Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.13, 2015
www.iiste.org

Mapping of Water Distribution Network using GIS Technology in Bauchi Metropolis, Nigeria

A.M. Pindiga and M.J. Sani*
Department of Surveying and Geoinformatics, Federal Polytechnic, Bauchi, Bauchi

Garba T.
Department of Environmental Technology, Abubakar Tafawa Balewa University Bauchi, Nigeria

Abstract
Increase in Population as well as demand for portable pipe-borne water in most of the cities of developing countries and the activities of the people greatly affect the pipes networks quietly laid beneath the ground. Locating such pipes and the features installed in them has been a task to tackle. Therefore to ensure proper surveillance and monitoring of laid down pipe around the metropolis need to be properly guided with modern technology like the use of Geographic Information Technology. Hence, to solve these problems analogue data was acquired from the Bauchi State Water Board (BSWB) and converted to digital map (Raster format). (GPS) coordinate was used to locate pipes within the network, the nodes, valves, water hydrants, and busters). Finally, the position of each of the identified features within the network was obtained and recorded in the events table. Digital map of water distribution network of the metropolis was produced and queries were raised while the node valves or pipes underground were easily located using GPS coordinates by navigating from the surface. The study recommends the use of GIS as a decision making tool for municipal water system authorizes or agencies for proper management and evaluation of their installations.
Keywords; GIS, GPS Coordinates, ArcGIS, Bauchi Metropolis and Water distribution network

INTRODUCTION

Water distribution network co-exist with human society for about two million years. They serve people's daily water consumption quietly after being laid underground. They are necessary and important but seldom notice by the public, except when they are under construction or maintenance. Then people notice the inconvenience when this network is under unhealthy conditions. Accidents caused by poor quality water distribution network can be found in every country for example, in the United States, 24% of the water-borne diseases outbreak over the past decade was caused by contamination entering the water distribution system when there is leakage (Wikipedia, 2005). Recently, the news reported that filthy water leaked out of a pipe and poured in to the section of the subway line that is under construction in Lagos, Nigeria. This burst caused the nearby road to sink into a huge hole, 20m long, 10m wide and 10m deep, in a busy section of on the ring roads in-cycling the city (Daily Trust, 2014). Moreover, in most Nigerian cities, most of the water infrastructures are up-to, and in most cases over fifty years old. Due to deterioration, infrastructures of this age are likely to suffer from problems such as internal tuberculation and corrosion, cracking and leakage, which can result in several operational problems. Meanwhile, the water distribution network problems are usually very difficult to define, so until now management planning methods for network rehabilitation are still poorly developed when compared with the financial and technological investment involved in. The rapid growth of computer technology, such as Geographical Information System (GIS), has been widely used in various fields since it was borne in year 1989. A GIS is a powerful configuration of computer hardware and software used for compiling, storing, managing, manipulation, analyzing, and mapping (displaying) spatially-reference information. The ultimate goal is to provide the most cost efficient system of maintenance and repair of water distribution networks, with aim to guarantee the security of water supply that meet social, health, economic and environmental requirements.

The Bauchi state water board (BSWB) is an agency under the Bauchi state ministry of water resources. The BSWB is responsible for providing the metropolis and its environs with portable pipe borne-water. The method adopted in distributing the water to the point of consumption requires the expertise of city planners and civil engineers who must consider many factors such as location, current demand, future growth, leakages, pressures, pipe size, pressure loss, fire fighting flows etc. But the question here is 'if any section or part of the water distribution network fails or need emergency repairs or in case of fire outbreak, how can this problem be solved or traced without disrupting other users on the network? Thus, this is one of the questions amongst others that this research will answer by employing a GIS techniques approach.

Osama (2012) conducted a listening survey of water distribution pipes in Canada, via Leak Noise Mapping, In-Pipe Leak Detection Systems, Leak Noise Correlation Surveys and Leak Noise Logging. Leak noise mapping is an enhanced form of general listening survey that was developed at the Halifax Regional Water Commission. This approach follows the usual practice of listening to leak sounds at easily accessible contact points with water pipes. In Canada, fire hydrants are generally 150 meters apart and hence provide convenient

contact points. Sounding is performed using electronic listening devices that are equipped with a sound level display, either analog or digital. Listening surveys, including leak noise mapping, are mainly suitable for small-diameter metallic distribution pipes

Avi and Elad (2004) adopted a methodology for finding the optimal layout of an early warning detection system (EWDS). The detection system is comprised of a set of monitoring stations aimed at capturing deliberate external terrorist hazard intrusions through water distribution system nodes-sources, tanks, and consumers.

