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Determining the Side Channel Area in the Ciliwung Watershed for Decreasing the Hydrograph Flood

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Abstract. The condition of Jakarta with high population density and green open space switch function, causing the condition of flooding to be one of the risks that occur when the rainy season. Ciliwung River that flows from Katulampa into Jakarta bay, is considered as the largest contributor to flood discharge. This study will analyze the flood discharge plan on the side channel area to lower the flood hydrograph peaks and extend the detention time. The area to be side channel is Ciparigi with an area of 608.7 hectare and the slope of 8-10%. The result of flood discharge planning analysis at Ciparigi region (Sub watershed of Middle Ciliwung), obtained the amount of flood discharge for return period 2 yearly equal to 10.10 m^3/sec, 5 yearly equal to 12.77 m^3/sec, 10 yearly equal to 14.17 m^3/sec, 25 yearly equal to 15.32 m^3/sec, 50 yearly equal to 16.63 m^3/sec and 100 yearly equal to 17.52 m^3/sec. The percentage of flood discharge plans that will be reduced by 10% of the total flood discharge plan in sub watershed observation is 1.28 m^3/sec with reservoir volume of 4.608 m^3 which will be fully charged for 1 hour. This will extend the flow time from the control point in Depok to the Manggarai waterway to approximately 5 hours.

1. INTRODUCTION

The occurrence of periodic floods that hit the capital city of Jakarta, is inseparable from the Ciliwung River that flows to the north coast of Jakarta. The condition of land use around the Ciliwung river flow that has changed function as residential, building and other infrastructure causes the rainwater catchment to be reduced. Parameters to be considered in flood control planning are landscape, environment, usage, and safety [1]. Catchment area is an important factor in knowing the amount of discharge that will occur in a flood event [2]. Land use in the Middle Ciliwung area from 2008-2011 has increased for residential areas by 16% [3]. This land use change affects the hydrological function of the catchment area of the Ciliwung River, which results in an increase flood discharge in the middle flow by 24% and 15% [3]. The important component to the catchment area management is the hydrological conditions of the surrounding area (local area) [4]. The catchment area has very specific characteristics and is influenced by topography, soil type, vegetation and land use [5]. Ciliwung River flow which is divided into upstream, middle and downstream into a single unit in the existing flood control planning. This research takes the middle area of the river Ciliwung as the area that will be an extension of detention time on the hydrograph that will be formed on the Manggarai Water Gate as the end point of the middle stream. The peak drop of the hydrograph is obtained by reducing the flow time in the center of the Ciliwung by making the side channel in the designated area. Side Chanel is used as a bypass that will meet the reservoir dimensions on the side of the river body that has been determined. The amount of water that is accommodated will make the main streaming flow time will decrease. The hydrological analysis carried out in this study was in the period of rainfall from 2007-2016 for the three rain stations in the central region which included the Katulampa Bend rain station, the Gadog rain station and the Bogor rainforest park. The collection of three rain stations is based on the determination of the side channel area located in Bogor Regency.

2. METHODS

2.1 Study Area

The geographical location of Ciliwung watershed is located on 6°37'48" – 6°46'12 South Latitude and 106°49'48" - 107°0'0" East Longitude. The length of the main river flow ciliwung is 120 km with the area division shown on figures 1 and 2. The middle part of the Ciliwung basin covers an area of 15,706.1 ha which is a wavy and hilly area with variations in elevation between 100 m to 300 m dpl. The middle part there are two tributaries namely Cikumpay and Ciluar that empties into the Ciliwung River. The center is dominated by a slope up to 8% with a 46.6% percentage of the total area of Ciliwung Tengah sub-basin [3].

