2015 FIG WORKING WEEK SOFIA BULGARIA 17TH – 21ST MAY, 2015

- **GEOGRAPHIC INFORMATION SYSTEMS BASED URBAN DRAINAGE EFFICIENCY FACTORS**

(PAPER 7526, TS03D - Disaster and Land Management)
Commission: 3

This is a peer reviewed paper.

BY

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1.0 INTRODUCTION

- The dangers of flooding are becoming increasingly real 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 and constructions restrict where flood water can go.

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INTRODUCTION contd.

- 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]

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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.
- Owerri previously considered a non-flooding area now floods continuously. The drainages generally follow the road edges and are constructed to protect the paved roads, and not necessarily to mitigate flooding.

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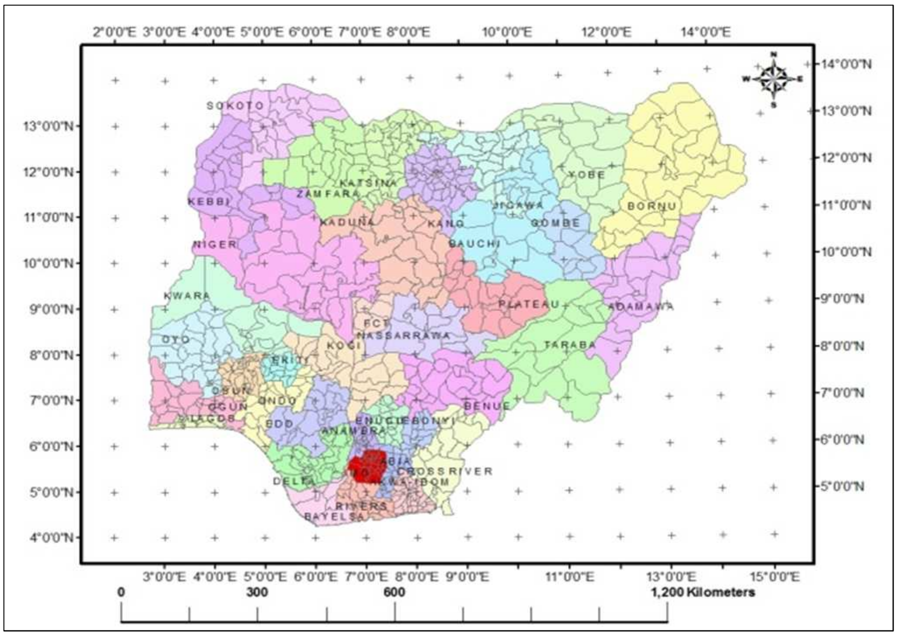

Fig. 1a Map of Nigeria with LGAs, showing Imo State South East Nigeria in deep red colour

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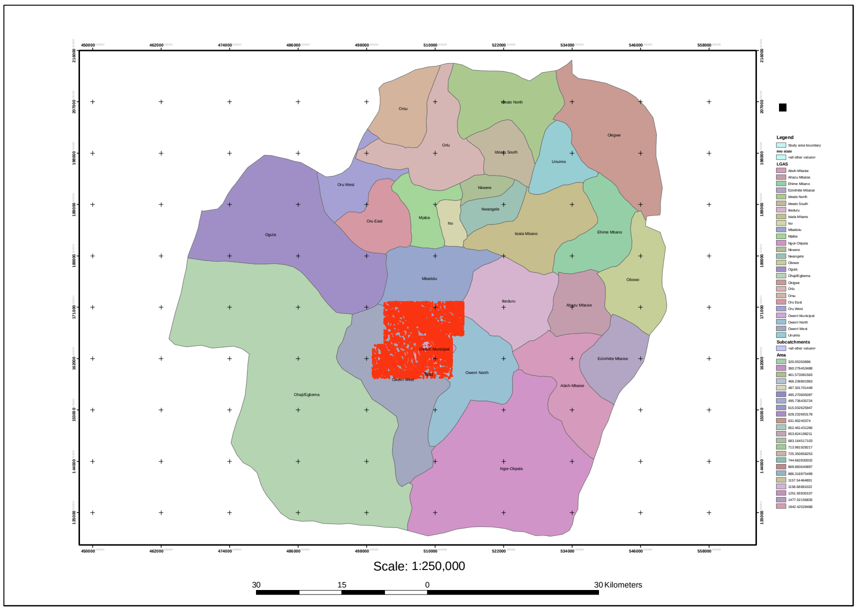