Goulter (1992) employed the use of system - analysis techniques, and in particular optimization, to design water - distribution networks reveals that in spite of the considerable development of models in the literature they have not been accepted into practice. This system - analysis technique reviews several strategies used to survey for leaks using acoustic equipment and presents recent experience with regard to their performance.

Michael,Saviour and Naa (2011), applied GIS technique to investigate the water supply network of a section of Tarkwa Municipality in South Western Ghana. Digital maps of the study area were re-projected to the WGS84 UTM Zone 30 North projection. Analogue maps of the mains and lateral pipelines were scanned and geo-referenced to the same projection. The pipelines and node valves were then manually digitized, their attribute tables created and a geo-database model developed. A geo-database that supports improved operations and performance and to determine costs of asset replacement was created. The resource data used for the study includes shape files of roads, contour lines, cultural features and the analogue map of main and lateral pipelines, and attributes information of the pipelines. The valve and hydrant location points were acquired with handheld GPS receiver instrument .The methods used for this study included development of a geo-database, building geometric network and carrying out spatial and attribute queries in GIS. Also map layouts were generated from the spatial analysis and graph plotted using attribute data. The analysis of the pipeline network database indicates that more than half of the Tarkwa network is over aged and require replacement. The study also provides detailed spatially referenced information on pipelines and the associated cost of replacement as they reach the designed lifespan.

Fyassa (2009) enumerated some of the specified standards for laying water distribution pipelines. The strip of land lying between the source of water supply and the distribution area should be surveyed to obtain the levels for fixing up the alignment of the rising main. This main will carry treated water to the distribution reservoir(s) located in the distribution area. The distribution area should also be surveyed and detailed maps of are prepared showing the positions of roads, streets, lanes, residential areas, commercial locality, industrial areas, gardens etc. A topographical map of the area should be prepared to identify the high and low areas, the position of existing underground service lines like electric and telephone lines, sewer lines, existing water supply lines and a tentative layout of the distribution line should be marked showing the location of the treatment plant(s), distribution mains, distribution and balancing reservoirs, valves, hydrants, etc. The fire hydrants are placed at 50 to 100m intervals on straight runs, and on street junctions. The pipes should be designed for a discharge ranging from 2.25 to 3 times the average rate of supply. For populations over 50,000, the distribution mains should have a capacity of 225% of average rate of supply, while for population below 5000; the distribution pipes should have a capacity of 300% for the average rate of supply. The flow required for fire-fighting should be added to this maximum flow, to get the total flow. The pipes should be able to carry this total flow without excessive pressure drops. The length of pipelines should be kept as short as possible.

According to Fyassa (2012) pipe leakages occurring as a result of aging of pipe material, poor quality of workmanship, poor quality of material, high pressures, water hammers etc., contribute to loss of water. The points of leakage not only allow water to be lost, but may also allow contaminants to enter. The sound transmitted by the pipe wall can be heard by listening at the hydrants, main valves, and curb valves in order to detect water leakages. Leak detection aims to locate and repair small defects in a pipe network before failures occur and huge amounts of water are lost from the system. The ability to detect leaks in municipal water distribution pipes is a critical aspect of leakage management programs.

STUDY AREA

The project site is located in Bauchi State. The state lies approximately between latitude of 09.3° and 12.3° **N**orth of the equator and between longitudes 08.5° and 11.0° **E**ast of the Greenwich meridian. The state is bordered by seven (7) states namely; Kano and Jigawa to the north, Taraba and Plateau to the south, Gombe and Yobe to the east and Kaduna to the west. Thus, the state occupies a total land area of 509,259.01km square, representing about 5.3% of the land mass of Nigeria.

