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Environmental and Rainfall Intensity Analysis to Solve the Problem of Flooding in Owerri Urban

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Abstract

Hardships, economic wastes, and loss of lives due to yearly Owerri urban flooding pose a challenge to environmentalists. In this study, environmental field investigation, analysis of drainage and reliable rainfall data (2006-2013) were carried out. Drainage blocked with refuse, buildings obstructing natural drainage, increasing urban cementation and the low topographic landscape of Owerri urban were observed as major causes of the flooding. A flood risk map showed Owerri urban as vulnerable. Analysis of rainfall intensity (RI) revealed a tradition of one year drop after two years of rising. Change in RI from the one year of the drop to the two years of the rise was observed in a fairly decreasing order (41%-23%). Hyetographs showed the highest peak of RI in July 2006 measuring 595.l mm/hr. and lowest in May 2013 with 330.7 mm/hr. With a 3-phase drainage network channeling runoff to Nworie River, flooding in Owerri urban will come to an end. The law allowing ≤ 70% of impervious surface per developed plot of land should be enacted and be enforced to support natural infiltration.

Keywords: Urban flooding; Rainfall intensity; Drainage analysis; Flood risk map; Hyetograph; 3-Phase drainage; Sustainable development

Introduction

Flooding occurs when the amount of rainfall exceeds a certain amount normal for that region, and capable of causing significant environmental consequences. Owerri Urban is the capital city of Imo state Nigeria, and the hub of economic and industrial activities. In 2007, Nigerian population commission made a population projection of 610,211 people by 2010, as unevenly distributed over a land area of 57.966783 km^2. There is vigorous infrastructural development and intensified human activities in the area. The increasing persistence of flood occurrences in recent times has attracted public concern about the need to combat this environmental hazard to improve environmental quality in the area. It is because of this that the government of Imo State started desilting of the gutters before the rainy season as this would help to create more space for water in the channels and increase the capacity to contain excess water. More so, to further combat the menace of flooding in the study area; government is in the process of expanding roads and reconstructing drainage channels to increase their carrying capacity and improve the flow of water during rainy seasons. In addition to this, the state government fixed last Saturday of every month for clean up, so that all the refuse that accumulated within the month would be cleaned and evacuated

Owerri is located in the South East region of Nigeria, in the rainforest belt of West Africa. It is precisely located between Latitudes 5° 24' N and 5° 33' N and Longitudes 6° 58' E and 7° 06' E (Figure 1). The area is drained mainly by River Nworie and River Otamiri and their tributaries.

Geologically, Owerri urban is underlain by the sedimentary sequence of the Benin Formation (Miocene to recent). The Benin Formation is made up of friable sands with minor intercalations of clay. The sand units are mostly coarse-grained, pebbly poorly sorted and contain lenses of fine-grained sand near-surface. In terms of relief, Imo state is characterized by high, medium and low areas and Owerri urban falls within the low areas. The study area records average maximum and minimum temperatures of about 32°C and 25°C respectively and annual mean rainfall of about 2000 mm to 2500 mm [1]. Relative humidity varies with the season at an average value of about 70%-95%. It has two major seasons i.e. rainy and dry season. Rainy season ranges from April to November with its peak in July and September, and a short break in August. The dry season ranges from December to February with the influence of Harmattan felt between the months of December and January. These seasonal changes in temperature, runoff, humidity, atmospheric and moisture content of topsoil thus affecting disintegration and washing away of the soil during storms. Vegetation ranges from light rainforest to Savannah with high trees particularly oil bean and palm trees around stream banks and swamps.

Flooding remains the most common of all environmental hazards worldwide. Estimation of flood damage potential helps in flood risk management. In Owerri Urban, the flood has caused loss of lives and properties and obstructed socio-economic activities. Ogundele et al. described flood as an environmental issue which remains threatening to man [2]. Urbanization causes extensive changes to the land surface beyond its immediate borders particularly in ostensibly rural regions, through alterations by Agriculture and forestry that support the urban population [3]. Within the immediate boundaries of cities and suburbs, the changes to natural conditions and processes brought by urbanization are among the most radical of any human activity. Recently at Ibeme Street/Relief Market junction Owerri, flood submerged many houses and destroyed properties worth millions of naira. The flood collapsed fences, submerged cars, and other properties, while some of the residents were trapped in their homes. This was as a result of a rain which lasted for hours and shortly resulted in a flood disaster [4]. This area is called Egbu road flood disaster basin, all the

