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Development of a Model to All Eviate Flooding in oko-Erinarea, Kwarastate

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ABSTRACT:
Floodsanditsimpactonbothindividualsandcommunitieshavesocial,economicandenvironmental consequences. The aim of this study is development of intensity duration frequency in Oko-Erin, to mitigate frequent events of flooding in the area. Thirty (30) years rainfall data of Ilorin metropolis,obtained from Nigeria Meteorological Station Kwara State for runoff computation of the catchment area.Theannualmonthlyaveragerainfallmovingaverageswerecomputedandthereaftergraphsdrawntoshow the overall trend over the 30-year period. Furthermore, the Log-Pearson Type III distribution wasused to fit the frequency distribution data to predict the design flood for a river at some site by estimatingmean (**μ**)and Standard deviation (**σ**)from 10 to 120 minutes. Flood routing model of the area wasdeveloped and calibrated. The maximum rainfall data for Ilorin has a R^2 value of 0.9125. The mean andstandard ranged 64.61-320.21 and 20.84 - 103.59, respectively and computed Runoff varied from (281.61-1444.61) mm^3. Also, 10 minutes' duration is notably of higher intensity than the longer duration rainfall.The calibrated flood routing model on the study area was $x_T = 122.47 \ln(T_r) + 205.17$. The developed curvecanbeusefulforfloodforecastingin Ilorinmetropolis

KEYWORDS: Development,Model,Alleviate,FloodRoutine,RainfallIntensityandLogPearsonTypeIII.

I. INTRODUCTION

Flood is a major natural hazard with often immeasurable impact, affecting annually 170 millionpeople therefore, flood risk management needs to overcome national borders, geographic location andsocio-economiclimitations.Floodingisoneofthemainnaturalhazardsjeopardizinglivesandpropertiesof the people, and causing relevant economic losses (Ciampa et al., 2021). Flood risk management isusually divided into flood risk assessment and flood risk mitigation. This distinction takes into accountapart from the hazard also its impact, since the total elimination of risk is neither possible nor efficient(Kazakisetal.,2015).Indisputably,strategies againstfloods'impactataregionscalerequiretheidentification of prone areas to provide early warning, facilitate quick response and decrease the impact ofpossiblefloodevents (Biswas, 2018).

Itnotedthatinspiteofextensiveresearchonriverflooding,urbanfloodinghasnotbeenconsidered extensively important and is yet to be studied. In particular, among developing countries, urbanfloodplanningandmanagementisoftencarriedoutbyusingtraditionalapproaches,suchaschannelization(dischargingtherainwaterintothechannelnetwork), withoutconsiderationofnoveltechniques (source control approaches) such as Low-Impact Development (LID) and best managementpractices(BMPs).

It is, therefore, necessary to study the capabilities of novel storm water measures such as detentionbasinsforurbanfloodcontrolindevelopingcountries (Gesareetal.,2016).

Removal of excess storm water is of utmost importance and concern for every community. Floodcontrolmeasuressometimesconcentrateonretentionordetentionofthesameextremestormevent.This requirement is usually specific to a single basin with the goal of containing a certain storm event flowvolume retention or obtaining a specific peak flow reduction detention (Travis & Mays, 2008). Thereforedesigningfloodcontrolstructuresinisolationwillworsenthesituationratherthanprovidingsolutiontothe problem (Ahmadisharafet al., 2016). For instance, Ravazzaniet al., (2014) noted thata singledetention pond will tend to offset the time of concentration and reduce the peak flow of its contributingwatershed. However, the resulting outlet hydrograph can combine with the other watershed flows in theregiontoproduceflowsthataremoredamagingthanthepredevelopedcondition.

Frequencies of extreme flood events were increased in line with the global climate change (Sari etal., 2018). An alternative to detention is to require every site to retain its own storm-water runoff. Variousstudies have shown that retention basins are successful flood control measures, particularly for perviоussoilsandfrequentstorm.Unlikedetentionbasins,retentionbasinstypicallyuseinfiltrationastheirprimary means of storm-water disposal and thus are referred to as infiltration basins. Retention basins aredefined as flood control ponds wet or dry designed to store water to mitigate flooding, and infiltration isassumedtheonlymeansofoutletflowofthestoredwater.Thepresentedmodelisthisstudyisflexibleandcanincorporateevaporationorbleedoffstructuresifneedbewithoutunduedifficulty.

