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Flood Risk Assessment of Port Harcourt, Rivers State, Nigeria

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ABSTRACT

The rapid rates of urbanization and population growth of Port Harcourt city in the last ten years have led to uncontrolled and uncoordinated development of swamps, floodplains and natural drainage channels thereby aggravating the risk of flood hazards in the city. This study examined the flood risk in Port Harcourt using rainfall data, soil texture and other factors. The proportions of clay slit and sand particles in the soils were determined. Permeability result obtained is within the range of low-very low permeability (10^{-4} – 10^{-6} cm/sec). Years with high rainfall events which correspond to years of high flood risk in Port Harcourt include 1998, 2000, 2002, 2003, 2004, 2006 and 2007. The percentages of rain events with high intensities in these years are; 39.4%, 52.7%, 32.7%, 40%, 35.8%, and 44.6% respectively. Rainfall intensity obtained is within the range of 53.8 – 20.4% for high to low intensities. Rainfall intensity is high in Port Harcourt due to climatic changes such as high rainfall volume and duration. The result of this study shows that the risk of the occurrence of potentially damaging flood in Port Harcourt increases with increasing rainfall intensity. Also, the risk of flood is bound to increase in the future with increasing urbanization hence the need to demarcate the flooded areas for effective flood mitigation.

Keywords: flood, urbanization, permeability, rainfall, Port Harcourt, drainage.

INTRODUCTION

Flood is a natural even that can have far reaching effects on people and the environment; put simply as too much water in the wrong place. Also, flood is a large quality of water covering a dry land as a result of flow from storm water (rain) and other sources such as river overflow due to the volume of water within a water body exceeding the total capacity of the body. (Ceylon, 2004).

Flooding is a common occurrence in many parts of the entire mangrove belt of Nigeria and fresh water especially at the high tide or during rainy season. Flooding also occurs in floodplains of large rivers and many areas and town especially those located on flat or low-ling terrain where adequate provisions have not been made for surface drainage or drainages have been blocked by municipal wastes and eroded soil sediments. Cities like Port Harcourt, Lagos, Warri, and Bayelsa are within the mangrove and fresh water belt. They experience annual flooding.

Flooding occurs when the amount of water on the land (from rainfall, snow melt, surface flow, and flow in water courses or inundation by the sea) exceeds the capacity of the land to discharge that water by infiltration, surface flow, piped drainage or surface water courses.

Flooding also occur if water accumulates across an impermeable surface and cannot rapidly dissipate it.

There are various factors that enhance flooding, these include; the degree of urbanization, lack of vegetation cover due to deforestation, land development; presence of impermeable soils and existence of low-lands (Andrew, 1993).

STATEMENT OF THE PROBLEM

Port Harcourt metropolis, like most urban areas of the third world, has in most times experienced accelerated population growth which has led to changes in the land use activities. Depth of flood water in affected areas has escalated significantly in the past ten years due to combined effect of uncoordinated, uncontrolled rapid urbanization, development of swamps, flood plains and natural drainage channels. (Akpokodje, 2007).

Table 1.1: Depths of flood water (2007) as revealed by marks on building walls I some parts of Port Harcourt. (Modified from Akpokodje, 2007)

Flooded area	Depth of flood marks on walls (2007)
Mgbuoba	70-150cm
Rumudara	70-80cm
Nkpolu community secondary school	66-110cm
Airport/Rumupokwu	90-99ccm

The overflow of Ntawogba creek in 2002 and 2004 caused untold hardship to inhabitants living along the street bordering the creek in Port Harcourt. Disposal of refuse into the creek is another contributing factor. Port Harcourt is articularly at risk from sea-level and flood because of its low elevation over extensive areas.

The most recent devastating flood in Port Harcourt occurred in 2006. Although the flood in 2007 was lower than 2006, it is still higher than pre-2006 floods (Akpokodje, 2007). The flood risk in Port Harcourt is bound to increase in future with increasing urbanization, hence the need to demarcate the flood prone areas for effective flood mitigation in port Harcourt.