Figure I: Map of Bauchi state showing the study area

METHODOLOGY

The method used to accomplish the task includes the following:

i. Obtained an analogue map (plan) showing the water distribution network of Bauchi metropolis.
ii. Using a GPS to acquire the geographical co-ordinates (Easting and Nothing) of some selected points which are clearly identified both on the map and on the ground.
iii. Scanning of the existing analogue map so as to convert it to digital raster format.
iv. Geo-referencing and Digitizing the scanned map using ArcGis9.3 (Software).

METHOD OF DATA ACQUISITION

This is the process of acquiring the needed data and imputing them into the appropriate computer software so as to convert them into digital format. It also deals with processing and conversion of the data into different structures to serve different purposes.

WORKING WITH THE GPS

Global Positioning System (GPS), is a satellite based system that uses the constellation of 24 operational satellites orbiting around the earth at an altitude of 12000metres above mean sea level transmitting information to its users all around the world (Wikipedia, 2005).The accuracy of the GPS device at which we obtained our observations was 0.3m. T he GPS was use to capture the coordinates of the features as in appendix A

The table below shows the acquired coordinates of the selected points.

POINTS	EASTINGS(M)	NORTHINGS(M)	ACCURACY(M)
1.	582092.568	1138668.219	0.3
2.	598011.306	1138689.558	0.3
3.	591929.750	1145667.342	0.4
4.	598066.553	1136192.919	0.6

Figure II: The scanned map (raster format) Source: Bauchi State Water Board.

DATA PROCESSING

The data involves were transformed into different structures to serve different functions. The data processing carried out includes; image importation, geo-referencing and on-screen digitizing.

GEO-REFERENCING USING Arc GIS

Geo-referencing is the process of creating a geographical relationship between the software coordinates and the map coordinates. It is also referred to as the process of associating the various object positions with their corresponding ground positions. This simply means that every pixel of the scanned image gets a new dimension besides its location in the image, it gets a real-world coordinates as well.

ON-SCREEN DIGITIZING

On-screening digitizing means the tracing of features on the scanned map which are display on VDU (Screen) of the computer system. It involves insertion and manual tracing of all the features on the geo-reference map.

DISCUSSIONS AND RESULT

All the GPS coordinates (spatial data) of the node valves, the T-junctions, busters etc were captured as indicated on appendix A and represented on the map using ArcGIS. As many as possible queries were raised, one of the queries is the identifies the fire hydrants within the network as in figure III below others are in figure IV and Figure V. Figure VI is the composite map showing the water distribution network within Bauchi metropolis.

To identify or to locate pipe line or valves underground all we need are the coordinates of the valve or pipe in question to be imputed into GPS and then navigate

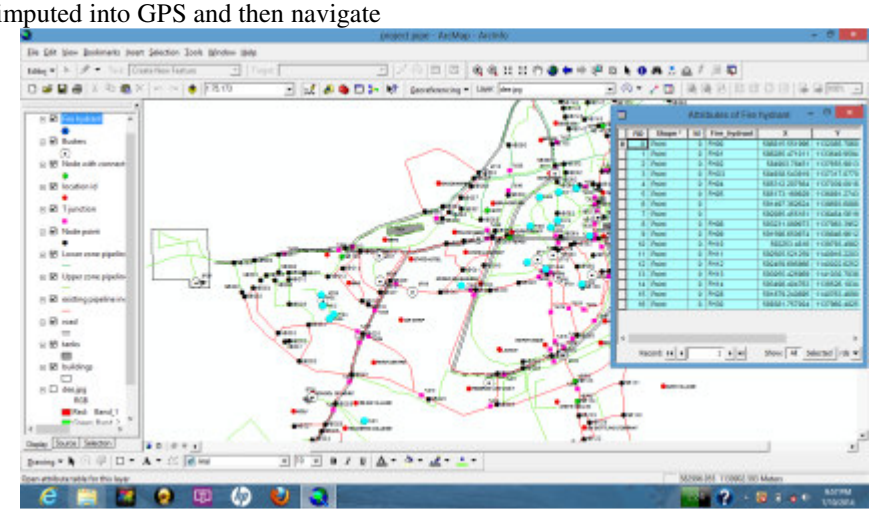

Figure III: Query identifying fire hydrants.(Source: Author's Lab.)

