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# Analysis of Bed Load Security Transportation on Kamp Wolker River – Jayapura Province Papua, Indonesia

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**Abstract**

Kamp Wolker River is a clean water source for people of Abepura City.The activities of the community such as the opening of agricultural land and household waste along the river is the largest contribution of the sedimentation process to the Lake Sentani estuary resulting in a decrease in water volume from year to year and affect the community's water needs. However, in the winter season there was an increase in the volume of water that caused sediment from the upper stream which impacted the occurrence of siltation in the form of delta-delta and certain areas experiencing scouring due to the sedimentation process. The purpose of this research is to know the amount of sediment transport rate of basin and the basic sediment characteristic in the form of sediment diameter (D50), sediment weight and amount of bed sedimentation rate.the analysis of the basic sediment of the Wolker River has a critical shear rate of 0.025 m / s base sediment, a critical voltage of 2.036 N / m² and based on shield graphs the relationship between critical shear rate and sedimentary diameter indicates that bedtime sediments in rivers for period flood conditions reset 5, 10 and 25 years of moving. Based on Einstein's equation, the magnitude of the bed load rate at the flood discharge with a 25 year return period is ± 14,287 ton / day.

keywords : basic sediment, sedimentation, sediment transport rate

## 1. Introduction

Sedimentation sourced from human activities along the river Wolker Camp is the largest contribution of the sedimentation process at Lake Sentani estuary. Activities include the clearing of agricultural land, household waste, vegetation clearance by the river and so on. These activities then result in a decrease in water volume resulting in reduced water source from year to year but in the rainy season there will be an increase in the volume of water that causes sediment from the upstream of the river carried to the mouth of the river and form a delta along the mouth of the river to get into Lake Sentani which impact on the occurrence of siltation and not only that there are certain areas that begin to experience scouring due to the sedimentation process. The problems that will be discussed in this research are: the characteristics of grain sediment at the bottom of the channel and large rate of basic sediment transport flowing in Sungai Kampung Wolker.

In this research work There are some limitations of the problem in this research, among others: sediment rate is analyzed based on design flood conditions and the equations used in the calculation of sediment transport Einstein's equations. Objectives to be achieved authors in this study is to analyze characteristics of sediment grains at the bottom of the channel and the amount of sediment transport downstream of Wolker River

## 2. Literature Review

### a. River Basin

River basin is defined land areas that are a union with rivers and tributaries, which function to store, store, and drain water from rainfall to the sea naturally, whose boundaries on land are topographical and boundary separators in sea until the waters area that still affected by the mainland activity (Government Regulation of Republic of Indonesia Number Year 2011 About River).

A river channel can be divided into three parts.Three parts are upstream, middle and downstream. The flow of water in a channel can be a flow in an open channel, and can also be a stream in a pipe (closed channel). In open channels, the water stream has a free surface that is affected by the velocity, viscosity, gradient and channel geometry. This is what usually causes difficulties in obtaining accurate data about the flow on open channels.

### b. Hidrology Analisis

Hydrology (derived from the Greek: hydros = water and logos = science, hydrologia, "water science") (SNI No.1724-1989-F in Soemarto, 1999). Hydrology is studied by people to solve problems related to water, such as water management, flood control, and water-building planning. There are several forms of continuous (theoretical) distribution functions that are often used in frequency

analysis for hydrology namely, Normal distribution, Log Normal, Gumbel and Log Person Type III.
Effective rainfall (rainfall) or excessrain-fall is part of the rain that flows directly into the river (Triatmodjo, 2008).

$$P_e = \frac{(P - 0{,}2\,S)^2}{P + 0{,}8\,S} \quad (1)$$

With :
Pe = effective depth of rainfall (mm)
P = depth of rainfall (mm)
S = maximum water potential retention by soil, which is largely due to infiltration (mm)