Locations of the study area

The study area, Port Harcourt is located in the Niger Delta region of Nigeria, and is the capital of Rivers State. (Fig 1.1). It has the second largest sea ports in Nigeria. It is located on the Bonny River about 64km, (40miles) from the sea)

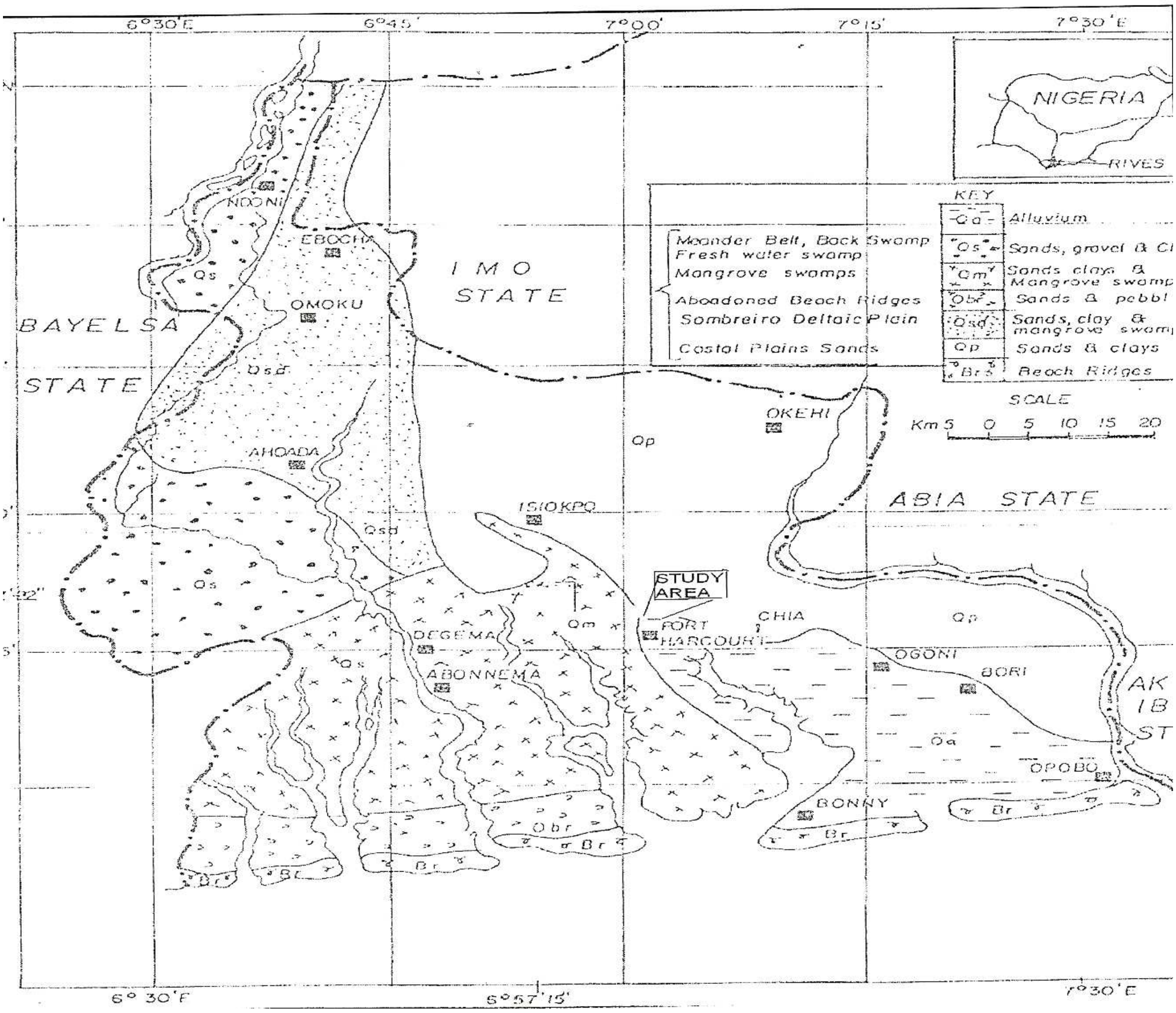

Fig 1. Location of the study area

The areas lies between longitude $6^0 4^1$S- $7^0 1^1$E and latitude 4^0 40^1- $5^0 00^1$N. It covers an estimated area of 1811.6 square kilometer. The city is slightly elevated but no significant structural control on the evolution of the drainage network and surface forms are dissemble.

Port Harcourt is the hub of industrial, commercial, administrative and other activities in the state. The city is often referred to as the treasure base of the nation.

