STUDY OF CAPACITY IMPROVEMENT OF PLANGWOT-SEDAYU LAWAS FLOODWAY

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Abstract. One of the problems that occur in the Bengawan Solo watershed is the high flood discharge from upstream, causing flooding downstream, especially in Lamongan Regency and Gresik Regency. In order to anticipate this, BBWS Bengawan Solo has built the Plangwot-Sedayu Lawas Floodway with an initial capacity of 640 m^3/s. However, due to flooding still occurring in Lamongan and Gresik regencies, BBWS Bengawan Solo is working on increasing the capacity of the Plangwot-Sedayu Lawas Floodway to 1000 m^3/s. This research was conducted to examine the effect of adding the inlet gate of the Plangwot-Sedayu Lawas Floodway to the reduction of flood discharge in the Bengawan Solo River.

The analysis was carried out by modeling the existing operating manual with 3 (three) inlet gates (capacity 640 m^3/s) and 5 (five) inlet gates (capacity 1000 m^3/s). The modeling uses flood discharge at the 50-year return period. The modeling is done using Hec-Ras 5.0.7 software.

Based on the results of hydrological analysis, it was found that the peak flood discharge at the 50-year return period of Bengawan Solo Hilir River was 4191.70 m^3/s. Simulation using 3 (three) inlet gates shows that the peak flood discharge can be reduced to 3628.94 m^3/s (reduced by 13.43%). For the simulation using 5 (five) inlet gates, it shows that the peak flood discharge can be reduced to 3298.6 m^3/s (reduced by 21.31%). The highest discharge that can enter the floodway during modeling using 3 (three) inlet gates is 562.8 m^3/s so that there is deviation of 12.1% from the design capacity of 640 m^3/s. The highest discharge that can enter the floodway during modeling using 5 (five) inlet gates is 893.1 m^3/s so that there is deviation of 10.7% from the design capacity of 1000 m^3/s.

1. Introduction

The Plangwot-Sedayu Lawas Floodway reduces flooding in the Lower Solo River by accelerating the flow of rivers to the sea. The Plangwot - Sedayu Lawas Floodway connects the Lower Solo River in Plangwot to the Java Sea at Sedayu Lawas[1]. Floodway Plangwot - Sedayu Lawas has a capacity of 640 m^3/s[2]. In 2009 there was a big flood which caused most of the area in Bojonegoro, Lamongan and

Gresik Regencies are submerged. The flood discharge recorded at that time was 2040 m^3/s. Only 472 m^3/s of the flood discharge entered the floodway, and the remaining 1568 m^3/s entered the Bengawan Solo estuary in Ujung Pangkah, Gresik Regency, which caused flooding in Lamongan Regency and Gresik Regency. One of the government's flood control efforts through the Bengawan Solo River Basin is to increase the capacity of the floodway to 1000 m^3/s so that the discharge flows into the estuary at Ujung Pangkah is reduced. It can also reduce flood inundation in Lamongan and Gresik Regencies[3].

2. Overview of the Study

As already explained, the Plangwot - Sedayu Lawas Floodway is an infrastructure included in the main flood control system of the Lower Bengawan Solo Basin. The discharge flowing into the floodway is the discharge from the Bengawan Solo River, which has passed through the Babat Weir. The Plangwot-Sedayu Lawas floodway is an open channel with a length of 12.3 km with a base width of 100 m, the slope of the channel is 1: 4110. The inlet section is equipped with gates to regulate the flood flow passed to the floodway. About 3 km from the floodway estuary, a rubber weir has been built to form long storage in the floodway and at the same time to withstand seawater intrusion so that during the dry season the floodway can function as a raw water supplier. There are 3 (three) inlet gates with a width of @12.5 m and a threshold elevation of +2.12 m for the existing condition (capacity of 640 m^3/s) and the addition of 2 (two) inlet gates with a width of @7.5 m and a threshold elevation of + 2.12 m for the improvement condition (capacity 1000 m^3/s).