Fig. 1b Map of Imo State with LGAs, showing the project area in red

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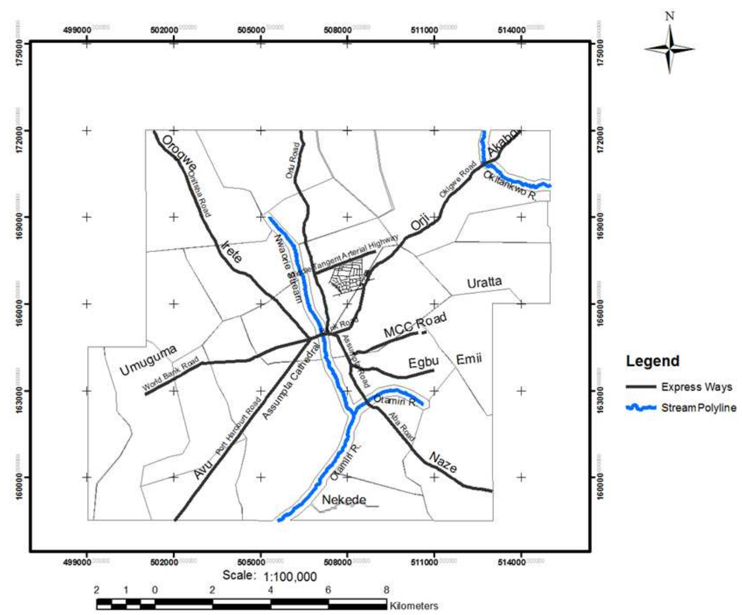

Fig 1c: Map of the Project Area

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2.0 LITERATURE

2.1 Literature in Jeddah - Western Saudi Coast, Kingdom of Saudi Arabia

- 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 1:50,000 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

2.2 Literature in Kukatpally Municipality, India

- 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 in Kukatpally Municipality, India finds 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.

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2.3 Literature in University of Zimbabwe

- A 2002 paper 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) concluded that 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[5].

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2.4 Literature in New Orleans Drainage Pumping Station No 4 Basin

- 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.

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2.5 THEORETICAL FRAME WORK

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2.51 GENERAL SUB-CATCHMENT LAYOUT

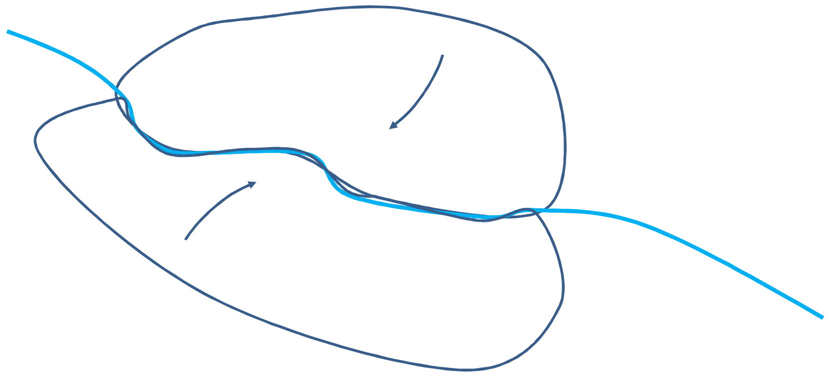

Fig. 2 General properties of a sub-catchment

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GENERAL PROPERTIES OF A SUB-CATCHMENT

- Fig 2 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.

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3.4. PROCESSING DEM TO DELINEATE RIVE NATURAL RUNOFF FLOW ROUTES

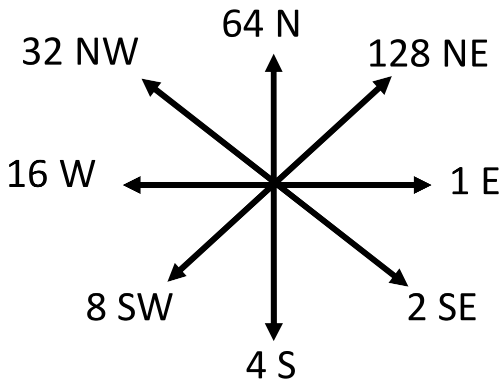

Fig. 7 Flow Direction Scheme

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141	140	140	141	142	142	141	142
139	138	137	139	139	139	139	140
138	135	135	136	137	136	137	139
134	134	132	134	135	134	136	138
131	131	129	133	133	132	134	137
128	127	126	132	131	130	132	133
126	123	124	126	128	129	131	133
124	120	125	127	129	129	130	132

