*Available online www.jsaer.com*

***Journal of Scientific and Engineering Research*, 2017, 4(11):177-188**

**Research Article**

**ISSN: 2394-2630**
**CODEN(USA): JSERBR**

# Towards Effective Storm Water Drainage and Management System in Yenagoa city, Bayelsa State, Nigeria

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**Abstract** Yenagoa, capital city of Bayelsa State, lies in floodplain and surrounded by freshwater swamp and tributaries of the Nun River, Ekole and Epie Creeks, lakes and other natural drainage paths. But the City is annually inundated most times of the year. The goal of this research is to assess and recommend an effective storm water management system in the city. Objectives of the study include: assessing the challenges posed by storm water, identify climatic and hydrological settings of the study area, (c) develop an effective management strategy to mitigate the problem. Multi-stage sampling procedure was adopted and purposively select 6 communities from 22 identified communities, 95 questionnaires were administered. Spearman Rank Correlation was used to test the relationship between adequacy of drains and annual flooding incidence. The study found that; extensive uncontrolled development on wetlands fuelled rapid urbanisation, lack of drainage in many communities and the major roads in the city, development along natural drainage paths and poor waste management practices, thus blocking the natural paths of storm water flow and storm water challenges have caused environmental, health, economic and social problems for the residents. The study recommends that the 2004 Yenagoa Master be implemented and adopt the modified 2002 Model of Urban Stormwater Improvement Conceptualisation (MUSIC) framework. Communities should be planned and appropriately laid out before development commences. Drainages should be provided with roads and linked to the natural discharge points. Natural drainage paths and wetlands should be cleared with adequate storm water infrastructure provided.

**Keywords** Challenges, Flooding, Planning, Storm water management, Wetlands

## 1. Introduction

Urban storm water management in modern times has been a significant challenge to city managers and dwellers alike. According to Bryan [1] most urban centres in developing and developed countries have been inundated with storm water which has been channelled along streets as runoff courses but unable to effectively drain off leading to inundation.

In most of Nigerian cities, there is the tendency of flooding after heavy precipitation which has caused colossal losses to humans and the physical environment. Most of these damages are associated with anthropogenic causes like the creation of heat islands in the urban centres in the guise of urbanization and city development.

This phenomenon over the years has caused significant social, environmental, economic and health complications within the built environment in both developed and developing economies [2]. This is a very prominent occurrence in developing societies of the Global South.

In the recent past, most of the developed cities are wrought with single system that handles both storm water runoff during heavy rainfall before discharging to any natural water bodies as well as sewage. Currently most of the developed countries have moved to the level where cities separate storm water runoff and sewage for ease of handling and treatment [2].

It is a known fact that natural landscapes such as: grasslands, forests and the soil play vital roles in the absorption of storm water. Also, plants hold storm water close to where it discharges. But storm water in built-up environments, if not properly managed most times causes two major problems such as the volume and timing

of runoff water (flooding) and the other related to potential contaminations from pollutants that the runoff is carrying (water pollution) [3-4].

Storm water is a veritable resource because the global demand for water far exceeds the available quantity of water especially in urban centres. Amidst this challenge of water security, there is the need for sustainable technique to harvest storm water from the point source. Storm water management and purification (treatment), can transform the urban centres with sufficient water supply to sustain the city's water needs.

Storm water in this part of the world has been a major contributor to environmental degradation of urban waterways because of poor environmental management practices. In most cities after precipitation, the runoffs carry along with it debris from construction and demolition wastes, household wastes, agro-allied wastes, industrial and human wastes.

The phenomenon of extreme precipitation has been severe in recent decades and it is apparent that the magnitude and occurrence of floods have also increased [5].

Owing to increasing human development activities mostly in urban areas, poor surface and ground water drainage has increased runoffs. This has triggered the need for the handling, treatment and monitoring of storm water to guarantee improved quality of ground and surface water through effective engineering solution [1].