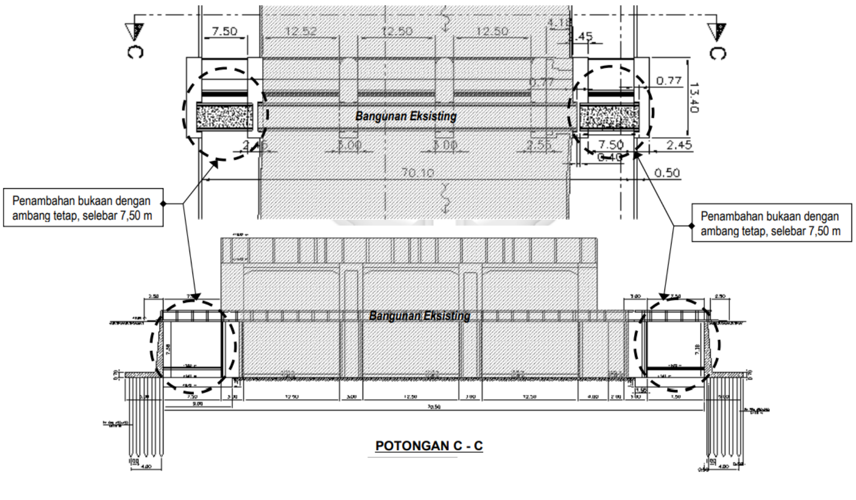

Figure 1. Inlet Gates Addition Planning on Floodway
Source : Kajian Teknis Pengendalian Banjir Floodway, Jabung Ring Dike dan Bendung Gerak Babat di Kab. Lamongan

3. Research Method

The research was conducted by collecting the data needed for hydrological and hydraulic analysis. Topographic data (DEM), rainfall data from 13 rainfall stations in the Bengawan Solo watershed, discharge measurement data at the Cepu AWLR, rating curve of Plangwot and Babat AWLR was collected. The hydrological analysis was carried out using rainfall data for 2001-2020 to produce a 50-year return flood discharge that was calibrated with the measurement discharge data at the Cepu AWLR. The hydraulic analysis modeled 2 (two) flood scenarios, namely the existing condition with 3 (three) inlet gates and the improvement condition with 5 (five) inlet gates. The modeling for the existing conditions was calibrated against the rating curve of Babat AWLR and Plangwot AWLR to obtain manning values that match the conditions in the field. The manning value is then used in the improvement scenario modelling. The reduction of Bengawan Solo River flood discharge is compared between the existing and improvement condition scenario to get the effectiveness of the floodway.

4. Result

4.1. Topographic Analysis

The topographical analysis of the Bengawan Solo watershed was carried out using GIS software. The results of the watershed delineation with an outlet point at the Babat Weir show that the area of the Bengawan Solo watershed is 13983.8 km^2 and the river length is 442.2 km. The curve number for the Bengawan Solo watershed is 69.56. Watershed delineation with the outlet point of Cepu AWLR was also carried out for the calibration process of flood discharge. It was found that the area of the Cepu watershed is 10764.9 km^2 with a river length of 309.7 km. Thiessen polygon analysis using GIS was carried out to determine the extent of influence of each rainfall post in the watershed area.

4.2. Hydrological Analysis

The hydrological analysis uses rainfall data from 13 (thirteen) rainfall stations in the watershed and the results from topographic analysis as input in determining the flood hydrograph. The flood hydrograph used is the Snyder SUH calibrated with measurement discharge data at Cepu AWLR. After the calibration process is complete, the watershed parameters obtained from Cepu watershed are used to analyze the flood discharge hydrograph in the watershed of the Study Location (Outlet in the Gerak Babat Weir). The flood hydrograph for the Cepu PDA watershed can be seen in **Figure 2**.

