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The Effect of Crib Installation with Placement Variations in River Bends Using Laboratory Model Tests

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Abstract: Scour or landslide is a problem that occurs at river bends. Many methods are used for scouring or landslide protection. One of the protections for scouring construction is crib model by using gabions and current-aligning bamboo. The purpose of this study is to determine of the effect of variations in the placement of the crib by using of gabions model and the current-aligning bamboo on the river bends. This research is an experimental test of the hydraulic model using river flume model with 5m on bend length, 0.8m width, 0.5m height and a constant discharge of 7.07lt/sec. The test consists of testing control, that is a bend without reinforcement and testing with reinforcement at the bends. The reinforcement at the bends using placement variation was twice carried out with the variation 1 consisted of 3 current-aligning bamboo, 4 gabions, 3 current-aligning bamboo and the variation 2 contains the opposite. The test results showed that the maximum scouring occurs in variation 1 with -5.4cm, -5.2cm on landslides and 0.61cm on scour. The results of the Surfer App and cross sections of stations P00 until P07 are more effective using gabions, while P08 through P24 are more effective using current-aligning bamboo.

Keywords: landslide, scour, crib, bends

1. Introduction

River is an open flow that has free water level and flows from upstream to downstream. In the Law of the Republic of Indonesia Number 7 of 2004 concerning Water Resources, it is stated that the river is one form of surface water channel that must be managed thoroughly, integrated and environmentally-friendly by realizing the sustainable use of water resources for the maximum prosperity of the people. The river is a systematic nature that we must maintain its sustainability and condition as it functions.

The existence of laws governing water resources shows that rivers are a form of waterways with enormous benefits. Therefore, the management of water resources must be carried out in an organized and sustainable manner.

The process of crushing and transporting sediments is a natural phenomenon that exists and occurs in river flows [1]. The crushing process occurs naturally as part of the river morphology in the form of curves or narrowing of the flow and can also occur due to the existence of river buildings (man-made structures) that block the flow as in the form of cribs, pillars, bridge abutments and so on. Strengthening check dam is effective at river bend models using 85 cm in distance for the beginning and the end of the bend while for the middle using a distance of 102 cm. For Gabion reinforcement a distance of 34 cm, effective for use at the beginning and the middle of the bend. For the end of the bend, the most effective using gabion with a distance of 17 cm [2]. The effect of installing the crib can reduce the volume of collapse and the best installation is with the distance of the crib installation equal to the height of the cliff. Then the best angle of crib installation is 135° upstream [3]. Tighter spacing, an effective in scour reduction for large turning angles with scour reduction reaching 70% [4].

The existence of the river structure is considered to be able to change the flow geometry and the river flow patterns where by the occurrence of scour and sedimentation, the river morphology can change both the location and size of the river. Therefore, this will disrupt life support infrastructure downstream of the river, such as dams, checks, bridges, and other infrastructure. The cliff at the river bend is expected to be managed in such a way that the infrastructure and morphology of the river stand as it should.

The Opak River is located in Guwosari, Pentholan, Pajangan Kidul, Bantul Regency, Special Region of Yogyakarta, which has many benefits for local residents, but there is scouring that often happened on the river banks. Therefore, this test was carried out with the aim of knowing the scouring before and after the reinforcement of the channel wall with laboratory models.

The results of laboratory testing are expected to have a theoretical good benefit in the form of knowledge transfer, especially in the normalization of river curves and practically in the form of donation of test results to the construction of river bend normalization.

2. Basic Theory

The Open channels are channels where water flows with free water levels. At all points along the channel, the pressure at the surface of the water is the same, which is usually atmospheric pressure [5]. A closed-channel flow pipe that is not full (there is still a free water level) is still included in the open channel flows, because it must have a free water level and the flow is usually related to liquid in which its general form is water. In open channels such as rivers (natural channels), the flow variable is very irregular in both space and time. These variables are channel cross-section, hardness, base slope, turn or curves, flowrate and so on.

River as an open channel will be very free in adjusting the morphology in reaction to changes in the hydraulic conditions of the flow. River morphology is the science that studies geometry, types, properties and behavior of rivers with all aspects of their changes in the dimensions of space and time, thus concerning the dynamic nature of rivers and their environment which are often related [6]. River morphology describes the integration between abiotic characteristics (physical-hydrology, 8 hydraulics, sediments, etc.) and biotic characteristics (biology or the ecology of flora and fauna) of the area along its path.

