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Overcoming Flood in Batang-Takung Downstream Using Numerical Simulations

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***Abstract*— Batang-Takung River empties into Batang-Pangian River in Sijunjung Regency, West Sumatra Province. The downstream of Batang Takung is frequently flooding in the rainy seasons. The water-surface level at the intersection between Batang Takung and Batang Pangian is higher than that in the Batang-Takung downstream. This situation is then getting worse since the river bed of the Takung downstream is relatively flat. As a result, backwater phenomenon occurs along the Takung downstream and then it floods up to the surrounding residential and plantation areas. The present study is devoted to overcome the flood in the Batang-Takung downstream by numerical simulations using the existing software of HEC-RAS 4.10. In the present study, the software is applied to predicting the flow depths in both the uniform and varied flows and in the one-dimensional, steady-state condition for all simulation scenarios. In the first scenario, Batang Takung, Batang-Pangian Hulu (Batang-Pangian part from the intersection upward) and Batang-Pangian Hilir (Batang-Pangian part from the intersection downward) are in the existing condition. Similar to the first scenario but Batang-Pangian Hulu is put aside in the second scenario. The third scenario is the same as the first one but Batang Takung is put aside. The fourth scenario is the same as the first one but the upstream of Batang-Pangian Hilir around 1013 m long is straightened. In the fifth scenario, an additional intersection of Batang-Pangian Hulu and Batang-Pangian Hilir is made about 1762 m downward of the existing intersection. This is done by making a new trace in the downstream of Batang-Pangian Hulu. The simulation results show that straightening the river trace or normalizing the river is not effective in overcoming the flood in the Batang-Takung downstream. However, by making an additional intersection between the Batang-Pangian Hulu and the Batang-Pangian Hilir located about 1762 m downward, the flood in the Batang-Takung downstream could be solved.**

***Keywords*— flood; backwater; river intersection; meander; simulation.**

I. INTRODUCTION

Flood disaster during the rainy seasons is the main problem in residential areas as happened in Kamang Baru Sub-district in Sijunjung Regency. This flood is due to the Batang-Takung River overflowing. Batang Takung is a tributary of Batang Pangian. The intersection of Batang-Pangian Hulu (*i.e.*, the upper part of Batang Pangian), Batang-Pangian Hilir (*i.e.*, lower part of Batang Pangian) and Batang Takung is located in the coordinate of 101°23’14.24” E and 0°54’10.73” S (see Fig. 1). Based on the present authors' visit to the field when the flood flow occurred, the water-surface level of the upstream of Batang-Pangian Hilir near the intersection was higher than that of the Batang-Takung downstream. This lead to the flow of Batang-Takung being held back by that of Batang-Pangian Hilir. As a result, the backwater phenomenon occurred in the downstream of Batang Takung. This backwater phenomenon is the same as happened in an estuary due to flood tide that increases the mean-water level as discussed by Cai *et al*. [1]. This situation was also exacerbated by the bottom slope of Batang Takung near the intersection being relatively flat. The flow of Batang Takung eventually turned to meander in which the outer bank of the river was gradually collapsed. The outer bank produced sediment and then the sediment was deposited along the Batang-Takung channel. So, the river bottom became shallower. The present authors are sure that all mentioned above are the causes of the flood that inundating the residential zones and plantation next to Takung River.

To follow our observation up technically and in more detailed, the present authors use a public-domain software called HEC-RAS (Hydrologic Engineering Center – River Analysis System) just to predict water depths for three parts of the rivers. The flow is assumed to be in the steady-state condition for both uniform and varied flows. Consequently, sediment deposition as in the work of Hu *et al*. [2] and vegetation effects as in the work of Wang *et al*. [3] are not discussed in the present research, even though this software features sediment analysis. The flow is conserved [4]. The effects of bridge piers are also not discussed [5]. The backwater in the present research is also considered as a steady-state. More discussion regarding unsteady-state backwater can be seen in a model developed by Fan *et al*. [6] and then applied to Yangtze River by Lee *et al*. [7] using the continuous slope-area method.

Fig. 1 The river intersection of Batang Takung and Batang Pangian

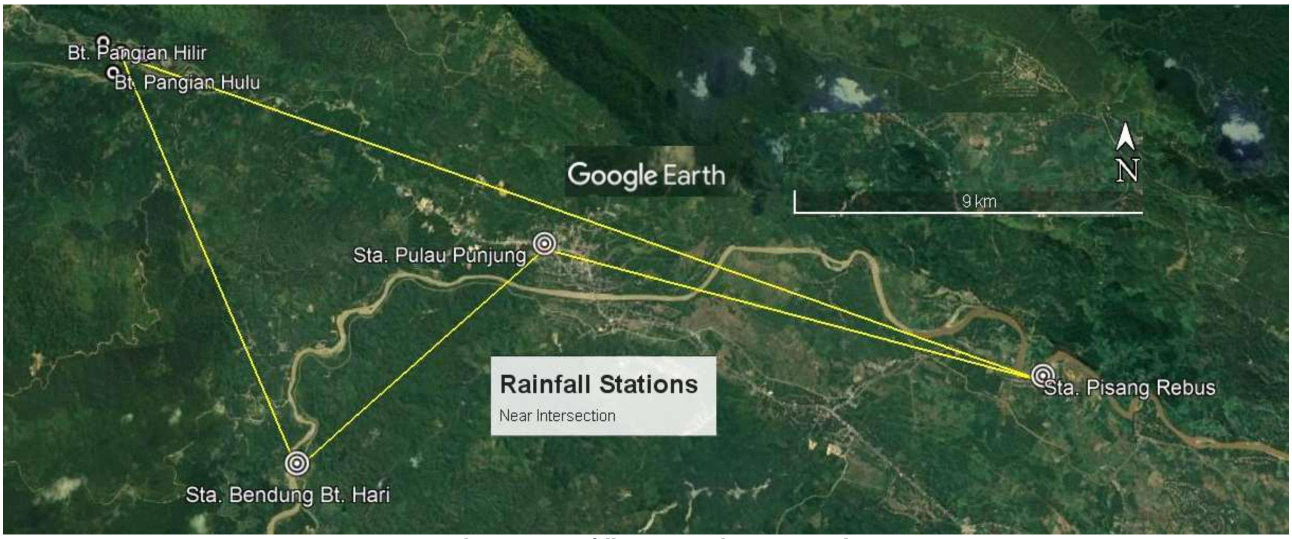

Fig. 2 The nearest rainfall stations to the present study area

This study aims to overcome the flood, which occurred in the downstream of Batang Takung by numerical simulations. These simulations consist of five scenarios. Firstly, Batang Takung, Batang-Pangian Hulu (Batang-Pangian part from the intersection upward) and Batang-Pangian Hilir (Batang-Pangian part from the intersection downward) are in the existing condition. Secondly, the same as the first scenario but Batang-Pangian Hulu is put aside. Thirdly, the same as the first scenario but Batang Takung is put aside. Fourthly, the same as the first scenario but the upstream of Batang-Pangian Hilir about 1013 m long is straightened. Finally, an additional intersection between Batang-Pangian Hulu and Batang-Pangian Hilir is made about 1762 m downward of the existing intersection.

