ASSESSMENT AND MANAGEMENT OF STORMWATER DRAINAGE FACILITIES IN RESIDENTIAL AREAS OF ENUGU CITY

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The objectives of this paper are to assess the quality of artificial drainage facilities in residential premises of Enugu city and profer appropriate strategies for managing them. An appraisal technique, which employs a checklist of seven simple classifications of specified qualities, is utilized to achieve the aim. In this approach percentage penalty points (Pp) are assigned to drainage facilities having observable defects. A total of 366 drains in 20 residential areas of the city are appraised. The poorest condition of drainage system is observed in Ogui Urban area with the highest penalty points of 88% followed by Abakpa with 87.5% penalty. Only three layouts (Ekulu, G.R.A, and Independence Layout) have less than 25% penalty points rated as good condition of drainage. None of the residential areas in the city has excellent drainage facilities as none scored less than 10% penalty. A more integrative legislation on urban land use planning and management to protect the drainage facilities against dysfunctional uses or abuse and a comprehensive urban drainage system network coupled with proper maintenance (inspection, regular schedule of cleaning blocked drains and repair) are strongly recommended to prevent the hydrological consequences of unregulated storm water drainage construction in the residential layouts of Enugu city.

Keynote: appraisal technique, drainage facility, inspection, maintenance, stormwater

INTRODUCTION

The goal of providing storm water drainage facilities in an urban environment is the efficient disposal of the resulting surface runoff from the built up environment. Since the approaches to designing of city drainage facilities are becoming increasingly sophisticated, an urgent need has therefore arisen in urban hydrology and planning to develop a more rigorous technique in assessing, managing and maintaining the quality of the city drainage facilities in urban areas (Annan, 2001; Chukwu, 1995; 2002; 2004; DFID, 2007; Nnodu, 2008). The development of tools of analysis for urban drainage facilities has gone beyond the filed measurement base that supports their validity. McPherson (1981) and Chukwu (1995; 2002; 2010) have therefore recognized the need in every part of the globe for more field observations from representative and experimental urban areas to improve the reliability of such analytical techniques of drainage systems.

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When a rural area becomes urbanized, the amount of pavements, artificial drainage network and houses (the built up environment) increases with attendant increase in the density of population (Chukwu, 2004; 2010). The stream flow in the natural drainage systems of the city comprises four main components, viz channel precipitation, overland flow, interflow (or through flow) and the base flow (Essagha, 2004; DFID, 2007; Chukwu, 1995; 2010). A lot of work has been done on overland flow and flooding, the only components most likely to respond quickly to artificial drainage systems in built up environment (McPherson, 1981; Hall, 1984; Ebisemiju, 1989; Essagha, 2004; Chukwu 1995; 2004). In contrast, little work has been done on the prevailing conditions and management status of the urban drainage facilities, which influence the volume of discharge and rates of peak flow in populous urban centers. These drainage facilities therefore require an investigation into their current features.

As a result, this calls for the adoption of an appraisal technique to assess the physical quality of the drainage facilities in urban settlements to ascertain their prevailing maintenance and management status. The objectives of this work are set against this research problem in order to close the research gap.

AIMS AND OBJECTIVES OF THE PAPER

The broad aims of this work are to assess the quality characteristics of the drainage facilities and explore appropriate management and maintenance strategies to be adopted for their efficient services. To achieve these twin aims, the specific objectives are designed to:

i. Evaluate the numerical strength and types of the drainage facilities in various streets of Enugu city.
ii. Assess the current quality and maintenance status of the existing drainage facilities in Enugu city.
iii. Explore appropriate strategies for the management and maintenance of the drainage facilities in Enugu city.

DESCRIPTION OF THE STUDY AREA

Enugu, the political and administrative headquarters of Enugu State in Nigeria, covers a latitudinal extent of $6^0$2' to $6^0$30'N and longitudes of $7^0$26' to $7^0$37'E. It occupies a land area of about 182lm^2.

The Enugu escarpment in the western part of the city is part of Nsukka-Okigwe cuesta (Ofomata, 2002). Though this upland rises to a peak of about 450m above sea level in Enugu city, which lies at the foot of the eastern escarpment at a height of about 230m (a.s.l). the relief is characterized by groups of dome shaped and flat-topped residual hills and ridges forming saucer shaped depressions in some places. As a result of the constraints posed by the rugged scarpland on development westward, the direction of urban expansion is southward towards Agbani and eastward towards Abakaliki (Onokala, 1981; Chukwu 2004).