The formation of river starts from the accumulation of water on a land surface that is higher than its surroundings either from rain, springs, or glacier fluid. From the height difference, the pool of water will move towards a lower place so that a channel is formed from upstream to downstream. Initially, the upstream to downstream connecting channels are relatively simple and short in shape. However, over time, the water will erode the area in its path which then results in an upstream connecting channel with a wide and long downstream so that a river is formed.

In general, the type of open channel flow is turbulent in which caused by the flow velocity and roughness of the cliff that is relatively large. The open channel flow will be turbulent if the Reynolds number (Re) is> 1,000 and will be laminar if the Re number is> 500. In this case, the characteristic length that exists in the Reynolds number is the hydraulic radius which is defined as the ratio between the wetted perimeter [5].

In addition, open channel flow can be divided into subcritical flow and supercritical flow. The flow is called sub-critical if a disturbance that occurs at a point in the flow can spread upstream. Sub-critical flow is influenced by downstream conditions and, in other words, downstream conditions will affect upstream flows. If the flow velocity is large enough so that the disturbance does not spread upstream, then the flow can be categorized as super critical. In this case, the upstream conditions will affect the downstream flow. Factors affecting flow in an open channel are:

$$Fr = \frac{U}{\sqrt{gD}} \tag{1}$$

Given:
Fr   = Froude number
U   = Flow Velocity
D   = Hydraulic depth
g   = Acceleration of Gravity, m/s²

Flow rate (Q) on a channel cross-section for transverse flow is expressed by [7]:

$$Q = V \times A \tag{2}$$

Given:

Q   = Flow rate, m³/s

V   = Average Velocity, m/s

A   = The cross-sectional area that perpendicular to the direction of flow, m².

For the calculation of the basic roughness coefficient, several experts have proposed several forms of the Chezy's coefficient (C) based of the general formula below [5]:

$$V = C \sqrt{R\,I} \tag{3}$$

Given:

V   = Average Velocity

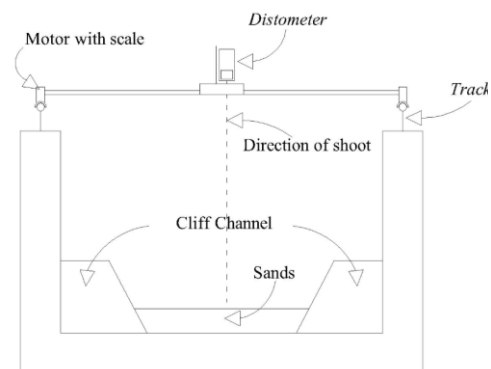R   = Hydraulic channel radius

I   = Channel slope

C   = Chezy's coefficient

3.   Research Methods

This test aimed to determine the effect of gabions and current-aligning bamboo installments at the river bends with variations in placement. This test was carried out by modeling the river on a laboratory scale in the form of a trapezoid in which printed on a flume channel with a bend length of 5m, a high angle of 0.5m, width of 0.8m, and a 90 ° bends or curve. In conserving water usage during the testing process, a closed channel was formed where water in the downstream of the flume was accommodated and sedimented in a settling basin and pumped in a reservoir and then be drained upstream of the flume channel. The process above can be seen in Figure 1. The test consists of testing control, that is a bend without reinforcement and testing with reinforcement at the bends. The reinforcement at the bends using placement variation was twice carried out. For the first variation test (variation 1), 3 current-aligning bamboo, 4 gabions, and 3 current were used. For the second variation (variation 2), the combination of 3 gabions, 4 bamboo and 3 gabions were mounted. The measurement and retrieval of scour data is carried out before and after the running process and the retrieved data was analyzed using Microsoft Excel and Surfer. The further details is available in Figure 13.
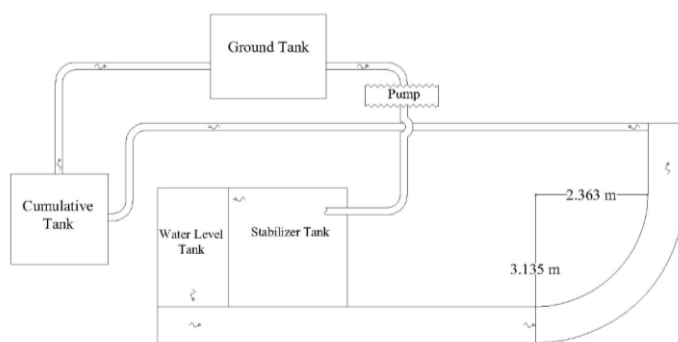
**Figure 1.** Closed channel flow cycle   **Figure 2.** *Track* motor systemization.

