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Relationship Between Flow Velocity And Sediment Transport In The Downstream Walanae River, Soppeng Regency, Indonesia

Andi Rumpang Yusuf[1], Nurlita Pertiwi[2]
[1]*(Department of Civil Engineering, Universitas Bosowa, Indonesia)*
[2]*(Department of Civil Engineering Education and Planning, Universitas Negeri Makassar, Indonesia)*

Abstract:
Background*: As dynamic ecosystems, rivers store water and flow it from upstream to downstream. This study aims to determine the amount of sediment volume based on flow velocity data and river flow discharge. This study has three variables: flow velocity, wet cross-sectional area and sediment transport volume.*
Materials and Methods*This research is quantitative research. The sampling point is downstream of the Walanae River, which crosses the area of Kebo Village, Lililau District, Soppeng Regency. Measurements were made to obtain primary data in sediment transport, flow velocity, and cross-sectional area carried out at normal water levels (no rain conditions) and during flood water levels.*
Results*: Data analysis showed that the relationship between flow velocity and sediment transport during normal times obtained the value of* $R^2 = 0.95$*, while R2 = 0.58 was obtained during floods. For flow discharge and sediment transport during normal times, R2 = 0.14 is obtained, while R2 = 0.09 is obtained during floods.*
Conclusion: *The resulting regression equation does not represent the flow characteristics based on the relationship of velocity, flow rate and sediment transport in the downstream area. This is because the downstream areas experience the risk of backflow from the overflow of Lake Tempe, where the backflow conditions cannot be predicted based on the flow of the Walanae River. Based on Lake Tempe inlet data, it originates from nine rivers in the Walanae watershed.*

Key Word*: Downstream, Flow velocity, Wet cross-sectional area, Sediment volume.*

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I. Introduction

As dynamic ecosystems, rivers store water and flow it from upstream to downstream. As a natural open channel, river flow tends to be complicated to describe due to its free and deformed surface. There are straight river channels, there are winding, and some are branching. This condition causes the risk of changes in river morphology due to its flow. River morphology is determined by erosion, transport and redeposition of sediments. Water flow as a carrier of fluvial deposits illustrates the relationship between river hydraulics and its morphology [1].

River flow velocity is a determining factor for flooding and scouring along river banks. The fast flow causes high kinetic energy of the flow against the river bank. As a result, the release of soil mass occurs more quickly. This fact describes the relationship between river velocity and erosion. Erosion and sedimentation are two series of interrelated events. Both of these events must be controlled to minimize the occurrence of landslides and floods.

The flow velocity in the river body is not the same along the river body. The flow velocity depends on the shape of the cross-section, the river wall's roughness and the river flow's pattern. Previous studies have described that in meandering rivers, the maximum velocity zone is on the outside. While in the middle of the cross-section, the flow velocity is relatively smaller. This pattern is closely related to the risk of lateral erosion of river bodies and river migration patterns.

The hydraulic geometry of the river causes a change in the acceleration of the water flow. The flow velocity with full bank conditions at the confluence of the river increases sharply. It causes a high zone of shear stress. The acceleration of river flow also increases with the reduction of river roughness in that zone [2].

In addition, the vegetation on the riverbanks determines the friction on the channel walls. Therefore, the river's flow is not uniform in the cross-section of the channel. Erosion and sedimentation processes significantly affect the balance of the river bed configuration. The configuration of the river bed depends on the flow velocity, flow duration and depth. Slow river flow causes high river sedimentation. As a result, the riverbed changed its configuration. Flow parameters significantly affecting the speed and risk of riverbank erosion are sediment transport or the number of sediment particles measured momentarily [3].

River flow as an aspect of hydraulics is also closely related to the ecological aspects of the river. Flow velocity has a reciprocal relationship with regional ecology. The better the environmental conditions of the river area, the better the hydraulics of the river, in terms of reducing the risk of major floods, reducing erosion of the river bed and reducing river sedimentation in the downstream area. Conversely, if the natural retention conditions of the river decrease, the flow velocity will be higher, erosion will be higher, flooding downstream will be higher, and river sedimentation downstream will also be more elevated, which will decrease the river's ecological condition.