DIGITAL ELEVATION MODEL

2	2	4	8	4	4	4	8
2	4	4	8	2	4	8	8
4	2	4	8	2	4	8	2
4	2	4	8	2	4	8	8
2	2	4	8	2	4	8	4
2	4	4	8	8	8	16	16
2	4	16	16	16	16	16	16
1	0	16	32	32	32	16	16

FLOW DIRECTION SCHEME

Fig. 8 Digital Flow Direction Scheme

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1	1	1	1	1	1	1	1
1	2	4	1	2	2	3	1
1	3	5	1	1	8	2	1
2	1	10	1	1	12	1	1
3	3	12	1	1	12	2	1
1	4	17	1	1	17	2	1
1	53	47	27	24	3	2	1
1	57	1	1	1	3	2	1

Figure 9 Flow Accumulation Grid

		1					
		1			1		
		1			1		
		1			1		
		1			1		
	1	1	1	1			
	1						

Figure 10 Drainage Route Cells

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Runoff Flow Routes

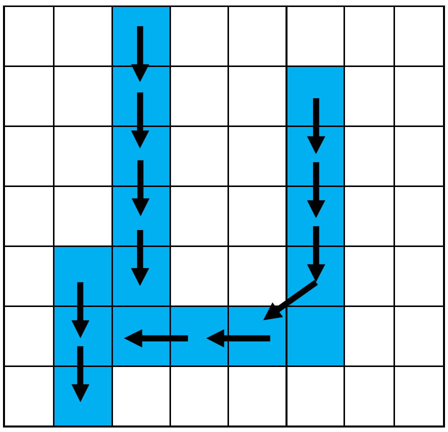

Figure 11 Drainage Route

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Layout of efficiency factored landscape drainages

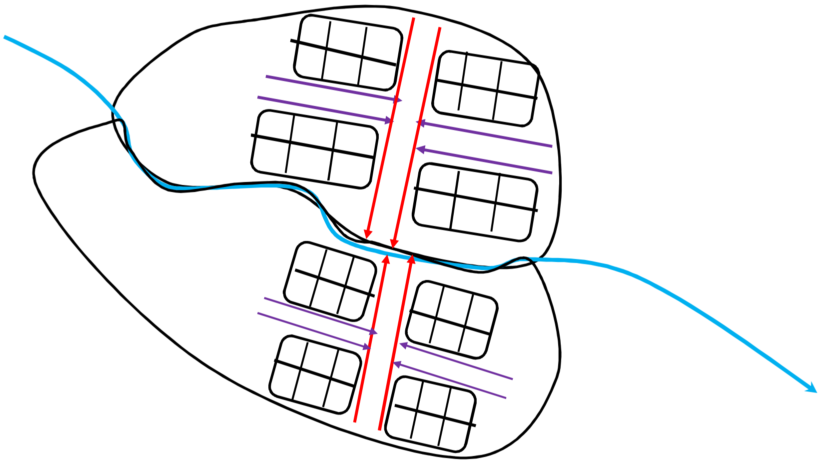

Fig. 12 Layout of efficiency factored landscape drainages

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3.5 SCHEME OF DRAINAGE DESIGN

- TERTIARY DRAINAGES: 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.

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SECONDARY AND PRIMARY DRAINAGE NETWORKS

- SECONDARY DRAINAGES: 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.
- PRIMARY DRAINAGES: They convey runoff from Secondary drainages. 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.