At present, no attention is paid on model for flood routing of Oko-Erin, this call for conceptedefforttodevelop IntensityDurationFrequencyCurve.

II. MATERIALSANDMETHODS

2.0 DescriptionofStudyArea

Oko-ErinCommunityislocatedintheIlorinWestLocalGovernmentAreaofKwaraState,Nigeria about 327 km West of Abuja, the country’s capital town. The Community is bordered by Taiwoand Saw-Mail/Osere Communities. It is one of the densely populated and well-known community in theIlorin Metropolis as it houses notable institutions such as Government Girls Day Secondary School, Oko-Erin, Atoto Press Plc to mention but a few and it is closer to the Ilorin International Airport. Map of Oko-Erin and its environs is presented in Figure 2.1. Over the years, the area is known with cases of floodingdue to other factors, which often not had led to flooding, which leads to loss of lives and properties in thecommunity.One major factor that is likely responsiblefor the incessant flooding in the area is thedumping of refuse in drainages system or buildings on waterways, which lead to erosion of bridges in thearea.

Figure2.1:MapshowingOko-Erinanditsenvirons.

2.1 TemporalVariationof RainfallIntensityinOkoErin

In this study, Annual Maxima Series was used for plotting of the IDF curves. The values of theannual maxima precipitation from a given area for a number of years constitute a hydrologic data seriescalledtheannualmaximaseries.Thedataarearrangedindecreasingorderofmagnitudeandtheprobability of each event being equaled to or exceeded (plotting position) was calculated by plotting-position formula. Weibull’s plotting-position formula was used for frequency studies involving hydrologicparameters.

The magnitudes of yearly maximum rainfall depths corresponding to storm durations 24hrs, 48hrs,etc. for all past years for which data is available. Various hourly magnitudes of rainfall for each year wereconsidered to identify the maximum rainfall in continuous time duration and rainfall depths were arrangedin decreasing order of magnitudes. These were repeated for other continuous durations of 48, 72, 96 and120hrs.Theformula forFrequencyDistributionFunctionisexpressedin Equation2.1:

$x_t=\bar{x}+k\sigma$ 2.1

Where,

x_t= valueofthevariatexofarandomhydrologicserieswitha returnperiodT,

$\bar{x}$meanofthevariate,

σ=standarddeviationof thevariate,

The collected rainfall data for Ilorin were fitted with a probability density function and ExtremeValue Gumbel TypeIdistribution which is commonly used for rainfall analysis for a given rainfallduration 't'. The Extreme Value Type I distribution frequency factor for annual maximum rainfall depth isexpressedinEquation2.2:

$$k= \left(\frac{\sqrt{6}}{3th4}\right)^{0t2::2+\log e \log e} \qquad \frac{T}{Tth}$$

Rainfall depths were calculated using K value for various frequencies of occurrence for variousdurations. The depths were converted to rainfall intensities by dividing the rainfall depths (mm) withdurations(hr).Thus,setsofvaluesofrainfallintensitiesweregeneratedforcorrespondingsetsofdurations anddrawnusingspreadsheet software.Theequations ofthesecurveswere determined.Thetrend line function found in any spreadsheet equation of the curve, with the R^2value were determined. Theobtainedequationswere obtainedintheformshownin equation2.3

i=at^{-b} 2.3

From this the parameters, (a,b) were determined. With the parameters determined, the intensity ofrainfallforanyduration foragivenreturnperiodwere determined.

2.3.1 Rainfall-RunoffComputation

The monthly and the annual average rainfall were computed for the years. The graph showingtrends of rainfall intensities were drawn. According to the World Meteorological Organization, in theabsence of a climatological standard, provisional for normal can be computed from at least 10-12 years ofthepriorobservationstakenbeforetheperiodunderreview.

In this case, average rainfall records used were from Nigerian meteorological station for Ilorinwhich had observations from 1989-2019, therefore the normal was computed for a 30-year period and wasused as the baseline. The average rainfall were computed for each month within the period to obtain theannual and monthly anomalies. Rainfall runoff was computed by multiplying the rainfall intensity, runoffcoefficientand CatchmentArea.