Planning for river protection against flooding and erosion risks considers flow velocity and sediment transport. This study focuses on drift sediment concentration and sediment discharge. Predicting sediment volume based on flow discharge data is important information in laying protective structures. On the other hand, the protection of riverbank vegetation should also consider the velocity of the river flow.

II. Material And Methods

This quantitative research is carried out in the Walanae River Downstream, Soppeng Regency, located in the Walanae Watershed in South Sulawesi Province. Sediment transport, flow velocity and cross-sectional area measurements were carried out at normal water levels (no rain conditions) and flood water levels. Measurements were made at five points with an observation distance of 200 meters.

III. Result and Discussion

The measurement results of sediment transport also showed a significant increase. The amount of sediment transport at normal times at the six-point observation points shows the numbers that vary between normal and flood conditions, as presented in Table 1.

Table no 1: Walanae River Sediment Transport in Kebo Village.

Location	Normal Sediment Transport (mg/ltr)	Flood Sediment Transport (mg/ltr)	Comparison of Normal and Flood Sediment Transport
Observation Point 1	33	175	0.189
Observation Point 2	46	219	0.210
Observation Point 3	31	163	0.190
Observation Point 4	51	223	0.229
Observation Point 5	56	231	0.242
Observation Point 6	52	267	0.195
Average	**45**	**213**	**0.209**

The measurement results in Table 1 show that sediment transport varies between 31 – 56 mg/ltr at normal times. Meanwhile, sediment transport varies between 163 mg/ltr and 267 mg/ltr during floods. On average, the ratio of sediment transport during normal times and flood conditions is 0.21 and sediment transport during floods is 4.7 times compared to normal conditions.

Furthermore, the cross-sectional area of the Walanae River was measured in two conditions: the cross-sectional area when the water level was normal and the cross-sectional area when the water level rose/flooded.

Table no 2: Cross-Sectional Area of the Walanae River in Kebo Village

Location	Wet Cross-sectional Area of Normal Water Conditions (mg/ltr)	Cross-sectional Area of Flooded Water Conditions (mg/ltr)	Comparison of Wet Cross-sectional Areas of Normal and Flooded Conditions
Observation Point 1	36.77	75.41	0.488
Observation Point 2	32.35	67.44	0.480
Observation Point 3	32.11	68.98	0.465
Observation Point 4	13.58	44.96	0.302
Observation Point 5	17.53	53.52	0.328
Observation Point 6	28.7	61.56	0.466

Average	**26.84**	**61.98**	**0.421**

The measurement results in the table show that the wet cross-sectional area of the Walanae River varies between 13.58 – 26.77 mg/lt at normal times. Meanwhile, during floods, the cross-sectional area varies between 44.96 mg/lt – 75.41 mg/lt. On average, the ratio of sediment transport during normal times and flood conditions is 0.421 and sediment transport during floods is 2.3 times compared to normal conditions.

The flow of the Walanae River in the dry and rainy seasons has differences in the speed of the Walanae River at six observation points.

Table no 3: Normal River Flow Speed in Kebo Village

Location	Flow Velocity (0.2 m from the surface) m/s	Flow Velocity (0.8 m from riverbed) m/s	Average Flow Velocity (m/s)
Observation Point 1	0.3	0.4	0.35
Observation Point 2	0.3	0.6	0.45
Observation Point 3	0.3	0.4	0.35
Observation Point 4	0.4	0.5	0.45
Observation Point 5	0.4	0.6	0.5
Observation Point 6	0.3	0.6	0.45
Average	**0.33**	**0.52**	**0.43**

