Analysis of Bolifar River Flood Protection in East Seram Regency, Indonesia

Agung Tahta Hidayatullah, Farouk Maricar, Rita Tahir Lopa

Abstract: ***Flood is a natural phenomenon that is destructive, both in terms of material and loss of life. Floods can come from overflowing rivers. One of the rivers that often experience a flood is the Bolifar River located in Maluku Province, Indonesia. This study aims to determine the flood discharge, water level and determine the dimension of the embankment as one of the efforts of flood control. The topography measurement of the Bolifar River is conducted, then obtaining rainfall data, watershed characteristics, and soil mechanics examination. The flood discharge is calculated with Hidrograf Unit Synthetic (HSS) Nakayasu method. The return period Q2Tahun = 341,446 m³ / sec, return period Q5Tahun = 433,956 m³ / sec, return period Q10Tahun = 486,583 m³ / sec, and return period Q20Tahun = 521,211 m³ / sec and with hydraulic calculations resulted in a flood water level of 2.6 meters from the river bed. From the calculation result, the dimension of embankment with h = 2.5 meters, width of the embankment = 4 meters, and the slope ratio of 1: 1.5 where the embankment is planned to be stable against bolsters, stable to the soil support force and the slop stability is quite safe.***

Keywords: Embankment, Flood control, HSS, Rainfall, Topography measurement

I. INTRODUCTION

The increase in population and the increasing demands of human interests led to a tendency to use land around the river [1]. Especially in urban areas, many rivers experience a decline in function, narrowing, silting and pollution. Finally, the function of the river has completely changed into a wastewater and garbage disposal site so that the river is polluted, shallow resulting in flooding and other environmental problems [2]. Flooding is a natural phenomenon that is very detrimental, both in terms of material and loss of life. Flooding not only causes rice fields to be inundated and damages housing and settlements, but floods also damage public facilities that can hinder the social and economic activities of the community [3, 4]. The river is one of the aquatic ecosystems which influenced by many factors, both by natural activities and human activities in the watershed [5]. The river is a network of grooves on the surface of the earth that are formed naturally, ranging from small forms in the upstream to large parts in the downstream. Rainwater that falls on the surface of the earth on its way a small portion evaporates and most of it flows in small forms, then into grooves while continuing to collect into one big or main groove. Thus it can be said that the river functions to accommodate rainfall and flow it into the sea.

Flood control is part of a more specific water resource management to control rain and flooding generally through flood control dams or improvement of river water drainage systems and prevention of potentially damaging things by managing land use and flood areas. Thus, reduce the level of risk of threats to the human soul and property due to flooding to the level of tolerance and minimizing the impact of flood disasters[6, 7]. In Indonesia, as many as 5,590 main rivers and 600 of them had the potential to cause flooding. The flood-prone area which covers the main river reaches 1.4 million hectares [8]. Based on these data, Indonesia has a large flood potential so that appropriate flood control methods are needed. One of the rivers in Indonesia that often causes flooding is the Bolifar River. Bolifar River is located in BulaTimur District, East Seram Regency, Maluku Province. The latest data shows that BulaTimur sub-district experienced a flood due to the overflowing of the Bolifar River. (KompasTimur, 2016). Based on interviews with local residents, the Bolifar River often overflows even with low rainfall intensity.

Based on rainfall data, Maluku Province total of 2,108 mm for 1 year with the highest rainfall occurring in June at 718 mm. Rainfall in Maluku Province tends to be high in January to July and December and tends to be low in August to November (Maluku in Figures, 2016). This shows that a high level of rainfall intensity occurs during 8 months a year in Maluku Province. Based on these data indicate that the high rainfall in an area can potentially cause river flooding, so it is expected that further research on flood control in the Bolifar River. Thus this study determines the flood discharge, water level and determines the dimension of the embankment as one of the efforts of flood control.

II. METHODOLOGY

Research conducted is a type of quantitative research and conducted for 2 months in Bolifar River which divides the East Seram Regency from East to West empties into the Banda Sea. To be exact, the study location is in the Bula District, East Seram Regency, Maluku Province at 130 ° 52'0 "and 02 ° 58'0" LS up to 3 ° 32'0 "LS. The data is obtained directly through topographic measurements, while

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for data obtained indirectly are rainfall data, soil mechanics testing and characteristics of watershed data.The Bolifarriver flood discharge plan is used to determine the return period of 2 years, 5 years, 10 years, and 20 years, Bolifar river flood water level, as well as embankment dimensions that can accommodate flood discharge as flood mitigation efforts.