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2.5 Drainage Efficiency Factors

From the Literatures the drainage efficiency factors would include:

- ✓Location of Drainage
- ✓Horizontal Alignment
- ✓Vertical Alignment
- ✓Size of Drainage
- ✓Inlet numbers and Positions

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- 3.0 MATERIALS AND METHODS

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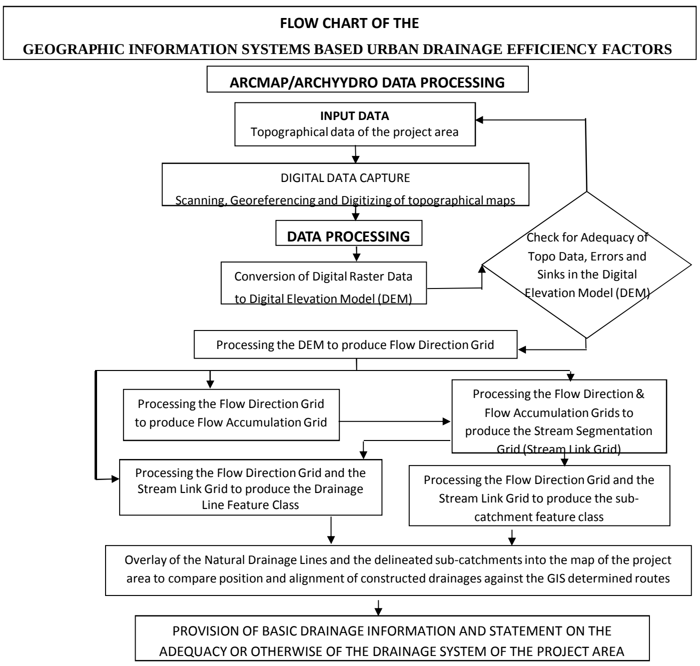

Fig. 3 Flow Chart of the Project Methodology

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3.1 DATA ACQUISITION

- The research essentially involved the analysis of topographic data of the about ***186.024 Sq. Km, (18,602.38 Ha***) project area.
- Thankfully ***topographic maps*** of the wide area of coverage of Owerri Nucleus area were made available by the Imo State Surveyor General and the Head of the Survey Department, Owerri Capital Development Authority.

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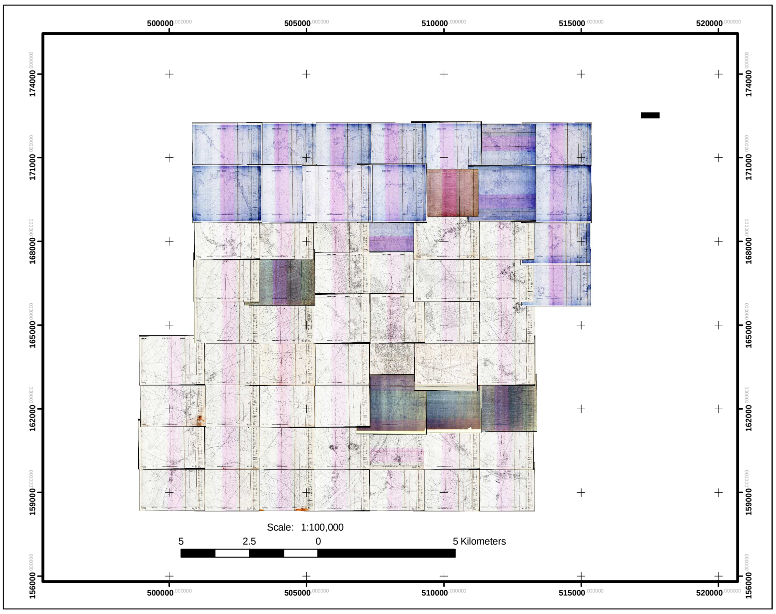

