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THE EFFECTS OF BATANG KANDIS RIVER FLOOD CONTROL IN PADANG CITY-PALAPA METROPOLITAN URBAN AREA

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ABSTRACT: Floods often occur in Lubuk Buaya residential housing in Padang city, which has a population of 6,500 citizens per km^2. These natural phenomena happen due to sea level water rises and the change in the new river mouth of the Batang Kandis river. The construction of a 500 m floodway and a 700 m dike of Batang Kandis river were proposed to control flooding. The floodway was then damaged during the earthquake on September 30th, 2009, and wiped out by a flood on March 24th, 2016. Theoretically, to solve flood conditions downstream of Batang Kandis river with 70 km² of watershed area, the floodway is expected to be able to discharge 307 m^3/s. This study uses a numerical simulation using HEC-RAS software with three scenarios. The first scenario uses the existing condition of the river width of 50 m and a depth of 1 m, it experienced an inundated area of 0.60 km^2 for 5 hours. The second scenario is done by increasing 2.50 m embankment height, which gave the result of 2x700 m^2 flood inundation in several locations. The third scenario also carried out dredging of the river up to the elevation of 0.00 m above sea level, and there was no flood inundation. Thus, the third scenario is the best result that has been carried out to control the floods downstream of Batang Kandis river.

Keywords: Inundation area, Floodway, River mouth, Simulations.

1. INTRODUCTION

Structural flood control has long been carried out in the city of Padang in the Padang Metropolitan Urban Area, Lubuk Alung and Pariaman (abbreviated as Palapa Metropolitan Area). This activity began in the Dutch era, which was marked by the construction of the Banda Bakali river. This activity was carried out to divert a portion of the flow from the Batang Arau river which passed the Padang City trade center at that time.

Given the frequent occurrence of floods in the city of Padang, a more comprehensive study was conducted for flood prevention in 1983. This study was conducted by JICA (Japan International Cooperation Agency) under the name of the Padang Area Flood Control Project. This activity aims to conduct in-depth studies on flood control, drainage plans, and feasibility studies to identify and prioritize actions to be immediately implemented. The results of this study are the basis for flood control projects in the city of Padang [1].

Some of the activities that have been carried out for flood control in the city of Padang include the normalization of Canal Floods (Banda Bakali river) and the Batang Arau River in 1992-1997; normalization of the Batang Kuranji river, the Air Dingin river (widening, deepening and strengthening of concrete cliffs) and repairing the Padang coast in 1997-2001 [2] [3].

Pinang Bungkuk area in Lubuk Buaya Village, Padang City with a population density of 6,500 people per km^2 is an area that is often flooded. High rainfall and rising sea levels cause natural flood events at the confluence of the Batang Kandis river and the Batang Kasang river. The possibility of flooding, together with the construction of the Batang Kandis River floodway, can increase the risk of tidal flooding in the lowlands around the new inlet in Pinang Bungkuk with a distance of about 500 m upstream of the new inlet of the Batang Kandis river.

The flood control effort that has been carried out in the construction of a 500 m sea floodway and embankment at approximately 700 m to the left of the Batang Kandis river flow. The floodway condition was severely damaged by the 7.9 Richter scale earthquake on September 30th, 2009, and flooding on March 24th, 2016. To overcome the flooding that occurred in the lower reaches of the Batang Kandis river with a 70 km² river basin area, rehabilitation is being conducted on the floodways with numerical simulations using HEC-RAS software so that later it is expected that the river can discharge as much as 307 m^3/s.

The catchment area of Batang Kandis is located in the Koto Tangah sub-district of Padang city. The upstream part of the Batang Kandis river originates from the western part of Bukit Barisan (elevation +1.249 m) and has a catchment area of 56 km². The old Batang Kandis river flows westward through new residential areas and then joins the Batang Kasang river which has a catchment area of 14 km² in the area of Pasir Jambak village. The figure below shows the location of the latest Batang Kandis river estuary and the location of the research area.

Fig. 1 Location of Batang Kandis River.

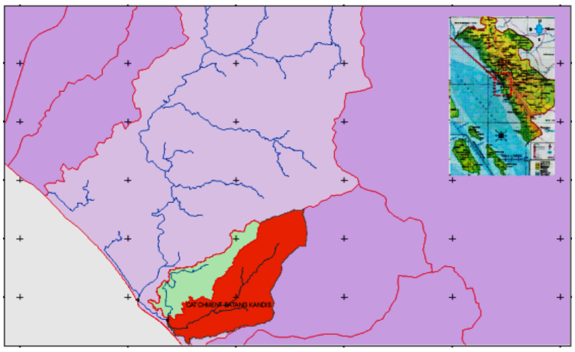

Fig. 2 Area of study in Batang Kandis river.