The concentration time (tc) is the time required by falling rainwater to flow from the furthest point to the point to be reviewed (control point). The concentration time can be calculated by the following equation:

$$t_{c=0{,}606\,(L.n)^{0{,}467}.S^{-0{,}234}} \quad (2)$$

The rain distribution model developed to divert the daily rain to the hourly rain is divided into three types of rain-hour distribution models; Uniform rain distribution, Triangle, Alternating Block Method (ABM) (Chow.et.al, 1988 in Daniel B.P. Allo, 2012).
Calculation of rain intensity reviewed using Mononobe method, is as follows:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad (3)$$

With :
I = rain intensity during t (mm/jam)
t = duration of rainfall (jam)
$R_{24}$ = maximum rainfall for 24 hours (mm)

This concept is widely used to transform from rain to flow discharge. The unit hydrograph method is a simple, easy-to-implement method, and gives relatively accurate results of hydrograph flood prediction.
The calculation of flood discharge plans for drainage channels in urban areas can be done using rational or unit hydrograph formulas.
Unit hydrographs derived from different cases, will obtain different unit hydrographs. Therefore, to obtain the hydrograph of a representative unit (hydrograph unit) of a particular river basin, the hydrograph of the units of hydrograph needs to be averaged. Here are some of the equations needed to produce HSS Nakayasu.

$$Q_p = \frac{A.\,R_e}{3.6\,(0{,}3\,T_p + T\,0{,}3)} \quad (4)$$

$$Tp = t_g + 0{,}8t_r \quad (5)$$

$$tg = 0{,}4 + 0{,}058L \text{ for } L > 15 \text{ km} \quad (6)$$

$$tg = 0{,}21L^{0.7} \text{ For } L < 15 \text{ km} \quad (7)$$

$$T_{0{,}3} = \propto .\, t_g \quad (8)$$

$$\propto = \frac{047\,AL^{0.25}}{Tg} \quad (9)$$

$$t_r = 0{,}5t_g \ldots\ldots t_g \quad (10)$$

With :
Qp = Flood peak discharge (m^3/dt)
A = River basin (km^2)
Re = Rain unit (mm)
Tp = the time from the beginning of the flood to the top of the hydrograph (jam)
$T_{0,3}$ = the time from the flood peak to 0.3 times the peak discharge (jam)
$t_g$ = concentrate time (jam)
Tr = the time unit of rainfall (jam)
α = coefficient of river basin characteristics
L = lenght of main river (km)

### c. Open Channel Geometric Elements

An open channel cross section is defined as a cross section perpendicular to the direction of flow in an open channel. Below are the formulas used in analyzing the geometric of the cross-section.
Table 1. Formulas-geometric roots for multiple cross sections

| | Square | Trapezoidal | Circle |
|---|---|---|---|
| Wet Sectional Area | b.y | $(b + my)y$ | $\frac{1}{8}(\varphi - sin\varphi)D^2$ |
| Wet Roving (B) | B + 2y | $b + 2y$ | $½\varphi D$ |
| Top Width (B) | b | $b + 2y\sqrt{(1+m^2)}$ | $\frac{1}{4}\left(1 - \frac{sin\varphi}{\varphi}\right)D^2$ |
| Radius Hydraulic (R) | $\frac{bh}{b+2h}$ | $\frac{(b+my)y}{b+2\sqrt{1+m^2}}$ | $\frac{1}{8}\left[\frac{\varphi - sin\varphi}{sin(½\varphi)}\right]D$ |

### d. Sedimentation

Sedimentation is a process whereby sediments that occur due to inhibition of the water flow are deposited in the drains, open drains or in the drain pipe (Dusk Term PU, 2008).This sedimentation occurs through the process of precipitation of material transported by water, wind, ice, or glacier media in a hollow.

According to the source of origin, sediment transport is divided into: bed material load and wash load.

Meanwhile, according to the transport mechanism is divided into: suspended load n bed load

The coarse particles that move along the bottom of the river as a whole are called the basic bed load (Bed Load). The existence of the basic sediment load is indicated by the movement of the riverbed particles, the movement can be shifted, rolled or bounded, but never loose from the bottom of the river.

Sediment particles are said to move in suspended load when they move without touching the bottom of the channel.

