FLOOD REDUCTION ANALYSIS BY USING MULTIPLE DAMS SCENARIO IN KARANG MUMUS RIVER, SAMARINDA

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ABSTRACT

Flooding issues in Samarinda have high depending on the capacity of Karang Mumus river. Considering the ability of Karang Mumus river to drain off flood discharge, there were evidence that the constriction of River will drive to flooding issues, especially in rainy/wet season (October-April). The constriction of river happens because many people build non-permanent houses and building on the river and river banks. Flooding potentially damages to the houses, roads, and other public facilities increasingly. To cope the issue, Government of Samarinda has tried many solutions to overcome the issue by building The Benanga dam and it has been planned to build multiple Dams in Karang Mumus sub-Watershed. This paper aims to analyze the effectiveness of flood control effort using multiple dams scenario in Karang Mumus Sub-Watershed. Analyzing process including hydrology simulation, the relationship between hydrographs and rise of water level simulation in Karang Mumus River. The result of this paper shows water level when peak discharge flows out existing river bank. Analyzing result also shows that flood control scenario is effective to reducing flood discharge until fifty percent compared without existing conditions.

Keywords: Flood, Multiple Dam, River, Samarinda

1.INTRODUCTION

Southeast Asia has long experienced of monsoon climate by dry and wet season (Julien et al. 2010). In the rainy season, rainfall is very high, especially in Kalimantan. Based on data from the Central Bureau of Statistics, Kalimantan region has an annual rainfall of more than 750mm. With high rainfall, it is potentially flooding, especially in most cities in Indonesia. Urbanization also exacerbates flooding problems due to the increased runoff from impervious area. As a result, the sediment transporting capacity of rivers also increases, thus causing major perturbations to river equilibrium (Chang et al. 2005).

Flooding is common issue happened in part of Indonesian area, especially in densely populated area such as urban area (Kodoatie, 2013). Urban flood control can be accomplished through different structural measures that modify the urban basin landscape, such as detention or retention reservoir, infiltration structures, reforestation action, and channel enlargement or implementation, among others (Miguez et al. 2009).

Samarinda one of city in Indonesia (Southeast Asia) with maximum average annual rainfall is more than 2000mm (*Center of Statitics Agency, BPS*), the very intense rainfall of Samarinda have caused frequent floods.

Based on data from the daily *Tribun Kaltim* (2017) stated that the floods inundated many regional points in the city of Samarinda. The height of the flood reaches 50cm. The worst floods are in North Samarinda sub-district, especially along the riverbed of Karang Mumus River located in Gunung Lingai. In the region, the water level is estimated to reach one to 1.5 meters, causing more than 1000 houses to be flooded (Djumena, 2017).

The objective of this paper is to review important issued relative to flood control in Samarinda and to specifically use the Karang Mumus River Flood as an example highlighting key aspect of river flood control by using discharge reduction with multiple dams scenarios.

Figure 1 Flooding at Samarinda (2017)

Samarinda Flooding Issues

Samarinda is the capital of East Borneo Province. flood happens every year especially in rainy/wet season. Based on hydrological conditions, Samarinda influences about 20 Watersheds and Karang Mumus Watershed is the big one. The total area about 365,27 km²

(50,09% from total area of Samarinda) with total length of river about ± 40 km. As the biggest Watershed, Karang Mumus has a lot of issues related to Samarinda's flooding.

Figure 2 Bangkuring Residential Area flooded from Karang Mumus River
Source : <http://www.tribunnews.com> (2017, April)

Figure 3 Samarinda Flooded Area
Source : <http://www.tribunnews.com> (2017, April)

Figure 4 Potential Flooding Area in Karang Mumus Watershed
Source : Ramadhani, Adi (2013)

Issues encompasses about land use change, high rainfall (more than 128mm), topography (relatively flat), lack of drainage systems and decreasing river capacity (caused by river's silting and constriction). River constriction has caused by people living along river bank (people build non-permanent houses and buildings there). In addition, this condition affects decreasing river ability to drain off the discharge.

Figure 5 Existing Condition of Karang Mumus River

To cope the flooding issue, the Government of Samarinda has tried several solutions to overcome the issue such as built the Benanga Dam, plans to build several dams in this watershed and did the several flood control studies like river normalizing and built river embankment. From several solutions, government also have huge problem to implementing the solution, it's because to many resident live in river banks. Based on fact above, the reliable and promises solution to reduce the flood is controlling discharge flows in Karang Mumus River. This paper aims to analyze the effectiveness of discharge control by multiple dams's scenarios to decreasing discharge flows in Karang Mumus river.