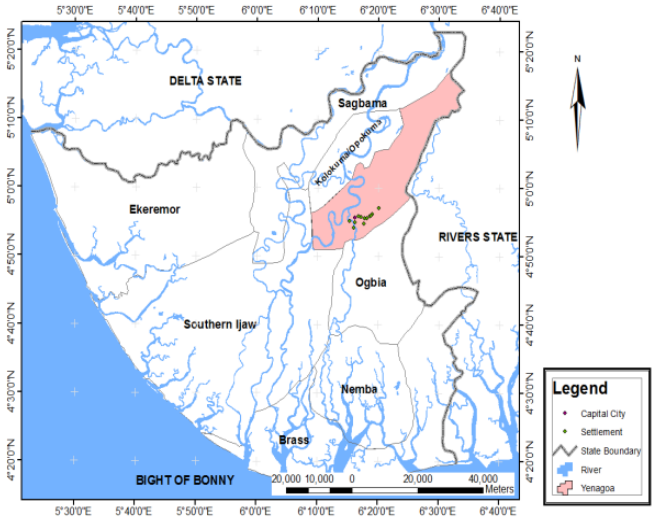


*Figure 1: Map of Bayelsa State Showing Yenagoa City LGA [6]*

Yenagoa city is in the heart of the Niger Delta region of Nigeria which lies within floodplain. The city has experienced urbanization without effective urban planning and management of land use. The city and residents of the city have been encumbered with continuous inundation, ecological challenges, social and economic consequences due to ineffective storm water management system.

The question that arises is how to mitigate the poor storm water management and planning from causing regular flooding and the consequential environmental complications faced by city.

### 1.1. Statement of the Problem

Over the years there have been several studies done on storm water management and its attendant ecological consequences in Yenagoa city. The studies have not provided effective storm water management strategy for the city like the Yenagoa Master Plan, (2004) and Yenagoa City Development Strategy (2007) [7-8].

As the inundation continues unchecked, challenges such as environmental degradation (erosion and biodiversity loss), public health issues (pollution and contamination of surface and underground water), and socio-economic issues (loss of lives, distortion of livelihoods chain and properties and displacement of people) will be exacerbated. Therefore, there is an urgent need to address this urban menace. Hence, this study intends to assess the storm water management system of Yenagoa City and proffer a workable and appropriate strategy for effective storm water management in the city.

### 1.2. Aim and objectives of the Study

#### 1.2.1 Aim of the study

The aim of the study is to provide a strategy for effective storm water management in Yenagoa City.

#### 1.2.2 Objectives of the Study

To achieve the aim of the study, the following objectives would be considered:

i. To examine the existing storm water problems and challenges in Yenagoa City;
ii. To examine the climatic and hydrological setting of Yenagoa City;
iii. To develop an effective storm water management framework for Yenagoa City.

### 1.3. Scope of the Study

The geographical scope of this study covers selected communities in Yenagoa City Local Government Area. The parameters to be measured in the study include the climatic and hydrological characteristics of the study area; patterns of land use and their growth direction in the study area; the main causes of inadequate storm water management system in the study area as well as the factors inducing flood related problems and challenges (see fig.1)

### Technologies for Storm Water Management in Urban Areas

The management of storm water poses great ecological challenge in most urban centres globally. Over the years developed countries have enacted laws and adopted policies to tackle the menace of storm water management incorporated into their environmental management plan that encourages sustainable development. These plans and policies have been incorporated into master plans of cities.

The growth and development urban centres significantly changes, alters, affect and/or make impression on the environment. The building of structures, infrastructure and roads has extensively changed the properties of many human settlements. Some settlements have been identified physically to be less permeable or even impermeable to storm water and these areas are depressed and raised to check ponding or dishing to trap runoff in the environment.

The limited vegetation cover in the environment exposes the soil to the impact of rain during precipitation that lead to increased erosion and flooding in the environment. Rationally, the direction of water systems may be canalized to more effectively route flows through the development with the assistance of drainages. Storm water management entails application of design and technology to limit negative impacts of storm water on the environment and enhance the positive impacts associated with storm water.

A more sustainable approach in managing storm water to prevent flooding and environmental degradation is Integrated Urban Water Management (IUWM) (United Nations Environment Programme (UNEP) [9]. The IUWM system uses the following activities:

- Enhance improved supply and efficiency in water consumption
- Ensures that state of the act technology is put in to the system to make available quality water supply for drinking and other uses
- Allows the diversification of water supply sources
- Bring about improved community system and education on water management
- Encourage sustainability in management practices
- Sustain the capacity building and development of institutions and personnel that are involved in IUWM system; and
- Makes for investment in the economic by proper and efficient use of water

Many techniques have been developed by the IUWM system for storm water management over the years. These techniques have been applied in many urban areas, they include retention ponds, detention ponds, permeable surfaces, rainwater harvesting, green roof, constructed wetlands, infiltration trenches, grass filter strips, grass swales, pervious pavements, infiltration basin, surface and subsurface groundwater recharge, and other sources control measure [10]. There are issues involved in the application of these strategies for storm water management in any environment. These issues concerned include cost consideration, operation and maintenance and application.