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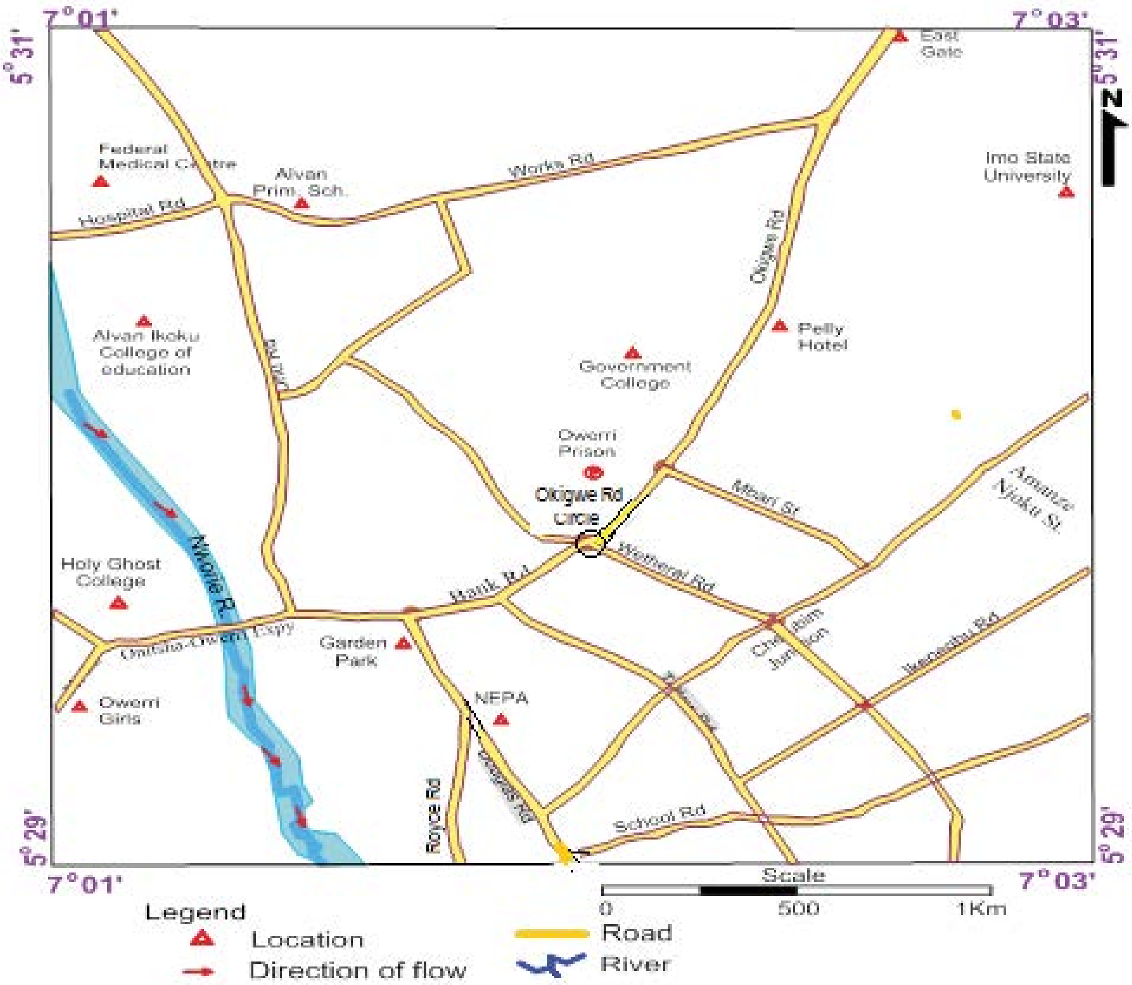

Figure 1: Map of Study Area.

flood from Egbu road power station, Chukwuma Nwoha, IMSU, and Uratta axis anchor on this area.

More so, economic activities suffered a great set back in Owerri due to a heavy downpour that submerged residents and shops in Amakohia area of Owerri. The rain resulted to a heavy flood that overtook major roads and streets in Owerri Urban causing uncontrollable traffic congestion. The residents stayed awake all through the night as the entire environs were totally submerged. According to the community leader Mr. Jude Ewurum, the monetary value of household properties and structures destroyed yearly by flood worth millions of naira. He blamed their misfortune on the state government for destroying the drainage system the community had been managing for years without any practical effort to rebuild them. Another area where the flood wreaked havoc was Umuguma in Owerri-West and its environs as the road leading to the Local Government Headquarters was covered by the flood.

In a related development at World Bank Estate, vehicles and residents were equally trapped by the flood. The market was a no go area as people had resolved to stay in their homes until the heavy flood dries out [5]. In addition, within Owerri Urban, the Civil Defense junction along Okigwe road was terrible. At this location, flood held the low and the mighty captive for about two hours. On several occasions, uniformed men escorting their masters swim the dirty flood in an attempt to ensure that their masters' vehicles escape struck in sand pile below the flood. If one hundred lighter automobiles especially "Keke" plied this route during a heavy downpour, 90 will not be able to cross on their own except with the aid of the passengers who would alight and push the Keke or hired laborers at some cost [6].

Furthermore, the flood around the layout of the works and Odunna Crescent left a sympathetic tale when all the drainages were blocked with refuse as a result of heavy rainfall. At the Okigwe road location, flood events provided cash and carry business to able youths who hang-out to lift commuters particularly women across the flood on their backs. For many years, the flood has devastated residents in different parts of Owerri urban. These affected areas have lost accessibility and become the hideout for criminals. The problem of flooding is all over Owerri urban, including places like Ikenegbu, Wetheral and Douglas Road where the biggest market, Ekeukwu Owerri is situated. Market waste, garbage can be found dumped in the open drainage channels, obstructing drainage and causing flooding at several locations. Often traders hardly find access to their shops to salvage their goods for hours, resulting in damages. Attempts by government to relocate the market failed, until recently when government combined human and extra-human forces to succeed.

Literature Review

Flooding occurs as a result of one or more events such as rainfall filling rivers, streams and ditches, coastal storms resulting in over-topping and breaching of coastal flood defenses, blocked or overloaded drainage ditches, drains and sewers, heavy rain resulting in runoff flowing overland, or rain soaking into the ground and raising groundwater levels [7]. Tobechukwu and Amechi, viewed flood as that which brings about moment of doom and leave to be remembered tales of sorrows, tears, and events which many people in their lifetime would find difficult to forget [8]. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water. Nelson defined flood as the natural consequence of streamflow in a continually changing environment [9]. Ologunorisa defined flood as any abnormally high water stage which may result in significant detrimental effects such as property damage, traffic Congestion, nuisance, and health hazard [10].

Flood is one of the extreme natural hazards that affect a wide range of human activities such as Agriculture and transportation [11]. In the tropical and subtropical regions, severe flood hazard resulting from heavy thunderstorms, torrential monsoon downpours, hurricanes, cyclones and tidal wave surges in coastal and estuarine environments are becoming yearly occurrence and are linked to global warming which produces climate change [12]. Urban flash flood associated with torrential rainfall is the major type of flood in Owerri. Rainfall is the primary source of flood water in Owerri. Flood water is associated with significant damage to property, traffic congestion, and health hazards. This has led to the blockage of the drainage channels in Owerri. Poor drainage network and refuse disposal system in addition to lack of good tarred roads increase flood risk in informal settlements [13].

