Geographic Information Systems Based Urban Drainage Efficiency Factors

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SUMMARY

Urban areas in the developing world are experiencing increasingly dangerous flood events due to urban constructions and climate change. Urban flooding has become a major global concern, and for obvious reasons it is mostly an urban phenomenon. Urbanization creates impervious ground surfaces, inhibiting infiltration. Ill-advised urbanization practices lead to the blockage of natural flow routes. Urban centres are growing very fast in Africa. Where drainages are constructed they are mostly road edge drainages constructed to protect the roads instead of landscape drainages. Urban flooding can only be taken care of by efficient landscape drainages. The research work reported here determined efficiency factors of drainages which include the locations, alignments, slopes and sizes of drainages on a Geographic Information Systems (GIS) platform. The aim of the drainage efficiency factors guidelines is to ensure that the drainages will serve to convey runoff in ways that eliminate the danger of either erosion or flooding to the environment. The research effort created a Digital Elevation Model (DEM) of Owerri in Southeast Nigeria, using data from topographical maps of the city. The data was authenticated using three dimensional (3D) coordinates of sample points derived from Global Navigational Satellite Systems (GNSS) surveys. The DEM was processed by the ArcHydro software to determine primary natural flow routes and the sub-catchments that flood them. The primary landscape unit for drainage design is the subcatchment. The size of each sub-catchment useful for computing volumes of runoff that would have to be conveyed by the constructed urban drainages were determined using GIS. A scheme of urban drainage network as a runoff collector system that conveys runoff from the entire landscape to the primary drainage routes is suggested. The efficiency factors determined for Owerri were used to test the existing drainage systems. The failure of the existing drainages to conform to the guidelines explains why the study area would flood at every rain storm event.

1.0 INTRODUCTION

Urban flooding is increasing across the globe as a consequence of the twin issues of urbanization and global warming. Urban areas are springing up steadily in the developing world. The United Nations projects that by 2030 half of all of Africa's population will live in urban centers.[1] Urbanization has been reported to aggravate flooding by creating impervious ground surfaces which reduce infiltration. Constructions restrict where flood waters can go, sometimes obstructing sections of natural channels. Building lined drains that ensure that runoff moves to rivers faster than it did under natural conditions often inundate the river channels leading to urban flooding too. As more people crowd into cities, so the dangers of flooding intensify.[2] However, most of the governments of Africa have not given needed attention to the issues of runoff management.

Records show that since 2007, the flood situation in West Africa is becoming more and more recurrent and the impact on the population and infrastructures is becoming more severe.[3] It is estimated that over the years more than 60% of Nigerian states have recorded some form of serious flooding. It is noted that at least 20 per cent of the total national population is at risk of one form of flooding or another.[4]

In conceiving urban areas, a number of drainage decisions will need to be taken at the conception stage in the light of the runoffs that would be generated in urban areas. Such decisions will include the location of natural drainage routes to ensure that they are left free of constructions in the new urban area plan. The installation of drainage systems will require that location of runoff drainages and storages, alignment of the drainages, the slope and the sizes be fitting for efficiency. These decisions need terrain information which may be provided using the Geographic Information Systems. Researchers are agreed on the fact that for functional and economic efficiency, drainage networks will have to be designed considering the natural flow routes and their sub-catchments.

Rao, D. R. M., Ahmed, Z., Reddy, K. R. M., Raj, E. (2013) a technical paper on the selection of drainage network using Raster GIS – A Case Study of Kukatpally Municipality, India. Its general findings are that for efficiency, selection of drainage layout should be based on a good understanding of topography. The paper concludes that alignment of sewers and storm water drains should follow natural drainage patterns considering topography, land use, land cover and right of way for both drainage and economic efficiency.[5]

Al-Saud M. (undated) reports on the use of Remote Sensing and Geographic Information System to analyze drainage systems in flood occurrence in Jeddah - Western Saudi Coast, Kingdom of Saudi Arabia. The paper reports that 1:50000 topographic maps of 20m contour interval together with DEM were used to extract the related parameters for drainage systems after delineating the drainage flow routes and their basins directly in the GIS in the study area covering about 1947km^2.

Gumbo, B., Munyamba, N., Sithole, G., Savenije H. H. G. (2002), reports on the assessing of the efficiency of the then newly constructed drainage system of the University of Zimbabwe by combining a Digital Elevation Model (DEM) with a rainfall-runoff model based on the Soil

Conservation Service - South African Manual (SCS -SA). The natural drainage routes and their corresponding sub-catchments of the area were delineated automatically using the DEM. The average runoff and peak discharge from each basin was computed using the SCS method and wet antecedent moisture condition (AMC). By superimposing the map of the constructed physical drains on the DEM containing automatically generated natural flow lines, the sizes and orientation of the drains were assessed for effectiveness. While the drainage sizes were seen to be suitable, visual on screen inspection showed that the orientation of the drains required a lot of improvement. It appeared that overall, the drain orientation was dictated by the orientation of the road network and position of building lines.

Giron (2005) reporting on the development of a SWMM-GIS flood model for New Orleans Drainage Pumping Station No 4 Basin, concludes that high intensity rain events flooding might be caused by inadequate inlet capacity, and not just by lack of capacity in the main trunk system or insufficient pumping capacity. The time it takes for water to be drained into the sewer system is critical. If the inlet is inadequate, very heavy storms even over a very short period can produce flooding and significant damage. The point of the inlets as an efficiency factor in drainage design is clear.

In order to mitigate urban flooding it is important to construct right sized drainages that are correctly aligned horizontally and vertically at the right locations. This study located the optimal positions of drainages by delineating the natural flow routes of the sub-catchments of Owerri South East Nigeria, and their alignments to check if the city's drainage systems can mitigate against flooding. In every city, except for the theoretically flat ones, there are already existing natural flow routes. These routes are the result of the natural morphology of the landscape and have efficiently drained the runoff of their sub-catchments over the years. For large areas these natural flow routes are the primary runoff conveyance routes of the sub-catchments, and should form the primary drainage routes of the sub-catchment. If these routes are not located for construction of the primary drainage routes, there will need to be excessive engineering constructions if at all the drainage of that sub-catchment can be got right. It appears that in the developing world there will hardly be any Government willing to waste such resources if they can find it. The drainage sizes are dependent on the area of land that charges the constructed drainages and the amount of precipitation of the design storm event.

