Effects of Width Ratio and Offtake Angle on the Morphological Characteristics of an Offtake Channel

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Abstract

River channel bifurcations play a crucial role in shaping fluvial systems, yet their morphological behavior remains a significant challenge in water resource engineering. The present study is an attempt to investigate the effects of different off-taking angles (15, 30, 45, 60, 75, and 90 degrees) and width ratios (0.2, 0.4, 0.6, 0.8, and 1) on the morphological behavior of offtake channels through a numerical modeling approach using SRH-2D. To comprehensively understand the morphological behavior of the offtake channel, the discharge ratio and the area of the separation zone were also analyzed. The result shows that the discharge ratio decreases with an increase of offtake angle, but discharge ratio increases with an increase of width ratio. The area of the separation zone decreases with the decrease of both offtake angle and width ratio. The morphological analysis showed the presence of deposition dominance near the offtake mouth for all offtake angle.. These findings significantly contribute to understanding morphological characteristics in offtake channels of river bifurcations.

1 Introduction

River channel bifurcations occur when one channel splits into two or more channels. The point where a main river channel bifurcates into two channels is called the offtake of the bifurcated channel (Malik & Matin, 2018). The morphology and development of a bifurcation are primarily governed by the dominant sediment transport mechanism. This mechanism determines the partitioning of sediment discharge into the two downstream branches. If the suspended load is dominant, then the sediment discharge rates into the downstream channels are closely related to the partition of water discharge, regardless of the bed topography at the bifurcation. Conversely, if bed load is dominant, the effect of local bed slope may play a crucial role in governing sediment partition, particularly at low values of Shields stress, which typically characterize gravel braided rivers (Pittaluga et al., 2003). River bifurcations can have various effects on the area, such as altering the movement of water, sediment, and nutrients through a watershed and delta. The process can cause changes in the landforms and terranes in a location due to the movement of bifurcations, leading to erosion and deposition and the formation of new landforms. Although bifurcations have significant importance, they are not studied as widely as confluences. One of the unsolved problems in water resource engineering is the morphological behavior of bifurcations in rivers (Roosjen & Zwanenburg, 1995).

2 Background and Objectives

Agunwamba et al., (2009) imply that large off-take angles will encourage more intake of sediments by the canal. According to Redolfi et al., (2019), water and sediment distribution by river bifurcations is often highly unbalanced. This may result from a variety of factors, such as migration of bars, channel curvature, and backwater effects. Previous research has focused on the importance of understanding river bifurcations and the challenges in creating predictive models due to the lack of detailed physical descriptions of sediment distribution and flow partitioning. Previous studies have also investigated the effects of various parameters such as nose angle, off-take angles, and channel slope on sediment dispersion and flow partitioning in river bifurcations. The research highlights the need for further investigation to enhance our understanding of river morphology. This study utilizes 2D modeling to explore the hydrodynamic and morphological changes that occur due off-take angle and width ratio at river bifurcations. The study will also observe the length of the separation zone in the off-take channel.

3 Methodology

3.1 Simulation setting up

This research involves conducting simulations with different off-take angles and width ratios using 2D modeling through the SRH-2D software. To simulate a 90° off-take angle and equal-width branching channel, Figure 1 shows the setup used. The setup comprises a main channel and an offtake channel, with the length of the main channel being 11.997 m and the offtake channel being 4.0 m. The main channel's width is 0.147 m, and both channels have a bed slope of 0.0025. The water flows from the left to the right and is then redirected into the offtake channel.

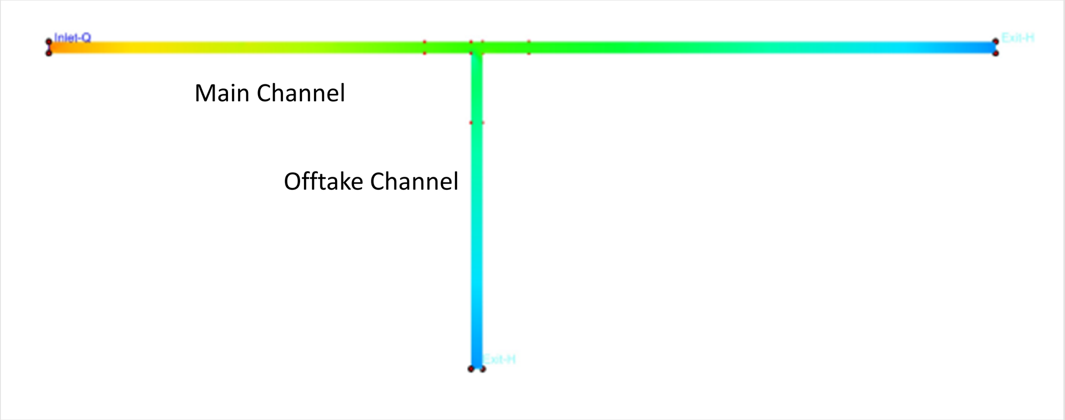

Figure 1: Simulation layout of a branching channel

3.2 Boundary conditions

The upstream discharge has a constant flow rate of 0.00537 cubic meters per second. The downstream boundary conditions for the main and offtake channels are normal depths. The Manning's roughness coefficient for both channels is 0.025. The gradation of the sediment is input in the 'Gradation Curve' where the mean diameter of sediment is 0.16mm.