The occurrence of flood represents a major risk to riverside populations and floodplains, in addition to causing substantial impacts on the environment, including aquatic fauna, flora, and bank erosion. Flood hazard is the probability of occurrence of a potentially damaging flood event of a certain magnitude within a given time period and area [14]. Flooding is a phenomenon but its impact is more pronounced in low-lying areas due to rapid growth in population, global warming, poor governance, deforestation, erosion, decaying infrastructure, lack of proper environmental planning and management, the poor practice of dumping waste/climate change coupled with inadequate preparedness.

Globally, the economic cost of flood hazard is great. Flooding affects people on an annual basis than any other form of natural disaster. According to Etuonobve [12], between 1971 and 1995, flood affected more than 1.5 billion people or 100 million in a year, out of these 318,000 people were killed and more than 81million left homeless. Flood is a principal agent of environmental degradation. Disasters can be substantially reduced if people are well informed and motivated to a culture of disaster prevention [15]. This requires the collection, compilation, and dissemination of relevant knowledge and information on hazards and assessments. Based on the mode of occurrence and duration of the flood event, urban flash floods occur in Owerri.

Overbank flooding occurs when a river overflows its banks and spreads across the land around it as a result of heavy rain. This type of flood can take days to dissipate and is common in the Midwest. In mountainous areas where water flows together through steep valleys the flood water tends to move faster and linger for a shorter duration [16]. Floods occur within the urban regions. This is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems such as storm sewers. It is sometimes triggered by events such as flash flooding or snowmelt. Urban flooding is a condition characterized by its repetitive and systemic impacts on communities that can happen regardless of whether or not affected communities are located within formally designated floodplains or near any body of water [17].

A change in climate has also exercabated the occurrence of floods. Climate is a vital environmental factor that shapes and reshapes human activities. Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years. It may be a change in the average weather condition or a change in the distribution of weather events with respect to an average. The National Emergency Management Agency (NEMA), attributed climate change to the worst flood disaster witnessed in the country in 2012. Climate change acts indirectly to aggravate urban flooding by altering pattern of flooding in flood-prone areas, thereby frustrating efforts of flood prediction [18]. Despite plausible factors contributing to flooding vulnerability and to the ineffective implementation of the city's flood corrective and preventive measures, Nawhath et al. also associated Flooding in Thailand's capital, Bangkok to climate change [19]. Maria and João associated urban flood to climate change, observing that public space may have found an enhanced protagonism under the climate change adaptation perspective [20]. In light of the conducted empirical analysis, which gathered existing examples of public spaces with flood adaptation purposes in Portugal.

Inu Pradhan and Jiba Raj associated urban flooding to the impacts of urbanization and climate change in Kathmandu [21]. Their research explored the relationship between the increasing urban runoff and flooding due to increased imperviousness and extreme rainfall events due to climate change in the study area. The findings of the research show that future climate change conditions with present urbanization will increase pluvial flooding. Schneider et al. reported on climate change impacts on urban flooding. In their paper, they estimated changes in the potential damage of flood events caused by increases of CO_2 concentration in the atmosphere [22]. This they presented in two parts:

1. The modeling of flood frequency and magnitude under global warming and associated rainfall intensities and
2. The use of greenhouse flood data to assess changes in the vulnerability of flood-prone urban areas.

Stephen observes that it is evident from research that residents contribute greatly to flood problems of their area and their act jeopardizes the environment which attracts many people for economic, social and recreational facilities [23]. Aderogba carried out a study to examine the peculiarities of the flood in Nigerian urban areas and its challenges [15]. The research involves a study on the incidence of the flood in twenty-five towns in Nigeria using data on flood depth, width, frequency, and duration obtained between 1981 and 2001. He observed flood and administered the questionnaire to obtain relevant information on the incident of flood and concluded that human factors are the cause of flooding in Nigeria. He asserts that torrential rain is not the main cause of flood but the living habits of the residents and lack of proper planning of the physical environment.

Ogundele et al. examined the environmental consequences of an urban flood on the growth and development of Ado-Ekiti, Nigeria by administering the questionnaire on respondents in the study area [2]. Results from this study revealed that high intensity of rainfall, surface roughness, dumping of refuse on drainage channels, poor construction of drainage channels and poor town planning practices are the main causes of urban flood problems in the study area. The result is in line with Adeloye and Rustum observed that the basic cause of the urban flooding was man's modification of the basic drainage network and channels characteristics during the process of settlement development on the floodplain [17]. He noted that natural surfaces were replaced by more impermeable roads and concrete which have very low infiltration capacity.

Olajuyigbe et al. observed that flood was the most of serious physical development problem in most cities in Nigeria [24]. The research methodology involved the use of remote sensing and questionnaire administration on one hundred and sixty-six households and members of the Lagos State Planning Authority. Three neighborhoods in the settlement that annually experience flood were used for the analysis. Data on population, the extent of areas affected by the flood, households, and buildings were collected and analyzed. The result showed that perennial flooding problem in Mile 12 was as a result of blockage of drainage channels by refuse and other wastes, consistent high rainfall, and water releases from the Oyan dam. Olajuyigbe et al. recommended the provision of sufficient set back from the river floodplain, construction of roads with good drainage, channelization, and building of more dams to avoid excess loading of the existing dam [25]. This research was in agreement with the conclusion of Nwafor who listed surges in water level [11], poor planning and development control, inappropriate drainage capacity and poor waste management as causes of urban flooding. From this literature review on the causes of the flood, the flood is associated with natural and anthropogenic factors.

After a detailed study of the gauge data and its descriptive parameters such as mean and standard deviation and applying probability theory, one can reasonably predict the probability of occurrence of any major flood event in terms of discharge or water level for a specified return period [26]. However, for reliable estimates for extreme floods, long data series is required; the use of historical data in the estimation of large flood events has increased in recent years. Actually, there is no methodology available that can determine the exact amount of flood. Various methods available are either based on probability or Empirical. The methods based on probability theory are Gumbel`s log normal and log Pearson III type etc. [26].