The scarp slopes which formed the eastern edge of the Enugu escarpment are heavily dissected by headwaters of six main streams, which drain the entire city and flow in the direction of low gradient more or less eastward into the Cross River plain . These streams are Nyaba river (a sixth and the highest segment order), Ekulu river (a fifth order), Idaw and Asata rivers (both, fourth order), Ogbete (third order) and Aria River (second order). The stream orders, numbers and bifurcation ratios in the city are shown on Tables 1 and 2.

A stream order is determined by the number of other lower stream tributaries which flow into it. Bifurcation ratio refers to the ratio between the number of a given stream order to the number of the next higher order. The first stream order therefore does not have a value.

Table 1: Streams orders, numbers and bifurcation ratios in Enugu city of Nyaba drainage basin.

Stream Order (U)	Number of Stream	Bifurcation Ratios
1	154	-
2	52	2.96
3	9	5.78
4	4	2.25
5	2	2.00
6	1	2.00

(Source: Chukwu, 2004)

Table 2: Stream segment orders in Enugu city (Strahler system) of Nyaba drainage basin

S/N	Name of Stream	Stream order
1	Aria	1st
2	Ogbete	2nd
3	Asata	3rd
4	Idaw	4th
5	Ekulu	5th
6	Nyaba	6th

(Source: Chukwu, 2004)

These natural streams form the potential outfall for the urban storm water drainage eastward of the city. The rainfall received in Enugu city is mainly of convective type. The onset and cessation of the wet season in the city are characterized by violent squalls and thunderstorms. The wet season (which is ushered in by the tropical maritime air mass) lasts from mid March to October with double maxima in June/July and September/October. The dry season is brought in by the tropical continental air mass and it lasts from November to early March inclusive. Annual rainfall is heavy, about 1800mm, most of which is received during the wet season. Temperature ranges between 25^0C in mid wet season to about 30^0C before the on-set of the rainy season. Thus, Enugu city is in the Koppen's humid tropical (A_w) wet dry climate (Chukwu, 2004).

The estimated population of the city by 2010 has exceeded the 0.8 million mark (actually 878,403 people) with high densities of about 400 persons/sq.km in some places. These peculiar characteristics of the city call for the adoption of objective method in appraising and maintaining the quality of the drainage facilities.

THE RESEARCH METHODOLOGY

The research design is partly survey and partly experimental. An appraisal technique is utilized in the analysis in order to prevent bias. This technique has been utilized by urban geographers in assessing the physical environmental quality of facilities in residential premises of cities (Quigley 1975; Sule 1980; Chukwu 2002; 2004). In this technique, a checklist of specified qualities, which yields seven simple classifications for the appraisal of the current state of 366 storm water drainage facilities in 20 residential areas of the city is employed. The stratified random sampling technique is applied in selecting the sample size. The classes are shown on Table 3. In this approach, penalty points (in percentage) are assigned to the artificial drainage channels having observable defects. These are numbered under classes 01, 04, 05, 06

and 07. Thus for any layout, penalty points. $P_{(p)}$ is given by the formula (Chukwu, 1995):

$$P_{(p)} = \frac{(\sum 01 + 04 + 05 + 06 + 07)\,100}{\sum 01 + 02 + - - - + 07)}$$

The answer is expressed in percentage. The results of this exercise are collapsed into five point class intervals (see Table 4).

Table 3: Checklist of Specified Qualities of Drainage Facilities

Class	Specified quality of the drainage facility
Class 01:	Closed sewer system clogged by refuse and sediment concentration.
Class 02:	Closed drainage facilities not clogged by refuse and sediment concentration.
Class 03:	Open drainage facilities not clogged by refuse and sediment concentration
Class 04:	Open drainage facilities clogged by refuse and sediment concentration
Class 05:	Absence of storm water drainage facilities in street.
Class 06:	Storm water drainage system worn away by denudation/soil erosion
Class 07:	Drainage systems destroyed by land slumping, soil creep or land slide

