Riverbed Erosion Analysis of Winongo River Using HEC-RAS 5.0.7

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Abstract. Winongo River originates from small rivers on the slopes of Mount Merapi. This creates potential debris floods that will carry material such as sand and gravel, which can cause erosion and sedimentation in rivers. Riverbed erosion is the process of transporting materials on the riverbed that causing the elevation on the riverbed to fall. If the riverbed elevation decreases, it will cause the retaining wall building to become unstable and collaps. If this happens, it will have a negative impact on the people who live along the riverbanks. The impact of erosion and erosion analysis at the bottom of Winongo River is carried out using HEC-RAS 5.0.7. There are 200 cross-sections that had been analyzed. The analysis reveals that the locations have the potential of erosion on the riverbed and the damage that can occur in the riverbank. From the results of the analysis that have been carried out using the 2-year return period (Q2), there are erosion in 9 cross-sections on Winongo River which is located in Bambanglipuro District and Jl. Parangtritis. The depth of erosion that occurs reaches 0.96 m in the cross-section WN 173. The erosion causes damage to the retaining wall, such as cracks, flattening, and collaps.

1. Introduction

Winongo River is a river in Yogyakarta that has a watershed area of ± 118 km², has water on the slopes of Mount Merapi, and empties into the Opak River. The length of Winongo River reaches 43.75 km. Winongo River flows through several districts in Yogyakarta, including Sleman Regency, Yogyakarta City, and Bantul Regency. These areas are densely populated so that there are many riverbank retaining structures along the Winongo River watershed. In addition, the upstream of Winongo River comes from small rivers on the slopes of Mount Merapi, creating potential for cold lava floods. Cold lava floods that occur will carry materials such as sand and gravel which can cause river morphological phenomena, namely sedimentation and riverbed erosion.

The collapse of the retaining wall building occurs due to riverbed erosion and riverbank erosion. Riverbed erosion is the process of transporting material such as soil or sand to the riverbed which causes a decrease in the elevation of the riverbed, while riverbank erosion (streambank erosion) is the scouring of soil on river cliffs and dredging the riverbed due to river water flow. Riverbed erosion will have a negative impact on the people who live along the riverbanks. The decrease in riverbed elevation causes the retaining wall to become unstable and collapse, making it the initial cause of damage to the retaining wall.
To analyze the erosion that occurs on the riverbed, it is necessary to make a mathematical model. The mathematical model used to analyze riverbed erosion is Sediment Analysis from the HEC-RAS version 5.0.7 software.

1.1. River Morphology
[1] stated that river morphology is the shape and size (geometry) or the cross-section, nature, type, and behavior of rivers in all aspects and their changes in space and time. River morphology is relevant from the formation of the river. Morphological processes will occur rapidly due to changes in land use. Meanwhile, other factors that cause river morphology are river cliff-forming materials, backwater (tides), and transportation. The widening of the river flow occurs due to erosion on the riverbed. River flow branching also occurs due to vertical erosion on the riverbed [2].

1.2. Riverbed Erosion
Riverbed erosion is the process of transporting material (soil or sand) on the riverbed causing a decrease in the elevation of the riverbed. According to [3], scouring of the structure is divided into 3 types, namely:
- General Scour is scouring that occurs due to natural processes without being influenced by a building structure on a channel or a river.
- Local Scour is scouring that occurs directly from buildings in the river flow.
- Contraction Scour is a scour that makes the flow of a river or channel become centered due to the narrowing of the river flow.

1.3. River Cliff Erosion
With the morphological explanation above, Winongo River has the potential to cause erosion and sedimentation. According to [4], riverbank erosion occurs due to landslides on river cliffs and the scouring of streams on the riverbeds. The scour of the riverbank erosion will become a landslide when the surface of the river recedes and the soil condition on the riverbank is saturated at the same time. Thus, landslides on the riverbank will occur after the large flow rate ends and recedes.

1.4. River Cliff Reinforcement Construction
[5] stated that river cliff reinforcement construction is used for unstable river cliffs, such as on winding outer riverbends. On the other hand, for a river channel whose bottom is not yet stable, erosion may occur and result in the lowering of the riverbed elevation.

1.5. Sediment Transport Analysis
According to [7], sediment transport analysis is used to analyze sediment transport in a river to identify changes in elevation on the riverbed. Meyer-Peter Müller introduces the sediment transport equation which is used to calculate the capacity of the sediment transport in a channel cut, namely the MPM equation, as shown in equation (1).

\[
\frac{\gamma}{\gamma_r} \gamma_{RS} = 0.047 (\gamma_r - \gamma) d_m + 0.25 \left( \frac{2}{g} \right)^{3/2} \left( \frac{\gamma_r - \gamma}{\gamma_s} \right)^{2/3} \frac{g_s^{2/3}}{G} \]

(1)

where:
- \( gs \) = sediment transport (mass/time/width)
- \( kr \) = coefficient of roughness
- \( kr' \) = grain-based roughness coefficient
- \( \gamma \) = specific gravity of water
- \( \gamma_r \) = density of sediment
- \( G \) = acceleration due to gravity
- \( Dm \) = average particle diameter
- \( R \) = hydraulic radius
- \( S \) = slope of the channel
2. Research Methods

a. Research sites
The research location is located on Winongo River with a river that was carried out by the researchers around ± 9.40 km, and the upstream is in Trirenggo Village area, Bantul Regency with coordinates 7° 54' 55.598" LS and 110° 20' 43.102" East Longitude, and empties into the river. Opak Kretek District, Bantul Regency with coordinates 7° 59' 20.3" South Latitude and 110° 18' 47.9" East Longitude. The research location on Winongo River can be seen in Figure 1.

b. Research data
a. Cross-section
Cross-section data were obtained from Serayu Opak River Basin Region in Yogyakarta Special Region (BBWSSO - DIY), namely a pre-design drawing of the Winongo River measurement in the form of a cross-section, totaling 200 cross-sections with .dwg format, made by PT. Sarana Bagja Bumi. Then, cross-section data were interpolated to became 274 cross-sections. The upstream of the river studied is the cross-section WN 200 and the downstream is the cross-section WN 2. Examples of cross-sectional measurements of Winongo River at the upstream, middle, and downstream are shown in Figure 2 to Figure 4.
Figure 3. The results of the measurement of the cross-section in the middle of Winongo River (Source: Data BBWSSO-DIY, 2017)

Figure 4. Cross-sectional measurement results at the downstream side of Winongo River (Source: Data BBWSSO-DIY, 2017)

b. Flood Discharge

The data of Winongo River flood discharge were obtained from Serayu Opak River Basin in the Special Region of Yogyakarta (BBWSSO - DIY), namely the flood discharge with a return period of 2 years (Q2), 10 years (Q10), 25 years (Q25), and 50 years (Q50). In this study, the data used were flood discharge data with a 2-year return period (Q2). Tables and graphs of the 2-year return period (Q2) interpolated discharge in Winongo River can be seen in Table 1 and Figure 5.

Table 1. The interpolated discharge for the 2-year return period (Q2) of Winongo River

| Time (Hour) | Q (m³/s) |
|-------------|----------|
| 0           | 0.2      |
| 1           | 16.71    |
| 2           | 33.42    |
| 3           | 31       |
| 4           | 24       |
| 5           | 19       |
| 6           | 14       |
| 7           | 10       |
| 8           | 7        |
| 9           | 5        |
Table 1. The interpolated discharge for the 2-year return period (Q2) of Winongo River (continue)

| Time (Hour) | Q (m³/s) |
|-------------|----------|
| 11          | 3.8      |
| 12          | 3.2      |
| 13          | 2.8      |
| 14          | 2.5      |
| 15          | 2.1      |
| 16          | 2.0      |
| 17          | 1.8      |
| 18          | 1.6      |
| 19          | 1.4      |
| 20          | 1.3      |
| 21          | 1.2      |
| 22          | 1.1      |
| 23          | 1.0      |
| 24          | 0.8      |

Figure 5. Graph of the 2-year (Q2) return period hydrograph of Winongo River

c. Sediment Grain Size Gradation
The sediment grain size gradation data were obtained by taking the material directly from the bottom of Winongo River to examine. The location of the material collection was in Kretak District, Bantul Regency. The data graph of Winongo River sediment grains can be seen in Figure 6.
Figure 6. Gradient graph of sediment grain size in Winongo River

3. Results and Discussion
   a. Simulation with HEC-RAS 5.0.7 Software

Riverbed erosion simulation using HEC-RAS 5.0.7 software was carried out in unsteady flow conditions (changing with time). Peak discharge data was obtained from BBWSSO-DIY. The hydrograph shape looks like a triangle, and the $T_c$ value is obtained from the AWRL measurement results in the Code River. The display of the results of unsteady flow analysis can be seen in Figure 7.
Based on sediment transport analysis simulation with HEC-RAS 5.0.7 software, the maximum depth data is filled with 1 meter. The boundary conditions used are Equilibrium Load, and bed gradation is filled according to the gradation of sediment grains in Winongo River. The display of the simulation results of sediment transport analysis can be seen in Figure 8.
### Table 2. Cross-section data on the occurrence of erosion on the riverbed

| Cross-section Data | Cross-section Layout |
|--------------------|----------------------|
| WN 173 to WN 175   | Sumbermulyo Village, Bambanglipuro District, Bantul Regency, DIY (7° 55' 36.192" LS dan 110° 20' 19.194" BT) |
| WN 131 and WN 132  | Mulyodadi Village, Bambanglipuro District, Bantul Regency, DIY (7° 56' 25.987" LS dan 110° 19' 54.984" BT) |
| WN 96 and WN 97    | Mulyodadi Village, Bambanglipuro District, Bantul Regency, DIY (7° 57' 13.126" LS dan 110° 19' 32.174" BT) |
| WN 86              | Parangtritis St. 16, Bantul Regency, DIY (7° 57' 26.093" LS dan 110° 19' 26.260" BT) |
| WN 58              | Parangtritis St., Turi, Sidomulyo, Bambanglipuro District, Bantul Regency, DIY |

b. **Conditions in the Field**
The results of field observations show that the condition of the riverbank safety structure had been damaging. The damage that occurred was cracking, collapsing, and collapsing with normalization. Damaged riverbank safety buildings can be seen in [Figure 9 to Figure 18].

![Figure 9](image)

**Figure 9.** Retaining wall collapses around the cross-section WN 173 to WN 175

![Figure 10](image)

**Figure 10.** The bottom of the retaining wall (right side) has been eroded around cross-section WN 173 to WN 175
Figure 11. The bottom of the retaining wall (left side) has been eroded around cross-section WN 173 to WN 175

Figure 12. Cracks of riverbank safety structures cross-section WN 131

Figure 13. Cracks of riverbank safety structures cross-section WN 132

Figure 14. Cracks of riverbank safety structures cross-section WN 96 (left)

Figure 15. Retaining wall collapse has been normalized in the cross-section WN 96 (right)

Figure 16. Crack of riverbank safeguard cross-section WN 97
4. Conclusion
Based on the results of erosion analysis at the bottom of Winongo River with HEC-RAS 5.0.7 software on the cross-section WN 200 to WN 2, it can be summarized as follows:

a. The cross-section that has experienced erosion is in the cross-section WN 173 to WN 175 (Sumbermulyo, Bambanglipuro, Bantul), cross-section WN 131 and WN 132 (Mulyodadi, Bambanglipuro, Bantul), cross-section WN 96 and WN 97 (Mulyodadi, Bambanglipuro, Bantul), cross-section WN 86 (Jl. Parangtritis 16, Bantul), and cross-section WN 58 (Jl. Parangtritis, Turi, Bantul).

b. The depth of erosion that occurs reaches 0.96 m, 0.84 m, 0.23 m, 0.09 m, 0.24 m, 0.11 m, 0.90 m and 0.83 m in the cross-section WN 173, cross-section WN 174, cross-section WN 175, cross-section WN 131, cross-section WN 132, cross-section WN 96, cross-section WN 97, cross-section WN 86, and cross-section WN 58 respectively.

c. The impact that occurs due to scouring, namely damage to the retaining walls, is marked by cracks and collapse. Small damage in the form of cracks will become major damage such as collapse if the retaining wall is not repaired immediately.

5. Acknowledgments
This research was funded by Ministry of Education and Culture of the Republic of Indonesia contract number: 165/E4.1/AK.04.PT/2021/ date 12th July 2021 through PDUPT scheme. The main title of the research is "Smart System Accelerometer for Sediment Disaster Mitigation".

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