Effect of Cohesive Material on Bank Erosion Process in Sesayap River, East Kalimantan Province, Indonesia

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1. INTRODUCTION

Riverbank erosion is a natural process that can cause the loss of useful land and endangers the safety of navigation, among others. Riverbank erosion becomes a problem or disaster, if it occurs in rivers around residential area, constructions, or others useful land. Bank erosion processes are essentially dominated by the complicated interaction between flow, sediment transport, and bank material (Duan, 2001). Horizontal shift speed of bank is changed rapidly when the bank is composed of both the non-cohesive material layers and the cohesive material layers such as the bank erosions that occurred in Sesayap River, East Kalimantan, Indonesia (Takebayashi, 2010). **Fig. 1** shows Sesayap River that passes at Malinau city. The phenomenon of bank erosion and sedimentation around the Sesayap River especially at Malinau city are:

1. Bank erosion at Seluwing area (**Fig. 2**) endangers the land transportation facilities in the town of Malinau and sandbars grows in the middle of the river,
2. Bank erosion at speedboat dock area (location 2).

The Sesayap River is 279 km long and the catchment has an area of about 18158 km^2. Sesayap River is a navigation channel which conducts between Malinau and Tarakan. At Seluwing area (location 1) riverbank was collapsed on April and September 2008. Those collapses gave damages on the road structure. The water depth on floodplains was 30cm during the November 2008 flood (**Fig. 3**). Based on the recent developments of numerical modeling, this study aims to apply horizontal two dimensional flow model whose equations are written in general coordinate system at the Sesayap River in order to understand the flow pattern, estimate the bank failure processes, and make a countermeasure of the bank erosion.

The river flow at Malinau reach is influenced by tide from Celebes Sea that creates a diurnal water level fluctuation. However, the flow is always on the downstream direction. Fluctuations of water level are around 1-2 meters. The high water level (HWS) and low water level (LWS) are +24.50 m and +22.50 m, respectively.

2. RIVER BANK CONDITION

The process of bank erosion is closely related to soil composition and mechanical properties of the riverbanks. **Fig. 1** shows the soil test location at the river bank. Soil mechanics test (hand bore and cone penetration test) carried out by Engineering Faculty of Gadjah Mada University.

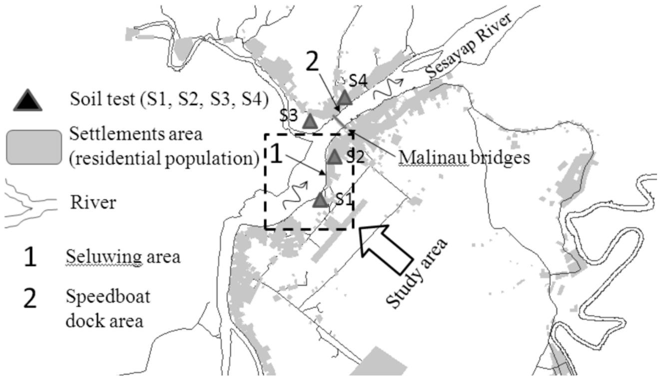

Fig. 1. Sesayap River at Malinau

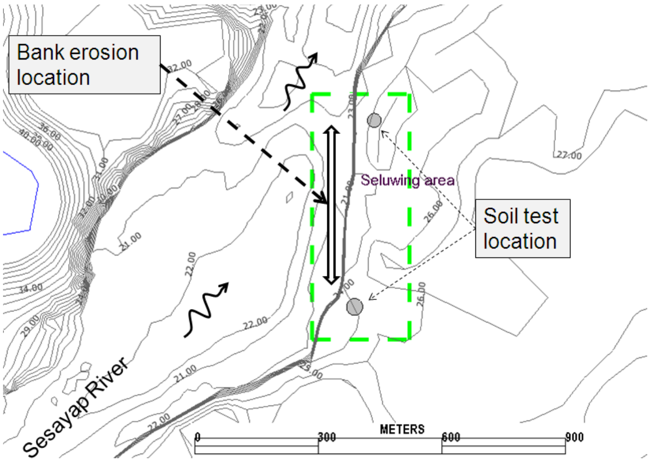

Fig. 2. Topography and cross section at Seluwing area

Fig. 3. Bank failure and flooding at Seluwing area

3. FLOW NUMERICAL SIMULATION

Numerical simulations for the case of the river Sesayap are performed using horizontal two dimensional flow depth averages. The purpose of this numerical simulation is to determine the water velocity and elevation of water level around the river bank failure under a variety of flow conditions. The boundary condition at the downstream is the water level elevation, which has elevation at +22.50 m (LWS) and +24.50 m (HWS). Magnitudes of upstream water discharges are 435 m^3/s, 450 m^3/s, 500 m^3/s, 600

m^3/s, 700 m^3/s, and 800 m^3/s. Computation of surface flow is carried out using momentum and conservation of mass equation, i.e., inflow and outflow of mass by seepage flow. Seepage flow is assumed as horizontal two-dimensional saturation flow (Takebayashi, 2005).