1.1 Study Area

The study area is the urban area of Owerri, Imo State, South East Nigeria and its environs. Owerri is the capital city of Imo State, south-eastern Nigeria. Owerri with a population of about 150,000 situates between 5^0 20'N, 6^0 55'E in the south-western corner and 5^0 34'N, 7^0 08'E in the north-eastern corner. The old city of Owerri is bordered on its south by Otamiri River and on its west by Nworie stream. However with the development of the New Owerri City across Nworie stream, on the western side, the two water bodies now transverse the town. Fig. 1 shows the project area.

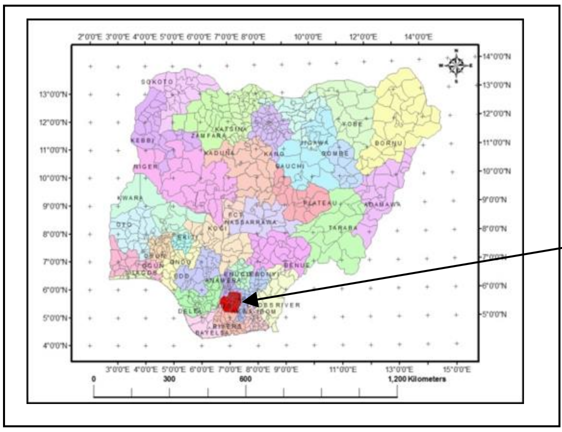

Fig. 1a Map of Nigeria with LGAs, showing Imo State South East Nigeria

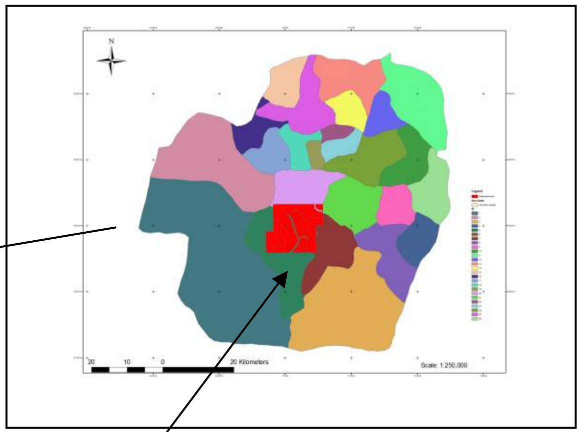

Fig. 1b Map of Imo State with LGAs, showing the project area

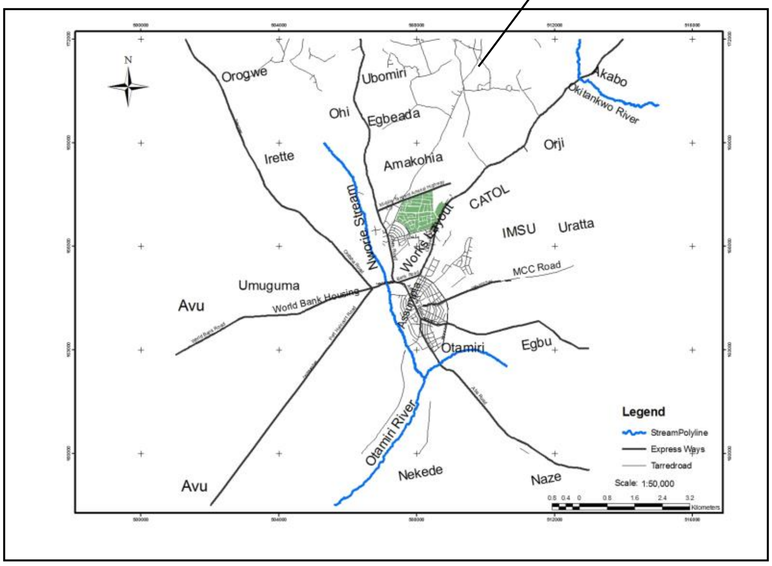

Fig. 1c Location Map of the Project Area in Owerri, South East Nigeria

Fig. 1 Maps of the Project Area

2.0 THEORETICAL BACKGROUND

2.1 GIS as a Tool for Drainage Data Generation

Urban Planners traditionally use aspect type approach of contour interpretation to determine routes to locate drainages in designing new urban layouts. Arrows representing water flow direction can be drawn perpendicular to each contour, in the direction of the steepest descent. This would be very labourious and error prone over large areas. A drainage route is a linear connection of land units that accumulate the most runoff in an area. Quantity of accumulation of runoff is determinable on a spread sheet when the sub-catchment and the area size is determined on a GIS platform.

Recently drainage areas have been delineated automatically using digital elevation models of the land-surfaces on GIS platforms. A digital elevation model (DEM) is a grid of rectangular cells of unique elevation values representing the land surface. By determining how water flows from cell to cell, the set of cells whose drainage flows through the cell at the outlet point location can be identified, and thus the drainage area determined.[7]

