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Analysis of Batang Kandis River Capacity With Variation of Design Flood Discharge

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***Abstract*—Batang Kandis River was located at Padang Pariaman Regency, West Sumatra Province. This river is one of the rivers that empties into the Batang Anai river, one of the large river that empties into the Indian Ocean. Location of this river is important because could resulting flood that can impacted on Minangkabau International Airport (BIM) environment and Padang city also. Flood that was occurred generally caused by exceeding of maximum flow at Bank full Capacity. In this study, a review will be carried out on the ability of river cross capacity to flood discharge. HEC RAS simulation was carried out with the upstream condition is flood discharge and tidal water elevation as the downstream condition. Study using discharge for a 10-year return period (524.42 m3 / s) and a 25-year return period (593.76 m3 / s) show flood overtopping along the river. Flooding due to velocity decrease caused by river meandering and influence of sea water intrusion. Modeling using unsteady flow can be done to see tidal propagation towards the river. Alternatives of river straightening can be simulated to see the changes in flow characteristics that occur and their impact on increasing discharge to the sea.**

Keywords*—flood, batang kandis, bank full capacity, numerical simulation

I. INTRODUCTION

Batang Kandis River was located in the Padang Pariaman Regency, West Sumatra Province. This one of the rivers that empties into the Batang Anai river, the large rivers that empties into the Indian Ocean (Indonesian Ocean). Batang Kandis have important position cause the overtopping of this one will resulting flood disaster can have an impact to Minangkabau International Airport (BIM) and also Padang city. One of the keys to overcoming this flood disaster is to normalize the river. In 2001 the flood control plan for Batang Anai and Batang Kandis was initiated, which was stated in the Anai-Kandis River Improvement. The Batang Anai and Batang Kandis flood control alternatives offered in the Anai- Kandis River Improvement planning report [1] are structural alternatives in the form of improvements to the flow and appearance as well as treatment that aims to reduce the peak discharge from the upstream [2].

Normalization effort was carried out by planning a 500 m river alignment, and a 700 m long dike to left of river flow and a 300 m floodway. Engineering that carried out on rivers environment will change character of the flow that occurs.

Fig. 1. Batang Kandis River and several flood spots.

Fig. 2. Batang Kandis River Floodway.

Several previous researchers have conducted studies on flood control efforts. Dalrino, et al [3] conducted a numerical modelling study of the flow patterns in the Batang Mahat river. Flow rate used in the model was obtained from the results of hydrological analysis based on daily rainfall data in the Batang Mahat sub-watershed. Result show that locations with increasing riverbed elevations tend to provide potential for flooding and inundation in the area. Batang Sumani flood control against three types of scenarios simulation, namely existing, widening and short cut conditions was conducted [4]. The results show that flooding is still occurring at several points in the whole scenario. Investigated the influence of El Nino was studied [5]. Study used satellite and ground monitoring systems, namely rainfall and water levels. Satellite data such as DEM (Digital Elevation Model) are used to track river networks. Study with GIS to estimating the potential of land sedimentation and river flow has been carried out [6]. The topic was to investigating the effect of rainfall anomaly caused by global warming to the Pangkalan flood event. SRTM data was used and overlaying with DEM topographical data to resulting discharge prediction that used later to HEC RAS simulation. Validation was conducted by fitting the simulation result with field data. Flood inundation simulations were also carried out in the Cilemer river channel using the Digital Elevation Model (DEM) Data [7]. Results showed variations in flood runoff above the embankment to the flood inundation area for several return periods. Analysis of the economic embankment as a flood control building for the Cihaur river, Central Java using a flood discharge for a return period of 2 years, 5 years, 10 years, 20 years, 25 years, 50 years and 100 years have been carried out. Study was carried out by considering the cost of embankments, risks and annual operations. Results showed that economic dykes were obtained when the flood discharge was planned for a 10-year return period [8]. Evaluation of land use changes in the Batang Kandis watershed has been carried out [9]. The study was conducted by comparing the land use conditions in 1985, 2004 and the Padang City Urban Land use Plan (RTRW) 2013. This study showed an increase in peak discharge by 11.28% due to changes in land use conditions from 1985 to land conditions in 2004, as well as 36.92% if the land use conditions are realized according to the 2013 RTRW of Padang City. The study also indicates a water level elevation of 25% -39% in river flow conditions with flood control designs. Flood events are generally caused by exceeding the maximum river flow cross-sectional conditions (Bank full Capacity). In this study, review will be carried out on ability of cross-sectional capacity of river according to design discharge that determined.