Sharma et.al studied flood risk zoning of Khan Do River [27] and Herath S carried out a flood damage estimation of urban catchments of a river in Chuba prefecture Japan using remote sensing and geographic information system Techniques [28]. He estimated economic loss due to flood based on property distribution within the area. He used stage damage function derived from past flood data while the property distribution was presented in GIS for the area of interest. GIS was applied using statistics corresponding to administrative units and land cover information obtained from the classified satellite image. He crossed the land use/land cover map with a map of the extent of the flood in different return periods to identify land use/land cover under risk of flooding.

Satellite-based rainfall estimates and products derived from them are accessible through the internet and are being used for many diverse meteorological, hydrological, agricultural and other applications throughout the world. Olorunfemi made a comparative assessment of the impacts and response to flood risk among the urban poor living in the highly vulnerable informal settlements in the Cape Town, South Africa and those of Asa in Ilorin Nigeria [28]. The paper explored the vulnerabilities of the two areas and suggested ways of tackling them. He employed an integrated hazard and vulnerability paradigm to examine the cause of vulnerability and impact of flood in the communities studied.

Anticipating floods before they occur allows for precautions to be taken in advance so that people could be warned to prepare for flooding conditions [29]. In order to make the most accurate flood forecasts for water ways, it is best to have a long time series of historical data that relates stream flows to measure past rainfall events. This historical information is combined with real-time knowledge about volumetric capacity in catchment areas such as spare capacity in reservoirs, ground water levels and the degree of saturation of aquifers to make accurate flood forecasts. Ologunorisa investigated flood risk mitigation strategies in the Niger Delta of Nigeria by examining the flood control measures in place and observed that the structural method of flood control tends to give a false sense of security to floodplain dwellers thereby encouraging investments in flood prone areas [30]. He observed that non-structural methods, (public relief funds, flood insurance, flood forecasting and warning schemes), though found frequently used in rural areas were basically behavioral adjustments to flooding [30].

Ologunorisa observed that no attempt was made by the people at risk to adjust to the hazard except to replace lost or damaged goods following a flood event [31]. He X-rayed the short comings inherent in the flood alleviation measures and recommended the establishment of coastal zone management authority, land use zoning and proper legislation to guide the use of land. Ishaya S et al. mapped flood vulnerable areas in developing urban centers in Nigeria using Geographic Information System and Remote Sensing Techniques [32]. Great advancement has been achieved in the prediction of flood damage via flood hazard maps of flood-vulnerable areas are possible based on physical variables collected from passive and active sensors. Gillespie et al. the delineation of flood zones has been undertaken by Sanyal and Lu using information derived from the satellite [33,34]. Researchers have pointed out the fact that one of the ways to study and understand flood behavior is by generating the flood extent of flood risk map because such maps are used for spatial planning and management of land [35].

Materials and Method

Data collection method

The study employed field mapping, historical rainfall data, use of camera for taking pictures of flood, recent flood incidents from Newspaper reports, and journal publications. The data used for the research were monthly rainfall data. These were obtained from the Agro-Meteorological station Owerri (No: 0507.20 Latitude 05° 261 251, N Longitude 07° 021 00» E Attitude 91 m (MSL) of the State Ministry of Agriculture and National Resources in Owerri, Imo State. The data covered a period of Ten (10) years from 2004-2013. These were monthly rainfall records spread over the time frame of the study. The rainfall data is measured in millimeters. The data is required in electronic format to enable effective analysis in Microsoft Excel. A handheld Global Positioning System (GPS) which is an aerospace Technology was used to measure elevation above mean sea level and coordinates (latitudes and longitudes) of the study area. The GPS was graduated in degrees and minutes. The points measured were randomly selected to reflect the topography of the area within Owerri Urban during the rainy season of 2013. The locations were selected because of observed changes in terrain elevation and slopes which are critical to natural runoff direction and determination of areas prone to flooding.

Elevation and coordinate readings were taken from Ugwu Orji, IMSU, Pelly hotels, Prisons, Government College, Garden Park, NEPA, Holy Ghost College, Owerri Girls, Alvan Ikoku Federal College of Education, Federal Medical Centre Owerri, Alvan Primary School, Ikenegbu Layout and Cherubim junction. The data was converted to the appropriate format and analyzed with surfer 10 in 2D format. In addition, Olympus Digital camera model no. TG-310 was used to take flood photographs on the 14th of September, 2013 for the visual interpretation and to know the areas which were prone to flooding and whose channels blocked with refuse. These areas include Chukwuma Nwoha, IMSU Okigwe road especially around Civil Defense Junction, Wetheral, Ikenegbu, Douglas, World Bank, Umuguma, Alvan, works Layout and Amakohia. This was done in the rainy season of 2013. The widths of the drainage channels were determined by measuring distances on both sides of the channels from one side to the other of the drainage channels. The marks made on the walls of buildings, trees and electric poles along the flood lines to the floor of the channels relatively show the marks from where the depths were determined. The widths of the drainage channels were measured with a 100-meter tape. Surfer 10 (software) was used to produce the flood risk map of the area showing different levels of vulnerability [36].

Analytical method

In analyzing the required data, simple statistical techniques such as Arithmetic mean, variance and hyetographs were used to analyze the results in Microsoft Excel. A hyetograph which is a graphical representation of rainfall intensity over time is an excellent tool for rainfall analysis. Method of statistical techniques that were used in analyzing data for the research was descriptive statistics such as mean, standard deviation and variance. Data analysis tools such as frequency distribution and hyetographs were also used to enhance analysis of data acquired.

