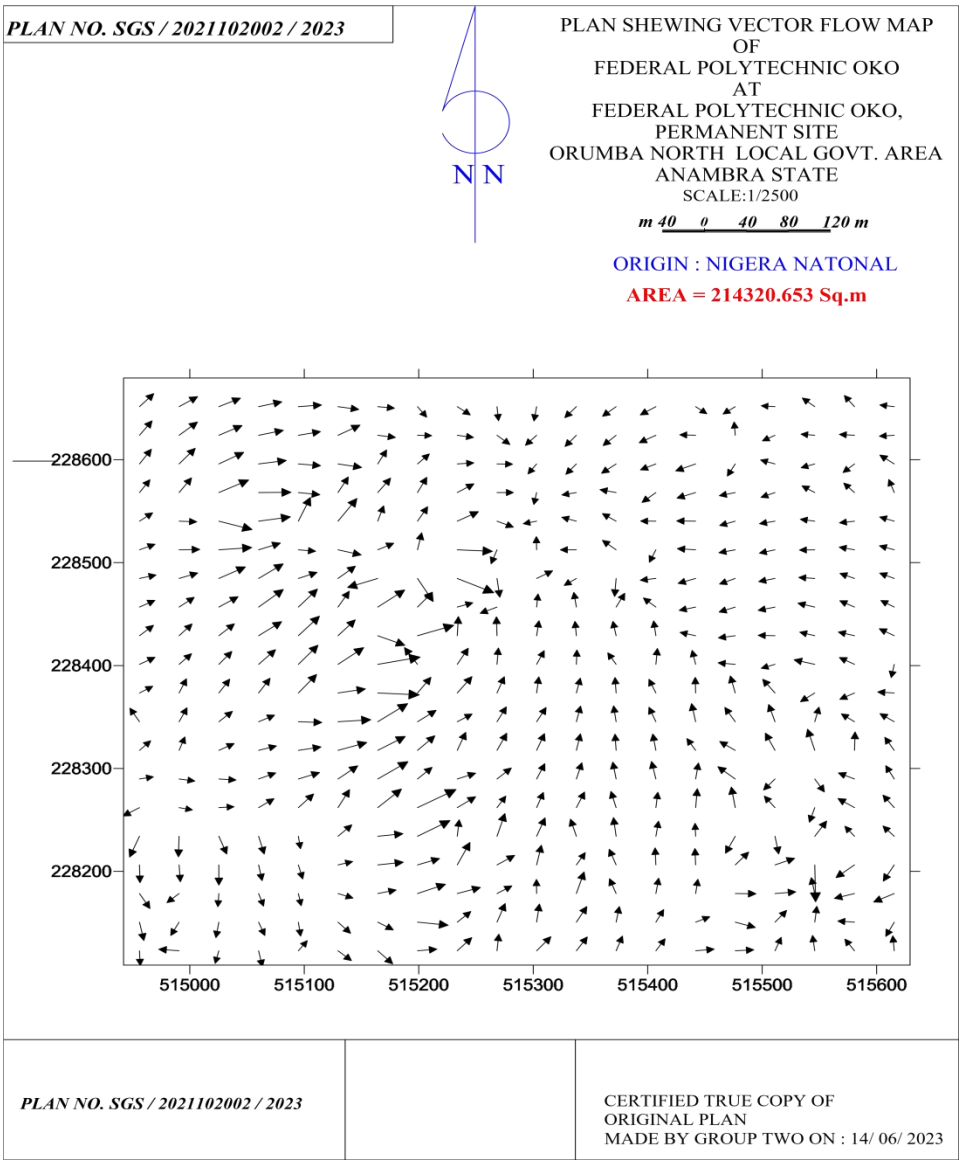


Fig. 3: 3D Wire frame map of the study area

Discussion: Wire Frame map of the research site which was used to represent the surface of the study area. Different colors in the map depict the different ranges of the terrain.



Analysis Four: Vector flow map of the study area

Fig. 4: Vector flow map of the study area

Discussion: The Vector flow map of the research site helped to know the undulation of the landscape and the direction of flow of water in the study area, so that it can help in citing building, drainages, boreholes pipes and other infrastructures. It will also help in flood control because it helps to know the direction of water for proper channel of water.

