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Modeling of Kahayan River Bed on the Section of Kahayan Bridge in Palangkaraya City, Center of Borneo Province, Indonesia

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Abstract*: This research intends to carry out the hydraulic model test in Kahayan River for knowing the changes of Kahayan river bed. This model uses 4 model discharge variations that are Q_1= 0.798l/sec, Q_2= 0.854 l/s, Q_3= 0.897 l/sec, Q_4= 0.994 l/sec by using the tilting slope ($4.58x10^{-5}$). The data that are used in this model are flow depth, flow velocity, and the river bed shape after being flowed on each discharge. The result shows that based on the analysis of Froude number, it can said that the flow is as sub-critical type, however, in the beginning of flowing, fraction shows the Froude number is more than 1. This event is only happened in the upstream model. The flow with the Froude number is less than 1 is mentioned as the low flow regime. From the modeling result and it is carried out the bed river contour drawing, it is seen that the configuration of Kahayan river bed is as the ripples type

***Keywords* : Kahayan River, modeling, hydraulic model test, river bed slope.**

I. INTRODUCTION

The water resources development project often faces the many complex problems, so it must be handled spesifically and accurately [1][2]. However, there is needed an accurate regulation in water usage so it is obtained the optimal result

Therefore, it is nacessary to assess the building dimension that has been designed by using the hydraulics physical model test for looking the building from hydraulic side and it is hoped to get high significance of strength, success, and safety in design [3][4]. The Center of Borneo is a province with the area is about 157.983 km^2 (it is about 1.5 times of Java island area). This province is divided into 13 regencies and one city. Geographically, this area is located in the south longest of 0°45 LU,3°30 and in the east longest of 111 ° BT dan 116° BT. The Center Borneo region consists of coastal area and swamp with the depyh in amount of 0-50 m from sea level and the slope is 0-8%, the hills with the depth in amount of 50-100 m and the average depth is 25%. Almost all of the Center Borneo are flowed by the big and small river that flow from north to south and the estuary is in the Java Sea. Kahayan river is one of the big river in the Center Borneo province. The Kahayan river has the width in about of 400-500 m and the length is 600 km, and the average depth is 7 m. The Kahayan river is through the Gunung Mas regency, Pulang Pisau Regency, and also Palangkaraya city. As the big rivers in Kalimantan Province, Kahayan river is also used as the commercial as well as non-commercial transportation facility. However, in the dry season, the Kahayan river is difficult to be bypassed because the decreasing of discharge and the silting up that causes the river transportation is hampered. In the rainy season, there is happened the over flow in the river bank, The silting up that is caused by the sedimentation is as the general problem that is almost happened in every river like in Kahayan river. It is aggravated by the rampant of illegal mining that is carried out in the Kahayan river. The sedimentation is of course influencing the original of river bed.

II. MATERIALS AND METHOD

Map of Kahayan river is presented as in the Fig

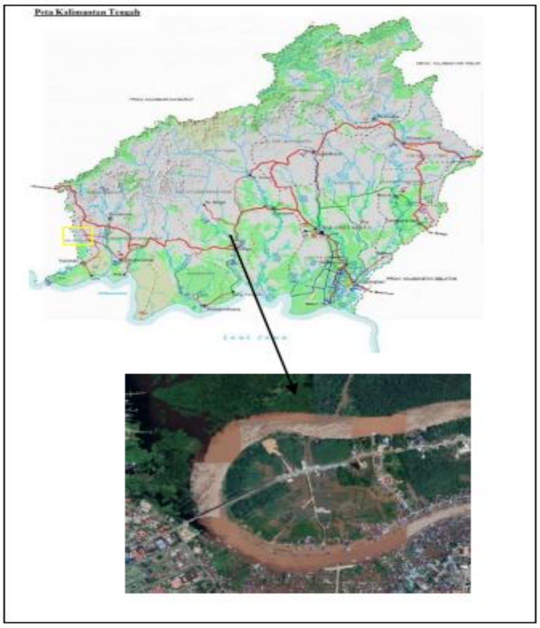

Fig. 1 Map of Kahayan River
Source: Google Image and Google Earth.

