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# The Limiting Physical Parameters of Synthetic Unit Hydrograph

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**Abstract:** This paper studied Synthetic Unit Hydrograph Model. The methodology consisted of analysis of observed unit hydrograph and the primary physical parameters of watershed. Results revealed that length of river and area of watershed were the primary physical parameters. Further research is needed focusing on roughness coefficient of the river.

**Key words:** Physical parameter · Model · Watershed area

## INTRODUCTION

Hydrological approaches in the watershed systems have granted great many contributions to hydraulic structured planning. It is very difficult to understand the process of run off thoroughly [1]. Researchers had come up successfully with models of the wellknown models Synthetic Unit Hydrograph. There are many patterns to develop SUH. One of them is based on regression analysis [2]. Statistical regression is one of the patterns for analyzing hydrological models [3]. It is considered that watershed is too complex and heterogen to identify its parameters detailly. Therefore, this paper studied the SUH model. This was intended to (1) find out the nature of watershed responses against precipitation data input, where by it could become the supportive warning systems to areas that are vulnerable to flooding, (2) resume up hydrograph data availability that are previously vacant due to the operational problem of the Automatic Water Level Recorder (AWLR) and (3) produce a specific SUH model for Indonesia (SUH Limantara) with a simple mathematical model and without the necessary parametric calibration prior of its application.

## MATERIALS AND METHODS

**Analysis of Observed Unit Hydrograph:** Observed Unit Hydrograph of each watershed was analysed with Collins Method, which step by step was followed as below: (1) Stage hydrograph was transformed to discharge hydrograph with calibration curve; (2) Base flow was separated from hydrograph with empirical method: Staright Line Method [3] (3) Effective Rainfall which was produced flood, was analysed with $\phi$ index; (4) Any unit hydrograph was fixed with giving them any ordinates; (5) The first trial unit hydrograph was timed with all of effective rainfall without the highest effective rainfall; (6) The direct run off hydrograph was minused with gauged direct run off hydrograph, in this session it was gained direct run off hydrograph which was produced by maximum rainfall, it was assumed as second trial unit hydrograph; (7) The second trial unit hydrograph was compared with the first trial one. If there was more different (according to standard of error which was determined before), then the fifth and sixth step were repeated according to the end of unit hydrograph; (8) etc, till to get the least error between the end of unit hydrograph with the unit hydrograph before.

Each watershed was found its observed unit hydrograph. To produce the observed unit hydrographs for all of watersheds, were done with averaging ordinates of observed unit hydrographs for the same hour, peak discharge dan time to peak, which was according to step by step as below: (1) To calculate the average of time to peak and peak discharge; (2) To calculate the average of observed unit hydrograph dimensionless; (4) To calculate the average of observed unit hydrograph.

**The Primary Physical Parametres of Watershed:** The watersheds' parameter, that was the easiest to get and unchanged relatively were geographical and morphological to the quality.of watershed [3]. According to the concept of storage, if all of the watersheds had been contributed in run off, it would reach the maximum flow which was unchanged the storage [4].

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**Analysis of Data:** The analysis of data was valid for each watershed. As it had been described before, to get observed hydrograph which could be valid for all of the watersheds, it was carried out with averaging the ordinates of hydrograph in the same hour, peak discharge and time to peak.

## RESULTS AND DISCUSSION

**Observed Unit Hydrograph:** According to obserbved unit hydrograph, it would to analyse obserbved unit hydrograph for each warershed by means of Collins method [5]. Data of discharge hydrograph which was used to transform obserbved unit hydrograph for each watershed was selected for the maximum one and just had single peak. The date of collecting data of AWLR (data of discharge hydrograph) had to be the same with collecting data from ARR (data of hourly eainfall) for each watershed. But, it was not necessary to get the homogeneous data among watersheds. It was considered that the aim of unit hydrograph analysis was only for high flow.

According to analyse the average of obserbved unit hydrographs in all of the watersheds, it was produced time to peak was 5,773 hours and the time recession was 9,859 hours, so that the time base was 15,632 hours. It was concluded that discharge hydrograph in the location of this study had characteristic of time to peak was shorter than the time recession, so that it was said that some selected watersheds in this study had long shape.

**The Limiting Physical Parameters of Model:** If peak discharge was as permanent variable and physical characteristics of watershed (A, L, Lc, S and n) were as independent variables, those produced 62 alternatives of regression curves. The selection of model was according to the rational model with had characteristic as above. From 62 alternatives of regression curves (with five, four, three, two and one variables), that is selected one general model of peak discharge (for all of the watersheds) such as:

$$Qp = 0{,}042.A^{0{,}451}.L^{0{,}497}.Lc^{0{,}356}.S^{-0{,}131}.n^{0{,}168} \quad (1)$$

With determination coefficient $R^2$ is 0.841 (level of significant = 5%) and the estimation of standard erros: SEY = 0.809. From this equation, it was concluded that the five primary physical parameters were influented to build the model of peak discharge., such as area of watershed (A), the length of main river (L), the length of river which was measured until the nearest point to the weight point of watershed (Lc)., the slope of river (S) and the roughness coefficient (n).

