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Improving Enugu Urban Water Sourcing and Distribution Using Geospatial Technologies

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ABSTRACT

Enugu Urban dwellers have experienced perennial scarcity of portable piped water for several years. The problem has always weighed more on Women and Children who are often expected to haul ground water for domestic uses. The inhabitants have consequently, resorted to purchase of drinking water from vendours who travel out of the urban area to 9th mile Conner, about 8 km away to obtain drinking water from bore holes .Children are therefore used to fetch the greater quantity of domestic water from open shallow wells found virtually in every compound in Enugu capital city . The government Agency (Water Corporation) in charge of pipe-borne water supply to households also sources water from Ajalli stream and Oji River which are outside Enugu town. This research which is already in progress, set to ameliorate the sufferings of vulnerable children is designed to achieve the following: i) produce the hydrograph of the surface water sources to determine the periodical discharge available for supply to consumers at various seasons of the year ii) to re-design the existing distribution network using EPANET software, to achieve a robust network that will include suitable locations for reservoirs, pressure brake tanks and pumps etc and iii) to determine locations of possible sources of underground water within the urban area through geophysical survey with ABEM Terrameter system to augment the quantity supplied by the existing water sources.

INTRODUCTION

Water is a fundamental human need. The United Nations considers universal access to clean water a basic human right, and an essential step towards improving living standards worldwide. Communities that suffer poor supply of water are typically economically poor as well, with their residents trapped in an ongoing cycle of poverty. Economic opportunities are routinely lost to the time-consuming processes of acquiring water where it is not readily available. Children and women bear the brunt of these burdens. Water is obviously essential for hydration and for food production. The state of drinking water supplies can be quantified by four important

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characteristics: quality, quantity, reliability, and cost. However, this research is centred on improving the quantity of treated piped water supplied by the State agency incharge of water distribution in Enugu metropolitan area of Nigeria.

As population grows by day, the challenge to meet user demands of water also increases. Inhabitants of Enugu metropolis currently depend largely on drinking water transported from boreholes at 9th mile corner, Udi local government area which is about 8km from the city, while vulnerable children are saddled with the responsibility of sourcing water for other daily domestic uses. This no doubt has contributed to child poverty. A lot of these house-helps (Children use for domestic strenuous labour) as they are popularly referred to, have sustained injuries while climbing story buildings with buckets of water on their heads. This exercise is usually a morning and evening routine and majority of them, who are opportune to be enrolled in schooling, learn nothing as they are bound to sleep off after the herculean task of hauling water from ground wells to the story buildings where their superiors reside. Needless to say that this method of water sourcing has encourage residents in the urban area of Enugu to scout for less privileged children in the villages and bring them to the urban area to be used as instruments of water hauling.

According to the state's agency incharge of piped water supply (Water Corporation), there are about six water distribution zones (Government Reserved Area (GRA), Ogui, Uwani, New Haven, Independence Layout, Emene, Idaw River/ Achara Layout, Trans-Ekulu and Abakpa). None of these zones can boast of adequate water supply within all its environ. Some sections of these areas are not supplied with water at all, while others experience limited supplies. These inadequacies have been traced to the following factors:

- Topography; because of the hilly nature of Enugu metropolitan area, certain places inhabited by people (demand nodes) are of higher altitude than the location of the reservoir(s) (input nodes) that supply water to the area.
- Poor distribution network; the network of the pipes did not follow any of the standard patterns; grid network, radial or ring network and the branch network. This makes it difficult to supply water to the zones whenever fault occurs in the existing network.

This ongoing research has been designed to address these challenges by the application of Geo-spatial technologies.