II. Materials and Method

The present study area is a vicinity of the intersection of the rivers of Batang-Pangian Hulu, Batang-Pangian Hilir and Batang Takung. The topography data of the related rivers are collected from the PSDA [8], *i.e.*, elevation data of cross-sections of three related rivers. The present authors also visit the field to predict the cover materials of the river channels and then match them with the list of resistance coefficients [9]. The topography and resistance coefficient data are then used to simulate the flow. The resistance coefficients used in this model consider neither the effects of the cross-sectional geometry as in the work of Mera *et al*. [10] nor the effects of the flow and depth as in the work of Kim *et al*. [11].

The flow discharges are predicted by trial and error method, *i.e.*, by measuring the water depths in several points in the field when the flood occurred. By some trials, the flows that make the water depth as high as in the field can be predicted by numerical simulations. This way has to be done because neither rainfall station nor water level recorder is available in the vicinity of the study area (see Fig. 2). The nearest rainfall station is about 12 km far (Sta. Bendung Batang Hari), and the others are about 13 km far (Sta. Pulau Punjung) to 23 km far (Sta. Pisang Rebus). This is in contrast to the other researches in which the measurement instruments are available [12]–[16].

The simulation results show that the flow discharges that make the Batang-Takung downstream overflowing is 170 m^3/s in Batang Takung and is 208 m^3/s in Batang-Pangian Hulu. Both flows are then called flood discharges for the corresponding rivers. Both flows are then used in the simulation processes for all related scenarios to predict the water depths. So, the flows are not predicted using a rating curve as in the work of Hidayat *et al*. [17].

III. Results and Discussions

Some simulations using HEC-RAS software are applied to overcoming the flood in the Batang-Takung downstream. The first scenario is, of course, to simulate the existing condition using the flow discharges, which are previously predicted.

A. First Scenario: Existing Condition

In this scenario, all rivers are simultaneously simulated with a flow of 208 m^3/s in Batang-Pangian Hulu and a flow of 170 m^3/s in Batang Takung. Both rivers then merge in Batang-Pangian Hilir. The topography data are as they are. The plan of the simulation result is shown in Fig. 3, and the longitudinal section of the flow; (which consist of: flow depth or water-surface elevation – WS PF1, river-bed elevation – Ground, left-bank elevations – LOB, and right-bank elevations – ROB) is shown in Fig. 4 through 6.

Based on the three figures of the longitudinal sections can be seen that only Batang Takung is flooded, that's Sta 401 (near the intersection) through Sta 443 (Fig. 4). This scenario is run just to show what the three rivers are. This simulation result shows similarly what happened in the field as the authors saw. However, the first scenario is not enough as a basis for overcoming the flood in Batang Takung. Some other scenarios are needed to do.

B. Second Scenario: Batang-Pangian Hulu is Excluded

In the second scenario, the river of Batang-Pangian Hulu is put aside. Consequently, it is only the flow of 170 m^3/s, which is flowing from Batang Takung to Batang-Pangian Hilir. The plan of the simulation result is shown in Fig. 7, and the longitudinal section of the flow (which consists of the elevations of flow depth, river bed, left bank and right bank) is shown in Fig. 8.

Based on the simulation result of the second scenario can be seen that there is no part of the rivers being flooded, neither Batang Takung nor Batang-Pangian Hilir. It indicates that the flood that occurred in Batang Takung is not caused by the internal Batang Takung itself. Hence, another scenario is needed to find out what causes the flood in Batang Takung.

C. Third Scenario: Batang Takung is Excluded

In the third scenario, the river of Batang Takung is put aside. As a result, it is only the flow of 208 m^3/s, which is flowing from Batang-Pangian Hulu to Batang-Pangian Hilir. The plan of the simulation result is shown in Fig. 9, and the longitudinal section of the flow (which consists of the elevations of flow depth, river bed, left bank and right bank) is shown in Fig. 10.

Based on the simulation result of the third scenario can be seen that there is no part of the rivers being flooded, neither Batang-Pangian Hulu nor Batang-Pangian Hilir. In this stage, the problem of flood in Batang Takung becomes interesting. Consequently, the fourth scenario should be done.

D. Fourth Scenario: the Upstream of Batang-Pangian Hilir is Straightened

In the fourth scenario, all the rivers are simultaneously simulated as done in the first scenario. However, the upper part of Batang-Pangian Hilir about 1013 m long is straightened. The length of the trace considered is based on the field condition. Consequently, the river trace of 1013 m long reduces to 700 m long. The flow discharges are the same as used in the first scenario. The plan of the simulation result is shown in Fig. 11, and the longitudinal section of the flow (which consists of the elevations of flow depth, river bed, left bank and right bank) is shown in Fig. 12 through 14.

The fourth scenario results show that the Batang-Takung downstream is still flooded even though the upstream of Batang-Pangian Hilir trace has been straightened. In this scenario, straightening the river trace has not been able to overcome the problem of flooding in the study area. Another scenario is needed.

E. Fifth Scenario: an Intersection is Added

In the fifth scenario, all the rivers are simultaneously simulated as done in the first scenario. However, an additional intersection of Batang-Pangian Hulu and Batang-Pangian Hilir is made 1762 m downward of the existing intersection by considering the field condition. It's about 803 m before the existing intersection, the trace of the Batang-Pangian Hulu is divided to the additional intersection. The length of the additional trace of Batang-Pangian Hulu is about 1433 m. The flow discharges are the same as used in the first scenario. The plan of the simulation result is shown in Fig. 15, and the longitudinal section of the flow (which consists of the elevations of flow depth, river bed, left bank and right bank) is shown in Fig. 16 through 18.