II. Methodology

Model was carried out to obtain an overview of flow profile so that can be determined the capacity of the river face capacity to flow design discharge. Hydrological analysis was carried out on rainfall data for 9 years (2009 - 2017) at 3 rainfall posts, namely Batu Gadang, Kasang and Khatib Sulaiman posts. Location of the rainfall station for the Batang Kandis Sub-watershed was shown in Figure 3 and Figure 4. Average rainfall for the Batang Kandis Sub-watershed was carried out using Thiessen polygon method, as resulted in Table I.

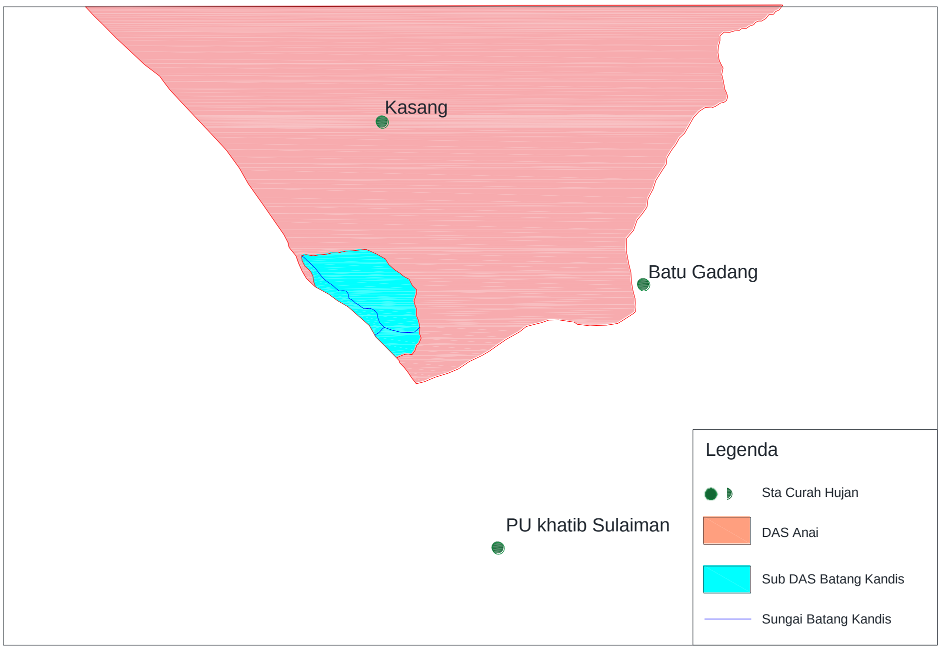

Fig. 3. Location of rainfall station at Batang Kandis sub-watershed.

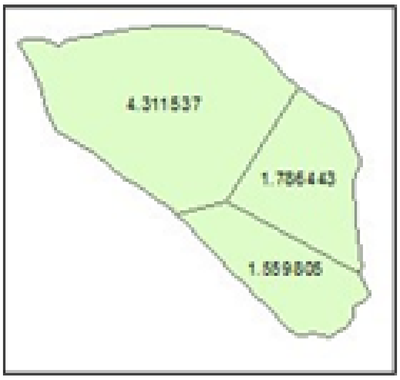

Fig. 4. Influence area of rainfall station on the area of Batang Kandis sub-watershed using Thiessen polygon method.