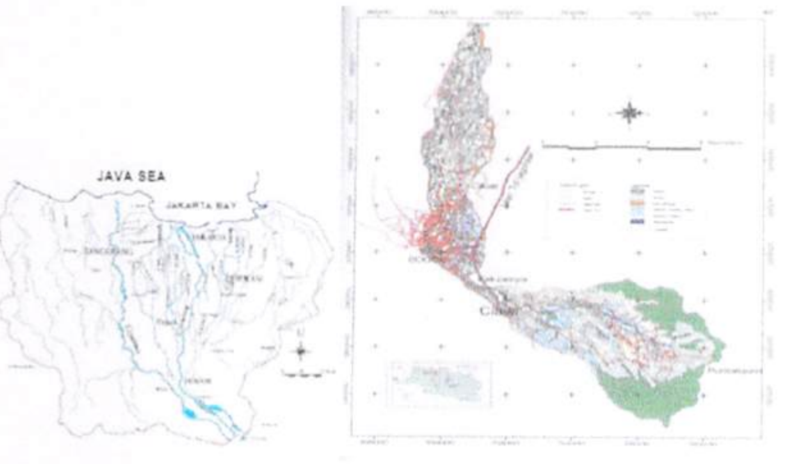

Figure 1. Ciliwung River Flow Map/Study Area

Ciliwung River main stream also get the amount of flood discharge from several small rivers that contribute to the flow discharge downstream. The flow scheme will determine the laying of the reservoir building to withstand the rate of flood discharge to the Manggarai water gate. The water level control point on middle Ciliwung river flow is in Depok area of Ratu Jaya which has travel time drainage until Manggarai water gate for approximately 4 hours.

Figure 2. Ciliwung River Basin Scheme

Rainfall data used in this study, is the rainfall data obtained at the Meteorology and Geophysics Agency for the data collection year 2007-2016. Rainfall density used in a study will produce a better quantity because it can represent variations in rainfall in the area [6]. Observation rain station which used as hydrological calculation of area in middle region is three (3) rain stations with maximum rainfall data that happened in 1 year. The maximum rainfall value that shown on figure 3, analyzed and tested consistency between the rain station Katulampa Dam with two other observation rain station that is Gadog rain station and rain station Bogor Botanical Garden.

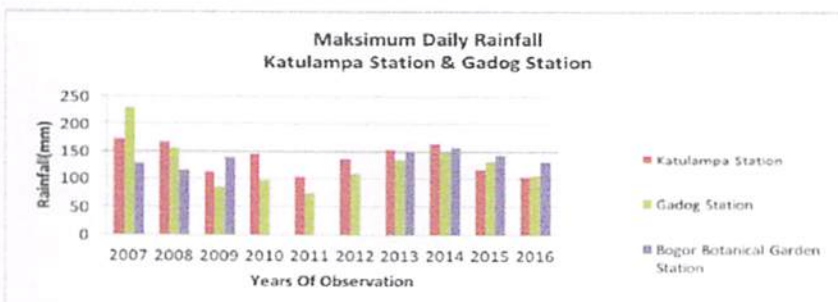

Figure 3. Maximum Rainfall Data in three (3) Stations Observations

Observation data for 2010-2012 at Bogor gardens observation station is deficient because the tool used for measuring rainfall data was damaged.

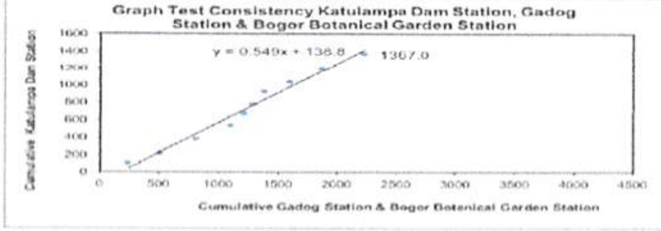

Figure 4. Test the Consistency of Katulampa Dam Station with Gadog Rain Station and Bogor Botanical Garden Station

This consistency test (figure 4), included in the calculation of the average rainfall by using the average calculation method (algebraic) with the following formula,

$$R = \frac{R_1+R_2+R_3 ... R_n}{n} \quad (1)$$

where: R is the rainfall observation area (mm), R_1, R_2, R_3 ... R_n is the rainfall at each observation point (mm) and n is the number of observation points.

The analysis of rainfall plan in this study was conducted by using three (3) methods namely normal distribution, Gumbel and Log Person III. The frequency matching of frequency distribution is Kolmogorov Smirnov test for the above three methods. Normal Distribution method equations is,

$$X_{Tr} = \bar{X} + K_{Tr}.S_x \quad (2)$$

where, X_{Tr} is the magnitude of the rainfall plan for the T repeat period of years, $\bar{X}$ is the average price of the data, K_{Tr} is the Gauss reduction variable and S_x is standard deviation [7].
The Gumbel method equation is,

$$X_{Tr} = \bar{X} + K.S_x \quad (3)$$

where, X_{Tr} is the magnitude of the rainfall plan for the T repeat period of years, $\bar{X}$ is the average price of the data, K is the frequency factor which is a function of the reset period and the frequency type and S_x is the standard deviation [8]. To calculate the frequency factor, equation (4) is used:

$$K = \frac{Y_t - Y_n}{S_n} \quad (4)$$

where, Y_t is the reduction as a function of probability, Y_n and S_n are the a quantity that is a function of the reset period and the frequency type.
The Pearson Log method equation is,

$$logX_T = \overline{logX} + K_{TR}(S_{logx}) \quad (5)$$

where, $logX_T$ is the magnitude of the rainfall plan for the T year re-period, $\overline{logX}$ is average, K_{TR} is the frequency coefficient and S_{logx} is the standard deviation [8].