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Description of the study area

Enugu city is located between **Lat. 06°, 26'** and **06°, 30' N** and **Long. 07°, 27'** and **07°, 37' E** and lies east of Niger Delta. With a population of about **996,481** (2017 Census projection). It is one of the largest cities 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. Figure 1 is map of Nigeria with Enugu state verged in red colour

Fig 1: Map of Nigeria with Enugu State verged in red colour (Source:Administrative Map of Nigeria from Wikipedia Image ,2016)

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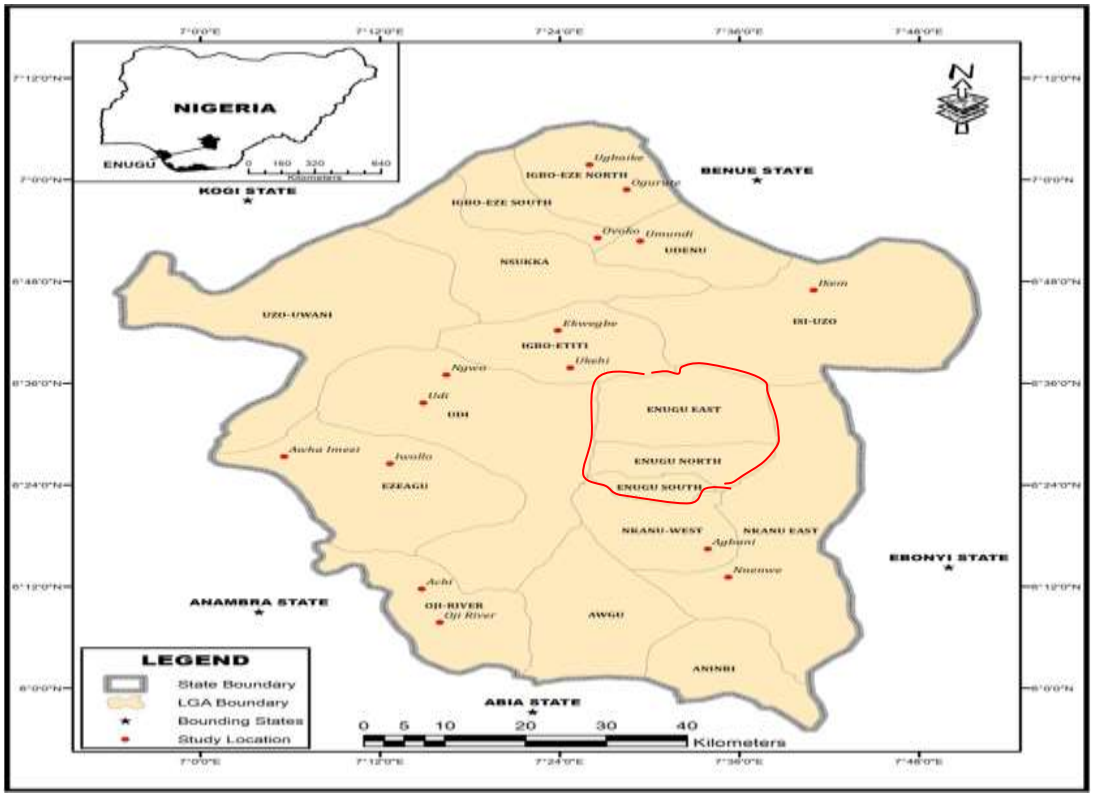

Figure 2: map of Enugu state with Enugu metropolis(Enugu North, Enugu South and Enugu East Local Government areas) vergesd in red colour. (Source:Administrative map of Enugu state, Wikipedia ,2016)

MATERIALS AND METHOD

The current situation of piped water supply in Enugu Urban

At present, five supply sources exist with estimated supply volumes as shown in table1.

Table 1: Enugu Urban water supply sources and quantities generated per day

S/N	**WATER SOURCE**	**EXPECTED VOLUME PER DAY(Design capacity)m^3**	**Actual volume per day (2014) m^3**	**Actual volume per day (2015) m^3**	**Actual volume per day (2016) m^3**	**Actual volume per day (2017) m^3**	**Average volume per day m^3**	**Average Volume per day in litres**
1	**The Eva(water Head) Spring**	4,500	1,747.4	2,085	1,527.18	1,129	1,622.15	1,622,150