Table 4: Rating of P_P of storm water Drainage Facilities

Class interval of P(p)	Rating Scale
0-10	Excellent
10-25	Good
25.1-45	Fair
45.1-65	Poor
65.1-85	Very poor
Over 85	Horrible

The ultimate aim is to appraise the poor state of the current drainage facilities in the residential areas of Enugu city as this helps to throw more light on the extent of performance of such facilities and effective strategies for managing them. The adoption of a maximum 100-point scale is a deviation from the use of 21-point scale by Sule (1980) in assessing the facilities of housing in Calabar town. This is to prevent getting entangled in a very cumbersome and vexing measurement. To this, Quigely (1975), remarked that difficulty in measuring the physical environmental quality of residential facilities is the most vexing problems encountered in assessing attributes of residential services in built up environments of major cities. The final results of this technique are exploited in determining the quality and state of the drainage facilities in Enugu city.

RESULTS AND DISCUSSION OF RESEARCH FINDINGS

Street Layouts and Drainage Facilities

Enugu street guide map shows that there are about 350 streets in the city that have artificial drainage channels. These streets have about 700 storm water drainage facilities with an estimated total length of 600,000m. Enugu layout drainage plan portrays a rigid grid iron system of network. The drains consist mainly of channels with open trenches, which may be either trapezoidal or rectangular in shape with concrete linings.

These artificial drainage channels are concentrated in the older street layouts of the city such as Ogbete, Uwani, Asata, Achara Layout, New Haven and the CBD as well as Ogui New Layout. Only about 40% of the residential districts of the city are

sewered. This is so because the city lacks a comprehensive urban drainage network plan and according to Chukwu (1995; 2002) the construction of drainage systems is dominated by piece meal planning approach in the city.

Hydraulic structures like culverts, bridges and stormwater runoff detention facilities are also constructed in specific locations of the residential districts like Ekulu, Ogbete, Asata, CBD and G.R.A. They facilitate the disposal of large volumes of surface runoff in the city and in the case of culverts and bridges afford passage for both vehicular and pedestrian traffic across a body of stream in the city.

THE CURRENT STATE OF THE ARTIFICIAL DRAINAGE FACILITIES IN ENUGU CITY

Although most of the existing drainage facilities in Enugu city are open systems, an increasing number of closed and piped sewer network is being constructed especially by private individuals, industrial and business concerns to enhance efficient disposal of rain water around their residential and business premises.

Table 5: Distribution of observable defects and penalty points for artificial drainage systems in Enugu city

S/No	Residential layout area in Enugu	No of Defects in various classes*							Total No	No with Defects	%Pp
		01	02	03	04	05	06	07			
1	Ogbete	5	3	1	8	0	2	1	20	16	80.0
2	Uwani	7	2	5	3	0	2	0	19	12	63.2
3	Ekulu	1	2	18	1	1	1	0	23	4	16.7
4	Ogui Urban Area	1	2	0	11	4	0	0	18	16	88.9
5	Ogui Nike Layout	2	5	8	4	0	1	0	20	7	35.0
6	G.R.A.	0	9	10	2	0	1	0	22	3	13.6
7	Ogui New Layout	4	2	3	6	0	3	0	18	13	72.2
8	Asata Layout	3	3	7	4	1	4	1	23	13	56.5
9	Abakpa	1	0	2	3	7	2	1	16	14	87.5
10	Independence Layout	1	6	10	1	2	0	0	20	4	20.0
11	C.B.D.	3	4	8	5	0	1	0	21	9	42.9
12	Awkunanaw	2	1	6	6	2	1	3	21	14	66.7
13	Emene	1	2	2	9	5	2	0	21	17	81.0
14	Achara Layout	3	2	5	4	1	2	0	17	10	58.8
15	Scarp Face	0	0	3	1	2	3	1	10	7	70.0
16	Idaw River Layout	3	2	6	7	1	1	2	22	14	63.6
17	New Haven	2	3	7	3	0	2	1	18	8	44.4
18	Obeagu	0	0	5	0	4	1	0	10	5	50.0
19	Amechi	1	1	4	1	4	0	0	11	6	54.5
20	Ugwuaji	0	1	5	1	6	1	1	15	9	60.0
	Total	40	50	115	80	40	34	11	366	21	55

(Source: Field Work)

* Key to the Class Description

Stands for closed sewer system clogged by refuse/sediment

Stands for closed sewer system not clogged by refuse/ sediment

Stands for open sewer system not clogged by refuse/sediment concentrations

Stands for open sewer system clogged by refuse/sediment

Stands for absence of storm water sewerage system

Stands for storm water sewer system worn away by denudation/erosion.