### Strategies for Storm Water Management

There are two basic storm water management strategies covering hard and soft engineering projects. *Hard engineering* projects are concerned with construction of artificial structures, through the combination of science, technology and a bit of force to prevent rivers and rainfall from causing flooding. *Soft engineering* projects are the opposite. These projects use natural resources and local human knowledge of the river and precipitation to reduce the risk of flooding [11].

Hard engineering developments are usually successful but most times have significant impact on the river system and this is the major challenge in adopting hard engineering approach to rivers. The hard engineering approaches generally has the capacity to hold large volume of water when released, their impacts are worse when the river flows naturally. The construction, operation and maintenance of these hard engineering solutions are quite expensive and requires advance technology to build, expertise and huge monetary resources. The hard engineering technologies include projects like: diversion spillways, dams, dykes, channel straightening and artificial levees [11].

The soft engineering projects are centred on reducing and mitigating the impacts of storm water problems resulting to flooding incidents rather than preventing them. The major benefit of soft engineering is cost

efficiency and effectiveness as they are cheaper to embark upon which developing countries can also undertake. Generally, they don't disturb the natural processes and ecological systems in river basin like their hard engineering project counterparts but integrate with the natural system to achieve environmental sustainability. The soft engineering technologies include flooding zoning, afforestation, wetland restoration and river restoration [11].

## 2. Methodology

The study adopted a multistage sampling technique and the participant observation method. The study identified and listed twenty-two (22) communities within the study area, six (6) communities: Azikoro, Amarata-Epie, Okaka-Epie, Ekeki, Yenegoa and Yenezue-Gene were purposively selected. The sample size of 95 respondents were selected at random and criteria for selection of the communities was based on the degree of vulnerable to failed storm water management system and the population of the communities. Primary data was collected with the aid of pre-coded questionnaires, participant observation and pictures and secondary data like maps, metrological data were collected through documented works from the Nigerian Metrological Agency (NIMET), Capital City Development Authority (CCDA) Bayelsa State other online sources.

**Table 1**: Questionnaire distribution in the study area

| S/n | Community | Number of Questionnaire |
|---|---|---|
| 1 | Azikoro | 4 |
| 2 | Amarata-Epie | 11 |
| 3 | Okaka-Epie | 19 |
| 4 | Ekeki | 6 |
| 5 | Yenegoa | 46 |
| 6 | Yenezue-Gene | 9 |
| | Total | 95 |

## 3. Findings and Discussions

### 3.1. Flood Problems and Challenges in the Study Area

The findings from the field data indicate that the area is prone to annual flooding. This is mostly during the rainy season between April and October and it is occasioned by poor and/or no drainage system to evacuate storm water after precipitation.

Furthermore, it is evident from available data that most of the communities were not planned before developments commenced. This has led to rapid uncontrolled urbanization that has triggered urban inundation over time. Besides, based on available data respondents' assert that the occurrence of flooding in the study area has contributed to several challenges ranging from: economic, social, ecological and health as evidenced in figures 2,3,4 and 5

However, the phenomenon of annual flooding experienced in the study area could also be occasioned by climatic and hydrological factors as evidenced in (Figs. 8 and 9).

Another dimension on the causes of poor storm water evacuation is hinged on the attitude of some residents and developers alike, who are interested in building along the natural drainage channels. This action over time narrows and subsequently clogs the drainage paths giving room for stagnation of the runoffs, growth of water hyacinths and collects domestic wastes along the path of flow and further degrades the environment (see plate 1)

The government has not effectively studied the storm water flow pattern and proper soil investigations, before constructing roads and drainages in the communities of the study area. This has led to failure of many roads and buildings both public and individuals.