Limited rainfall data (< 20 years), can result in too large a deviation if the calculation of design flood discharge was carried out using the probability analysis method. On the other hand, data on the amount of discharge in the river is also not available due to the absence of AWLR (Automatic Water Level Recorder). To overcome this problem, design flood discharge was determined by the synthetic unit hydrograph method. Hydrograph can be described as a graphical representation of one of the flow elements with time. The hydrograph shows the watershed's overall response to certain inputs according to the nature of watershed in question [10].

TABLE I. MAXIMUM DAILY RAINFALL FOR EACH STATION

No	Year	Batu Gadang (mm)	Khatib Sulaiman (mm)	Kasang (mm)	Average Rainfall (mm)
1	2017	192	195	162	175.72
2	2016	110	270	294	246.19
3	2015	128.3	206	173	169.29
4	2014	140	100	194	162.26
5	2013	155	128	193	170.90
6	2012	125	145	157	147.09
7	2011	80	200	200	172.01
8	2010	170	220	260	230.86
9	2009	150	160	240	202.71

For the Batang Anai watershed, Snyder Synthetic Unit Hydrograph (HSS) was found to be compatible with the peak time value approach [11], so it is further used in this study. The value of the discharge quantity obtained is the upstream boundary condition of model with downstream boundary conditions of sea level fluctuation due to tides.

Hydraulic analysis was carried out to determine capacity of river to the ability of flow rate drain. The hydraulic aspects that will be studied in this case are the cross-sectional capacity of the river at the Batang Kandis and Muara Baru Kandis sections and the flood water level at design flood discharge Q10 and Q25.

Fig. 5. Batang Kandis river layout.

Model schematic was depicted on the geometric data in the form of coordinates with the number of coordinates on the three segments being 158 points. The roughness of the manning used for the Left Over Bank (LOB) and Right Over Bank (ROB) were 0.06 , the reason was because the sides are still in natural condition with the presence of trees. Meanwhile, the Main channel is set at 0.07 because in this section the flow is slow, the river is deep and close to the river mouth. Simulation was carried out to determine the impact of the flood overflow on the same discharge in each river segment which is influenced by the high tide which is considered constant so that permanent flow modeling (Steady Flow) was used. Modeling scheme layout was shown in Figure 5. Validation was carried out by comparing the simulation results with field conditions related to flood height on March 22, 2018. Based on discharge calculations rain data on March 22, 2018 by Hydrological Unit Balai Wilayah Sungai Sumatera V, the estimated discharge amount is 523 m3 / s. This value will then be validated with design flood discharge from the calculation of the 10 year return period. The water surface profile is calculated from a cross section of the channel to the next by solving the energy conservation equation using an interactive procedure called the Standard Step Method. The energy conservation equation is written as follows:

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad (1)$$

Where Y is water depth in cross section, Z is elevation on the main channel, V is average speed (total number of discharges), α is high coefficient of velocity and he is energy loss.

The energy loss between two cross-sections results from energy loss due to friction and expansion or contraction. The equation for the high energy loss is written as follows:

$$h_e = L\bar{S}_f + C\left[\frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g}\right] \qquad (2)$$

Where L is the distance along the span under consideration, Sf is the friction slope between two cross sections, C is the coefficient of expansion or contraction.

The distance along the span under consideration, L, is calculated by the equation:

$$L = \frac{L_{lob}\overline{Q}_{lob} + L_{ch}\overline{Q}_{ch} + L_{rob}\overline{Q}_{rob}}{\overline{Q}_{lob} + \overline{Q}_{ch} + \overline{Q}_{rob}} \qquad (3)$$

Where Llob, Lch, Lrob is the distance along the cross section of the stream observed on the left overbank (lob), main channel (ch), and right overbank (rob). Qlob, Qch, and Qrob is the discharge along the cross section of the stream observed on the left bank of the river (lob), the main channel (ch), and the right bank of the river (rob).

