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A simulation for the gated weir opening of Wonokromo River, Rungkut District, Surabaya

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Abstract. The gated weir is a weir that the crest elevation could be operated based on the flow through the river. The upstream water level of the gated weir could be controlled with gate opening or closing. This study applied a simulation with HEC-RAS 4.0 program in order to know the river hydraulic condition after the gated weir has built. According to the rainfall intensity from each sub-watershed, Distribution Log Pearson III with return period 50 years (Q₅₀) was determined to calculate the design flood discharge. By using Rational Method, the design flood discharge is 470 m³/s. The results show that capacity of the river is able to accommodate Q₅₀ with discharge 470 m³/s and the gate should be fully opened during flood. This condition could passed the normal discharge at + 5.00 m elevation.

1. Introduction

Weir structure is a building across the river which function is to increase water level elevation from the dammed river so that it can be tapped and streamed to the canal through intake structure. Gated weir is a changeable type of weir. In movable weir, the upstream water level elevation could be controlled up or down accordingly by opening or closing the gate.

The background of constructing the gated weir is based on the fact that the water can be provided is not as much as it is required. In this case, it deals with the quantity. Therefore, there has to be a solution conducted continuously in efforts to satisfy or fulfill the need of current water. Due to the limited water resources, the gated weir is much required to be built in order to collect or hold the water during the rainy season so that the water in the river is not wasted away. Therefore, it would be very beneficial if the gated weir in Wonokromo River has to be built. Besides, the existence of the gated weir/dam will be capable of maintaining the groundwater surrounds it in efforts to conserve the water resources and its making use of it efficiently. Located in Wonorejo Timur, RT 04, RW VII, Rungkut – Surabaya, this gated weir was built across the Wonokromo River With its width ± 78 m. In Surabaya, this area was chosen as the development of water resources and in efforts to control the flood. By considering the issue mentioned above, it is necessary to review the flood discharge plan which flows in Wonokromo River as well as to analyze the hydraulic analysis occurred when the gate is opened and closed using HEC-RAS 4.0. By considering the issue mentioned above, it is necessary to review the flood discharge plan which flows in Wonokromo River as well as to analyze the hydraulic analysis occurred when the gate is opened and closed using HEC-RAS 4.0. The purpose of this research is to find out the hydraulic condition and the most optimum gate opening in that gated weir by conducting simulation using the help of HEC-RAS 4.0.
2. Literature and Method
Weir structure is one of the main building’s structures. Based on the Indonesian National Standard (SNI) of 03-2401-1991 about hydrology planning guidelines and hydraulic for one structure in a river is that this structure could be designed and built as a fixed/ permanent weir / structure, gated weir, or the combination of those two structures. They all have to be capable of controlling the stream and as a cargo transport in the river. This activity is expected to be capable of raising the water level, so that the water can be utilized efficiently in accordance with the people’s needs. Furthermore, the main function of weir structure is to raise the elevation of water level of the river being dammed up so that the water can be tapped and streamed to a certain canal through intake structure.

2.1. Hydrology analysis
The method used to determine the maximum daily mean daily rainfall is the Thiessen Polygon Method. Frequency analysis of rainfall data plan can be done by using Distribution Log Pearson III. The examination of the frequency fitness test (The Goodness of Fit Test) is intended to find out the truth of the frequency distribution hypothesis Log Pearson Type III.

2.2. Rational method
Rational method was made by taking into consideration that flood was coming from the unvarying raining intensity which lasts for a long period of time on the watershed.

2.3. Hydraulic Analysis
To ease up the canal hydraulic calculation, a program named HEC-RAS version 4.0. is being used. HEC-RAS is a helping program or a mathematical River Analysis System model developed by Hidrologic Engineering Center US Army Corps of Engineering. It is an auxiliary program which able to solve a one dimensional open channel flow equation under steady flow or unsteady flow. In hydraulic canal model using HEC-RAS program, the discharge on upstream boundary condition on primary upstream weir and secondary weir as well as its base slope or water face elevation in downstream as a downstream boundary condition and the discharge from the river’s right and left canal which is a lateral inflow towards the canal system modeled should be inputted. In addition to the boundary condition mentioned above, the required canal geometry are the cross-sectional profile and the distance between one cross-section to another as well as the left and right edge of the canal’s height which will be used as the sectional boundaries to be calculated. Meanwhile, the required hydraulic parameter is the canal roughness coefficient which is manning coefficient. The output of the hydraulic modeling are discharge (Q), flow rate (V), and water level elevation (H).