4. RESULTS AND DISCUSION

The results from numerical simulations are shown at **Table 1**. Flow velocities that occur at the LWS condition are ranged from 2.613 m/s – 4.806 m/s and water surface elevation is +22.49 m. Flow velocities that occur under conditions of HWS is between 0.916 m/s – 1.685 m/s and water surface elevation +24.48 m. **Fig. 5** shows the velocity contour near the bank erosion.

The results from soil test shows that cohesive soil layer (clay) is above of +23.25 m, between elevations +21.00 m to +23.25 m is transition of soil layer from cohesion soil to non-cohesive soil (sandy-silt). Below the elevation of +21.00 m is non-cohesive soil presence by sand. Elevation of river bed is +19.71 m and presence by non-cohesive materials. **Fig. 4** shows the stratification of river bank. These condition give high potential of flow to exposes the non-cohesive layer of bank. According to the water level, velocity (numerical simulations) and bank stratifications (field survey) indicate that the processes of bank failure at Seluwing area are as follows:

- Erosion process: At low tide (LWS), the water flow with high velocity causes erosion at the bank toe on the part of non-cohesive soil layer (sand),
- Overhang process: The erosion at non-cohesive layer develops cantilever of cohesive layers on riverbanks.
- Bank failure process: The susceptibility of bank to mass failure depends on their geometry, structure, and material properties.
- Temporarily protect, during bank failure and collapse, block of bank material slide or fall toward the toe of the bank, where they remain until they are broken down or entrained by the flow. Failed block, in turn, may temporarily protect the toe of the bank from erosion.

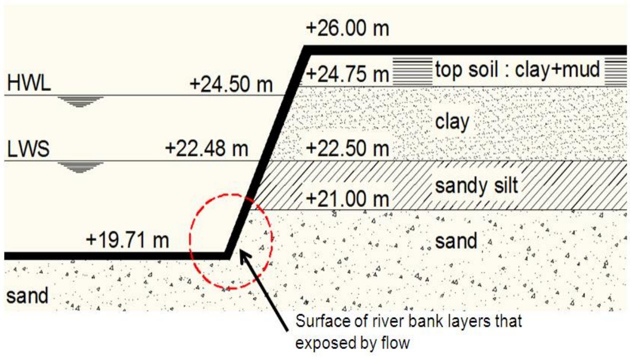

Fig. 4. Stratification of river bank at Seluwing area

Table 1. Velocities near the bank at Seluwing area.

Upstream input discharges (m3/s)	Intial downstream stages			
	22.50 m		24.49 m	
	Average WSE (m)	Average velocity (m/s)	Average WSE (m)	Average velocity (m/s)
435	22.49	2.613	24.48	0.916
450	22.49	2.703	24.48	0.948
500	22.49	3.004	24.48	1.053
600	22.49	3.605	24.48	1.263
700	22.49	4.205	24.48	1.474
800	22.49	4.806	24.48	1.685

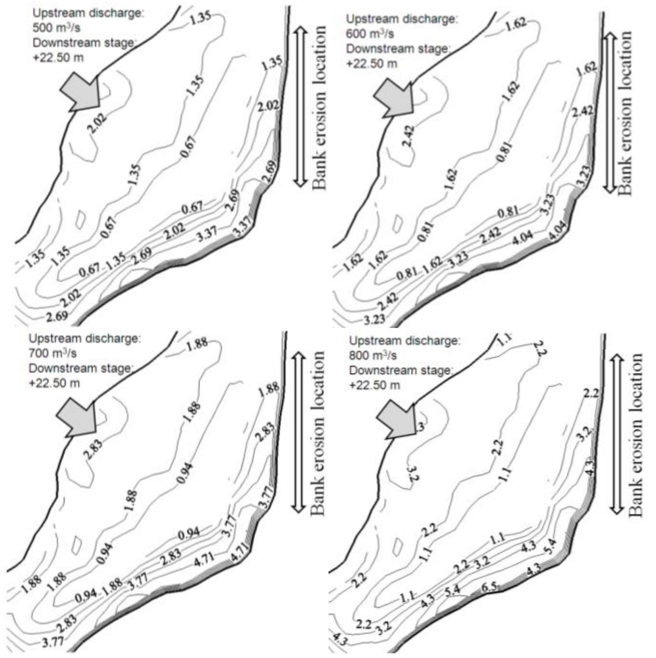

Fig. 5. Results example of velocity contour

5. CONCLUSIONS

The results from numerical simulation and soil survey provides evidence that the river bank collapse in the river Sesayap begins with erosion at the bank toe at the sand layer. Composition of bank layers at Sesayap river give high potential of bank failure. Preventing actions to the flow to exposes the non-cohesive layer of bank is a basic treatment to countermeasure of bank erosion processes.

6. REFERENCES

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