The next testing process, after conducting a frequency distribution analysis is to conduct Smirnov Kolmogorov test is a horizontal deviation test on the test data in this study. This test compares three acceptable methods of rain distribution according to the existing hypothesis. Equation in this test is,

$$\Delta_{maks} = |P_E(X) - P_t(X)| \quad (6)$$

where, Δ_{maks} is the difference between theoretical and empirical probability data, $P_E(X)$ is the position of the data x according to empirical spread and $P_t(X)$ is the position of the data x according to theoretical distribution.

Based on the calculations obtained, the maximum difference between theoretical distribution and empirical distribution called Δmaximum. Then value Δmaximum calculation results compared with Δo obtained from the table for a certain degree [9]. This study uses a critical value of α = 5% with the condition Δo > Δmaximum then the hypothesis is acceptable.

2.2 Determination of Side Chanel Area

Ciliwung Middle are divided into 8 sub basins consisting of independent, K. Baru 2, K. Sugutamu, Cikumpa, Ciliwung Central (Cibinong, Bogor East), Ciluar, Ciparigi and Cibuluh, with a broad area are presented in table 1. Area sub basin which is used as a research location, taken Ciparigi sub watershed, with 608.7 ha wide with the slope of 8-10% and is close to the rain station Botanical Garden.

Table 1. Area of Middle Ciliwung Basin

Area	Basin	Area (Ha)
Middle	Cijantung	3154.2
	K. Baru 2	1192.1
	K. Sugutamu	1518.3
	Cikumpa	3305.2
	Ciliwung Tengah (Cibinong, Bogor Timur)	3192.3
	Ciluar	1430.6
	Ciparigi	608.7
	Cibuluh	1304.7

Flood discharge planning analysis with rational method is often used in observation areas. The amount of debit is a function of watershed, rain intensity, runoff coefficient and river slope [8]. Flood discharge equation plan with Rational method that is,

$$Q_p = 0.278.C.I.A \quad (7)$$

where, Q_p is the peak discharge (m^3/sec), C is the runoff coefficient, I is the intensity of rainfall (mm/hour) and A is the catchment area (km^2).

The runoff coefficient is ratio between the surface flow and the rain intensity for a particular catchment area. This coefficient is basically calculated from amount of runoff to the amount of precipitation received with low infiltration and high runoff [8]. The area of the middle Ciliwung, which is the area of this study, is an area that has significantly changed land use that shown in figure 5. The condition of the number of settlements on the side of Ciliwung river flow, making the runoff coefficient (C) becomes larger than before.

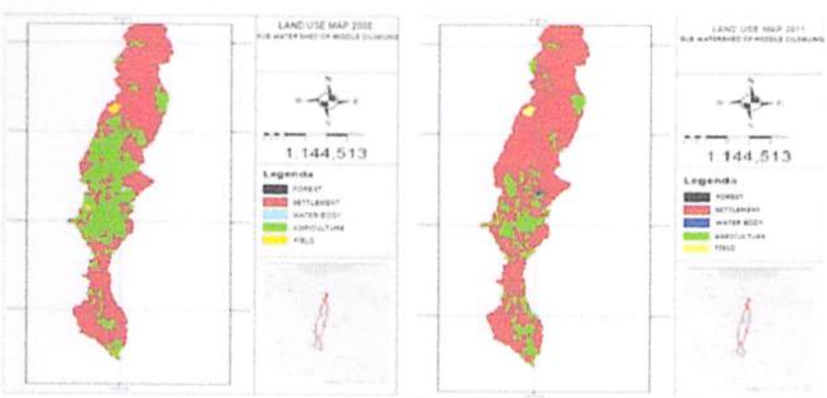

Figure 5. Change of Land Use of Middle Ciliwung Sub-Basin Year 2008 and 2011 [3]

The intensity of rainfall is the amount of rain expressed in the height or volume of rain per unit time. The intensity of the precipitation to be analyzed in this study will result in an intensity and frequency curve for a period of 10 years in the drainage region. The rainfall intensity formula used is,

$$I = \frac{R_{24}}{24}\left[\frac{24}{t}\right]^{2/3} \quad (8)$$

where, I is the intensity of rainfall (mm/hour), R_{24} is the maximum daily rainfall (mm) and t is the rainfall time occurs (hour).