Geology and hydrogeology settings

The study area, Port Harcourt, is located in the Niger Delta Basin of southern Nigeria. The Niger Delta is located on the West African continental margin where the east trending Equatorial coast turns south towards the Equator. It is presently inhabited by about seven million people. High resident population, concentrated in the two urban cities of Port Harcourt and Warri, is attributed to the rapid growth in the oil and gas industries.

The development of Niger Delta resulted from the formation of the Benue trough as a failed arm of the rift triple and South American continents and subsequent opening of the South Atlantic (Murat 1970; Evamy et al 1978; Whiteman 1982)

The Benue – Abakailiki trough was filled with sediments during the early Createaceous time, later it underrivent folding, faulting, and uplift with subsidence of the adjacent Anambra basin to the West and Afikpo Syncline to the East during the Santonian. The proto-Niger Delta ended in the Paleocene time.

The coastal sedimentary basin of Nigeria was the scene of three depositional cycles. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase in Santonian time. The second included the growth of a proto-Niger delta during the late Cretaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to recent, marked the continuous growth of the main Niger delta. The Niger delta subsurface has a few three fold lithostratigrahic subdivision, comprising an upper sandy Benin formation, an intervening unit of alternating sandstone and shale named the Agbada formation, and a lower Shaly Akata formation. These three units extend across the whole delta and each ranges in age from early Tertiary to recent.

A separate member of the Benin formation is recognized in the Port Harcourt area. This is the Afam clay member, which is interpreted to be an ancient valley fill formed in Miocene sediments.

There are 11 proven reservoirs in the Niger Delta Basin. The Agbada groups of reservoiur are the main contributors of reserves. The most significant reservoir is Agbada stratigraphic-structural play which accounts for 58% of the basin recoverable oil reserves (34,603 MMb) and 55% of the basin recoverable gas reserves (114,925 Bcf). Subsurface structures are described as resulting from movement under the influence of gravity and their distribution is related to growth stages of the delta. Rollover anticlines in front of growth faults form the main objectives of oil exploration, the hydrocarbons being found in sandstone reservoirs of the Agbada formation.

The Agbada structural play accounts for another 40% of hydrocarbon reserves. The structures for both of these plays are best developed at the proximal margin of each successive depobelt, i.e. at the point of major growth faulting and associated roll-over. The stratigraphic traps elements are typically facies-related pinchout about 45% have been found offshore. The outer shelf and slop is currently being subjected to a major exploration campaign. A considerable volume of 3D seismic has been acquired and successful drilling is taking place.

The delta is dissected by a dense network of rivers and creeks, which maintain a delicate but dynamic equilibrium between saline, estuarine and freshwater surface bodies with complex underground extensions (Abams 1999). The Rivers Niger drains a large part of West African and discharges its waters, sediments and other loads including exotic species into the Niger Delta and its extensions into the Atlantic Ocean. Over the years, this process has resulted in the formation of a complex and fragile delta with rich biodiversity (Awosika 1990). In order to accommodate this natural diversity, the delta is divided into ecological zones (Abams 1999). The extent of the variation is usually a function of hydrology topography and soil type. Changes in any of these factors may alter existing ecological conditions and boundaries.

The dense network of rivers and creeks in the dissected surface of the delta creates a condition of delta-wide hydrological continuity. Disasters such as oil pollution and flooding in one part of the delta can readily be felt in other parts (Whiteman J 1982). The rivers network conveys water and sediments through some 20 estuaries into the Atlantic Ocean to support the dynamic equilibrium of the coastal hydrological processes. This means that a spill in an upstream location not attended to, has the possibility to spread across these estuaries. This may affect a significant part of the delta, comprising sensitive low-lying swamps. Also, the region is dominated by south-westerly air currents and complex ocean water circulation patterns.

Relief and drainage

The area falls within the coastal belt dominated by low lying coastal plains which structurally belong to the sedimentary formations of Niger Delta.

Izeogu and Aisuebeogun (1989) view the ridge barrier islands as depositional land forms which receive fine to course grained sands from the sea with elevation of just about 13m above sea level. Although the region may be said to be essentially composed of gently rolling coastal plains or lowlands, the composite landform features can be more clearly discerned at the micro-relief level.