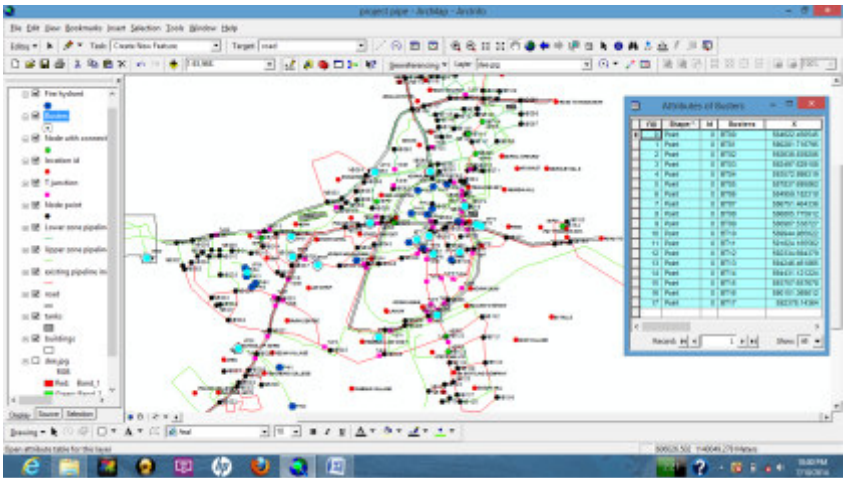

Figure IV: Query identifying the Busters.(Source: Author's Lab.)

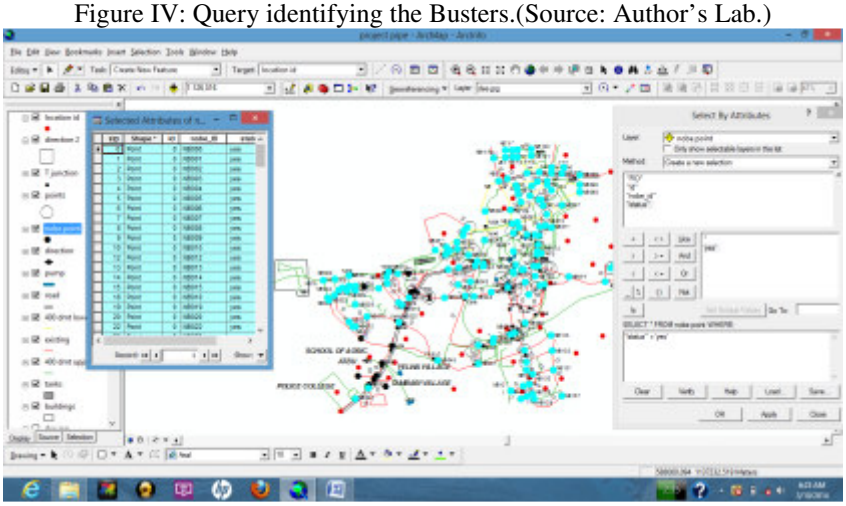

Figure V: Query identifying the Node points. (Source: Author's lab.)

DATA PRESENTATION

Information regarding the extent of the study is in form of digital map. Thus, the processed data (Information) were presented. Such presented information is a spatially reference digital map showing the water distribution network of Bauchi metropolis as in figure VI.

Figure VI: The Composite map of the study area (source: Author's lab.)

SUMMARY, RECOMMENDATION AND CONCLUSION

SUMMARY

This research was carried out in accordance with Survey rules and regulations whereby after reconnaissance, a Global Positioning System (GPS) was used to obtained the co-ordinates of some selected points which are clearly identified on the existing analogue map and also on the ground. Other processes include; Scanning, Geo-referencing and digitizing of the existing analogue map.

RECOMMENDATION

The following recommendations were drawn at the end of this research;

i. The research recommends the use of GIS as a decision making tool for municipal water system authorizes or agencies for proper management of their installations.
ii. The direct beneficiaries should employ the use of GPS coordinates (navigation) in tracing the locations of pipes underground.
iii. This study will also be of use to the fire service in determining the location of node valves to be used as fire hydrants within the metropolis.
iv. The composites map (digital map) can also be of useful to the ministry of works and state development board in designing road and any other construction work.