3.1. Data Collection Techniques

Every data collected is taken using the same, stable flow rate and depth. Data retrieval is done by observing the scouring that occurs around the cliff and river channel floor until the scour is stable. Data is collected as follows:

- On the lip of the channel, measurement station markers were made from 0 to 24.

- Scaled Track Motors were assembled and marked with a horizontal spacing of 1 cm by 21 points and 5 cm by 8 points thereafter.
- The distometer was mounted on the scaled track motors.
- *Scaled Track Motors we*re positioned from the 0th station. The condition of the right and left wheels must occupy exactly at the station to be reviewed.
- The measurement started by pressing the enter key on the laptop for each distance.
- The distometer mounting was moved horizontally according to the prepared space.
- The process was repeated for stations 0 through 24.
- The data measurement process was carried out twice for each variation, which is before and after the running process. The data obtained were analyzed using Microsoft Excel and Surfer.

3.2. Testing Stages
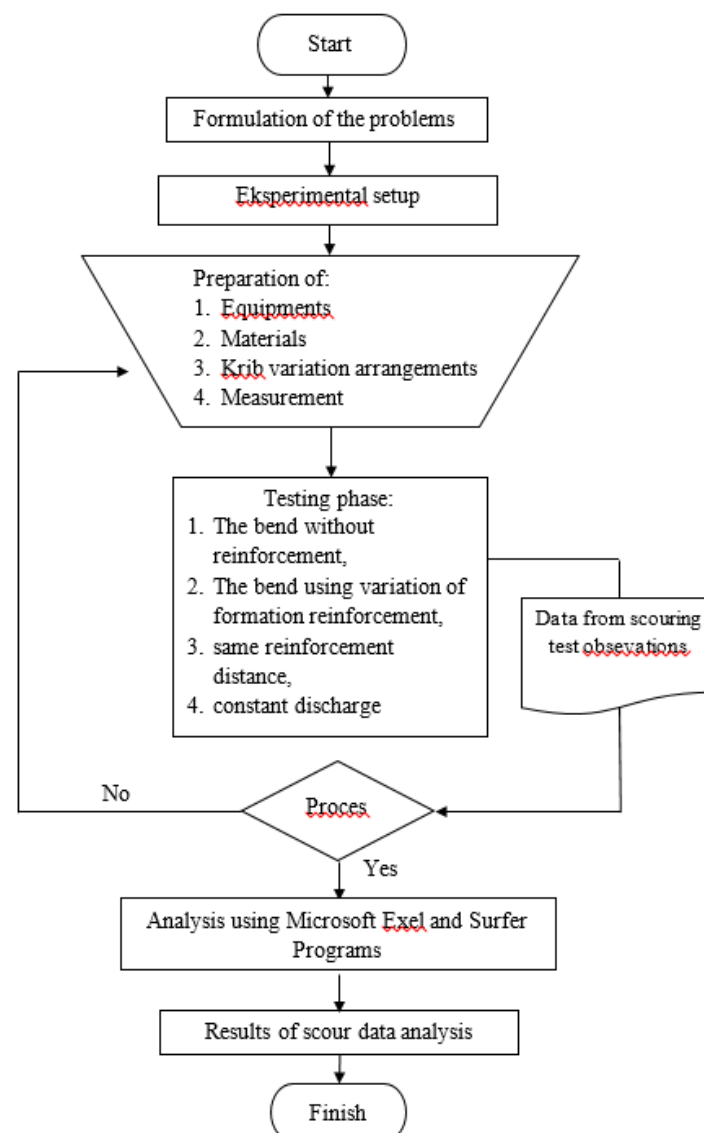
Figure 3. testing stage flow charts

The research that was carried out is an attempt to strengthen the river channel model by installing crib using gabion and current-aligning bamboo in which divided into two variations of placement. The test results were obtained by measuring the depth of scour with a laser meter from the upper wall of the

channel. The results of scour then compared with the results of scouring of river channel model without reinforcement. The stages of strengthening testing conducted in this study is presented in Figure 3.

