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Hydrological Aspects of Flood Management-An Overview

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Abstract : *This paper describes some of the procedure for estimation of design discharge, flood frequency analysis, identification of plan from of the stream which are essential for flood management studies.*

1. Introduction

A flood is defined as a flow that overtops the natural or artificial banks of a stream. As such, a "flood" is not a purely hydrological notion but a geomorphological and water management one since it involves the parameter of bank capacity governed by a complex interaction of many elements of which hydrology is one, the others being geology, topography, geophysical forces and man-made changes of the environment.

In hydrological analysis the term flood had been generally used to denote a discharge wave characterised by a certain peak discharge and, eventually, this peak discharge itself. Whether a wave or a peak discharge will or will not cause a flood depends on whether or not it will overtop the banks of a stream.

For management of flood, water resources engineers take recourse to structural measures such as storage reservoir, embankments on one or both banks of the river, diversion of excess waters through artificial or natural channels etc. For all these works, estimation of design discharge and identifying plan form of the river are the aspects which are directly linked with hydrology. These aspects will be discussed in the subsequent paragraphs.

2. Estimation of design discharge

The earliest available procedure for estimation of design discharge is the empirically developed mathematical correlations linking the design discharge, which was taken as the maximum flood, with catchment characteristics, specially the contributory area. Dicken'n method, Ryves method, Inglis method etc. can be placed in this category which even now are in use amongst many water resources engineers. Apart from the fact that such equations are based on some kind of loose correlations, these yield estimates of maximum flood, not the flood of T-year frequency, for which the flood management structure is to be designed. This may not be applicable in all circumstances. For example, the Rashtriya Barh Ayog (1980) recommends that the embankments should be designed for providing safety against 100 year flood in urban areas and for flood protection works in rural and agricultural areas, 25 year flood should be adopted as design flood. Use of Dicken's etc. formula in this situation is not at all appropriate and should be discouraged. Superimposition of rainfall sequence over unit hydrograph has also been attempted for estimation of design discharge. Central Water Commission has taken-up such studies and various reports indicating the correlation between catchment characteristics and parameters of synthetic unit hydrograph ordinates to estimate the design flood of frequency same as that of the rainfall. This procedure has certain limitations which prevents its widespread utilisation by water resources engineers. One, it presupposes that a T-year storm will generate a T-year flood. Two, unit hydrograph theory is applicable to small areas only. Three, duration of rainfall is dependent upon catchment characteristics and since the catchment characteristics are fixed parameters, it appears that for generating a discharge of T-year return period, a storm of specified duration is required. Generation of flood of certain return period is a dynamic phenomenon consisting of various other processes involving complex interaction of meteorological, soil-moisture, shape of basin, valley storage of the river and outfall conditions of main draining channel. This procedure fails to take note of these aspects and hence is of limited utility so far as estimation of design discharge is concerned.

2.1 Flood Frequency Analysis

Instead of using indirect methods of estimation of discharge, certain distribution functions which exhibit flood like properties, were fitted through observed maximum discharge data. Statistical distributions such as log normal, Gumbel, log Pearson type III etc. are in use in this procedure. Parameters of the distribution function are usually estimated by the method of moments. Inadequate length of available data results in variable estimates of the T-year flood. Added to this is the difficulty in identification of appropriate flood frequency distribution suitable for the given set of annual maximum discharge data. Choosing between distributions is by no means trouble free as the sampling variations inherent in small samples from skewed, heavily tailed populations tend to mask true between-distribution differences. Goodness of fit indices such as X^2 calculated on the histogram, Kolmogorov-Smirnov index based on cumulative histogram and sums of squares of deviations on probability plots all tend to be inconclusive. This is in part due to the fact that each distribution being tested has its parameters calculated from the same data which forces a strong resemblance on the very distribution which the tests seek to discriminate (Cunnane, 1987). Subsequently, it was observed that the annual maximum discharge sequences available at many sites in region, in natural form or in transformed form, exhibit similar flood behaviour. This characteristic led to a new procedure of flood frequency analysis which is known as regional flood frequency analysis. The underlying assumption of this procedure is that the discharge data at individual sites in a region exhibit hydrologically identical flood behaviour and information available at all these sites in a homogeneous region can be pooled for estimation of floods of desired frequency. Another development in this procedure has been in the form of application of probability weighted moment for estimation of parameters of the chosen distribution function. This procedure is stated to be superior to the conventional procedure of method of moments. It is linear and therefore, errors in observation of discharge data do not get magnified, but on the contrary, results indicate that this procedure performs nearly same as the method of maximum likelihood. A detailed description of this procedure is available in Hosking (1986).