The Bonny River begins its flow from the West towards the East before turning sharply to flow down to the south smaller rivers drains the southern part of Diobu and creeks which empty into the West-East, reach of the Bonny River at its northern bank eg. The Elechi creek. This creek joins the trunk known as the primerose creek which links Bonny River with the New Calabar River. The Abonnema River drains the Southern part of Diobu. Surface run-off from Rumuigbo area mainly empties into mini Apalugbo stream, which flows Northeast wards before joining the Woji River which itself flows south Easterly to trans-Amadi industrial area which then flow into a mangrove swamps ear port Harcourt zoological garden. Virtually the whole of rainbow town which is drained by Elekahia River flows into Amadi creek. Amadi creek is also joined at the Western flank by the Ntwaogbo River which has a lengthy course of up to 9km and virtually divides port Harcourt built-up areas nto two portions. The Ntawogba river drains Rumuokwuta, Ikwerre road, G.R.A. phase I, II, III and IV and Amadi flats. With the Bonny River to the West and Amadi creek to the East Dockyard lies to the south of Port Harcourt Township and Borikiri areas where it makes a unique network with swamps and several creeks including Isaka River and Dick Fiberesima creek.

A close observation of the rivers and creeks in Port Harcourt and its environment shows that the network pattern created does not easily fit the convectional, typical dendritic and trellised pattern of drainage. The entire area is criss-crossed by several rivers and creeks which empty into the Atlantic Ocean.

Aims and objectives

The objectives of the study are;

- Determine the major causes of flood in Port Harcourt
- Determine flood prone areas in port Harcourt
- Produce a provisional flood risk map of Port Harcourt.

Methodology

The study methods included:

i. Study of the flooded areas in the rainy season and measurement of flood characteristics such as extent and depth of flood water.
ii. Collection of soil samples
iii. Laboratory analysis
iv. Analysis of rainfall intensity.

Sampling

The areas that were severely affected by the 2006 flood were sampled.
The four areas affected include:

- Nkpolu community secondary school, East – West road by Nkpolu junction.
- Airport road by Rumuopkwu
- NTA Mgbuoba road
- Streets in Rumudara (Akpokodje 2007).

Two auger holes were drilled in each of the above four areas. A total of 25 samples were collected from the four areas, including the control samples.

Samples were mixture of cohensionless and cohesive soils. The samples were adequately labeled at the time of collection. Notes were taken on the historical background of flooding in each of the areas.

Laboratory Method

Sample was analyzed in the laboratory using BS or ASTM laboratory standards. The particle size distribution was determined using wet sieve analysis for coarse soil particle and sedimentation for fine grain fractions. The permeability of the different soil samples was also determined. Typical values of coefficients of permeability and rating are seen in Table 2.1.

Table 2.1: typical values of coefficients of permeability and rating

Degree	Permeability (k) (cm/sec)
High	Over 10^{-1}
Medium	10^{-1} to 10^{-3}
Low	10^{-3} to 10^{-5}
Very low	10^{-5} to 10^{-7}
Practically impermeable	Less than 10^{-7}

The permeability (k) was obtained in cm/sec since the rating range is in cm/sec. Therefore, D10 obtained in mm from the sieve curve was converted to cm using m = 10mm.

Field Mapping Procedures

At the initial stage of the field mapping, public and research libraries were consulted for available information about the flooded areas in Port Harcourt.

The area was first visited for reconnaissance survey to confirm and ascertain the information gathered from the literature review to assist in the detailed mapping.

During the detailed field mapping exercise, various tolls were used. These include Topographic base map, ink, pen, pencils, metric rules and measuring tapes.