3.3. Type of research
This study uses a qualitative approach in the form of calculation of scouring results on a cliff at a river bends using Microsoft excel and Surfer program.

3.4 Time and place of research
This research was conducted on January 25, 2019 to April 15, 2019 at the Hydraulic Laboratory of the Department of Civil Engineering and Planning Education, Faculty of Engineering, Yogyakarta State University

4.   Results and Discussion
The results of observations of scour depth that occurred in the early minutes showed a fairly large scour due to unstable flow conditions. Stations 00 until 06 do not show any sediment that occurs on the outside or inside the channel which can be seen in Figures 4 and 5.

Figure 4. Upstream channel variation 1.
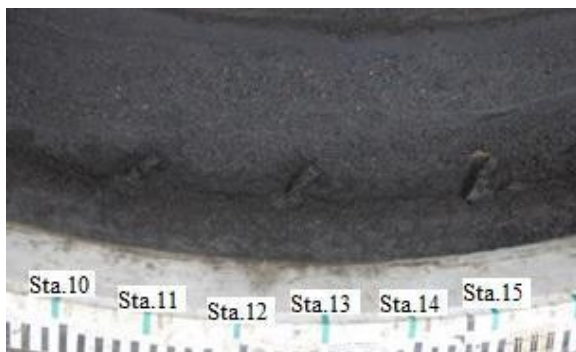

Figure 5. Upstream channel variation 2.
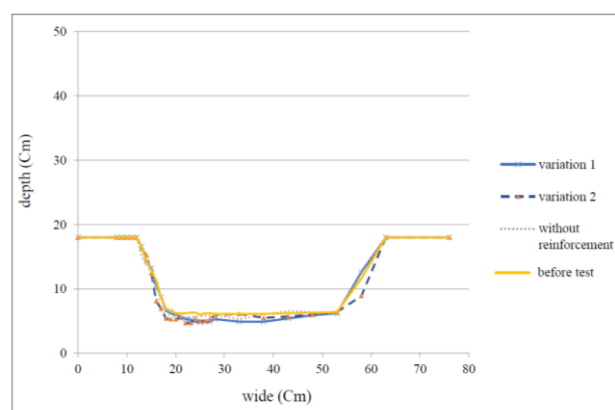
Figure 6. Graph P07-comparison of variations 1, 2, and
without reinforcement.

The scouring on the upstream channel in Figure 6 shows the comparison between station P07 and the cliff without reinforcement treatment and variations 1 & 2. Variation 1 has a scouring value of -1.6 cm while variation 2 has -1.3 cm. Sediments that occur in variation 1 and variation 2 have the same value, which is +0.2 cm. The outer cliff of the channel also decreased in height from its original point by 0.7 cm in variation 1 and 1 cm in variation 2. The results of computational calculations with cliff without reinforcement showed that variation 1 can reduce scour by 1.98% and 2.57% for variation 2.

Figures 7 and 8 show the condition of the center of channels 10 to 15. At this station, there are scours on the outer edge of the cliff and floor of the channel, and there are also sediments on the inner side of the channel. This result is seen both in variations of formation 1 and 2, but the results of scouring and sedimentation are more extreme in variation 1.
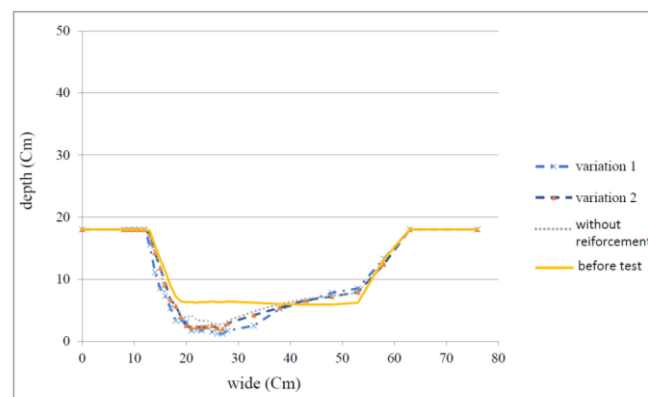
The scouring on the upstream channel in Figure 7 shows a comparison between station P17 with without Reinforcement treatment and variation 1. It is shown that variation 1 gives a deeper scouring effect than variation 2 which is 5.4 cm compared to -5.2 cm in variation 2. It can also be seen that the sediment in variation 1 is +2.6 cm and +2.2 cm in variation 2. Avalanches on channel cliffs in variation 1 have a deeper impact than variation 2. Variation 1 has an avalanche value of -5.2 cm compared to -3.3 cm in variation 2. The results of computational calculations with cliffs without reinforcement shows that variation 1 has an increase in scour value of 3,473% and variation 2 has a scour decrease of 1.91%.


