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Phenomenon of Sedimen Transport in the Vary Distance of Check Dam Series

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ABSTRACT

This study investigated the flow and sedimentation patterns at a series of check dams on the Kuranji River. A physical model was built in the laboratory at a specific scale to simulate field conditions. The models were built using an approach to existing conditions with a dam height scale of 1:125 while the check dam spacing was 1:300 while the field condition spacing between check dams of scenario 1 (89.00 cm), scenario 2 (94.00 cm), scenario 3 (200 cm). All models were conducted in a 40 x 40 cm rectangular open channel in the laboratory of Fluid Mechanics and Hydraulics, Faculty of Engineering, Andalas University, Padang. Sediment material was used from the Kuranji Trunk. Furthermore, each experiment with variations in flow discharge was observed and measured the sediment distribution pattern before and after the check dam building. From the test results, it was found that the sediment balanced condition ranged from 10-19 minutes after the water came out of the dainhole. Sediment distribution patterns are influenced by two main factors, namely the distance between check dams and flow discharge. The use of too far a distance results in sediment having a greater chance of moving away downstream, on the other hand, with a close distance between check dams, the sediment distribution moves not too far. Discharge variations affect the scouring depth. The greater the flow discharge, the greater the energy to scour and carry the greater sediment.

Keywords: *Check Dam Series; Sediment; Flow Discharge; Channel; Scour.*

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INTRODUCTION

The main problem that often occurs in rivers is sedimentation. Sedimentation is the process of deposition of solid particles transported by water flow from upstream and carried downstream of the river in a volume per unit time called the sediment rate [1][2]. Sedimentation can cause siltation of rivers, downstream estuaries, damage river cross-sections and reduce reservoir performance. Knowing the magnitude of the impact caused by sedimentation, a sediment control building in the form of a check dam is needed. Check dams are water buildings that function as sediment control, accommodate sediment and reduce the speed of water flow. As for the check dam building, it is necessary to know the spread or phenomenon of sediment after the building.

Several check dams have been built along the Kuranji River precisely in the middle segment. However, visually there are still piles of sediment downstream of the building and scouring. The construction of check dams in the middle segment has established 4 check dam buildings with check dam spacing categorized as close together. The construction of the check dam is considered less efficient against sedimentation which results in uneven buildup along the river flow. Several researchers have conducted studies on check dams built along the river including the following.

Latif, et al (2018) conducted research on sediment movement due to discharge fluctuations in open channels (laboratory tests), aiming to determine the effect of sediment movement due to discharge fluctuations and determine the influence of changes in the channel bed (Agradation and Degradation) due to sediment movement. This research was carried out by measuring the water level and flow speed. Measurements are carried out when the water is stable, measurements of scour height and deposition are carried out when the channel is dry. This research shows that the sediment grains tend to start moving. The greater the flow rate, the greater the sediment movement. The depth of scour that occurs is influenced by variations in discharge, the greater the discharge, the greater the scour that occurs. [3]

Thaahaa, et al (2017) conducted research on the effect of sill layout on double cylinder pillar scour. This research study is about physical modeling in the laboratory which observes the depth of scour due to the layout of the sill to the pillar by varying the distance of the sill to the pillar. Then it was tested with 3 variations of discharge to see the depth of scour and differences in scour characteristics. The scour characteristics of the first sill layout. The scouring occurred significantly at the start of the water flow but the bottom of the channel became stable (scorching and settling stopped) after a few minutes the water overflowed from the verge while in the The location of the second threshold occurs in reverse where the reverse flow significantly influences the formation of the flow structure. [4]

Surya, et al (2022) conducted research on the effectiveness of ring net barriers in controlling sediment which was carried out using laboratory tests. This research uses water structures such as closed type sabo dams , slit types and ring net barriers as a comparison of the three water structures' performance to see the volume of sediment retained. This research carried out changes in elevation upstream and downstream of the building using a scale of 1:60, a sediment concentration of 10% and varying the flow discharge. The flow discharge used is the debris flow discharge. From varying the flow discharge, the test results show that the closed type sabo dam holds more sediment than the slit type sabo dam, while the slit type sabo dam has the ability to hold more sediment than the ring net barrier. [5]

Darwizal Daoed, et al (2015) conducted experimental test research on strengthening channel banks with gabions at bend 1200 against flood discharge. The results of the research showed that gabion failure occurred at the beginning and end of the bend, and after it was strengthened with combined horizontal and vertical reinforcement (into a compact element) and an extreme channel bottom slope of up to 7%, only the downstream part of the bend experienced collapse and vice versa for steeper slopes, so the collapse accelerates. It can be concluded that the part downstream of the bend requires a design with more stable reinforcement. [6]

Daoed (2008) conducted research on river bend angles that have a significant effect on the sedimentation process. Scouring generally occurs at the beginning of the bend, while deposition occurs at the end of the bend. This phenomenon is caused by changes in the speed and direction of water flow along the river bend. The study used an open channel model to simulate the effect of bend angle on sediment transport. The model is 12.5 meters long, 40 cm wide, and 40 cm high. The sediment material used came from the Kuranji River. The four variations of bend angle tested were 600, 900, 1200, and 1500. The simulation results show that there is a relationship between the bend angle and sediment transport discharge. The greater the bend angle, the greater the sediment transport discharge, and vice versa. This increase in sediment transport discharge occurs exponentially as the bend angle increases. [7]