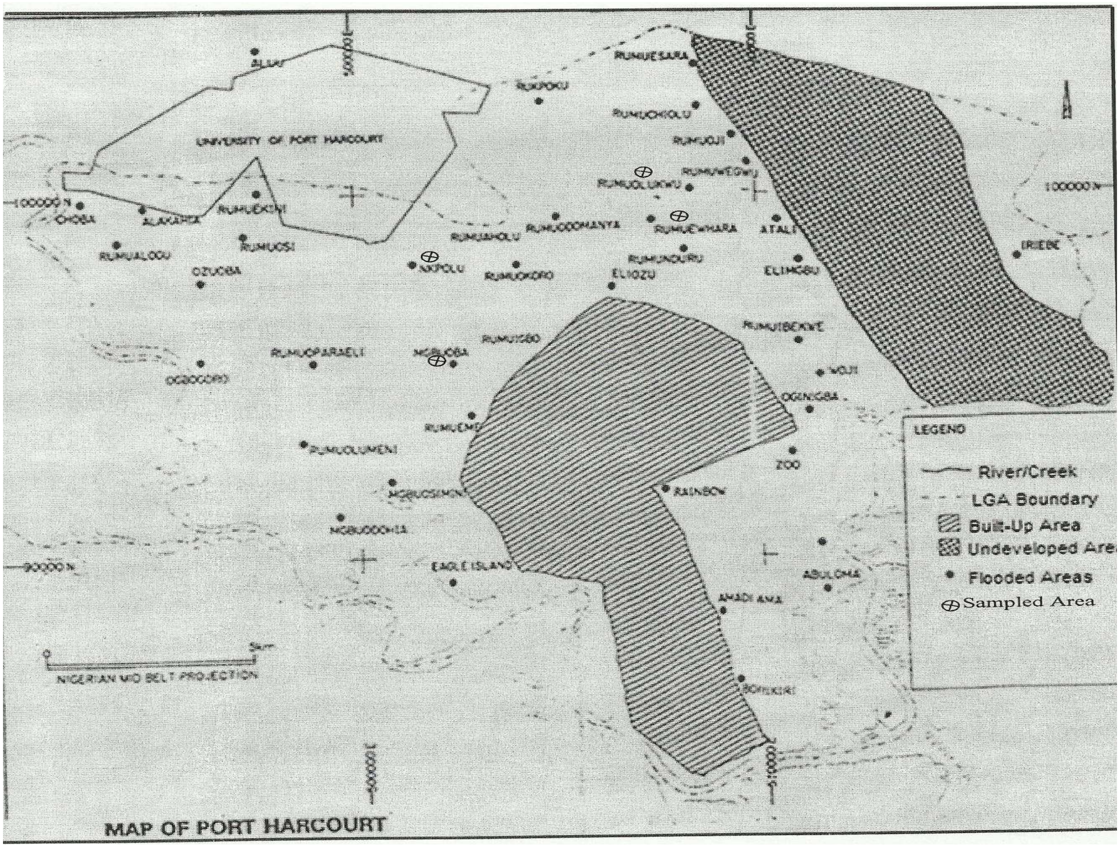

Fig 2.0 Map of Port Harcourt showing the flooded areas and sample points

In each location, the depth and the extent of flood water were measured and recorded using metric rules and measuring tapes respectively.

The different locations were carefully represented on the base map. Oral interview was conducted in each location and their responses were recorded.

The drainage system and settlement pattern in each location were observed and the observations were recorded.

At the end of the field study, a tentative flood risk map was produced (fig 2.0) and also, based on the above information, a tentative filed interpretation was done.

Rainfall Data Analysis

This section examined the temporal changes in rainfall of different intensities, daily, monthly and annual rainfall pattern that occurred in the past years and during the period of study focusing on the relationship between rainfall and flood events in Port Harcourt.

A conclusion was made on whether the increase in frequency of flooding can be related to rainfall changes. In view of this, rainfall data with varying intensities was sourced from Nigeria Metrological Agency, Port Harcourt. The data was within the period of 10 years (1998 – 2007), it was analyzed and the necessary deductions were made from it.

Presentation of results

The particle size distribution curves were produced from the particle size distribution test and these curves were used to infer the sol description. The permeability test was used to determine the permeability of the soil samples; while the rainfall data analysis was to determine the rainfall intensity the study area. (Table 3.1) The results obtained are presented below.

PARTICLE SIZE DISTRIBUTION REST RESULT

Table 3.1 soil particles in percentage and description

Sample no	Borehole no (BH)	Clay%	Silt %	Sand %	Gravel %	Soil description
1	1	1	44	55	0	Silty sand
2		1	40	58	1	Silty sand
3		4	41	55	0	Silty sand
4	2	1	38	60	1	Silty sand
5		0.5	41	57.5	1	Silty sand
6		1.5	41.5	57	0	Silty sand
7	3	0.5	61.5	38	0	Silty sand
8		3	48	49	0	Silty sand
9		3	44	53	0	Silty sand
10	4	3	47	49	1	Silty sand
11		3	40	57	0	Silty sand
12		3	38	58.5	0.5	Silty sand
13	5	0	14	85	1	Silty sand
14		0	13	86	1	Silty sand
15		0	23	73.5	3.5	Silty sand
16	6	0	38	56	6	Silty sand
17		0	36	58	6	Silty sand
18		0.5	29.5	64	0	Silty sand
19	7	0	29.5	69	1.5	Silty sand
20		0	26.5	71.5	2	Silty sand
21		0	26.5	71.5	2	Silty sand
22		0	22.5	76.5	1	Silty sand
23	8	0	25	74	1	Silty sand
24		1.5	56.5	41.5	0.5	Silty sand
25		3.5	49	45	1.5	Silty sand
Av. %		1.20	34.30	60.80	0.86	