Stands for storm water sewer system destroyed by land slumping, soil creep and land slide.

The percentage penalty points for 366 artificial drainage networks in 20 residential layouts of Enugu city are computed as shown on Table 5. This varies from less than 25% (rated as good condition of drainage system) in G.R.A., Ekulu, and Independence layouts to 65% (rated as very poor state of stormwater drainage facilities) in Ogbete Layout, Ogui Urban Area and Abakpa. The poorest condition of drainage facilities is

observed in Ogui Urban Area with also the highest penalty points of 88.9% followed by Abakpa with 87.5% penalty (see Table 5).

The condition of the facilities which have percentage penalty points ranging from 25% to 45% is rated as fair while for other layouts, which have percentage penalty points of 65%, the condition of the sewers, is rated as poor. None of the layouts scored less than 10% penalty. This shows that none of the drainage facilities is excellent in the town. These findings form the basis of the measures recommended for the management and maintenance of the stormwater drainage facilities in the city.

SUSTAINABLE MEASURES FOR MANAGEMENT AND MAINTENANCE OF THE STORMWATER DRAINAGE FACILITIES

Management Strategies and Instruments

It is discovered that artificial drainage systems in Enugu city are probably the least cared for, of all the infrastructural facilities and public utilities in the city (Chukwu, 2004; 2010. For instance, some artificial drainage facilities in the city are wrongly used for commerce and light industries, as well as receptacles for refuse. This situation calls for an urgent need to formulate and essentially to enforce a more embracing legislation on urban land use to protect the city's drainage facilities against abuse. A careful attention should be paid to protecting the natural drainage systems in an area where construction work on sewered streets are contemplated.

A law should be passed to prevent the current unregulated development along river valleys and flood plains for building construction in the city because they are subject to occasional extreme runoff events with associated losses due to flooding. Equally, land suitable for recreational use and agricultural activities within the city should not fall prey to unregulated urban expansion. This will enhance the infiltration capacity of the urban land and hence water transmissibility capacity of the soil profile (Chukwu, 2004).

The suggested legislation should also provide that sewers may be used for no other purpose other than for that which it was designed, prohibiting, for example, its use for dumping refuse and solid waste as well erecting market stalls, light industries, water borne pipes and underground electric cable line.

There should also be an ordinance to provide rules for making connections to the storm water sewers with power to strictly enforce the regulations placed in the hands of the liquid waste management department of Enugu State Waste Management Authority (ESWAMA) and the sewer department of Enugu Town Planning Authority. Such legislation is known to work well in the city of London (Babbit and Baumann, 1998).

Maintenance of Artificial Storm Water Drainage Facilities in Enugu City

The storm water drains in Enugu city should not be forgotten or disregarded as they cannot maintain themselves. It is discovered that many of them clog or otherwise erode or slump or simply deteriorate which explains why Chukwu (1995) has warned that the poor level of maintenance of the storm-water drainage facilities forms one of the principal dimensions or urban flooding. Therefore, the principal efforts should be in the maintenance of storm water sewers in the Enugu city. Maintenance work comprises three major activities: inspection, cleaning of the blocked drains, repair and improvement of storm water sewers.

Inspection of Artificial Storm Water Drainage Facilities
There should be an inspectorate division within the ESWAMA that should specifically carry out routine inspection of sewers to detect and prevent clogging in the channels, to examine the condition of the structures and measure the rate of flows in the storm sewers. Regular attention should be paid to the artificial channels with high percentage penalty points in the residential areas of Ogui Urban Area, Asata, Ogbete and Abakpa areas.

A record of inspection should be kept which will document the sewer conditions, actions taken to effect maintenance, a brief description of the methods used in flow measurement and flows observed together with the dates. Preventive maintenance experience in Canadian and British cities shows that it is more economical to foresee clogging of drainage channels through forecast based on records than to depend on corrective maintenance (Babbit and Baumann, 1998).