Figure 7. Middle channels of variation 1.   **Figure 8.** Middle channels of variation 2.

Figure 9. Graph P17-comparison of variations 1, 2, and without reinforcement.

The scouring on the upstream channel in Figure 10 shows a comparison between P22 station with without Reinforcement treatment and variation 1. Variation 1 has scour values of -5.3 cm while variation 2 has -4 cm. Sedimentations that occurs in variation 1 is +2 cm and +1.9 cm in variation 2. The results of computational calculations with cliffs without reinforcement shows that variation 1 can reduce scouring by 3.02% and 4.86% in variation 2.
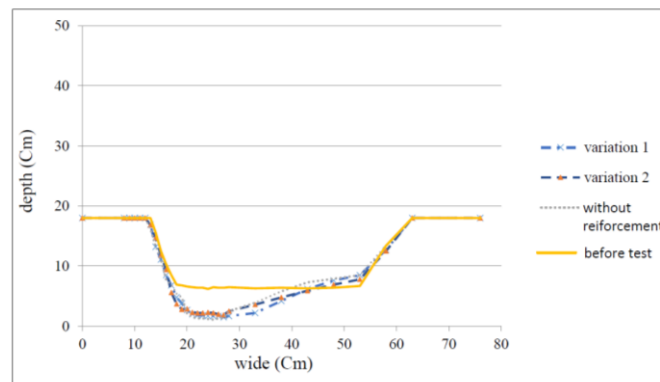
Figure 10. Graph P22-comparison of variations 1, 2, and without reinforcement.

Figures 11 and 12 shows the conditions in the center of channel 17 to 24. At this station, there are scours on the outer edge of the cliff and the floor of the channel. Likewise, there are sedimentations on the inside of the channel. This result is seen both in variations in formations 1 and 2, in contrast to the extreme middle side scours that occur in variation 1.

**Figure 11.** Downstream channels variation 1.


Figure 12. Downstream channels variation 2.

After the running process has been completed for 180 minutes with water without sediment and constant discharge, a channel contour will be produced vertically scouring on the sand layer and scouring in the form of an avalanche that occurs on the bank of the channel. The results of the channel contour are measured in depth by using distometer. The distometer is placed on a scaled track motor and then moved transversely with the spacer scale that was made on the motor. Measurement using distometer will produce Z data on the 3-way axis. Z data will describe the depth of the channel.

X-axis data is taken by measuring the 0th point at each station. Y data is taken by measuring the 0th point of each station. Measurements were done using the Cartesian chart which is depicted as the top view on the channel. The line at point 0 of each station is drawn to the left to get the Y axis and down to get the X axis. After X, Y, and Z data are obtained, the data is processed to be drawn in 3 dimensions using the Surfer application.
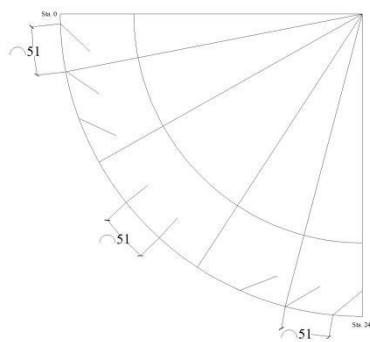
**Figure 13.** Reinforce placement systemization.
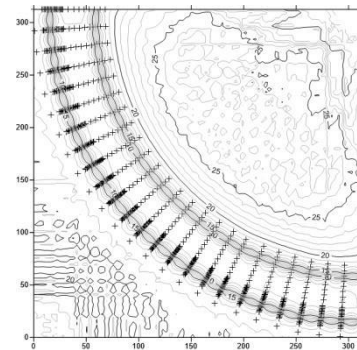
Figure 14. Measurement point systemization.