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The Kahayan River is located in the bridge section of Kahayan. The river length is 600 km with the width is 400-500 m and the depth is in average of 7 m. One of the main river functions is fpr good transportation, however, in the dry season this river is difficult to be passed because there is happened the silting up of river bed that is caused by the sedimentation. In the rainy season, the river will be flooding because the river capacity exceeded.

The knowledge about sediment transport is as one of the complex knowledge, remembering that there are many components that form the sediment transport. Sediment is one of the river problems in almost the whole river as well in Kahayan River in Center Borneo. One of the river problems that are happened in this river are water quality and sedimentation. The high sedimentation causes the Kahayan River water becomes brown and murky.

A.Sediment Transport

Sediment transport is functioned to know a river in a certain condition weill experience the degradation, aggradations or equilibrium transport, and to estimate the sediment concentration that is transported in the process [5].

A.1. Degradation

Degradation is a condition which the sediment discharge that enters into river is less that the equilibrium sediment discharge in a certain period. The degradation process will cause the happening of river bed elevation decreasing so the river bed slope will be changed is getting steeper. The degradation is usually happened in the weir or dam upstream and the river regulator structures.

A.2. Aggradation

Aggradation is a condition which the sediment discharge that enters into river is more than the sediment discharge in a certain period. The aggregation process will decrease the river bed slope or it is happened the silting up and it may be happened the river widening process.

A.3. Equilibrium

A river is said in the equilibrium condition if the sediment that passes a river section is fixed or the sediment discharge that enters is the same as the sediment discharge that is going out in a certain period.

B.Initial Motion

The equilibrium of particle in the flow bed is disturbed if the resultant effect of force that disturb (pull force, lifting force, thickness force in the particle surface) becomes more that the equilibrium force like gradient and cohesion. Cohesion or attractive force only applies clay sediment or silt range or find sand which the silt content is big enough. Acting force has to be expressed in a dimension that can be known as velocity or basic shear strength. Both of them will have the value that is very fluctuate so the initial motion will also have the statistical aspect [6].

Some approaches in definition the initial motion of sediment granules that is related with the flow condition [7]:

1. There are some sediment granules are moving
2. An amount of sediment particle are moving
3. The bed material granules generally have been moved.
4. There is happened the sediment granules and the initial moving of sediment is as the situation when the amount of sediment transport is zero.

C.Bed Load Transport

When the flow condition fulfills or goes beyond the criteria for the initial motion so the sediment particle along the alluvial layer will begin to move. If the sediment particle motion is rolling down, shifting, or sometimes is floating along the layer, this case is mentioned as bed-load transport. Generally, river bed load sediment rate is in amount of 5-25% of suspended load. However, the percentage of sediment is higher for the raw material. It may be coming from the sediment transport mainly for the bed load [8]

D.Bed Shape and Alluvial Roughness

Generally, the sediment bed shape can be classified as follow [5]:

1. Low flow regime (Froude number: Fr < 1 with the transition is not sharp)
   a. Flat bed of sediment transport without shape change and the motion is soaring and spinning. The bed shear stress is right over the critic.
   b. The ripples is sediment with the size < 0.6 mm and the bed shear stress getting smaller. The shape of sediment is as regular wave with the length of 5-10 cm and the depth is 1 cm (the bed shape is as regular wave with the amplitude is relatively smaller than the wave length).
   c. A dune is for the whole sediment shape and the shear stress is getting big to the front direction. The front side is more sloping, but the back side is steeper. The erosion is happened along the upstream side and the precipitate is happened in the downstream side.
2. Transition area (Froude number: Fr = 1), the bed configuration of dunes is towards the plain bed or anti-dunes.
3. The high flow regime (Froud number: Fr > 1), the flow resistance is relatively small and the sediment transport is big:
   a. Plane bed, flow velocity is gradually ridden; sediment transport has the average depth. The particle moving is rolling or shifting and keep changing in the certain place. For the sift material, there is happened saltation.
   b. Anti-dunes, the material precipitate is happened in the dunes upstream, however, the erosion is happened in the downstream. The wave shapes more and less is symmetric. The anti-dunes is moving to the downstream and it is happened in the Fr > 1.
   c. Chute and pools are happened on the relatively big slope, velocity, and sediment discharge. The bed shape is as the big precipitate hills. The flow condition in the chute is super-critic and sub-critic.

E. Model and Dimension Analysis

Some technical modeling that is related with the fluid flow is sometimes difficult or cannot be analytically solved. Therefore, it is needed a trial or observation for solving the problem. The direct observation in field for the problem or big work like river will spend very big cost and very long time. To avoid the constraint, observation can be carried out by using prototype or model in the laboratory and it is known as a peoject of physical model test. The model has the similar shape with the problem in field but it has the size or scale smaller that in real [9][10].

F. Distortion Model

Distortion model is a model that has horizontal and vertical different scale. This model is used if the dimension of prototype is very big like river, beach, etc [9]. If the horizontal scale is nL and the vertical one is nh, so [9]:

$\frac{Lp}{Lm} nL$.. (1) and

$\frac{hp}{hm} nh$.. (2)

Then, the distortion coefficient is as follow:

$r = \frac{nL}{nh}$.. (3)

The differentiations of some other parameter are desxibed as follow: Skala luas

$nA = \frac{Ap}{Am} = \frac{bp\ hp}{bm\ hm} = nL\ nh$ .... (4)

a. Scale of volume

$nV = \frac{Vp}{Vm} = \frac{Lp\ bp\ hp}{Lb\ bm\ hm} = nL\ nL\ nh$............. (5)

b. Scale of velocity

$\frac{Vp}{Vm} = \left[\frac{hp}{hm}\right]^{1/2}$ .... (6)

c. Scale of discharge

$nQ = nA\ nV = nL\ nh\ nh^{\frac{1}{2}} = nLnh^{3/2}$............................ (7)

G. Hypothesis

The hypothesis of this research is the Froude number will influence the river bed shape. Every river bed shape is affected by the Froud number that is whether it is classified as high or low flow.

H. Research Method

This research is conducted in Hydraulics Laboratory as follow::

a. The Kahayan River hydraulic model test with the winding river and the distortion model that is the vertical scale is 1 : 100 and the horizontal scale is 1 : 250
b. Water pump for supplying the model is one unit.
c. The water storage for supplying the model is completed with the discharge measurer.
d. The discharge measurer of Rechbox.
e. The point gauge, Pitot tube for measuring the velocity. water pass, measuring tube, measuring glass, and bucket.

I. Variable

There are some variables are used in this research as follow: 1) dependent variables that consist of total sediment discharge (Qs), flow depth (y) on the TWL (Tail Water Level), Froude number (Fr), and river bed alteration; and 2) independent variables that consist of flow discharge (Q), type of sediment material, and viscosity.

J. Research Design in Laboratory

The research design consists of: 1) To measure prototype physic, discharge, flow velocity, taking the sediment material from Kahayan River as the base of modeling.; 2) To design and to make the hydraulic physical model oh Kahayan River.; and 3) To prepare the area for setting up the experiment. The activity of setting up experiment consist of a) to build and to take place the storage and regulator bucket in the downstream of river model; b) To install the rechbox (discharge measure tool) on the storage bucket; c) To build downstream storage bucket for storing the sedimen that is transported on the flow process; and d) to install the discharge measure tool of Thompson type for calibration process; 4) To formulate the flow hydraulic phenomena in the river model; 5) To calibrate the tool before carrying out the flow test in modeling. The calibration activity consists of a) To set the water level (H) over the rechbox and to check the downstream by the water level (H) of Thompson; b) To measure the discharge manually in the downstream of structure with the certain duration; c) To calculate the discharge due to the Rechbox, Thompson, and manual measure; and d) To compare the relative error (KR) among the three measurements and then to validate the available formulas to prove and verify from the right result; 6) To measure the river bed with the fixed and movable bed. The measurement on the fixed bed condition includes the measurement of flow velocity (v) and depth (y). For the flow with sediment bed, the flow measurement includes flow velocity (v) and depth (y), and measurement of total transported sediment (Qs). The measurement is carried out by using measurement tool like Pitot tube, plain Sipat, and ruler; 7) To analyze the available parameters and to check the research result. Fig. 2 presents the physical model test of Kahayan River.

Fig. 2 Physical Model Test of Kahayan River

.III. RESULTS AND DISCUSSION

A. Calibration of Discharge

This research is conducted in the Laboratory of River and Swamp, Department of Water Resources, Faculty of Engineering, University of Brawijaya, Indonesia.

The first step in this research is to calibrate the discharge by using the formulation of Rechbox and Thompson and then to measure the discharge directly in the downstream of channel with the certain taking time. The next step is to compare the discharge analysis with the Rechbox and Thompson due to the direct measurement. Based on the comparison above, there will be appear the relative error from each comparison. In this research, the minimum relative error is by using the Rechbox discharge measurer.

B. Analysis of Slope in the Kahayan River Model

Slope in the model of Kahayan River is calculated by using data that are obtained from field. It is hoped the slope that is used can be close to the existing condition of Kahayan River. In this analysis, it is used the real slope of Kahayan River that is 0.0019 with the tilting slope is 0.0739.

C. Model Discharge

Discharge in the model test of river is determined from the probability of river discharge that is happened in Kahayan River (prototype) with the probability of 10% (Q_{10}), 4% (Q_{25}), 2% (Q_{50}), and 1% (Q_{100}). Therefore, the discharge that are used in this model is presented as in the Table- I.

Table- I. Discharge and the probability

P	Q	Qptp		Qmdl	
		m/sec	l/sec	m/sec	l/sec
10%	Q10	122.4012	122401.2	0.0005	0.4896
4%	Q25	182.1116	182111.61	0.0007	0.7284
2%	Q50	199.3799	199379.87	0.0008	0.7975
1%	Q100	213.5554	213555.4	0.0009	0.8542

Source: own study.

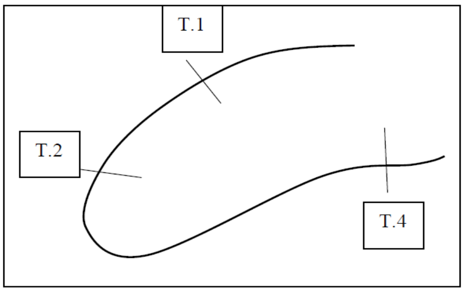

Fig. 3 Scheme of data taking Source: drawing result 2018.

C.The condition of Initial Motion

The analysis of initial motion is carried out before the taking of data in the movable bed for knowing whether the sediment particles are theoretically moved and to know the minimum velocity for moving the sediment particle. The analysis of initial motion is carried out on the 3 points as presented in the Fig. 3 and Table- I

Table- II. Initial Motion on T.1 point

No	Date	H (m)	V (m/dt)	D90 (mm)	U^*_{cr}	U*	T_{ocr}	T_o
1	12/09	5.41	0.61			0.05		2.43
2	22/09	4,21	0.21	1.37	0.027	0.04	0.50	1.89
3	29/09	4,21	0.46			0.04		1.89
4	06/10	4.03	0.42			0.04		1.81
5	08/10	6.39	0.61			0.05		2.87
6	13/10	4.89	0.45			0.05		2.20
7	20/10	5.41	0.54			0.05		2.43
8	27/10	5.48	0.56			0.05		2.47

.Table- IV. Initial Motion on T.4 point

No	Date	H (m)	V (m/dt)	D90 (mm)	U^*_{cr}	U*	T_{ocr}	T_o
1	12/09	6.13	0.54			0.05		2.76
2	22/09	5.55	0.25	1.37	0.027	0.05	0.50	2.50
3	29/09	4.72	0.18			0.05		2.12
4	06/10	5.02	0.34			0.05		2.26
5	08/10	6.88	0.76			0.06		3.10
6	13/10	4.97	0.36			0.05		2.24
7	20/10	5.55	0.42			0.05		2.67
8	27/10	5.67	0.56			0.05		2.55

On the T.1 point, the sediment particle with diameter d_{90} is moving with the average velocity of 0.48 m/sec, maximum velocity of 0.61 m/sec, and minimum velocity of 0.21 m/sec.

Table- III presents the initial motion on the T.2 point.