2. LITERATURE REVIEW

Corry Eriza [4] examined the alternative performance of the flood control of the Batang Anai river and Batang Kandis river in West Sumatra. The study aims to review various alternatives in planning the control of the floods of the Batang Anai river and Batang Kandis river over the current condition of the watershed. His research uses the HEC-RAS (Hydrological Engineering Center, River Analysis System) with three alternatives which were based on data availability. Alternative 1 requires the repair of grooves and widening of the face (with embankments) in both rivers and the addition of floodways on the Batang Kandis river. Alternative 2 is similar to Alternative 1, except for the removal of dikes on the Batang Anai river and additional sluices on the Batang Kandis river. Alternative 3 for the Batang Anai river is similar to Alternative 2, and the appearance along the Batang Kandis river is widened. The analysis includes calculation of the flow adequacy inflowing the design and analysis of sediment transport for the best performance alternatives. From the three alternatives, the best alternative was found as alternative 3 because it was able to drain the design discharge Q_{50} (1471 m^3/s) on the Batang Anai river and Q_{25} (293 m^3/s) on the Batang Kandis river. Sediment transport simulation on the Batang Anai river with the application of Alternative 3 shows the most significant trend of erosion and deposition in a location next to the National Bridge downstream.

The narrowing of the river channel accompanied by siltation and sediment accumulation causes the volume of the plan to be incompatible with the coming discharge, as a result when the rainy season comes there is some runoff and flooding can no longer be overcome.

Simulations with HEC-RAS are also used to review the flow of the Cilember river in West Java, also in Segamat town, Malaysia and on the Batang Takung Sijunjung river, West Sumatra [5] - [7]. Based on the simulation results using HEC-RAS software in the Cilember river in West Java, the overflow of Cilember River clearly influences the inundation height on Jalan General H. Amir Machmud which connects the city of Bandung and the city of Cimahi.

2.1 Hydraulics Analysis

The approach performed by HEC-RAS is to divide the cross-sectional area based on the value of n (Manning roughness coefficient) as the basis for cross-section distribution. Each flow that occurs is calculated using the Manning equation.

$$Q = A \times \left(\frac{1}{n}.\ R^{2/3}.\ S^{1/2}\right) \quad (1)$$

Where :

Q: discharge (m^3/s)

n: manning roughness coefficient

A: cross-section area (m^2)

R: hydraulic radius (m)

S: energy slack.

For steady flow in the HEC-RAS device, energy equations are used except in places where the depth of flow exceeds the critical depth [8]. The energy equation between two cross-sections is as follows:

$$Y_2 + Z_2 + \frac{\alpha_2 v_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 v_1^2}{2g} + h_e \quad (2)$$

Where :

Y_1, Y_2: flow depth (m)

Z_1, Z_2: channel base elevation (m)

V_1, V_2: average speed (m/s)

α_1, α_2 : speed coefficient

g: gravity acceleration (m/s^2)

h_e: lost energy (m)

2.2 Modeling with HEC-RAS

Analysis of the existing cross-section using HEC-RAS aims to determine the condition of the actual river (existing) and water level profile during a flood. HEC-RAS software is integrated with graphical user interfaces, hydraulic analysis, management and data storage, graphics, and reporting.

a. Graphical User Interface is the link between users and HEC-RAS. Things that can be done using this feature include file management, inputting and editing data, doing hydraulic analysis, displaying input data and analysis results in the form of tables and graphs, preparing reports and accessing online help.
b. Hydraulics analysis. The hydraulic analysis provided includes two analyses, namely, steady flow, and unsteady flow.
c. Data storage and data management. Storage of input data in HEC-RAS can be grouped into projects, plans, geometry, steady flow, unsteady flow, and sediment data.
d. Graphs and reporting. The graphics facilities provided by HEC-RAS include X-Y river flow graphs, cross-views, curves rating, hydrographs, and other graphs which are X-Y plots of various hydraulic variables.

3. RESEARCH METHODOLOGY

This study is conducted in the following stages:

a. Collected data on bathymetry maps and discharge data for the Batang Kandis river obtained from the Sumatra V River Basin Office [8].
b. Calculated speed using the Manning formula
c. Calculated debit using the Rational formula
d. Conducted simulation in HEC-RAS by plotting previously calculated data and inputting existing river flow and geometry data.
e. Compared the results of the calculation of the bathymetry measurement data so that the inundation height is obtained based on the measurement data and the results of running the application.
f. Identified flood control efforts towards the opening of a new estuary on the Batang Kandis river.