Saputra, et al (2015) conducted research on the stepped spillway model by varying the position of the stepped spillway by 3 positions at the bend with 3 variations in discharge. The results of the research on small discharges form a flow profile that follows steps, whereas for large discharges there is a jump. The greater the scour discharge downstream of the spillway, the greater and greater on the contrary. The smallest scour volume occurs on the spillway which is as far as the width of the spillway before the bend and conversely the large scour volume occurs when the spillway is placed near the bend and which is very far from the bend. [8]

Putri, et al (2018) conducted a study of porous concrete kribs at the bend, this aims to determine the value of compressive strength, porosity, and infiltration rate in porous concrete, as well as its effectiveness as a krib construction for protection at the bend of the river. This study uses porous concrete mixtures with variations in the ratio of cement and aggregate 1:4 and 1:6, and different sizes of coarse aggregate. The coarse aggregate used was split stone from UD. Maju Jaya Stone Crusher Konda, Kab. Konawe Selatan. Tests were conducted at 14 and 28 days of concrete age. The highest compressive strength value at 28 days was found in the 1:4 mix with 1-2 cm coarse aggregate, which amounted to 12.17 Mpa. The highest porosity value at 28 days was found in the 1:4 mix with 0.5-1 cm coarse aggregate, which was 15.6%. The larger the coarse aggregate size, the greater the infiltration rate. The highest infiltration rate was found in the 2-3 cm coarse aggregate, which amounted to 2804.71 inches/hour. Porous concrete with 1:4 mix and 1-2 cm coarse aggregate meets the planned concrete quality requirements (12 Mpa). Porous concrete type krib construction effectively reduces the velocity of water flow behind the krib due to friction with the construction part, thus reducing scouring and allowing sediment deposition. [9]

Azwarman (2013) tested the movement of bottom sediments and scour in straight channels, especially in high altitude areas with alluvial soils, strongly influenced by erosion and sediment transport that can change the shape of the channel. In daily flow, sediment scour will occur if the flow velocity produces a critical shear stress that exceeds the permissible velocity and shear stress. Sediment scour is greater for flow in bends than straight channels. Research on straight channels in the direction of the bend shows that the flow in the bend can destroy the outside of the channel bank, while on the inside of the bend there is a large deposition. This depends on the channel discharge and its slightly changing morphology. The time it takes for flow to reach steady state is also important. Steady state is reached when there is a balance between sediment carried away by the flow and sediment entering, so that changes in cross-sectional shape are almost non-existent. In the alluvial channel assessment experiment, six variations of flowing time were conducted with the same discharge (q=0.00354 m3/det) and D_{50}=0.0004. A sandfeeder was installed upstream of the channel to control sediment supply. This study aims to further understand the dynamics of sediment movement and changes in alluvial channel shape due to variations in flow time. [10]

Wardani (2018) carried out laboratory tests by installing gabion stone check dams at bends by varying the distance of the check dams with the aim of knowing the amount of scour that occurs on river banks and knowing the effect of installing check dams by varying the distance between check dams. The test used a flume with a turning length of 5 m, an internal width of 0.8 m and a height of 0.5 m. trapezoidal shaped channel with a bend angle of 900 , there are 7 check dams on the bend with the distance between the check dams being 68 cm. Observations were made with constant discharge and 3 variations in the distance of check dam installation. The results of the research showed that check dams located in bends were effective in reducing scour at the beginning and end of bends, while those in the middle of the channel were effectively used. [11]

Ramli (2013) conducted research on the Manggottong sabo dam against scour. Mangottong sabo dam is located in Kampala village, East Sinjai sub-district, built in 2009. A few months after completion of construction there was a flood that caused damage to the right side of the sabo dam wing, and damaged the energy reducer. In May 2012 there was damage to the lighthouse of the sabo dam. The purpose of this paper is to analyze the stability of the Mangottong sabo dam in Sinjai district, while the objectives are to determine the dimensions of the sabo dam due to changes in river width by flooding, analyze the condition of the sabo dam and its equipment whether it is still safe and can function after changes in river dimensions, analyze the stability of the sabo dam against the influence of the position of the building after flooding. From the results of the analysis carried out, the value of the forces obtained that the stability of the sabo dam building design is still safe and can function properly. [12]

Islami (2014) conducted laboratory test research on the analysis of meander changes in soil channels due to discharge variations. The research method used a hydraulic model with a trapezoidal channel and a bend angle of 90 degrees, the walls and bottom of the channel were made of poorly graded soil. Three different water discharge variations were used (Q_1 = 38.16 L/min; Q_2 = 49.65 L/min and Q_3 = 63.01 L/min). Observations were made at 13 channel cross sections. Results The largest change in meander radius occurs at the highest discharge (Q_3 = 63.01 L/min), which is 1.005 times the initial radius. This study shows that variations in water discharge affect the change in the radius of the meander in the soil channel. Higher water discharge causes greater changes in the meander radius. However, the changes were relatively small. This shows that the soil has a fairly good resistance to changes in water flow. [13]

