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Prediction of The Depth Erosion in Rivers with Scale Models

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Abstract— Flood is a disaster that often hits, especially urban areas, so that it can harm human activities and other living things. Palembang City itself has 108 tributaries. There are 4 (four) major rivers that cross the city of Palembang, namely the Musi River, Komering River, Ogan River, and Keramasan River. The drainage system of the city of Palembang, which always experiences flooding every year, includes the Buah river watershed. The Buah River, with the main river being 7.93 km long, has many meanders and a river wall reinforcement has been built.

The research was conducted to see the flow phenomenon in the river with hydraulic modeling, namely by using the river/channel scale model in the hydraulics laboratory.

The relative erosion depth (de/t) on the riverbed precisely at the mouth of the Buah river is 2.16 cm in the model with a significant level of R of 74.22% or 0.7422. This means that the speed (v) and time (t) simultaneously have quite an effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

Other factors that influence the magnitude of the depth of bottom erosion (bed load) at the mouth of the Buah river as the dominant variables are flow velocity (v), grain diameter (d), and changes in water level (h).

Keywords—Buah River; Bedload; Scale Models; Erosion Depht.

I. Introduction

A river or open channel is a channel where water flows with a free water level. In an open channel, for example a river (natural channel), the flow variable is very irregular with respect to time and space. These variables are the cross section of the channel, roughness, bottom slope, curvature of the flow rate and so on (Triatmodjo, 2003). A river is a long channel on the surface of the earth where water flows from rain and is always touched by the flow of water and is formed naturally (Sosrodarsono, 1994).

The complexity of the river system can be seen from the various components of the river, for example the shape of the river flow and branching, river bed form, river morphology, and river ecosystem. The river branch will resemble a river tree starting from the first order to the nth order river. The river bed formation, when examined at a glance, is very difficult to identify and characterize. The shape of the meander groove is influenced by the longitudinal slope of the landscape, the type of river bed material, and the vegetation in the area (Maryono, 2007). The biggest benefit of a river is for agricultural irrigation, raw materials for drinking water, as a drainage for rainwater and waste water, and it has the potential to become a river tourism object. In Indonesia, there are currently 5,950 watersheds.

Palembang City itself has 108 tributaries. There are 4 major rivers that cross the city of Palembang, namely the Musi River, Komering River, Ogan River, and Keramasan River. Of the 4 major rivers above the Musi River, the largest river with an average width of 504 meters and a maximum width of 1,350 meters is located around Kemaro Island. (Syarifudin, A, et al, 2018)

Based on the division of the river area there are 21 sub-watersheds, but only 18 sub-watersheds in the city of Palembang which empties directly into the Musi river in the city of Palembang, namely the Rengas, Lacak, Gandus, Lambidaro, Boang, Sekanak, Bendung, Lawang Kidul, Buah, Juaro, Batang, Keramasan, Kertapati, Kedukan Ulu, Aur, Sriguna, Jakabaring and Plaju. (PUPR Department of Palembang City, 2018).

The urban drainage system which always experiences flooding in Palembang every year, among others, is the Buah river basin. The Buah River, with the main river being 7.93 km long, has many meanders and a river wall reinforcement has been built. The sub-watershed of Buah, with an area of 10.79 km2, is generally a residential, industrial and swampy area. (PUPR Office of Palembang city, in Ayu Marlina and Reni Andayani, 2020)

The Buah Watershed is one of the 33 flood-prone areas in Palembang City. This is because, until now the Buah Watershed does not yet have pumping facilities. As a result, the Sapta Marga, Sekojo, and Urip Sumoharjo areas, which flow into the Sungai Buah watershed, are also frequently flooded. (Sripo, 24 November 2020)

The simulation uses a program with different conditions, namely existing conditions, normalization of river flows, cut-off, retention ponds, a combination of a pump system and the construction of embankments, showing that there are seven inundated areas in the existing conditions. After the flood management simulation with normalization and cuttings has been carried out, the runoff height has decreased to 0.11 m in the downstream part of the river. Another flood management simulation is the construction of a retention pond that can reduce runoff height by up to 0.9 m in the area where the retention pond is built. Combined simulation with a pump system with a capacity of 11 m3 / s and 4 m3 / s in the lower reaches of the Buah river can reduce runoff by up to 0.22 m. The height of the embankment reaches 0.68 m in the Sei Buah sub-district. (Ardian, Syaifudin, and Djoko Luknanto, 2009).

II. RESEARCH METHODS

The research was carried out in the Hydrology and Hydrology laboratory of Bina Darma University with a laboratory scale (scale model) as shown in Figure 1.

Fig. 1. Two dimentional standard flume physical model

2.1. Materials and tools

The materials used in this study include:

- Sand with a diameter of 0.025 mm to 2.36 mm is considered to be a sedimentary material that previously carried out sieve analysis to obtain a uniform grain diameter (ds) originating from the Buah river material.
- Water, as a medium for moving the sedimentary material flow in the channel,
- The instrument used in this research is a laboratory facility for the Masters in Civil Engineering Hydraulics at the Postgraduate Program at Bina Darma University. The specifications of the tool are as follows:

- Standard channel (standard flume): flexiglass
- Effective length: 400 cm
- Width: 15 cm
- Depth: 20 cm
- Scour depth measuring instrument meter, to measure the location of the scour.
- Photo camera to take pictures when doing the experiment.
- Video recorder to record experiment implementation.

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2.2. Research preparation

This research was conducted using a laboratory approach method with various variations in the flow rate, flow rate and time. The standard channel (flume standard), most of its components are made of glass and have important parts, namely:

a. The aqueduct, the main place in this experiment, to drain the water. In the form of water flume with a size of 400 x 20 x 15 cm. This channel has transparent walls for easy observation,

b. A reservoir that functions to accommodate water that will be flowed into the channel or out,

c. Water pump, functions to pump water so that it can be distributed along the gutter. The pump is equipped with an automatic on / off switch for a 220/240 V, 50 Hz supply of electricity,

d. Discharge faucet, is a faucet that functions to regulate the size of the discharge that comes out of the pump. Has a discharge scale of 6-9 range,

e. The tilt adjustment wheel, located upstream and downstream of the channel, can be manually turned to adjust the desired bed slope. This bed slope adjustment wheel has a scale for maximum positive bed slope + 3.0% and maximum negative bed slope - 1.0%.

2.3. Research Step

The steps of this research are divided into:

- The first, collecting references from journals, books, and other secondary data sources such as the BBWSS-VIII office, PU Pengairan, South Sumatra Province and PUPR Palembang city as well as from other related agencies.
- The seconds, conducting a field orientation survey to obtain the current conditions (existing) in the field, taking photos of the field (site) so that they can be used as initial research data.
- The third is to collect the river bed material, survey data and measure the topography of the channel to be used as input data in simulating the model in the laboratory.
- The fourth, performs experimental simulations with various variations of flowrate, velocity and flow time.
- The fifth, obtaining the experimental results, namely, the location and magnitude of the erosion (scour) that occurs with various flows, velocities and times of flow.
- The sixth, analyzes the simulation results and conducts discussions
- The seventh, makes research conclusions and provides suggestions for further research by other research.

III. RESULTS AND DISCUSSION

The dimensional analysis in this study uses the Langhaar theorem, this theorem is seen as more appropriate to current conditions and in accordance with research because it has relatively few parameters. The results of determining the dimensionless numbers are as in table 1 below:

TABLE I. THE RESULT OF DETERMINING OF DIMENSIONALESS NUMBER PARAMETER

ki	**k1**	**k2**	**k3**	**k4**	**k5**	**k6**
Parameter	**de**	**x**	**h**	**t**	**ρ**	**g**
π1	1	0	0	-1	0	0
	0	1	0	-1	0	0
π3	0	0	1	-1	0	0
π4	0	0	0	1	0	0.5

f (de/t ; x/t; v) = 0 (v ≈ 0)

(de/t) = f (x/t)

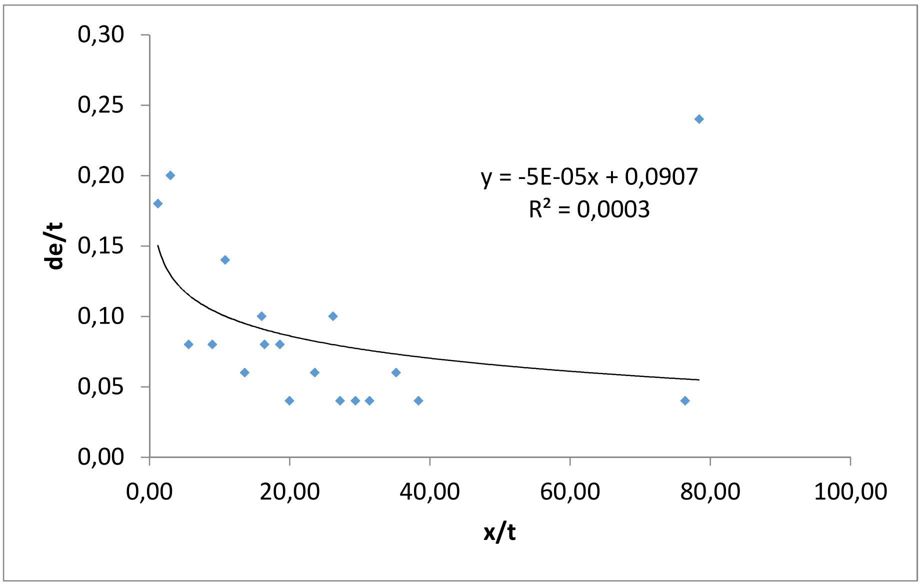

Fig. 2. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 5 minute experiment

Based on the results of the analysis as shown in Figure 2. it can be said that at the starting point in the Buah river within 5 minutes, there is a relative erosion depth of 0.15 cm (in the model) then the trend decreases at a relative distance (x/t) of 80 cm with erosion of 0.04 cm.

With a coefficient of determination R^2 of 0.00 or an R value of 0%, it means that the speed (v) and time (t) simultaneously do not affect the depth of erosion (de) that occurs.

This is because the farther in the river, the greater the relative depth of erosion or the maximum relative depth of erosion depending on the flow velocity in the river.

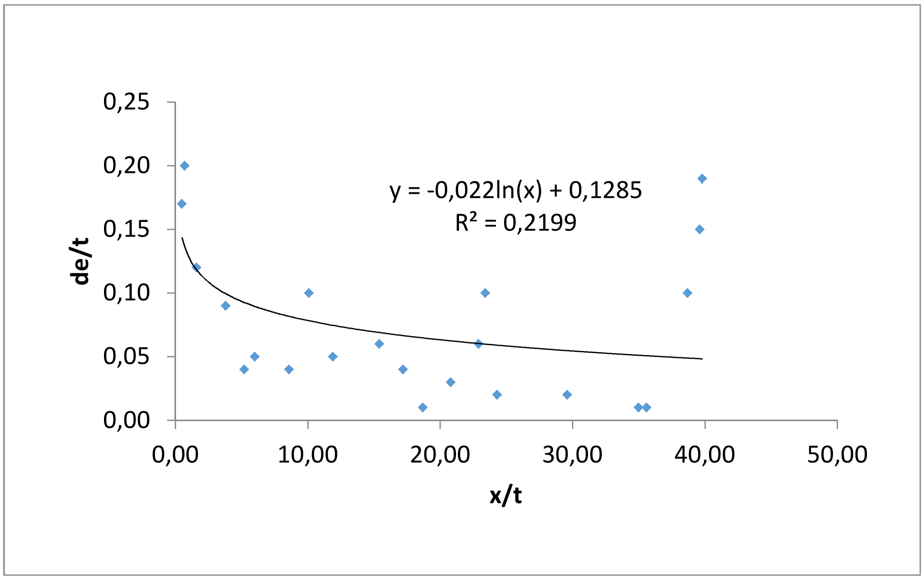

Fig. 3. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 10 minutes

Based on the results of the analysis as shown in Figure 3. It can be said that at the initial point in the Buah river within 10 minutes, there is a relative erosion depth of 0.14 cm (in the model) then the trend decreases at a relative distance (x/t) of 40 cm with an erosion of 0.05 cm.

With a coefficient of determination R^2 of 0.219 or an R value of 46.79%, it means that speed (v) and time (t) simultaneously have no effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

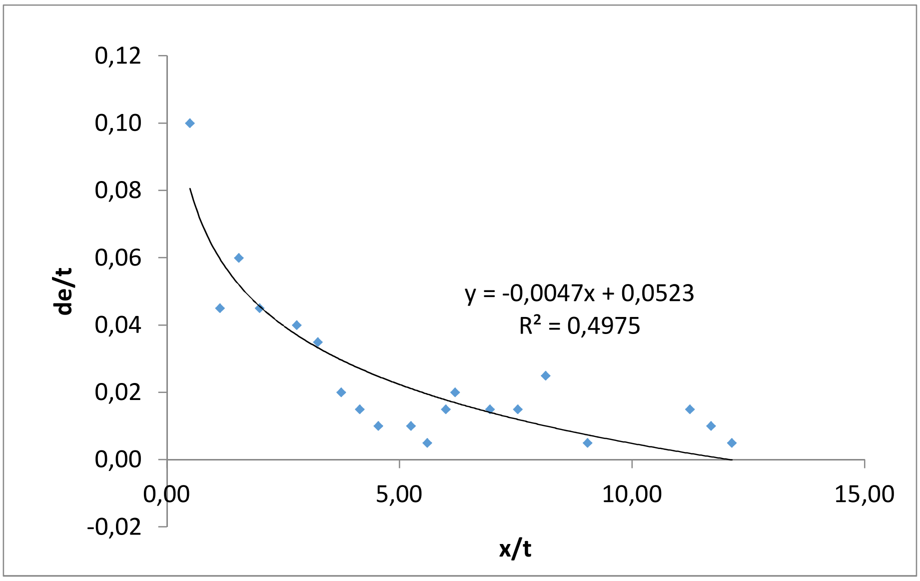

Fig. 4. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 15 minutes

Based on the results of the analysis as shown in Figure 4. it can be said that at the starting point in the Buah river within 15 minutes, there is a relative erosion depth of 0.14 cm (in the model) then the trend decreases at a relative distance (x/t) of 40 cm with erosion of 0.05 cm.

With a coefficient of determination R^2 of 0.497 or an R value of 46.79%, it means that speed (v) and time (t) simultaneously have no effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

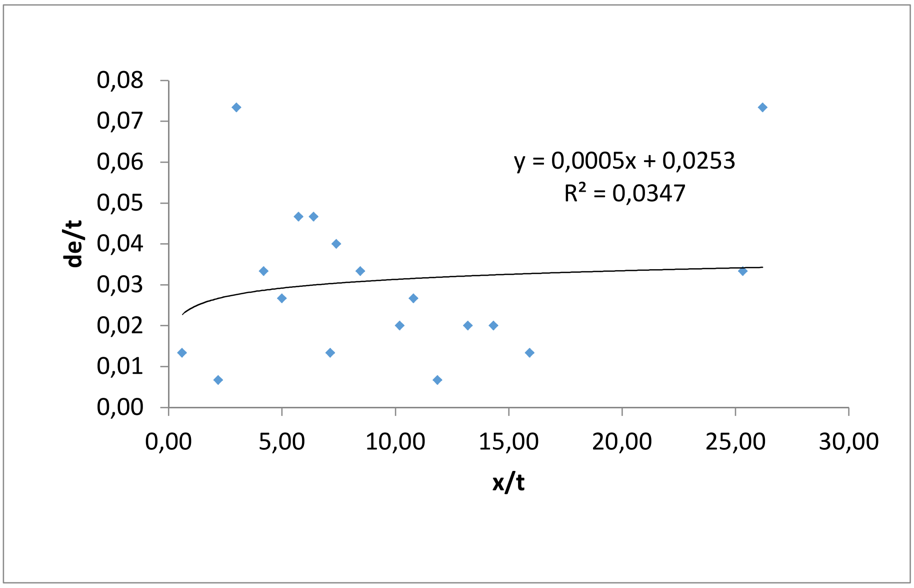

Fig. 5. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 20 minutes

Based on the results of the analysis as shown in Figure 5. It can be said that the relative erosion depth (de/t) increases starting at the relative distance (x/t) 26 and the maximum erosion depth (de) is 0.035 cm (in the model).

With a coefficient of determination R^2 of 0.034 or an R value of 18.43%, it means that speed (v) and time (t) simultaneously have no effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

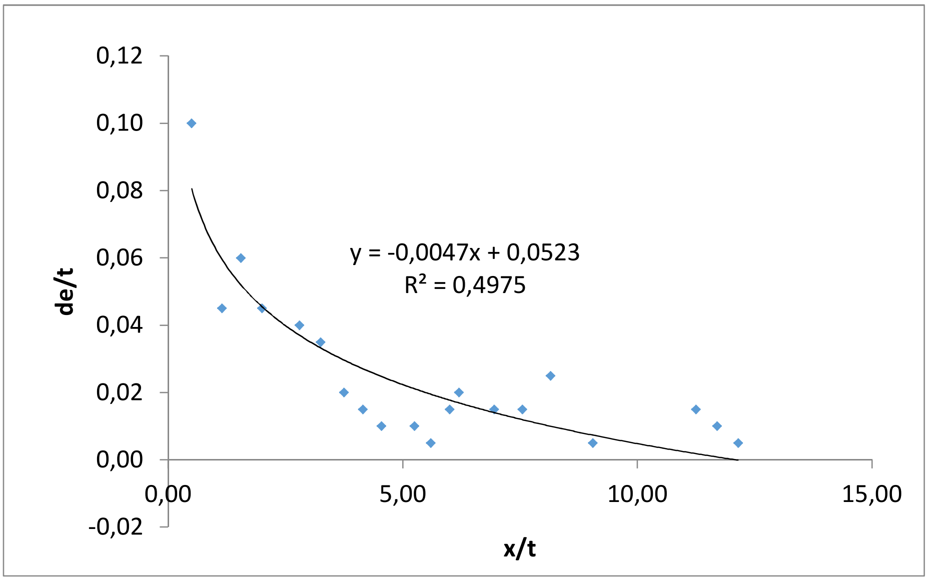

Fig. 6. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 25 minutes experiment

Based on the results of the analysis as shown in Figure 4.5. it can be said that at the initial point in the Buah river within 25 minutes, there was a maximum relative erosion depth (de/t) of 0.08 in the experiment for 20 minutes, meaning that at 20 minutes there was an erosion depth of 1.56 cm in the model. This is the optimum erosion in the channel.

With a coefficient of determination R2 of 0.497 or an R value of 70.49%, it means that the speed (v) and time (t) simultaneously have quite an effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

