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Impact of Landuse/Landcover characteristics on Flood Frequency of Nambul River Basin, Manipur

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Abstract

A reliable estimation of extreme flood events is of great significance in minimising damage by facilitating proper planning and design of several structures. In spite of efforts to control floods and its danger, a new dimension of flood has arisen particularly more in urbanised area which may be attributed to changing LULC characteristics in the region. Physiographically the area is low lying plain surrounded on all sides by denudo-structural hills affected by frequent occurrence of floods. An accelerated rate of unchecked deforestation for different purposes and jhumming cultivation practices on the hill slopes are the primary source of recurrence of floods in the valley. The main thrust of the present study is to analyse a flood frequency of Nambul river by using Log Pearson Type III probability distribution method. It is a purely statistical method which attempt to fit extreme value probability distributions to measured peak flow records. The method is data intensive and can be applied only to guage watersheds. Peak flood magnitudes for 2-, 5-, 10-, 25-, 50-, 100- and 200-year recurrence intervals were estimated. In this paper 14 years (1990-2013) annual peak discharge series of the Nambul river has been worked out together with LULC maps (1990 and 2012) . This may further benefit the planners and decision makers in carrying out the water resource management and flood protection programmes.

Key words: *flood frequency, water discharge, recurrence interval, annual maxima series, partial duration series.*