The time of concentration is the travel time required by water from the most distant place (upstream of the watershed) to the point of observation of water flow (outlet) [8]. The equation of the concentration time is,

$$T_c = \frac{0.6628.L^{0.77}}{S^{0.385}} \quad (9)$$

where, Tc : time of concentration (hour), L is the lengthy (km) and S is the river slope.

3. RESULTS AND DISCUSSION

The maximum monthly rainfall data for the last 10 years is in 2007 is 176 mm for regional rainfall. Frequency distribution analysis methods used in this study, basically through the stages of the analysis process is relatively similar. The rated monthly rainfall will be used to calculate the mean and standard deviation of 10 years of existing data. Based on the results of frequency distribution analysis, obtained $X_{rata\text{-}rata}$ value for Normal Distribution and Gumbel method of 119.99 while Log Person III method obtained 2.057. The standard deviation value for Normal Distribution is 37.89, Gumbel Method 37.81 and Log Person III Method is 0.152. Value of S_n and Y_n for Gumbel method is obtained based on the calculation table that is 0.4952 and 0.9496. The value of coefficient of congestion (Cs) on Gumbel Method and Log Person III Method is 0.879 and -0.730.

The results of the Smirnov-Kolmogorov Test obtained by the Normal Distribution method, Gumbel and Log Person III are presented in Table 2. Based on the $\Delta_0 > \Delta_{maksimum}$, it can be deduced hypotheses for analysis of the frequency distribution of the three accepted methods. The coefficient of skewness (Cs) Gumbel method is 1.139 while the results of calculations in the study obtained Cs value of 0.879 so, the distribution used is the Gumbel Method.

Table 2. Smirnov-Kolmogorov Test Results Normal Distribution Methods, Gumbel and Log Person III

No.	Difference For Critical Values 5 %		
	Normal	Gumbel	Log Pearson III
1	28.57	17.86	7.75
2	9.17	7.05	8.86
3	2.38	0.33	15.34
4	11.40	13.68	25.87
5	5.73	9.29	17.79
Difference Max	11.398	13.676	25.874
Match Test	Accepted	Accepted	Accepted

Based on the results of the calculation of flood discharge plan with return period 2 year, 5 year, 10 year, 25 year, 50 year and 100 year, obtained the value of rainfall plan empirically shown in table 3 and table 4 which shows the result of flood discharge plan with Rational Method.

Table 3. Rainfall Frequency Analysis Plan

Return Period (Year)	Rainfall Frequency Analysis Plan (mm)		
	Normal	Gumbel	Log Pearson III
2	120	115	119
5	152	160	156
10	168	190	226
25	182	228	191
50	197	256	200
100	208	283	206

Table 4. Result of Flood Discharge Plan with Rational Method

Parameter	Return Period T (Year)					
	2	5	10	25	50	100
Tc (hour)	0.35	0.35	0.35	0.35	0.35	0.35
I (mm/hour)	83.24	105.27	116.81	126.25	137	144.35
Q (m3/sec)	10.10	12.77	14.17	15.32	16.63	17.52

Based on the results of flood discharge calculation plan and significant land-use changes take place within 5 years, for the return period 5 year have flood discharge plan 12.77 m^3/sec. The flood debit value of the plan is used to determine the percentage of discharge to be channeled to the side channel on the Ciparigi sub watershed and the reservoir dimension in the sub watershed. The percentage of expected flood discharge to reduce the flood discharge in Ciliwung river flow is 10% of the total flood discharge in the Ciparigi sub watershed so the amount of discharge to the side channel is 1.28 m^3/sec. The volume of water that will fill the maximum reservoir within 1 hour is 4,608 m^3 assuming the reservoir shape is rectangle.

4. CONCLUSIONS

Based on the results of the analysis that has been done, the conclusions that can be taken in this research are,

1. The area that will be used as the side channel in the middle flow of Ciliwung is the Ciparigi sub watershed with the catchment area of 608.7 ha and the slope of the land is 8-10%
2. Value of flood discharge in sub watershed Ciparigi for return period 2 year 10.10 m^3/sec, 5 year 12.77 m^3/sec, 10 year 14.17 m^3/sec, 25 year 15.32 m^3/sec, 50 year 16.63 m^3/sec and 100 year 17.52 m^3/sec.
3. The expected flood reduction percentage of the planned flood is 10% so that the flood discharge quantity to the side channel is 1.28 m^3/sec to the rectangular reservoir and has a volume of 4,608 m^3 which will be fully charged for 1 hour.
4. Extension of detention time for 1 hour when 10% flood discharge plan flows towards the reservoir in the side channel area, will increase the flow time from the control point in Depok to the Manggarai Water Gate to approximately 5 hours.

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