International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 01 | Jan-2016 www.irjet.net p-ISSN: 2395-0072

DEVELOPMENT OF A GIS-BASED SYSTEM FOR MANAGEMENT OF WATER DISTRIBUTION NETWORK OF ACHARA LAYOUT ENUGU, ENUGU STATE, NIGERIA

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Abstract - *The inefficiencies in water distribution and management of water distribution facilities is commonly attributed to absence of a functional management system. This has been identified as a major issue facing water distribution agencies in Enugu State, Nigeria. Thus, there is need to develop a system that will help improve service delivery and facilitate infrastructural maintenance. This study applies Geographic Information System (GIS) in the management of water distribution network for Achara Layout Enugu, Nigeria. To execute this study, a number of datasets were used such as Achara layout design plan, map of existing water pipelines, the design plan and map of existing water pipelines. These datasets were obtained from the Ministry of Lands and Survey, Enugu State and Enugu State Water Cooperation. They were used for characterizing the location of distribution facilities spatially and analyzing the status of service presently in the area. In addition to these, attribute data such as parcel IDs, parcel street number, street names, use of parcels and nature of buildings in each parcel were obtained by visual observation and interviews. The existing maps and data layers were processed and analyzed in ArcGIS environment. The maps were geo-referenced and maps digitized while shapefiles and database were also created. Queries were created from which service delivery appraisal was conducted. Results of the study show that some water taps in the area do not provide water due to insufficient pumping pressure from the source. It also showed that public facilities were solely dependent on alternative sources of water. This suggests the efficiency of the developed system in enhancing understanding and management of water distribution management.*

Key Words: *GIS, Management, Water distribution, Facility, Utility, Management*

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1. INTRODUCTION

Water is a chemical compound consisting of two hydrogen atoms and one oxygen atom, the name water refers to the liquid state of the compound. The solid phase is known as ice and the gas phase is called steam. It is a tasteless, odorless and transparent liquid, an essential utility and commodity, to living things. It is considered to play very crucial role in the survival of humans, animals and plants. Hence, it is one of the essential needs to sustain life. Furthermore, water is at the center of economic and social development, it is a key element in all kinds of development and planning (Debabrata, 2011) [1]. It is vital to maintain health, grow food, manage the environment and create jobs (World Bank, 2014) [2]. Sources of water include rivers, lakes, excavated dams, rock catchment areas, springs, surface water bores and wells. Water is available everywhere but the question is how is it made clean, treated and transported to the communities? The answer is Water Supply. Collins English Dictionary (2003)[3] , as an arrangement of reservoirs, purification plants, and distribution pipes etc. for providing water to a community, it is also the supply of treated and purified water for the community. Lawal (2003) [4], reported that water supply is one of the most important public infrastructure service being provided by government. It is a service critical to sustainable development and economic competitiveness of any nation (Kashim, 2012) [5]. The connection of pipes and pumps that makes water supply possible is called Water Distribution System. For a healthy population to be maintained there is need for regular and efficient water supply.

The area is located between Latitude 60 22”N and 60 24''N and Longitude 60 30''E and 60 35”E, was approved as a residential area in 1978. It is categorized as medium density area, with a population of about 96,788. It was discovered in the study area that, there is inconsistent supply of pipe borne water; some areas in the layout are left without this commodity culminating to people walking some distances just to have access to portable water. Residents’ around Ozalla Street, Afikpo Street and Idodo Street do not have access to portable water. They depend on wells and water vendors for water, these sources of

water are not proven reliable sources of drinking water, this points that the health of these residents is in jeopardy as a result of the unreliable source of water they use. Water distribution pipes on the ground surface in some locations in the study area have been leading to wastage of treated water which is detrimental to the service provider and results to lack of resources to the customers on that service line. It was also observed that water consumed by customers are not metered thereby leading to undercharging and overcharging of water rates. This unmetered consumption has resulted in buildings of different use and capacity paying a flat consumption rate which adversely affects the revenue generation because consumers being overcharged are reluctant to pay their rate rather they prefer to bribe the corporation workers to allow them use the resource at a very low rate. There is need for an appropriate system to proffer solution to the above stated problems thus this study. This study aims at applying GIS in the Management of Water Distribution Network for Achara Layout Enugu and will be achieved through the objectives which include creating a visual representation of existing water distribution network, creating a consumer database and provide information for the siting of overhead reservoirs for apartment to apartment water delivery.