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	Water Scheme							
2	**The Oji Augmentation**	50,000	13,832	6,670	5,135	10,118	8,938.75	8,938,750
3	**The Ajalli River Greater Enugu water scheme**	77,000	8,300	5,614.29	3,427	829	4,542.57	4,542,570
4	**The 9th Mile (Old Road)**	6,000	271	56.25	Nil	Nil	81.81	81,810
5	**The 9th Mile Crash programme (bore Holes)**	17,280	Nil	Nil	246.44	Nil	61.61	61,610
6	**TOTAL**	**154,780**	**24,150.4**	**14,425.54**	**10,335.62**	**12,076**	**15,246.89**	**15,246,890**

(Excerpt from progressive water production from 2014-2017. Engineering Department Water Cooperation Enugu)

From table 1 it can be seen that only **16%**, **9%**, **7%, 8%**, and **10%** for the year 2014, 2015 2016 and 2017 respectively of the expected volume were actualized. It therefore, calls for urgent attention to remedy the situation

Without considering water loses as a result of pipe leakages and other wastages, it can be seen from the table that **15,246.89m^3** of water is supplied to residents of Enugu Urban on daily bases for domestic uses.

Based on the last Nigerian national census of 2006, the population of Enugu metropolis (Enugu North-244,852, Enugu South-198,723 and Enugu East-279,089) is estimated to be 722,664.

According to UN,(1974), the projected growth rate is given as (Growth rate =1/t x ln (P_1/P_0)

Where; t= time interval, ln = Exponential or natural log, P_1= current population, and P_0= previous population. (United Nations, 1974)

The projection from 2006 to 2017 produced 354883,260102 and 381496 for Enugu North, Enugu South and Enugu East local government areas respectively. This gave a total of **996,481** inhabitants of Enugu metropolis. The computation was done using linear population projection method of United Nations.

$P_1=P_0 (1+\gamma)^t$.

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In combination with the census data of 1991, the projected population growth rate of 0.030431520656, 0.0247710715 and 0.02882288845 for Enugu North, Enugu South and Enugu East local government areas were respectively obtained. (National and State Provisional Totals 2006 Census,2007)

Where; P_1= Projected population, P_0= Base population or the starting point of estimation

γ =Growth rate, t= time interval (United Nations, 1974)

From the foregoing analysis it implies that 996,481 persons residing in Enugu metropolis had 15,246,890 litres of water per day for their domestic needs in 2017. This goes to show that neglecting water loses through broken pipes that an average of **15.3 litres** of pipe born water was supplied per capita per day through out 2017 by Enugu State Water Corporation. Comparing this to the recommendation of the World Health Organization on the minimum water requirement per capita per day we discovered that the supply is only enough for drinking. Hence, with the available supply if at all the quantity is uniformly distributed, the inhabitants of the metropolis could only access 5.3litres of water to cook food in a day, while none is available for personal washing such as birthing, washing clothes or even cleaning the house. From the World Health Organization's minimum requirement, 150 litres is the least quantity of water needed per capita per day. There are yet other important needs such as keeping garden and sanitation which have been estimated to consume a minimum of extra 130 litres.

This goes to show that Enugu Water Corporation requires additional **134,225,260** litres (134,225.26m^3) of water to be able to supply **150** litres to each inhabitant of Enugu metropolis in 2017. The 150 litres of domestic water specified by World Health Organization (WHO) per Capita per day is specified thus: Drinking (10litres), Cooking (20L), Personal washing (30L), Washing of clothes (40L) and Cleaning of the house (50L) (Reed B. J, 2005). As a result of the prevailing situation, inhabitants of Enugu urban now resort to the two options as shown in figures 3 and 4 for their daily domestic water sources.

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Fig. 3 Water hauling from shallow well

Fig. 4. A sample of drinking water supplying vehicle

Existing design of the Distribution Network

It is quite disheartening that there is no map describing the extent of water pipes laid within the urban area, even the existing ancient map collected from Enugu State Water Corporation (ESWC) depicts that none of the four (***Grid, Ring, Radial*** **and** ***Dead End System***) fundamental

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systems of water distribution network were adhered to.