Analysis Five: 3D surface of the study area

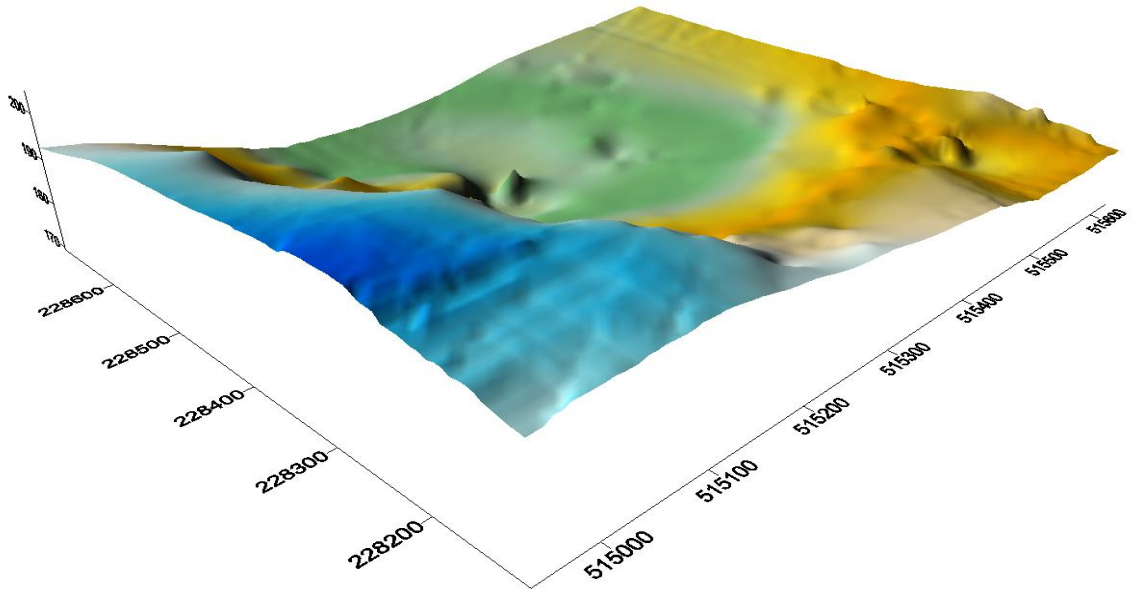


Fig. 5: 3D surface of the study area

Discussion: This shows the nature of the terrain of the study area in different tone of color which describes how the configuration of the study area looks like. This information can be used in designing drainage pattern of the study area.

4.2 Proposed Water Distribution

According to the topographic plan, thhighest points searched out on the two sections, the 200m on the section A and 182m on the section B. If an urban tank is positioned at the peak of 200m on the section A water will be distributed through all the major pipes into all the buildings with ease under normal gravitational force. But in the case of section B, the urban tank has to be positioned on an elevated metallic frame (like 8m high) towards the security post at the first gate because the contour is up to 182m. The proposed water distribution is shown in Fig. 6. It is show as plan number SGS/2023/17.

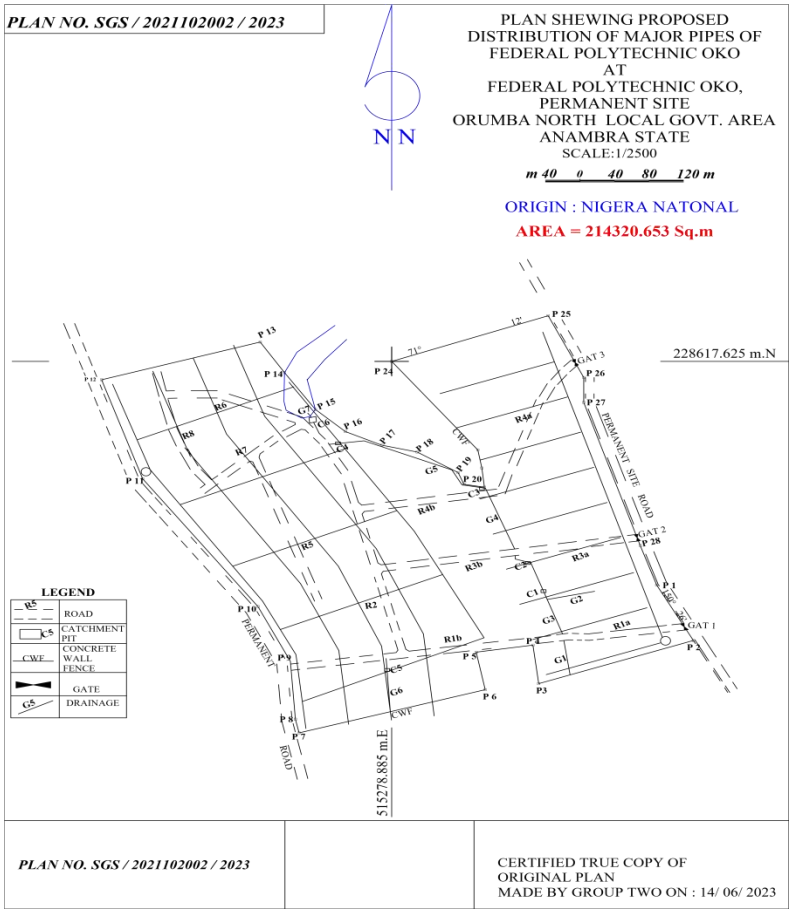


Fig. 7 Proposed water distribution design

5. SUMMARY AND CONCLUSIONS

Topographic data have been the core of a topographic mapping which helped us to determine the terrain models of permanent site part of Federal polytechnic Oko. Application of topographic survey helped to know the possible spot to site the large tank to store water for proper distribution to every corner of the study area. It help to design how the major pipes from the tank can be laid all across the study area so to distribute water closer to the buildings in the study area. The topographic plan gave the assurance that water distributed all across the study area will flow freely under gravitation force to each building with ease.

This research is an eye opening to implementing and knowing where appropriate to stand the urban tank for the study area and how to channel the major water pipes closer to each building in the geographical area. It also reveals some structures (e.g. drainages) to pass sub pipes form one building to the other.

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