Regular Schedule of Cleaning Blocked Drains
A regular schedule of cleaning blocked drains should be maintained by ESWAMA and urban council workers. This is because many of the sewers in some residential areas like Ogui Urban Area, Asata, Ogbete, Abakpa and even parts of the Central Business District are so clogged that no free channel whatsoever remains available for stormwater disposal. In such a situation, velocity of flow and discharge increase around such obstructions. Unfortunately, there is currently no comprehensive drainage plan for the city in general. As such there is no regular maintenance crew for artificial drains in Enugu city despite the sincere efforts of the present administration of Enugu State in the current urban beautification and renewal activities of the city. In each urban layout, there should be adequate number of maintenance crew which should consist of labourers, a junior engineer in charge, oilers and a truck driver with all the essential working implements. This will be based on the size of the layouts and number of drainages it contains. Scraping instruments which should be dragged through sewers to loosen sludged banks, detritus, and dislodge obstructions should be provided to the maintenance crew. Projections from the channel sides must be removed because of their tendency to build up obstacles to free flow of storm runoff and flood water.

Repair and Improvement of Stormwater Sewers
The Enugu urban council in collaboration with ESWAMA is strongly advised to engaged in constant repairs and improvement of storm sewers because of their present poor state. Common repair to these artificial drains should consist of relining eroded concrete sewers with bricks, precast blocks and gunite. Other types of repair should also include replacing the street inlet and covers broken by traffic flow, tightening loose manhole covers which rattle under vehicular traffic flow – especially along Zik Avenue Road in Uwani layout, and the stretch of the section of Agbani Road that passes through Ogbete Layout.

Connections from the house sewers to the main channels are a common source of drainage problem especially in Awkuanaw, Abakpa, Asata, Ogui and Ogbete areas due to poor construction. Their construction should therefore be undertaken by ESWAMA together with sewer department of Enugu Town Planning Authority. The Authority is also strongly advised to construct new channels in Abakpa, Ogui Urban Area, parts of Emene and Achara Layouts which suffer severe drainage problems due to inadequate stormwater drainage facilities.

Suggested Comprehensive Drainage Facility Network for Enugu City
A comprehensive urban drainage facility plan is strongly advised to replace the present piece-meal planning approach adopted in constructing stormwater sewers in the city. Good practice demands that a comprehensive drainage plan be designed and implemented for the needs of the entire urban area and that sewers be constructed in accordance with this plan as the need for them arises (Babbitt and Baumann, 1998; Chukwu 1995; 2004).

The gross drainage network of Ekulu, Nyaba, Aria, Ogbete, Idaw and Asata Rivers indicates a large scale solution to the storm water drainage problem of Enugu urban area and therefore should be utilized for this purpose. An appropriate model of a comprehensive urban drainage plan which incorporates the natural drainage network in designing a workable comprehensive stormwater drainage system in the entire urban area should be adopted. This is because the artificial drainage facilities and the natural drainage system are actually extreme and complementary members of the same continuous series. This will help to put a stop to the present haphazard construction of storm sewers in Enugu city. Adequate capacity drainages should be constructed especially at the locations where they are mostly needed such as Ogui Urban Area, Emene, Abakpa and parts of Awkunanaw which will take care of their peculiar drainage problems. There is also the urgent need to establish hydrometeorological stations in Enugu city with the purpose of acquiring data for research work on urban hydrology and drainage problems.

For these recommendations to work, there should be a willing co-operation from the Enugu State Waste Management Authority, Enugu Town Planning Authority, Urban Council, estate developers and the public in general.

CONCLUSION

This paper has shown that majority of the drainage facilities are concentrated in the order residential districts of the coal city and are in very bad condition. The poorest condition of drainage facilities is observed in Ogui Urban Area with the highest penalty point. Legislation to protect the city's drainage facilities against abuse, inspection of drainage facilities, regular cleaning of blocked drains, repair of damaged severs as well as plan have been recommended as sustainable measures for management and maintenance of stormwater drainage facilities in Enugu.

Inspite of this, much more collaborative researches are required to sensitize the appropriate government agencies and the urban dwellers on the need to develop the culture for maintenance of the drainage facilities in residential

It is by this way that the urban hydrologists, town engineers and environmental managers can help in sustainable management and maintenance of the city drainage facilities to prevent the hydrological problems of extreme runoff events and associated flood losses in residential areas of the city.

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