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Intensity-Duration-Frequency Relationship using Event Based Approach

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Abstract—*Managing different resources of water is becoming a complex task, owing to the increasing demand of water over time. An effective water management system is necessary especially in India due to its rapid increase in population and recent developments. The design of any water management structures requires information about rainfall intensity, duration and frequency. Intensity-Duration-Frequency (IDF) curves are needed for this purpose. Usually, IDF curves are derived using single variable frequency analysis, which does not explain the whole behavior of rainfall events. In this study, rainfall storm is considered as an event to capture the storm variability. An event considered two associated variables i.e., rainfall intensity and rainfall duration. The distribution of extreme events is determined, which helps to analyze the frequency of the extreme events. Kendall's tau is used to show dependence statistics between these two variables. The concept of peak over threshold events is taken into consideration, while estimation of IDF curves. This approach gives additional information about occurrence of storm events and dependency between storm variables, which helps policy makers and designers in better understanding of storm phenomena and thereby designing economic hydraulic structure more economically and managing water management systems more efficiently.*

1. INTRODUCTION

Water management is becoming a big issue in India, as it is one of fastest growing economies in the world. Large scale industrialization and urbanization and demand for stability in agricultural condition further signify the importance of water management. Along with these,rapid improvement in the standard of living of 1.25 billion people increase the requirement of water for several purposes.

Water is a renewable resource and it is non-uniformly distributed which makes the management of this highly complex. To control the uncertainty in the availability of water, management demands construction of several hydraulic structures, which are designed on the basis of amount of water availability. Generally, IDF curves are estimated using empirical methods [3, 4, 9, 10] or using single variable statistical analysis [2, 5, 11, 12] in which duration of rainfall is presumed. This approach is questionable since it does not capture any physical characteristics of storm. Hence, IDF curve generation approach should take into account of the storm characteristics in general, for its usage in hydraulics structure designs. In this study, to capture the storm characteristics, each storm is considered as event. In general annual maximum extreme events [1, 14] are considered but it has been proved peak over threshold events consist more information[8]. This study also considers the dependence between storm variables.

2. DATA

Hourly rainfall data of Palam station, Delhi is obtained from Indian meteorological department, for the period Jan 1981 to December 2004. Missing values are replaced with weighted average method. However, for the present analysis yearswithtoo many missing values are not taken into consideration.

3. EVENT SERIES

Hourly rainfall series is converted into an event series, in order to capture the storm behavior more accurately. An event captures storm variability which can have direct or indirect impact on design of hydraulic structure. The characteristics considered are rainfall intensity and rainfall duration. An event is captured for the duration of wet period of storm and constant rainfallintensity for whole the period.

4. DEPENDENCE STATISTICS

Dependence statistics shows the relation or dependency of one variable of storm on other variable. For example, if one variable is increasing with the increase in the other variable, then it is called positive dependence and vice versa. Many dependence statistics have been used in various studies, of which Kendall's tau is most commonly used in hydraulic studies [6, 7, 13]. It is a non- parametric measure of correlation. Kendall's Tau gives an association between paired variables. Suppose one variable x is correspond to variable y for some phenomena and two paired observation of variables are (x_a, y_a) and (x_b, y_b). This pair of observation is called concordant if $x_a < x_b$ and $y_a < y_b$ or $x_a > x_b$ and $y_a > y_b$ i.e. $(x_a - x_b)(y_a - y_b) > 0$ and it is called discordant if $x_a < x_b$ and $y_a > y_b$ or $x_a > x_b$ and $y_a < y_b$ i.e $(x_a - x_b)(y_a - y_b) < 0$. So

Kendall's Tau = Probability of concordance – Probability of discordance (1)

5. METHODOLOGY

In order to generate additional information with IDF curves, distribution of peak over threshold events are analyzed using scatter plot of storm variables and dependence statistic using methodology described below.