2.4 RainfallDistributionusingLog-PearsonTypeIII

The Log-Pearson Type III distribution is a statistical technique for fitting frequency distributiondata to predict the design flood for a river at gauged site. Once the statistical information is calculated forthe river site, a frequency distribution were constructed. The probabilities of floods of various sizes wereextracted from the curve. The extrapolation of the values for events with return periods were beyond theobserved flood events (Satheet al., 2012). The Log-Pearson Type III distribution is calculated using thegeneralEquation2.1.

Where k = frequency factor determined from Gamma and Log-Pearson Type III Distributions table.However, the Log Pearson Type III distribution of X, which has been widely adopted to reduce skewness,isequivalent toapplyingLogPearsonTypeIII tothetransformedvariablelogXasshowninEquation 2.4

$\log □ =\overline{\log □}+K\sigma_{\log □}$ 2.4

WhereXistheflooddischargevalueofsomespecifiedprobability,$\overline{\log □}$istheaverageofthelogX discharge values, K isfrequencyfactor.σ_{logx}isthestandarddeviationoflogx values.

The frequency factor K is a function of skewness coefficient and return period and can be readfrom published tables developed by integrating the appropriate probability density function. The floodmagnitudeforvariousreturn periodsisfoundbysolvingthegeneralequation.Themean,standarddeviationandskewnesscoefficientarepresentedinEquations 2.5– 2.7.

$$\overline{\log □}=\frac{\sum \log □}{n} \qquad 2.5$$

$$\sigma \log □ = \left[\frac{\sum(\log □ - \overline{\log □})^2}{(n-1)}\right]^{1/2} \qquad 2.6$$

$$g=\frac{\sum(\log\text{[illegible]})^{3}}{(\text{[illegible]}t2)^{3}\log x}\qquad 2.7$$

WherenisthenumberofentriesofX ,*log*鼠iistheaverageofthelogxdischargevalue.TheLog PearsonType IIIdistributionisgiven inEquation2.8

$$T=\frac{n+0t2}{m\,t0t4}$$

wherenisthenumberofyearsofrecord,mistherankobtainedbyarrangingtheannualfloodseriesindescendingorderofmagnitudewiththemaximumbeingassigned therank of1.

III. RESULTS AND DISCUSSION

3.0 RainfallVariationinEko-Erin

TherainfalltrendinIlorin betweentheyear 1989–2019ispresentedinFigure3.1 Theaveragerainfall intensity from January to December as shown in Figure 3.2. The month of September has themaximumrainfall.

Figure3.1:Distributionof theAmountofRainfallfrom1989–2019

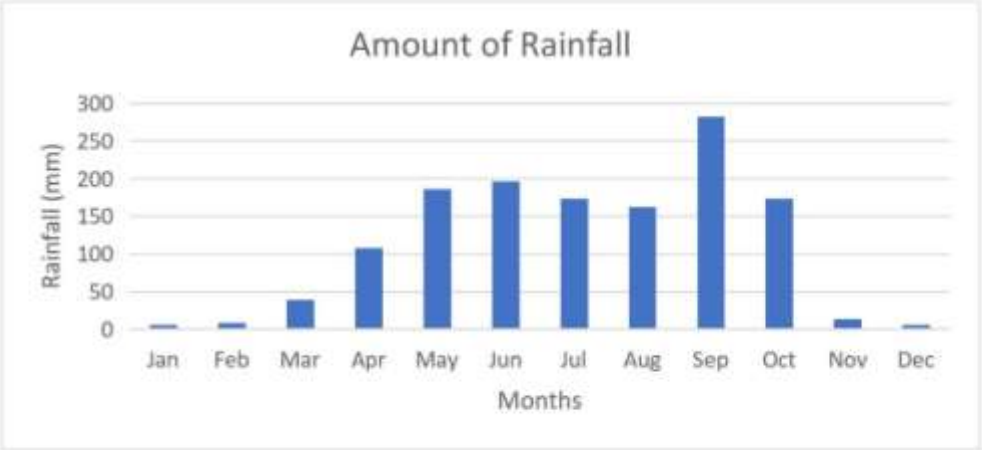

Figure3.2:DistributionoftheAmountofRainfallfromJanuary–December

3.1 DistributionofRainfallDatausingLog-PearsonTypeIII

The maximum rainfall data in Ilorin showed a high correlation on the Log-Pearson Type IIIdistribution. It was observed that maximum rainfall data for Ilorin has a R^{2} value of 0.9125 when fitted tothemodel.The probabilityplotforLog-Pearson Type III isshown inFigure3.3.

