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RESEARCH ARTICLE

MODEL OF PEAK DISCHARGE (Q_P) & RETURN PERIOD (T) OF RIVER SUBERNAREKHA, INDIA

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ABSTRACT

An empirical model between Peak Discharge (Q_P) and corresponding Return Period (T), obtained from Plotting position formulae, has been developed at Kharkai Barrage Site, India. Mathematical model has been developed by using Least Square Principle, Computer Programing and Software Packages. The model thus developed has been found to be highly satisfactory as the values of percentage deviation and standard deviation of percentage deviation are too low i.e. 0.94 and 0.57 respectively. High positive correlation has been identified between parameters involved in the study with value of Correlation Co-efficient lying always above 0.74. For any desired Return Period (T), the corresponding Peak Discharge (Q_P) can be computed readily from the developed model. The corresponding Stage (G) can also be ascertained from the rating curve (Mukherjee, M,K., Sarkar, S., 2007). The Stage (G) values will be extremely helpful to the exsisting flood warning system and for the construction of different hydraulic structures.

INTRODUCTION

The problem of predicting Flood Hydrograph resulting from a storm in a catchment has received considerable attention. There are many methods to develop Flood Hydrographs. Among these methods, the unit hydrograph technique (Sherman, 1932) is used widely. The unit hydrograph method, notwithstanding its certain limitations, is used to develop Flood Hydrograph, Extension of Flood Flow records based on rainfall records and the flood forecasting and warning system based on rainfall. The technique has been successfully applied in hydrological studies for predicting Peak Discharge for catchment, where the unit hydrograph for different durations can be prepared from the observed rainfall and run-off records. In the present study, one catchment was the subject of investigation i.e. Kharkai Barrage Site, India. It is pertinent to mention here that Kharkai Barrage is constructed on the river Subernarekha, India. The Subernarekha (http:\\www. springerlink.com/ content/7885062173413017/) is an inter-state river flowing through Bihar, West Bengal and Orissa states. It starts in the Chotanagpur Plateau of Bihar and flows into the Bay of Bengal. The upper part of the Subernarekha and its tributaries run through the fertile land of Bihar, but the farming in this region mainly depends on the inadequate and ultimate rains, and the water resources of the Subernarekha river system remain largely untapped. The upper basin, besides containing fertile land, also contains large reserves of minerals. A number of important industries have therefore grown along the banks of the river. Catchment characteristics such as, stream order, drainage density, stream density, length, shape, slope, etc., (Reddy, 1998) was not available.

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Instead, one 6-h unit hydrograph for Kharkai Barrage Site was used for the present study (Data Source: Irrigation International Building, Salt Lake City, Kolkata, Government of West Bengal, India).

Processing of the Computer Output Data

By using the method of superposition, the unit hydrographs of different durations have been obtained. In this method, if a D-hour unit hydrograph is available, and it is desired to develop a unit hydrograph of nD-hour duration, where n is an integer, it is easily accomplished by superposing n unit hydrographs with each graph separated from the previous one by D-hour (Subramanya, 1994). A Computer Program has been developed for this purpose. First of all, from the computer output, the unit hydrograph for each duration of Kharkai Catchment has been developed. Then from the unit hydrograph thus developed, the Q_p and corresponding D have been identified. Before use, the data has been statistically checked for consistency and continuity.

Methodology for the Development of Model

It has been successfully showed that mathematical and graphical relationships can be established between Q_p and Corresponding Return Period (T) (Mukherjee, 2009). Plotting Position formulae, such as Weibull formula, California formula, Hazen formula etc., which are frequently used in practical field, have been used in this study. These formulae are furnished below:

a) Weibull Formula

- $P = m / (N+1)$ and the ... (3.1)
- Return Period $T = 1/P = (N+1) / m$ (3.2)

b) California Formula

- $P = m / N$ and the … (3.3)
- Return Period $T = 1 / P = N / m$ … (3.4)

c) Hazen Formula

- $P = (m – 0.5) / N$ and the … (3.5)
- Return Period $T = 1 / P = N / (m – 0.5)$ .. (3.6)

d) Chegodayev Formula

- $P = (m – 0.3) / (N + 0.4)$ and the (3.7)
- Return Period $T = 1 / P = (N + 0.4) / (m – 0.3)$… (3.8)

d) Blom Formula

- $P = (m – 0.44) / (N + 0.12)$ and the (3.9)
- Return Period $T = 1 / P = (N + 0.12) / (m – 0.44)$ … (4.0)

e) Gringorten Formula

- $P = (m – 3/8) / (N +1/4)$ and the … (4.1)
- Return Period $T = 1 / P = (N + 1/4) / (m – 3/8)$ … (4.2)

f) Beard Formula

- $P = (m – 0.31) / (N + 0.38)$ and the … (4.3)
- Return Period $T = 1 / P = (N + 0.38) / (m – 0.31)$ … (4.4)

g) Adamowski Formula

- $P = (m – 0.24) / (N + 0.5)$ and the … (4.5)
- Return Period $T = 1 / P = (N + 0.5) / (m – 0.24)$ … (4.6)

- Where P is probability of an event equaled to or exceeded and dimension-less.
- m is Order Number and dimension-less.
- N is Sample Size and dimension-less.
- T is Return Period in Years.
- Q_p is Peak Discharge in Cumec.