Table 3.2: Daily rainfall intensity in percentage (1998-2007)

Daily rainfall intensity in percentage						
Year	1998			1999		
Intensity ratings	High	Moderate	Low	High	Moderate	Low
July	9	7	10	4	6	11
August	8	4	7	4	3	13
September	11	4	8	8	5	12
Total	28	18	25	16	14	36
Total raining day	71			66		
Total percentage %	39.4	25.4	35.2	24.2	21.2	54.6

Daily rainfall intensity in percentage						
Year	2000			2001		
Intensity ratings	High	Moderate	Low	High	Moderate	Low
July	14	4	2	2	3	9
August	6	1	8	4	4	9
September	9	6	5	4	5	9
Total	29	11	15	10	12	27
Total raining day	55			49		
Total percentage %	52.7	20	27.3	20.4	24.5	55.1

Daily rainfall intensity in percentage						
Year	2002			2003		
Intensity ratings	High	Moderate	Low	High	Moderate	Low
July	5	7	6	9	4	5
August	3	7	4	6	8	11
September	2	2	13	11	7	4
Total	10	16	23	26	19	20
Total raining day	49			65		
Total percentage %	20.4	32.7	46.9	40	29.2	30.8

Daily rainfall intensity in percentage						
Year	2004			2005		
Intensity ratings	High	Moderate	Low	High	Moderate	Low
July	9	6	7	3	5	12
August	6	6	9	4	5	7
September	10	8	5	7	5	9
Total	24	20	23	14	3	28
Total raining day	67			55		
Total percentage %	35.8	29.9	34.3	25.5	23.6	50.9

Interpretation of rainfall data

Rainfall in Port Harcourt occurs almost throughout the year with a short dry season between January, February, and December. The peak of raining season in Port Harcourt is July, august and September. The volume of rainfall in these months is very high except for August that may experience break in some years. The period of maximum flooding is usually July- September.

In order to determine the relationship between rainfall and flooding, rainfall volume, duration and intensity for a ten years the period was analyzed. The respective rainfall intensities were calculated and classified for each raining day in July, August and September. The following rainfall intensity threshold values were used in classifying the rainfall events into high, moderate, and low according to Isesco Water Resources.

Table 4.1: classification of rainfall events (according to Isesco Water Resources)

Rainfall intensity (mm/min)	Class
< or = 0.004	Light
>= 0.004 – or < 0.13	Moderate
>0.13	High

Discussion, conclusion and recommendation

The analyzed result carried out on the soil samples shows that port Harcourt soil is within the group of fairly uniform sands (Allen Hazen, 1911).

The hydrometer sieve analysis was carried out on the soils samples collected from Nkpolu community secondary school along Rumuokoro Road, Mgbuoba –NTA road, Rumuodhara area and Rumuopkwu – Airport road of the study are (most flooded area in 2006 flood) shows a higher percentage of sand and silt with minute amount of clay and gravel.

At Mgbuoba NTA – road, the control samples (BH2) shows clay, silt, sand and gravel with average percentage sol composition of 1%, 40%, 58.2% & 0.67% while the soil sample collected from the flooded areas (BHI) shows an average percentage composition of 2%, 41.7%, 58.2% & 1% for the clay, silt sand and gravel respectively as calculated from the sieve curves. Sand and silt has the highest percentage composition in the two boreholes, the soil description is silty sand.

At Nkpolu community secondary school control samples (BH4) shows average percentage soil composition 3%, 41.7%, 54.8%, & 0.5% for clay, silt sand and gravel while the soil samples in the flooded area (BH3) shows 2.2%, 51.2% 46.7%, & 0% for clay, silt, sand & gravel respectively. Silt has the highest percentage composition followed by sand in (NH3). The soil description is sandy silt. In BH4, sand has the highest percentage composition following by silt. The soil description is silty sand. Control samples collected in Rumudhara (BH5) area has an average percentage composition of 0%, 16.7%, 81.5% & 1.8% for clay, silt sand and gravel while the soil samples collected in the flooded area (BH6) shows 0.5%, 34.5%, 59.3%, 4% for clay, silt, sand & gravel respectively. Sand has the highest percentage composition followed by silt in the two soil samples. The soil description is silty sand.