In general, the form of sediment particles is differentiated based on grain size of sediment. Specification of sediment grain size can be seen in table 2.

Table 2. Classification of grain size according to AGU ( American Geophysical Union )

| Interval Range (mm) | Name | | Interval Range (mm) | Name |
|---|---|---|---|---|
| 4096 - 2048 | Very Large Boulders | | ½ - ¼ | Medium Sand |
| 2014 - 1024 | Large Boulders | | $^1/_4 - ^1/_8$ | Fine Sand |
| 1024 - 512 | Medium Boulders | | $^1/_8 - ^1/_{16}$ | Very Fine Sand |
| 512 - 256 | Small Boulders | | $^1/_{16} - ^1/_{32}$ | Coarse Silt |
| 256 - 128 | Large Cobbles | | $^1/_{32} - ^1/_{64}$ | Medium Silt |
| 128 - 64 | Small Cobbles | | $^1/_{64} - ^1/_{128}$ | Fine Silt |
| 64 - 32 | Very Coarse Gravel | | $^1/_{128} - ^1/_{256}$ | Very Fine Silt |
| 32 - 16 | Coarse Gravel | | $^1/_{256} - ^1/_{512}$ | Coarse Clay |
| 16 - 8 | Medium Gravel | | $^1/_{512} - ^1/_{1024}$ | Medium Clay |
| 8 - 4 | Fine Gravel | | $^1/_{1024} - ^1/_{2048}$ | Fine Clay |
| 4 - 2 | Very Fine Gravel | | $^1/_{2048} - ^1/_{4096}$ | Very Fine Clay |
| 2 - 1 | Very Coarse Sand | | | |
| 1 - ½ | Coarse Sand | | | |

The percentage of translucent (% through) percentages of each particle size particle diameter can be calculated by the following equation:

$$100 - \left(\frac{\text{weight of sample of sieve}}{\text{total sample weight}} x100\right) \quad (11)$$

The particle density can be determined by laboratory testing, after which it is analyzed using the equation below.

$$\text{Specific gravity} = \frac{m}{(pa + m) - ps} \quad (12)$$

Where :
m = dry sample weight (gram)
pa = weight pycnometer and water (gram)
ps = weight of pycnometer + water + example (gram)
(pa+m)-Ps = example volume (=volume of water moved)

Beginning of sediment grain motion is very important in relation to the study of sediment transport, degradation of river bed / channel, stable channel design, and others.

Since the movement of sediment particles / granules is very irregular, it will be very difficult to define with certainty, under what flow conditions, sediment particles begin to move (critical condition).

Beginning sedimentary motion can be calculated as follows:

$$(U_{*c})^2 = \{[(\rho_s - \rho_w)/\rho_w]gd\} \quad (13)$$

Where :
$(U_{*c})^2$ = Critical Slide Speed
$\rho_s$ = weight of sediment (kg/ m³)
$\rho_w$ = weight of water (1000 kg/m³)
g = gravitation ( m/det² )
d = sediment diameter (m)

$$\tau_{0=}\ \rho_w\, g\, h\, S_o \quad (14)$$

Where :
$\rho_w$ = weight of water (kg/ m³)
g = gravitation ( m/det² )
h = depth of water (m)
$S_o$ = the basic slope of the channel

$$\tau_c = 0.04\ (\rho_s - \rho_w).g.\ d \quad (15)$$

Where :
τ_c = tegangan kritis ( N/m²)
ρ_s = weight of sediment (kg/ m³)
ρ_w = weight of water (kg/ m³)
g = gravitation ( m/det² )
d = sediment diameter (m)

If τo >τc thensediment grain moves.