5.1 Event Distribution

Steps:
1. Hourly data of depth of wet period is summed up to get cumulative depth.
2. Corresponding duration is obtained.
3. Cumulative depth is divided by corresponding duration to get corresponding rainfall intensity.
4. Taking rainfall intensity as criteria, 95 percentile value is calculated.
5. Events having greater extremity than 95th percentile, are selected.
6. Scatter plot between rainfall intensity and corresponding duration of these events is obtained.

5.2 Kendall's Tau Calculation

Steps
1. Rainfall intensity and rainfall duration are extracted in terms of pairwise observation.
2. Concordance pairs are found.
3. Discordant pairs are found.
4. Tau value is calculated using equation 1.

6. RESULT AND DISCUSSION

6.1 Event series generation

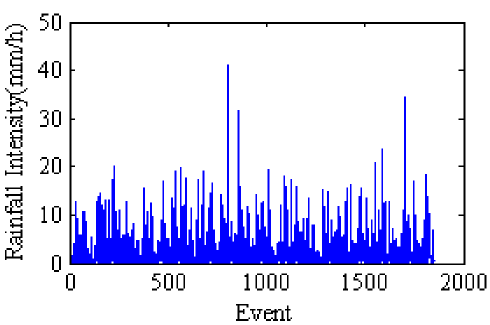

Fig. 1: Rainfall intensity of events

Using available data at Palam station, events are extracted and all the events in terms of rainfall intensity are shown in Fig. 1 and there corresponding duration of storm are shown in Fig. 2. Out of these events, events above 95 percentile are taken as extreme events, which can be considered for the design of hydraulic structures.

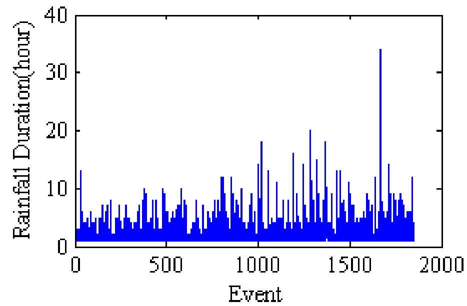

Fig. 2: Rainfall duration of events

6.2 Event distribution

In order to obtain the distribution of events, scatter plots are drawn. Extreme events above 95 percentile over Palam station are found out and relationship between rainfall intensity with corresponding rainfall duration is obtained. Scatter plot of Palam station is shown in Fig. 3. It shows distribution of peak over threshold events. Most extreme event is having an intensity of 41.1 mm/h with corresponding duration of one hour. The 95 percentile value of rainfall intensity is obtained as 10.0525 mm/h and least extreme event has a rainfall intensity of 10.1 mm/h with duration of four hour. It is evident from Fig. 3 that maximum of these events are low duration events. Events with storm duration more than five hour are a few and more than ten hour are rare for Palam station.

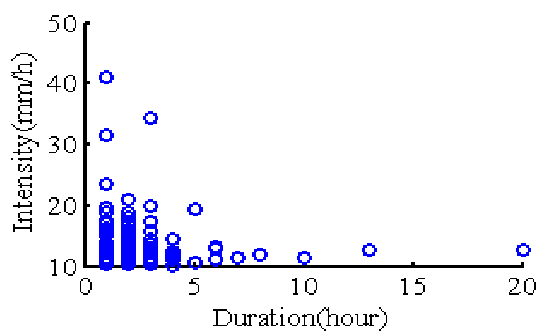

Fig. 3: Distribution of peak over threshold events

6.3 Dependence statistics

It is seen from scatter plot, storm variables are negatively dependent and to measure the dependency Kendall's tau is calculated. For Palam station, Kendall's tau value for extreme events comes out to be -0.2035. This value confirms the negative dependence between the variables but dependence is found out to be less negatively correlated.

7. CONCLUSION

In the study, peak over threshold events are analyzed and the dependence between storm intensity and duration is found out to less negatively correlated. This shows there is less possibility to occur very high rainfall intensity events over large periods.

It is also revealed that since many extreme events are with low durations, design of structures should take into consideration of lower duration frequent floods. The information provided through the event analysis will help designers, policy makers to efficiently design water management structures.

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