Table no 4: Velocity of Flood River Flow in Kebo Village

Location	Flow Velocity (0.2 m from the surface) m/s	Flow Velocity (0.8 m from riverbed) m/s	Average Flow Velocity (m/s)
Observation Point 1	0.7	0.9	0.80
Observation Point 2	0.7	1.3	1.00
Observation Point 3	0.7	0.8	0.75
Observation Point 4	0.9	1.1	1.00
Observation Point 5	0.9	1.5	1.20
Observation Point 6	0.7	1.3	1.00
Average	**0.77**	**1.14**	**0.96**

At the normal flow velocity of the Walanae river presented in Table 3, it can be seen that the highest normal flow velocity is at safety point 5, namely 0.50 m/s and the most negligible normal flow velocity is at safety points 1 and 3, namely 0.35 m/s. While the flow velocity during the flood is presented in table 4, the largest flow velocity is at safety point 5, which is 1.20 m/s and the smallest is at safety point 3 which is 0.75 m/s.

Table no 5: Normal River Flow Debit in Kebo Village

Location	Average Flow Velocity (m/s)	Cross-sectional Area (A) m^2	Flow Discharge (Q) m^3/s
Observation Point 1	0.35	36.77	12.87
Observation Point 2	0.45	32.35	14.56
Observation Point 3	0.35	32.11	11.24
Observation Point 4	0.45	13.58	6.11
Observation Point 5	0.5	17.53	8.77
Observation Point 6	0.45	28.7	12.92
Average	**0.425**	**26.84**	**11.08**

Table no 6: Flood River Flow Debit in Kebo Village

Location	Average Flow Velocity (m/s)	Cross-sectional Area (A) m^2	Flow Discharge (Q) m^3/s
Observation Point 1	0.80	75.41	59.95
Observation Point 2	1.00	67.44	67.17
Observation Point 3	0.75	68.98	51.77
Observation Point 4	1.00	44.96	45.14
Observation Point 5	1.20	53.52	64.33
Observation Point 6	1.00	61.56	61.68
Average	**0.96**	**61.98**	**58.34**

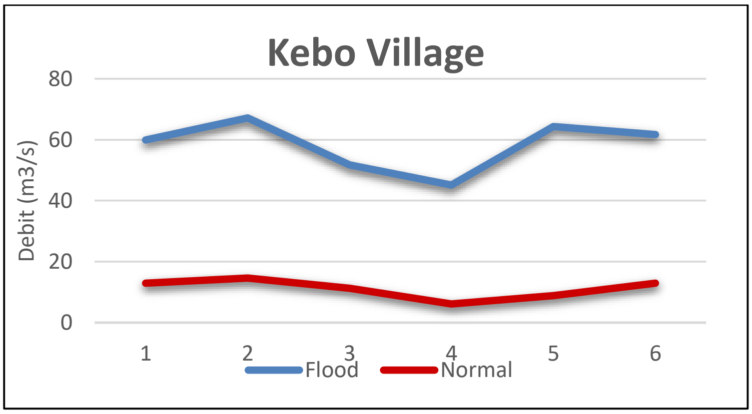
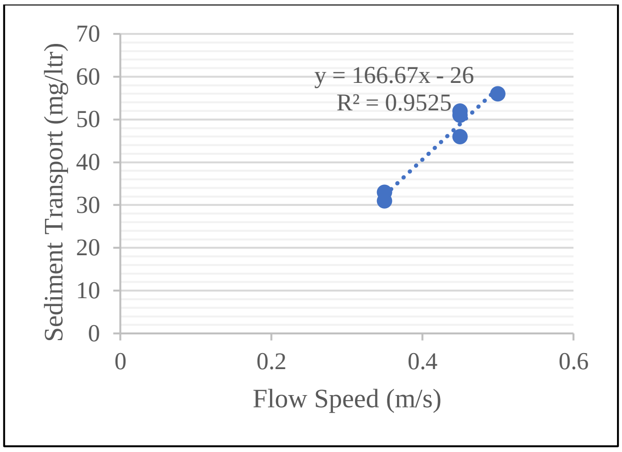


Figure no 1: Graph of Comparison of Normal River Flow and Flood Discharge in Kebo Village

The flow rate of the Walanae River in Kebo Village can be seen in Figure 1. There is a difference between the flow rate when the water level is normal and when the water level rises. In Table 5, the flow rate at normal water level shows that the largest water discharge is at observation point 2, 14.56 m3/s and the lowest at observation point 4, 6.11 m^3/s. While Table 6 when the water level rises/floods the water discharge increases, where the largest water discharge is at observation point 2 which is 67.17 m^3/s and the smallest is at observation point 4 which is 45.14 m^3/s.