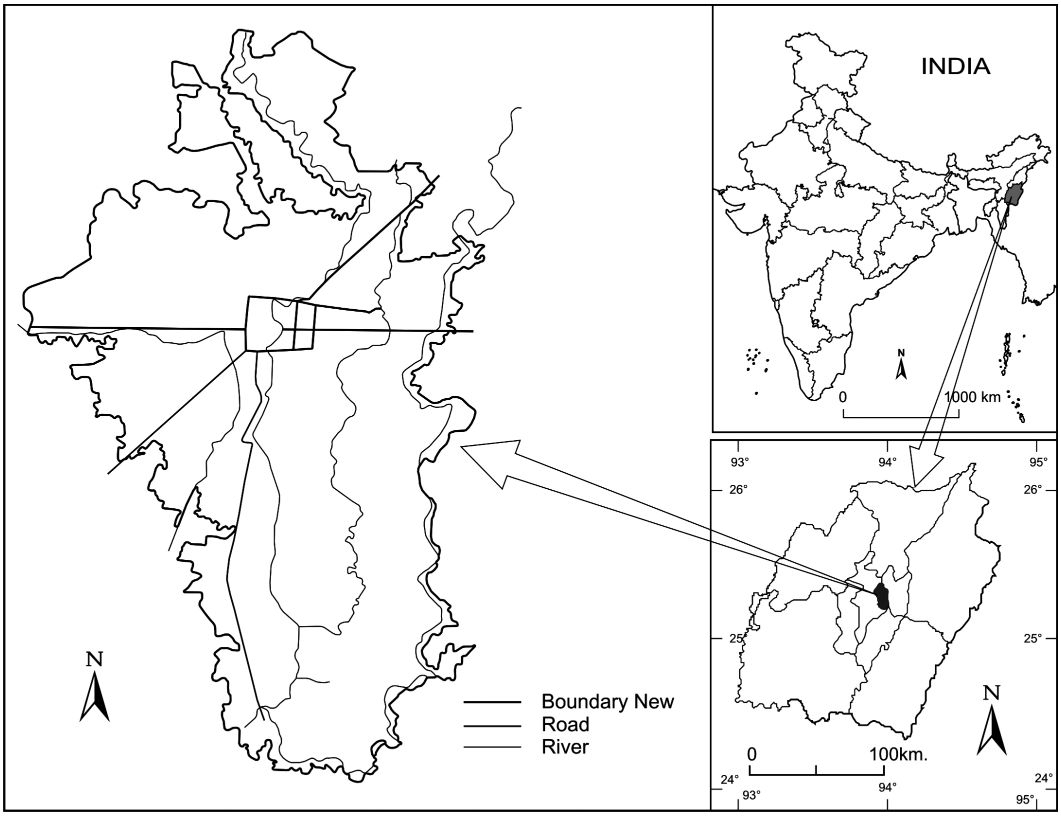
Introduction

Floods are one of the most common natural disasters worldwide, leading to economic losses and loss of human lives (D. D. Alexakis,et al.2014). Physically a flood is a high flow of water which overtops river embankments. Generally flood results from flood prone areas knowingly or not enhancing the extent of vulnerability. At a given location in a stream, flood peaks vary from year to year and their magnitude constitutes a hydrologic series which enable one to assign a frequency to a given flood peak value. One method of decreasing flood damages and economic losses is to use flood frequency analysis for determining efficient designs of hydraulic structures (Khan Mujiburrehman, 2013, T. A. Ewemoje et.al, 2011). Flood frequency analysis involves the fitting of probability model to the sample of annual flood peaks recorded over a period of observation for a catchment of a given region (Never Mujere, 2011). It is an analytical technique that involves using observed annual peak flow data to calculate statistical information (Rajdeep B. Gohil et.al, 2013). It is one of the alternative methods to estimate the magnitude of flood peak. The result obtained in the analysis reveals likelihood of various discharges as a function of recurrence interval. A reliable estimation of extreme flood events is of great significance minimising damage by facilitating proper planning and design of several structures (Gamal Abdo et.al, 2013). However, the accuracy of flood estimates based on flood frequency analysis deteriorates for values of probability much greater than the record length. Therefore, alternative procedures are recommended using estimates from precipitation data, comparison with similar catchments, etc. (Ponce,V.M.,1989). The probabilistic method of Log Pearson's Type III Distribution was adopted to determine the frequency of flood in the Nambul river basin. There is an evidence of flood in the area, especially its urban and peri-urban areas causing economic loses and hinder the normal routine. Research has been carried out to determine the reasons behind this increased number of floods. Among various factors, LULC change is one of the suspected causes due to which its effects on water have been studied. Flooding and associated flood impacts have long been linked to urbanisation and the proliferation of impervious surfaces (Anderson 1970). Although weather and climate are the main drivers of flooding, changes in land cover can also influence the occurrence and frequency of floods by changing the responsiveness of river flows to rainfall. In addition, the frequency of flood events increased as the total area of land cover change also increased in a catchment. (Solín, L., Feranec, J., Nováček, J., 2011). Inadequate land-use planning in areas adjacent to the drainage basin and uncontrolled river encroachment are vital factors adding to the consequences of water challenges and security in the country (Adefioye Sunday Adewumi, 2013).

Study Area

With its outlet in the Loktak sub-basin, the Nambul is one of the main rivers extending from 93.45'E to 94.0'E and 24.35'N to 25.0'N passing through the heart of Imphal valley. It rises from the Kangchup hills in the west and has a total catchment area of about 183.45 sq.kms. with a total length of 54.70 km and 12 km within the study area. Despite its short length encompassing the area, the river often overflows during the rainy season which extends from mid-April to October. Due to its flashy nature, widespread flood occur in its surrounding areas of Sagolband, Wangoi, Lamphel and Uripok.

Rainfall and Water Discharge: The changes of hydrological response in relation to rainfall may be attributed to changes in interception and use of water by vegetation, shifting of interflow to overland flow and changes in the storage capacity of the landscape. In the study area the amount of rainfall for a period of the last decade is slightly in decreasing trend, approximately from120 Cm to 90 Cm. Whereas, the discharge rate for the same period is in increasing tendency that the average rate comes up from 100 to above 200 cumecs although annual fluctuations are happened to occur. It reveals that the changes in hydrological response are mainly attributed



to the shifting of the rate of interflow to the rate of overland flow. In the upper catchment area of Nambul river Basin the change in land use system is apparent since last 10-20 years. Due to increased population growth there is pressure on land both in the hill as well as in the valley. (Fig.1)

However, from certain common schemes of LU/LC classification in different three years it is found that the built-up (Rural area) in the upper catchment area has increased from 6.16 Km^2 to 22.77^2 during the last decade, which creates the reduction in the forested and other vegetal cover areas. Contrary to the information of increasing number of agricultural land, the corresponding LULC data of 1990, 2005 and 2012 show a decreasing trend. Another human factor affecting the discharge rate in the study area is higher rate of urbanisation in the valley. The increased impermeable surface area and construction of dense drainage networks have contributed to the further reduction of lag time and increase in peak discharge. This phenomenon is very prominent as the Nambul river drains in the heart of the Imphal City. (Fig.2 See page No.38)