Basic sediment with Einstein appraoch :

$$\Phi = f(\psi) \qquad (16)$$

With :
Φ = the intensity of the basic sediment load
f (ψ) = flow intensity

$$\Phi = \frac{q_b}{\rho_s}\left(\frac{\rho}{\rho_s-\rho}\cdot\frac{1}{g.D^3}\right)^{1/2} \qquad (17)$$

With :
qb = discharge of basic sediment load (kg/det/m)
ρ = specific gravityfrom water (1,00 ton/m^3)
ρs =specific gravity of the basic sediment load (ton/m^3).
g = gravitation = 9,81 m/det²
D = sediment diameter

$$f(\psi) = \frac{\rho}{\rho_s-\rho}\cdot\frac{D}{S\,R_{b'}} \qquad (18)$$

R^'R ^ 'is the hydraulic radius that holds the basic sediment charge and S is the base slope of the channel.

$$R' = R_b\left(\frac{n'}{n}\right)^{3/2} \qquad (19)$$

n is the actual roughness value that can be calculated by Manning formula:
n' (coefficient of roughness of river basin) can be calculated with

$$V = \frac{1}{n}R^{2/3}S^{1/2} \qquad (20)$$

$$n' = \frac{D_{90}^{1/6}}{26}$$

**Table 3. Relationship Ø and Ψ**

| Ø | Ψ | Ø | Ψ |
|---|---|---|---|
| $10^{-4}$ | 27.0 | $5.10^{-3}$ | 11.5 |
| $5.10^{-4}$ | 24.0 | $10^{-1}$ | 9.5 |
| $10^{-3}$ | 22.4 | $5.10^{-1}$ | 5.50 |
| $5.10^{-3}$ | 18.4 | 1 | 4.08 |
| $10^{-2}$ | 16.4 | 10.00 | 0.70 |

Average flow can be determined with :

$$V = \frac{Q}{A} \qquad (21)$$

Einstein approach :

$$\Psi = \frac{\rho_s-\rho}{\rho}\cdot\frac{D_{35}}{R\left(\frac{n'}{n}\right)^{3/2}S} \qquad (22)$$

The baseline sediment load rate per unit width of the river bed is calculated by the formula:

$$\Phi = \frac{q_b}{\gamma_s}\left(\frac{\rho}{\rho_s-\rho}\cdot\frac{1}{g\,D_{35}^{3}}\right)^{1/2} \qquad (23)$$

The sediment load rate across the width of the river bed is:

$$Q_b = q_b.W \qquad (24)$$

With :
Qb = Basic sediment load rate across the width of the cross section (kg/det)
qb = basic sediment load rate per unit width (kg/det/m)
W = base width of the channel (m) Relationship betweenΦ andΨ

## 3. Research Methodology

**Research location**

The research was conducted at the River Wolker River Flowing Area in Heram district of Jayapura. This river flows down the Cycloops mountains from North to South and empties into Lake Sentani. The length of the river is about 14.5 km with a width of 35 m. Specifically, sediment collection is conducted downstream of Wolker River Camp. The location of research can be seen in the picture below.

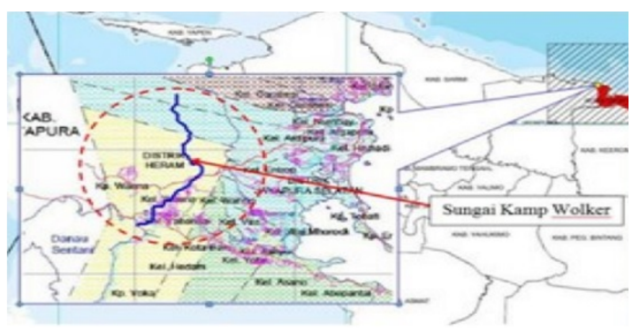


**Figure 1. Location Map of Research**

**Sediment Sampling**

The basic sediment sampling (bed load) is done at the midpoint of the river by dredging the bottom of the river. It is hoped that the taking at the midpoint of the river can represent the basic sediment at each point of the location of the taking. Taking is done by dredging the river bottom sediments at each point of location. The following points to consider in the sampling location are as follows:

1. Sampling of basic sediment loads should be selected in locations not affected by waterlogging or reverse flow.
2. The location of sampling of basic sediment loads is selected by taking into account the following provisions:
   1) Basic sediment load measurements were performed at the discharge measurement sites.
   2) The river bed is evenly distributed.
   3) The cross section should be perpendicular to the flow direction.