At Rumuopokwu – Airport road the control samples (BH8) shows clay, silt, sand and gravel with average percentage soil composition of 1.7%, 43.5%, 53.5% & 1% while the soil samples collected from the flooded areas (BH7) shows an average percentage composition of 0%, 26.3%, 72.1% & 1.63% for the clay, silt, sand and gravel respectively as calculated from the sieve curves. Sand and silt has the highest percentage composition in the two soils, the soil description is silty sand.

Out of the 25 soil samples collected 22 are silty sand with an average percentage of 63.4% for sand 31.4% for silt while the remaining 3 are sandy silt with an average percentage of 41.6% for sand and 55.7% for silt. The overall average for sand is 60.8%, silt 34.3%, clay 1.2% and gravel 0.8% as calculated from the sieve curves. (See table 3.1)

It was observed from the sieve curves that the dominant sand fraction is fine and medium in size. The permeability data generated using Hazen Allen (1911) methods show that the permeability rating for the soil samples indicates low to very low permeability according to Terzaghik and Peck, (1967).

Most of the sand grains are fine – medium in size. The soils are therefore most likely to have low infiltration due to the very low permeability state of the sol. Soils with such attributes as above contribute to flooding.

Another observation from the study is that samples from the control boreholes 2, 4l 6, 8 from non flooded areas have almost the same compositions with the ones collected from the boreholes in the flooded areas, the control areas are never flooded due to the fact that they are upland areas (>35m) while the flooded areas are low lands (<25m). This shows that topography is a major contributing factor to flooding in the study area.

The details of rainfall intensity in Port Harcourt for the period 1998-2007 were earlier presented in table 3.4.
The following presents the interpretation of the data in table 3.2 in terms of the risk (probability) of flood occurrence in the various years within the period (1998-2007).

- In 1999, there was no flood due to high percentage of low intensities rainfall (54.6%). There was low probability for flood risk.
- In 2000, the percentages of rainfall with high and low intensities are 52.7% and 27.3% respectively. There was high probability for rainfall in this year. The 2000 flood risk was higher than 1998 flood.
- The year 2001 was another year without flood because of the high percentage of low intensity rainfall (55.1%). Low rainfall probability.
- The year 2002 was not severely flooded due to high percentage of low rainfall intensity (46.7%) while the percentage of high and moderate intensity rainfall (20.4% & 32.7%). Flood risk probability was moderately low.
- The year 2003 has high probability for flood; the percentages of high and moderate intensity rainfall are 40% and 29.2% respectively. Flood risk in 2000 is higher than flood risk in 2002 & 2003.
- In 2004 there was high probability for severe flooding. The percentages of high and moderate rainfall are 35.8% and 29.9% respectively and low intensity rainfall is 34.5%.
- There was low probability for flooding in 2005. Low percentage of high intensity rainfall (23.6%) and high percentage of low intensity rainfall (50.9%)
- The year 2006 recorded the highest flood risk probability in Port Harcourt. The percentages of high and moderate intensities rainfall are 53.8% and 25% respectively.
- There was high probability for flooding in 2007 but not as high as 2006 flood risk. The percentages of high and moderate rainfall intensities are 44.6% & 19.6% respectively.

Analysis of rainfall intensities data for July-Sept reveals that 1998, 2000, 2002, 2003, 2004, 2006 & 2007 had high risk of flood within the period 1998-2007.

Records actually show that severe flooding disasters were actually experienced during these years.

The rainfall intensity data was used to plot a bar chart (fig 3.2) showing variation in rainfall intensity recorded at the peak of rainy season (July, Aug, and Sept) from 1998-2007 in order to compare yearly variation in flood and its magnitude.

Rainfall intensity is one of the major determinants of flood but its ability to cause flood depends on rainfall duration. High intensity means high volume of rainfall and not necessarily the reverse. Increase in rainfall intensities implies increase in flood risk. The progressive increase in the severity of flooding experienced over the past years may be strongly related to increase in urban development that involved the development of swamps and river channels due to increase in population and accommodation demands.

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