4. RESULTS AND DISCUSSION

In this research, we developed three scenarios of flood simulation as described below. We set up benchmark stations along the rivers, abbreviated as BKS for Batang Kandis river and BKSG for Batang Kasang river.

4.1 Scenario 1: existing conditions

The simulation results of scenario 1 are for conditions that do not experience flooding starting from the downstream, namely BKS 0 to BKS 4A along 315 m (from the new estuary of the Batang Kandis river to the meeting with the Batang Kasang river) and BKS 4 to BKS 10 along 562 m (the existence of flood dam buildings built in the 2007 and 2008 fiscal years), while the other parts are generally affected by the flood inundation of the Batang Kandis and Batang Kasang rivers [9]. The following are examples of the existing conditions of the flow that did not occur with flooding.

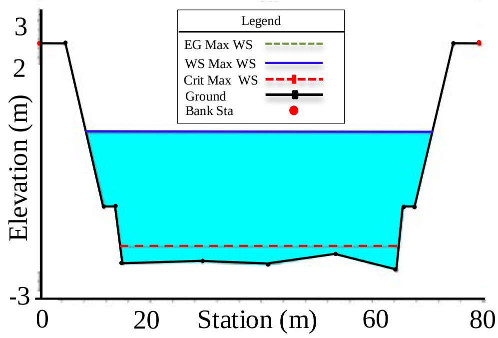

Fig. 3 BKS 0 (no flooding occurs)

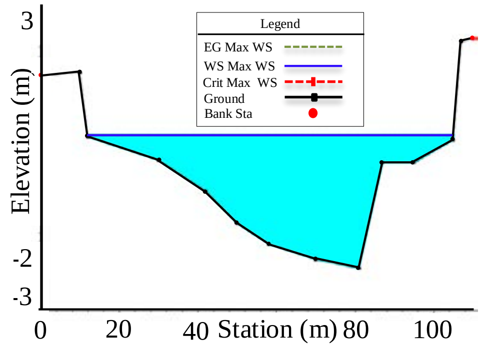

Fig. 4 BKS 1 (no flooding occurs)

The following is an example of the existing conditions of the flow that occurred in flood runoff.

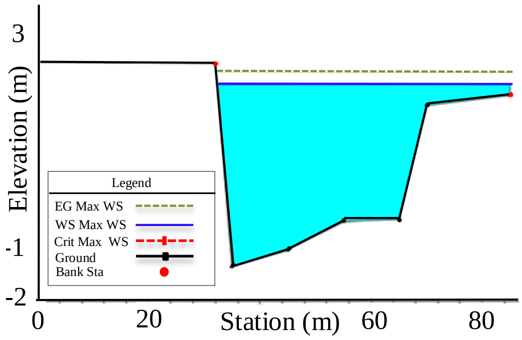

Fig. 5 BKS 16 (in the left part of the flow there is a flood)

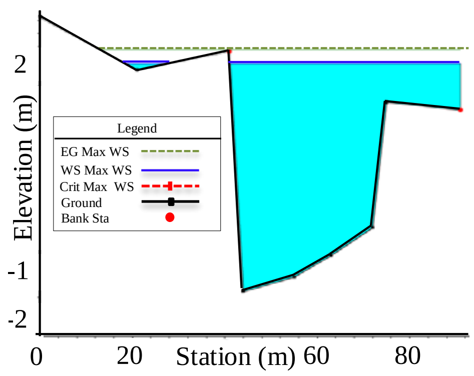

Fig. 6 BKS 17 (on the left side of the flow there is a flood)

4.2 Scenario 2: given the left and right embankments of the flow without any river dredging or flowing

Scenario 2 is simulated by installing embankments on flood banks. At the flood point, embankments were made both on the banks of the river's left-hand flood, the riverbanks of the right-hand floods and the two floodplains by the conditions of the flooding. From the simulation results of scenario 2 it can be seen that from BKS station 0 to BKS 13 along 1,227 m Batang Kandis river and BKSG 1 to BKSG 6 along 491 m Batang Kasang river there is no flood inundation; while at BKS station 14 to 17 BKS along 250 m of the Batang Kandis river is still flooded, this is caused by the inadequate cross-section of the river to pass the flood discharge of the Batang Kandis river. The following is an example of the existing conditions of the flow that did not occur with flooding.