3.3 Model validation

The numerical modeling of branching channels in SRH-2D software was first validated with another laboratory experiment by Hsu et al., (2002) by comparing the effect of varying upstream flowrates (Qu) to the discharge ratios (Qr) which is the ratio of upstream flowrate and the flowrate of offtake channel. The configuration of both experimental and model are same.

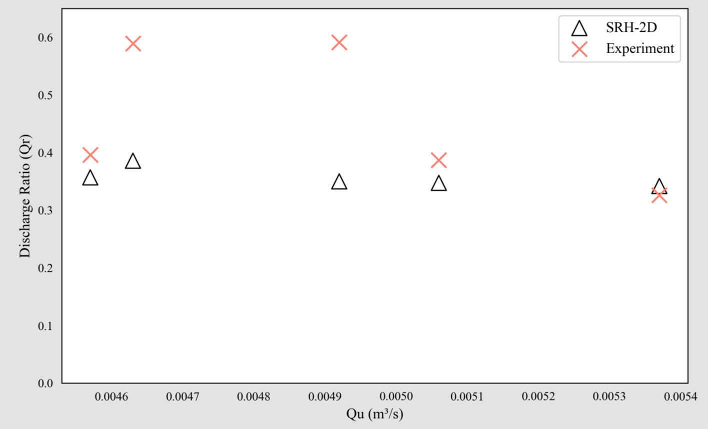

Figure 2: Validation result between experiment and SRH-2D

Figure 2 presents a comparison between the results obtained from the SRH-2D and the experimental. The findings indicate that when the upstream flowrate increases, the amount of flowrate into the diverted channel decreases. The difference between the results acquired from the SRH-2D and the experimental is differ at a minimal value.

4 Results

4.1 Relationship between discharge ratio with offtake angle and width ratio

The measurements of discharge for the upstream and downstream sections of the main channel were taken at four channel widths from the left and right edge points of the entrance of the offtake channel, respectively. Similarly, the section for the offtake channel were taken at six widths from the offtake entrance. Figure 3 depicts the relationship between discharge ratio and offtake angle, where it shows that as the offtake angle increases, the discharge ratio decreases. The maximum discharge ratio is observed at 30-degree offtake angle.

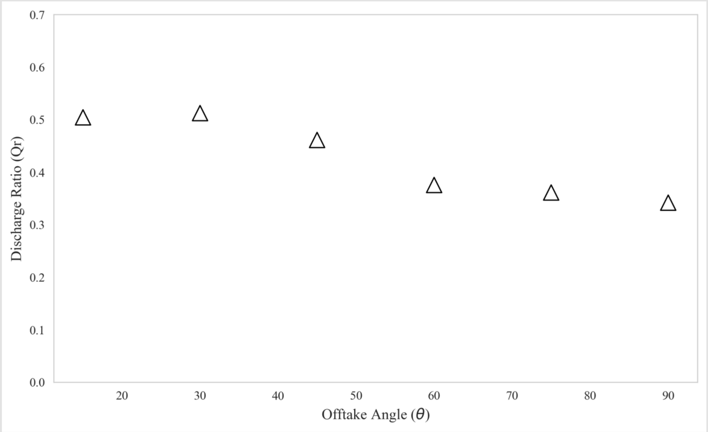

Figure 3: Variation of discharge ratio with respect to offtake angle

Figure 4 shows the changes of discharge ratio with width ratio. Width ratio (Br) is the ratio of offtake channel width to the main channel width. As the width ratio increases, the discharge ratio also increases.

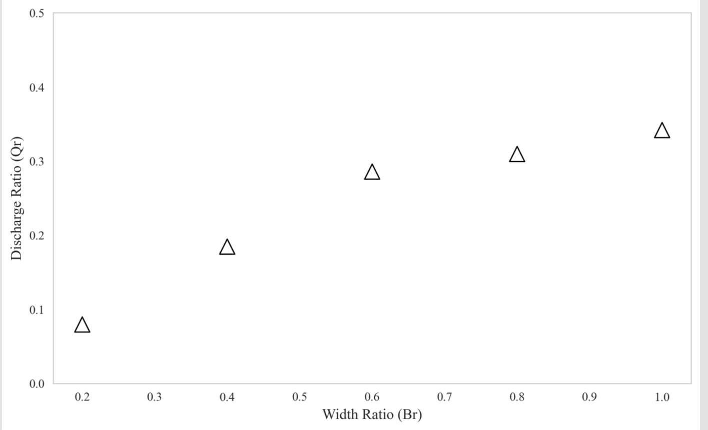

Figure 4: Variation of discharge ratio with respect to width Ratio

4.2 Area of separation zone with offtake angle and width ratio

In Figure 5, we can see how the area of the separation zone changes with the offtake angle. As the offtake angle decreases, the area of the separation zone also decreases. Even beyond 45 degrees, the separation zone does not create a significant area because the sharp edge of the entrance of offtake is reducing.