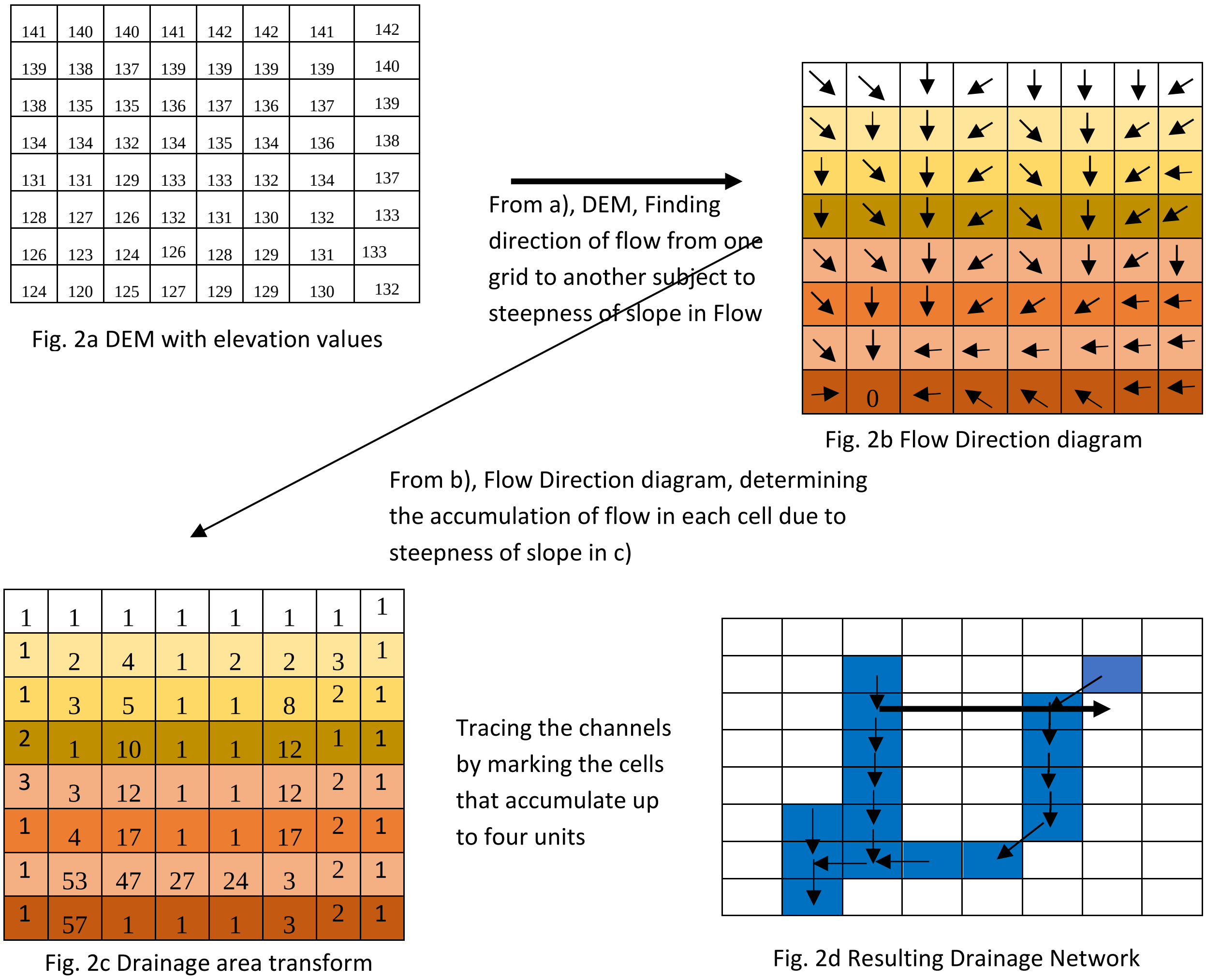

Fig. 2 Concept of the "hydrological approach" of delineating drainage network from a DEM

Of all the possible methods used in Geographic Information System based delineation of hydrologic features at present, the most commonly used method appears to be the so-called "hydrological approach" proposed by Mark (1984). In this method, the "drainage area" of each DEM elevation grid (i.e., the number of cells that drain into a cell of interest) is first determined by climbing recursively through the DEM (Figures 2a and 2b). This process results in a matrix, called the "drainage area transform" (Figure 2c), that contains the drainage areas for all the grids in the DEM. The information in the drainage area transform is then used to trace the "channel pixels," as identified by those grids with large drainage areas. Channels are recursively followed upstream until there is no more point that exceeds a minimum threshold (Figure 2d). Once the drainage network has been delineated, ridges may be delineated either by gray-scale thinning of all non-channel pixels or by tracing the boundaries of the catchment area.[8]

An interpolation process to connect broken line segments into a properly connected drainage network may be needed. On the other hand, if the channels and ridges consist of multiple adjacent lines, a thinning process is required to turn them into continuous lines of one grid width.

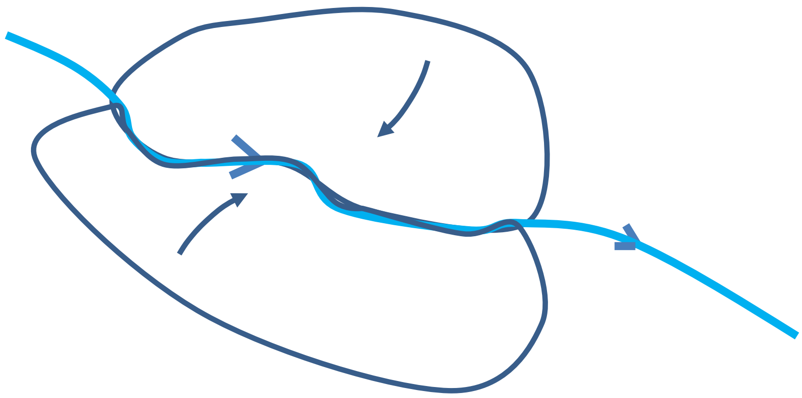

Fig. 3 General properties of a sub-catchment

Fig 3 illustrates the general properties of a sub-catchment. The natural drainage line flows between the two leaves of each sub-catchment. This is the basic unit of each landscape. When an urban area is planned the drainage of the area should be planned in consideration of the lay out of the sub-catchment. The design should anticipate the capture of runoff from the landscape before it builds up enough to create a flood or to erode the landscape. These drainage plan should convey captured runoff to the free flowing natural flow route.

Naturally there would be three levels of the drainage network. The primary level would drain the entire sub-catchment. The secondary level would drain the blocks of the layout design and empty them into the primary drains. The tertiary level would collect the runoffs of each plot and empty them into the secondary level drains. In Fig. 4 the primary drainage line, which conveys all runoff of the entire landscape is shown in blue and is located on the natural flow route of the sub-catchment. The secondary drainage lines are shown in red and they collect runoff from the layout blocks and convey them into the primary drainages. The tertiary level drainages, which collect runoff from the individual plots are shown in purple. The tertiary drainages convey runoff into the secondary drainages.