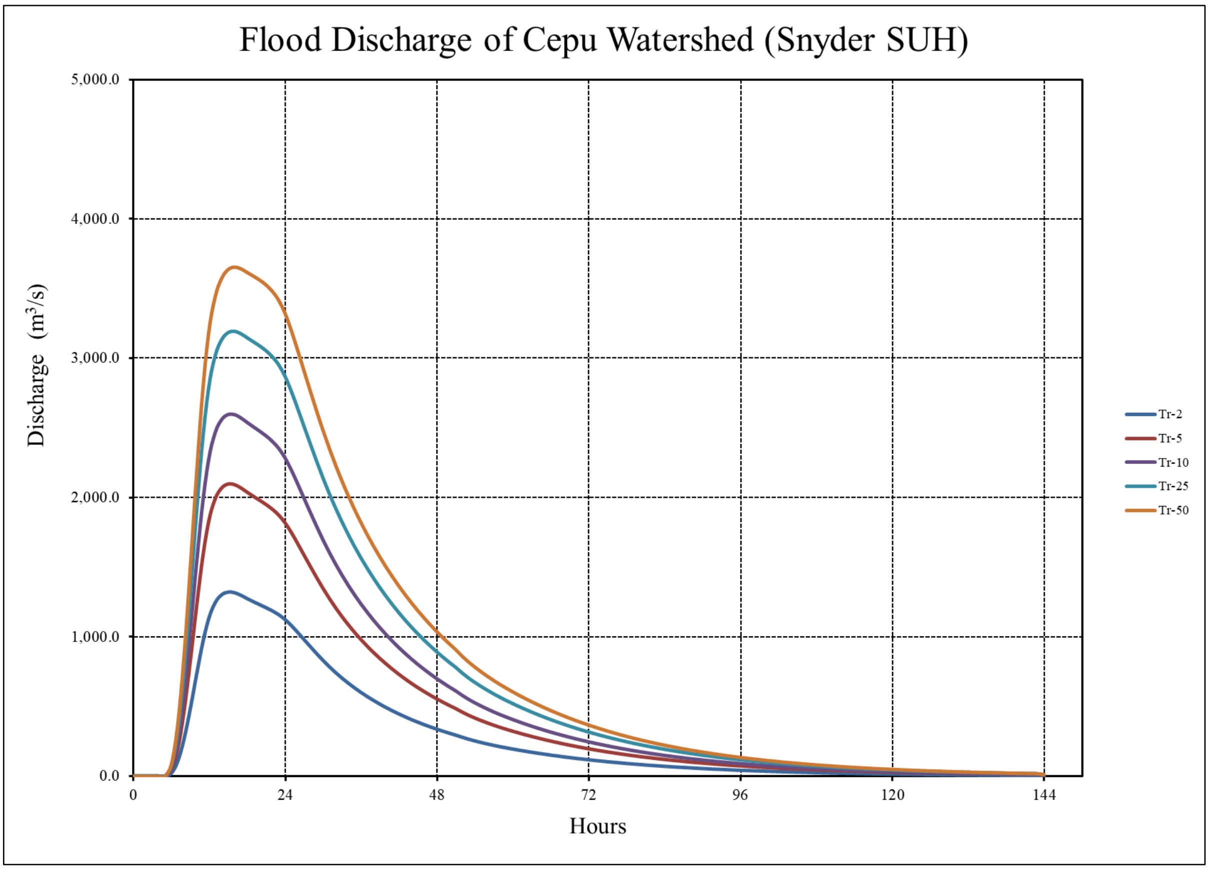

Figure 2. Flood Discharge Hydrograph of Cepu Watershed

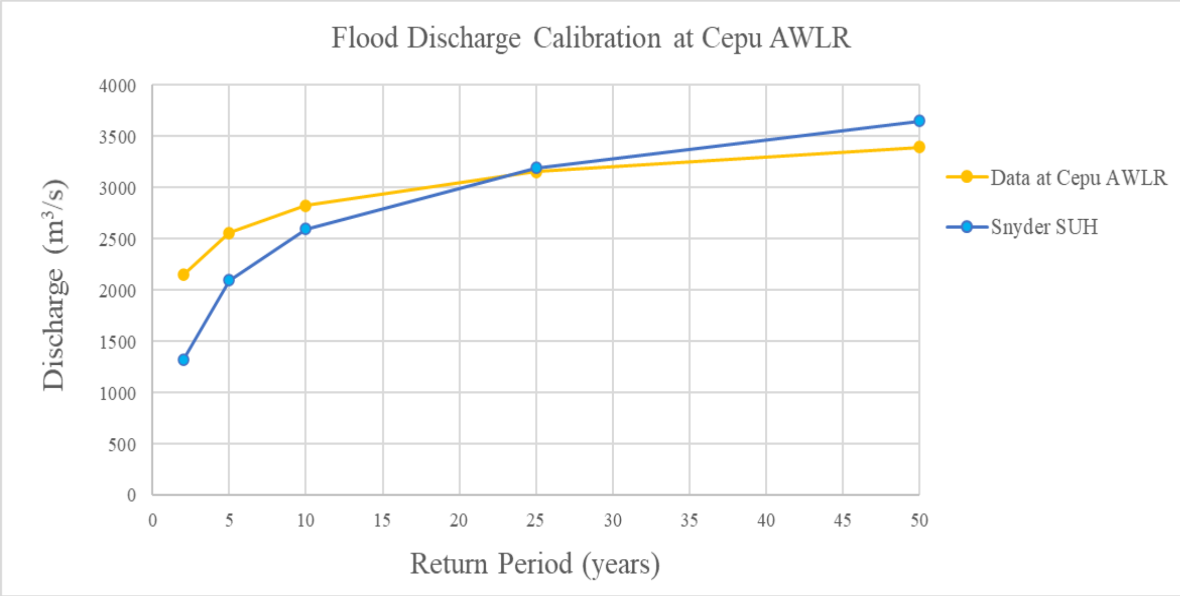

Figure 3. Snyder SUH Calibration Result with AWLR Cepu Discharge Data

The calibration of the discharge analysis with flood discharge measurements at the Cepu AWLR showed that the Ct value corresponding to the Bengawan Solo watershed was 0.5. Furthermore, the value of Ct is used to calculate the flood hydrograph in the watershed of the Study Location (Outlet at Babat Weir), which will be the input for the upstream boundary in flood flow modeling using Hec-Ras. The flood discharge used is the 50-year return flood discharge.

Table 1. Flood Discharge Peak at Bengawan Solo Watershed

Return Period (Years)	Flood Discharge Peak (m^3/s)
2	1755.45
5	2225.39
10	2764.37
25	3435.33
50	3949.76