Regional flood frequency analysis has been extensively studied by the hydrologists and water resources managers. Various methods and their merits have been described in "Methods and their Merits of Regional Flood Frequency Analysis" by Cunnane (1988). In case of ungauged basins regression relation linking characteristic flood wiih catchment characteristics are established first and thereafter, estimating the characteristic flood from known set of catchment characteristics, flood of desired frequency can be estimated. Mean annual maximum flood is usually chosen as the characteristic flood. It has been noticed that the statistical worth of such regression equation is less than a year. In other words, even one year of observed data is better than the regression equation. (Nash and Shaw, 1966). It is therefore, felt that the as soon as a project is identified, works for observation of discharge data should immediately be taken-up so that by the time techno-economical clearance is accorded to the project, construction design could be based on actually observed data.

For comparing the various available methods in this field some simulation studies have been taken-up by Hebson et. al. (1987). The study was conducted with data of British rivers. Standard error of various estimators viz. (i) at site only - by using discharge data of a site alone, (ii) regional/at site - i.e. regional flood frequency analysis for estimation of quantile and characteristic flood estimated from at - site data and (iii) regional only-regression relation for estimation of characteristic flood and regional analysis for estimation of quantile; have been obtained by simulation experiments. These are presented in Table 1 below :

Table 1. Standard errors of T-year quantile by (a) at-site estimator (b) regional/at-site estimator and (c) regional only estimator. (Sample Size = 10)

Return Period (years)	At-site estimator (a)	Regional/ at-site estimator (b)	Regional only (c)
10	5.6	3.4	18
100	15	6.7	28
1000	39	11	39

It is clear that the estimates of flood by regional/at-site procedure yield results with least standard error. It is therefore, felt that the managers of flood works should come up with base work which include complex and time consuming procedure of identification of homogeneous zone, standardisation of the procedure of flood frequency analysis using suitable distribution function and estimator of its parameters in order to enable the practicing engineers to use the procedure without getting lost into its algebraic details.

3. Identification of Plan Form of the Stream

Flood management works such as design of embankments, designing waterway for passage of design discharge through bridges, culverts etc. require appreciation of the plan form of river/streams. The questions usually posed before the water resource manager in these situations are–what should be the distance of embankment from bank line, what should be the spacing of embankment if both banks are to be embanked and what should be the appropriate waterway for passage of design discharge through a bridge etc.

In our country the currently accepted practice is to use Lacey's equations. Our various design codes and specifications also recommend the use of Lacey's system of equations. These are

$P_w = 4.75\sqrt{Q}$ where P_w = Wetted perimeter

$R = \frac{5}{2}\left(\frac{V^2}{f}\right)$ R = hydraulic mean depth

V = Velocity

f = Silt factor

$f = 1.76\sqrt{dmm}$ dmm = Average particle size in mm.

These equations were put forth by Lacey for designing artificial canals in Western Uttar Pradesh and Punjab provinces. The objective of developing these equations was to facilitate movement of irrigation waters through canals for a no-silting no-scouring conditions-referred to as "regime" condition for the canals. In case of river flow, the range of variation of discharge in our country is so wide that existence of regime conditions does not appear to be feasible. Success of Lacey's system in design of canals has led to its use in river flow problems also. It must, therefore, be kept in mind that use of Lacey's system of equations is an empirical way of estimating various physical features of the river and its use may some time yield conservative or even unsafe results in some circumstances.

Most important physical feature which is required in flood management works is the horizontal top width of river required for the passage of design discharge. Lacey's system yield estimates of wetted perimeter which in very wide rivers may be taken as equal to the top width of the river course. In the absence of any other scientific approach, this practice continues to be in vogue, however need for evolving realistic correlation based upon actual discharge and top width of the river, taking into account other relevant factors is emphasised.

One of the recently developed approaches in this field makes use of the principle of least work which is successful in many other branches of physics. It is assumed that the river will develop the dimensions that enable it to transmit its water and sediment with the minimum expenditure of energy. Another assumption is that the river has got a level bed across the cross-section. It has been shown that the principle of least work implies to assuming that the river will have the dimension which maximise the sediment transport. To use this principle in a particular case following procedure may be followed.

(i) Known parameters and variables are discharge (Q), Slope(S), Sediment Size (D) and we wish to calculate what width(W) and depth(R) the river will adopt.

(ii) Assuming basic geometrical shape that will be adopted by the river and choosing a surface width (W) discharge per unit width $q=Q/W$ may be calculated.

(iii) With this value of q, using one of the sediment transport formulae and also one of the sediment friction, depth (R), average velocity ($\overline{u}$), average silt load ($\overline{C}$) and silt discharge per unit width (qs) may be calculated.

(iv) Using various values of W, Qs values may be obtained.

(v) The value of W that gives maximum Qs is the value that the river should adopt if it has no constraints.

(vi) Corresponding to this value of W, other variables R, u, C may also be obtained.

4. Conclusion

It is felt that hydrologists and water resources managers should come forward and standardise the procedure of estimation of design discharge of different frequencies which will be based on actual observed data. Similarly, better relationship supported with the available appropriate data base about geometry of the river should be evolved so that the design procedure may be based on updated scientific approach.

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