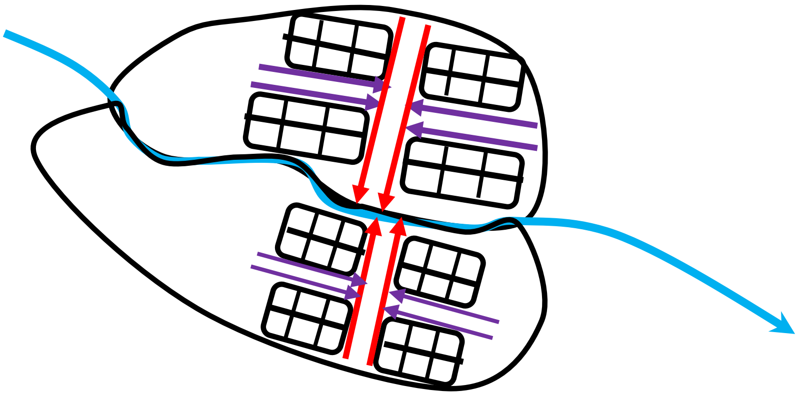

Fig. 4 Layout of efficiency factored landscape drainages

It is obvious then that the proposed efficiency factored drainage scheme is built upon the delineation of the natural flow routes and their sub-catchments. The location of the natural flow route of each sub-catchment provides the horizontal alignment of the primary drainage. The slope is read off the topographic information of the DEM our superimposed contours. As can be seen the layout is planned in such a way that the runoffs are captured by tertiary drainages which are aligned near parallel to primary drainage lines. The tertiary drainage lines run across the slope direction of the landscape. The tertiary drainages ensure immediate capture of runoff from each plot or across each road before they build up to flood or erode. The secondary drainage lines are aligned along the slope directions. They collect runoffs from the tertiary drainages and empty them into the primary drainages which convey the runoffs away from the sub-catchment. With the area of the sub-catchment known the sizes of the drainages can be calculated with a good knowledge of the designed peak rain storm event.

The aim of this research is to provide needed information for the construction of efficient drainages to mitigate against urban flooding and erosion. This effort involved creating a Digital Elevation Model (DEM) of Owerri and carrying out the geospatial elevation analyses of the study area in order to delineate the natural flow routes and their charging sub-catchments in a GIS environment and to indicate these drainage routes on the map of Owerri. These GIS generated drainage information of the study area were checked out in the field to see if they have been adhered to in constructing drainages in Owerri.

3.0 MATERIALS AND METHODS

The research being reported involved the use of already existing topographic maps to create a Digital Elevation Model (DEM) of the project area on a GIS platform and by GIS processing delineate drainage routes on the map of the study area.