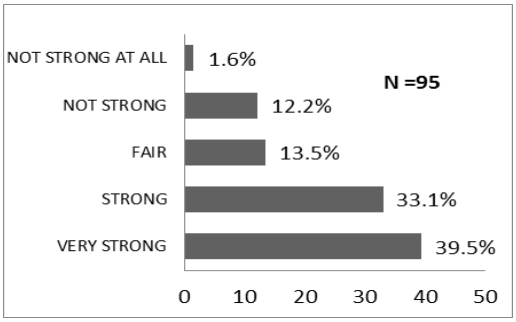


*Figure 2: Perception of the economic effect of no storm water management system on the respondents. Source: Researchers' Fieldwork, 2016*

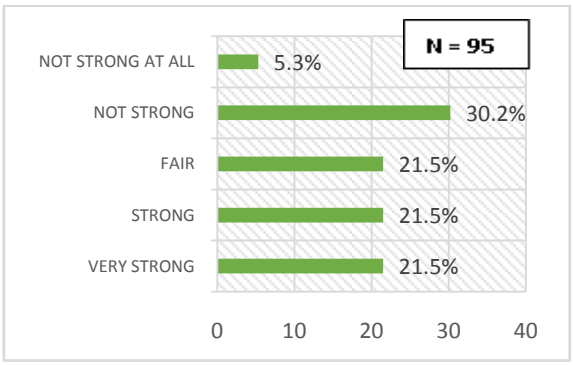


*Figure 3: Perception of social effect of no storm water management system on the respondents.*
*Source: Researchers' Fieldwork, 2016*

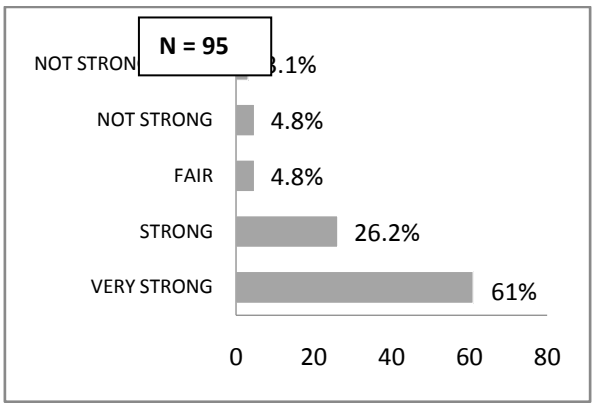


*Figure 4: Perception of health impact of no storm water management system on the respondents.*
*Source: Researchers' Fieldwork, 2016*

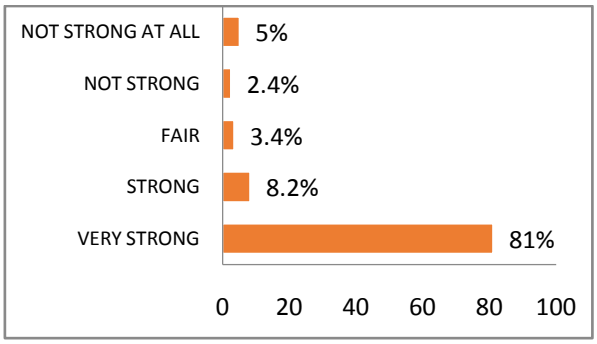


*Figure 5: Perception of environmental Effect of poor storm water drainage system on the respondents.*
*Source: Researcher's Fieldwork, 2016*

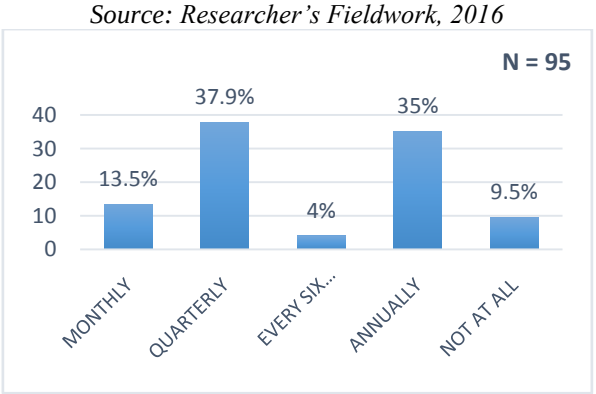


*Figure 6: Frequency of flooding incidence in the Communities*
*Source: Researcher's Fieldwork, 2016*

*Plate 1: A section of a natural drainage system at Amarata Community up with Water Hyacinths and Wastes*
*Source: Researchers' Fieldwork, 2016*

### 3.2. Climatic, hydrological and geological conditions of the study area

The data on the climatic condition of the study area as obtained from the Nigerian Metrological Agency (NIMET) informed the study that July to September are the peak months with heavy rainfall in the year while between December and January are the months with least rainfall. (see Fig. 7). This is not different from the records in the coastal region in the Nigeria.