Fig. 4 Georeferenced Topo Maps of the Project Area in mosaic

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THE RESULTING DIGITAL CONTOUR OF THE PROJECT AREA

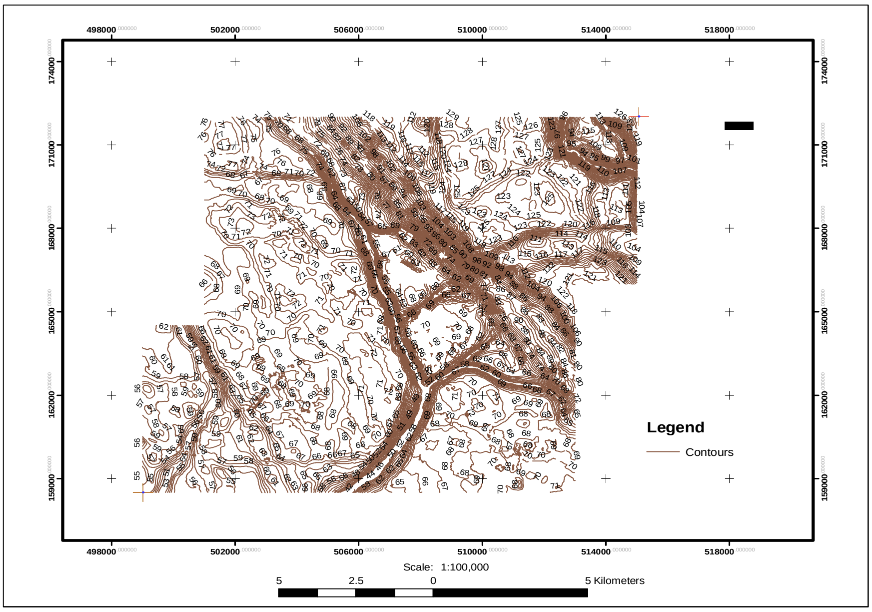

Fig. 5 Resulting Contour of the Project Area

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3.2 DATA PROCESSING AND ANALYSIS

DEM The Digital Elevation Model (DEM) created in ArcGIS using the contour features. The DEM is a digital grid in which each cell holds the elevation value of the land space the cell represents.

Fig. 6 Screen Print of DEM of the Project Area

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3.3 DEM VALIDATION

- The DEM was validated using orthometric heights derived from GPS surveys of random points across the project area. The full details are in the paper proper. But Table 1 shows the statistics

Table 1: Statistics of the Validation: GPS orthometric height value minus DEM value

	Topo Sheet DEM	ASTER DEM of Study Area	SRTM of Study Area
Average	-0.372	5.064	-4.124
RMSE 1	1.513	7.555	4.549
RMSE 2	0.731	7.834	4.237

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COMPARING WITH OTHER POSSIBLE SOURCES OF DEM

SOURCES OF DEM	RMSE – Open Areas	RMSE – Forest Areas
SPOT - flat terrain	2.97m	3.66m
SRTM X-band	3.97m	4.49m
SRTM C-band	4.25m	6.14m
ASTER	7.29m	8.08m
Updated Topo Map	Without outlier distorted site 0.731m	With 2% outlier of badly distorted site 1.513m

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GIS Delineated Drainage Lines of Owerri

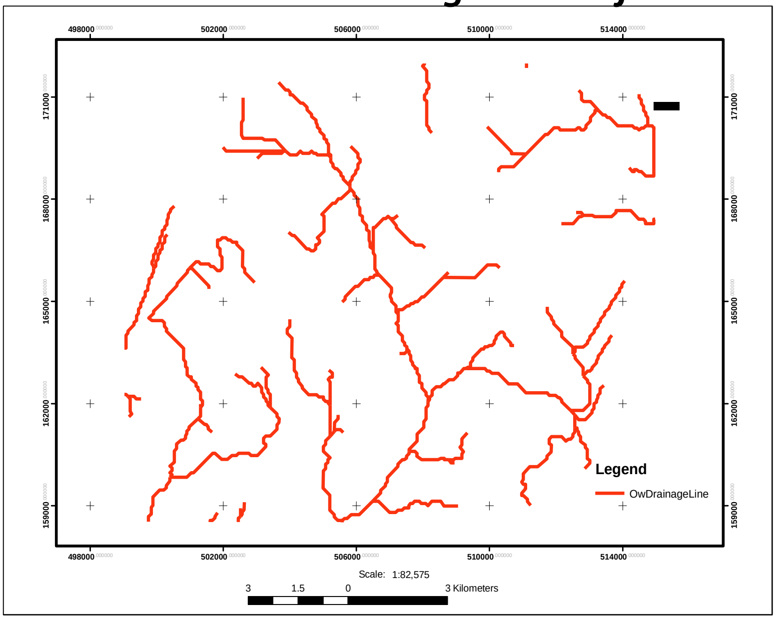

Fig. 13 Owerri Drainage Network.