Applicable mathematical relation

Slope=tan-1 $\frac{\delta E}{\delta H}$ (1)

$$Slope = tan - 1\frac{\delta E}{\delta H}$$

Where E=Difference in Elevation

H=Difference in Horizontal distance

Rainfall Intensity (RI)= $\frac{Total\ Rainfall(mm)}{Duration(hr)}$ (2)

$$Rainfall\ Intensity\ (RI) = \frac{Total\ Rainfall(mm)}{Duration(hr)}$$

RI=mm/hr

Average or Mean, $Ave.RI = \frac{\sum RI}{N}$ (3)

N = Number of rainfall

$$Variance\ (S^2) = \frac{\sum (x-\mu)^2}{N} \quad (4)$$

$$Standard\ deviation\ (S) = \sqrt{\frac{\sum (x-\mu)^2}{N}} \quad (5)$$

Where X be a discrete random variables of RI with mean μ.

% Change in intensity per flood event $(Ei) = \frac{Fi - Pi}{Fi} x100$ (6)

Fi=Final intensity of storm event

Pi=Intensity ofprevious flood event

The probability of a hydrologic event (X) taking place is defined as the relative number of occurrences of the event after a long series of trials.

The probability that event X will occur in any year is P(x)=n/N (7)

Results

Environmental field assessment

The flood photograph from Civil defense junction to IMSU roundabout area (Figure 1) shows that drainage channels along the road were blocked with sand and garbage, and the road was flooded with water. Some people, cars were trapped in the water (Figure 2a and 2b). The flood pictures of the area from Chukuma Nwoha junction

a

Figure 2a: Flooding Civil Defense Junction to IMSU Roundabout along Okigwe Road.

b

Figure 2b: The flood incident in front of Civil defense junction along Okigwe Road.

along Aladimma mortuary shows that there are no drainages around these areas and erosion had eaten up part of the road. As a result of abandoned construction, water flows on the road thereby making it impossible for cars and people to cross the road during peak periods (Figure 3a). The flood picture along works layout shows that the drainage from works layout down to FUTO staff quarters was blocked with refuse by the residents living in this area thereby making it impossible for the free flow of runoff water (Figure 3b). Figure 4a is a topographic map produced from the GPS data showing significant topographic variation, with a relief of 170 ft (51.8 m) (Figure 4a). Figure 4b is the cross-section A-B used to determine the drainage (Figure 4b). An average drainage slope of 7.6^o, (N-S) degrees was obtained.

Analysis of environmental field assessment

The waste management practice in Owerri urban is poor. Refuse is dumped indiscriminately in undesignated areas, gutters and along

a

Figure 3a: Part of road along Aladimma Hospital.

b

Figure 3b: Waste disposal along Works Layout.

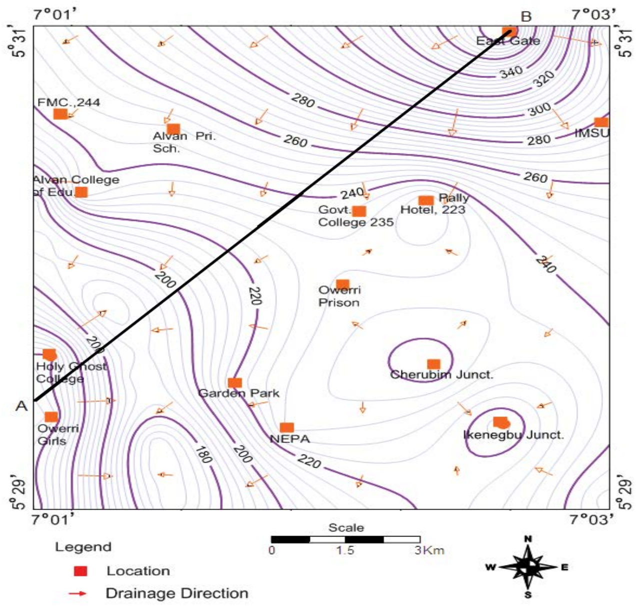

Figure 4a: Topographic and drainage analysis map.

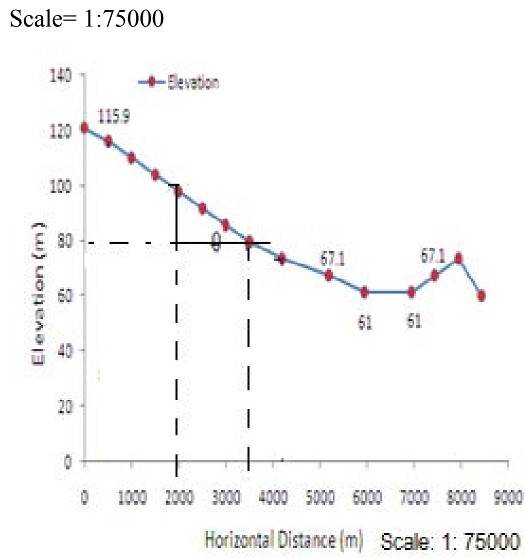

Figure 4b: Cross section A-B and slope.

the streets causing blockage of drainage channels. As seen in Figure 3b, wastes are indiscriminately disposed in the drainage channels along the road. The wastes are not readily collected by the relevant authority with the result that a good number of the waste gets into the drainage system and cause blockage of drainage facilities which causes the flood in Owerri Urban. Runoffs from north-east, north-west on a steep slope of x would naturally drain into Nworie River in the south-west direction despite buildings and other anthropogenic obstructions (Figure 5). Specifically, Figure 5 is a flood risk map of Owerri urban derived from drainage analysis. The most vulnerable area is shown in yellow, comprising Owerri urban and Owerri-West lying predominantly on the topographically low areas on the south-west segment of the map. The channels of Nworie and Otamiri Rivers are the two natural drainage collection axes that must be preserved.