Silva, et al (2016) conducted laboratory tests and numerical simulations on slit type check dam buildings to assess the efficiency of slit type weirs (open type weirs) and determine the performance of weirs as shortterm structural mitigation measures against debris flows in steep channels by carrying out different tests on the shape of parallel slit check dams and V-shaped slit check dams. From the second test of changes in slit shape, it was found that parallel type slit weirs are more appropriate for use in steep flowing channels to hold material. [14]

Wiyono, et al (2011) conducted research on the comparison of local scour of live-bed scour and transportation types that occur around vertical wall abutments without wings and with wings in straight channels in various channel conditions (straight, 90 ° bend, and 180 °) with variations in flow discharge. Tests were conducted with flow discharge variations of 4, 5, 6, and 7 liters/second. The physical parameters measured were scour velocity and depth. The measurement results were compared with analytical calculations using Laursen (1960), Froehlich (1989), and Melville (1997) formulas. Research Results On abutments without wings, the Laursen Formula (1960) gave the closest results to the observations with an error of 20.02%. On abutments with wings, the Froehlich Formula (1989) gave the closest results to the observations with an error of 28.17%. The results show that abutment type and channel geometry affect the scour and sedimentation patterns that occur. This information can be useful in bridge planning and design to minimize the risk of scour damage. [15]

From some of the research results above, researchers see great potential to provide further understanding of the effectiveness of check dam buildings in sediment control such as tests conducted by Wardani by conducting tests on straight channels, adding varying distances and

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discharges, and also channel slopes. modeling of check dam buildings based on the Kuranji rod located in Padang City, West Sumatra. The Kuranji River in the middle segment has been built several check dam buildings that contain more than one sediment control building (Check Dam Series) with the location of the distance between check dams categorized as close together. Modeling of 1:125 scale check dam buildings using clear acrylic material and check dam spacing of 1:300. Channel modeling of clear acrylic material with dimensions of 40 cm x 40 cm channel length of 12.8 m. sediment material used from Kuranji Rod that passes the No. 4 filter retained by the No. 100 filter. The purpose of this study was to determine how the distance between buildings affects the flow pattern and sediment deposition.

Location Of Study

This research takes check dam modeling and check dam spacing located in Kuranji Batang, Padang, West Sumatra. The check dam was built in the middle segment of the Kuranji Batang. The distance from check dam 1 to 2 is 267.01 m, check dam 2 to 3 is 280.57 m and check dam 3 to 4 is 597.49 m. The following is the placement of each check dam in Figure 1.

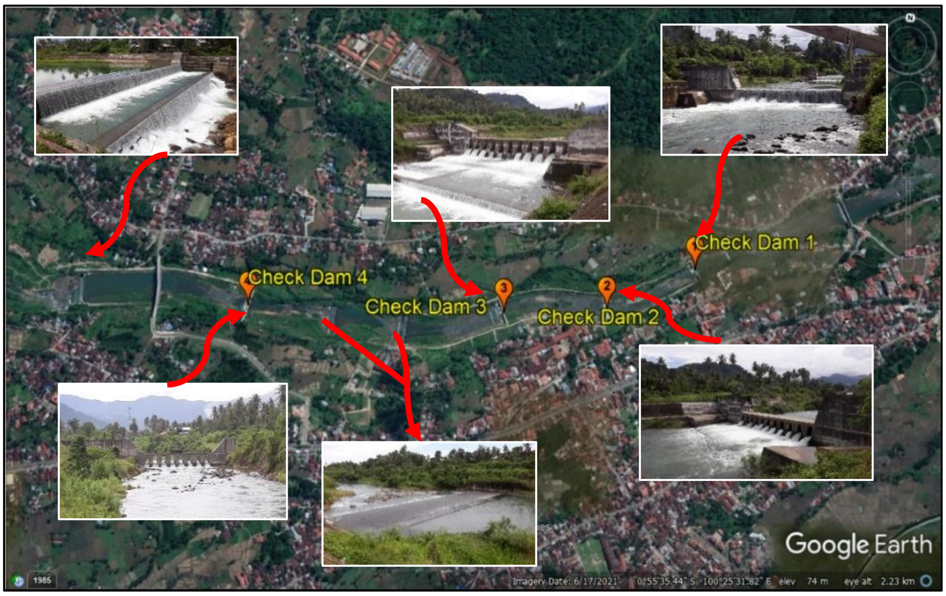

Figure 1. Location of Batang Kuranji Check Dam

METHOD

Research Approach

This study aims to determine how sediment spreads based on the distance from the check dam and flow discharge. Sediment height data obtained from laboratory testing will be processed and visualized using the Surfer application. This research is expected to provide additional information and complement similar studies that have been conducted previously.

