ISSN 2229-5518

Overcoming the challenges of terrain irregularity in portable water distribution in Enugu metropolis.

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ABSTRACT

Inhabitants of Enugu metropolis have over the years, suffered untold hardship accessing portable water. Unlike other cities in Nigeria, construction of bore holes is not attainable in the city of Enugu. This is because of the underlining coal deposits. The people now resort to private commercial water vendors that supply water from bore holes established at Ninth (9^{th}) mile in Udi local Government of Enugu State and shallow water wells that sometime dry up during the dry season which are normally constructed within their premises

It is not that there are no streams in the neighbourhood of the city, but the government agency in charge of domestic water supply, Water Corporation, is not living up to expectation. None of the water distribution zones in Enugu urban city can boast of adequate water supply. A pilot project carried out on part of one of the zones revealed that topographic study of the environment was not considered in the design of the distribution network. In the course of the research work, an existing water distribution network of Ekulu East estate was scanned, geo-referenced with the help of the data acquired during ground truthing and digitized. LIDAR (Light Detection And Ranging) satellite imagery of the area was downloaded and spot heights of the area extracted. A superimposition of the spot heights on the digitized map on Surfer software environment depicted the relative heights of the portions of the estate that sparingly access water and portions that do not access water at all. Areas of higher altitude do not access water whereas persons leaving within the areas of lower altitude sparingly access portable water. The is basically because of poor pressure which can only be correct by adequate consideration of the terrain topography in the location of reservoirs, pressure brake tanks , pumps and other facilities.

INTRODUCTION

Providing sufficient water of appropriate quality and quantity to her citizens has been one of the most difficult problems faced by the government of Enugu State. As population grows, the challenge to meet user demands of water also increased. Inhabitants of Enugu metropolis currently depend largely on water transported from boreholes at 9th mile, Udi local government area and bucket-drawn water wells dogged manually by inhabitants within their houses, for their daily water needs. According to the information gotten from the Government Agency in charge of water, Water Corporation, Enugu urban has been classified into nine (9) zones to facilitate water distribution. These zones are; Government Reserved Area (GRA), Ogui, Uwani, New Haven, Independence Layout, Emene, Idaw River/ Achara Layout, Trans-Ekulu and Abakpa. In spite of these efforts, none of these zones can boast of adequate water supply within all its environs. Some sections of these areas are not supplied with water at all, while others experience rickety supply. These inadequacies are mainly as a result of none consideration of the terrain irregularity in location of water reservoirs and in the choice of distribution network/ pattern.

This clue is tapped from a pilot project carried out on one of the zones (GRA), to determine the reason why a section of the area do not enjoy water supply.

STUDY AREA

Enugu city is located between **Lat. 06° , 26’** and **06° , 30’ N** and **Long. 07° , 27’** and **Long. 07° , 37’ E** and lies east of Niger Delta. With a population of about **907,666** (2016 projected population for Enugu North, Enugu South and Enugu East LGAs), it is one of the largest city in Nigeria. Its importance dates back to the colonial days when it served as the capital of the defunct Eastern Region. Subsequently it became the capital of the East Central of Eastern State; it is surrounded by the Udi hills and stands at an elevation between **125m** and **380m** above mean sea level with intervening hills and valleys.

Fig 1. Administrative Map of Nigeria from Wikipedia Image (2016)