Measurement Tool

The following are some of the tools used in this study,

1. GPS (Global Position System) is used to take the form of a river flow and mark coordinates of the location.
2. Total Station is used for river topography measurement, so that the contour map of the research location is obtained.
3. Digital cameras are used to take pictures of river conditions at the research location.
4. Measurement meter is used to determine the distance of measurement
5. AutoCAD software is used to process the measurement results so that the existing profile is obtained from the research site.

Data Analysis

There are three main data analysis included in this study, namely hydrological analysis, hydraulic analysis and embankment planning.

1. Hydrological Analysis

In hydrological analysis the first step that must be done is to process the existing rainfall data. After that determine the statistical parameters (Sd, Cs, Ck, and Cv) to choose the appropriate rainfall frequency distribution method. The rainfall frequency distribution referred to in this case is the normal method, normal log, type III log pearson, and type I gumbel. After obtaining the rainfall frequency distribution method that fits the criteria, the next step is to test the accuracy of the results of the method by using the Chi Square method and looking for the distribution of hourly rain using the mononobe method. The results are then used to find flood discharge plans with the HSS Nakayasu method.

2. Hydraulics Analysis

In hydraulics analysis the river cross-section is calculated using the Manning formula by trial and error. Based on the data of river width data, the slope of the trough and the base slope of the channel can be determined. The flood water level data is used to calculate the wet cross-sectional area (A), Wet circumference (O) using Autocad software, Hydraulic radius (R), Flowing Speed (V), until it is known flood discharge (Q). From the flood water level figure, it was tried to get the same Q20 flood discharge or decree Q from the hydraulic analysis.

3. Embankment Planning

After knowing the flood water level in the river, the embankment dimension which can effectively control floods can be analyze. The planned embankment must consider the factors such as, the stability of the dike to the forces that work, calculation of Embankment Slope stability, control of shear force, control of soil carrying capacity and control of seepage and leakage.

III. RESULTS AND DISCUSSION

Hydrological data analysis is done based on rainfall data. The rainfall data obtained comes from BMKG Station Geser, Seram Section Timur. From this data, maximum daily rainfall, monthly rainfall and annual rainfall are obtained.

Dispersion Calculation

Dispersion calculation shown in Table1 in the form of calculating standard deviation, coefficient of variation, Skewness coefficient, and Kurtosis coefficient is done to determine the type of rainfall frequency distribution that can be used in processing rainfall data plan.

Table. 1 Average Calculation of Results

Year	Xi	Xi – X	(Xi – X)^2	(Xi – X)^3	(Xi – X)^4
2007	97	-24.89	619.512	-15419.7	383795.24
2008	108	-12.89	192.932	-2679.83	37222.795
2009	73	-48.89	2390.232	-116858	5713209.5
2010	172	50.11	2511.012	125826.8	6305181.8
2011	175	53.11	2820.672	149805.9	7956191.1
2012	97	-24.89	619.512	-15419.7	383795.24
2013	175.3	53.41	2852.628	152358.9	813748.08
2014	127.3	5.41	29.268	158.34	856.622
2015	76.3	-45.59	2078.448	-94756.4	4319946.5
2016	118	-3.89	15.132	-58.864	228.98
Total	**1218.9**	**1**	**14129.35**	**182957**	**25914176**

Calculation of Maximum Rainfall with Type III Log Person Method

Table 2 tabulates the calculation of Type III Log Person is used to analyze the rain plan. This method has been calculated for the average value (X) and Standard Deviation (S), for the value of K (Type III Log Person coefficient, $Xt=X+K.Sx$).

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Table. 2 Calculation of Maximum Rainfall for Period Return Type III Log Person Method

Return Period	K	X	S	Xt(mm)
2	-0.067	121.890	39.622	119.218
5	0.815			154.195
10	1.318			174.093
20	1.692			187.185

Chi Squared Alignment Test

Table. 3 Calculation of the Chi Square Method

Each Class's Limit Value	*Ei*	*oi*	*(oi−ei)*	$(oi-ei)^2 / Ei$
175.3 < Xi < 154.840	2	3	1	0.5
154.840 < Xi < 134.380	2	0	-2	2
134.380 < Xi < 113.920	2	2	0	0
113.920 < Xi < 93.460	2	3	1	0.5
93.460 < Xi < 73.000	2	2	0	0
Total	10	10	0	3
Chi Square (c^2) = 3				

Degree of Freedom, $Dk = G - (R + 1)$, while (R = 1 for Dist. Log Person Type III), thus $Dk = 5 - (1 + 1) = 3$

Based on Chi-Square values for Dk = 2, using significanceα = 0.05, the Critical Chi-Square value is 7.81. The results of the calculation above obtained Chi Square <Chi Critical = 3 <7.81 so it can be concluded that the Distribution of Type III Log Person meets the requirements.