2.4 The steps in analyzing the data, as follows:
(1). Create a watershed area Wonokromo by looking at topographic maps.(2). Processing the mean rainfall data by using the Thiessen Polygon Method. The Wonokromo watershed has 3 rain stations that include: Wonokromo Station, Wonorejo Station , and Keputih Station. (3). Calculating statistical parameters of data analyzed, including standard deviation (Sx), coefficient of variation (Cv), kurtosis coefficient (Ck) and symmetric coefficient (Cs). (4). Calculate the frequency distribution of rain by using Log Pearson III. (5). Conducting Chi Square Test and Kolmogorov Smirnov Test. (6). Calculation of land use. (7). Calculation of effective rainfall. (8). Plan the discharge plan using Rational Method. (9). Flood discharge analysis using HEC-RAS 4.0 program.

3. Results and discussion

3.1. Determining the Regional Average Rainfall
Determine the percentage of area of influence on the Wonokromo River watershed. At Wonokromo station with area of 17,11 km² with weight of coefficient of polygon 0,39. Wonorejo station with an area of 18.40 km² with the weight of polygon coefficient 0.42 and Keputih station with an area of 8.56 km² with the weight of polygon coefficient 0,19.
In order to determine the regional average rainfall using Polygon Thiessen Method, maximum rainfall is produced.

3.2. Calculating rainfall frequency distribution

Before calculating the rainfall distribution, it is important to take a look at the statistical parameter. It was found out that $S_x = 20.92; C_s = 0.09$; and $C_k = 4.73$. By taking into consideration the parameter values, the appropriate frequency distribution is Log Pearson Type III frequency distribution. The annual rainfall plan using various scales, such as $R_2 = 85,506$ mm, $R_5 = 121,115$ mm, $R_{10} = 146,926$ mm, $R_{25} = 182,179$ mm, $R_{50} = 210,426$ mm and $R_{100} = 240,27$ mm.

3.3. Frequency Distribution Fit Test

Frequency distribution fit test was carried out through Chi Square Test and Smirnov Kolmogorov Test. From Chi Square Test, $R^2 = 5.2$ was acquired based on chi square table using $\alpha = 0.05$ and $\alpha = 0.01$. With degrees of freedom equal to 1, $R^2$ is equal to 3.841 and 6.635. Thus, since $R^2 \text{accounted} < R^2 \text{table}$, then the distribution calculation result above is acceptable.

From Smirnov Kolmogorov Test, it was found out that $D_{\text{max}} = 0.490$ based on Smirnov Kolmogorov table with $\alpha = 0.05$ and $\alpha = 0.01$ while $N = 10$, $D_{\text{max}}$ value is equal to 0.41 and 0.67. Finally, because $D_{\text{cr}} \text{accounted} < D_{\text{cr}} \text{table}$ then the distribution calculation result above is acceptable.

3.4 Flood Discharge of Rational Method

Flood discharge calculation using Rational Method for $Q_{50}$. The coefficient of watershed of Wonokromo River, for sub watershed PDAM coefficient of drainage = 0.3, sub watershed Kali Merr coefficient of drainage = 0.44, sub watershed Kali Sumo coefficient of drainage = 0.92, sub watershed Medokan coefficient of drainage = 0.98 and sub watershed Keputih coefficient of drainage = 0.48. The calculation of Rain Intensity using Talbot, Sherman, Ishughoro, and Mononobe method is using rainfall intensity precipitation formula with $R_2$ until $R_{50}$. The result of flood discharge plan calculation using Rational method. In the Jagir gate $Q_{50} = 370$ m$^3$/sec, the PDAM channel $Q_{50} = 2,637$ m$^3$/sec, the channel of Kali Mirr $Q_{50} = 9,958$ m$^3$/sec, the channel of Kali Sumo $Q_{50} = 43,632$ m$^3$/sec, the channel of Medokan $Q_{50} = 65,333$ m$^3$/sec and the channel of Keputih $Q_{50} = 9.67$ m$^3$/sec.