The results of mathematical analysis can be used as a marker of river flow patterns based on velocity and sediment transport. The description of the relationship between these variables is illustrated in Figure 2 and Figure 3.



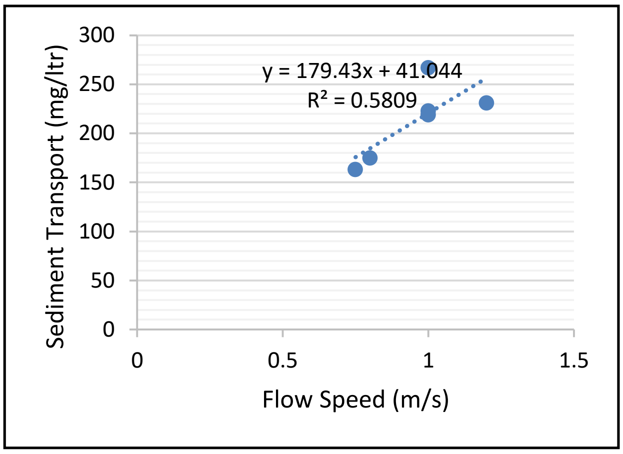


Figure no 2: Graph of Relationship Between Flow Velocity and Sediment Transport with Normal Water Levels in the Walanae River, Kebo Village

Figure no 3: Graph of the Relationship of Flow Velocity and Sediment Transport During the Flood Water Front in the Walanae River, Kebo Village

Table no 7: Relationship of Flow Velocity and Sediment Transport

Observation Location	Equation		R-Squared Value	
	Normal	Flood	Normal	Flood
Walanae River Kebo Village	y = 166.67x - 26	y = 178.42x + 42.032	0.9525	0.5856

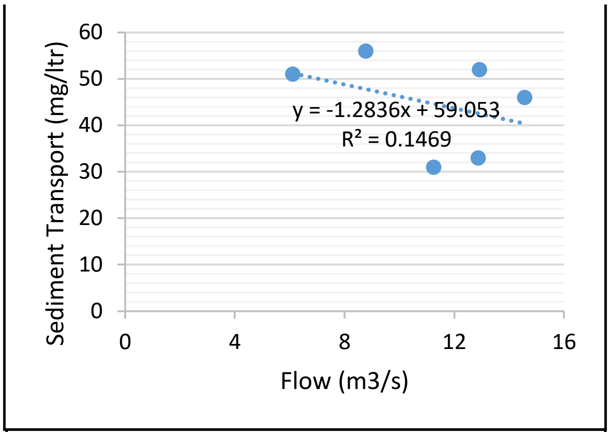
Based on the regression analysis results in the observation area with velocity data between 0.3 m/s to 0.5 m/s at normal times, the value of $R^2 = 0.95$ was obtained. Meanwhile, during the flood, the value of $R^2 = 0.58$ was obtained.

This description proves that the resulting regression equation does not represent the flow characteristics based on the relationship between velocity and sediment transport in the downstream area. This is because the downstream area is at risk of backflow from the overflow of Lake Tempe where the backflow conditions cannot be predicted based on the flow of the Walanae river. Based on Lake Tempe inlet data, it originates from nine rivers in the Walanae watershed.

The flow velocity and sediment transport described by [4] demonstrated that the flow velocity profile for the Fraser River in Canada is irregular although consistent. Meanwhile, irregular sediment transport is caused by differences in sediment transport in streams at various points of the river cross section. Sediment transport adjacent to the river bank is relatively higher than the point in the middle of the river cross section.