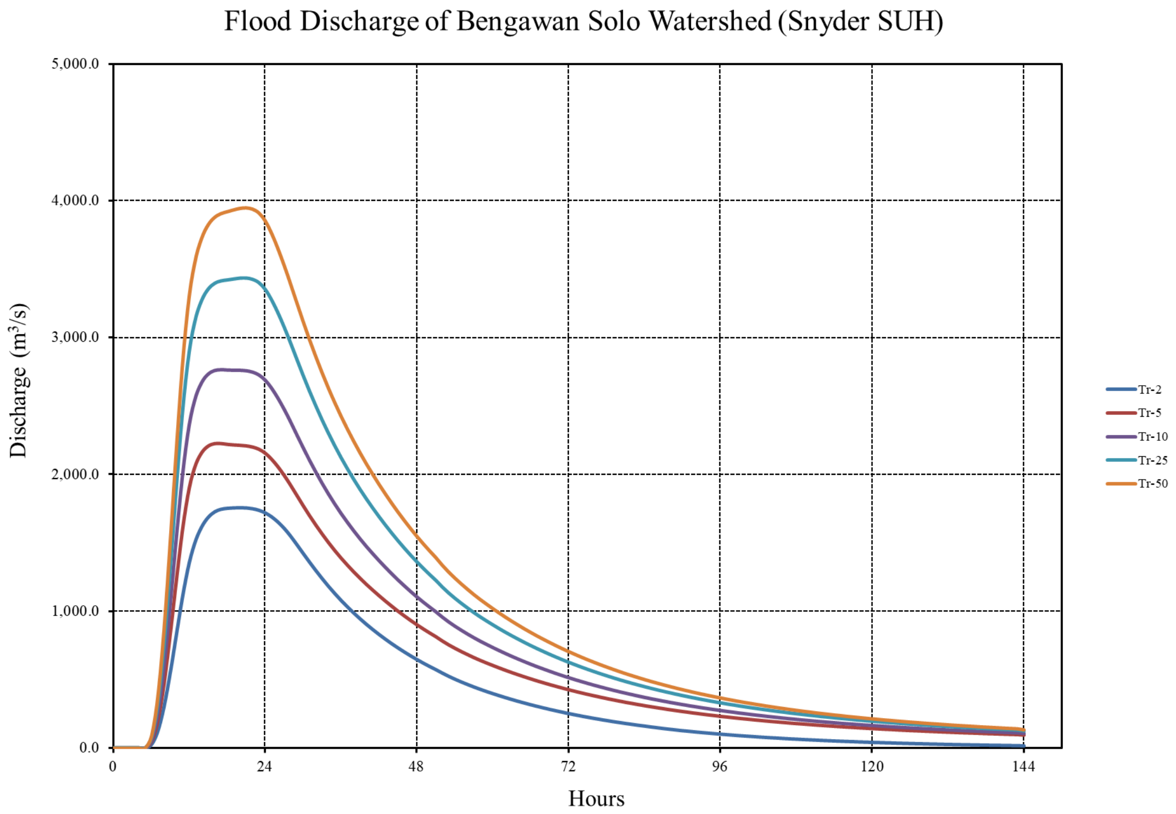

Figure 4. Flood Discharge Hydrograph of Bengawan Solo Watershed

4.3. Hydraulic Model Analysis

Hydraulic analysis for flood modeling using HEC-RAS software using 50-year return flood discharge in the study area watershed from the results of the hydrological analysis. The analysis was carried out in 2 (two) scenarios, namely the scenario of the existing condition (capacity 640 m^3/s) and the scenario of upgrading conditions (capacity of 1000 m^3/s). The difference between the two scenarios lies in the number of inlet gates used. The first scenario only uses 3 (three) inlet gates, while the second scenario uses 5 (five) inlet gates. There are 3 (three) existing inlet gates, each with a width of 12.5 m and a threshold of +2.12 m. The additional inlet gates, which consist of 2 (two) gates, are on the right and left of the existing inlet gates, each with a width of 7.5 m and a threshold of +2.12 m. Calibration is carried out on the existing model to obtain a manning value following the conditions in the field. Calibration was carried out using rating curve data from Babat AWLR and Plangwot AWLR, located upstream of the modeling and inlet gate.