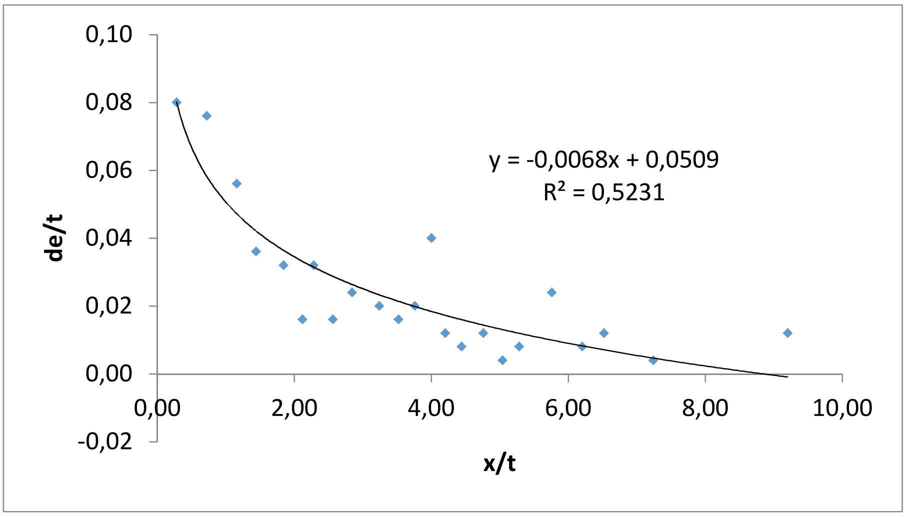

Fig. 7. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 25 minutes experiment

During the 25-minute experiment as shown in Figure 7 above, there was a decrease in erosion at the beginning of the channel/river with a relative erosion value (de/t) of 0.08, meaning that the magnitude of erosion in the river was 2 cm in the model. The result is significant with R^2 = 5.23 or R = 72.3% significant. The results can be used in the field (prototype).

With a coefficient of determination R^2 of 0.523 or an R value of 72.31%, it means that speed (v) and time (t) simultaneously have quite an effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

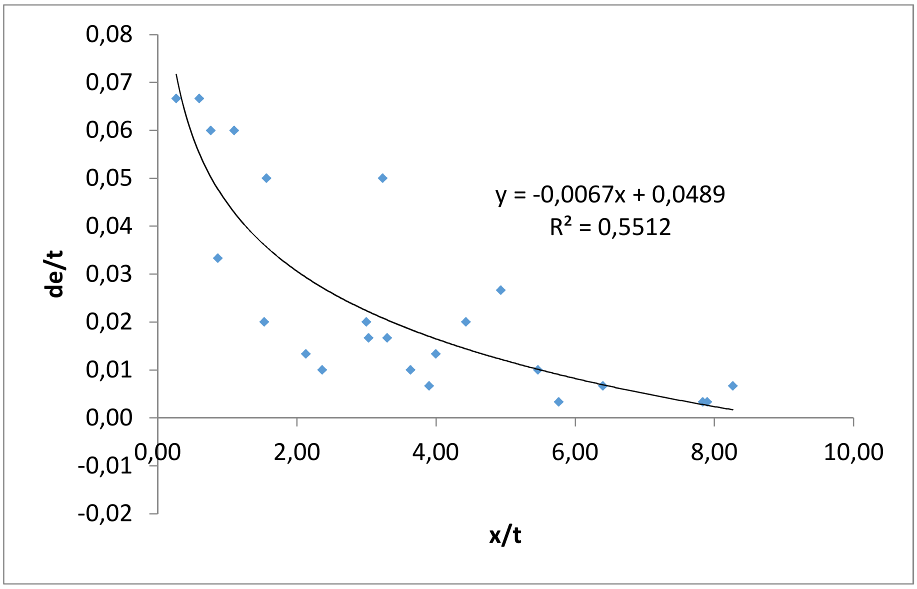

Fig. 8. Plotting The Results of The Dimensionless Analysis Between (de/t) versus (x/t) For 30 minutes experiment

During the 30-minute experiment as shown in Figure 8 above, there was a decrease in erosion at the beginning of the channel/river with a relative erosion value (de/t) of 0.072, meaning that the magnitude of erosion in the river was 2.16 cm in the model. In the prototype (actually) with a scale of 1: 100, the bottom erosion in the Buah river will be 2.16 m.

With a coefficient of determination R^2 of 0.551 or an R value of 74.22%, it means that the speed (v) and time (t) simultaneously have quite an effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

IV. CONCLUSION

The relative erosion depth (de/t) on the riverbed precisely at the mouth of the Buah river is 2.16 cm in the model with a significant level of R of 74.22% or 0.7422. This means that the speed (v) and time (t) simultaneously have quite an effect on the depth of erosion (de) that occurs at the mouth of the Buah river.

Other factors that influence the magnitude of the depth of bottom erosion (bed load) at the mouth of the Buah river as the dominant variables are flow velocity (v), grain diameter (d), and changes in water level (h).

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