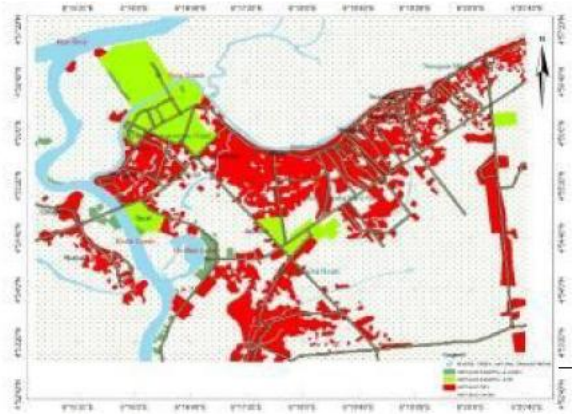

*Figure 7: Hydrological settings and development characteristics of the study area*
*Source: Google Earth, modified in the GIS lab of department of Urban and Regional Planning, Rivers State University (2016)*

Also, from records in the study area it rains at least for 9 months in every year and increases the ground water table within the environment and makes the environment vulnerable to pluvial flooding.

The temperature of the study area from records shows that the month January and April in the year experiences the highest temperatures while the months of July and August are having the lowest. Generally, the yearly average temperature for the study area is observed to be between the ranges of 25.780$^{o}$C – 29.14$^{o}$C.

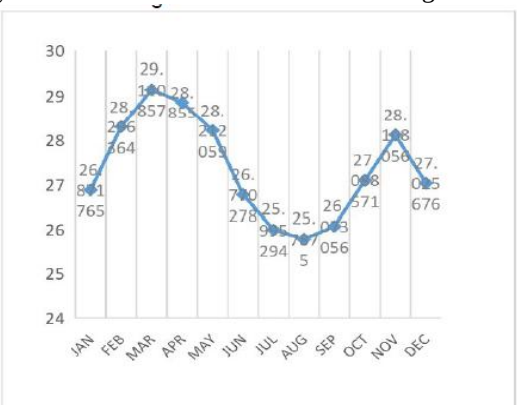


*Figure 8: Monthly average temperature distribution of Yenagoa City [12]*

The soil types from the soil profile investigation based on empirical deductions in the study area of 30m depth of excavation reveal that the top soil is peat having the characteristic of sand and brownish fine-grained. Furthermore, immediately beneath the peat soil, sets in the silty clay soil that is brownish grey and soft silty, next is sandy clay also brownish grey and soft sandy and the last is fine-medium sand which is dark brown, grey, medium dense and sandy in nature.

The soil profile characteristics revealed a weak soil formation from the top soils with poor water retention capacity not allowing water permeability immediately after precipitation which aids fluvial and pluvial flooding in the environment during and after heavy rainfall.

The analyses of data from the field as expressed in Table 1 reveals the flow direction, flow accumulation, channel network and determination of floodplains and wetlands in the study area. Some of the communities that are situated within these areas are: Swali, Yenagoa, Kpansia, Biogbolo, Okaka, Yenezue-Epie and Yenezue-Gene Communities and they are vulnerable to inundation after rains.

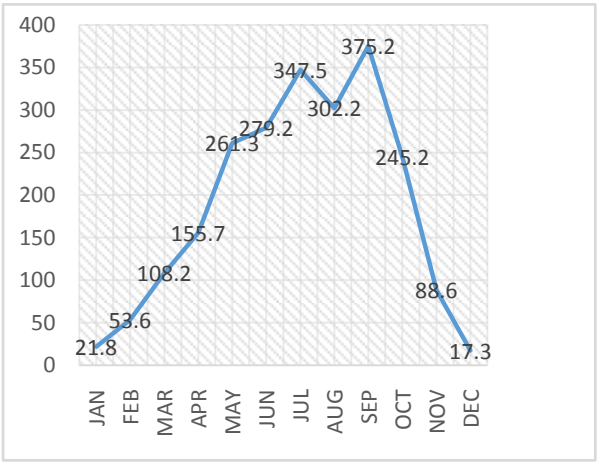


*Figure 9: Monthly average rainfall distribution trend of Yenagoa City [12]*

**Table 1:** Hydrological Settings and Development Characteristics in the Study Area [13]

| Hydrological and Land use Description | Area in Square Metre (Sqm) | Area in Hectare (Ha) | % |
|---|---|---|---|
| Wetland Undeveloped | 87922860.21 | 8792.2 | 75.76 |
| Wetland Developed | 16585232.45 | 1658.52 | 14.29 |
| Wetland sand fill & Developed | 4834206.44 | 483.42 | 4.16 |
| Wetland Sand fill Undeveloped | 709105.72 | 70.91 | 0.61 |
| Rivers/Creeks/Natural Drainage Paths | 5904921.55 | 590.49 | 5.09 |
| Roads | 104729.44 | 10.47 | 0.09 |
| **Total** | **116061055.3** | **11606.10** | **100** |