The results of the analysis using the Surfer Apps illustrate that the biggest scour takes place in the middle of river turn. Meanwhile, on the opposite cliff, sedimentation occurs when entering the middle to the downstream. River floor material shown in light green. The biggest scour is shown in whitish green. Sedimentation is shown in yellow. The 3-dimensional contour fill material is shown in blue on the inner turn and white on the outside turn. The scouring of the river floor starts from the middle to the downstream of the channel that shown by the whitish green color on the outside of the channel bottom and still connects to the downstream of the channel. Sedimentation occurs on the inner side of the channel bottom. Sedimentation can be seen in the middle of the channel that connects to the upstream channel in yellow.
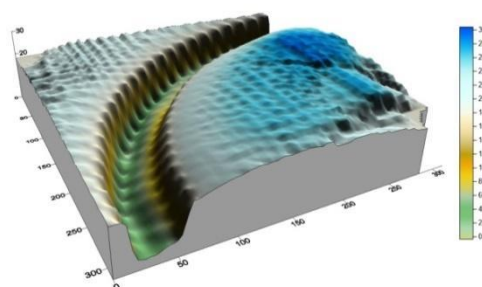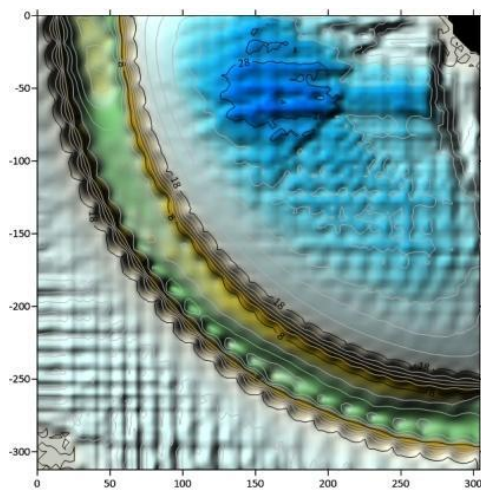

Figure 15. Variation 1-contour pattern on downstream view after *running*.
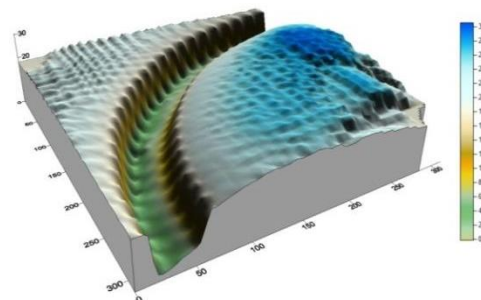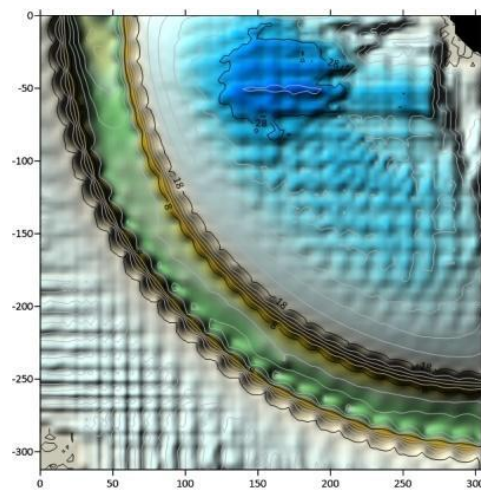

Figure 16. Variation 2-contour pattern on downstream view after *running*

The scour pattern that is formed due to the influence of the installation of the crib using variation 2 is a decrease in the floor that occurs from upstream to downstream. The greatest scouring occurs in the middle to downstream channel. The scour on variation 1 which has 2.84cm in length can be seen in Figure 15 and variation 2 which has a length of 2.23cm can be seen in Figure 16.

Figure 17. Variation 1-Contour Pattern on Top View After *Running*

Figure 18. Variation 1-Contour Pattern on Top View After *Running*

5.   Conclusions and Suggestions

The results of the analysis using Surfer App and Microsoft Excel show the following outcomes:

a)   The maximum bottom scouring occurs in variation 1, which in in the middle of a river bend with 5.4 cm and a cliff avalanche of -5.2 cm from its original point. The scour shape on the bottom of the channel drawn using the surfer program also shows that variation 1 has a longer shape than variation 2, which is 0.61 cm.

b)   The results of the 3-dimensional analysis using the Surfer App and cross-section graphs show that, at stations P00 to P07, the use of gabions is more effective in strengthening the outer cliffs of the channel. At stations P08 to P24, channel reinforcement outside the channel is more effective using flow-aligning bamboo. At stations P08 to P24, the use of gabions is less effective.

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