From the selected equation, it was concluded that the most dominant parameters of watershed was the length of main river (L), with its exponent was 0.497, after that there had to do with area of watershed (A), its exponent was 0.451 the length of river which was measured until the nearest point to the weight point of watershed (Lc), its exponent was 0.356 the roughness coefficient (n), its exponent was 0.168 and the slope of river (S), its exponent was 0.131. The formula of streamflow continuity was as follows:

$$Q = = V \times A \; (V = {}^{1}/n \times R^{2/3} \times S^{1/2}) \quad (2)$$

It showed that discharge was the functions of radius, which was analoged to the length of main river (L) and the area (A) was analoged to the area of watershed (A). Therefore the primary parameters of watershed to discharge model was analoged to the formula of streamflow continuity.

Asdak [6] found that the longer main river as long as the distance between dropping rainfall point with outlet. It was caused due to the length of river. It gave the chance of rainfall to flow as run off so that that loses of water was much more. It was meant that if the length of river becomes longer, it would produce the less peack discharge. The explanation was not the same as the production of this study. The length of main river ( L) was the primary factor of the discharge model and its exponent was 0.497. It was meant that the longer of the length of river resulted in the higher peack discharge.

The longer watershed area, run off needed a long time to reach outlet, so that the time base of hydrograph was more longer and peach discharge was being reduced [3]. That was not the same as production of this study. If the watershed area was the second primary factor and its exponent was 0.451, it was meant that the bigger area of watershed, it would produce the higher peak discharge. It was interlaced that the bigger area of watershed, it would cause the rainfall distribution did not average distributed. He said that the unit hydrograph has been as direct run off hydrograph which was produced by average effective rainfall in watershed. The measurement of watershed determined the maximum standard of using unit hydrograph. There was not really certain of measurement, but according to Soemarto [7], it was taken maximum 5000 $km^2$, as it was done in this study. So that if it occured average rainfall distribution in a watershed, the bigger watersehed area was, run off would reach outlet fastly and it would rise the peak discharge.

The length of river which was measured until the nearest point to the weight point of watershed (Lc) was the third primary factor in this study. Its exponent was 0.356, it was meant that the longer Lc, it would produce the bigger peak discharge. But, if the exponent was small relatively, Lc was not too influented to peak discharge. Of course, there was difference between Lc which was inclining to the direction of upstream and the Lc which was in the center of watershed, but the difference was small relatively.

The roughness coefficient (n) was estimated in the range of 0.035 and 0.070. All watersheds rich in forest, the roughness coefficient of watersehed was 0.070. In the other side, if there was no forest, the roughness coefficient of the watershed was 0.035. It was known that forest was generally cropping the big trees, so that it was assumed as rough surface that could pursue the entrance of rainfall. But dry fiekds, rice fields, real estates, etc were assumed as not too rough surfaces, so that they were not supported in calculation of roughness coefficient of watershed. Roughness surface would pursue the enterance of rainfall to river. So trhat, the rtoughness coefficient was rationally not too supported peak discharge, it was meant that it compared upside down to the peak discharge (Qp). Because of discharge in this contex was flood discharge, in certain contex, the land would be saturated. In saturated condition of land, the rainfall was running off although it was not as big as if there was no forest, so that the roughness coefficient of wartershed did not pursue peak discharge. In this study, the roughness coefficient of watershed was remained to influent peak discharge model, which had exponent equal 0,168 and it was the fourth primary factor of 5 parameters of watershed which were used in this study. Because of having the positive exponent, it was meant that the roughness coefficient was comparesd upside up to peak discharge. According to the above explanation, the roughness coefficient of watershed was estimated to give support to peak discharge, but it was only in little amount.

The slope of river (S) that was produced in this study had exponent equal -0.131. In many cases, that slope gently of watershed would rise peak discharge. It was caused that if it was slope gently, it was meant that time base of hydrograph became long and would rise the recession of slope gently hydrograph, so that the peak discharge would rise.

## CONCLUSIONS

The characteristic of average unit hydrograph showed that the shape of watershed was pursued long.This study suggested the length of main river (L) and watershed area (A) were the primary factor. In addtion, it was suggested to study the roughness coefficient of watershed (n).

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