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GIS Delineated Drainage Lines and Sub-catchments of Owerri

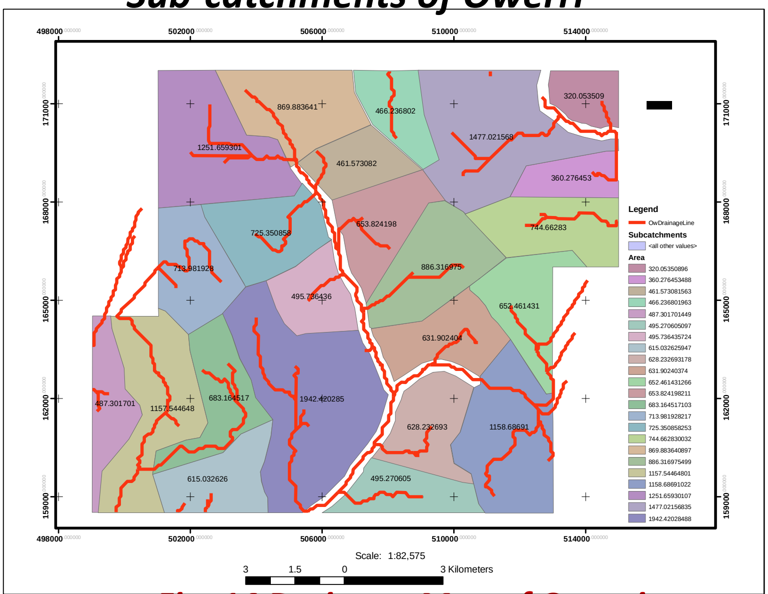

Fig. 14 Drainage Map of Owerri

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GIS EXTRACTED SUB-CATCHMENT DETAILS FOR COMPUTING DRAINAGE SIZES

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	161700.48	500830.80	1432.11	0.486	8082.77
S2	320.05	171227.33	514032.48	722.51	2.366	4429.68
S3	615.03	159539.54	502904.44	2522.83	0.396	2437.86
S4	456.57	170762.16	508281.35	1085.99	1.03	4204.19
S5	495.74	165118.87	505752.40	1140.55	0.069	4346.50
S6	886.32	166016.09	509332.90	2149.93	2.315	4122.56
S7	1477.02	170084.91	511135.03	1469.61	0.748	10050.43
S8	354.97	168725.92	513545.97	2135.11	0.234	1662.54
S9	744.66	167223.58	513030.31	1192.08	1.786	6246.73
S10	869.88	170901.82	505192.39	2618.87	1.743	3321.58
S11	653.82	167330.77	507795.25	2450.65	1.743	2667.94
S12	461.57	169178.96	507050.22	2771.70	2.374	1665.30
S13	1158.69	160768.00	511673.93	2009.05	0.163	5767.36
S14	631.90	163851.51	509725.27	1332.84	1.808	4741.01
S15	1251.66	169670.38	502672.01	1494.89	0.331	83507.46
S16	683.16	162022.01	502794.91	966.39	0.425	7069.17
S17	725.35	167044.46	504362.61	1297.33	0.679	5591.08
S18	487.3	161855.52	499520.62	2063.47	0.606	2361.56
S19	495.27	159135.15	508560.42	844.39	0.012	5865.40
S20	713.98	165955.20	502086.13	1836.94	0.543	3886.79
S21	1942.42	161975.48	505499.64	2040.57	0.213	9518.99
S22	652.46	164832.79	512204.07	2404.46	1.262	2713.54

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OVERLAY OF THE GIS DELINEATED PRIMARY DRAINAGE ROUTES OF OWERRI WITH THE EXISTING ROAD EDGE DRAINAGES

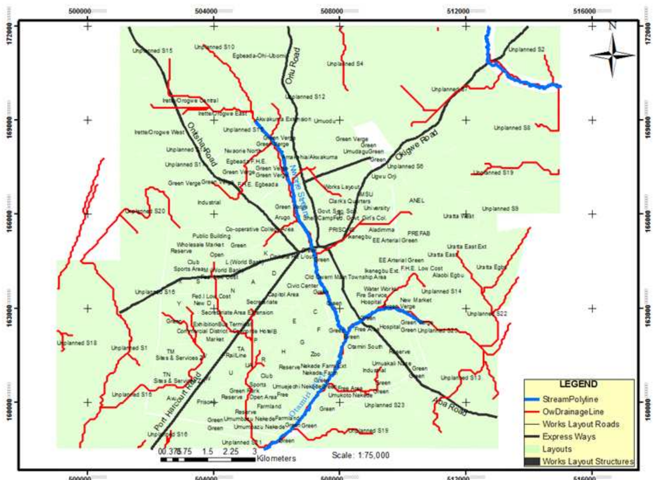

Fig. 15 Map of the Project area showing the natural flow routes, roadside drainages, streams and rivers.