Research sites

Tests were conducted at the Fluid Mechanics and Hydraulics Laboratory, Department of Civil Engineering, Faculty of Engineering, Andalas University, Padang.

Data collection technique

The primary data used is data obtained in the field in the form of direct measurements of check dam buildings in Batang Kuranji as a guide to the size of check dam modeling in laboratory research. The testing method of fine aggregate and coarse aggregate sieve analysis is

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determined based on SNI ASTM C 136-06. [16]

Laboratory Testing Procedures

1. Before conducting research, things that must be paid attention to first are calibrating the tools that will be used so that the research process runs smoothly, such as:
    - Set the slope of the channel to be used
    - Ensure that the water pump and measuring level can be used properly
    - Ensure that the channels do not leak when the water is flowing and are clean
    - Regulate the water flow that will flow into the channel
    - ensure that the water that will be distributed is clean water
2. The placement of the Check Dam buildings in the channel consists of 3 Check Dam buildings with the arrangement of the first Check Dam building at the beginning (after the damper basin), in the middle and at the end adjusted to the scale obtained from the distance between the Batang Kuranji Check Dams.
3. Place the sediment material into the open channel before the building and after the building for a length of 50 cm with a material height of 10 cm. The sediment material that is put into the channel is ensured that the surface is flat using a spirit level.
4. The water pump is turned on and observe the phenomenon of sediment spreading in the channel before and after the building.
5. Calculate the water flow rate using a water storage container and stopwatch.
6. If there is no sediment movement the pump is turned off.
7. Measure the height of the sediment after the water recedes using a measuring level.
8. After all the Check Dam series laboratory test processes were completed, the researcher carried out a comparison of each data obtained during the laboratory test and input the data into Excel and into the surfer application to obtain a contour image during testing in the laboratory.

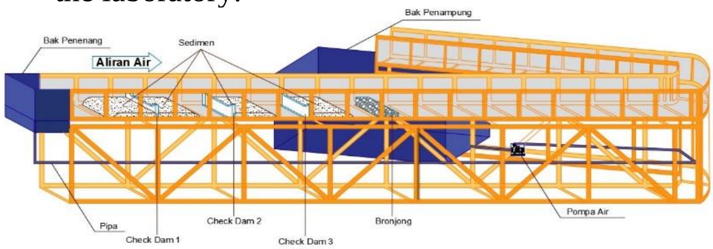

Figure 2. Check Dam Series and Sediment Staging in the Laboratory

RESULTS AND DISCUSSION

The results of the sediment distribution in this research are in the form of images and information obtained during testing in the laboratory. The following are the results of the study that have been obtained with the basic slope of the channel 1.13^0.

1. Check dam distance 89 cm discharge 0.81 l/s

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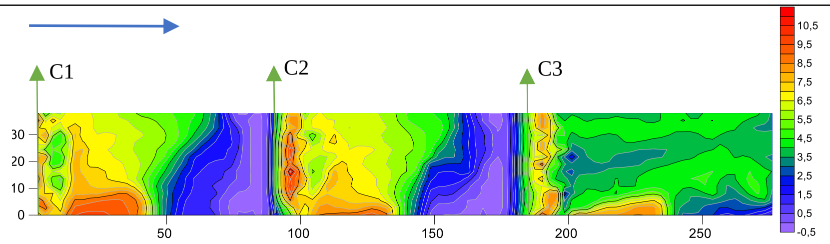
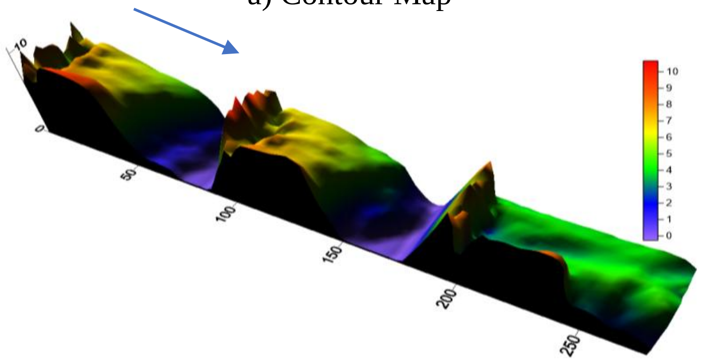


a) Contour Map

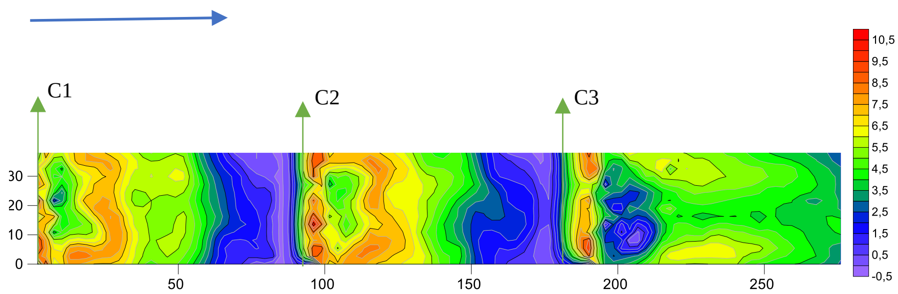


(b) 3D image

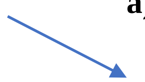
Figure 3. Sediment distribution distance 89 cm discharge 0,81 l/s