**Source: Google Earth & Researchers' Field Survey, 2016**

### 3.3. Dynamics of Land use in the Study Area

The pattern of Land use is a major determinant to which storm water management strategy will be the best for any environment. In the study area, it was observed that the pace of the urbanisation process is very rapid and this is an indicator that urban evolution is fundamental to all concerned but there must be elements of development control alongside to manage these changes in the urban form and prepare adequately for storm water management.

The dynamics of urbanisation process which includes land use patterns and directions were observed in the study area from map analyses. The study indicates that there are sprawls, uncontrolled developments mostly on floodplains and there are no effective storm water management strategies put in place to control and/or minimize the effects of these fluvial and pluvial inundations as developments progresses.

Another fundamental observation is the spatial expansion and urban development. The urbanisation process in the city is very active and rapid as urban lands are being invaded by developers both government and individuals especially towards the southern part of the city where land is available for development.

Also, the intensity of development in the study area calls for concern. The core of the developed areas on the maps indicate dense and compact development towards the south end of Yenagoa and developers are invading more wetlands and natural drainage paths in the city.

The densification process is observed to be predominantly occupied by residential land use in the study area and some form of commercial developments such as retail outlets, banks, offices, petrol stations and other social facilities and services. Most of these commercial developments are located along the major arterials in the city.
The area in the city zoned for Central Business District (CBD) has not been laid out for development, though, building development are on-going. Even most of the residential areas are not planned as evidenced in Plates 2 and 3.
All these conditions have contribution of storm water management challenges in the study area as drainages are not provided ab initio in most of the existing land uses from personal observations, field experiences of the researchers. These areas are wetlands but are earmarked for development by the government without proper soil investigation for easy flow of storm water during and after precipitation.
The natural drainage systems in the wetlands are not maintained by preservation and conservation allowing development to take place on them which has been a leading cause of the menace of inundation.

*Plate 2: An Environmental Sensitive Area (Wetland) not properly Planned earmarked as Central Business District at Swali*
*Source: Researcher's Fieldwork, 2016*

*Plate 3: Unplanned Residential Neighbourhood within a Floodplain Area with a Wood Footpath "Monkey Bridge" to Access Buildings.*
*Source: Researcher's Fieldwork, 2016*

There are no proper studies and analyses of hydrologic, topographic, geologic, land uses and urbanisation information in the study area by government. This would have served as a guide to the provision of effective storm water infrastructure to determine the type, flow direction and gradient and networking of runoffs to enhance the functionality of the natural drainage paths and storm water drainages in the study area.
The identified wetlands and floodplains have not been adequately protected from development as they serve as water retention ponds to enhance their natural functions.

**3.4. Physical planning issues**

Physical planning by its standing is the driver of physical development by ordering the use of land in any given environment.
This principle has not been adhered to in Yenagoa as the city has experienced gross lack of physical planning and urban management over the years. Most of the communities in the study area are not planned and are without well laid out streets with the required street infrastructure and amenities.

This can be attributed to poor development control processes in the city because the government has failed to implement the Yenagoa Master Plan of 2004 and the Yenagoa City Development Strategy of 2007 which is fallout of the master plan.

There are few planned areas within the city which form parts of the communities in the study area. These planned areas are mostly gated neighbourhoods developed by the government for employees and political office holders. These are: Azikoro Housing Estate, Civil Servant Estate at Ovom, and Opolo Housing Estate I and II.

However, these estates still experience inundation because the drainages provided are not well channelled to the natural drainage paths around them.

These unplanned urban growths thrive sprawl and slum developments. Most of the access roads in the study area are not well laid out and/or designed wrongly because the drainages beside the roads collect runoffs but hardly drains water from the streets during and after rainfall.

Even the streets that have drainages are not properly channelled to the natural drainage paths because of absence of effective planning and enforcement of physical planning standards and regulations as provided by the master plan of the city.

It was also observed that people develop properties close to the natural drainage paths without proper setbacks and narrowing these paths, and even to the wetlands intensifying the level of densification in the communities. The wetlands that are supposed to be conserved to serve its natural function of water retention as the available lands for development are reduced and limited see Plate 1.