Processed result of rainfall data

Figure 6 represents a composite hyetograph, comprising 10 curves, plotted to cover the study period from 2004 to 2013 (Figure 6). Here, computed rainfall intensity values (mm/hr) were plotted against time (month) in varying color codes. This is followed by hyetographs of maximum rainfall intensity for each year (Figure 7a) and minimum rainfall intensity for each year (Figure 7b). Each flood event is preceded by a drop in rainfall intensity identified with a blue cap, and the drop is found to be in a decreasing order. The peak of each flood event is identified with a green cap, and the peaks are found to be in a decreasing order with years (Figure 7a). A set of three hyetographs representing a graph of rainfall intensity against month for the peak of each flood event were created as in Figures 8a-8c. These hyetographs were used to measure average rainfall intensity per month, for each flood event,

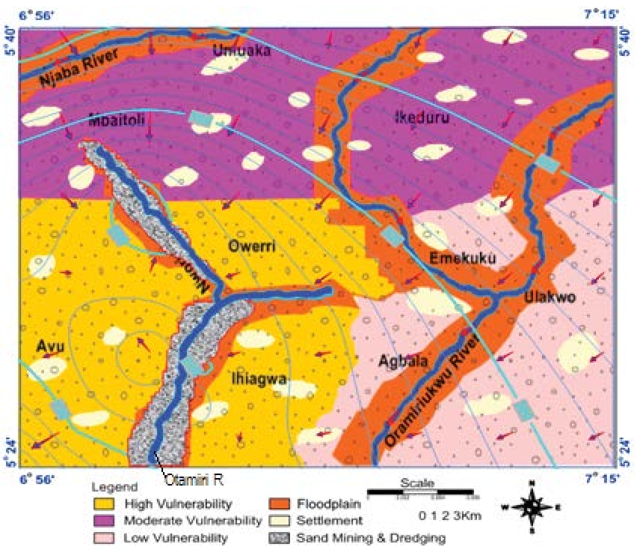

Figure 5: Flood risk map of study area, based on drainage analysis.

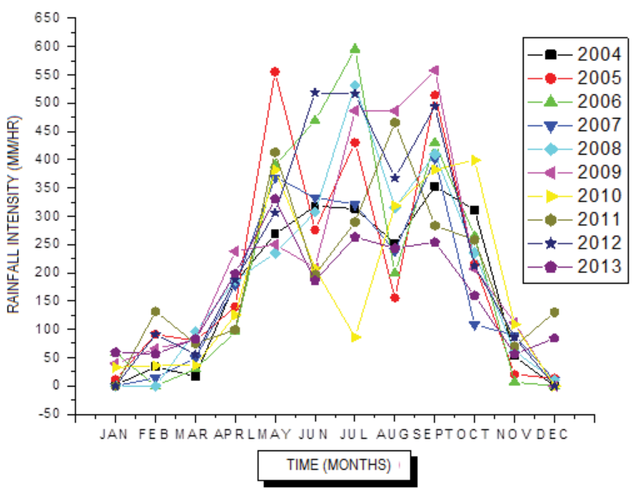

Figure 6: Composite Hyetograph of Monthly Rainfall Intensity (RI) for the 10 years.

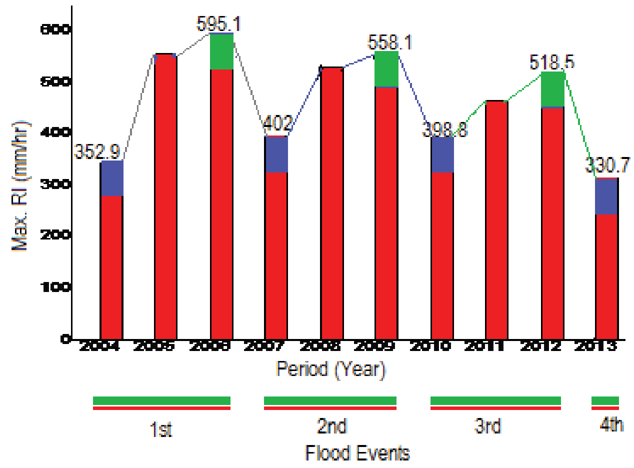

Figure 7a: Hyetograph of Maximum Rainfall Intensities (2004-2013).

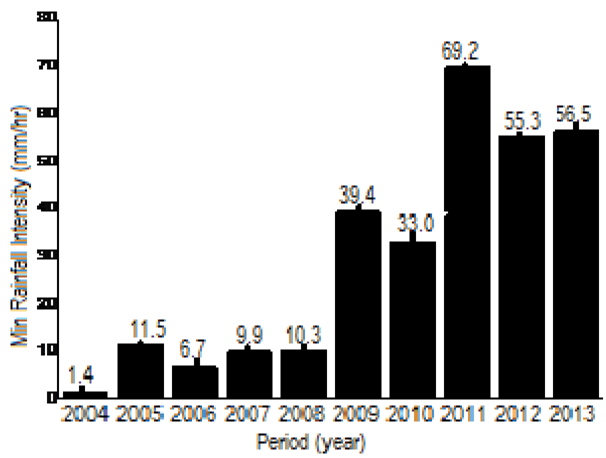

Figure 7b: Hyetograph of Minimum Intensities (2004-2013).