From the picture above with a distance of 89 cm, scour occurs at the beginning of the fall of the water flow from the check dam building. The water flow flows off towards the water reservoir, so the flow energy is still large and causes scouring, this indicates that the energy of the water flow is still quite large after passing through the check dam, thus eroding the sediment downstream and the height of the remaining sediment after check dam 3 is ± 2 cm (marked in light blue). This indicates that most of the sediment has been eroded by the water flow. Sediment conditions after check dam 1 and check dam 2 show a decrease in sediment (sedimentation). The water flow is obstructed by the check dam building, so the flow speed is reduced and causes the sediment to settle. Water flow tends to flow in the center and left of the channel. This indicates that the water flow is not evenly distributed across the width of the channel. The uneven water flow causes sediment accumulation on the right side of the channel. There may be other factors that affect the flow direction, such as channel geometry, surface roughness, or other obstacles.

2. Check dam distance 89 cm discharge 2,24 l/s



a) Contour Map



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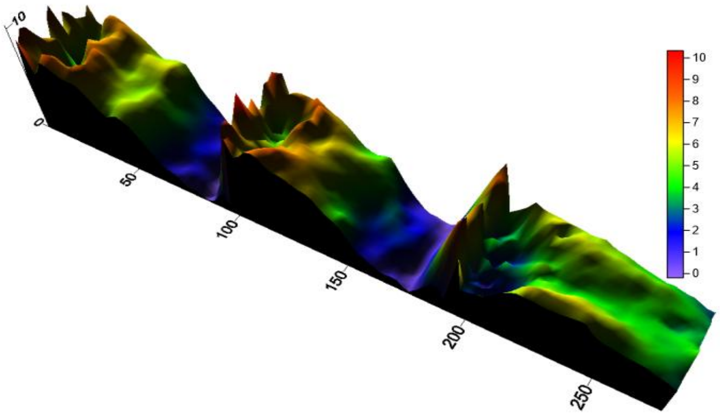
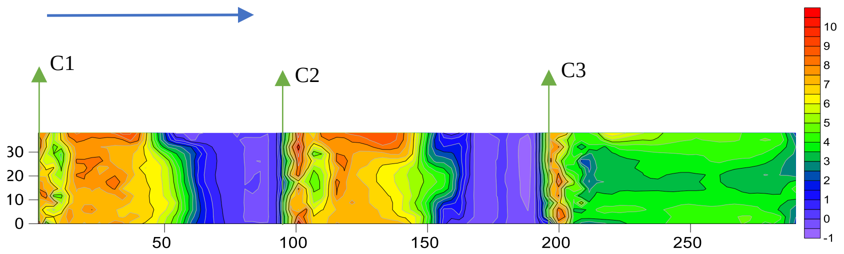


(b) 3D image

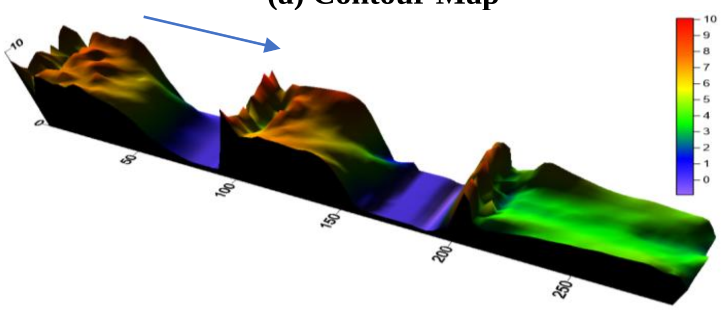
Figure 4. Sediment distribution distance 89 discharge 2,24 l/s

Sediment conditions in the check dam building after testing with a distance of 89 cm and a discharge of 2.24 l / s. Extreme scour at Check Dam 3 with very significant sediment scour. This is characterized by a sediment height of ± 1 cm (blue color). This scour indicates that the water flow at this point has considerable energy to erode the sediment. The water flow tends to flow in the center of the channel, resulting in sediment accumulation on the right and left sides of the channel. This sediment buildup area is marked in yellow. This indicates that the energy of the water flow in this area is not strong enough to carry the sediment, so the sediment settles. The sediment condition after building check dams 1 and 2 has decreased. This shows that the check dam functions well in retaining sediment from upstream. The presence of check dams causes the flow of water to be restrained and rotate back upstream. This reduces the energy of the water flow and allows the sediment to settle. Check dams work by slowing down the speed of water flow, so the ability of water to carry sediment is reduced.