The LULC classification of 1990, 2005 and 2012			
Land Use / Land Cover Class (Details)	Area (sq.km) 1990	Area (sq.km) 2005	Area (sq.km) 2012
Agricultural land crop land-Kharif crop	105.728	53.954268	55.0591
Built up Area: Built up area (Rural)	6.16618	22.28426	22.7745
Built up Area: Urban	27.1238	27.174805	27.7748
Forest : Evergreen / Semi-evergreen (Dense_closed)	6.7862	8.15863	8.33959
Forest : Evergreen / Semi-evergreen (open)	34.8701	28.180174	28.8079
Forest - Blank		3.832808	3.91662
Forest – Scrub Forest	46.1181	43.736711	44.7003
Tree Clad Area - Open		38.257751	39.147
Wetland: Scrubland dense scrub		0.433144	0.421349
Wetland: Scrubland open scrub	0.33493	0.33493	0.342001
Wetland: Lake/Pond Perennial	0.059735	0.059735	0.0610
Wetland: Stream / River Perennal	0.385457	0.385457	0.393929

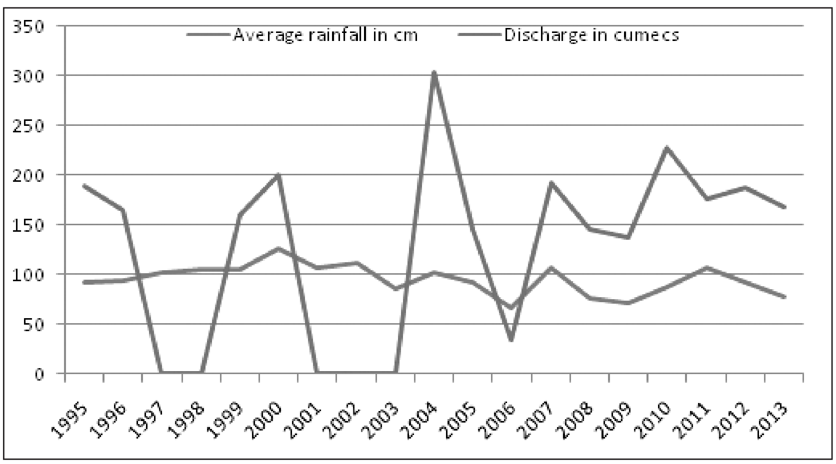


Fig.3: Rainfall and Discharge Graph of Nambul River At Hump Bridge Station

Flash floods respond to the causative storms in a short period of time, with water levels in the drainage network reaching peak levels within a few minutes or hours, allowing for a very limited time window for warnings to be prepared and issued (Koutroulis and Tsanis, 2010; Grillakis et al., 2010). This paper aims at estimating return period associated with flood peaks of varying magnitude from floods using statistical methods. Here, the Log Pearson Type III Distribution Method is used for the analysis. The Log Pearson Type III Distribution is recommended by the U.S.

Water Advisory Committee on Water data (1982) for flood frequency analysis. Also it is the standard technique used by Federal Agencies in the U.S

Methodology

Daily water level record of the Nambul river has been collected from 1990 to 2013 at Hump Bridge station in the Imphal city. All readings of water level were taken at a particular time interval for each day to avoid inconveniences while calculating. As the estimation of extreme flood events is very much necessary especially because of planning and design of water resource projects and flood plain management, practical application on frequency and peak discharge is important. From the daily water level data of Nambul river, flood depth marks, cross-section, area and velocity were calculated with prior necessary information from Flood Management Circle, IFCD, Manipur after which the required data on water discharge was obtained on daily basis. This data was used for frequency analysis using the Log Pearson Type 3 Distribution and the Gumbel's Extreme Value Distribution. There are two types of flood series: (1) the Partial Duration Series and (2) the Extreme Value Series. The partial duration series consists of floods whose magnitude is greater than a certain base value. The partial duration series is used for frequency analysis involving short return periods ranging from 2 to 10 years. In the extreme value series, every year of record contribute one value. It is used for return periods ranging from 10 to 100 years and more. Since the return period for the ongoing analysis is of 15 years, the extreme value series (annual maxima series) is adopted.