Determining the total flow distribution and velocity coefficient for a cross section requires dividing the flow into units so that the velocity is evenly distributed. The approach used was divide the flow area at the edge of a channel or river by using the input value of n in the cross section where the value of n changes as the basis for division. The distribution/ flow is calculated in each subsection of the following form of the Manning equation:

$$Q = KS_f^{1/2} \text{ and } K = \frac{1{,}486}{n} AR^{2/3} \qquad (4)$$

Where K is the distribution for a subsection, n is Manning roughness coefficient for the subsection, A is the area of flow in the subsection and R is the hydraulic radius of the subsection. Additional distribution on the edge of the channel was added to get the distribution on the left and right of the river bank. The main channel dispensing is calculated in the usual way as a one-channel dispensing. The total amount of distribution can be obtained by adding up the three sub-sections of distribution, namely the left side of the river bank, the main channel, and the right sub-section of the river bank.

III. Results and Discussion

The results of the calculation of design flood discharge for the 10 year return period get a discharge amount of 524.42 m3/ s, while for the 25 year return period it is 593.76 m3 / s. The results of this calculation have a difference of about 1.42 m3 /s close to the conditions in the field when the flood occurred on March 22 2018 (return period of 10 years) so that it can be used as a reference in the simulation in each scenario of the 10 year and 25 year return period. The simulation results using flood discharge data for a 10-year return period (524.42 m3 / s) and a 25-year return period (593.76 m3 / s) are shown in Figure 6 , 7, 8, 9 and Table II. Analysis showing that flood overflow along the river and new estuaries in both Q10 and Q25. Result that compared with Q50 and Q100 show flooding that indicated along the river but with no location spot and maximum overtopping height clearly [2]. Table II show the number of overtopping spot and its maximum height. The results show that flooding at some of these locations is likely due to flow slowdown due to river meandering morphology and the influence of sea water intrusion due to tides. Areas that experiencing flow slowdown, it will cause mass water to accumulate, that causing overtopping. This problem can be overcome by speeding up the flow that reducing some of the causing of slowdown. River normalization by increasing of river width and depth also can be a suggestion to overcome these impacts. On the other hand, increasing the flow rate can also be done by straightening the river [1,2]. However, it must take into account elevation difference in between of upstream and downstream of the straightened river section. Flow slowing will also greatly affect the occurrence of sedimentation, especially at river bends. The sedimentation that occurs will result in a narrowing of the river channel so that capacity of river cannot serving of the flow that passes through it. This condition causes overtopping in several river segments, especially before the river deflection.

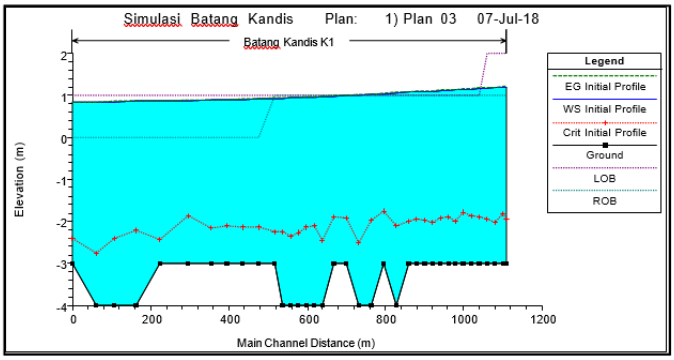

Fig. 6. Longitudinal Batang Kandis river and its water surface level using design flood discharge Q.10.

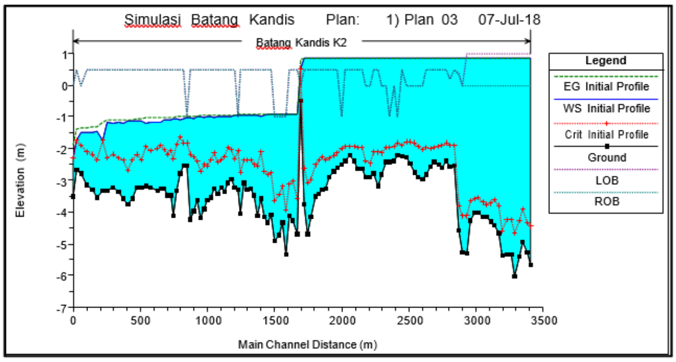

Fig. 7. Longitudinal Batang Kandis river and its water surface level using design flood discharge Q.25.