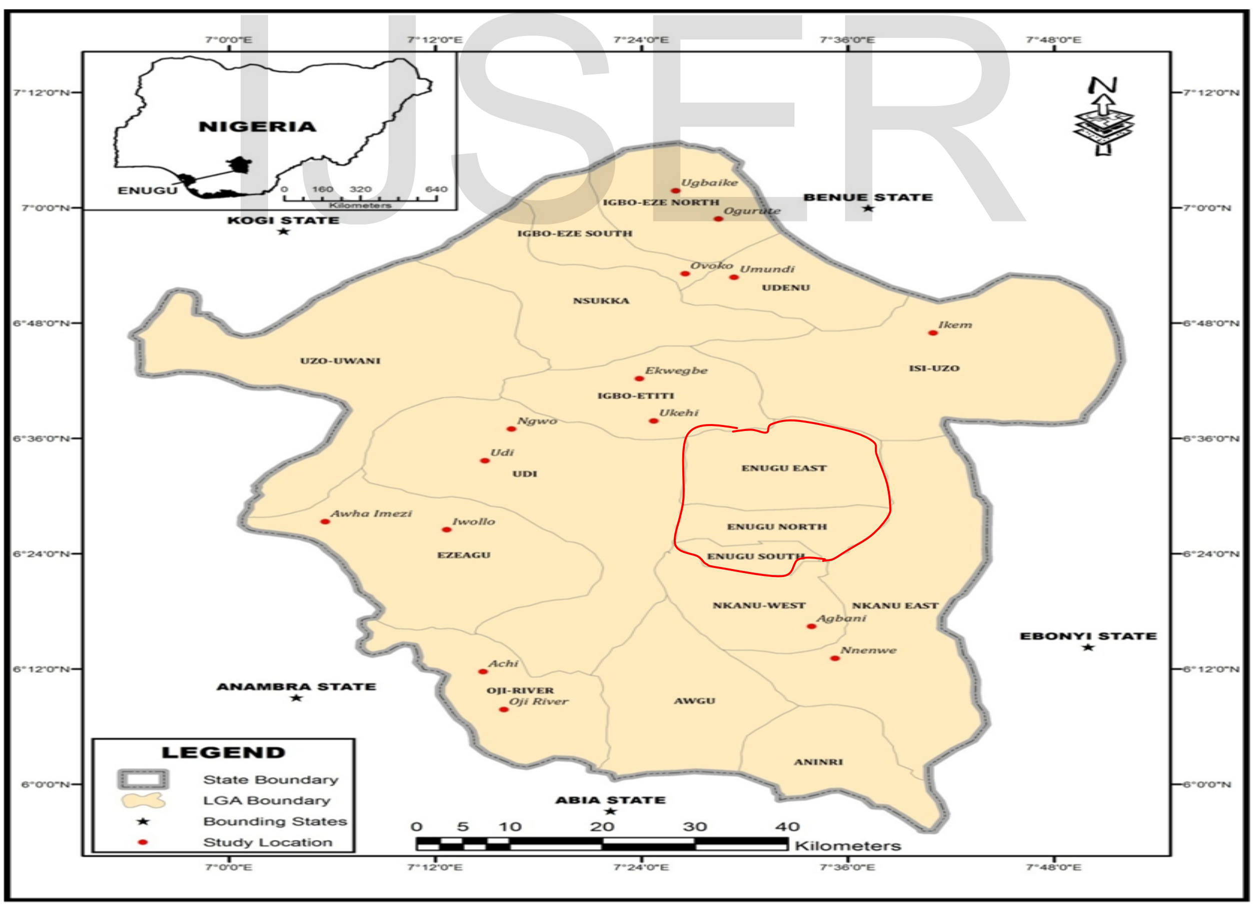


Fig.2 Map of Enugu State showing Enugu Metropolis verged in red colour

STATEMENT OF FACTS

At present, five supply sources exist with estimated supply volumes as follows:

Table 1: Enugu Urban water supply source

S/N	Water Source	Volume per day (Expected)	Volume per day (Actual)
1	The Eva(water Head) Spring Water Scheme	4,500 m^3	1,527 m^3
2	The Oji Augmentation	50,000 m^3	5,135 m^3
3	The Ajali River Greater Enugu water scheme	77,000 m^3	3,427 m^3
4	The 9th Mile (Old Road)	6,000 m^3	325 m^3
5	The 9th Mile Crash programme (bore Holes)	17,280 m^3	unpredictable
6	TOTAl	154,780m^3	10,414m^3

(Excerpt from progressive water production from 2014-2016. Engineering Department Water Cooperation Enugu)

From table 1 above it can be seen that only 7% of the expected volume is actualized. It therefore, calls for urgent attention to remedy the situation

The Crash programmes at 9th Mile are people's private establishments and are therefore unquantifiable. The other ones are government owned and shall form the bases for this discussion. This is because it is the responsibility of the government to provide safe water for her citizens.

Without considering water loses as a result of pipe leakages and other wastages, it can be assumed from the above that 10,414m^3 of water is officially supplied to residents of Enugu Urban on daily bases for domestic uses.

The estimated population of Enugu metropolis in the year 2016 is (Enugu North-319,316, Enugu South-239,248 and Enugu East-349,102) 907,666. The United Nations stipulation on daily water consumption per person ranges between 50 and 100litres(www.un.org/en/sections/issues-depth/water/).This is the range for the minimum and the maximum rates of water consumption per person daily. It therefore, means that if 907666 inhabitants of Enugu metropolis consume the minimum quantity (50litres) of water per day. It follows therefore, that 45,383,300 litres or 45,383.30m^3 is needed to be supplied per day.

Looking at table 1 and the analysis thereafter, it can be concluded that the State's water agency requires additional 34,969.3m^3 of water supply to meet the minimum requirement.

EXTRACTION OF SPOT HEIGHTS FROM LIDAR SATELLITE IMAGERY

LIDAR (light Detection and Ranging) is a remote sensing technology that collects point clouds of the earth surface. This technology is being used for a wide variety of applications including high-resolution topographic mapping and 3D surface modeling as well as infrastructure and biomass studies. Airborne LIDAR instrumentation uses a laser scanner with up to 400,000 pulses of light per second. The laser transmits pulses and records the time delay between a light pulse transmission and reception to calculate elevation values. These values are integrated with information from the aircraft's Global Positioning System (GPS) and orientation (pitch, roll, and yaw) data from inertial measurement technology to produce point cloud data. Each data point is recorded with precise horizontal position, vertical elevation and other attribute values.

Point cloud data represent the elevation of landscape features including crops, forests, roads, railways, airports, bare earth, mountains, valleys, lakes, rivers, glaciers, buildings, of the spectrum with a nominal pulse spacing (NPS) of 3 meters or finer. Since LIDAR can be reflected from any object the laser pulse strikes, up to five returns are collected per pulse. The multiple returns are recorded and each point is assigned a classification to identify landscape features. The intensity of the reflected energy is also captured and can be analyzed to provide additional information on terrain characteristics. LIDAR discrete- return point cloud data are available through Earth Explorer in the American Society for Photogrammetry and Remote sensing (ASPRS) LAS format. The LAS format is a standardized binary format for storing 3D point cloud data and point attributes along with header information and variable length records specific to the data. Millions of data points are stored as a-3D data cloud as a series of x (longitude), y (latitude) and (elevation) points. Earth Explorer offers LIDAR data in LAZ format which is a lossless compressed file with a high compression ratio. (http://Ita.cr.usgs.gov/Lidar_digital elevation; Accessed on 28-7-2017.)