These are simple empirical technique to arrange the given extreme value series (Q_p here) in descending order of magnitude and to assign an order number m. Thus, for the first entry m=1, for the second entry m=2 and so on till the last event for which m=N=Number of events. The probability of an event equaled to or exceeded (P) (Subramanya, K., 1994) and Return Period (T) have been computed by equations (a) to (g). They are implemented by computer programs developed for this study and software packages. Various mathematical equations (or approximating curves) have been developed in the form of Straight Line Fitting, Logarithmic Fitting, Exponential Fitting, Polynomial Degree-2 Fitting, Polynomial Degree-3 Fitting and Power Fitting for developing relationships between Q_p and T. Model have been selected by considering the highly satisfactory values of Average % Deviation, Standard Deviation of % Deviation and Correlation co-efficient between the parameters involved in this study. Least Square Principle has been widely used in every mathematical equations or curve fitting (http:\\mathworld .wolfram. com/ LeastSquaresFitting.html). Field data is often accompanied by noise. Even though all control parameters (independent variables) remain constant, the resultant outcomes (dependent variables) vary. A process of quantitatively estimating the trend of the outcomes, also known as regression or curve fitting, therefore becomes necessary. The curve fitting process fits equations of approximating curves to the raw field data. Nevertheless, for a given set of data, the fitting curves of a given type are generally *not unique.* Thus, a curve with a minimal deviation from all data points is desired. This *best-fitting curve* can be obtained by the method of least squares. The method of least squares assumes that the best-fit curve of a given type is the curve that has the minimal sum of the deviations squared (*least square error)* from a given set of data. Let the data points are, (x_1, y_1), (x_2, y_2), …. (x_n, y_n) where x is the independent variable and y is the dependent variable. The fitting curve f (x) has the deviation (error) d from each data point, i.e., $d_1=y_1- f(x_1)$, $d_2= y_2- f(x_2)$,….., $d_n= y_n- f(x_n)$. According to the method of least squares, the best fitting curve has the property that:

$$\Pi = d_1^2 + d_2^2 + \dots + d_n^2 = \sum_{i=1}^{n} d_i^2 = \sum_{i=1}^{n} [y_i - f(x_i)]^2 = \text{a minimum} \qquad \dots\dots\dots (4.7)$$

Computer Programming and various software packages have been used for developing such mathematical relationships.

RESULTS

The results are furnished in Table-1 to Table-8 and in Figure-1 to Figure-8 (Page No- 8 to 15). The Synopsis Table has ben furnished in Table-9 (Page No- 16).

DISCUSSION

I. The model relating Q_p and T developed here, are found to be highly satisfactory based on values of percentage deviation and standard deviation of percentage deviation of the Q_p (Field value) and Q_p (Computed Value from the developed model) .

II. Synopsis of the obtained results and the developed model have been furnished in Table-9. It has been observed from Table-9 that, out of eight cases, Polynomial Degree-3 equation best represents the data set (used in the study) in seven cases. Moreover, out of these seven Polynomial Degree-3 equations, the California Formula is the best one, because the values of percentage deviation and standard deviation of percentage deviation are too low i.e. 0.94 and 0.57 respectively. Though all the equations used in this study are empirical formulae, but still giving reasonable estimate of the hydrological parameters involved in this study.

Conclusion

- For any anticipated T, Q_P can readily be estimated from the developed model stipulated in Table-9.
- However, the model will give reasonable estimate of Q_P for any desired value of T, without any instrumentation and expensive and time consuming field work.
- For any anticipated value of T, Q_P can readily be ascertained from the developed model suggested above and the Stage (G), Corresponding to Q_P, can be estimated (Mukherjee, M,K., and Sarkar, S., 2007).
- These Stages may be obtained from Stage-Discharge (G-Q) model, corresponding to Q_P. Therefore, the values of G thus obtained are on conservative side.
- If presently adopted Danger level for 'Flood' for the river Subernarekha at the gauging site, is lower than the

stage computed from (G-Q) model, then there is no problem.

- If presently adopted Danger level for 'Flood' for the river Subernarekha at the gauging site, is higher than the stage computed from (G-Q) model, then the presently adopted danger level for flood needed to be changed.
- Therefore, emergency evacuation may be adopted by propagating well advanced 'Flood Warning' that may save thousands of lives from the fury of flood, may be put in place.
- 'Flood Plain Zoning' may also be introduced to protect the lives of thousands of people and their properties, to minimize the socio-economic disaster created by flood.
- Moreover, Peak Discharge (Q_p) is a potential tool for designing important hydraulic structures like Concrete Gravity Dam, Weir, Barrage, Bridge across the river, Guide bank etc.
- The entire water resource of river Subernarekha is largely untapped. Hence, construction of hydraulic structures will be helpful for resource generation also.

Notations used in the Paper

- G - Stage
- Q_p - Peak Discharge of Unit Hydrograph
- T - Return Period
- m - Order Number
- N - Sample Size
- P - Probability of an event equaled to or exceeded
- Devn. - Deviation
- Ave - Average
- Ave % devn - Average percentage deviation
- STDEV - Standard Deviation of percentage deviation
- RC1 - Correlation Co-efficient between Peak Discharge (Q_p) (Field Value) and Return Period (T) obtained from Plotting Position Formulae.
- RC2 - Correlation Co-efficient between Peak Discharge (Q_p) (Computed from the developed model) and Return Period (T) obtained from Plotting Position Formulae.

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