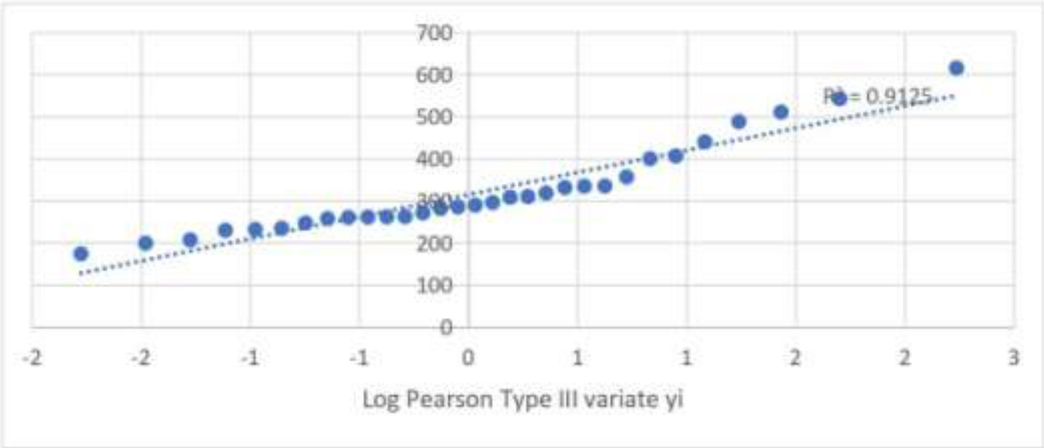

Figure3.3:ProbabilityPlotforIlorinMetropolis

After the result of the analysisof best fit were completed, Log-Pearson TypeIIIdistributionmodelwithhighestR^{2}valuewasusedtoestimatetheexpectedrainfallamountbyfirstestimatingfrequency parameters σ and μ for each of the durations. The resulting parameters are shown in Table 3.1.Subsequently, the expected maximum rainfall intensity for Ilorin in mm/hr was calculated using returnperiodsof2,5,10,25,50and100years.Theresultarepresentedin Tables3.2-3.4fordurations10,20, 30,60, 90and120minutes.

Table3.1:ComputedLogPearsonIII StatisticalParametersforIlorin

Parameters	**Duration**	**10min**	**20min**	**30min**	**60min**	**90min**	**120 min**
TotalData	**n**	31	31	31	31	31	31
Mean Value	**μ**	64.61	98.50	126.05	192.15	245.85	321.10
Standard Deviation	**σ**	20.84	31.78	40.66	61.99	79.31	103.59

Table3.2:RainfallDepthComputedfromLog-PearsonIIIModelforIlorin

IlorinRainfallAmount(mm)						
	ReturnPeriods					
Duration	**2 Years**	**5 Years**	**10Years**	**25Years**	**50Years**	**100Years**
10min	61	80	92	107	119	130
20min	93	121	140	163	181	198
30min	119	155	179	209	231	254
60min	182	237	273	319	353	387
90min	233	303	349	408	451	495
120min	304	396	456	533	590	646

3.4 FloodRoutineModel

The result in Table 3.1 and 3.2 implies that mean value and standard deviation values is increasingas the duration at different return period increased. This is similar to previous work of (Ciampa et al.,2021).

Figure 3.4 shows the computed rainfall intensity-frequency for Ilorin in the linear logarithm form.This was obtained by plotting rainfall intensity values from the Log-Pearson Type III Distribution againstthe return periods. Equations derived from the plot are shown in Table 3.5. The equations were used toestimaterainfallintensityforthedurationsatdifferent returnperiodsthatcouldaccuratelyreadofftheIDF curve. Ten (10) minutes' duration is notably of higher intensity than the longer duration rainfall. Thissuggests that early stage of rainfall is of higher intensity and the rainfall decreases in intensity as itsduration progresses. Figure 3.5 and Figure 3.6 shows graphical representation frequency of occurrence andintensityrainfallcurve plotted respectively.