Considering the literatures reviewed, it was observed that there are some research gaps this study intends to close. Researchers did not incorporate detailed customer information; which helps service delivery appraisal and monitoring consumer behavior which are vital aspects of management. There was no query on customer information, none of the researchers linked customer information with water distribution facility information using a unique identifier which poses as an impediment in the management of distribution facilities. This study is based on two concepts: the Concept of Developing Utility Information System for Management of Water Distribution Network and the Concept of Integrated Urban Water Management (IUWM).

2. METHODOLOGY

2.1 Data Requirement

Data that was used in study includes. The Layout Design Plan of the study area, Coordinates of control points, Existing Water Distribution maps and Attribute data. These required data were acquired thus.

2.1.1 Primary Datasets

These are data obtained through field visits peculiar to the study and include:

i. The coordinates of points to be used as control points were obtained using handheld GPS.

ii. Non-spatial (attribute) data describing the characteristics of features of interest was collected on ground by visual observation and face to face interviews.

2.1.2 Secondary Datasets

The following secondary datasets were obtained from different government agencies including:

i. The Layout Design Plan of the study area approved and produced by the Town Planning Unit of the Ministry of Lands and Survey Enugu State.

ii. Existing Water Distribution Network Maps from the Enugu State Water Cooperation.

iii. Unpublished /published records kept by statutory bodies and organizations example records from various government agencies.

2.2 Hardware and Software

The hardware components include the physical equipment that was used for the execution of the study and they include:

i. Handheld GPS (Garmin 76XCS) was used for collection of co-ordinates of features and control points.

ii. Laptop, HP Core 2 Duo 2.6 GHz, 320G hard drive, 8 RAM with full multimedia capability for storing and processing data.

iii. An A0 scanner was used for scanning of the analogue maps

iv. An A3 printer was attached to a laptop for printing and presentation of the result in hardcopy format.

The software components used for processing and production of the result of the study includes:

i. ArcGIS Software version 10.1 which was used for vectorization and spatial analysis.

ii. Microsoft Word which performed the task of processing, editing and display of textual information.

iii. Microsoft Excel was used to key in the attribute information in a tabular form.

There is a high level of frustration regarding access to information about the water distribution system, since so little of the information is automated and readily available. The user requirement survey was carried out; this is an intellectual and technical process that is very essential in all GIS project. This was carried out by conducting face-to-face interviews for the sake of this study, in order to

identify appropriately the spatial data needed, the accuracy of the data required and the format of the required output so as to satisfy the needs of the potential user maximally. The required data as identified from the survey was collected from the following agencies; The Layout Design Plan of Achara Layout was collected from the Town Planning Unit of the Ministry of Lands and Survey Enugu State. Existing Water Distribution Network Map was from the Enugu State Water Corporation.

The existing pipeline layout map and the layout design plan of the study area were scanned using an A0 scanner. The hardcopy parcel maps were converted to digital form using a scanner which recognizes the black and white value of each pixel location on the map. The scanned maps were saved in a storage media and later saved in a computer. The scanned maps were georeferenced in ArcGIS 10.1. Using the coordinates of control points from a handheld GPS, points of known coordinates were chosen for the purpose of georeferencing. Ten points were used in this case. Shapefiles were created. Each shapefile stored features belonging to a single feature class. Shapefiles created in this study for features that includes end caps and gate valves as point features, pipes and streets waterways as line features, land parcel and gullies as polygon features.

3. RESULTS AND DISCUSSION

The results obtained includes: Street guide map, as shown in fig1. The map shows the street network of the study area. This map would help in identifying the best route to a consumer or parcel and the best route for new proposed pipes.