2. METHODOLOGY

This research approach includes hydrological analysis and arrangement of the flood reduction scenario. Hydrological analysis includes existing condition and planned condition (SCS Curve Number) and it's done by partial analysis in each sub-Watershed of Karang Mumus.

2.1. Rainfall Analysis

Rainfall in Karang Mumus Watershed has influenced by 3 gauge stations during a recording data periods from 2014-2015. The location and spatial distribution of the rainfall gauges are shown in Figure 6. To analyzes the spatial distribution of rainfall, Thiessen Polygon's map were developed for Karang Mumus Watershed. Thiessen polygon shows the boundaries of influence area of each rainfall measure. Time-series with maximum daily values were created for each rainfall measures. All statistical analysis was performed using 24-hours duration rainfall. The rainfall depth plan has selected by choosing maximum rainfall in several months from each rainfall measures and multiplies with Thiessen Coefficient (C_i)

Figure 6 (a) Karang Mumus Sub Watershed, (b) Rainfall Gauge Station distribution

Analysis of rainfall distribution was performed by using some methods, there are Normal, Gumbel and Log Pearson Type III, its parameters are (Soewarno, 1995):

$$\text{Normal Distribution} \quad : \quad X_{TR} = \bar{X} + K_T \times S \quad (1)$$

$$S = \sqrt{\frac{\sum (X_1 - X_2)^2}{n-1}} \quad (2)$$

$$\text{Gumbel Distribution} \quad : \quad X_{TR} = \bar{X} + S \times \frac{\left(-\ln - \ln \frac{T-1}{T} \right) - Y_n}{S_n} \quad (3)$$

$$\text{Log Pearson Type III} \quad : \quad \log X_{TR} = \log X + K_T \times S \log X \quad (4)$$

Statistical distribution test was performed by using Chi Square and Smirnov-Kolmogorof method. This analysis is done for choosing the suitable rainfall's distribution. Chi Square has used to determine whether the rainfall distribution which is already representing the analyzed data.

$$\text{Chi Square equation} : \chi^2 = \sum_{i=1}^G \frac{(O_i - E_i)^2}{E_i} \quad (5)$$

Meanwhile, Smirnov-Kolmogorof method is non-parametric statistical test. It's used to determine maximum deviation between theoretical distribution and empirical distribution ($D_{\max}$). The Regulation of Smirnov-Kolmogorof test is $D_{\max} < D_{\text{critical}}$.

2.2. Hydrological Analysis

Hydrological modelling analysis was completed using HEC-HMS developed by US Army Corp of Engineers (USACE). The hydrologic model includes basin (Watershed), metrological and elevation-storage data component. The HEC-HMS model incorporates (1) the hydrologic parameter for each sub-Watershed, (2) the rainfall data from historical events, (3) the elevation-storage-discharge data representing dams and storage feature in the sub-Watershed. Figure 7 shows the Karang Mumus's Watershed model setup with symbols representing sub-Watersheds, junctions, reaches, and reservoir.

2.2.1 Basin Data

The Watershed data component used several methods to represent each element in the runoff process. Physical characteristics of Karang Mumus Watershed, literature review and studies helped to determines which methods were selected. The runoff volume element addresses the volume of precipitation that fall on the Watershed and how much infiltrates or becomes runoff. The method for the runoff volume used in the model is the SCS Curve Number with parameters such as initial abstraction, curve numbers, and percentage imperviousness (USACE, 2010).

Initial Abstractin (I_a) equation : $I_a = 0,2 \times S$ (6)

$$S = \frac{25400 - 254(CN)}{(CN)} \quad (7)$$

The direct runoff or transform element addresses in what happens to the water does not infiltrate as it moves over or just beneath the Watershed surface. The transform method used in the hydrologic model is the SCS Unit Hydrograph (UH) with main parameter required is Time Lag. Time lag parameter gets from 0,6tc (E.I. Daniil, S.N. Michaas, 2005). Its Parameter used for calculation of peak hydrograph's time, and automatically SCS Model will arrange ordinates for peak hydrograph and time function.

The reach routing methods simulate the one-dimensional channel flow in the Watershed. Its parameters are (1) length of reach, (2) slopes, (3) channel's shape, and (4) Manning's coefficient. In this paper, Manning coefficient calculation was completed using U.S. Geological Surveys Water Suvey (USGS) which is developed concept proposed by Woody L. Cowan (1956).

$$\text{Manning Coefficient equation } (n) : n = (n_0 + n_1 + n_2 + n_3 + n_4) m_5 \quad (8)$$

2.2.1 Meteorological Data

The hydrologic response of Watershed is driven by the precipitation that falls on the Watershed area. The meteorological data used in the hydrologic analysis included historical rainfall data, and rainfall distribution. In this paper, Karang Mumus Watershed divided into 20 sub-Watersheds and meteorological data inputs based on each rainfall gauges. It's because each sub-Watersheds have different rainfall data.