Based on the fifth scenario results can be seen that there is no part of all rivers being flooded. This indicates that making an additional intersection can prevent the flood in tributaries. The additional intersection makes the additional trace of the downstream of Batang-Pangian Hulu straight. Consequently, the flow rate will be faster than the previous one. The increase in the flow rate will decrease the water depth. The old trace should always be used to keep the river environment, and the new trace is used during the rainy seasons or the flood flows. This means that the normal flow uses the old trace only, and the flood flow uses both traces.

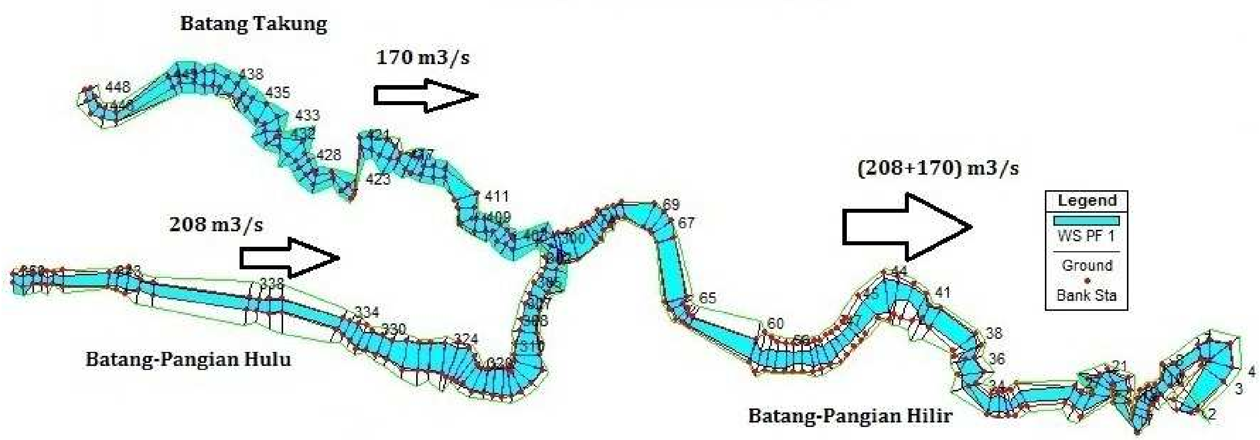

Fig. 3 The first scenario: The plan of the simulation result

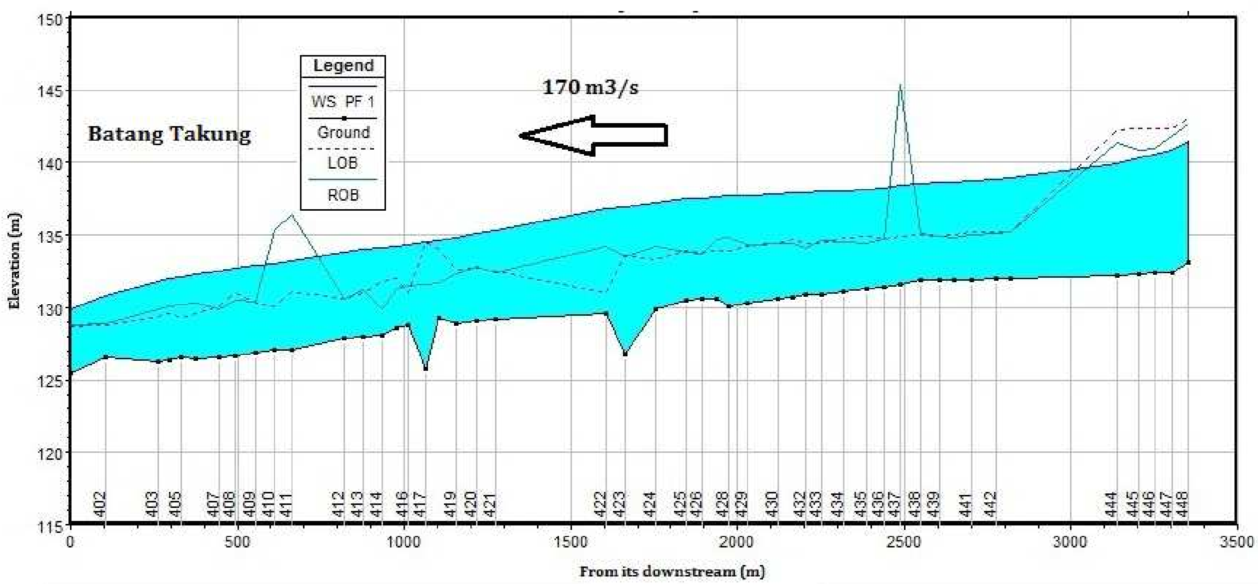

Fig. 4 The first scenario: The longitudinal section of Batang Takung and its water depth based on the simulation result, in where WS = water-surface elevation, Ground = river-bed elevation, LOB = left-bank elevation, and ROB = right-bank elevation