OTHER GEOSPATIAL TECHNOLOGIES THAT CAN BE EMPLOYED IN THE DETERMINATION OF TERRIAN UNDULATION.

a) **CLASSICAL GROUNG SURVEY TECHNIQUE:** This method encompasses the processes of coordinating the turning points and positions of features and grid lines that would be used to represent the topography of the area; by any of the traditional ground survey methods such as triangulation, traversing, trilateration, intersection and resection.

b) GNSS SURVEY: GNSS is an acronym for Global Navigation Satellite Systems. It seeks a solution for one of man's longest and most troublesome problems. It provides an answer to the question 'where on earth am I?' It determines the position of a stationary or moving object (carrying GNSS radio receiver) anywhere on or above the earth' surface by using radio signals to measure distances between the object and at least four satellites whose positions are (V.N Uzodinma et al, 2013).

c) PHOTOGRAMMETRY and REMOTE SENSING: is defined as the "the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from noncontact sensor systems" (Colwell, 1997) examples (TERRA-MODIS, LANDSAT-ETM+, QUICK-BIRD,LIDAR,).

PLANNING AND DESIGN:

The next step is to use the terrain data set obtained from any of these technique or a combination of techniques to plan and effectively design the pipe water distribution system taking into cognizance the differences in elevation of points to strategize the location of overhead reservoir tanks, pipes and other appurtenances; and also the population growth factor to estimate present and future water demand, in other to have an efficient and effective pipe water distribution.

DESCRIPTION OF THE PROCEDURE EMPLOYED IN THE EXTRACTION OF THE SPOT HEIGHTS FOR THE PILOT PROJECT

- **Acquisition of the existing water distribution network map of the area.**

The hard copy of Ekulu East Estate was collected from Enugu state Water Corporation

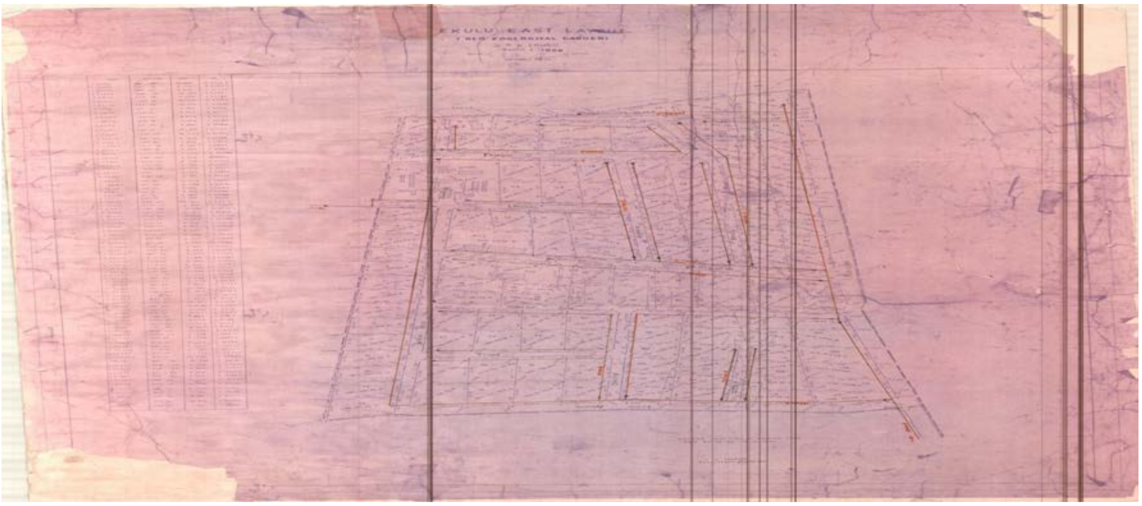


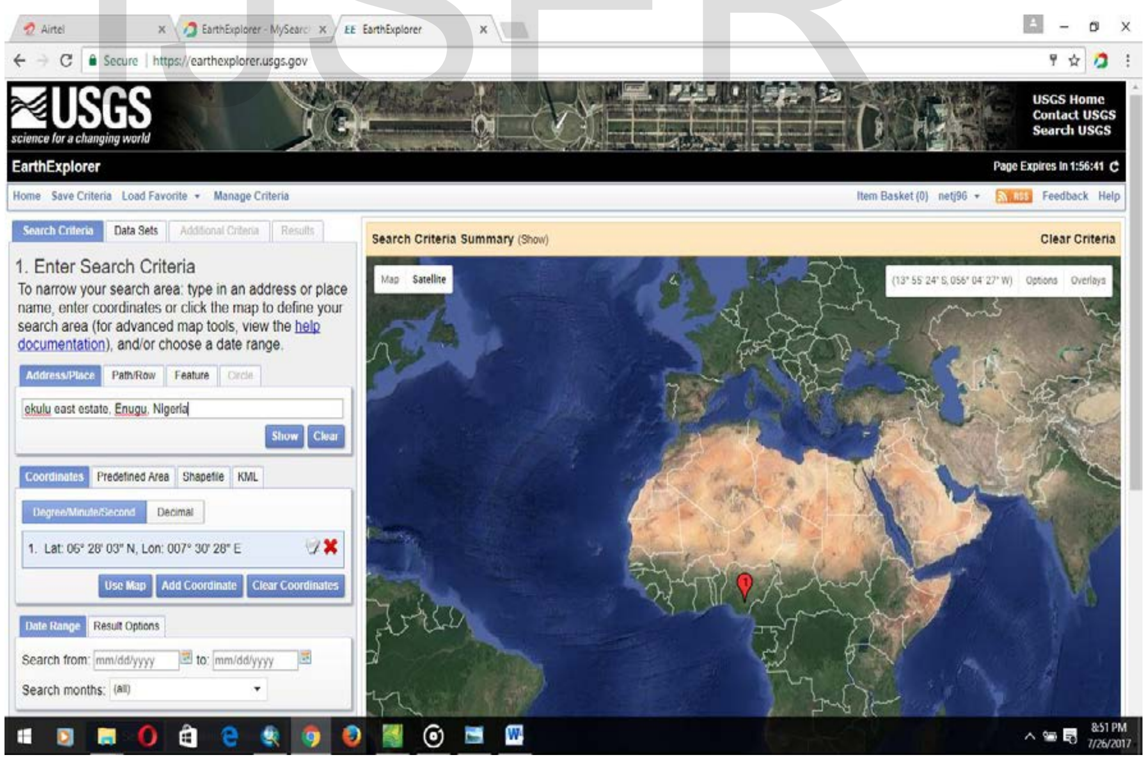
Figure 3: Scanned hard copy map of Ekulu East Estate water pipe network.