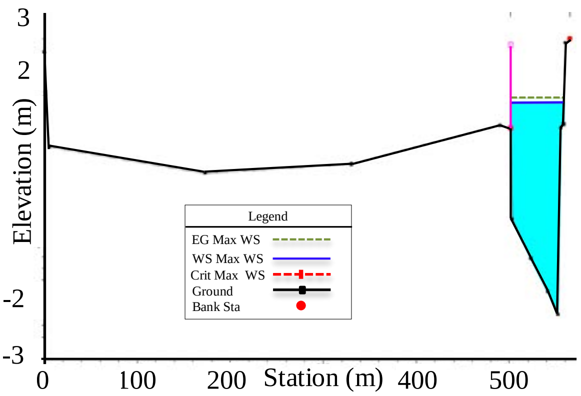

Fig. 7 BKS 6 (no flooding occurs)

The following is an example of the existing conditions of the flow that occurred in flood runoff.

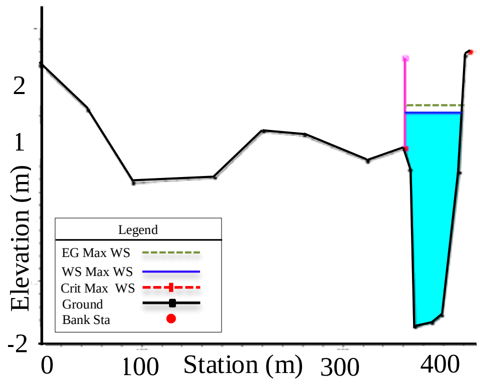

Fig. 8 BKS 10 (no flooding occurs)

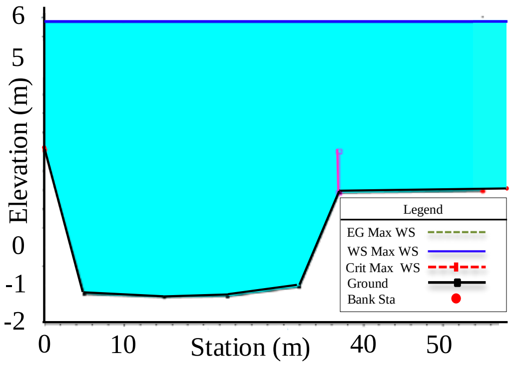

Fig. 9 BKS 15 (flood inundation in the upstream part)

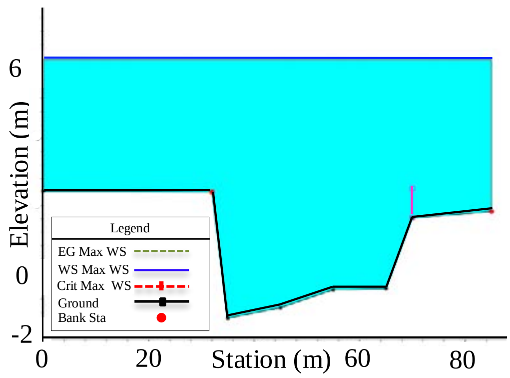

Fig. 10 BKS 16 (flood inundation in the upstream part)

4.3 Scenario 3: given the left and right embankments of the flow with the dredging and widening of the river

In scenario 3 it is simulated by combining the installation of the left and right embankments with river dredging and widening. The embankment height was taken at an elevation of 2.50 m above sea level as high as the peak height of the Jetty building at the new estuary of the Batang Kandis river and the peak of the existing embankment on the left flow between BKS 3 to BKS 10 along 676 m. The width and depth of dredging are adjusted to the existing conditions by referring to 0.00 m above sea level. From the simulation results in scenario 3, it can be seen that from the BKS 0 to BKS 17 stations along the 1,583 m Batang Kandis river and BKSG 1 to BKSG 6 along the 810 m Batang Kasang river there is no visible flood inundation. Therefore, to identify flood handling in the lower reaches of the Batang Kandis river, there is no need to do another scenario simulation.

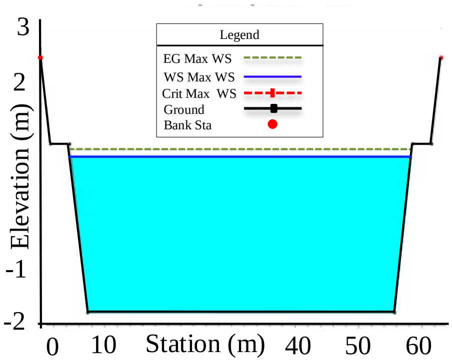

Fig. 11 BKS 9 (no flooding occurs)