3. Check dam distance 94 cm discharge 0,78 l/s



(a) Contour Map



(b) 3D image

Figure 5. Sediment distribution distance 94 cm discharge 0,78 l/s

Based on the figure above, the water flow tends to flow to the right side of the channel with a discharge of 0.78 l/s at a distance of 94 cm. This causes a flow imbalance that results in uneven

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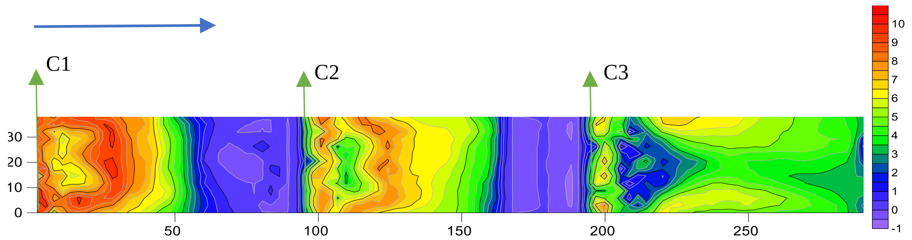
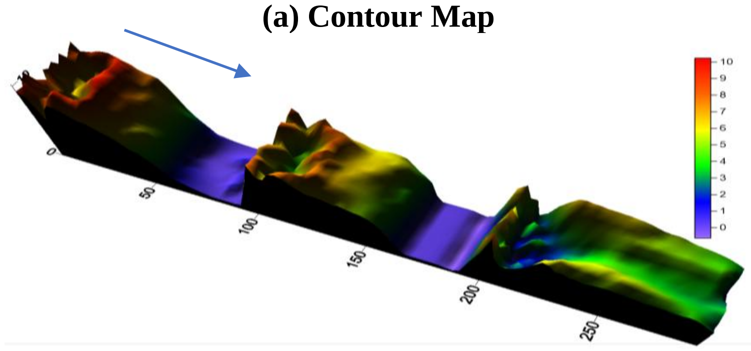
sediment buildup around the check dam. In check dams 1 and 2, sediment accumulation occurs on the left side of the channel with a height of ± 9.5 cm (marked in red). This is due to the stronger water flow on the right side, so that the sediment is carried away and deposited on the left side where the flow is calmer. While in check dam 3, sediment accumulation occurs on the left side of the channel with a height of ± 6 cm (marked in yellow). However, this sediment tends to be evenly carried downstream of the channel. Possibly, this is due to the flow conditions at check dam 3 compared to check dams 1 and 2. The discharge and speed of water flow greatly affect the ability of water to carry sediment. Stronger flows will carry more sediment and can cause erosion. The type and size of sediment carried by the water flow will also affect sediment accumulation. Finer sediments will be more easily carried and deposited.

4. Check dam distance 94 cm discharge 2,17 l/s



(a) Contour Map



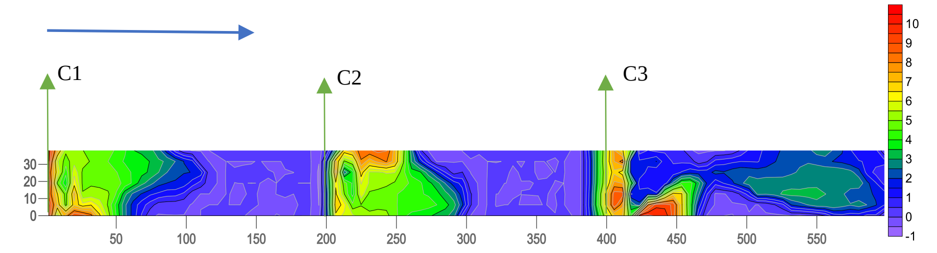
(b) 3D image

Figure 6. Sediment distribution distance 94 cm discharge 2,17 l/s

Based on the picture above the check dam distance of 94 cm with a discharge of 2.17 l/s, the largest scouring occurs after check dam 3, precisely in the middle of the channel. This is indicated by the blue colored channel bottom surface. The largest scour is caused by the flow of water that tends to flow in the center of the channel after passing check dam 3. This concentrated flow in the center of the channel causes greater erosion in that area.

In check dams 1 and 2, water flow tends to be more dispersed and less concentrated at one point, thus reducing the potential for scour. Several other factors that can affect scour in the channel, the greater the water discharge, the greater the energy possessed by the water flow to erode the channel bottom, high flow velocity also increases the potential for scour, different soil types have different levels of resistance to erosion. Softer soils will erode more easily than harder soils and channels with steep slopes will have higher flow velocities, increasing the risk of scour.