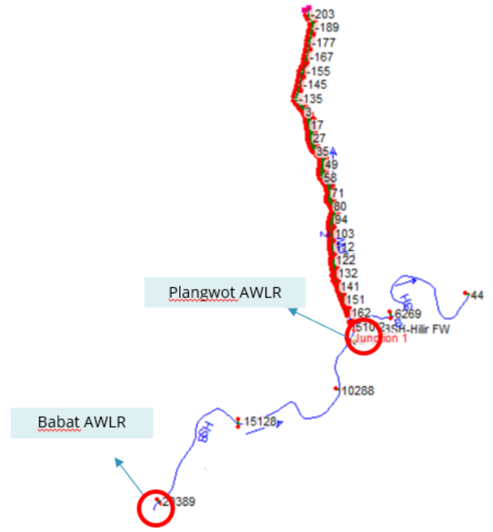

Figure 5. Babat and Plangwot AWLR Location

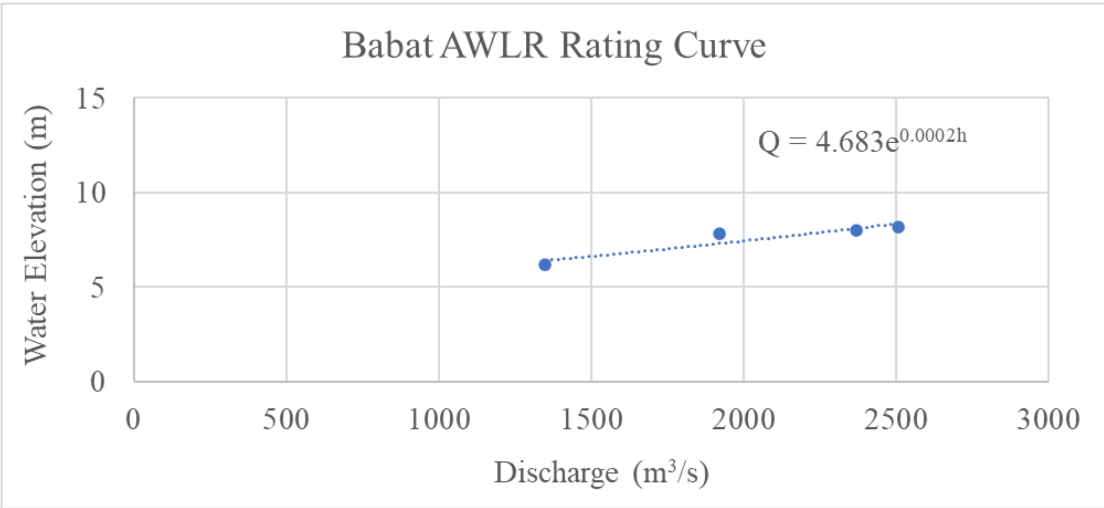

Figure 6. Babat AWLR Rating Curve

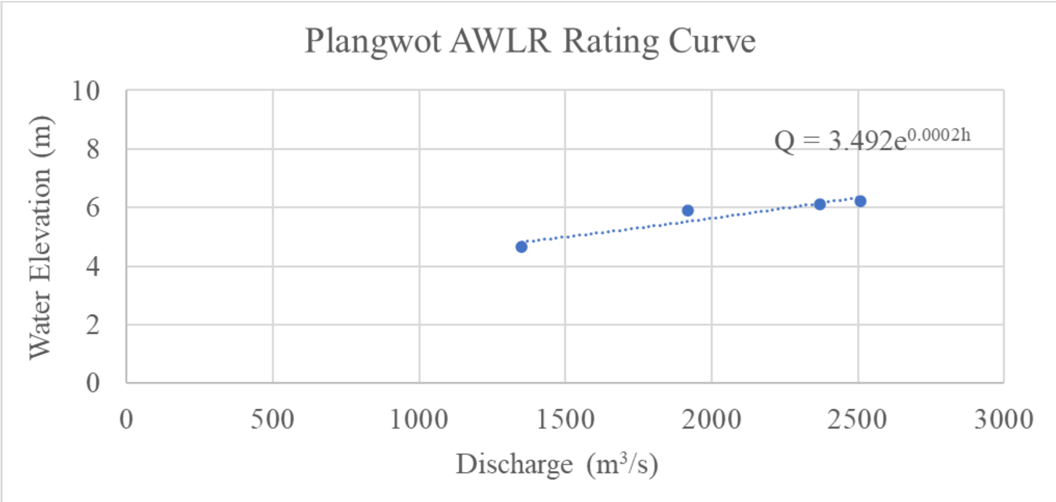

Figure 7. Plangwot AWRL Rating Curve

The results of the hydraulic model calibration in the existing conditions get the Manning value on the Bengawan Solo section upstream of the floodway of 0.023, the Bengawan Solo section on the downstream floodway of 0.012, and 0.02 for the floodway. When compared with the Manning value used as a reference in the Ven Te Chow Book [4] the Bengawan Solo River section upstream of the modeling has met the criteria by the conditions in the field, namely a short grassy soil channel with few nuisance plants which has a Manning value of 0.22 – 0.33. The floodway section has met the criteria for a clean and weathered earth channel with a Manning value of 0.018 - 0.025. The Bengawan Solo River section downstream of the modeling is also following the field conditions where the embankment has begun to be installed so that it has a Manning value of 0.011 - 0.014.

After the modeling was carried out for the scenario of 3 (three) inlet gates and 5 (five) inlet gates with a discharge input of a 50-year return period, the results showed an increase in the reduction of flood discharge in the Bengawan Solo River, as shown in **Table *2***.