CONCLUSION

In conclusion the capabilities and importance of GIS is demonstrated through this research. A digital map showing the water distribution network of Bauchi metropolis was obtained. Criteria were drawn based on the analogue map and information obtained from the Bauchi State Water Board (BSWB).Such criteria were used to carry out the project successfully.

Having the positions (coordinates) of the various features within the water distribution network helps the management of the Bauchi state water board in decision making, strategic planning, effective resource and operation management, so as to achieve the business objectives such as customer satisfaction, business growth and customer based expansion.

REFERENCES

Avi, O. and Elad, S. (2004) Optimal Layout of Early Warning Detection Stations for Water Distribution Systems Security. Journal of Water Resource Planning and Management. 130(5), 377–385. Permalink: http://dx.doi.org/10.1061/(ASCE)0733-9496(2004)130:5(377)

Bruce, A. DeVantier, and Arlen, D. F. (1993). Review of GIS Applications in Hydrologic Modeling. Journal of Water Resource Planning and Management. 119(2), 246–261 Permalink: http://dx.doi.org/10.1061/(ASCE)0733-9496(1993)119:2(246)

Fyassa (2009).Technical Guidelines for the Construction and Management of Drinking Water Distribution Networks. A Manual for Field Staff and Practitioners developed in Partnership with UNICEF April 2009.

Goulter I. C. (1992).”Systems Analysis in Water - Distribution Network Design: From Theory to Practice.” Journal of Water Resource Planning and Management. 118(3), 238–248. http://dx.doi.org/10.1061/(ASCE)0733-9496(1992)118:3(238)

Latif I A, Mohamad S A R, Nor L M K, Tan M L (2012). Investigation of Ground Water Quality using Remote Sensing and GIS Technique. Conference Paper presented at the 33rd Asian Conference on Remote Sensing (ACRS2012) 26-30th Nov. 2012 at Ambassador City Jomtien Hotel, Pattaya Thailand.

Michael S A, Saviour M and Naa D T(2011). GIS in Water Supply Network Maintenance in Tarkwa, South Western Ghana. Research Journal of Environmental and Earth Sciences 3(6): 737-744, 2011 ISSN: 2041-0 Published: November 10, 2011 © Maxwell Scientific Organization, 2011.

Osama Hunaidi (2012).Acoustic Leak Detection Survey Strategies for Water Distribution Pipes.Halifax Regional Water Commission, Canada

Wikipedia,2005,2006,2014.

APPENDIX A: EVENT TABLE

S/N	NUMBER ID	EASTINGS(M)	NORTHINGS(M)
1	BT00	584622.450	1134406.040
2	BT01	590281.710	1134862.260
3	BT02	592638.830	1135742.100
4	BT03	592497.620	1138207.850
5	BT04	593572.990	1138283.890
6	BT05	587837.690	1137762.490
7	BT06	584959.180	1137469.210
8	BT07	586751.460	1138913.900
9	BT08	586805.770	1138088.360
10	BT09	580907.530	1138023.190
11	BT10	589944.980	1139457.020
12	BT11	591824.160	1138783.550
13	BT12	592334.690	1138935.620
14	BT13	594246.460	1139370.120
15	BT14	594431.120	1139326.670
16	BT15	593757.650	1140119.620
17	BT16	590151.360	1141488.270
18	BT17	592378.140	1141509.990
19	NB000	582765.380	1138745.850
20	NB001	582966.970	1138117.340
21	NB002	582362.180	1137737.860
22	NB003	582433.330	1137595.560
23	NB004	582717.940	1137868.310
24	NB005	583144.860	1138271.500
25	NB006	583417.610	1138105.480
26	NB007	583524.340	1138935.590
27	NB008	583536.190	1138366.370
28	NB009	583856.380	1138354.520
29	NB010	583844.520	1138141.060
30	NB011	584354.450	1138330.800
31	NB012	585113.410	1138235.930
32	NB013	585670.770	1139137.190
33	NB014	585587.760	1138496.820
34	NB015	586145.120	1139018.610
35	NB016	586761.780	1139018.610
36	NB017	586904.080	1138034.330
37	NB018	586394.150	1137334.660

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar