FLOOD FREQUENCY ANALYSIS USING GUMBEL DISTRIBUTION EQUATION IN PART OF PORT HARCOURT METROPOLIS

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Abstract – The adequacy of the Gumbel distribution equation for hydrological extremes, with regards to rainfall extreme, is very paramount in hydrologic studies and infrastructural development of any region. This study investigates how the Gumbel distribution equation model and rainfall data set can be used to analyse flood frequency and flood extreme ratio of any given spatial domain and underscore its significance in the application of the model in geo-analysis of varying environmental phenomena. The classical approach of periodic observation of flood heights was deployed over a consistent number of rainfall days in addition to the determination of rainfall intensity and flow rate using relevant hydrological models over a period of time from available rainfall information. The geospatial height data of the western part of the Port Harcourt city metropolis being the study area was also provided. The result showed that a flood peak of 82cm was determined to have a sample mode of 0.532 in relation to sample size of 30 with an associated standard deviation of 1.1124. The result showed that from the frequency curve, the occurrence of smaller floods with a flood peak height of 90cm will be symmetrical and skewed. We assert that the Gumbel distribution equation model serves as a veritable tool for quick and efficient flood analysis and prediction for the study area.

Keywords: Flood, Spatial Domain, Frequency, Gumbel Distribution, Rainfall

1. Introduction

A flood is an overflow of water that submerges land which is usually dry (Wikipedia 2019). The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water. In the sense of “flowing water”, the word may also be applied to the inflow of the tide.” (Robert, 1979). Floods are natural hazards causing loss of life, injury, damage to agricultural lands, and major property losses (Fill and Stedinger, 1995). Morristown (2010) defined flood as an overflow of water onto normally dry land, the inundation of a normally dry area. In the same vein, Caldwell (2012) affirmed that flood is any high flow, overflow, or inundation by water which causes or threatens damage.

Flooding can rise from overflowing rivers (river flooding), heavy rainfall over a short duration (flash flood) or an unusual inflow of sea water onto land (ocean flooding). Flood is an overflow of water that comes from a river or other bodies of water and causes or threatens damage. Flood frequency analysis (FFA) is the estimation of how often specified flood events will occur. Before the estimation can be done, analysing of the stream or river flow data is important in order to obtain the probability distribution of flood (Ahmed, Shabri, and Zakara, 2011). Because, one of the greatest challenges facing the hydrologist is to gain a better understanding of flood regimes. To do this, flood frequency analysis is most commonly used by civil engineers and hydrologists and consists of estimating flood peak quantities for non-exceedance probabilities. However, the geomatics engineer (i.e. the Surveyors) provides geospatial information of flood vulnerable areas and the variables that are required in determining flood frequency analysis.

The validity of the results in the application of FFA is theoretically subject to the hypothesis that the series are independent and identically distributed (Stedinger and Vogel 1993).

Flood disaster is now a re-occurring event in Port Harcourt in particular and Nigeria in general either due to climate change and or anthropogenic activities. Its destructive tendencies are sometimes enormous. In Nigeria, flooding displaces more people than any other natural disaster with an estimated 20,000 to 300,000 of the population at risk (UNFLOOD LIST, 2019). It is difficult to determine the extent of flood damage and to compare in a satisfactory manner one flood with another, mostly due to the relative tendency to overestimate flood damage, particularly at the time of the event (Edmund, 2013). Flooding in Nigeria occurs in three main forms: river flooding, urban flooding and coastal flooding (Igbokwe et al., 2008).

Some of these floods are as a result of heavy rainfall. In Nigeria, flood occurrence can cause panic nationwide. Flood events have caused astronomical price hikes in food crops, resulting to an estimated 2% rise in rate of inflation (Onwuka et al., 2015). By far, this is the worst environment-induced economic disaster Nigeria faces. Port Harcourt and its environment, like most urban areas of the third world cities, 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). Hence, this research tends to examine the flood frequency occurrence of some selected areas in the western section of Port Harcourt metropolis of Nkpolu-Rumuigbo and Mgbuoba-Ozuoba communities using Gumbel distribution equation model. The associated parameters therefore are the rainfall intensity of the location, flow pattern, direction and rate of flood risk as applicable.

The specific objectives thereof are to determine flood prone areas in the western part of Port Harcourt metropolis from rainfall intensity data among other parameters and to produce a flood frequency analysed data and frequency model curve map of the study area. This work brings to the fore the appropriateness of using Gumbel distribution equation in flood frequency analysis of any given micro location.

1.2 The Study Area

The study area, the western part of Port Harcourt metropolis which is located within the Part of Obio/Akpor Local Government Area of Rivers State in the Niger Delta region of Nigeria. (Chiadikobi, Omoboriowo, Chiaghanam, Opatola and Oyebanji, 2001).The areas lie between longitude 6^{0} 30' E to 7^{0} 30'E and latitude 4^{0} 40' N to 5^{0} 00'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 (Chiadikobi, *et, al*, 2001).

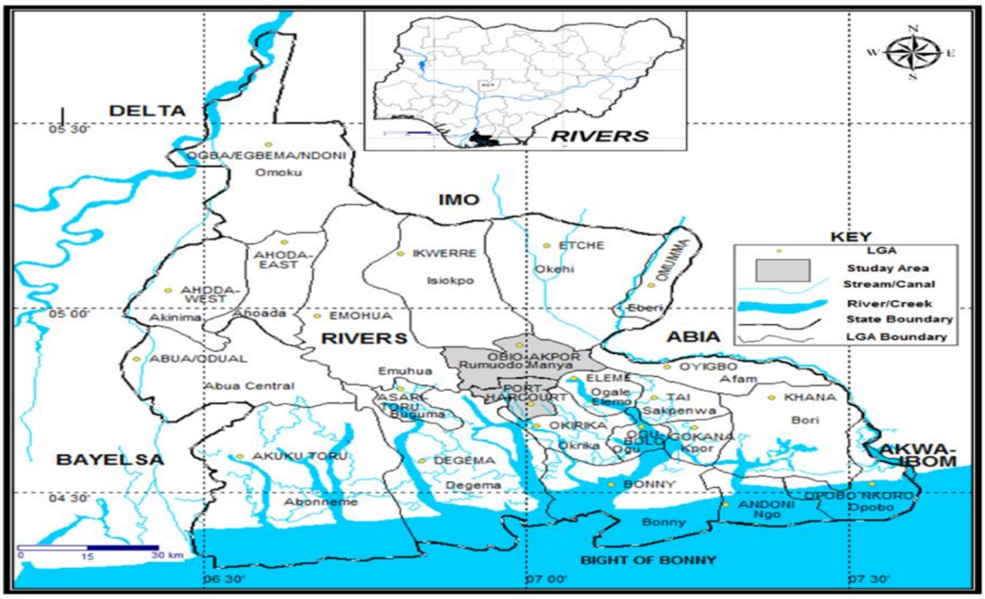

Figure 1.0: Map of Rivers State showing Port Harcourt metropolis. Source: GIS Lab, Rivers State Office of the Surveyor General, Rivers State Ministry of Lands and Survey, Port Harcourt

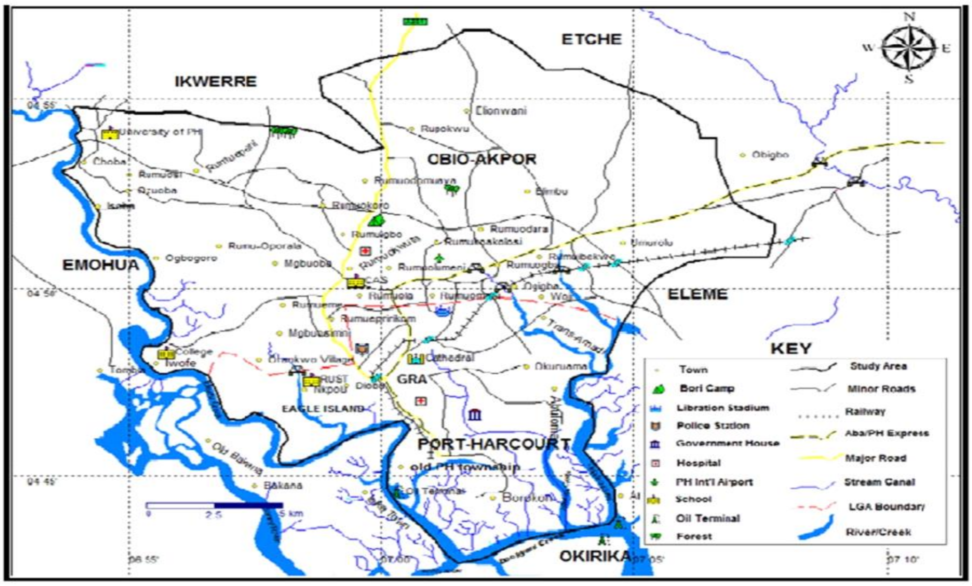

Figure 2.0: Map of Port Harcourt metropolis. Source: Adapted from SPOT Imagery (2018).

2.0 Extreme-Value Probability Distribution or Gumbel Method

The advocacy to use an extreme-value probability distribution for analyzing the magnitude-frequency relation of annual peak discharges, and his method still enjoys great favor among hydrologist-statisticians (Fill et al, 1995). Although a more recent publication by Gumbel (1958, p. 236, 272) describes three basic distributions of extreme values which may be used for flood studies, the distribution he originally advocated is still the most widely used (Cruff et al, 1965). The U.S. Weather Bureau is one of the chief proponents of the Gumbel method and uses it for both precipitation-frequency and flood-frequency studies at individual sites. To apply the Gumbel method, an area of probable hydrologic homogeneity is first selected (Cruff et al, 1965). The base-period mean and the standard deviation of annual peak discharges are then computed for each gaging station in the region with 10 or more years of peak-discharge record within the base period." The only difference is that in the Gumbel method natural values of peak discharge are used, and not their logarithms (Stedinger and Vogel, 1993). The base period means (M) and standard deviation (S) are then regionalized by correlation with basin and climatological parameters in the homogeneous region. From these regional relations, a flood-frequency curve can be constructed for any site in the region, whether gaged or ungagged, by use of the formula:

$$Q_T = M + K'_T S, \qquad (1.0)$$

Where,

Q_T: is the discharge corresponding to a recurrence interval of T years,

M: is the mean of the peak discharges,

S: is the standard deviation of the peak discharges,

and K'_T is a characteristic of the extreme-value probability distribution; for the purpose of this may be defined as a coefficient corresponding to a recurrence interval of T years.

The table 1.0 gives values of K' corresponding to selected values of recurrence interval, RI.

Table 1.0: values of recurrence interval, RI and characteristics of extreme value, K'

RI (Years)	K'
2.33	0
5	0.72
10	1.30
20	1.87
50	2.59
100	3.14

If plotted on extreme-value probability graph paper with arithmetic ordinate, the computed flood-frequency relation will be a straight line.

The Gumbel distribution is a particular case of the generalized extreme value distribution (also known as the Fisher-Tippett distribution). It is also known as the log-Weibull distribution and the double exponential distribution (a term that is alternatively sometimes used to refer to the Laplace distribution). It is related to the Gompertz distribution: when its density is first reflected about the origin and then restricted to the positive half line, a Gompertz function is obtained (Oosterbaan, 1994).

In the latent variable formulation of the multinomial logit model-common in discrete choice theory-the errors of the latent variables follow a Gumbel distribution. This is useful because the difference of two Gumbel-distributed random variables has a logistic distribution.

One interesting example of the application of statistics to a hydrologic problem (i.e., stochastic hydrology), is Gumbel's theory of extreme values. The probability of an event of magnitude *x* not being equaled or exceeded (the probability of non-occurrence, *P'*), based on the argument that the distribution of floods is unlimited (i.e. for large values of n, say n > 50),

$$\boldsymbol{P' = e^{-e^{-y}}} \tag{1.1}$$

And the probability of the event x being equaled or exceeded (i.e. n probability of occurrence, P) is

$$\boldsymbol{P = 1 - P' = 1 - e^{-e^{-y}}} \tag{1.2}$$

Where e = base of natural logarithms

y = a reduced variate given by

$$\boldsymbol{y = \frac{1}{0.78\sigma}\left(x - \bar{x} + 0.45\sigma\right), \quad for\ n > 50} \tag{1.3}$$

x = flood magnitude with the probability of occurrence, PO

$\boldsymbol{\bar{x}}$ -= arithmetic mean of all the floods in the series

$$\boldsymbol{\bar{x} = \frac{\sum x}{n}, \bar{x}^2 = \frac{\sum x^2}{n}}$$

$\boldsymbol{\sigma}$ = standard deviation of the flood series

$$= \sqrt{\frac{\sum(x-\bar{x})^2}{n\ -\ 1}}$$

$$= \sqrt{\frac{n}{n\ -\ 1}\left[\bar{x}^2-(\bar{x})^2\right]} \quad (1.4)$$

$$= \sqrt{\frac{\sum x^2-(\sum x)^2/n}{n-1}} \quad (1.4a)$$

$\boldsymbol{n}$ = number of items in the series, i.e., the number of years of record, and the recurrence interval of the event of magnitude $\boldsymbol{x}$.

$$T = \frac{1}{P} = \frac{1}{1-e^{-e^{-y}}} \quad (1.5)$$

If the event $\boldsymbol{x}$, of recurrence interval T-yr, is $\boldsymbol{x_T}$, $\boldsymbol{then\ from\ Eq.}$ … ….(1.3)

$$x_T = \bar{x}\ +\ \sigma\,(0.78\,y - 0.45), \quad for\ n > 50 \quad (1.6)$$

Or in terms of flood discharge items.

$$Q_T\ =\ \bar{Q}\ +\ \sigma\,(0.78\,log_e\,T - 0.45),\ \text{for n} > 50 \quad (1.6a)$$

$\bar{Q} = Q_T$, when 0.78*y* = 0.45, or *y* = 0.577 which corresponds to *T* = 2.33yr. The final plot of 'flood items (*x*) versus recurrence interval (*T*); can be made on probability or semi-logarithmic paper. In the Gumbel-Powell probability paper, the plotting paper is constructed by laying out on linear scale of *y* the corresponding values of *T* given by Eq., (1.5) (after Powell, 1943) it is sufficient to calculate the recurrence interval of two flood flows, say mean flood $\bar{x}(or\ \bar{Q}\ with\ T = 2.33\ yr) and\ x_{150}\ or\ Q_{150}$ obtained from Eq. (1.6a) putting T = 150, and to draw a straight line through these points. A third point serves as a check, this straight line can then be extrapolated to read the flood magnitude against any desired return period (T). The Gumbel distribution does not provide a satisfactory fit for partial duration floods or rainfall data.

Actual observations of flood data reveal that there are a greater number of floods below the mean than those above it and variations above the mean are greater than those below the mean. Therefore, a curve which fits the maximum 24-hour annual flood data on a log-log paper will not be a symmetrical curve, but a 'skew curve' which unsymmetrical, i.e. the points do not lie on a straight line but the line bends off. The general slope of this curve is given by the coefficient of variation *Cv*, and the departure from the straight line is given by the coefficient of skew C*s*, while plotting the skew probability curves, three parameters have to be calculated from observed flood data as;

i. coefficient of variation, $C_v = \frac{\sigma}{x}$ (1.17)

ii. coefficient of skew, $C_s = \frac{\sum(x-\bar{x})^3}{(n-1)\sigma^3}\quad (Foster)$ (1.18)

iii. coefficient of flood $C_f = \frac{\bar{x}}{A^{0.8}/2.14}$ (1.19)

Where A = area of the catchment in km²

2.1 The Application of Gumbel Equation in Solving Hydrologic Problems.

In probability theory and statistics, the Gumbel distribution (Gumbel 1954) is used to model the distribution of the maximum or the minimum values of a number of samples of various distributions. For example, in hydrology, the Gumbel probability distribution is used to analyze variables such as monthly and annual maximum values of daily rainfall and river discharge volumes (Ritzema, 1994) and also to describe droughts (Burkeetal.2010). It is also used to predict when extreme events such as earthquakes, floods and other natural disasters will occur. Extreme value theory indicates that the Gumbel distribution will be useful for representing the distribution of maxima if the underlying sample data is of the normal or exponential type.

The Gumbel distribution is a specific example of the generalized extreme value distribution (also referred to as the Fisher-Tippett distribution). It is also known as the log Weibull distribution and the double exponential distribution which is sometimes also called the Laplace distribution. It is often wrongly called the Gompertz distribution (Willemse and Kaas, 2007).

The study by Javier et al, 2014, indicates that families of the Gumbel (type I), Fréchet (type II) and Weibull (type III) distributions can be combined in the generalized extreme value (GEV) family of distributions. Maximum and minimum values of diameters in forest stands can be used in forest modelling, mainly to define parameters of the functions used in diameter class models as well as in some practical cases, such as modelling maximum diameters for sawing and processing purposes.

The purpose of this study was to examine and compare two extreme value distribution functions (the Gumbel and the Weibull functions) in modelling the distribution of the minimum and the maximum values of representative sets of tree diameter samples. Both of these functions were applied to the lower and upper values of the diameter distributions of the main forest species in northwest Spain. Parameters of the Gumbel function were estimated using the mode and the moments of the distributions, and parameters of the Weibull function were estimated using the moments method. In their result the Weibull distribution was the most suitable model for describing the maximum diameters.

The mode method of the Gumbel yielded the best results for minimum diameters of birch and Monterrey pine. The Gumbel distribution, fitted by either the mode- or moments-based methods, proved more suitable than the Weibull distribution for describing the minimum diameters in maritime pine and Scots pine stands. They concluded that in some cases, better results were obtained with the Gumbel than the Weibull distribution for describing the distribution of extreme diameter values in forest stands in northwest Spain. This is the first example of the application of the Gumbel distribution in forest modelling.

Canfield, Olsen, Hawkins and Chen, (1980) in the study of Use of Extreme Value Theory in Estimating Flood Peaks from Mixed Populations, investigated on how to develop and evaluate an extension of extreme value theory for application to estimating flood frequency relationships for river flows drawn from nonhomogeneous populations. Before doing so, applications to homogeneous data were considered, and a functional form that limits flows to a maximum value was found preferable to the widely used Gumbel form. A relationship was then derived for fitting data mixing two distributions. The goodness-of-fit statistics indicate excellent fit for these mixture distributions (except when one of the sources has very few observed values).

The mixture distribution, however, has five parameters and therefore should be capable of fitting a wide variety of data sets. The real justification for its application lies in its basis in extreme value theory (Canfield, et, al, 1980). It was demonstrated that extreme-value distributions provide excellent fit for many river systems. The method of estimation (maximum likelihood) had some inherent difficulties which may have produced some of the poor fits. More efficient estimation methods are now available and should be tested. They concluded that extreme -value theory may not apply to all river systems. A large carryover storage may, for example, violate the hypothesis of the theory. However, the results of this study indicate that the theory does apply to many systems.

Fevzi and Tamer 2015, in the study of flood frequency factor for Gumbel Distribution using regression and GEP model explained that Gumbel distribution is a statistical method often used for predicting extreme hydrological events such as floods (Haan, 1977). Fevzi et al applied Gumbel Distribution for flood frequency analysis because of peak flow data are homogeneous and independent lacking long-term trends; the river studied is less regulated with a flow data of more than ten (10) years. The equation for fitting the Gumbel distribution to observed series of flood flow at different return periods T is given with the following mathematical expression:

$$Q_T = Q + Ka \qquad (2.0)$$

Where Q_T denotes the magnitude of the T-year flood event, K is the frequency factor, Q and a are the mean and standard deviation of the maximum instantaneous flows, respectively.

2.2 Flood

Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, (Glossary of Meteorology (June 2000) or it may occur due to an accumulation of rainwater on saturated ground in an area flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals.

Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry.

Some floods develop slowly, while others can develop in just a few minutes and without visible signs of rain. Additionally, floods can be local, impacting a neighborhood or community, or very large, affecting entire river basins.

3.0 RESEARCH METHODOLOGY

3.1 Application of the Gumbel Distribution Equation Model

In determining the design flood for the study area, the analysis is made by using Gumbel's distribution equation model, where the recurrence interval is the average interval in years between the occurrence of a flood of specified magnitude and an equal or larger flood (Lindsley et al., 1992). It is given by the following relationship;

$$T_r = (N + 1)/m \qquad (2.0)$$

Where, Tr = recurrence interval

N = number of years

M = the equaled or exceeded events.

According to Gumbel, the probability P of the occurrence of a value equal to or greater than any X can be expressed as;

$$P = 1 - e^{-e^{-b}} \qquad (2.2)$$

Where, e is the base of natural logarithm and

b is given by;

$$b = 1/0.7797\delta\,(X - x + 0.450) \qquad (2.3)$$

$$\delta = [\sum(X - x)2/N - 1]\,{}^{1}/_{2} \qquad (2.4)$$

3.1.1 Determination of Watershed Parameters

In achieving the peak values of the watershed/catchment parameters such as peak flow, lag time, time of concentration, the soil conservation service method is used, this method described by US SCS,1973, was developed for uniform rainfall using the assumptions of a triangular hydrograph, over many years of storm flow records for agricultural watersheds (Schwab et al., 1986). It can also be used to develop a dimensionless hydrograph for many drainage areas of varying sizes and different geographical locations, (Ojha and Michael, 2001). The peak discharge is given by;

$$Qd = 0.208 \ X \ A \ X \ Qd/Tp \qquad (2.5)$$

Where, Qp = peak discharge (m3 /s)

A = Catchment Area (km²)

Qd = quantity of runoff in mm and

Tp = peak time

Q = 2.78 C Ic A

Where C = characteristic discharge coefficient of watershed, 0.50

Ic = critical rainfall intensity for each month.

A = Area of Watershed, 100km2

Peak time Tp and lag time Tl are expressed thus (Schwab et al, 1983);

$$Tp = Tr/2 + T1 \qquad (2.6)$$

$$T1 = 0.6Tc \qquad (2.7)$$

$$T_c = 0.0195[L^{0.77}/S^{0.385}] \qquad (2.8)$$

Where, Tr = duration of excess rainfall

Tc = time of concentration, this is the longest travel time

Tl = lag time, is an approximation of the mean travel time

L = length of channel section

S = slope of the channel

3.1.2 Determination of Runoff and Rainfall Intensity

Runoff is defined as the portion of precipitation which is not lost in interception, surface detention, evaporation and infiltration. It is regarded as the output from a catchment area or watershed (Arora, 2004). The runoff can be calculated by the use runoff coefficient method which is;

R=KP (2.9)

Where, R = runoff in cm,

P = precipitation in cm and

K = runoff coefficient for catchment, 0.45

Rainfall intensity is defined as the ratio of total amount of rainfall (rainfall depth) falling during a period of time to the duration of the period, it is usually expressed in depth units per unit time (National Resources Management and Environmental Department, FAO, 1984).

Rainfall intensity is calculated thus

$$I_c = P/tr \ (tr + tc) \qquad (3.0)$$

Where, *Ic* = critical rainfall intensity,

Tr =storm period/rainfall days

Tc = time of concentration of storm, and

P = precipitation depth

3.2 Flood Height determination

Height around each study site was measured from ground to the highest water level marks on trees, around existing walls and fences of buildings on the month of July 2009. The geographic coordinates in UTM Zone 32 North, WGS 84 of the measured points were also recorded using Real Time Kinematic GPS receiver. A total of 30 flood height points was measured from each location of the selected study sites and two control sites (table 2.0). Measurements were carried out continuously for three (3) days to determine the receding time of the flood.

Table 2.0: Field Sampling Locations with coordinates and elevations

Sample Code	Easting (m)	Northing (m)	Surface Elevation (m)
NKPOLU-RUMUIGBO COMMUNITY			
RC1	274994	537171	13.00
RC2	275390	537142	14.00
RC3	275331	537361	13.00
RC4	275003	537899	15.00
RC5	275188	537728	14.00
RC6	275321	537648	16.00
RC7	275543	537803	13.00
RC8	275502	537548	18.00
RC9	275702	537650	17.00
RC10	275603	537386	14.00
RC11	275748	537180	19.00
RC12	276074	537453	18.00
RC13	276161	537241	18.00
RC14	276018	536868	15.00
RC15	276411	536816	17.00
MGBUOBA-MGBUOBA-OZUOBA COMMUNITY			
OC16	276190	535564	24.00
OC17	275637	535471	22.00
OC18	275991	535123	26.00

OC19	275639	534832	22.00
OC20	276223	534652	26.00
OC21	275790	534602	25.00
OC22	276262	535159	22.00
OC23	275301	535095	26.00
OC24	275832	534364	25.00
OC25	276208	534916	24.00
OC26	275329	534751	26.00
OC27	275771	535277	24.00
OC28	275854	535794	23.00
OC29	276132	534517	24.00
OC30	276119	534380	26.00
CS31	277973	534065	23.00
CS32	272630	536022	25.00

Source: Field data, Hycient, 2019.

4.0 DATA ANALYSIS AND DISCUSSION OF RESULTS

Flood Height Measurement

The terrain elevation in Rumuigbo area ranged from 13m to 19m and from 22 to 26m in Mgbuoba-Ozuoba area. At the control site, surface elevations are 45m and 53m respectively (Table 3.0). These results show that Nkpolu-Rumuigbo and mgbuoba-Mgbuoba-Ozuoba communities are situated at lower elevation than the surrounding environment. The highest flood mark recorded in the area ranged from 86cm to 104cm and 84cm to 98cm in Nkpolu-Rumuigbo and Mgbuoba-Mgbuoba-Ozuoba Communities. Flood heights are measured and monitored daily for three days of continuous rainfall in the area. These results are used to calculate flood encroachment rate as shown in table 3.0. The result shows a flood encroachment rate of which ranges from 9.47 cm to 19.67 cm in Nkpolu-Rumuigbo and 6.47 cm to 9.00 cm in Mgbuoba-Ozuoba area. On average, the flood encroachment rate is 14.57 cm and 7.73 cm in Nkpolu-Rumuigbo and Mgbuoba-Ozuoba areas respectively. These results show that the impact arising from rising flood level in Mgbuoba-Ozuoba is double when compared with Nkpolu-Rumuigbo area. Also, the daily flood recede time was calculated after monitoring the decrease in flood heights in the area for three days. The daily flood recede rate ranged from 0.87 cm to 3.93 cm and 5.00 cm to 8.00 cm in Nkpolu-Rumuigbo and Mgbuoba-Ozuoba areas. The average recede rates calculated for Rumuigbo and Mgbuoba-Ozuoba areas are 2.4 cm/day and 6.5 cm/day respectively. The average difference between the highest flood mark on wall and highest current flood levels is 38.13 cm and 23.20 cm in Nkpolu-Rumuigbo and Mgbuoba-Ozuoba areas. The results suggest that the effects recorded by flooding in the last quarter of 2018 are not the highest felt in these flood prone areas. The study areas; Nkpolu-Rumuigbo and Mgbuoba-Ozuoba communities are situated on a lower slope (< 26.0 m) compared to the surrounding communities (> 45.0 m), thus, rainfall will always drain into these communities from surrounding communities and causing flooding because they act as a sink due to their low-lying topographies (Hycient,2019). Highest flood marks on walls, fences, gates and buildings in Nkpolu-Rumuigbo and Mgbuoba-Ozuoba communities are relatively much higher than the current flood levels recorded, suggesting that they were periods in the past when flood incidents were much more intense in the area. In an earlier study conducted by Akpokodje (2007), flood marking on walls in Mgbuoba-Ozuoba area ranged from 70 to 150 cm as opposed to a range of 84-98 cm recorded in this study. This results as compared with earlier studies conducted in the area suggests that the flood incidents that caused the highest flood marks occurred in 2007. The average flood encroachment rate recorded in this study showed that flood water levels rises by about 14.57 cm/day in Nkpolu-Rumuigbo and 7.73 cm/day in Mgbuoba-Ozuoba area. This indicates that Nkpolu-Rumuigbo stands a greater risk of being flooded compared to Mgbuoba-Ozuoba area because it will take roughly twice the amount of rainfall that floods Nkpolu-Rumuigbo to cause flooding to occur in Mgbuoba-Ozuoba at significant levels. Based on these recorded encroachment rate, it becomes easy to quantify the flood heights after any given time, provided that the rains are continuous and heavy during this period (Hycient, 2019).