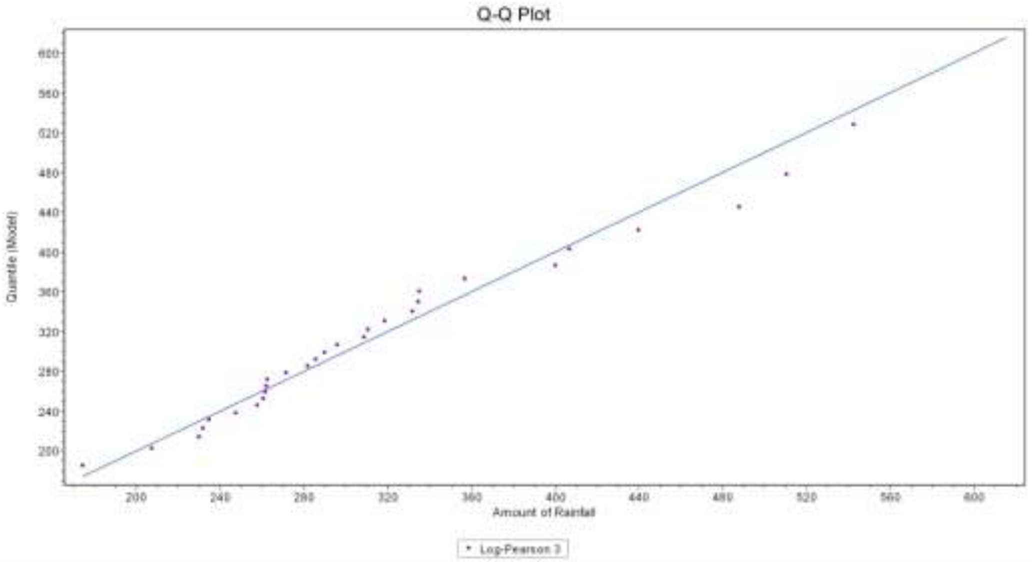

Figure3.4:Q-Q PlotDisplayingtheFittedLogPearsonTypeIIIoftheAmountofRainfall

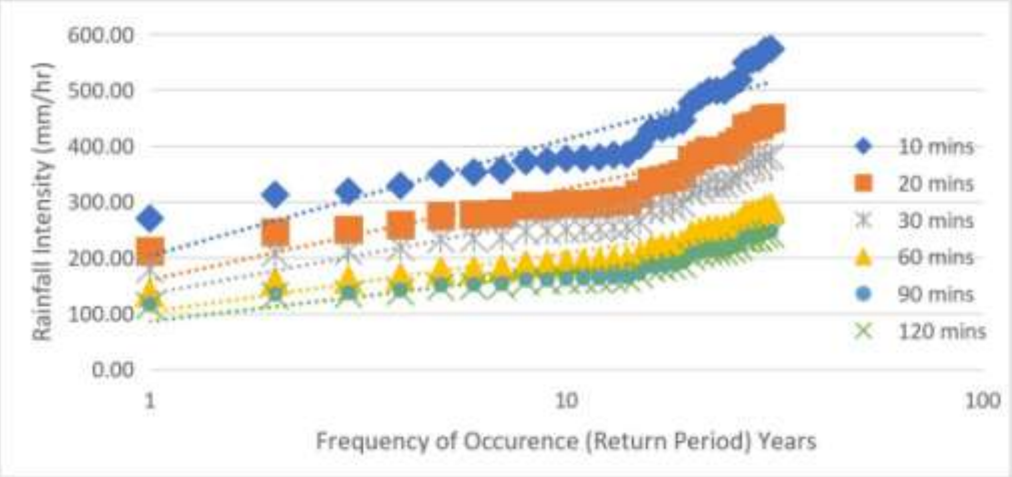

Figure3.5:RainfallIntensityFrequencyCurveforIlorin

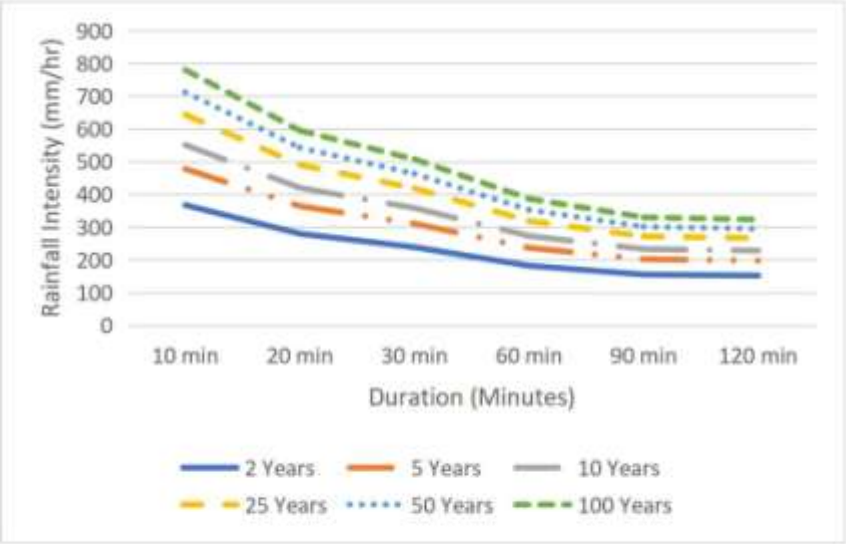

Figure3.6:IDFCurveforIlorin

Table3.3:ModelFloodRoutingwithintheCatchmentusingLogPersonTypeIIIModel

Duration(Minutes)	**Log-PearsonIIIModel**
10	$x_T = 24.642\ln(T_r) + 41.283$
20	$x_T = 37.568\ln(T_r) + 62.938$
30	$x_T = 48.075\ln(T_r) + 80.539$
60	$x_T = 73.288\ln(T_r) + 122.78$
90	$x_T = 93.766\ln(T_r) + 157.08$
120	$x_T = 122.47\ln(T_r) + 205.17$

Table3.4:RainfallIntensityComputedfromLog-PearsonIIIModelforIlorin

IlorinRainfallAmount(mm/hr)						
	ReturnPeriods					
Duration	**2Years**	**5Years**	**10Years**	**25Years**	**50Years**	**100Years**
10min	367	478	551	643	712	780
20min	280	364	420	490	543	595
30min	239	311	358	418	463	507
60min	182	237	273	319	353	387
90min	155	202	233	272	301	330
120min	152	198	228	266	295	323

Table3.5:PeakRunoffwithintheCatchmentusing30YearsRainfallIntensityData

IlorinRainfallRunoff(Qp)						
	ReturnPeriods					
Duration	**2 Years**	**5 Years**	**10Years**	**25Years**	**50Years**	**100Years**