Calculation of the Flood Hydrograph of the Nakayasu HSS Method Design

The calculation of the design flood hydrograph with the HSS Nakayasu method is carried out in several stages of calculation. First is calculation of the average calculation of rain from the beginning to the T-hour and follow by calculation of Effective Rainfall (Rn). The obtained effective rainfall distribution for hours is shown in Table 4. Figure 1 illustrates the Nakayasu HSS Hydrograph Ordinate Chart which indicates that the peak discharge is at 5.336 and occurs in the third hour.

Table. 4 Effective Rainfall Distributions for Hours

Clock to (Tr)	Rt	Effective Rainfall (Rn) (mm)			
		95.374	**123.356**	**139.274**	**149.748**
1	0.550 Rn	52.486	67.885	76.646	82.410
2	0.143 Rn	13.642	17.645	19.922	21.420
3	0.100 Rn	9.570	12.377	13.975	15.026
4	0.080 Rn	7.618	9.854	11.125	11.962
5	0.067 Rn	6.434	8.321	9.395	10.101
6	0.059 Rn	5.624	7.274	8.212	8.830

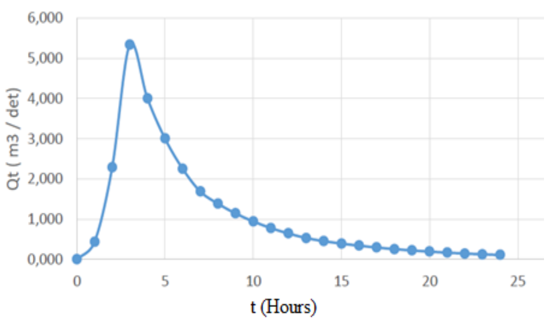

Fig. 1 Nakayasu HSS Hydrograph Ordinate Chart

Calculation of Water Flow Rate on the River

Calculation of river flow rate, calculated using the Manning formula by trial and error. It is assumed that the slope of the river wall follows the Trapezoidal shape.From the picture of the river situation, it is planned that the width of the river bed for the straight flow section is 110m, Slope of the talud1: 2, Base slope of channel 0.005with trial and error h taken 2 meters.

In the calculation of Wet Crossing Area (A) and Length around Wet Roving (O) is executed from AutoCAD. Where in the flood water level of 2 m, the Wet Crossing Area is 186 m2 and the Wet Roving Length is 223 m. the calculation of section size is tabulated in Table 5. Based on Table 5, the result of water level that is estimated to be able to accommodate Q20 flood discharge is 3 meters, where the flood discharge that can be accommodated is 522.997 m / sec. The embankment planning data:

- Depth of planned flood water = 3 meters
- The width of the embankment levees = 4 meters

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- Safety height = 1 meter
- Height of embankment = 2.5 meters
- Deep slope = 1: 1.5
- Outdoor slope = 1: 1.5

Table 5. Calculation of Section Size

Water Level	Wet Crossing Area	Traveling Wet	Manning Coefficient	Hydraulic Radius	Channel Slope	Flow Speed	Flood discharge
h(m)	**A(m2)**	**O (m)**	**N**	**R (m)**	**I**	**m/sec**	**m3/sec**
1	67	206	0,035	0,325	0,005	0,955	6,401,722
1,5	119	222	0,035	0,536	0,005	1,333	1,586,451
1,65	134	222	0,035	0,603	0,005	1,442	1,933,554
2	186	223	0,035	0,834	0,005	1,790	3,329,676
3	243	221	0,035	1,099	0,005	2,152	522,997

Dike Stability Control

Embankment stability control is one of the important stages for embankment development.The stability of the embankment for the forces acting on the embankment will be reviewed if the embankment is considered to be able to roll over, assuming that the embankment's body is a whole, the forces that work on the embankment and are dangerous to bolsters are Style due to own weight, Hydostatic pressure and Earthquakes. Figure 2 shows the schematic diagram of the embankment and Table 6 tabulates the results of moments working on the embankment.