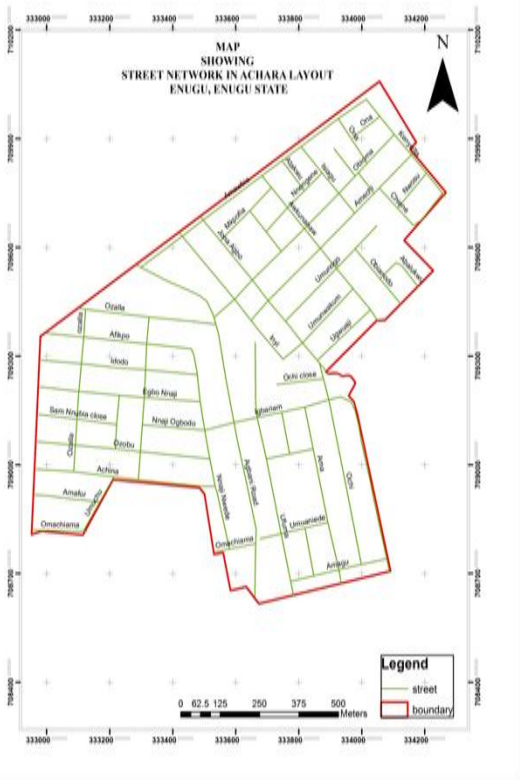

Fig 1: Street Network Map of Achara Layout

Water Distribution Pipe Map as shown in fig 2, acts as the basis for efficient management of existing pipelines. This allows one to know the location of water distribution pipelines in the area. It helps one to consider the extent of pipes and also obtain a visual representation on how the connections were linked. Water Distribution Network Management Map, as shown in fig 3, will be used for efficient management of water supply to consumers. The created database will help in cross checking generated revenue with the expected revenue. It will also enable efficient and speedy tracking of faults to facilitate consumer satisfaction.

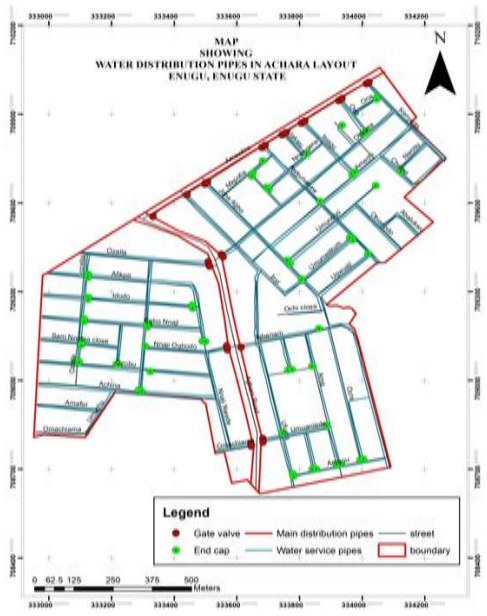

Fig 2: Water Distribution Pipes Map

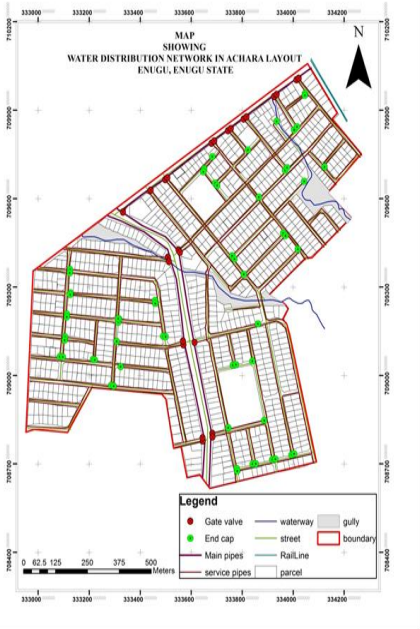

Fig 3: Water Distribution Management Map

1.1 Query Analysis

Queries were created at the end of the study to show the ability of GIS in solving problems related to water distribution. This is a factor that distinguishes GIS from other cartographic software. The query created in fig 4 was to find the buildings used for residential purposes only this can be used to regulate the billing system. The syntax "Use of Building"= 'Residential" was used. The answer to this query will enable the service provider to estimate the maximum consumption of each household to be able to appraise the quality of services rendered and it will make available the necessary information required for metering.

Query for the pipes installed in the year 2012 was created using the syntax install_yr=2012 was used as shown in fig 5. The information that will be generated from this query will help the decision maker to project times for maintenance and upgrading of infrastructures.