Table 3.0 Result of Flood Heights Measurement in Nkpolu-Rumuigbo Area.

S/N	Terrain Elevation (m)	Flood Heights (During Rainfall) cm		Peak	Flood Height	(After Rainfall Stops) in cm	
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
RC1	13.00	33.00	42.00	68.00	60.00	57.00	57.00
RC2	14.00	35.00	46.00	65.00	58.00	54.00	52.00
RC3	13.00	32.00	41.00	62.00	56.00	50.00	50.00
RC4	15.00	31.00	39.00	50.00	45.00	42.00	40.00
RC5	14.00	36.00	48.00	68.00	60.00	57.00	56.00
RC6	16.00	27.00	33.00	52.00	46.00	43.00	43.00
RC7	13.00	30.00	41.00	65.00	60.00	55.00	53.00
RC8	18.00	29.00	38.00	55.00	49.00	45.00	44.00
RC9	17.00	25.00	37.00	58.00	51.00	47.00	47.00
RC10	14.00	25.00	33.00	58.00	50.00	45.00	44.00
RC11	19.00	28.00	39.00	60.00	57.00	52.00	52.00
RC12	18.00	19.00	29.00	41.00	36.00	31.00	30.00

RC13	18.00	28.00	35.00	53.00	47.00	44.00	44.00
RC14	15.00	14.00	24.00	44.00	37.00	34.00	31.00
RC15	17.00	19.00	28.00	49.00	41.00	38.00	38.00

Source: Field data (Hycient, 2019)

Table 3.1 Result of Flood Heights Measurement around Mgbuoba-Ozuoba Area.

S/N	Terrain Elevation (m)	Highest Marking on wall (cm)	Flood Heights (During Rainfall) cm		Peak	Flood Height	(After Rainfall Stops) in cm	
			Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
OC 16	24.00	92.00	45.00	52.00	58.00	49.00	40.00	35.00
OC 17	22.00	98.00	77.00	81.00	88.00	80.00	71.00	66.00
OC 18	26.00	90.00	62.00	70.00	76.00	68.00	60.00	54.00
OC 19	22.00	98.00	68.00	74.00	81.00	73.00	64.00	60.00
OC 20	26.00	92.00	58.00	65.00	73.00	64.00	53.00	50.00
OC 21	25.00	98.00	58.00	64.00	72.00	60.00	52.00	47.00
OC 22	22.00	95.00	44.00	50.00	68.00	59.00	50.00	44.00
OC 23	26.00	91.00	56.00	61.00	69.00	59.00	49.00	43.0

								0
OC 24	25.00	91.00	50.00	58.00	65.00	54.00	44.00	40.00
OC 25	24.00	98.00	51.00	59.00	66.00	53.00	46.00	40.00
OC 26	26.00	87.00	49.00	55.00	62.00	54.00	45.00	39.00
OC 27	24.00	90.00	44.00	50.00	59.00	48.00	40.00	36.00
OC 28	23.00	95.00	52.00	60.00	72.00	60.00	51.00	46.00
OC 29	24.00	96.00	56.00	62.00	70.00	59.00	50.00	44.00
OC 30	26.00	84.00	45.00	51.00	68.00	58.00	48.00	44.00

Source: Field data (Hycient, 2019)

Table 3.2 Reduced mean ($\bar{y}n$) and reduced standard deviation (σn) as function of sample size n is as shown in table 3.3:

Size of Sample	$\bar{y}n$	σn
10	0.4952	0.2457
15	0.5128	1.0206
20	0.5236	0.0628
25	0.5309	1.6915
30	0.5362	1.1124
35	0.5403	1.1283
40	0.5436	1.1413
45	0.5436	1.1518
50	0.5465	1.1607
55	0.5504	1.1681

Table 3.3: Sample mean computation of flood measurement data for Rumuigbo and Mgbuoba-Ozuoba

S/N	Terrain Elevation (m) from RTK	Highest Markings (cm)	Flood Heights (During Peak Rainfall, cm)	Mean Flood Height (cm)		
			Day 1	Day 2	Day 3	(D1+D2+D3)/3
MEAN	19.966667	93.833333	40.866667	48.833333	63.166667	50.9556

From the table, the sample size n, is 30 and the annual flood peak ($\bar{Q}$) in the study area which has the recurrence interval occurring is 82cm, the reduced mean ($\bar{y}n$) to mode of the sample is 0.5362 with a reduced standard deviation of 1.1124.