### 3.5. Other factors contributing to storm Water management challenges in Yenagoa City

In carrying out the study several factors were identified that contribute to storm water management problems in the study area are numerous. Some of these contributory factors include dumping of refuse in drains and natural drainage paths (creeks) in the study area, poor drainage design and construction and the lack of drainage network for ease of evacuating storm water to natural discharge point.

Some properties are developed on identified wetlands in the study area with no approved building plans, adequate and functional drainage system (see Plates 4 and 5). And the existing drainages are not uniform in size (depth and width) across the study area and have effects on the flow and volume of storm water discharge.

However, from the authorities there are no specified standards for the construction of drainages in the study area but from observation a typical drainage in the study is 0.5m (width) X 0.7m (depth) in size. This size can be observed not to be adequate for the volume of runoff in the study area during raining season especially during peak months of rainfall as rainfall last at least for 9 months of the year.

Furthermore, some other factors identified as causing storm water management challenges are the non-functional drainages in the streets and communities because of absent of storm water network as earlier identified and poor maintenance of existing drainage systems.

It was also observed that all the major roads in the city do not have drainages for collection of storm water during and after precipitation especially on: Melford Okilo, Yenagoa-Mbiama, D.S.P. Alamieyeisegha, Isaac Adaka Boro and Swali-Imgbi Roads. These are the roads that connect various communities identified in the study area.

These identified factors mentioned are anthropogenic factors such: as the failure of government to perform her social responsibilities to the people by providing required basic infrastructure such as storm water infrastructure.

The research also revealed that there are no supports in financially and technically from any organisation (international, federal and private organisation) at any level to the state government to solving storm water management problems and challenges experienced in the study area.

*Plate 4: Isaac Adaka Boro Road one of the Major Road in the Study Area without Drainage*
*Source: Researcher's Fieldwork, 2016*

*Plate 5: A Street in Biogbolo Community without drainage System overtaken by grasses*
*Source: Researcher's Fieldwork, 2016*

The topography and landform of the study area reveals that the lowest height is 6m above sea level which is around the Swali and Yenagoa Communities axis depressing into a wetland serving as a watershed which flow into the Yenagoa Creek.

Other low points in the study area are: Amarata, Ovom, Onopa, Ekeki, Yenezue-Epie, Biogbolo, Yenezue-Gene, Kpansia and Azikoro area having between 3m – 6m height having one of the largest areas of wetland in the study area. The highest points are between 6m – 7m which are scattered across the study area, but mostly found at the south-eastern part of Biogbolo Community in the study area.

## 4. Conclusion

An approach towards effective storm water drainage and management system is a key factor to consider in the design, construction and implementation of city development plans globally.

The conventional storm water management systems in Yenagoa City has failed to solve the threat of storm water in the city. The city by its location, geomorphology and topography is susceptible to inundation.

There are some identified factors that has led to this monumental failure of the traditional practice of storm water management like: dynamics of land use patterns, lack of political will to implement the 2004 Master plan of the city, climatic, hydrological and geological conditions of the study area.

Layouts, buildings and roads are designed on faulty premise because reports on flood prediction are not put into consideration as design criteria. This has caused unquantifiable loss in terms of financial and material resources to individuals, government and corporate investors in all spheres of human endeavor in the environment.

Therefore, there is need to recognize modern sustainable storm water management approaches to balance the human demands of development and flood risks that are triggered by lack of storm water management in the study area.

There is the need for a collective participatory approach by government, residence and corporate organisations alike to combat these environmental threats caused by the lack of storm water management to manage this menace.

## 5. Recommendations

The recommendations are as follow:

- Implement the Yenagoa City Master Plan of 2004 to guide, monitor, control and manage the areas designated as urban lands to achieve sustainable urban growth and development.
- As a state policy and urgency, Storm Water Management Framework should be prepared for the city – Model for Urban Stormwater Improvement Conceptualisation (MUSIC), 2002 approach as attached
- Structural (engineering methods) and Non-structural (regulations and standards) Storm Water Management approaches should be employed to control and manage flooding challenges in the city;
- Development should not be allowed in any part of the city that has not been well laid out by the government and the communities e.g planning schemes in any area in accordance with the Yenagoa City Master Plan, 2004;
- HEC-1 and HEC-RAS software should be used to analysis and estimate natural drainage systems, hydrology, hydraulic and flow systems of channels with detailed topographical and geological surveys and analyses;