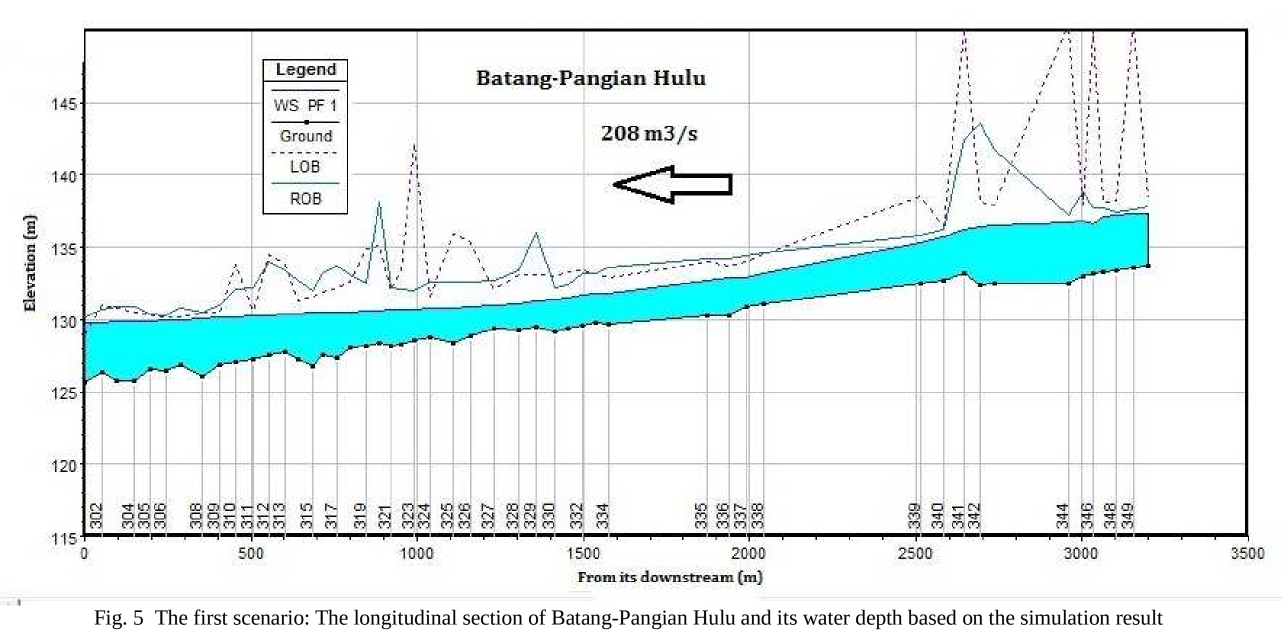

Fig. 5 The first scenario: The longitudinal section of Batang-Pangian Hulu and its water depth based on the simulation result

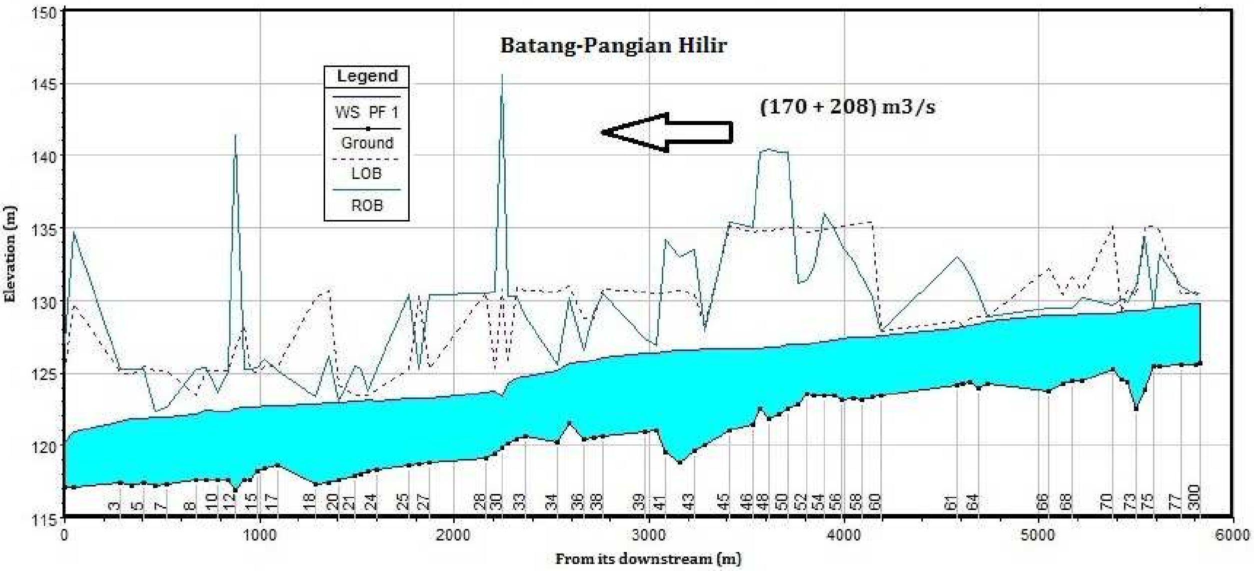

Fig. 6 The first scenario: The longitudinal section of Batang-Pangian Hilir and its water depth based on the simulation result

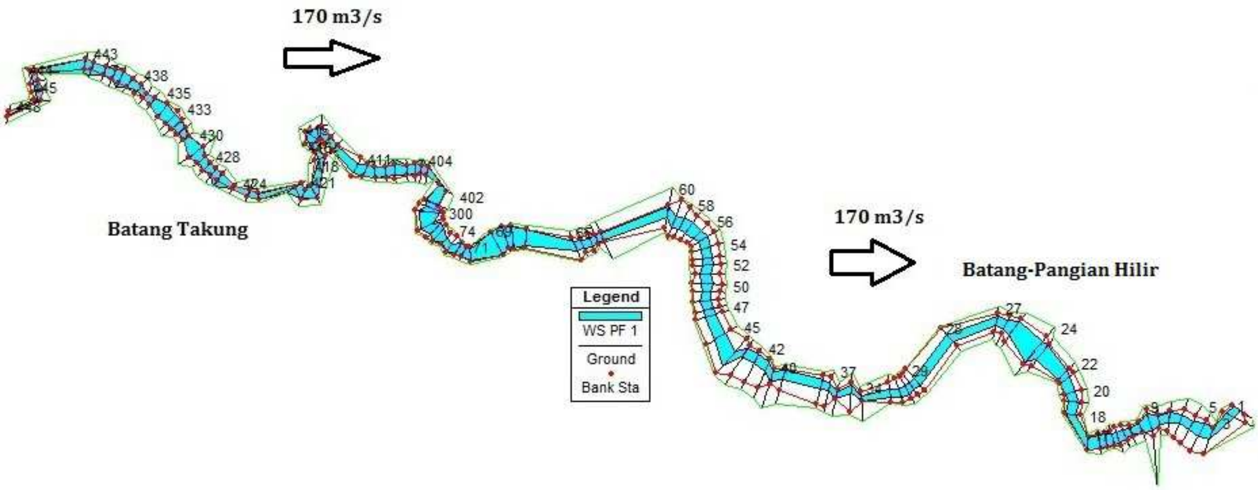

Fig. 7 The second scenario: The plan of the simulation result in which Batang-Pangian Hulu is not included