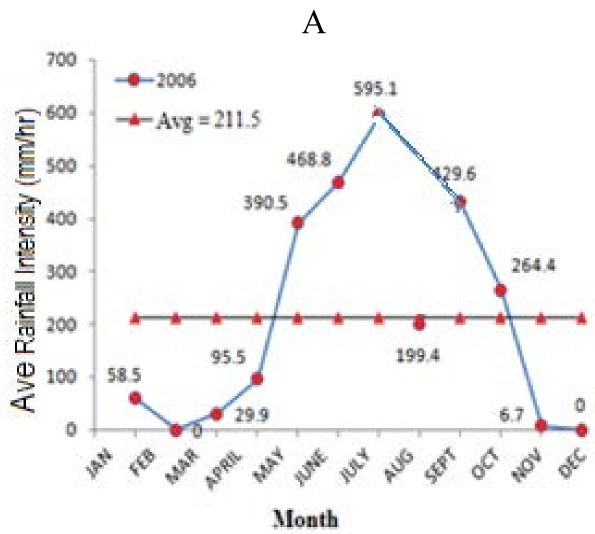

Figure 8a: Hyetograph showing average RI at 1st Flood Event

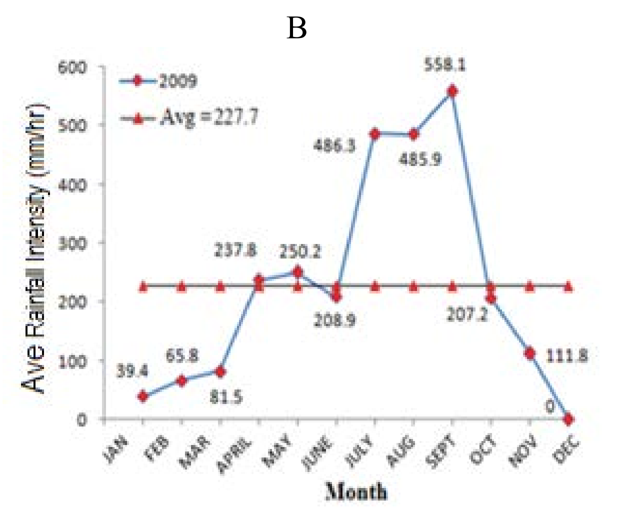

Figure 8b: Hyetograph showing average RI at 2nd Flood Event

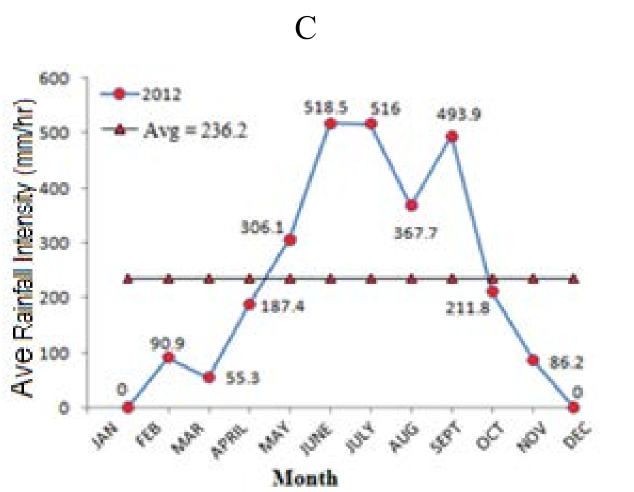

Figure 8c: Hyetograph showing average RI (236.2mm/hr) at 3rd Flood Event.

based on the peak. The measured average values were found to be on increasing order, but a hyetograph of average rainfall intensity for the 10 years showed some level of fluctuation similar to Figure 7a confirming the two-year flood event followed by a drop in rainfall intensity identified with blue cap (Figure 9). The final drop observed, also confirmed the decreasing order of rainfall intensity in the area.

Result analysis of rainfall data

The physical location of the settlements shows that Owerri has the high vulnerability to flooding with the color denoted as yellow in the flood risk map (Figure 5). Sources of flood risk identified ponding as caused by poor drainage facility, blocked drainage, and surface runoff caused by inadequate drainage. Seasonal calendar of flood risk shows that flood occurs mostly between May and August with the most severe occurring between July and August when the soil is saturated. Soil moisture saturation leads to the development of ponds and submergence of houses which is associated with certain illnesses, damage to buildings and infrastructural facilities, transport congestion, displacement of plants and animals and destruction of farmlands. It slows down economic activities among traders and artisans and causes pollution of rivers.

Figures 7a and 7b are hyetographs of Maximum and Minimum intensities for different years (2004-2013). It shows a tradition of the drop in intensity every 2 years. When floods occur after a rainstorm, analyses are used to estimate the probability of occurrence of a given event. A two-year flood has Probability of 0.5. Minimum rainfall was observed between 2006 and 2012 occurring mainly between the months of December and January, while maximum rainfall was usually associated with the months of September, May, and July. The result shows highest minimum rainfall intensity in 2011 followed by 2013 and 2012 while the least occurred between 2008 and 2004 contrary to the trend of maximum rainfall intensity. The traditional drop in rainfall intensity after every two years of flood event suggests that the study area is yet stable under natural condition. There is no indication of any anomalous change in rainfall behavior that could be attributed to the impact of global warming or climate change in the area. The variance varied from as low as 0.18 in 2008 and approximately 1.2 in 2011 to as high as 148.3 in 2012. Similarly, standard deviation varied from 0.43 in 2008 to 12.18 in 2012 (Table 1).

Discussion

It was observed that drainage channels were inadequate and often blocked with refuse. Wastewater was contributing as base flow to storm water in the drainage channels. Drainage was observed to flow in a

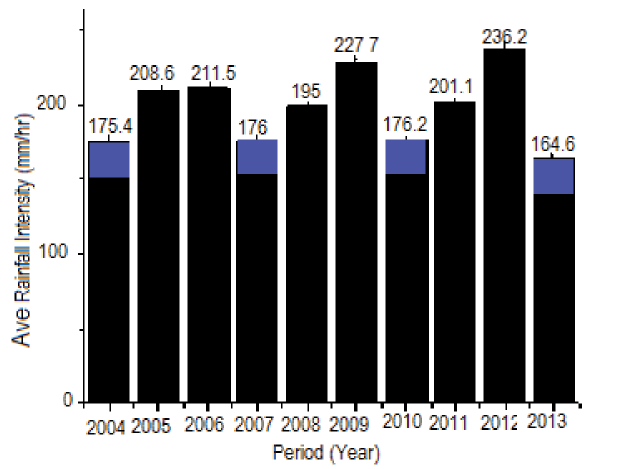

Figure 9: Hyetograph of average annual rainfall intensity from 2004-2013.