- **Determination of coordinates of existing monuments in the area with Global Positioning System(GPS):** The coordinates collected were used in giving the scanned pipe water distribution map, a spatial reference. The coordinates are as listed in the table below. Table 2: Control points data.

S/N	POINT ID	EASTINGS	NORTHINGS
1	GT1	335179	714842
2	GT2	335165	714840
3	C1	335151	714853
4	C1O	335026	714848
5	C1I	335035	714988
6	C2	334928	714861
7	C3	334779	714844
8	C4	334776	714951
9	C5	334928	714954
10	C6	334935	715049
11	C7	334785	715058
12	C8	334784	715076
13	C9	334794	715172
14	C10	334795	715190
15	C11	334811	715283
16	C12	334946	715265

- **Boundary delineation:** This was done using Arc GIS software by geo-referencing the scanned map of Ekulu East pipe water distribution system with the coordinates of the control point obtained by absolute positioning with a GPS and digitizing the boundary to obtain the perimeter of the Estate which gives an area of approximately 25 Hectares .
- **Ground truthing**: This is a physical investigation done at the project location by comparing what is on the map with the existing ground based structures and facilities.
- **Acquisition of LIDAR terrain data**: this was done using the following procedures-:
  - ✓ Go to “Earth Explorer” on your web address search box (www.earthexplorer.usgs.gov) and select US Geological survey earth explorer and sign in into your account which must be created prior to any access to data from the webpage;Type “Ekulu East estate, Enugu, Nigeria”, address/place search box on the earthexplorer.usgs.gov home page.

Figure 4: Satellite image of Africa



When this is done, you have to zoom to get a clearer view of the area as shown below

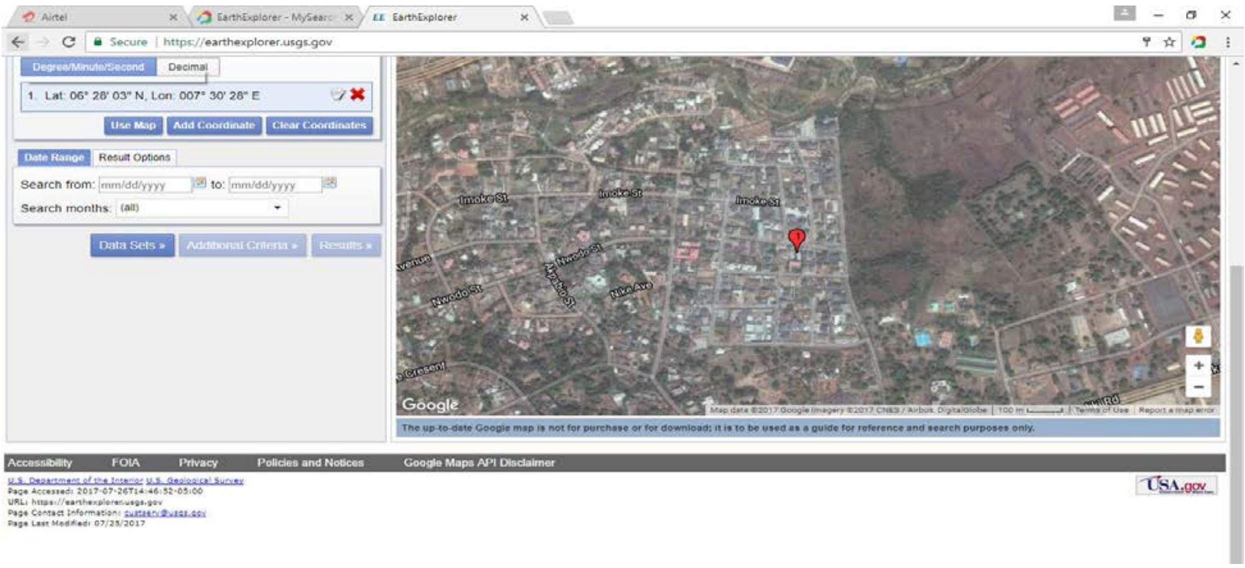
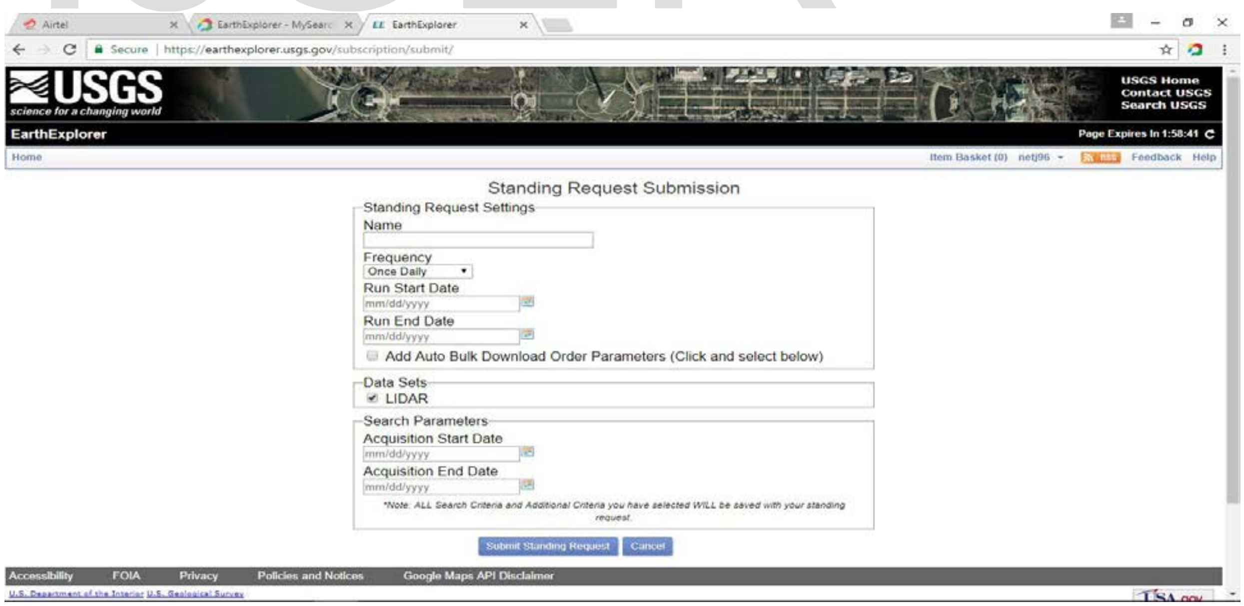