5. Check dam distance 200 cm discharge 0,69 l/s



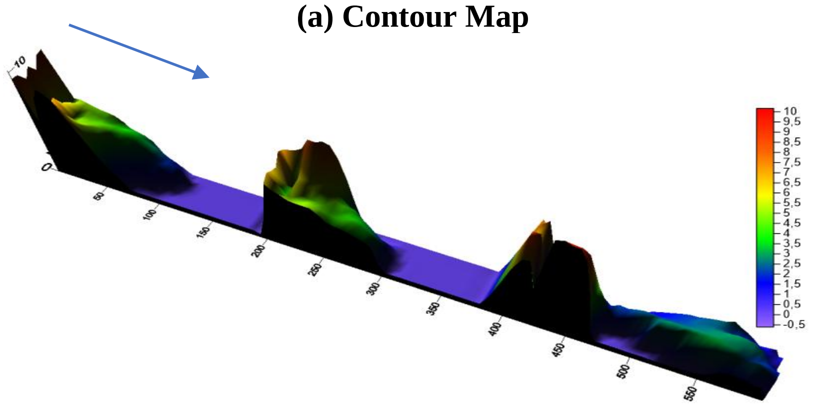


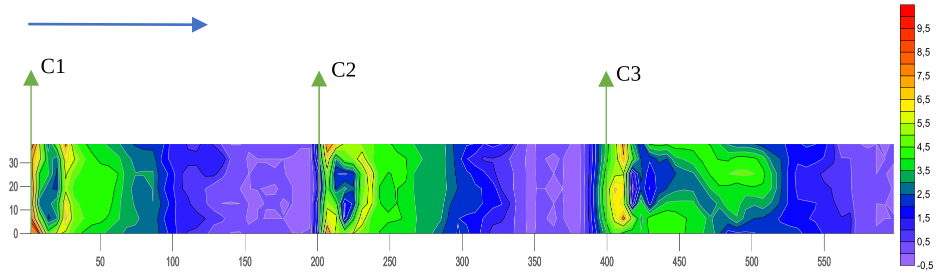
Figure 7. Sediment distribution distance 200 cm discharge 0,69 l/s

Based on the figure above, testing with a distance of 200 cm and a discharge of 0.69 l/s is one of the scenarios that produces sediment distribution that tends to move more towards the downstream channel. This indicates that this combination of distance and discharge produces flow energy that is strong enough to transport sediment further.

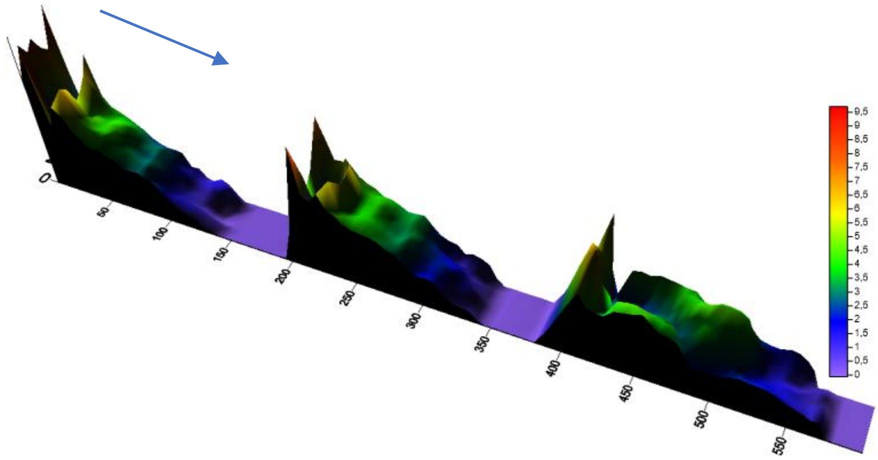
After passing check dam 3, the sediment experienced the most significant scouring. This condition resulted in the bottom surface of the channel being clearly visible. This scouring is most likely caused by the unobstructed flow of water after passing check dam 3 and going directly to the catch basin. Sediment accumulation occurs on the right side and center of the channel. This indicates that there are zones with lower flow velocities, so sediment settles in these areas.

The results of this study provide a valuable understanding of the dynamics of sediment transport in channels with variations in distance and discharge. Check dams, as sediment control structures, were shown to significantly influence sediment distribution patterns. However, it should be noted that the placement and design of check dams also play an important role in their effectiveness in controlling erosion and sedimentation.

6. Check dam distance 200 cm discharge 2,25 l/s



(a) Contour Map



(b) 3D image

Figure 8. Sediment distribution distance 200 cm discharge 2,25 l/s

Based on the figure above with a distance of 200 cm and a discharge of 2.25 l/s, the largest scour occurs at check dam 3, right at the point where the water flow falls from the check dam building. This indicates that the energy of the water flow is concentrated in this area, causing significant sediment erosion. Sediment movement tends to move downstream of the channel. This is a common pattern of sediment movement in watercourses, where sediment is carried by the water current to a lower place. The most sediment accumulation occurs at check dam 3, both on the left and right sides of the channel, even to the center of the channel. This indicates that check dam 3 is an effective barrier to sediment movement, so sediment accumulates around it.

Sediment in check dams 1 and 2 tended to disperse more towards the next building. This indicates that check dams 1 and 2 are less effective in retaining sediment than check dam 3. The scouring that occurs at the beginning of the fall of water flow from the check dam causes the channel bottom to be exposed. This indicates that the high energy of the water flow at that point eroded the sediment and exposed the underlying layer.