S No.	Year	Amount	Variance	SD
1	2004	175.358	49.61026	7.04346
2	2005	208.608	12.04866	3.47112
3	2006	211.533	19.32556	4.39609
4	2007	176	46.79287	6.84053
5	2008	198.992	0.184971	0.43008
6	2009	227.742	90.66145	9.52163
7	2010	176.208	45.89604	6.77466
8	2011	201.083	1.191382	1.0915
9	2012	236.15	148.3663	12.1806
10	2013	164.642	108.8337	10.4323

Table 1: The Rainfall Intensity Variance (*vs*) and Standard Deviation (*SD*) 2004-2013.

natural direction north-south on an average slope of 7.6°, (N-S). The depth of flood observed at different location averaged 0.7 m at peak periods, while resident time was estimated at 2-3 hours after the storm. Urban development marked with high concentration of buildings obstructing natural drainage flow, increasing percentage of impervious surface and the natural low topographic landscape were observed as major causes of flooding in Owerri urban. Analysis of rainfall intensity revealed one year of drop repeatedly every two years, representing a tradition of two year flood event. Percent change in rainfall intensity from the one year of drop to the two years of rise was obtained for each event and observed to be in a decreasing order of 41%-23% while annual average rainfall intensity has fluctuated to a final decrease of 10.8%. The decreasing order so obtained has no implication to climate change contrary to increasing order reported in some parts of the world.

Hyetographs showed the highest peak of rainfall intensity in the month of July 2006 measuring 595.l mm/hr and lowest in the month of May 2013 with 330.7 mm/hr, confirming the gradual decrease in rainfall intensity. Similarly, the respective annual mean of rainfall intensity was maximum in the year 2012 at 236.2 mm/hr. and minimum in the year 2013 at 164.6 mm/hr, also confirming a decreasing order. The maximum value of 2012 may have been influenced by the national flood disaster of 2012 caused by dam failure overflow into River Niger which extended from the north to the south. A flood risk map developed from the drainage analysis map showed that Owerri urban is topographically vulnerable to flooding. This study has shown that annual flooding in Owerri urban is the result of the poor drainage system and urban development obstructing natural drainage and infiltration. Soon as urban drainage system is improved, channeled to the natural collection axes of Nworie and Otamiri Rivers, and building and cementation laws implemented, flooding in Owerri will become a thing of the past.

Recommendations and Conclusion

Owerri Urban is the center of activities in Imo state. It is the seat of government where developmental projects and governmental activities attract the influx of people from the 3 zones of the state and beyond. The increase in built-up areas leads to the reduction in the infiltration capacity of the soil, which generates of the high magnitude of runoff. The increase in the population of people living in Owerri Urban has exacerbated the problem leading to more waste generation which fills the drainages. The failure of the government to develop along the city plan which took care of all the waste and runoff channels has also contributed to flooding incidents frequently recorded in Owerri.

Recommendations

The following measures are required to solve the problem of urban flooding in Owerri:

There is an urgent need for construction of a network of underground and open drainage channels to empty flood into Otamiri and Nworie Rivers. The network should incorporate primary drainage collectors originating from streets as phase (1) drainage channel. This phase 1 channels could be surface U-shape channels but covered with concrete slabs. These primary channels will empty into secondary underground channels phase (2) located in the urban roads. These secondary channels will finally empty into a tertiary (mega) underground drainage channel Phase (3) long established at the urban center through Okigwe Road circle to Bank Road and into the receiving axis of Nworie River (Figure 10). This represents a three-phase drainage system as illustrated in Figure 10. The priority urban roads are Douglas, Tetlow, Royce, Weatheral, Ikenegbu, School and Okigwe roads, as shown in Figure 10. These main urban roads and their adjoining streets will be linked to a network of drainage to solve the problem of flooding in Owerri urban.

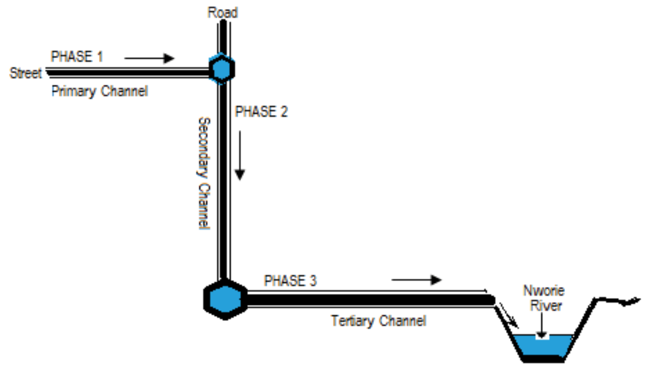

Figure 10: Cross-sectional Layout of Drainage Network for Effective Flood Control in Owerri Urban.

- The Town planners should incorporate a combined drainage and flood risk map (Figures 4 and 5) as a guide to help in site inspection and plan approval for construction of new buildings. As this would help to determine areas which should be avoided in the location of buildings for specific land use purposes.
- On the blockage of drains or channels with refuse, the government authority should adopt a house to the house waste collection system, such that every street and neighborhood will be aware of their waste removal date weekly. The existing practice of providing central waste dumping and collection points in every neighborhood has failed in many cities. Often the central collection bins overflow and spill into drainage due to lapses in evacuation by the county waste management authorities. Most often, neighborhood majority may find a location of the public waste dumping and collection point far, resulting to indiscriminate dumping into open drainage channels. It is also necessary that sanitary inspectors whose duty would include monitoring and prosecuting offenders according to legal provisions on indiscriminate waste dumping be commissioned and properly equipped.
- There is need to make and enforce laws on urban cementation: For example, ≥ 30% percentage of a plot of land should be reserved for natural infiltration when building a house. This should be specified and maintained within an urban setting. Provision of retention basins, rain gardens, lawns, and low impact development structures must be encouraged to minimize flooding in Owerri.

Conclusion

This study has shown that annual flooding in Owerri urban is the result of unsustainable development; poor drainage system and poor urban planning. Buildings are found obstructing natural drainage, while cementation and impervious surfaces are on the increase, reducing natural infiltration. Soon as urban drainage system is improved into a three-phase drainage network, channeled to the natural collection axes of Nworie and Otamiri Rivers, and building, cementation, and waste disposal laws are properly formulated and implemented, flooding in Owerri will become a thing of the past.

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