Figure 5: Satellite image of Ekulu East estate.

✓ Select the “Data set” button to highlight the remotely sensed database you require (LIDAR data). This brings up a request form where you state your name address, the Lidar data set, the application date and date of collection, etc. This is so because, the Lidar data is a commercial data set in which the applicant is expected to pay for the data requested for before delivery via an email.



✓

Figure 6: Lidar data acquisition request form

✓ Submit the form and wait for your data based on the stated date.

ISSN 2229-5518

DATA PROCESSING/ANALYSIS

- **Geo-Referencing of Scanned Map of Ekulu East Estate:** This is done in ArcGIS by using the "ADD CONTROL" tool in the geo-referencing tool box and adding coordinates of the control point to its corresponding location on the map.

  After adding the control points, you rectify and update your geo-referenced map.

- **Digitizing features of interest:** This is done in ArcGIS using the "point, line and polygon" tool in the "Editor" tool box and selecting appropriately, the corresponding shape file that was created in Arc Catalogue. The features include boundary lines, manholes containing the valves and the pipes ranging from distribution main to service main. The area is being supplied water from two reservoirs; source 1 and source 2 as shown in the figure below. The distribution main from source 1 is in yellow colour while that from Source 2 is purple. The service main are all in green colour.

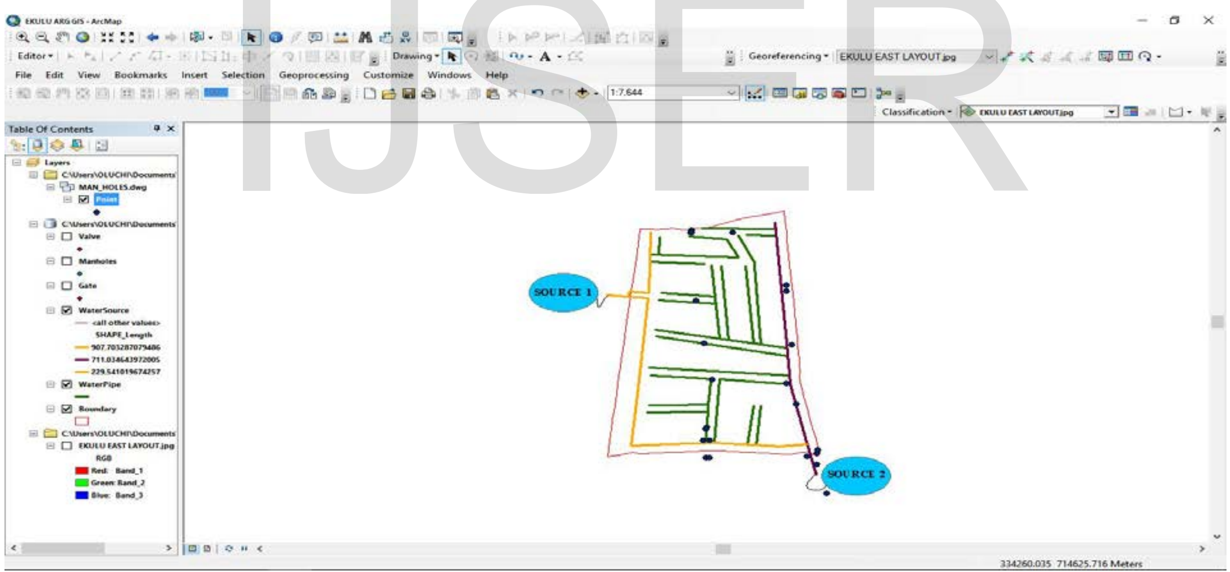


Figure 7: Vectorized map of Ekulu East estate.

- **Processing of LIDAR Data:** The dataset came as contour (line shape file with only elevation in its attribute table) which needs to be processed to obtain X,Y,Z values.