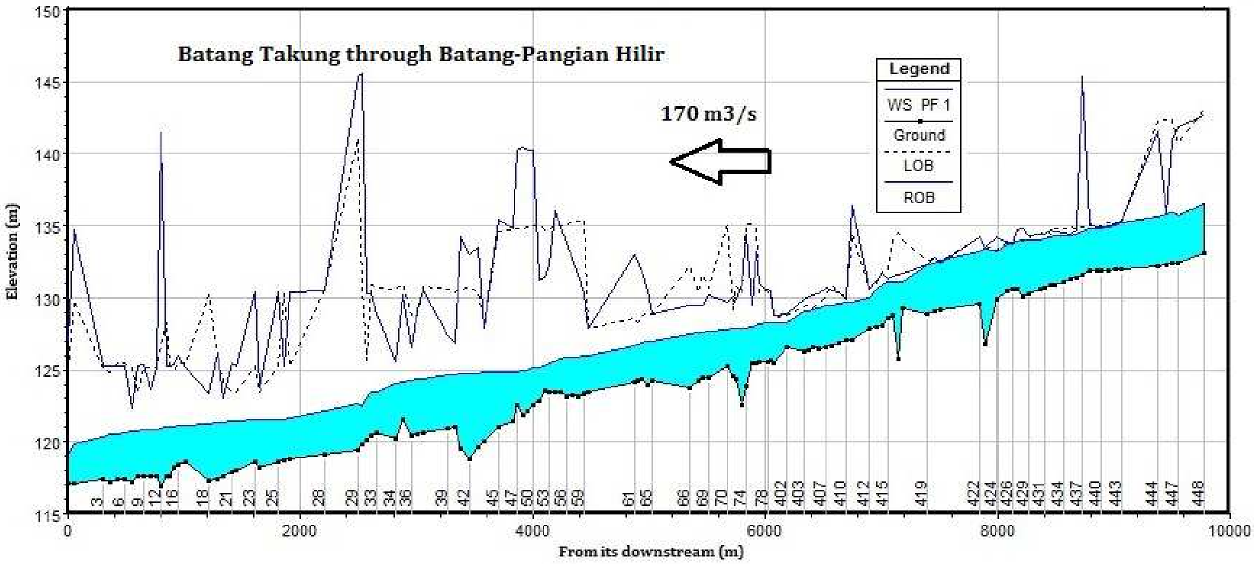

Fig. 8 The second scenario: The longitudinal section from Batang Takung through Batang-Pangian Hilir and its water depth based on the simulation result

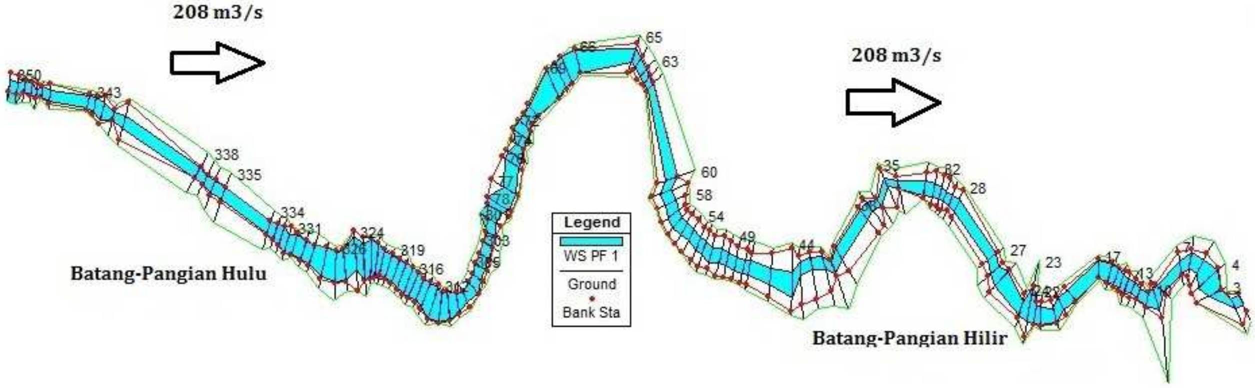

Fig. 9 The third scenario: The plan of the simulation result in which Batang Takung is not included

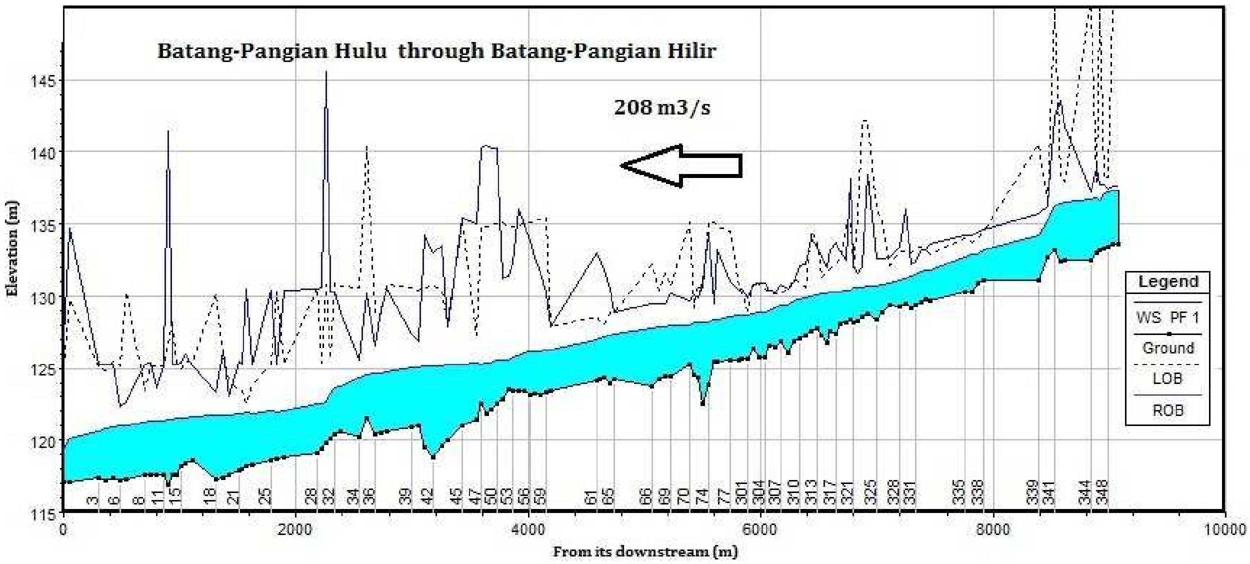

Fig. 10 The third scenario: The longitudinal section from Batang-Pangian Hulu through Batang-Pangian Hilir and its water depth based on the simulation result