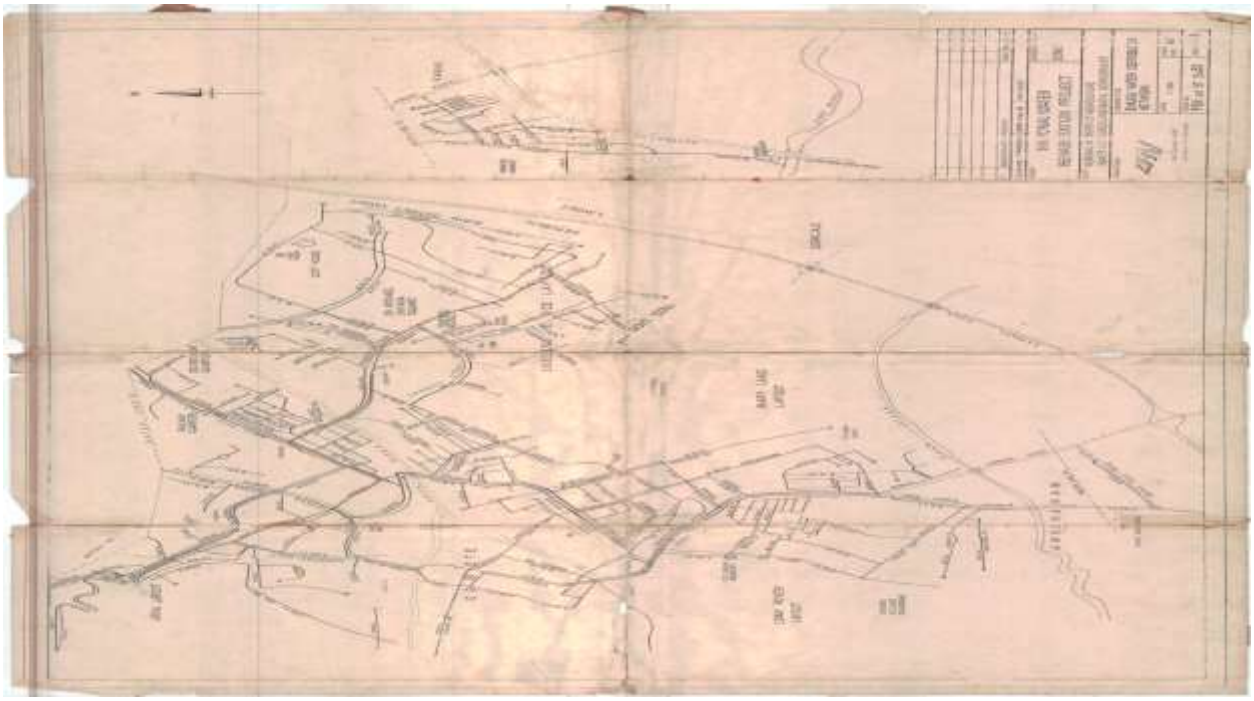

Fig 5: Sample of map showing part of existing water distribution network (Source: Enugu State Water Corporation)

It therefore becomes very difficult to resolve faults and to determine which reservoir services particular areas as the entire distribution network are interwoven

Water discharge determination and geophysical survey for alternative source

Monthly determination of water discharge at Ajalli sream (the major surface water source) which is designed to last for one year commenced since January 2018 .A hydrograph of the stream will be plotted at the end of the exercise to display the seasonal variation of water at that source. The Ajalli water scheme is a dam which was built in 1985 to supply 77,000m^3 of water daily to the inhabitants of Enugu. The discharge measurement and volume of water computation will enable us determine from season to season the quantity of water that can be derived from the stream. Oji Augmentation water scheme is a collection ground water sources established very close to Oji River to ensure constant supply of water. The Eva water source is a small spring water source harnessed to add to the quantity of water extracted from the major sources. The 9th mile old road and 9th mile crash programme are underground sources that are already neglected and dilapidated.

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If at the end of the discharge measurement, it is discovered that throughout the season or that at a particular time of the year there is likelihood of not having enough water at the sources, an underground water source whose location shall be determined by a robots geophysical survey within the metropolis shall be recommended to augment what is available.

Determination of topography.

To facilitate gravity flow of water, the location of the reservoir should be of higher altitude than the part of the settlement it supplies water. The topography can be determined using spirit leveling method or Global Positioning System, but for the large size of the area of interest, the spot heights, longitude and latitudes of all the locations of the area shall be extracted from LIDAR (Light Detection And Ranging) satellite imagery. The image shall be downloaded from USGS Earth Explorer, Geo-referenced and coordinates of points extracted using the 3D analyst tool in Arc GIS software.