Log Pearson Type 3 Distribution

The log Pearson type 3 distribution is given by the formula:

LogQT=ave(logQ)+[K(Tr,Cs)*σlogQ]

Where QT=discharge for the estimated Tr year return period, k = frequency factor determined from the table,

σ=standard deviation and

Cs=skew coefficient. σ ,

Cs are calculated by the following equations:

σ= $\sqrt{variance}$

Variance= $\sum_i^n (logQ - ave(log\,Q)^2/n - 1$

Cs=n*$\sum_i^n logQ - ave(logQ)))^3 /($

$/(n-1)(n-2)(\sigma logQ)^3$

Table 2: Observed Data

SL.No.	Water year	Annual Maxima Series(Q) in cumecs
1	2004	304.471
2	2010	228.32
3	2000	201.338
4	2007	193.488
5	1995	189.635
6	2012	187.25
7	2011	176.249
8	2013	168.847
9	1996	165.175
10	1999	159.799
11	2005	145.898
12	2008	145.898
13	2009	137.494
14	2006	33.831

Table 3: Computation Table by Log Pearson's Type III Distribution.

Q	LogQ	LogQ – Ave log	(LogQ – (Ave log))^3	T = {(n+1)/m}	Ex.prob.= 1/t
304.471	2.483546	0.077435	0.021548	15	0.066667
228.32	2.358544	0.023491	0.003601	7.5	0.133333
201.338	2.303926	0.009732	0.00096	5	0.2
193.488	2.286654	0.006623	0.000539	3.75	0.266667
189.635	2.277918	0.005277	0.000383	3	0.333333
187.25	2.272422	0.004509	0.000303	2.5	0.4
176.249	2.246127	0.001669	6.82E-05	2.142857	0.466667
168.847	2.227493	0.000494	1.1E-05	1.875	0.533333
165.175	2.217944	0.000161	2.03E-06	1.666667	0.6
159.799	2.203574	2.89E-06	-4.9E-09	1.5	0.666667
145.898	2.164049	0.0017	-7E-05	1.363636	0.733333
145.898	2.164049	0.0017	-7E-05	1.363636	0.733333
137.494	2.138284	0.004488	-0.0003	1.25	0.8
33.831	1.529315	0.456922	-0.30886	1.153846	0.866667
Mean= 174.1209	Ave.log QMax =2.205275	0.594201			

Variance=0.045708   Std.deviation (σ)=0.009772,skewness coefficient=-2.58877

Table 4: Estimated Discharge by Log Pearson Type III Distribution.

	Tr (recurrence interval	Probabi-lity	K (-2.589)	Log Q = ave (log) + k*S D	QT (in cumecs)
1	1.05	95	-2.012	1.775	60
2	1.11	90	-1.25	1.938	87
3	1.25	80	-0.518	2.094	125
4	2	50	0.359	2.281	191
5	5	20	0.71	2.357	228
6	10	10	0.771	2.369	234
7	25	4	0.793	2.374	237
8	50	2	0.799	2.375	238
9	100	1	0.8	2.376	238
10	200	0.5	0.801	2.377	239

Conclusion

The availability of data is very important for frequency analysis. The estimation of probability of return of occurrence of extreme floods is basically an extrapolation of limited data. Thus the larger the database the more is in the estimation. As per the present study is concerned the discharge values of 228, 234, 237, 238, 238 and 239 (in cumecs) for a recurrence interval of 5, 10, 25, 50, 100 and 200 years is estimated. With such prior information, certain preventive measures could be undertaken for reducing the losses.