From the parameters stated above the frequency factor K for the study area and the recurrence interval T can be determined and used to find the annual flood peak QT which can be used for predictions of floods of a particular frequency exceeding the observed floods by a safe margin and can be adopted in the design of structures in the study area.

Gumbel Flood Prediction Table 3.5 showing the annual flood peak QT and the frequency P for T years.

T(years)	XT=Log (Log/T-1)	Y=-0.834-2.3XT	K=(Y-YN)/On	QT=Q+Ka	P=(1/T) X100
1000	-3.362	6.8986	0.20692	117.78	0.1
200	-2.6622	5.289	0.15594	108.97	0.5
100	-2.36	4.5941	0.13393	105.16	1
50	-2.0568	3.8967	0.11184	101.34	2
10	-1.3395	2.2469	0.059596	92.307	10
2	-0.52139	0.3652	0	82	50

Using the above table, the flood peak QT, of the study area can be plotted with respect to the recurrence interval T, for the magnitude of flood can be obtained.

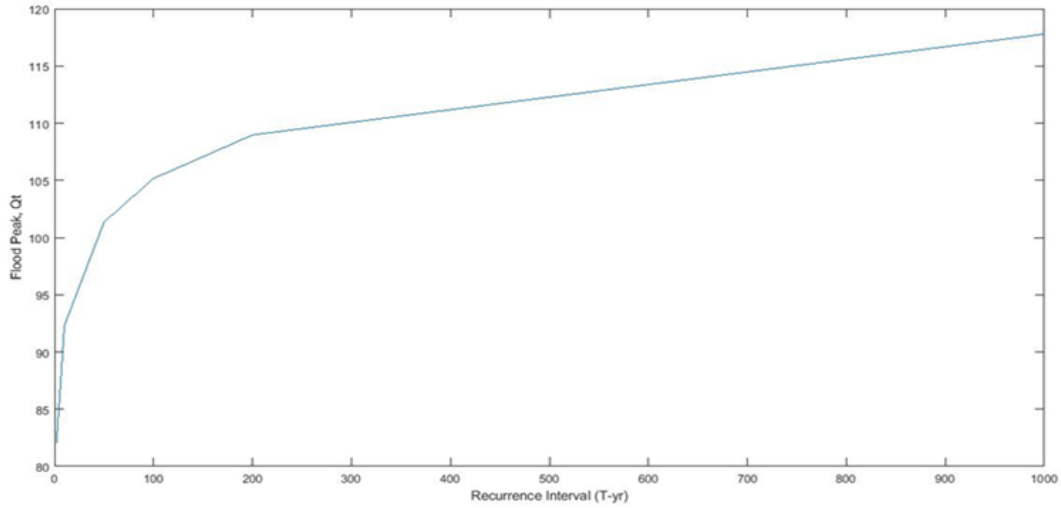

Figure: frequency curve of annual floods of the study area-Gumbel method.

The plotting shows that for smaller floods with peak value of 90cm the recurrence interval is symmetrical and skewed.

5.0 CONCLUSION

The western part of the Port Harcourt City metropolis is fast developing within the ambit of urbanization. This notwithstanding, the critical challenge in these locations with minimal urban planning framework is the issue of periodic flooding. Hence, having deployed the Gumbel Equation model in this work, it has shown that the maximum value (or last order statistic) in a sample of a random variable following an exponential distribution approaches can be determined to provide a guide for the future. This tool in hydrological analysis can be used to model variables as monthly and annual maximum values of daily rainfall, flood and river discharge volumes, (Oosterbaan, 1994) and also to describe droughts.

This model has also reveal that the estimator $r/(n+1)$ for the probability of an event — where r is the rank number of the observed value in the data series and n is the total number of observations — is an unbiased estimator of the cumulative probability around the mode of the distribution (Fevzi et al, 2015). Therefore, this estimator is often used as a plotting position.

The results of the tests and analyses shows that the Gumbel Distribution can be used in the available flooding data (Hycient, 2019) for the region and can therefore be used for the prediction of flooding within the study area.

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