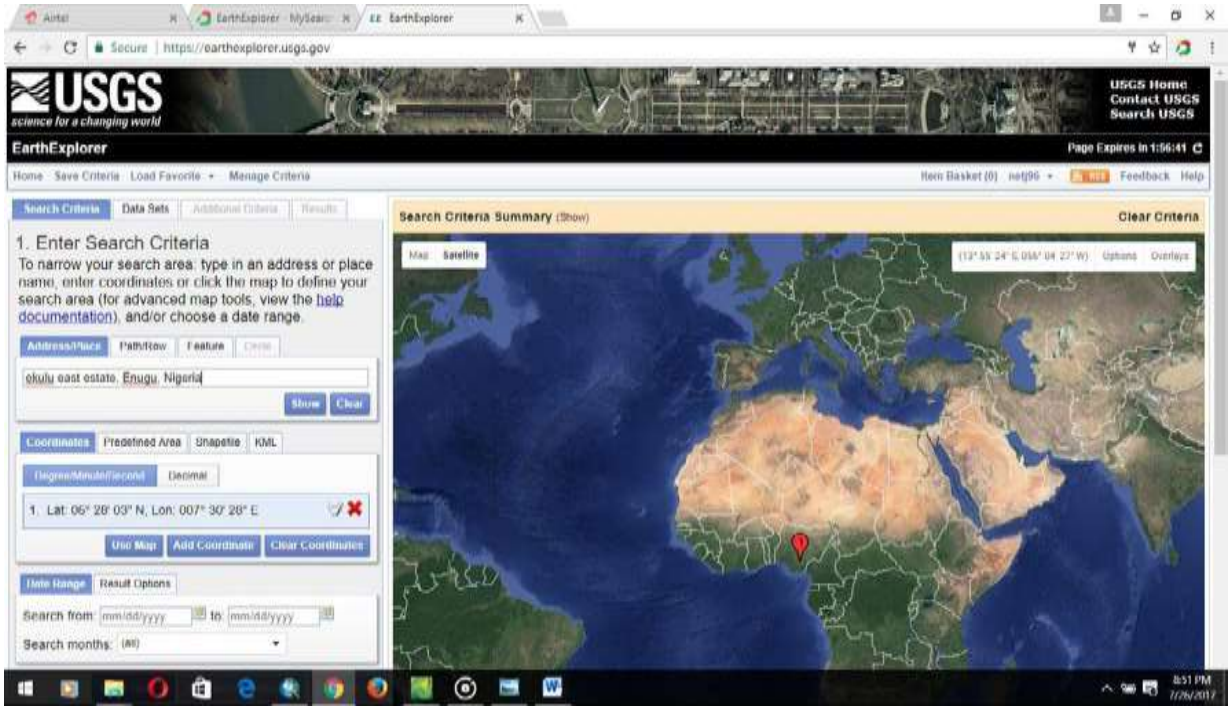

Fig. 6 satellite image of Africa

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When this is achieved you then zoom to the area of interest to obtain an image that is as shown in figure 7