Research Discussion

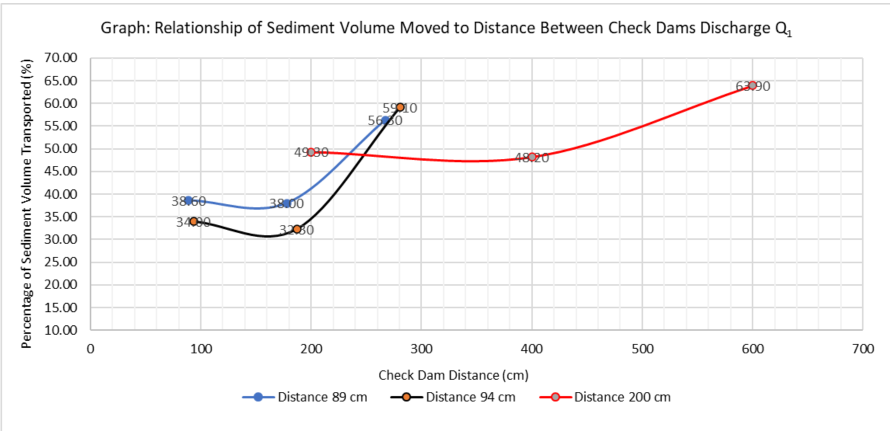


Figure 9. Relationship between the volume of moving sediment and the distance between check dam discharge Q_1

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Check dams with a distance of 200 cm produced the largest volume of sediment transported, namely 63.9% with a discharge of 0.69 liters/second. This indicates that the longer the distance between check dams, the more sediment moves. In check dam design, it is necessary to consider the optimal spacing between structures to achieve the desired sediment control effectiveness. In addition, understanding the relationship between check dam spacing, water discharge and volume of sediment transported is also important in sedimentation-related disaster risk management.

The relationship between the distance between check dams and the amount of sediment transported. The longer the distance between check dams, the greater the volume of sediment carried by the water flow. Check dam function to hold and control sediment carried by water flow. With the check dam, sediment will be trapped behind the building so that it does not continue to be carried downstream. The distance between check dams has a significant influence on the effectiveness of sediment control. Longer distances allow more sediment to be transported before being retained by the next check dam.

The volume of sediment transported indicates how much solid material is moved by erosion and water flow. The greater the volume of sediment transported, the greater the potential for environmental problems such as river siltation and infrastructure damage. High water discharge has more energy to carry larger amounts of sediment.

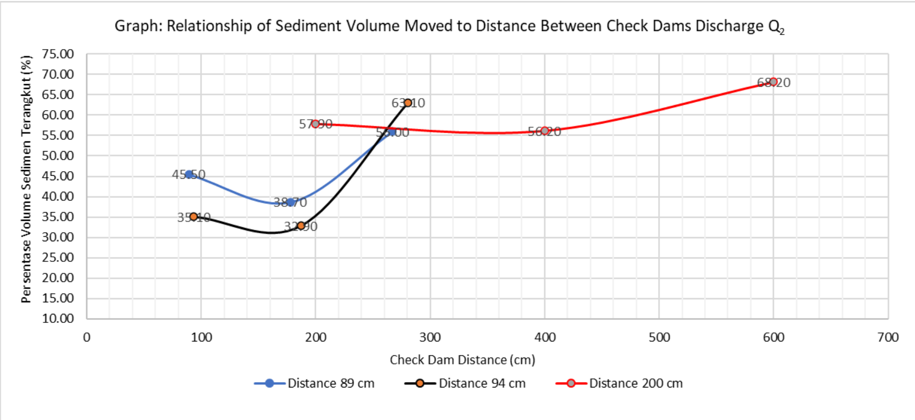

Figure 10. Relationship between the volume of moving sediment and the distance between check dam discharge Q_2

Based on the figure above, the check dam distance affects the volume of sediment that moves. Check dams with a distance of 200 cm show the largest percentage of sediment volume moving compared to other distances. Water discharge affects the volume of sediment that moves. The greater the water discharge, the greater the sediment that moves. This can be seen in check dam 3 with a discharge of 2.25 l/s which has the largest volume of moving sediment, namely 68.2%.

The distance between check dams is one of the important factors in the design of this sediment control building. Proper spacing will maximize sediment capture efficiency. Water discharge data is very important to predict the amount of sediment that will be carried by the water flow. The type of sediment is also important to determine the most effective control method. Different sediments have different characteristics, suggesting that there is a strong relationship between check dam spacing, water discharge and the volume of sediment moved.

CONCLUSION

From the test results and discussion carried out on the distance between check dams and varying the flow rate, it can be concluded that:

1. If the distance between check dams is too far, sediments have a greater chance of moving far downstream before finally being trapped by the next check dam. Conversely, if the distance between check dams is close, sediment will be trapped faster and cannot move too far downstream.
2. The greater the water flow discharge, the greater the energy the water has to erode and carry sediment. This causes the amount of sediment eroded to also increase. Conversely, if the flow rate is small, then the ability of water to erode sediment is also reduced, so that less sediment is eroded.
3. Sediment distribution patterns are influenced by two main factors, namely flow discharge and distance between check dams. Flow discharge is directly proportional to the amount of sediment eroded. The distance between check dams is inversely proportional to the movement of sediment downstream.

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