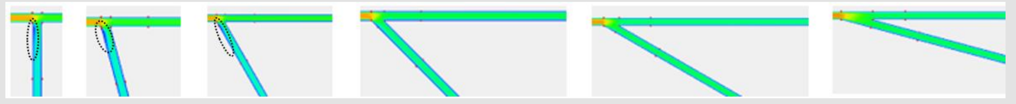

Figure 5: Separation zone for different offtake angles (from left 90, 75, 60, 45, 30 and 15 degree)

In Figure 6, we can see how the area of the separation zone changes with the width ratio. As the width ratio decreases, the area of the separation zone also decreases. Even beyond 0.6 width ratio, the separation zone does not create a significant area because the discharge is significantly low.

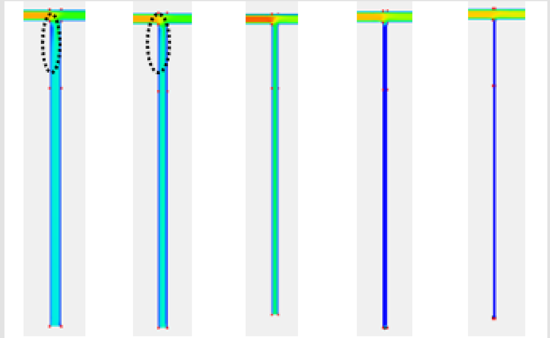

Figure 6: Separation zone for different width ratios (from left 1, 0.8, 0.6, 0.4 and 0.2)

4 Results (Cont.)

4.3 Erosion deposition at 0.15 m away from the mouth of the offtake

At lower width ratios, the discharge value is very low, which means that the velocity of water flow will also be very low. If the velocity remains low for lower width ratios, there will be no significant change in the bed level. The change of bed level with the change of width ratio can be negligible. We will examine the change of bed level or erosion/deposition at a cross-section 0.15 meters away from the mouth of the offtake, based on the offtake angle. In the erosion deposition profile, positive values denote erosion, and negative values denote deposition in the bed level. For every offtake angle, deposition governs. Near the right bank, more deposition occurs for a 90-degree offtake angle, and the lowest deposition occurs for a 30-degree offtake angle.

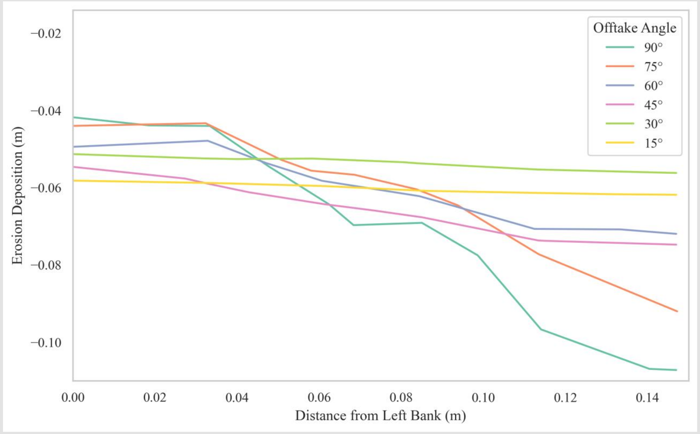

Figure 7: Erosion Deposition Bed Profile of Offtake Channel

Conclusion

The study has drawn the following conclusions:

i. When the offtake angle increases, the discharge ratio decreases.
ii. The discharge ratio increases as the width ratio increases.
iii. The area of the separation zone decreases as the offtake angle decreases.
iv. The area of the separation zone decreases as the width ratio decreases.
v. Deposition governs near the mouth of the off-take for every off-take angle.

References

[1] Agunwamba, J.C. and Nnaji, C.C., 2009. The effects of off take angle on the velocity distribution and rate of siltation of canals. Nigerian journal of technology, 28(2), pp.13-22.
[2] Bolla Pittaluga, M., Repetto, R. and Tubino, M., 2003. Channel bifurcation in braided rivers: Equilibrium configurations and stability. Water resources research, 39(3).
[3] Malik, L. and Matin, M.A., 2021. Experimental Study on Flow and Sediment Distribution at Off-Take Channel. International Journal of Environmental Science and Development, 12(2).
[4] Redolfi, M., Zolezzi, G. and Tubino, M., 2019. Free and forced morphodynamics of river bifurcations. Earth Surface Processes and Landforms, 44(4), pp.973-987.
[5] Roosjen, R. and Zwanenburg, C., 1995. Research on bifurcations in Rivers.
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