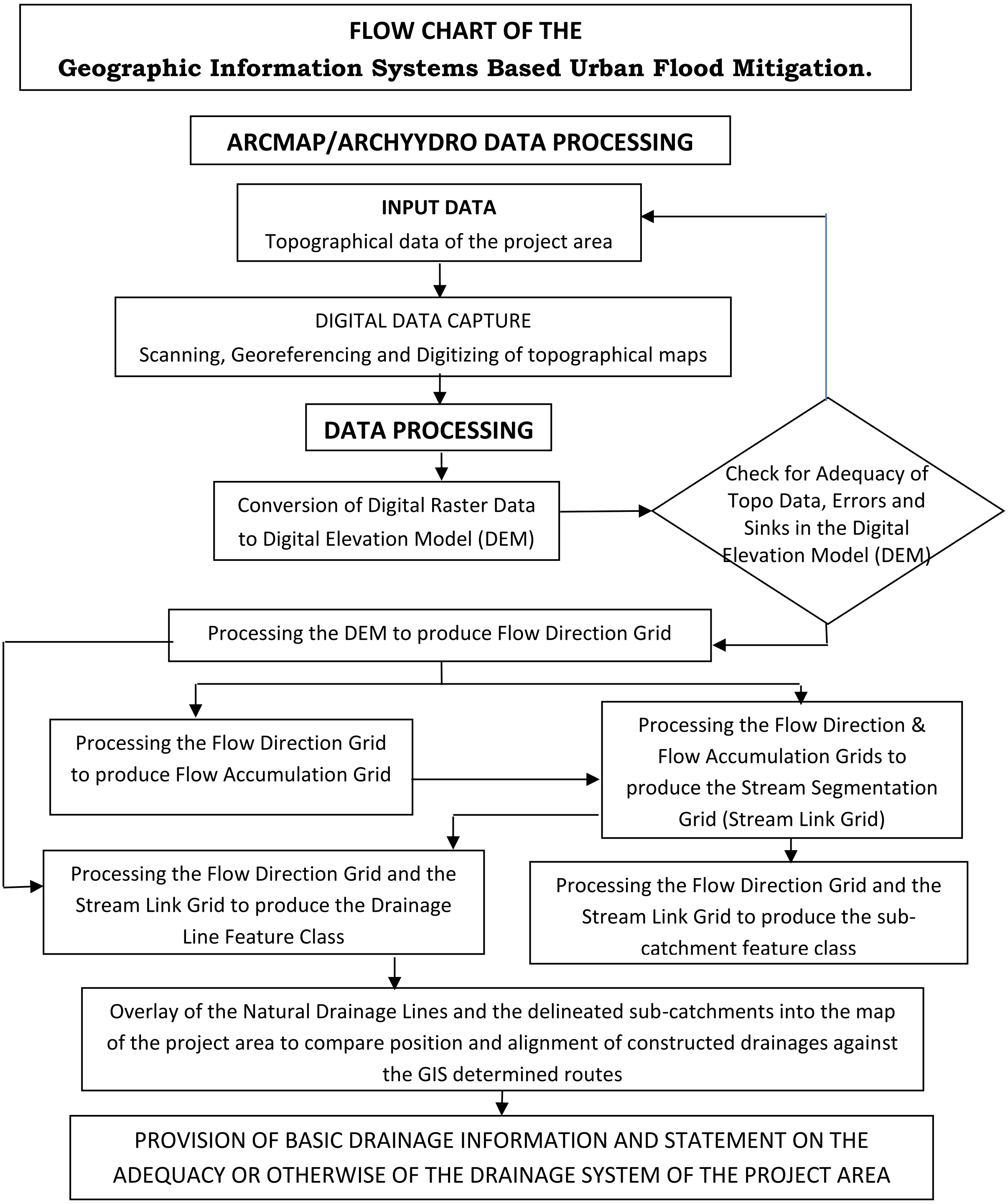

Fig. 5 Flow Chart of the Project Methodology

3.1 Data Acquisition

The research involved essentially analysis of topographic data of the about 18602.38 Hectares (186.024 Sq. Km) project area. A series of topographic maps of Owerri Nucleus area were made available by the Imo State Surveyor General and the Head of the Survey Department, Owerri Capital Development Authority. The Owerri Nucleus topographic map series was compiled and produced from Aerial Photographs of Owerri Nucleus dated 23 - 27 January, 1977 by Geodetic Surveys Ltd. for the Imo State Government[8]. Considering homogeneity of topographic data for consistency in the elevation model this map series was chosen as the basic data for the research work. A mixture of data sources needs a lot of care to avoid shifts which would easily introduce errors in the analysis. The age of the map series however, placed a necessity for current field validation of the data. Fig. 5 shows the flow chart of the project area.

3.2 Creation of the Digital Elevation Model

The topographic maps were scanned using the The Colortrac SmartLF Gx 42 Scanner. 62 number 1/2,500 topo sheets were scanned in the Tagged Image File Format (TIFF) and stored in compact disks. The topo sheets were added as data into ArcMAP software. These topo sheets which were referenced on the Nigerian Transverse Mercator frame were georeferenced in ArGIS using the transformation parameters of Owerri relative to the default ArcMap World Geodetic System 1984 (WGS 84) coordinate datum. The full transformation details from WGS 84 System to Minna B System used are the ones determined for Owerri by Chevron Nigeria Limited as are given here: dx = -93.179m, dy = -87.124m, dz = 114.338m Ωx = 0.00000", Ωy = 0.00000" Ωz = 0.00000", s = 0.00000ppm[9].

After georeferencing and checking for proper alignment the maps were fully digitized. Shape files were created in which digitized data were stored. The digitized contours of the entire project area were used to create the Digital Elevation Model (DEM) in ArcMAP. It was ensured that the DEM created was free of sinks before further use. Sinks are erroneous depressions that occur as some cells in the DEM assume values that are lower than the neighbouring cells. This is caused by the interaction between the algorithms that create the DEM and the data itself. The sampling distance chosen for creating the DEM was 2500. This resulted into cells of 2501 columns and 2120 rows with cell sizes of 5.598m x 6.368m. Fig. 6 shows the resulting DEM with its values coded in grey shed. The DEM values stretch in discrete values from 42 to 129; the lowest and highest contour values of the project area.

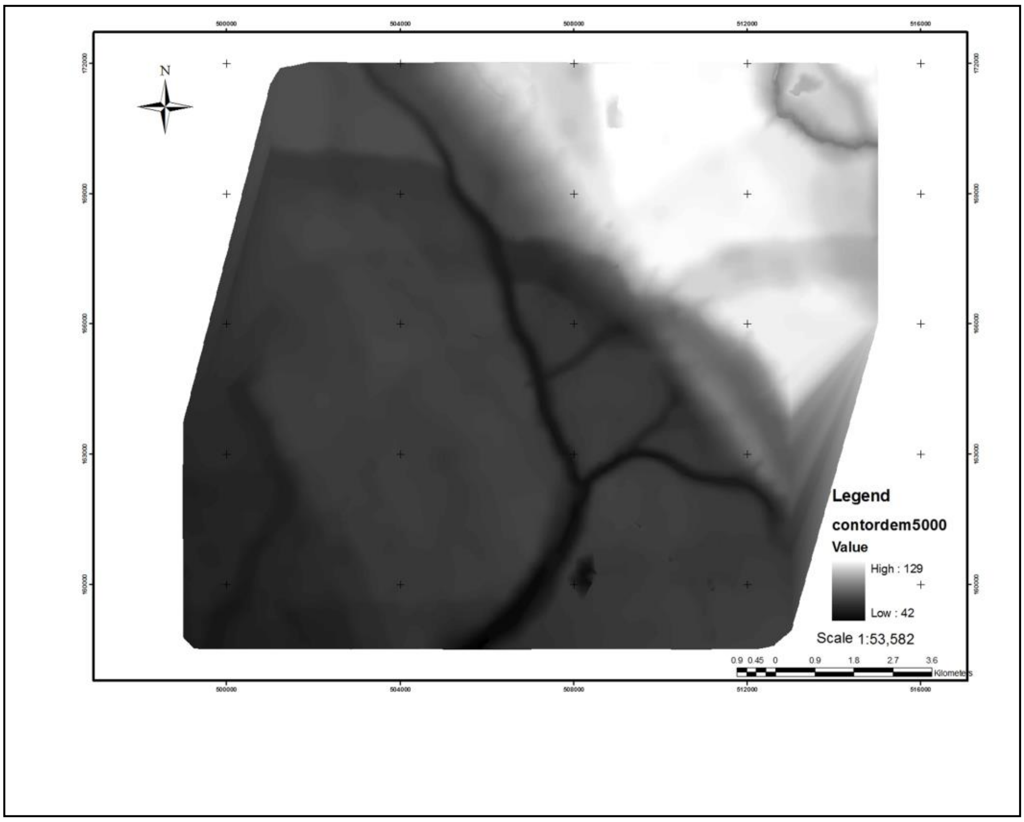

Fig 6 Map of the Digital Elevation Model DEM of the project

The elevation (pixel values) of points in the DEM of this project were compared to elevations of the corresponding points derived from GPS observations carried out between 2012 and 2014. Four known points where there were considerable cuts for constructions tended to bias the result. When the computation of bias statistic was carried out with all the points the average difference between the two surfaces (the topo map based DEM surface and the GPS generated surface) was -0.51m and the root mean square error (RMSE) was 1.95m. When those known cut points were taken out of the computations leaving 53 points, the average difference was 0.17m and the root mean square error was 0.60m.