Table 2. Flood Discharge Reduction of Bengawan Solo River

Return Period	Peak Flood Discharge (m^3/s)	Floodway Discharge (m^3/s)		Bengawan Solo River Discharge (m^3/s)		Reduksi Debit (%)	
		3 Gates	5 Gates	3 Gates	5 Gates	3 Gates	5 Gates
50	4191.70	562.76	893.1	3628.94	3298.6	13.43%	21.31%

It can be seen from the modeling results above that the reduction of flood discharge with the addition of inlet gates is getting higher following an increase in incoming flood discharge. The addition of the floodway inlet gates is the most effective for reducing flood discharge at the 50 year return period, increasing flood reduction value from 13.43% to 21.31%. The hydrograph of the floodway gates generated from the HEC-RAS model can be seen in **Figure *8***.

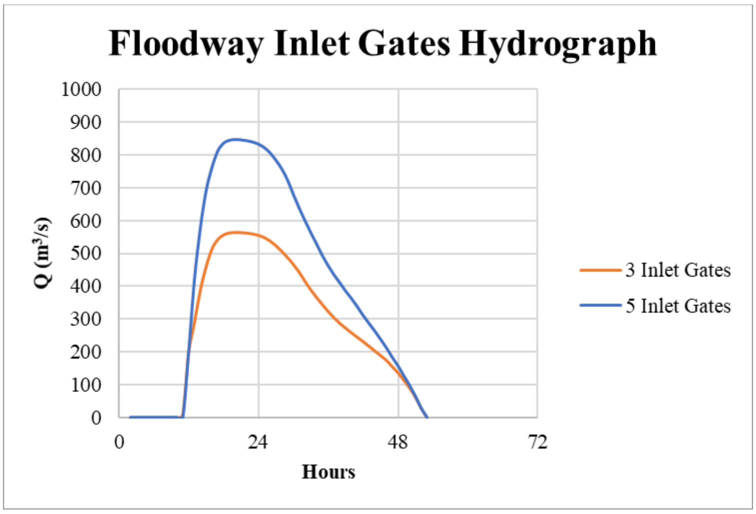

Figure 8. Floodway Inlet Gates with 50-years Return Period Discharge

From the modeling results, it is found that there is a deviation between the planned capacity discharge and the discharge that can enter the floodway during modeling. In the first scenario (existing condition), the highest discharge entering the floodway is 562.76 m^3/s, so there is a deviation of 77.24 m^3/s (12.1%) from the planned capacity discharge, which is 640 m^3/s. In the second scenario (upgrading condition), the highest discharge that enters the floodway is 893.1 m^3/s, so there is a deviation of 106.9 m^3/s (10.7%) from the planned discharge capacity of 1000 m^3/s. Due to model limitations, the deviation may be caused by widening the bend angle works, which have not been included in the modeling.

5. Conclusions

From this study, we can conclude that:

1) The flood discharge through the Bengawan Solo River on the Babat Weir section for the 2, 5, 10, 25, and 50 years return periods is 1755.45 m^3/s, 2225.4 m^3/s, 2764.37 m^3/s, 3435.33 m^3/s, and 3949.76 m^3/s.
2) The Manning value obtained from the model calibration results is 0.023 on the Bengawan Solo River section upstream of the floodway, 0.012 on the Bengawan Solo River section downstream of the floodway, and 0.02 along the floodway. The Manning value of the calibration results follows the actual conditions in the field.
3) In hydraulic modeling, there is a deviation of the discharge that can enter the floodway in the existing condition (3 inlet gates) is 77.24 m^3/s (12.1% of the design), and in the upgrading condition (5 inlet gates), it is 106.9 m^3/s (10.7% of design). Deviation can be caused by the model's limitations that have not been able to model the widening of the bend radius, which Government does.
4) The effectiveness of inlet gates operations on reducing flood discharge on the Bengawan Solo River after the addition of 2 emergency gates occurs when the flood discharge conditions are using 50 years return period discharge, with the percentage reduction from 13.43% to 21.31% of the peak flood discharge.

6. References

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