- All relevant ministries and government agencies involved in storm water activities should collaborate in monitoring storm water activities in the city such as the Bayelsa State Ministries of Works and Environment, Bayelsa State Physical Planning and Development Board, Bayelsa State Environmental Sanitation Authority and NEMA;
- Drainage systems should be concretised and embankment should be constructed along natural drainage paths. All the major roads should be provided with storm water drainages to effectively evacuate runoffs and storm water to the natural drainages systems in the study area;
- There should adequate public enlightenment to educate the residents of city not to dump their waste on the natural and artificial drainage systems in the city.
- There should regular de-silting of all make shift drainages and natural drainage systems in the city especially before and during raining season.
- Government should demolish all buildings along and within natural drainage paths to allow free flow of storm water.

**Formed Consent**

The consent of respondents was got before pictures were taken and questionnaire administered.

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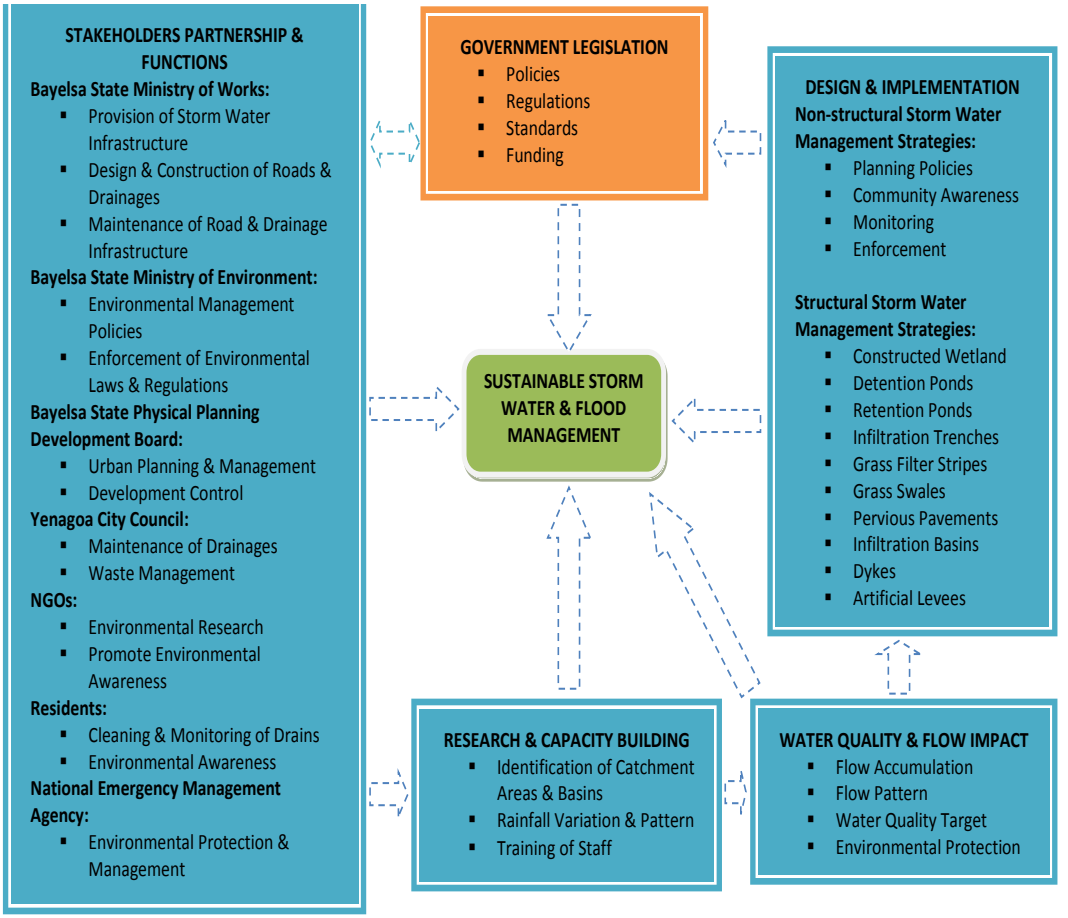
APPENDIX




**Proposed Sustainable Storm Water Management Framework for the Study Area**
**Adapted & Modified: Wong, et al, 2002 (Model for Urban Stormwater Improvement Conceptualisation – MUSIC, 2002)**