  This is done using the following procedure:

- ✓ **Add the LIDAR contour data** into Arc GIS using the "Add data" button. This process superimposes the lidar data (contours on brown colour) on the boundary shape-file (Ekulu East estate on blue colour), because both are in the same projection system (WGS 84, UTM ZONE 32) as depicted below

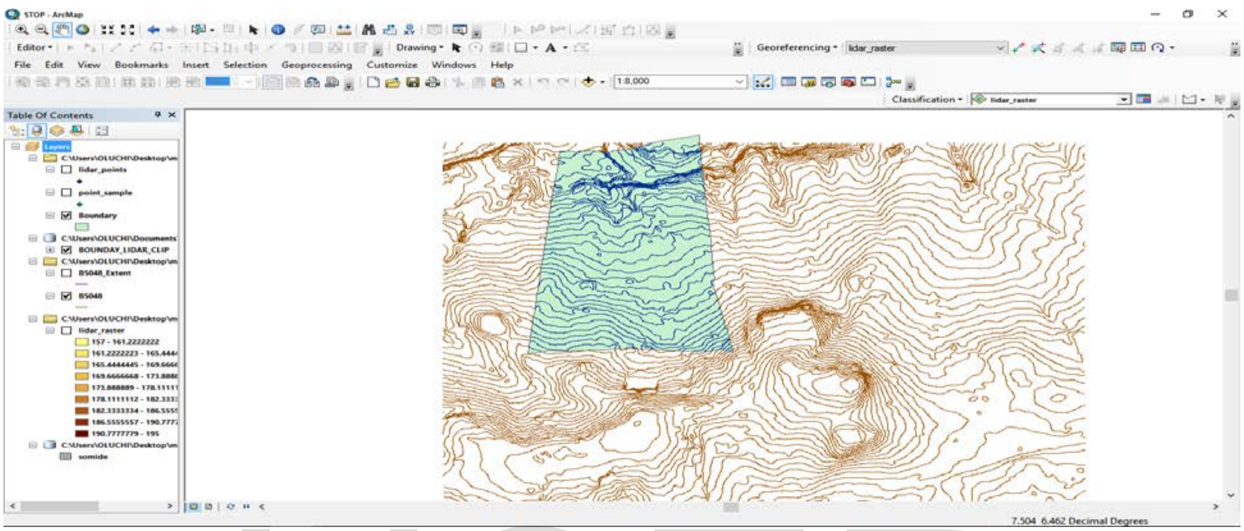


Figure 8: Acquired LIDAR terrain data set.

- ✓ **Clip out LIDAR contour for Ekulu East estate**: The LIDAR contour data has larger coverage i.e., covers Ekulu East estate and other areas. In order to extract lidar data for only Ekulu East estate which is our area of study, we use the "clip" tool in the ARC GIS tool box specifying the boundary shape-file of Ekulu East as the reference polygon/clip feature.

This brings out an image of Ekulu East boundary with contour lines clipped out from the Lidar contour data.

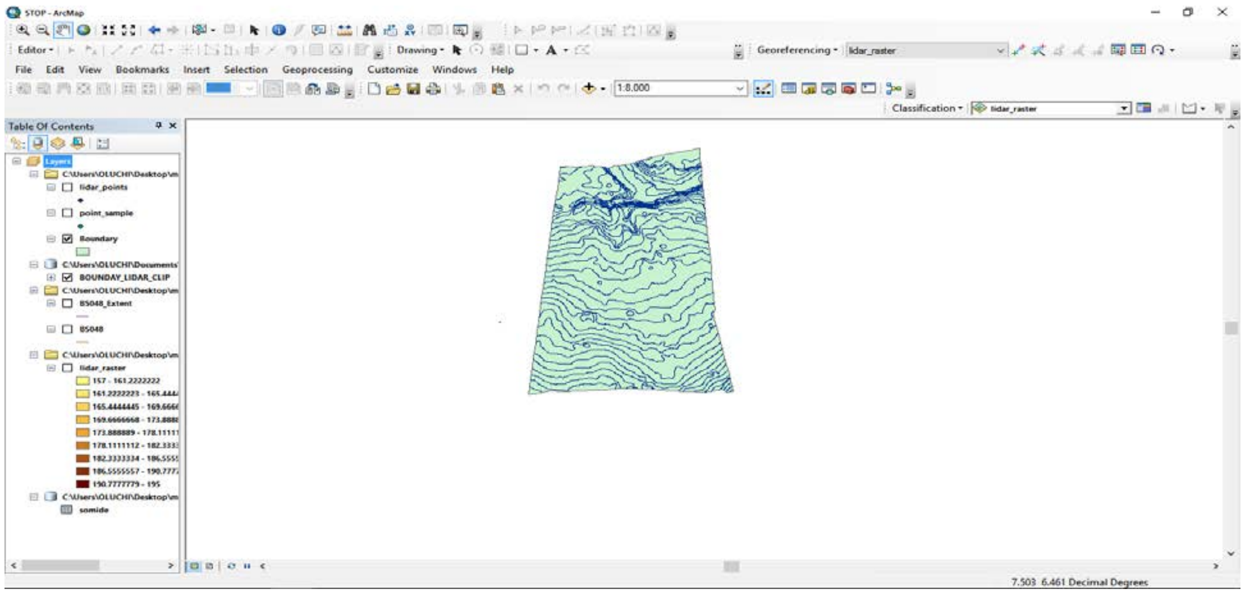


Figure 9: Subseted Lidar terrain data.

From the configuration of the contour lines, one can see the clustered contour lines showing a depression, which represents the area which gets a higher percentage of the pipe borne water supply.