No	Date	H (m)	V (m/dt)	D90 (mm)	U^*_{cr}	U*	T_{ocr}	T_o
1	9-Dec	5.22	0.61			0.05		2.35
2	22/09	4.08	0.42			0.04		1.84
3	29/09	3.43	0.33			0.04		1.54
4	10-Jun	3.92	0.45	1.37	0	0.04	0.51	1.76
5	10-Aug	3.95	0.5			0.04		2.78
6	13/10	3.65	0.4			0.04		2.64
7	20/10	3.95	0.5			0.04		2.78
8	27/10	4.5	0.56			0.04		2.02

In the T.2 point, the sediment particle with the diameter d_{90} is moving with the average velocity of 0.47 m/sec, maximum velocity of 0.61 m/sec, and maximum velocity of 0.33 m/sec. Table- IV presents the initial motion on the T.4 point

On the T.4 point, the sediment particle with the diameter d_{90} is moving with the average velocity of 0.43 m/sec, maximum velocity of 0.76 m/sec, and minimum velocity of 0.18 m/sec.

From the three point measurement, it can be concluded that the average velocity of Kahayan River is 0.46 m/sec with the maximum velocity is 0.76 m/sec, and the minimum velocity is o.18 m/sec. The velocity range can move the particle sediment with the diameter: d_{90} = 1.37 mm.

D.River bed shape and alluvial roughness

The river bed shape in the model test can be known through the observation of channel bed (sedikment) after the discharge flowing with the certain duration. The average flow time of the research is during 1.5 hours for every discharge. Besides with the observation of river bed, the determination of river bed shape type is also theoretically carried out that is by analyzing the Froude number. Table- V, VI, VII, VIII and

Fig. 4, 5, 6, 7 presents the theoretical analysis result for determining the river bed type each for Q_{10}, Q_{25}, Q_{50}, Q_{100}

Table- V. Froude Number on Q_{10}

Section	h (cm)	Fr	Note
1	2.20	1.42213	Super-critic
3	3.20	0.73480	Sub-critis
5	2.05	0.90092	Sub-critic
7	3.90	0.89175	Sub-critic
10	2.50	0.90154	Sub-Kritic
13	3.00	0.87402	Sub-Kritic
15	2.80	0.99277	Sub-Kritic
18	5.45	0.61072	Sub-Kritic
21	6.70	0.57791	Sub-Kritic
25	6.25	0.57253	Sub-Kritic
26	6.10	0.53054	Sub-Kritic
27	6.75	0.59416	Sub-Kritic
30	5.70	0.67127	Sub-Kritic

Source: own study, 2019.

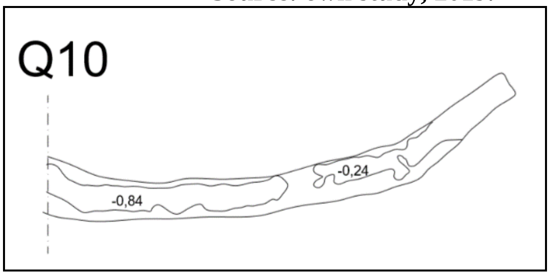

Fig. 4 Channel Bed on Q_{10} Source: drawing result.

Table- VI Froude Number on Q_{25}

Section	h (cm)	Fr	Note
1	2.20	1.45559	Super-critic
3	3.50	1.00252	Super-critic
5	2.05	1.1034	Super-critic
7	3.95	0.98046	Sub-critic
10	3.00	0.90338	Sub-critic
13	3.3	0.88267	Sub-critic

Table- VI (continued) Froude Number of Q_{25}

Section	h (cm)	Fr	Note
15	3.15	0.9645	Sub-critic
18	5.45	0.5289	Sub-critic
21	6.95	0.53965	Sub-critic
25	6.4	0.56358	Sub-critic
26	6.7	0.60594	Sub-critic
27	6.8	0.62743	Sub-critic
30	6.2	0.70438	Sub-critic

Source: own study, 2019.