Comparatively, some alternative and more recent sources of the DEM data include SPOT with standard deviation (RMSE) for flat terrain of 2.97m for open and 3.66m for forest areas; Shuttle Radar Topographic Mission, SRTM X-band with RMSE of 3.97m for open and 4.49m for forest areas; SRTM C-band with RMSE of 4.25m for open and 6.14m for forest areas; and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) with RMSE of 7.29m for open and 8.08m for forest areas[9]. So even when the five heavily cut sites are included the DEM from the 37 year old topo sheets compare very favourably, and far better when they are removed.

The difference recorded between the DEM values and the GPS derived elevations of the corresponding points result from a number of issues. The value of each DEM pixel is a generalization of all elevations possible to occur in the DEM cell, each cell in this case is of size of 5.598m x 6.368m (35.648 Sq. m), with a diagonal of 8.479m. The consistency of the DEM values with the field observed values is dependent on the resolution of the DEM. Thirdly, the topo sheets derived from aerial photographs introduced their own errors. Fourthly, the errors arising from the geoidal model for the GNSS orthometric height estimations need to be accounted for. Fifthly, the derivation of transformation parameters which may have introduced some lateral shifts so that there would be some errors in the registration leading to some errors in comparing the elevations. Lastly, and possibly very critical is the time-based changes in the topography. Areas with greater urbanization changes have ordinarily more bias than the virgin areas that have not yet changed, implying that constructions have also altered the terrain to some extent.

3.3 Dem Analysis for Delineation of Natural Flow Routes

The process of delineation of the natural flow routes is illustrated in Fig 2. The direction in which water will flow from a cell in consideration of its immediate surrounding cells yields the Flow Direction Grid. This is a grid of cells indicating the steepest direction from a cell to the surrounding cells. This grid was created directly from the DEM using ArcHydro extension.

Each cell of the area accumulates water that rains directly on it plus the runoff that flows from other cells through it. If water was to flow in 1 unit per cell, how many cells will the water in them empty into or through a cell of interest? The number of cells upstream that accumulate into a cell of interest is the value of that cell in the flow accumulation grid.

In consideration of the Flow Accumulation Grid, a threshold of what volume of flow (number of accumulating cells) defines a stream in the project was set. The idea here is that the grid cells that accumulate runoff from a set minimum number of cells are considered to be the stream (natural flow route) cells. Setting the threshold requires some fair knowledge of the project area so that the operator will be able to ascertain when a chosen threshold defines true streams. The resulting primary natural flow routes of the project area are presented in Fig. 7.

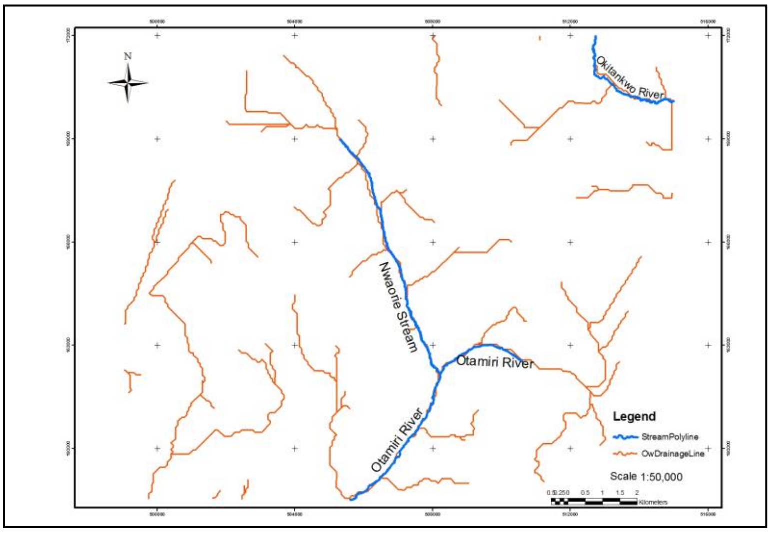

Fig. 7 Drainage Line map of the Project Area

3.4 Delineation of Catchments

The catchment grid delineation was processed to create a grid in which each cell carried a value called grid code, tied to the stream that they flow into. All cells of the same catchment had the same identifier. The Flow Direction Grid and the Stream Link Grid served as the input grids and the delineation produced the Catchment Grid. The map of the delineated sub-catchments is presented in Fig 8. The drainage lines that each sub-catchment charges are shown in red.

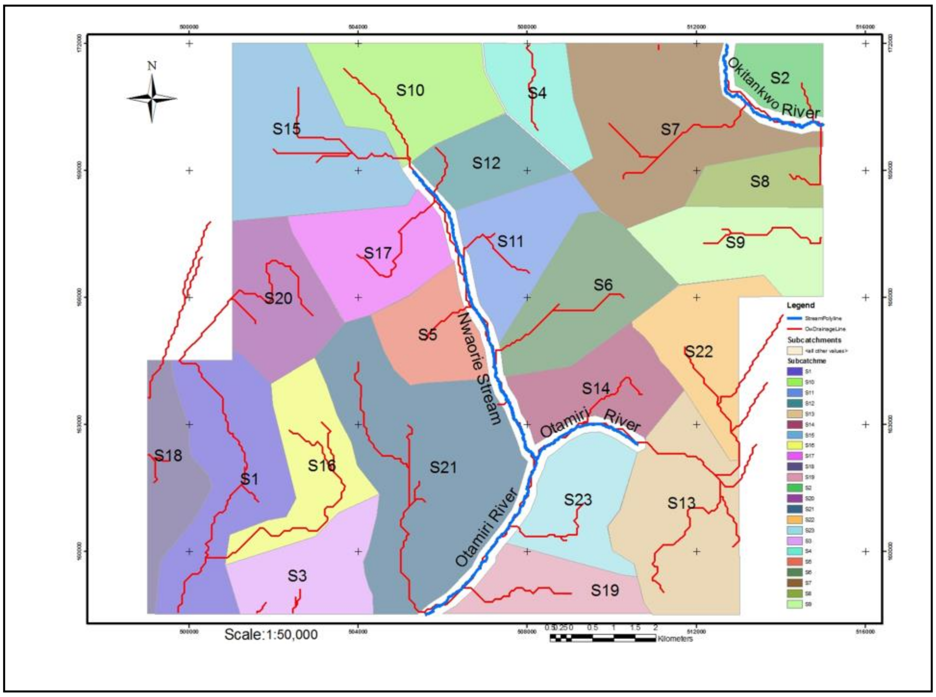

Fig. 8 Map of the Sub-catchments of the project area numbered S1 to S23

The catchment polygon was delineated by converting the catchment grid into a catchment polygon feature class. In this process all cells in the grid that had the same grid code were dissolved into a single area, after which the process vectorized the boundary. For more practical purposes such as drainage and flood management uses, some of the catchment polygons so produced may need further collapsing into a polygon since their drainage lines make up a single flow route. This need arises because the automatic method comes from the fact that the catchment polygons so produced were based only on the cells that are in each stream link only. The morphology of the area that accounts for a continuous drainage (stream) flow is the necessary definition of the sub-catchment. The sub-catchments so automatically created were generalized further in order to delineate sub-catchments more accurately defined.