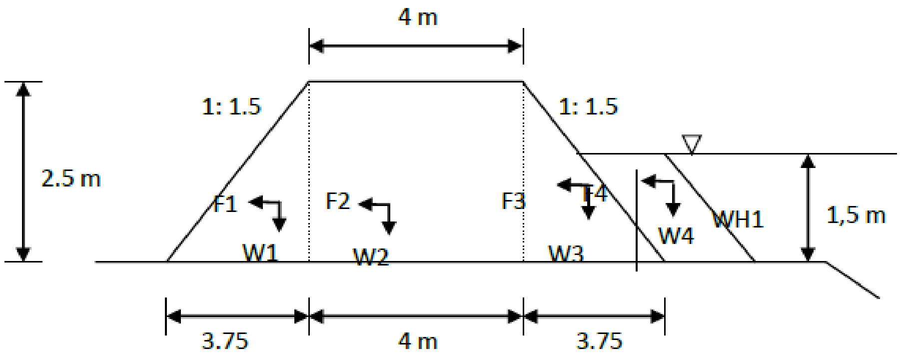

Fig. 2 Schematic diagram of the embankment

Table. 6 Calculation of Moments working on the embankment

Style (t / m)	distance (m)	moment (tm)
Due to own weight		
W1 = 9,375	x = 2,50	23,437
W2=20,00	x = 5,75	115
W3=9,375	x = 9,00	84,375
Due to Hydrostatic Style		
W4=1,68	x = 10,75	18,06
WH = 1,125	y = 0.5	0,562
Due to Earthquake Load		
F1 = 2,343	y = 0,833	0,285
F2 = 5,00	y = 1,25	6.25
F3 = 2,343	y = 0,833	1,951
F4 = 0,42	y = 1,667	0.700

Control of Bolster Stability
Total Resistance Moment = 240.87
Moment of Total Bolt = 9,186 Security Figures (FK)
= 240,87/9,186 = 26,221> 1,5……………..(Safe)
Calculation of Embankment Slope Stability
Requirements for embankment stability where Fs> 1.20
Using the Taylor stability chart
I = 26.5 °, ϕ = 15 °, Ns = 0,035
Fs = 87,571>8,571 > 1,2……………..(Safe)

Control of shear force
For the calculation of the shear force on the embankment where the safety factor is> 1.2
$Fk = \Sigma V.f \,/\, \Sigma H$
Where f = shear coefficient = (40.48 x 0.6) / 10,106
= 2,4> 1,2……………..(Safe)

IV. CONCLUSION

Following are the results of the analysis of the Bolifar River Flood Protection in East Seram Regency, it can be concluded that:

1. The results of the calculation of flood discharge with the Nakayasu Synthetic Unit Hydrograph (HSS) method is the return period Q2 Year = 341,446 m^3 / second, the return period Q5 Year = 433,956 m^3 / second, the return period Q10 Year = 486,583 m^3 / second, and the return period Q20 Year = 521,211 m^3 / second.
2. The results of calculation of river hydraulics produce a flood water level of 3 meters from the river bed.
3. From the calculation results obtained dimensions of embankment with h = 2.5 meters, width of the embankment = 4 meters, and slope with a ratio of 1: 1.5 where the planned embankment is stable against bolsters, stable to ground support force and sufficient slope stability secure.

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REFERENCES

1. Bappenas. 2008. KebijakanPenanggulanganBanjir di Indonesia.
2. Kodoatie, Robert J., dkk. 2002. BANJIR. PustakaPelajar : Yogyakarta.
3. A. Pauliková and O. Železník, "Multicriterial analysis of factors considering intensity and extent of floods," Proceedings of the 2014 15th International Carpathian Control Conference (ICCC), VelkeKarlovice, 2014, pp. 418-423.
4. P. Yingchun, "Quantitative research of urban flood-protection project to the added value of real estate: Based on Intervel-valued instuitionistic fuzzy sets theory," 2011 International Conference on Consumer Electronics, Communications and Networks (CECNet), XianNing, 2011, pp. 5142-5147.
5. Zhang Hongbo, Shi Jianjun, Xin Chen and Gao Fan, "Variation trends analysis and its ecological impact of sediment discharge in the mainstream of the Yellow River," 2011 International Symposium on Water Resource and Environmental Protection, Xi'an, 2011, pp. 1124-1127.
6. Sen Du, "Hydrological analysis of urban flood control planning," 2012 International Symposium on Geomatics for Integrated Water Resource Management, Lanzhou, 2012, pp. 1-4.
7. Liu Tao, Zhang Zijian, ZongXianguo, "Influence of sediment from Yellow River on aquatic ecosystems of rivers in Lubei Plain", Journal of China Hydrology, vol. 28, pp. 77-79, 2008.
8. N L Poff, J D Allan, M A Palmer et al., "River flows and water wars: emerging science for environmental decision making", Frontiers in Ecology and the Environment, vol. 1, pp. 298-306, 2003.