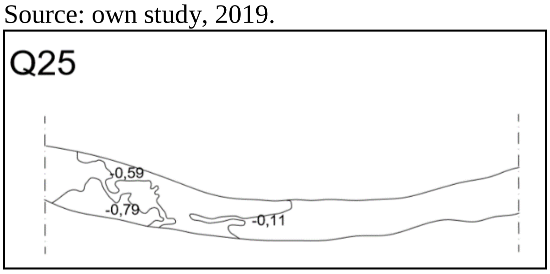

Fig. 5 Channel Bed result on Q_{25} Source: drawing result

Table- VII Froude Number on Q_{50}

Section	h (cm)	Fr	Note
1	2.25	1.50674	Super-critic
3	3.75	1.02817	Super-critic
5	2.25	1.40313	Super-critic
7	4.05	1.064	Super-critic
10	3.05	0.90998	Sub-critic
13	3.45	0.91078	Sub-critic
15	3.25	0.98653	Sub-critic
18	5.8	0.60606	Sub-critic
21	7.55	0.60687	Sub-critic
25	7.15	0.55621	Sub-critic
26	6.75	0.6627	Sub-critic
27	7.3	0.62793	Sub-critic
30	6.25	0.76201	Sub-critic

Source, own study, 2019.

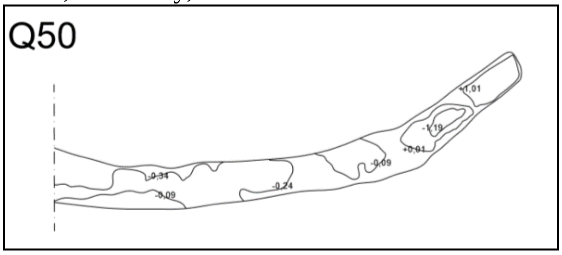

Fig. 6 Channel Bed on Q_{50} Source: drawing result.

Table- VIII Froude Number on Q_{100}

Section	h (cm)	Fr	Note
1	2.3	1.56618	Super-critic
3	3.9	1.02389	Super-critic
5	2.8	1.46546	Super-critic
7	4.3	1.1537	Super-critic
10	3.6	1.00641	Super-critic

Table- VIII (continued) Froude Number on Q_{100}

Section	h (cm)	Fr	Note
13	3.9	0.87856	Sub-critic
15	3.3	0.99338	Sub-critic
18	5.9	0.59939	Sub-critic
21	7.6	0.66846	Sub-critic
25	7.4	0.62405	Sub-critic
26	6.9	0.73729	Sub-critic
27	7.45	0.76	Sub-critic
30	6.35	0.7832	Sub-critic

Source: own study, 2019.

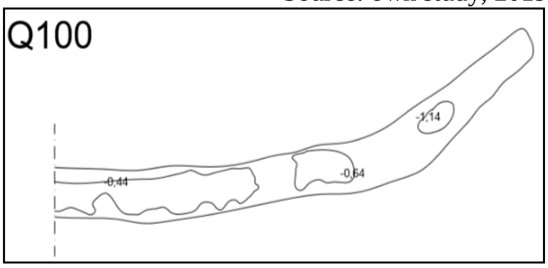

Fig. 7 Channel Bed Result on Q_{100} Source: drawing result.

IV. CONCLUSION

Based on the analysis above, it can be concluded as follow:

1. Based on the measurement in the Kahayan River modeling, theoretically the dominat Froude number is less than 1 or it is as the sub-critic flow which indicates that the Kahayan River has the low flow regime.
2. On the initial flow for each discharge, the average Froude number is more than 1 or super-critic. The super critic flow is happened in the downstream of model and it is dominant happened on the maximum discharge that is Q_{100}.
3. On the d_{90}=1.37mm has the value: U_{*cr}=0.027 and τ_{cr}=0.51.

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- Point 1 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, particle with d_{90} will move on the average velocity Point 1 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, particle with d_{90} will move on the average velocity of 0.48 m/sec, maximum velocity of 0.61 m/sec, and minimum velocity of 0.21 m/sec.
- Point 2 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, particle with d_{90} will move on the average velocity Point 1 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, will move on average velocity of 0.47 m/sec, maximum velocity of 0.61 m/sec, and minimum velocity of 0.33 m/sec.
- Point 4 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, particle with d_{90} will move on the average velocity. Point 1 $U_*>U_{*cr}$ and $\tau > \tau_{cr}$, particle with d_{90} will move on average velocity of 0.43 m/sec, maximum velocity of 0.76 m/sec, and minimum velocity of 0.18 m/sec

4. Based on the modeling result, there is obtained the river bed drawing after being flowed of each discharge. The Kahayan River has the ripples bed shape with the regular wave shape. The average Froud number in every section is less than 1 or sub-critic.

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