- ✓ **Conversion of Contour lines to Triangular Irregular Network (TIN):**This is done using the “3D Analyst tool

  This brings up an image of a Triangular Irregular Network

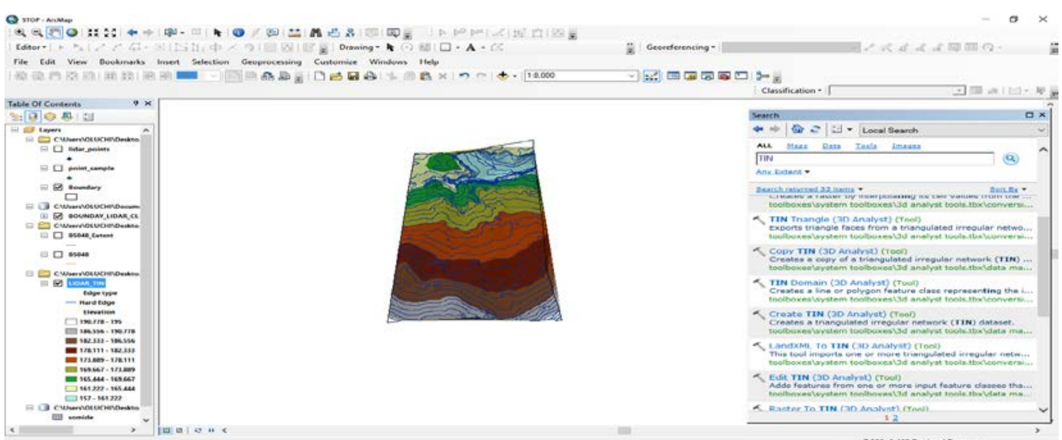


Figure 10: TIN map of Ekulu East estate.

✓ **Conversion from TIN to raster:** This is done using the "TIN TO RASTER (3D Analyst tool)"

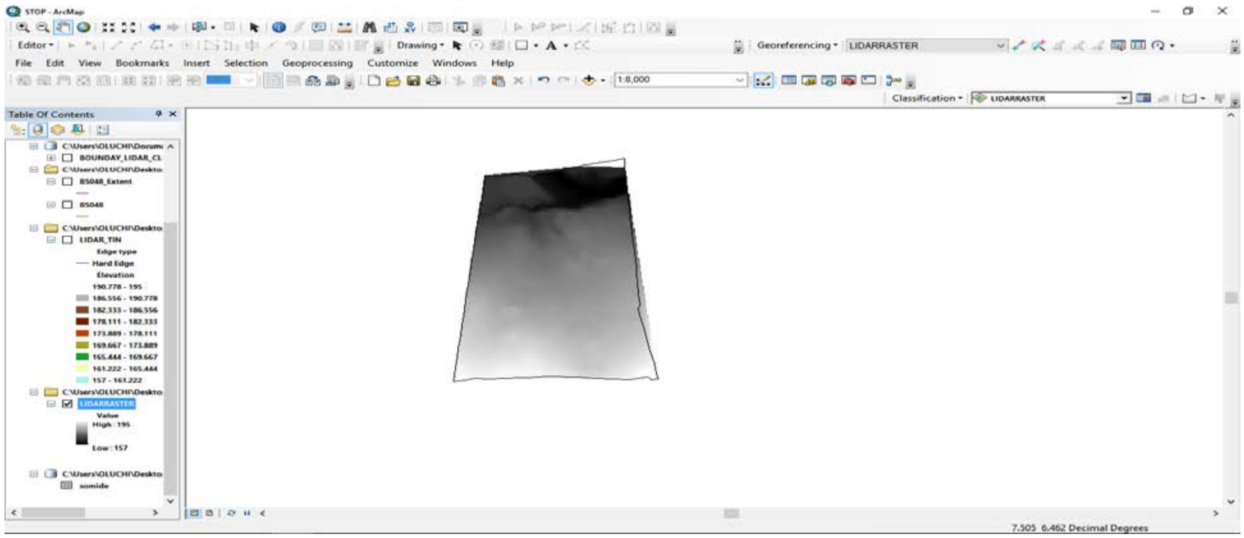


Figure 11: Raster image of Ekulu East estate.

Conversion from raster to point cloud data

This brings an image of Ekulu east estate with the point cloud having the X,Y,Z values of the spot heights

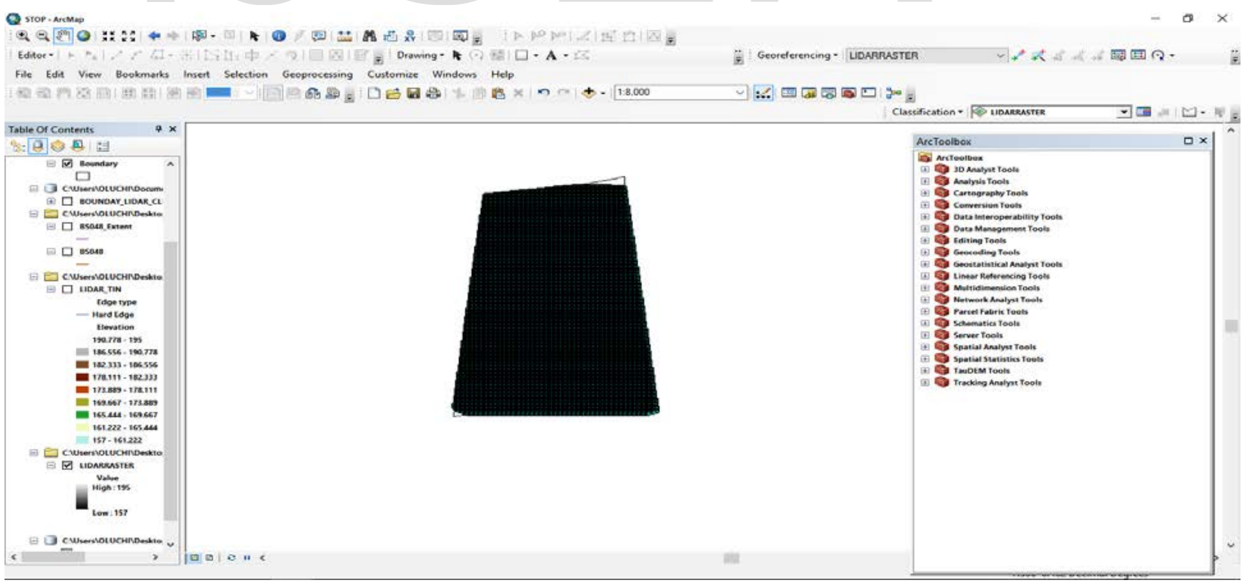


Figure 12: Analyzed Lidar terrain data

Export the attribute table to an excel table

This gives the coordinate of the LIDAR point cloud in an excel worksheet as depicted in the table below