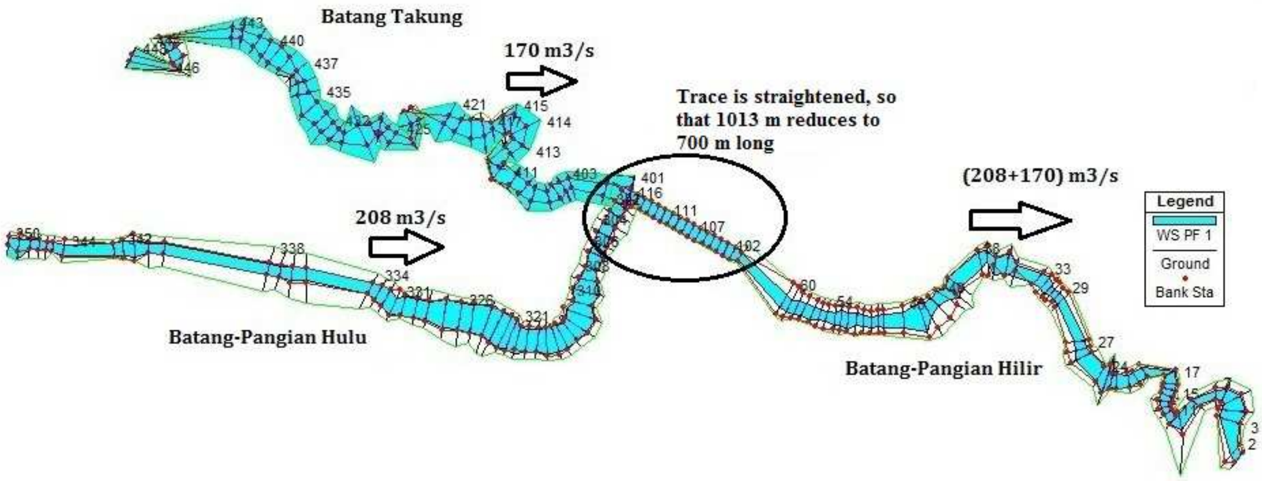

Fig. 11 The fourth scenario: The plan of the simulation result in which the upper part of Batang-Pangian Hilir about 1013 m long is straightened. As a result the trace reduces to 700 m long.

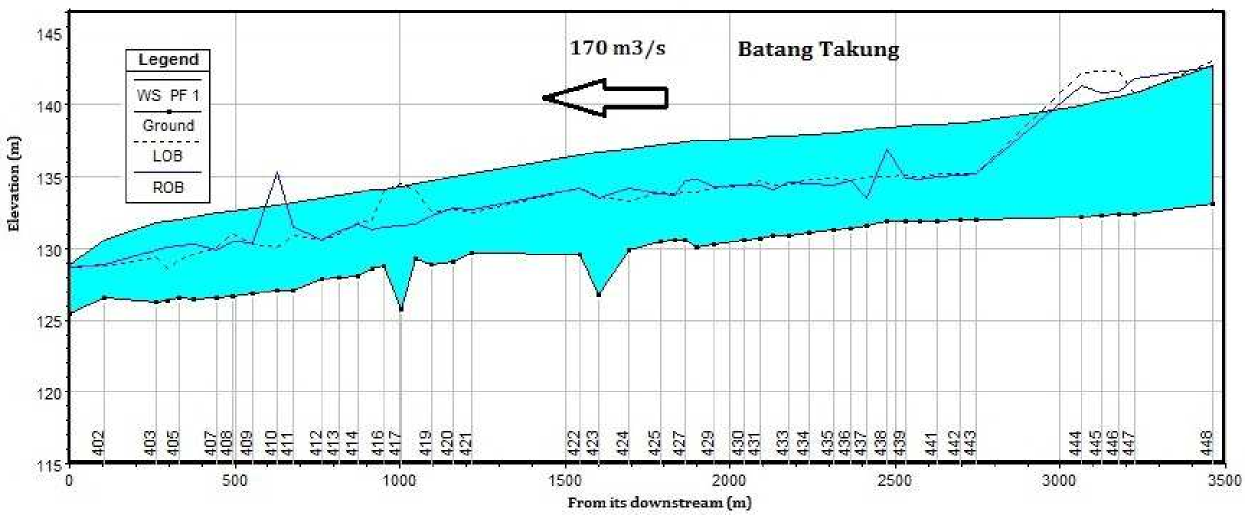

Fig. 12 The fourth scenario: The longitudinal section of Batang Takung and its water depth based on the simulation result

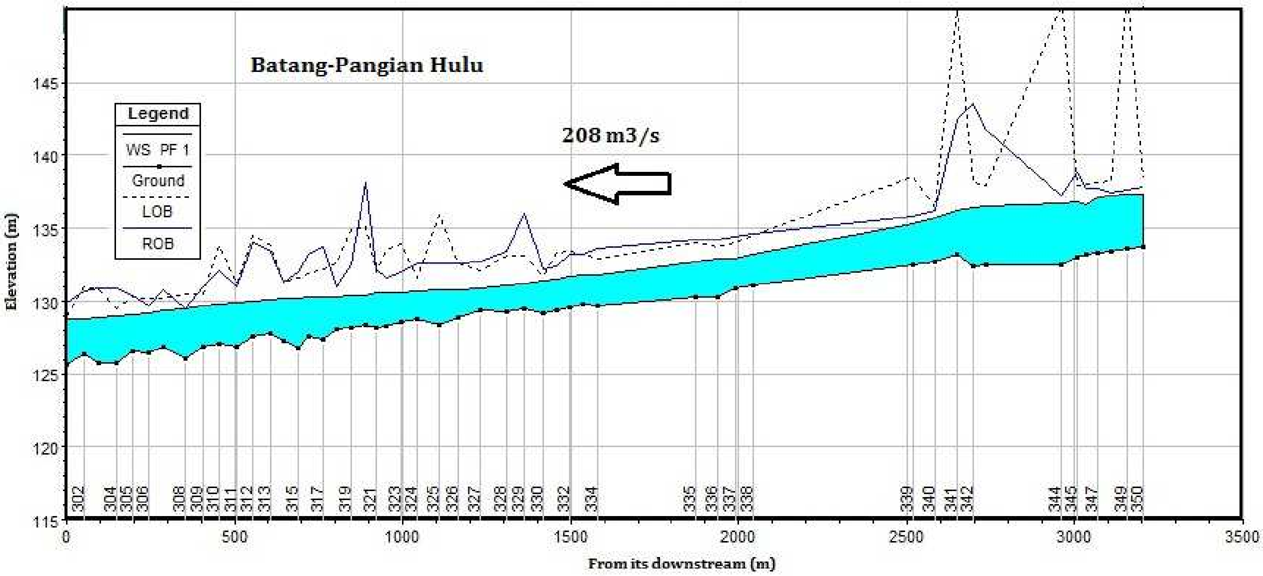

Fig. 13 The fourth scenario: The longitudinal section of Batang-Pangian Hulu and its water depth based on the simulation result