Rainfall data is entered at intervals of 1 hour and deviation of start and end time based on rainfall duration, which is 6 hours.

2.2.3 Flood Reduction Scenarios

The analysis of flood reduction was performed by analyze the Watershed topographic condition and Government's planning. The Samarinda's Government has been planned several dams in Karang Mumus Watershed. Based on Government's plan, Karang Mumus Watershed has a existing huge dams, named Lampake Dam and will built several new dams to reduce discharge in Karang Mumus River.

Related with explanation above, this paper develop 3 scenarios for flood reduction, there are :

1st Scenario : Normalization existing dams

2nd Scenario : Discharge control using multiple dams, based on Government's plan

3rd Scenario : Discharge control using multiple dams by adding several potential dams

This paper aims to analyze the effectiveness of flood reduction scenarios and find how many percent they can reduce the flood discharge.

3. RESULTS AND DISCUSSION

The result of hydrologic analysis shows discharge of 20 years return period reach out 139,4 m³/s (Figure 8).

Figure 8 Discharge of Karang Mumus Sub-Watershed (Q20)

To calibrate the result of the hydrological analysis, this paper used the hydraulics analysis using HEC-RAS 4.1 software which developed by USACE. The hydraulics analysis has done by controlling water surface at river cross sections after Benanga Dam.

Figure 9 Water surface profile (Q20)

Figure 9 provides evidence that the river not sufficient to drain of the discharge without overflowing. Its because the river cross section has many constriction along river channel.

To reduce the discharge, all scenarios calculation used several junctions (estuaries of sub Watershed) for noticed the changes of discharge reduction.

1st Scenario

The 1st Scenario tries to control discharge with assumes to normalizing the storage of Benanga dam to 2001's capacity.

Figure 10 Area Storage Capacity of Benanga Dam

Figure 11 Comparison of Existing Discharge and 1st Scneario Discharge

Figure 11 shows the result of 1st Scenario calculation is reducing discharge values from 0.31 percent until 13.69 percent from existing discharge.

2nd Scenario

The 2nd scenario was performed the calculation based on Government's plan. It's performed by calculating 6 future dams which separated in several sub-Watersheds. Figure 8 shows the spatial distribution of dams.

Figure 12 Spatial Distribution of Government's Plan Dams

Figure 13 Comparison of Existing Discharge and 2nd Scneario Discharge

Figure 13 shows the result of 2nd scenario, the Government's plan has quite a significant impact for flood discharge reduction. It's has discharge reduction start from 12,50 percent until 59,05 percent in several sub-Watersheds.

3rd Scenario

This scenario set up by adding the potential's dams in Karang Mumus Watershed. The location of potential's dams has been analyzed using existing topographic condition. Its locations shown in Figure 14. There are 4 dams distributed in several sub-Watersheds such as Lubang Putang, Bayur, Siring and Tanah Merah.

Figure 14 Spatial Distribution of Potential Dams

Figure 15 Comparison of Existing Discharge and 3rd Scneario Discharge

Figure 15 shows the result of 3rd scenario calculation reducing the discharge until 59 percent in Junction G (located after Benanga Dam). The average of reducing discharge in 3rd scenario 40.04 percent.

Result of Scenario Calculations

The discharge reduction scenarios were performing significantly. Each scenario has different values to reduce the discharge. It's because each sub-Watershed has different characteristics and topographic condition.

The Figure 16 shows that Government's plan has high effectiveness to reduce discharge. Adding 6 new dams provide high percentage of discharge reduction. Based on analysis, scenarios are very effective in upstream sub-Watershed. It's happen because the middle and downstream area of Karang Mumus Watershed dominated by high value of drainage coefficient (residential, industrial and office complex).

Figure 16 Percentage of Disharge Reduction

Figure 17 Value of Discharge Reduction

4. CONCLUSIONS

Hydrological analysis shows that the discharge runoff occurring in the Karang Mungus Watershed is quite big, is 516.4 m³ / sec. Meanwhile, after simulating hydraulics on the existing river conditions, the results showed that the capacity of the river is not sufficient and overflowing.

The result of flood discharge reduction scenarios analysis in the Karang Mumus Watershed is quite effective. The scenario of reducing flood discharge shows variative value for each sub-Watershed. The reduction value reaches 59 percent leading on certain sub-Watersheds (Sub Watershed after Benanga DAM). The cumulative value of the reduction in each scenario in the last junction (Junction U) is 0.31 percent (1st Scenario), 21.4 percent (2nd Scenario), and 26 percent (3rd Scenario) respectively. From this paper, could use to assist The Government in determining the next flood control measures.

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