Sediment transport on slopes and troughs is different due to differences in the distribution of sediment grain sizes. As a result, there are differences in the morphology of the river bed and affect the pattern of flow velocity. The weakness of this study is the absence of data on the distribution of sediment grain sizes so that the correlation between sediment transport and flow velocity cannot be validated precisely[5].

Flow characteristics characterized by discharge and sediment transport were also analyzed using mathematical equations based on Figures 4 and 5.



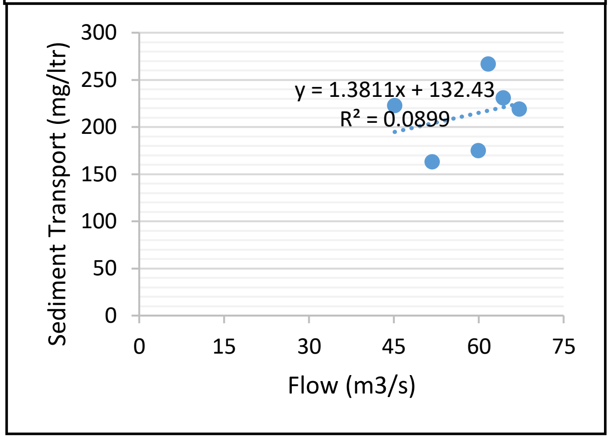


Figure no 4: Graph of the Relationship between Flow Velocity and Sediment Transport at Normal Water Levels in the Walanae River, Kebo Village

Figure no 5: Graph of the Relationship between Flow Velocity and Sediment Transport at Flood Water Levels in the Walanae River, Kebo Village

Table no 8: Relationship of Flow Debit and Sediment Transport

Based on the regression analysis results in the observation area with flow rate data between 14.56 m3/s to 6.11 m3/s at normal times, the value of $R^2 = 0.14$ is obtained. Meanwhile, the value of R2 = 0.09 was obtained during the flood.

According to [6], sediment transport data can affect flow discharge patterns where flow rate is a function of sediment transport frequency so that this pattern can be used to calculate the maintenance of river conditions and flow patterns. This has been proven in studies on the Walanae river, especially in the upstream and middle areas. Meanwhile, in the downstream area, the influence of the flow is also influenced by the backflow from the lake.

In the untrained group, the median systole blood pressure obtained at the initial measurement showed a value of 115 mmHg, and for the next measure, it showed a value of 115 mmHg. Further, the statistical test using the Wilcoxon test for this group obtained a value of 0.366 or value of $p> 0.05$. This result indicates that there is a significant influence on systolic blood pressure in the untrained group.

According to [7], sediment transport due to backflow significantly differs from normal current flow. The sediment transport formula in this condition needs to be studied in detail by considering the speed and backflow sediment transport.

IV. Conclusion

Based on the results of the data analysis that has been done, the authors can draw the following conclusions:

1. The value of R2 = 0.95 obtains the relationship between flow velocity and sediment transport during normal times, while the value of R2 = 0.58 is obtained during floods. This description proves that the resulting regression equation does not represent the flow characteristics based on the relationship between velocity and sediment transport in the downstream area. This is because the downstream areas experience the risk of

backflow from the overflow of Lake Tempe where the backflow conditions cannot be predicted based on the flow of the Walanae river. Based on Lake Tempe inlet data, it originates from nine rivers in the Walanae watershed.

2. The value of R2 = 0.14 obtains the relationship between flow rate and sediment transport during normal times, while the value of R2 = 0.09 is obtained during floods. This description proves that the resulting regression equation does not represent the flow characteristics based on the relationship between flow discharge and sediment transport in the downstream area. This is because the downstream area is at risk of backflow from the overflow of Lake Tempe where the backflow conditions cannot be predicted based on the flow of the Walanae river. Based on Lake Tempe inlet data, it originates from nine rivers in the Walanae watershed.

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