The area of each sub-catchment and other characteristics necessary for computing volume of flow with each sub-catchment were determined. These include the area, the centroid coordinates, the remotest overland flow distance, the average slope, and the width of each sub-catchment. These characteristics are presented in Table II.

Table II Characterized Sub-catchments of the Project Area

Sub-catchment	**Area(Ha)**	**Y_Centroid**	**X_Centroid**	**Remotest Overland Flow Distance, L (m)**	**Slope (%)**	**Width (m)**
S1	1157.54	161700.477	500830.797	1432.108	0.486	8082.77
S2	320.05	171227.331	514032.482	722.512	2.366	4429.68
S3	615.03	159539.542	502904.441	2522.827	0.396	2437.86
S4	456.57	170762.16	508281.351	1085.988	1.03	4204.19
S5	495.74	165118.868	505752.395	1140.55	0.069	4346.50
S6	886.32	166016.093	509332.900	2149.926	2.315	4122.56
S7	1477.02	170084.911	511135.034	1469.609	0.748	10050.43
S8	354.97	168725.922	513545.971	2135.109	0.234	1662.54
S9	744.66	167223.576	513030.312	1192.08	1.786	6246.73
S10	869.88	170901.815	505192.386	2618.872	1.743	3321.58
S11	653.82	167330.773	507795.247	2450.653	1.743	2667.94
S12	461.57	169178.956	507050.219	2771.695	2.374	1665.30
S13	1158.69	160767.995	511673.929	2009.049	0.163	5767.36
S14	631.90	163851.508	509725.267	1332.839	1.808	4741.01
S15	1251.66	169670.381	502672.013	1494.886	0.331	83507.46
S16	683.16	162022.01	502794.909	966.394	0.425	7069.17
S17	725.35	167044.464	504362.611	1297.333	0.679	5591.08
S18	487.3	161855.515	499520.616	2063.469	0.606	2361.56
S19	495.27	159135.150	508560.419	844.393	0.012	5865.40
S20	713.98	165955.200	502086.13	1836.938	0.543	3886.79
S21	1942.42	161975.479	505499.642	2040.573	0.213	9518.99
S22	652.46	164832.787	512204.074	2404.462	1.262	2713.54
S23	628.23	161125.197	509251.801	1178.818	0.202	5329.32

4.0 RESULTS AND DISCUSSION

Efficient drainage systems will mitigate urban flooding. Efficiency of drainages depend on the location of the drainages, the alignment of the drainages, the slope of the drainages, the sizes of the drainages and the locations of the inlets. The natural morphology of a land area has a primary natural flow route for each sub-catchment. The natural flow routes of the sub-catchments should form the primary drainage routes of each sub-catchment in the urban area. In most cases the artificially designed blocks of urban land use, often bordered by roads, should form the secondary routes that are channeled to empty into the primary drainages. The plots that make up the blocks are drained in the tertiary drainage scheme into the secondary drainage systems. The most critical urban drainages to mitigate flooding are the primary drainages. If they are not properly in place every other drainage may serve at best as blocked conduits and will not serve to mitigate flooding in the area.

The greater part of the drainages of the study area were constructed alongside the roads. The map of the delineated natural flow routes was superimposed on the map of the study area to create Fig. 9. It presents the main express routes with some sizeable drainages shown in black lines while the delineated sub-catchment natural flow routes are shown in red. The streams and rivers are shown in blue. While the dislocations of the roadside drainages from the delineated natural routes are obvious, the determination of the efficiency or otherwise of the city drainage system was ascertained by visiting the primary natural flow routes of each sub-catchment to determine the efficiency of the primary level drainages.

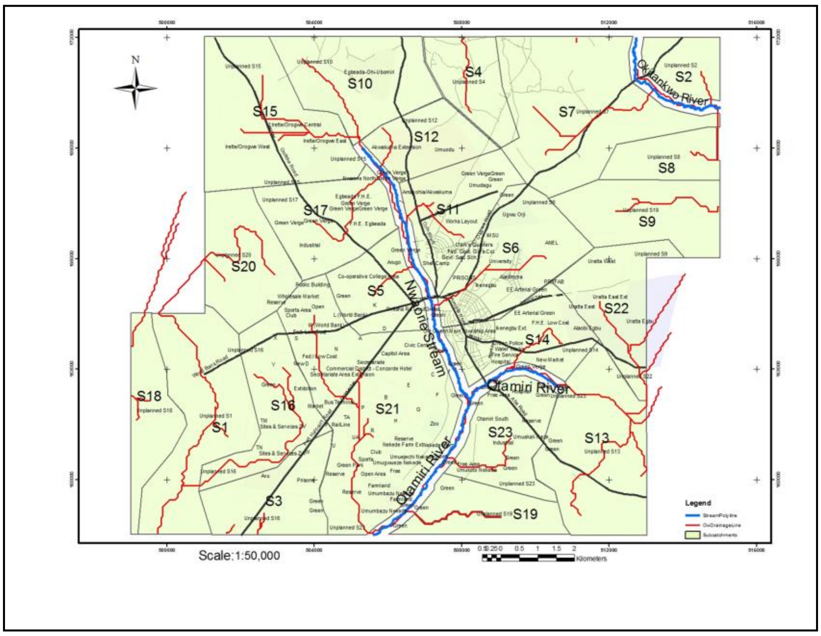

Fig. 9 Map of the Project area showing the natural flow routes, roadside drainages, streams and rivers.