Table 3:Sample of Lidar terrain spot height data for Ekulu East Estate Enugu

POINT ID	SPOT HEIGHT	EASTINGS	NOTHINGS
1	164.059	334977.845	715498.686
2	164.068	334980.472	715498.686
3	163.999	334983.099	715498.686
4	163.968	334985.727	715498.686
5	163.871	334988.354	715498.686
6	163.784	334990.982	715498.686
7	163.697	334993.609	715498.686
8	163.611	334996.236	715498.686
9	163.523	334998.864	715498.686
10	163.428	335001.491	715498.686

3D REPRESENTATION OF TERRAIN DATA SET:

This was done with "SURFER 10" software

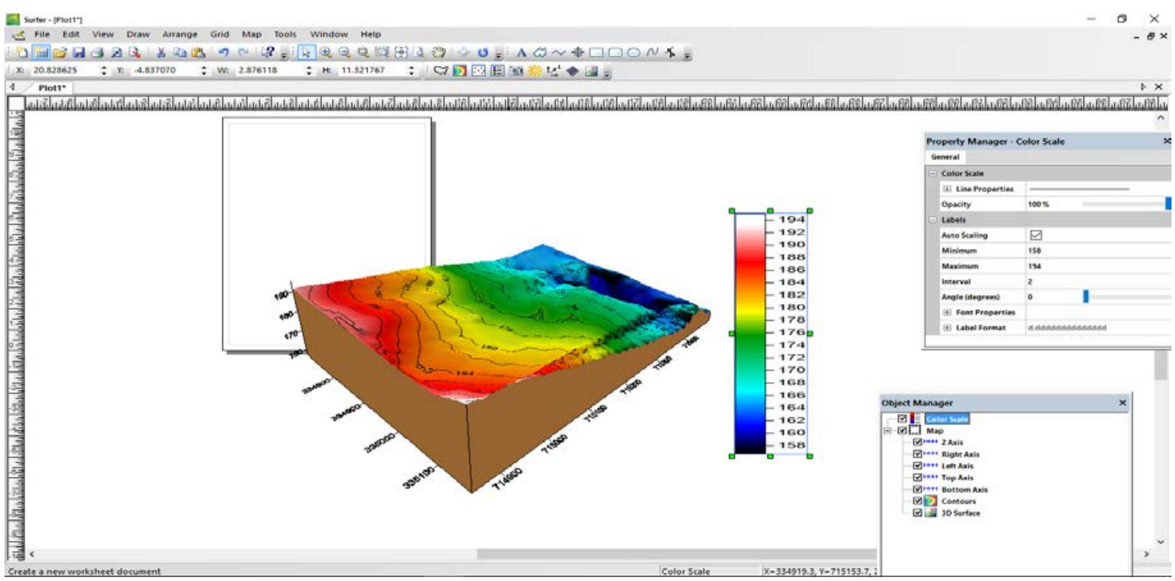


Figure 13: creation of 3D model of Ekulu East estate.

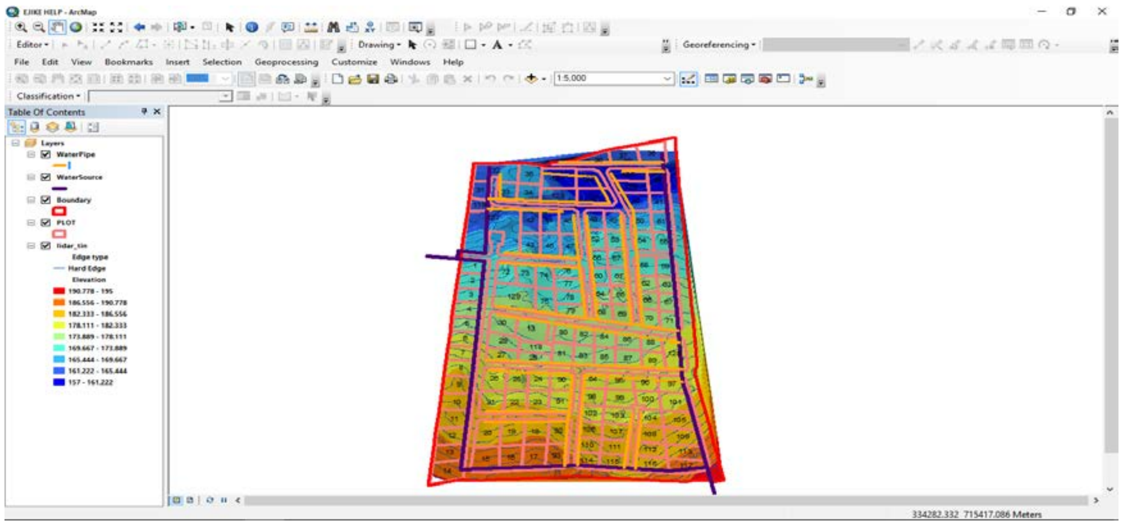


Figure 14: Creation of current water distribution map of Ekulu East estate.

CONCLUSION

To circumvent the problem of inadequate water supply in any city of irregular terrain, The topographic data of the area must be integrated in the design of the distribution network. This data is obtained from diverse geospatial technologies ranging from classical Surveying methods to the use of satellite imageries.

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