Modeling using unsteady flow conditions can be done to see an overview of the tidal wave propagation towards the river flow. Alternatives of river straightening can be simulated to see changes in flow characteristics that occur and their impact on increasing discharge to the sea. Determination of the design flood discharge value used in this model is a theoretical discharge prediction where the validity method for field flood events can still be developed further.

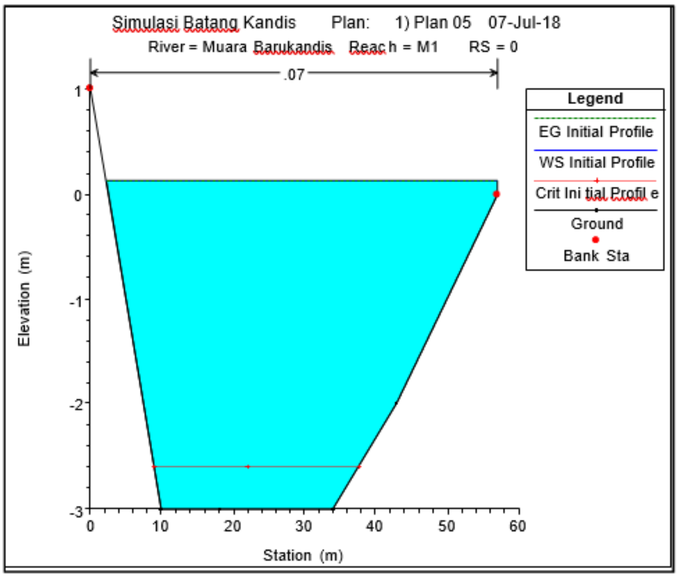

Fig. 8. Cross-section of Batang Kandis river and its water surface level using design flood discharge Q.25.

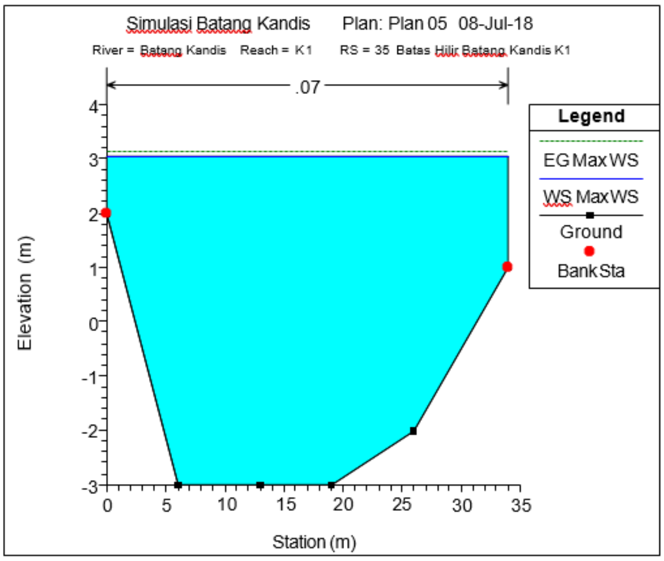

Fig. 9. Cross-section of Batang Kandis river and its water surface level using design flood discharge Q.25.

TABLE II. SIMULATION RESULTS

Return Period	Q(m^3/s)	Number of Overtopping Spot	Maximum overtopping height from river berm (m)
Q10	157,33	98	0,8
Q25	178,13	147	1

IV. CONCLUSION

This study is a preliminary study of the existing conditions of the Batang Kandis river in the review of the flood discharge plans Q10 and Q25. From the simulation results it can be concluded that the addition of a new estuary (floodway) which is intended to dispose of the flood discharge quickly towards the sea has not been able to completely eliminate the floods that have occurred. The construction of embankments along the river which is a flood spot can also be recommended. Alternatives to river straightening can be simulated further to see changes in flow characteristics and their impact on increasing discharge to the sea in the context of flood control. Determination of design flood discharge value used in this model is a theoretical discharge prediction where the validity method for field flood events can still be developed further.

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