The delineated natural flow routes of the project area were visited to determine the suitability of the constructed drainages. A number of the sites in the built up areas were flooded and there were no drainages constructed at the locations. In some cases houses have been constructed along the delineated natural flow routes. Some of these routes in the undeveloped parts of the project area are also being built upon. It was also observed that the routes were also blocked by roads constructed across the natural flow routes at raised elevations. This made the routes on the upstream side to hold back flow. The roads themselves are obviously endangered. The inhabitants of the Federal Housing Estate, Egbu Road, attested that they surfer perennial flooding that destroys properties in the hundreds of millions. A visit to that area shows that parts of the Estate was constructed on the main natural flow route of the sub-catchment. Fig 10 shows a number of such sites.

Fig. 10a Natural Flow route at Federal Housing Estate Area, Off Egbu Road Owerri photographed on 20th July 2012

Fig. 10b Natural flow route at Federal Housing Estate Area photographed on 20th July 2012

Fig. 10c Natural Flow route at Avu Owerri West L.G.A. photographed in June 2012. Buildings on the left are already blocking the natural flow routes.

Fig. 10d Natural flow route at Works Layout Area Owerri, blocked with buildings, photographed on 6th October 2011

Fig. 10e Natural Flow route at Chukwuma Nwoha Road Area photographed on 20th July 2012. The natural flow route here runs across the road from right to left. It has been blocked by the road to which this road joins.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This paper has demonstrated the determining of the drainage efficiency factors of location, alignment, slope and size using Geographic Information Systems. The determination of these factors relied completely on the use of Digital Elevation Model (DEM) of the area analyzed on a GIS platform. The DEM was derived from the digitization of the topographic maps of the study area on a GIS platform. The DEM was validated using GNSS observations

This research paper has demonstrated the determination of the flood mitigation factors which directly affect drainage efficiency. Owerri has been known to flood over the years. In 2001 alone 1000 houses, 150 electric poles, and 40,000 oil palm trees were destroyed, and over 10,000 people were displaced in Imo State[4]. In 2005 about 3,500 families in Owerri were reported to have been sacked by flood, putting the cost of the material loss at ₦200 Million[11]. Over the years the perennial flooding has not abated. This research effort has shown that not implementing of the flood mitigation factors of accurate location, alignment, sloping and sizing of Owerri drainages might be why Owerri continues to flood even at very little rain storm events.

5.2 RECOMMENDATIONS

In view of the forgoing the following recommendations are made:

1. Urban flooding will be mitigated if urban areas are provided with efficient drainages Drainage designs should adopt the GIS approach to be able to accurately determine the efficiency factors.
2. The need to constantly revise the topographic maps of urban areas every 5 years and undeveloped areas every 10 years cannot be over emphasized. Government is encouraged to carry out these revisions to provide accurate and up to date data for the revising of drainage efficiency factors.
3. Governments should ensure that the determined natural flow routes are marked on the ground both in urban and rural areas and even farmlands. Legislations should be enacted and people educated to stay off those routes for the inherent dangers of flooding the areas due to the routes being blocked by blockages erected along these drainage routes.
4. Since natural drainage routes are actually routes eroded over time by runoff, the Geographic Information System Based Approach to mapping of natural drainage routes will lend itself to erosion studies of the area.

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Dr. Akajiaku Chukwunyere Chukwuocha hails from Itu Ezinihitte Mbaise, Imo State Nigeria. He is a thorough bread Surveyor and a clergyman of the Anglican Diocese of Owerri, Nigeria. He is presently the Administrator and Vicar of the Cathedral Church of the Transfiguration of our Lord, Owerri. Dr. Chukwuocha holds a Ph.D. in Surveying and Geoinformatics from Nnamdi Azikiwe University Awka, Nigeria, M.Sc Geoinformatics and Surveying, University of Nigeria, Nsukka, B.Sc. (Hons.) Surveying and Photogrammetry, Enugu State University of Science and Technology Enugu, and Diploma in Land Surveying from the Federal Polytechnic, Nekede Owerri.

Dr. A. C. Chukwuocha is a member of faculty of the Federal University of Technology, Owerri, Nigeria. His research interests span Global Navigational Satellite Systems (GNSS), Geographic Information Systems (GIS) and Geodesy. He is a Registered Surveyor with the Surveyors Council of Nigeria (SURCON), a full member of the Nigerian Institution of Surveyors (NIS). He is a member of the National Association of Geodesy (NAG) of Nigeria, a member of the National Union of Radio and Planetary Sciences (NURPS).

Dr, Chukwuocha has a very wide field of experience in the Surveying Industry. From the time of graduation he has worked with the Owerri Capital Development Authority, Owerri Nigeria with leadership responsibilities in urban development design, monitoring and control. He later worked in the Oil mineral exploration industry in the Niger Delta region of Nigeria with the American Western Geophysical Company, and the French Compagnie General De Geophysique (CGG). Dr. Chukwuocha who played very important roles in the development control of the present Owerri Capital Territory of Imo State Nigeria by spearheading the densification of survey controls across the capital territory from the late 1980s to the mid-1990s still has interest in control densification using electronic methods.

He has published a number of works in Surveying and Geoinformatics including his Ph,D, research on “GIS – Based Approach to Urban Drainage Network Design” (2012), “Delineation and Characterization of Sub-catchments of Owerri, South East Nigeria” – American Journal of Geographic Information System, 2014, 3(1), pp. 1-9; GIS Based Mapping of Natural Drainage Routes of Owerri, South East Nigeria, - International Journal of Current Research, India. (Accepted 2013); “Modern Trends in Topographic Data Collation for Environmental Studies and Engineering, Journal of Environmental Design and Technology, Owerri. Vol. 1 (3). 2012., “GIS – Based Urban Planning and Monitoring Best Practices for West Africa” African Journal of Environmental Science and Technology, vol. 8(1), 2014, among others.

Dr. Chukwuocha also authored the book, “The War Within”, published in 2009 under the Hippo Titles of Zondervan publishers, Grand Rapids, MI, U.S.A. The book which explores the Christians quest to live up to the call to perfection in Christ may still be his most outstanding work.

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