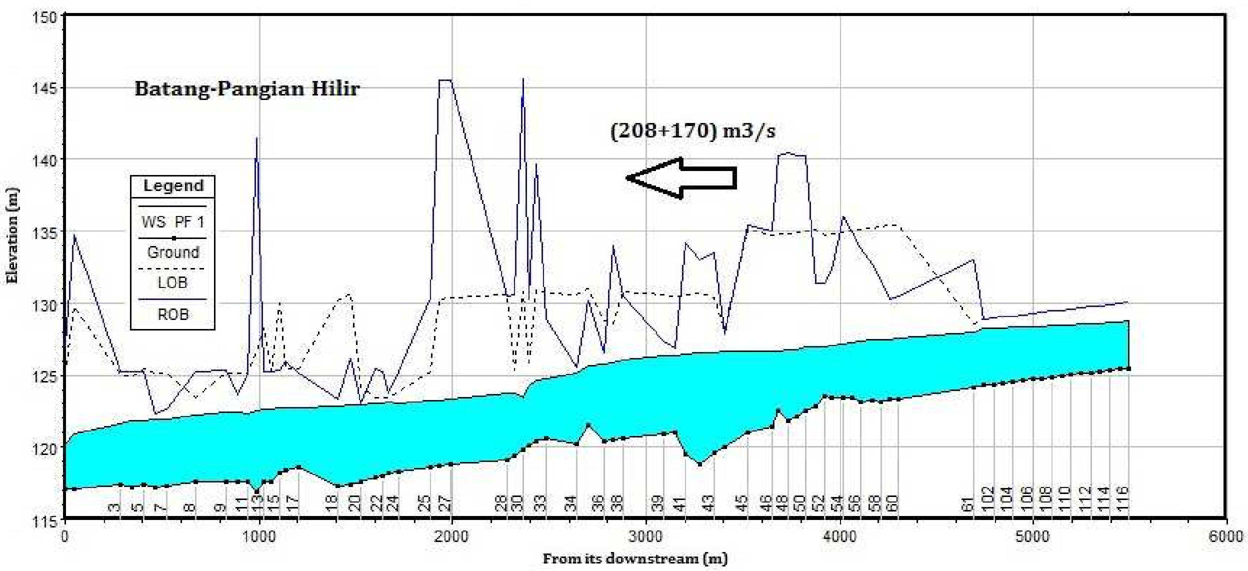

Fig. 14 The fourth scenario: The longitudinal section of Batang-Pangian Hilir and its water depth based on the simulation result

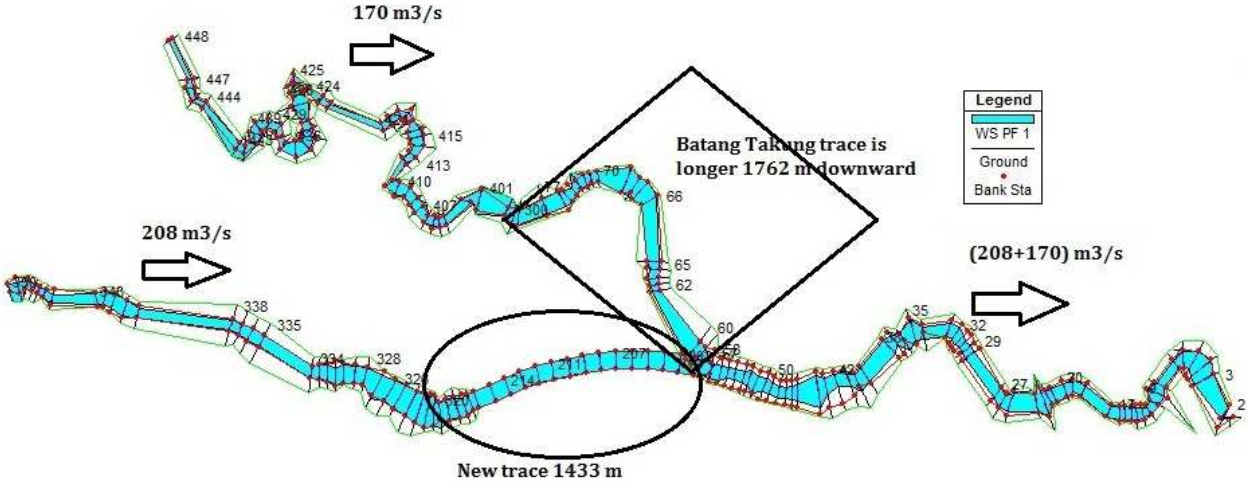

Fig. 15 The fifth scenario: The plan of the simulation result in which an additional intersection is made 1762 m downward of the existing intersection by dividing the flow 803 m before the existing intersection through a new trace.

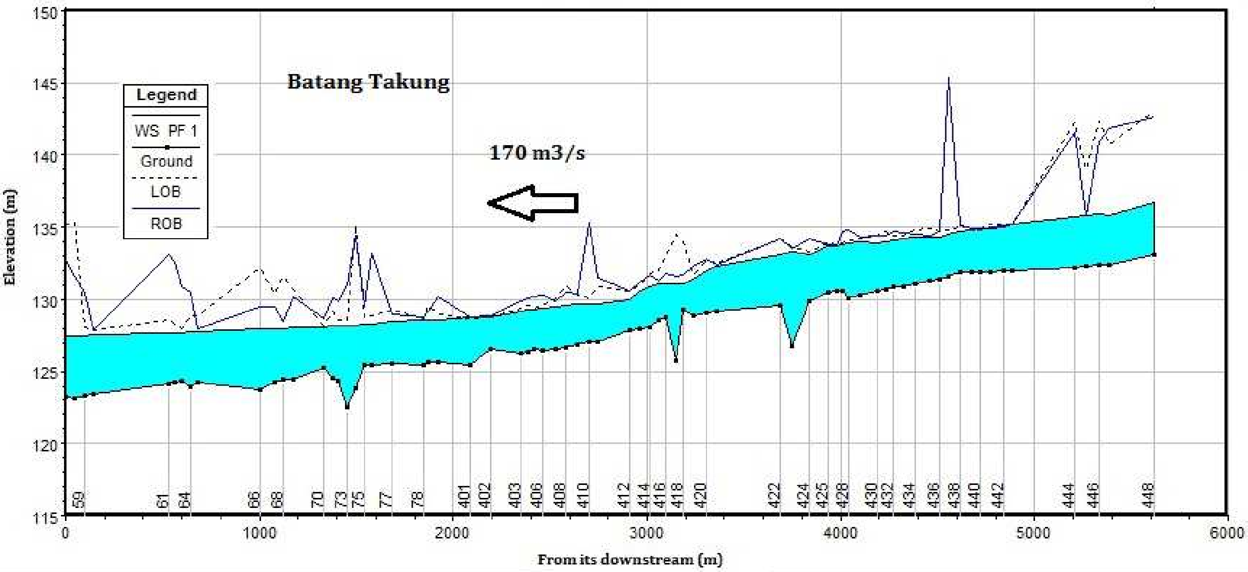

Fig. 16 The fifth scenario: The longitudinal section of Batang Takung and its water depth based on the simulation result