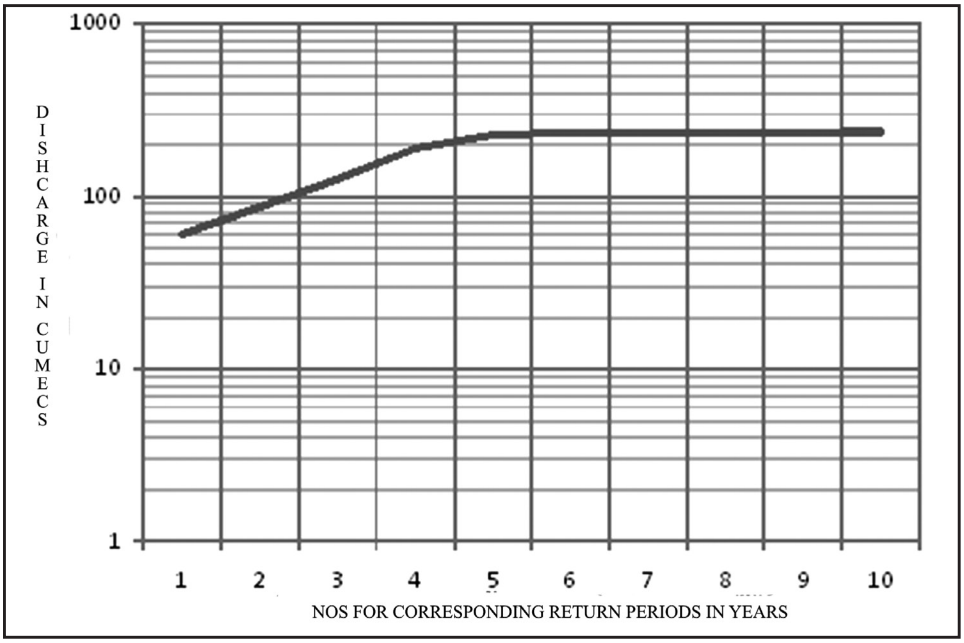


Fig.4: Graph showing estimated discharge by Log Pearson Type III

References

Abdo, Gamal, Sonbol, Mohamed & Willems, Patrick. (2013): Flood Frequency Analysis of the Eastern Nile Rivers.

Adefioye Sunday Adewumi, (2013): Analysis of Land Use/Land Cover Pattern along the

River Benue Channel in Adamawa State, Nigeria. *Academic Journal of Interdisciplinary Studies,Vol. 2,95-107.*

Alexakis D. D., Grillakis M. G., Koutroulis A. G., Agapiou A. , Themistocleous K., Tsanis I. K., Michaelides S. ,Pashiardis S., Demetriou C., Aristeidou K., Retalis A., Tymvios F., and Hadjimitsis D. G.(2014): GIS and remote sensing techniques for the assessment of land use change impact on flood hydrology: the case study of Yialias basin in Cyprus, Nat. Hazards Earth Syst. Sci., 14, 413–426

Anderson R. James, Hardy E. Ernest, Roach T. John, And Witmer E. Richard (1970): A Land Use And Land Cover Classification System For Use With Remote Sensor Data

Asad, Md. Abdullah, (2013): Flood frequency modelling using Gumbel's and Powell's method for Dudhkumarriver**.** *Journal of Water Resources and Ocean Science*. 25-28

Das, Luna, Moni & Qureshi, Zahid Husain. (2014): Flood Frequency Analysis for JiyaDhol River of Brahmaputra Valley. *IJSBAR,* Vol.14, No.2, 14-24

Ewemoje, T. A., Ewemooje, O. S. (2011). Best Distribution and Plotting Positions of Daily Maximum Flood Estimation at Ona River in Ogun-Oshun River Basin, Nigeria.

Gohil, Rajdeep, B., Chowdhary, Deepak, R.(2013): Study of Flood Frequency for Tan River at Station Amba, Gujarat*. Indian Journal of Research*, Vol.2, Issue 3, 132-133

Husain, Azhar. (2012): Estimation of Design Flood for Kol Dam and Rampur in Satluj River Basin**.***International Journal of Emerging Technology and Advanced Engineering.* Vol.2, Issue. 8, 163-166

Mujere Never. *(2011):* Flood Frequency Analysis Using the Gumbel Distribution*. International Journal on Computer Science and Engineering.Vol.3,No.7, 2774-2778*

Mujiburrehman, Khan. (2013): Frequency Analysis of Flood Flow at Garudeshwar Station in Narmada River,Gujarat, India. *Universal Journal of Environmental Research and Technology,* Vol.3, Issue 6: 677-684

Mukherjee, Dr.Manas Kumar. *(2013):* Flood Frequency Analysis of River Subernarekha, India, UsingGumbel's Extreme ValueDistribution*. International Journal of Computational Engineering Research,* Vol.3, issue.7*,12-19*

Ponce,V.M. *(1989): Engineering Hydrology, Principles and Practices.205-228*

Sathe ,B. K., Khire, M. V. & Sankhua, R. N. (2012): Flood Frequency Analysis of Upper Krishna River Basin catchment area using Log Pearson Type III Distribution. *IOSR Journal of Engineering (IOSRJEN).* Vol.2, Issue 8*,* 68-77

Singo, L.R., Kundu, P.M. , Odiyo, J.O., Mathivha, F.I. & Kuna, T.R. (2011): Flood Frequency Analysis of Annual Maximum Stream Flows for Luvuvhu River Catchment, Limpopo Province, South Africa

Solomon, Okonofua and Prince, Ogbeifun. (2013): Flood Frequency Analysis of Osse River Using Gumbel's Distribution, Vol.3, No.10, 55-59