Fig 4: Query Result showing Buildings used for Residential Purposes only

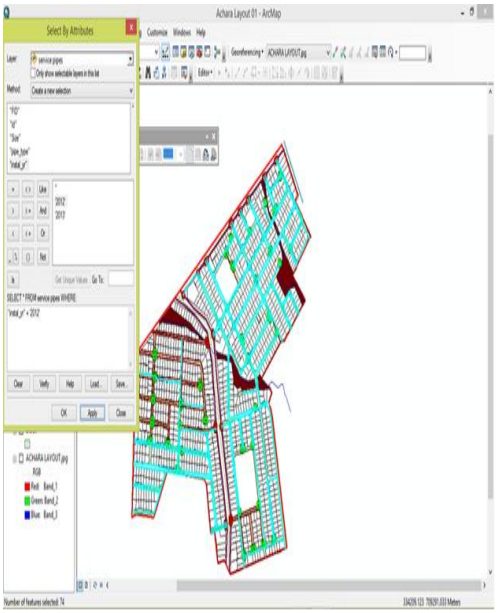

Fig 5: Query Result showing Service Pipes installed in 2012

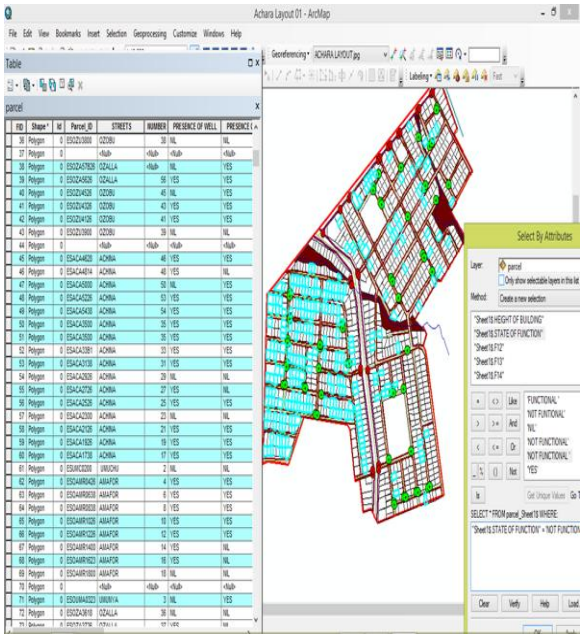

Fig 7: Query Result showing Parcels with Non functional Taps

3.2. Analysis of the Quality of Service Delivery

From the information generated from queries in figures 6 – 8, the quality of service delivery obtainable at the moment was analyzed.

Fig 6: Query Result showing Parcels with Functional Taps

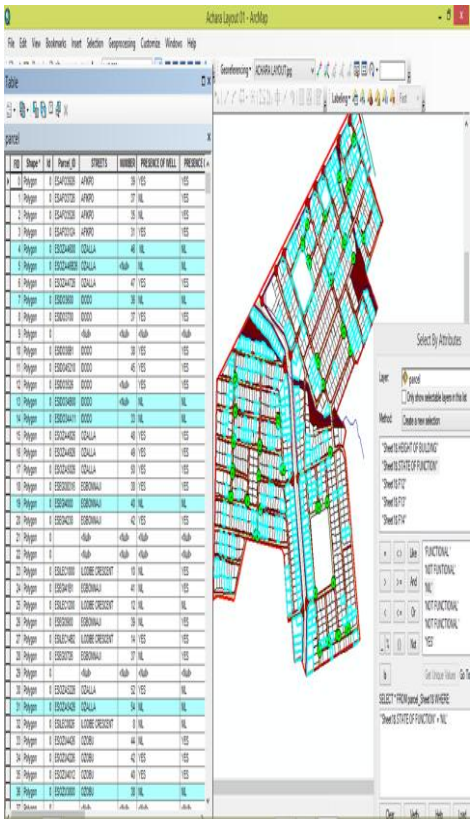

Fig 8: Query Result showing Parcels without Taps

Table 1: Summary of the Queries in Percentage

STATE OF SERVICE	NUMBER	PERCENTAGE (%)
Nil	297	27.73
Non-functional	231	21.57
Functional	543	50.70
Total	1071	100

From table 1, 50.7% of the total consumers have access to portable water, 27.73% of the consumers do not have facilities to convey water to them, while 21.57% have such facilities but they are not functional in the sense that there is no water available at those taps.. Summarily service delivery in the area presently is below average, which generally will affect the state of health, level of hygiene and development in the area adversely. This will also affect revenue generation from this sector negatively. It was also deduced that majority of the parcels without access to portable water are clustered within the same area having a higher elevation than other areas in the layout.

4. CONCLUSION

The Management of Water Distribution Networks using GIS is a very appropriate approach to solving water distribution issues. GIS functionalities have made it stand out as a very appropriate approach to efficient management of water distribution facilities. GIS makes use of accurate and up-to-date data, appropriate software for data processing, database creation and analysis. This study result is a map linking consumers and the assets that serve them, which will aid in improved service delivery and asset maintenance. It will also create a reappraisal platform for assessing service delivery and analysis of demand -supply trend.

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