3.5 Hydraulics analysis

Hydraulic analysis was performed using the HEC-RAS 4.0 program. In the calculation of hydraulics analysis will be calculated on the condition that is: (1). River capacity based on existing conditions, (2). Cross-sectional condition of river when flowing flood discharge, (3). Condition after the gate. The scheme of the river shows in figure 1.

![Figure 1. Scheme River](image-url)

3.6 Modeling With discharge 470 m$^3$/second.

Kali Wonokromo modeling was planned with its discharge of 470 m$^3$/second at the upstream section. In order to know its stream hydraulic occurs in Kali Wonokromo with its discharge of 470 m$^3$/second. Furthermore, to get to know the worst condition, hydraulic modeling could be assumed that the rain could happen simultaneous at the whole area of Kali Wonokromo and at the river’s estuary a high tide happened. The result of modeling on the existing condition as shown in the following figure 2.
The figure above shows one of the cross-sectional profiles of Kali *Wonokromo* at P5 (in front of Jagir water gate) and P210 (the planned location for the water gate), it can be seen that from the hydraulic modeling results on the left and right side of the embankment design either on the P5 front of Dam Jagir or P210 (the planned location for the water gate) able to accommodate discharge 470 m$^3$/sec. Visible elevation of water level still carried elevation of embankment. From the various results of hydraulics analysis that has been done that the conditions are safe for the planning of *Wonokromo* River dune motion by using the 470 m$^3$/sec discharge, with the discharge coming from each Sub-watershed and the highest discharge of 2014 which runs from the Jagir dam.

### 3.7 *Wonokromo* River’s Modeling with Full Open Gate

![Figure 3. Length profile on the condition of all open gate](image)

Figure 3 shows that the cross-profile and lengthwise maximum water level of $W_{smax}$ which occurred at the planned gate of 7 x 10 m. The maximum water level if the floodgate is in the worst condition, all of the floodgates must be opened when the flood of $Q_{50}$ and followed by the high tide reaching up to +5.00 coming simultaneously. Parameter of result of hydraulic analysis in the form of discharge, velocity and water level that happened at each section of Kali *Wonokromo* result of modeling with door plan 7 x 10 m.

### 3.8 *Wonokromo* River’s Modeling with 1 Opened Gate

![Figure 4. Length Profile open one gate](image)

Figure 4 shows that the maximum cross-profile and the lengthwise water level of $W_{smax}$ occurred at the planned gate of 7 x 10 m. Meanwhile, the maximum water level of the water /floodgate when the flood of $Q_{50}$ happened and high tide coming simultaneously by opening one of the water gates in efforts to to make the height of water level at the water gate reach up to +6.05 m.
3.9 Wonokromo River’s Modeling with the 2 Opened Gates
The maximum water level reached +5.39 m in the water gate when there was a Q50 flood and tide coming simultaneously followed by opening two of the water gates.

3.10 Wonokromo River’s Modeling with 3 Opened Gates
The maximum water level reached +5.30 m in the water gate when there was a Q50 flood and tide coming simultaneously followed by opening three of the water gates.

3.11 Wonokromo River’s Modeling with 1 meter Opened Gates

![Figure 5. Length Profile on 1 Meter Condition](image)

Figure 5 shows the maximum cross-profile and water surface max faces that occur on the 7 x 10 m gate plan. The maximum water level at the floodgates in the event of Q50 flood that coincides with the arrival of high tide by opening the floodgate as high as 15% (1 meter) then the water level at the gate reaches +6.41 m.

3.12 Wonokromo River’s Modeling with 3.5 Meter Opened Gates
The maximum water level at the floodgates during a Q50 flood that coincides with the arrival of high tide by opening the floodgate as high as 50% (3.5 meters) then the water level at the door reaches +5.18m. From the various analysis above can be seen that with the construction of the water gate in the area of Kali Wonokromo water rise in the location of the water gate. This happens because with the increase of cross section, thus slowing the speed of sea water to enter at the time of the tide and the discharge that flows also slightly less than before the construction of the water gate.

4. Conclusion
Based on the analysis and discussion that has been done, it can be concluded several things as follows: The backwater gives a great influence towards the flood water level (overflow). From the analysis it was found that the flow of 470 m^3/sec (Q50), where the cross section of the river is good in front of Jagir gate and the location of the door plan, the elevation of the embankment is still below the water level is + 5.00 m with all gates opened.

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