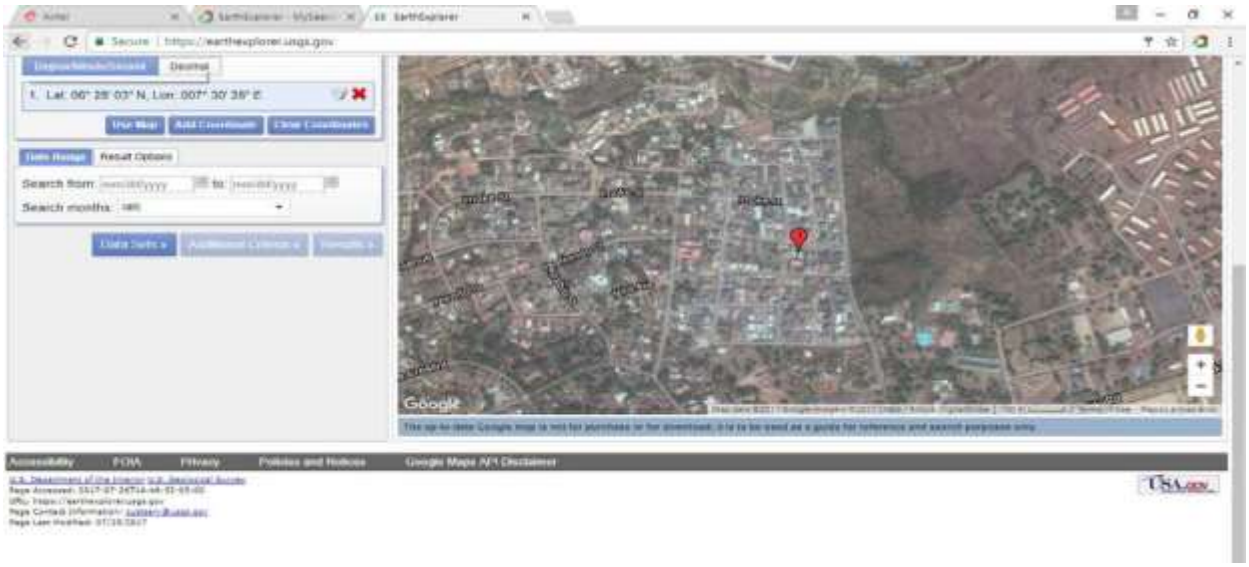

Fig. 6 Satellite image of the project area

Within the Arc GIS environment, the image is first of all converted to Triangular Irregular Network (TIN) which in turn is converted to raster using the 3D analyst tool and subsequently from raster to point cloud of Longitude, Latitude and Heights (X,Y, Z)

of every point in the image. The points are subsequently imported into Excel Worksheet and organized as shown in table 2

Water distribution network modeling

EPANET is open access software developed by the American Environmental Protection Agency for modeling of water distribution network. The software incorporates the topographic information of an area of interest to design water distribution network that ensures seamless flow of water through pipes. Its designs depicts appropriate positions of reservoirs, pressure pumps, break water thanks, sizes of pipes along distribution lines etc. It is a widely used program for modeling the hydraulic and water quality behaviour of drinking water distribution.

The systems are modeled as links connected together at nodes in some particular branched or looped arrangement. Links represent pipes, valves and pumps while Nodes serve as source points, consumption points and storage facilities.

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It also models water quality using the principle of conservation of mass and reaction kinetics.

The first step in running a multi-species analysis of a water distribution system is to prepare a standard EPANET input file of the system that contains all of the information needed to perform a hydraulic analysis of the system. The Windows version of EPANET 2 is to be used to draw the network layout and assign node and pipe attributes using the program's graphical editing tools.

The only condition for effective use of the software is that water demand is kept constant over time and that a 48 hour simulation period is needed.

RESULTS AND ANALYSIS

Results The hydrograph shall display the possible volume of water that can be obtained throughout the year. It is the rate of flow (discharge) versus time past a specific point in a river, channel, or conduit carrying flow. The rate of flow is typically expressed in cubic meters or cubic feet per second (cms or cfs). It can also refer to a graph showing the volume of water reaching a particular outfall

Analysis

The demographic data gives us the number of persons residing in Enugu metropolis while the bathymetric survey and the volume of water extracted monthly from the existing underground sources reveals the quantity of water that can be made available for the inhabitants. Where the volume of supply is not enough, the result of the geophysical survey will guide for recommendation on the appropriate locations for sourcing more water.

Having established that topography affect piped water distribution network, the coordinates extracted from the LiDAR image shall be introduced into the EPANET 2 software for adequate simulation of suitable distribution network that will stand the test of time

CONCLUSION.

The challenges faced in the sourcing and distribution of Pipe- born water in Enugu metropolitan area as a result of increase in the population, topography and city expansion without a corresponding increase in water sourcing and distribution by the appropriate government agency can be resolved by the application of geospatial technologies; mapping, hydrography, geophysical survey, topographic Survey, modeling and demography

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