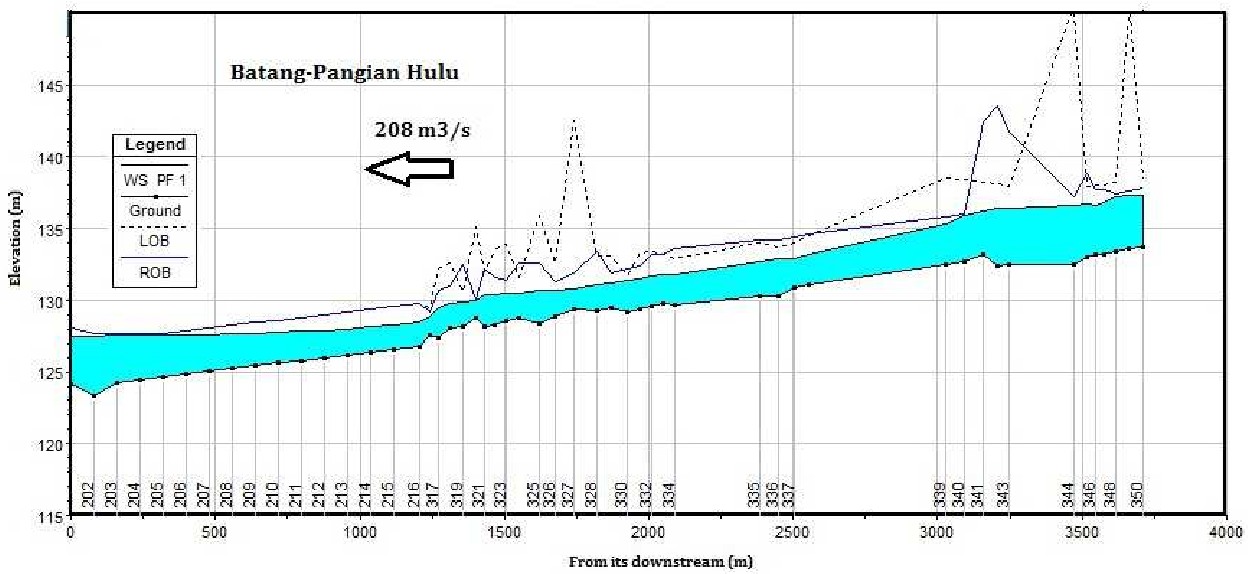

Fig. 17 The fifth scenario: The longitudinal section of Batang-Pangian Hulu with a new trace, and its water depth based on the simulation result

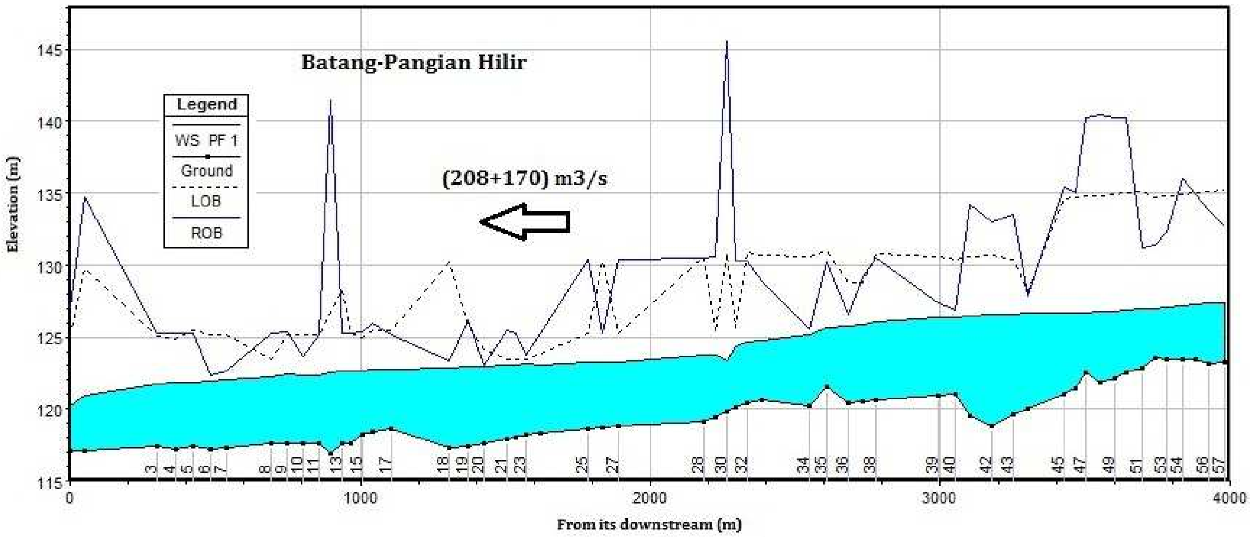

Fig. 18 The fifth scenario: The longitudinal section of Batang-Pangian Hilir and its water depth based on the simulation result

IV. Conclusions

The five scenarios of simulation result that straightening the trace or the river normalization is not effective in overcoming the flood in the Batang-Takung downstream. By making an additional intersection located about 1762 m downward of the existing intersection, of course by making an additional trace for Batang-Pangian Hulu, the flood in the Batang-Takung downstream could be solved.

The existing intersection is the cause of the backwater phenomenon in the Batang-Takung downstream. So, it can be said that the backwater is the main cause of the flood in Batang Takung. The other advantage of the additional intersection is the additional trace of the downstream of Batang-Pangian Hulu becoming straight. Consequently, the flow rate will be faster than the previous one. The increase of the flow rate will decrease the water depth.

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