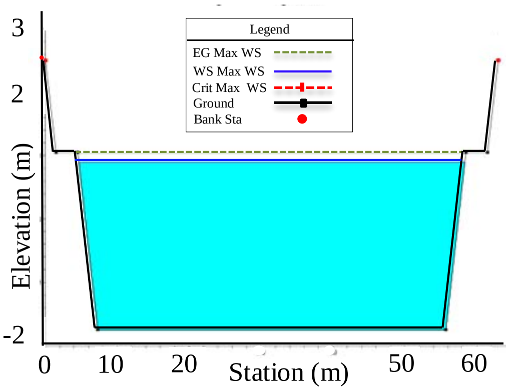

Fig. 12 BKS 10 (no flooding occurs)

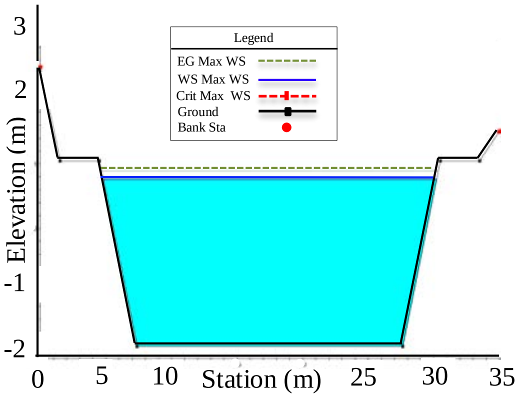

Fig. 13 BKSG 4 (no flooding occurs)

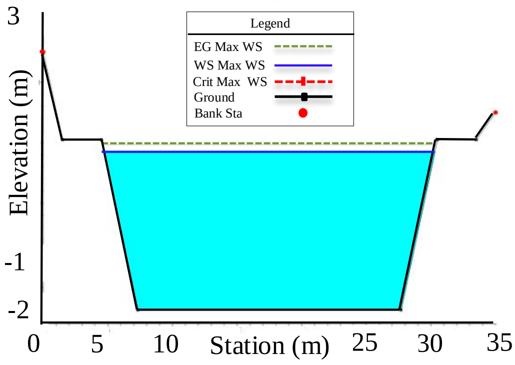

Fig. 14 BKSG 5 (no flooding occurs)

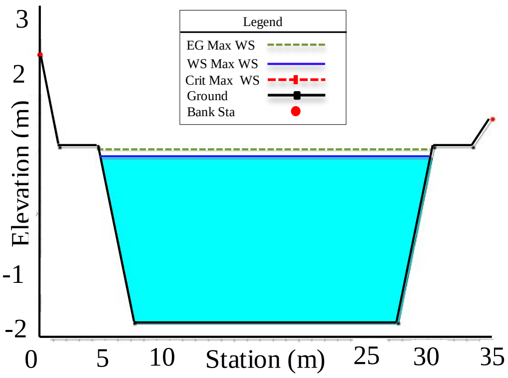

Fig. 15 BKSG 6 (no flooding occurs)

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

a. The first scenario with the existing conditions shows that the existing cross-section of the river segment is not flooded as it is in the downstream part of the river, namely: BKS 0 to BKS 4 A (from the new estuary the Batang Kandis river to the meeting with the Batang Kasang river), and in BKS 4 to BKS 10 left flow (the presence of flood embankments built in the 2007 and 2008 fiscal years by the Sumatra V River Basin Office, while the other parts in general are affected by the flood inundation of the Batang Kandis river and the Batang Kasang river.
b. From the simulation results in scenario 2 it can be seen that from BKS station 0 to BKS 13 and BKSG 1 to BKSG 6 there is no flood inundation on the Batang Kandis river, while at the BKS station 14 to BKS 17 there is still a flood inundation on the river of Batang Kandis. This condition is caused by the inadequate cross-section of the river to pass the flood discharge of

the Batang Kandis river in the condition of Q_{10} (Rational Method).

c. From the simulation results in scenario 3, it can be seen that from the BKS station 0 to BKS 17 in the Batang Kandis river and BKSG 1 to BKSG 6 the Batang Kasang river has not seen any inundation. Therefore, to overcome the inundation that occurs at the meeting between the Batang Kandis river and the Batang Kasang river, it is necessary to handle flooding in the lower reaches of the Batang Kandis river by simulating scenario 3.

Based on the simulated scenario at this conclusion, it is stated that scenario 3 is the best result of three scenarios that have been carried out to overcome flooding in the Batang Kandis river due to the opening of the new estuary of the Batang Kandis river.

5.2 Suggestion

a. To overcome flooding in the Batang Kandis river and the Batang Kasang river, serious attention needs to be paid from the Sumatera V River Basin Office.
b. For more optimal and proper handling of the meeting between the Batang Kandis river and the Batang Kasang river, further research is needed on the effect of sea tides on agricultural land.

6. ACKNOWLEDGMENTS

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