10min	679.975	884.6832	1020.218	1191.466	1318.508	1444.612
20min	518.326	674.3693	777.6836	908.2215	1005.062	1101.187

30min	442.1904	575.3129	663.4517	774.8152	857.431	939.4367
60min	337.047	438.5158	505.6971	590.5807	653.5522	716.0588
90min	287.482	374.0292	431.331	503.732	557.4431	610.7577
120min	281.6142	366.3949	422.5271	493.4503	546.0652	598.2915

IV. CONCLUSION

Thefollowingconclusionsweredrawnfromthestudy:

(i) Theintensity-duration-frequencycurveswasplottedandgeneratedequationswereusedtoestimaterainfallintensityforthedurationsatdifferentreturnperiods.

(ii) The 10 minutes' duration is notably of higher intensity than the longer duration rainfall. Thissuggeststhatearlystageofrainfallisofhigherintensityandtherainfalldecreasesinintensityasits duration progresses.

(iii) The maximum rainfall data in Ilorin showed a high correlation on the Log-Pearson Type IIIdistribution.

RecommendationfromtheStudy

Thefollowingrecommendationweremadefromobtainedresultinthisstudy

(i) ThedevelopedIDFCurvecanbeusefulasbaselinereportforfloodstudiesinIlorinmetropolis.

(ii) The estimated discharge can be used for redesigning of failed hydraulic structures in Oko Erincatchment.

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