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3.2.5 Results and Discussion

- From Fig. 15, it is seen that the road edge drainages do not match the delineated primary drainage routes of Owerri.
- 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 sizes and numbers of inlets of the drainages.

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3.2.5 Results and Discussion Contd.

- 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.

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3.2.5 Results and Discussion Contd.

- The greater part of the drainages of the study area were constructed alongside the road edges. The map of the delineated natural flow routes was overlaid on the map of the study area to create Fig. 15. 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.

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SITE CHECK FOR EFFICIENCY FACTOR

- The first set of drainage efficiency factors to consider are the location factors, the position of the drainages and the horizontal alignment.
- The second set of drainage efficiency factors are the flow factors, the size and vertical alignment depend on the first efficiency factors. They only need to be checked if the first factors are in place.
- The third drainage efficiency factors, the runoff capture factors or the inlet factors (number, size and location of inlets) are the fourth and are necessary to check if the second set are in place.

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3.2.6 SITE VALIDATION OF DRAINAGE AREAS

On 6th October 2011 and 20th July 2012 visits were taken to 3 of the sites delineated in the analyses to be drainage lines to check their state of flooding or otherwise after the rains. It was discovered that they were heavily flooded. The photographs presented hereunder are those of the visited sites.

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Works Layout Area 6th October 2011 : Conduit C11 series. Fully developed pond now due to high runoff coefficient of a developed urban area.

Plate 1

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Works Layout Area 6th October 2011 : Conduit C11 series.

Plate 2

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Works Layout Area, 6th October 2011: Conduit C11 series.

Plate 3

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Federal Housing Estate 20th July 2012: C14 series

Plate 4

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Federal Housing Estate: 20th July 2012 C14 series

Plate 5

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Federal Housing Estate: 20th July 2012 C14 series

Plate 6

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Federal Housing Estate: 20th July 2012 C14 series

Plate 7

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Chukwuma Nwoha Road Area 20 July, 2012: C14 series

Plate 8

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4.0 CONCLUSION AND RECOMMENDATION

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4.1 CONCLUSION

- **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.
- The paper has shown that drainages constructed for Owerri have not met the drainage efficiency factors.
- The paper concludes that it is the failure of the drainages of Owerri to meet the efficiency factors that make Owerri to flood when it rains.

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4.2 RECOMMENDATIONS

- In view of the forgoing the following recommendations are made:
- 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.
- 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.
- 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.
- 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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THANK YOU

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BIBLIOGRAPHICAL NOTES - DR. A. C. CHUKWUOCHA

- 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).

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BIBLIOGRAPHICAL NOTES - DR. A. C. CHUKWUOCHA contd.

- 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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BIBLIOGRAPHICAL NOTES - MRS. NGOZI B. AC-CHUKWUOCHA

- Mrs. Ngozi Blessing AC-Chukwuocha holds a Diploma in Quantity Surveying from the Federal Polytechnic, Nekede Owerri, B.Sc. (Hons.) Estate Management, Enugu State University of Science and Technology Enugu, M.Sc in Environmental Management, Enugu State University of Science and Technology Enugu. She is currently a Ph.D. candidate at the Rivers State University of Science and Technology, Port Harcourt, Nigeria.
- Mrs. AC-Chukwuocha is a Registered Environmental Specialist with the National Registry of Environmental Professionals, U.S.A. She is a member of the Nigeria Environmental Society (NES). She has published quite a number of works including, "Trace metal availability in soils of watershed in relation to land use in Owerri, South East Nigeria" Journal of Science and Sustainability (NREP), 2011, "A Comparative Analysis of emission of methane from live stock farms in Enugu, South East Nigeria", Journal of Agricultural Science and Technology, 2011, "Physio-chemical gradient and in-situ yield in pelagial primary production of the middle reaches of Imo River in Etche, South East Nigeria", Journal of Ecology and Natural Environment 2011.
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