**Fig. 2. Samples of sedimentary base of Kamp Wolker**

**Tests of Sediment Grain Size**

1. The sand to be tested / checked shall be dried in a furnace with heat between 100 ° C and 110 ° C until the weight is constant.
2. Arrange the sieve according to the arrangement with the largest sieve hole placed at the top and then the smaller hole underneath.
3. Insert the sample sand into the topmost sieve.
4. The arrangement of sieve is placed on the vibrator or sieved by hand. Generally, the vibration is done for 10 minutes.
5. The sand left in each sieve is moved to another vessel or paper. In order for no sand to be left in the sieve, the sieve must be cleaned with a soft brush. The sand is then weighed. Weighing should be done cumulatively, ie from coarse grains of sand first, then added with a finer grain of sand, until all the sand is weighted. Note the weight of sand at each weigh. In this step should be done carefully so that no sand is lost.

**Specific Gravity Test**

1. Dry the specimen in the oven at 110 ° C ± 5 ° C (230 ° F ± 9 ° F) for 24 hours, then cool in the desiccator;
2. Wash picnometer or measuring bottle with distilled water, then dried and then weigh (W1 gram);
3. Insert the test specimens into the pictograms or measuring bottles used, then weigh (W2 grams);
4. Add distilled water to the picnometer or measuring jar containing the specimen, so that the picnometer or measuring bottle is two-thirds;
5. For test specimens containing clay, leave the submerged specimens for 24 hours or more;
6. Heat the picnometer or measuring bottle containing the test specimen carefully for 10 minutes or more so that the air in the test piece goes out. To speed up the air-discharging process, piknometers or measuring bottles can be tilted once;
7. Air production can be done by vacuum pumps, with pressure of 13.33 kpa (100 mm Hg);
8. Soak picnometer or measuring bottle in a submersible bath, until the temperature is steady. Add enough distilled water to the brim. Dry the exterior, then weigh (W3 gram);
9. Measure the temperature of the picnometer or measuring bottle, to get the factor correction (K);
   If the picnometer or measuring bottle is not known, the contents are determined as follows:
   1) Empty and clean the piknometer or measuring bottle to be used;
   2) Fill picnometer or measuring bottle with distilled water the same temperature, then dry and weigh (W4 gram).

## 4. Result And Analysis

**Kamp Wolker River Characteristics**

Wolker River Camp is located in Heram District of Jayapura City, whereas based on the Watershed (DAS) map of Jayapura city, Wolker River Basin is included in Sentani District of Jayapura District. This river flows down the slopes of the Cycloops mountains from North to South and empties into Lake Sentani. The Camp Wolker River can be seen in the Picture below.

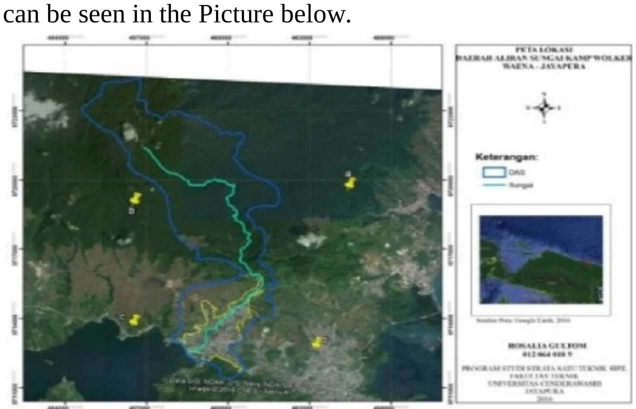


Fig. 3. Map of River Basin Area of Kamp Wolker River

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### Hidrology Analysis

Through hydrological calculation of Sungai Kampung Wolker, obtained by Nakayasu synthetic unit hydrograph as follows:

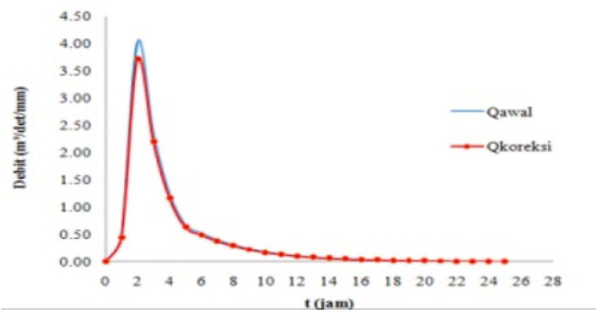


**Figure 4. The Nakayasu Synthesis Hydrograph**

### Geometric Channel Calculations

Based on the calculation of geometric cross section, the obtained debit that will be used in the calculation of the rate of basic sediment transport is the flood discharge with 25-year re-period.

### Bed Load

Basic sediment analysis was conducted to find out sediment characteristics of sedimentary diameter, sediment weight and base sediment transport rate (Bed Load).

### Diameter of Sediment Grains

Based on sediment grain filter analysis, the following filter graph is obtained:

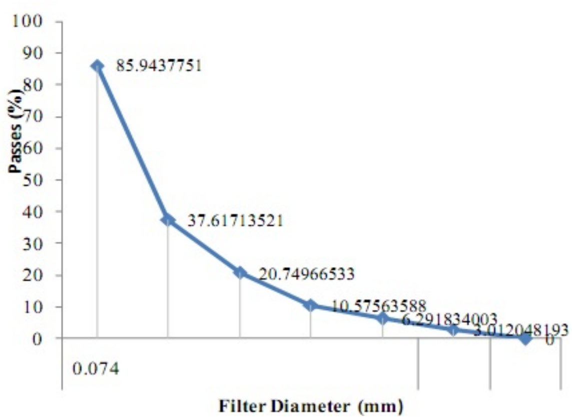


**Figure 5. Graph of the filter**

From interpolation D35 = 1.003 mm, D50 = 1.582 mm ,D90=4,98 mm

### Specific Gravity of Sediment

Through laboratory testing and analytical results obtained by weight of basic sediment type :4282.03 kg/m³

### Preliminary Analysis of Sediment Grain Motion

In calculating the beginning of sediment grain motion, whether it is critical shear rate, friction stress and critical stress of sediment diameter to be used is D50 with the following calculation:

Table 4. The result of initial analysis of the basic sediment grain motion is based on flood condition of return period 5,10 and 25 years

| Repeated Period (Year) | Height/h (m) | Speed/V (m/sec) | Shear Stress/τo (N/m²) | Critical Stress/τc (N/m2) | Infomation |
|---|---|---|---|---|---|
| 5 | 2.00 | 0.05 | 1569.6 | 2.034 | Moves Sediment |
| 10 | 2.15 | 0.05 | 1687.32 | 2.034 | Moves Sediment |
| 25 | 2.50 | 0.05 | 1962 | 2.034 | Moves Sediment |

From the result of initial analysis of sediment grain movement relation between critical shear rate to sediment grain size can be seen in the following Shields chart.

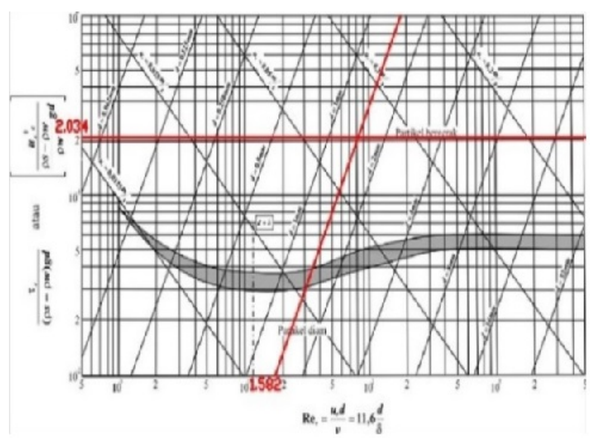


**Figure7. Shields Chart**

Analysis of Basic Sediment Transportation Rate (Bed Load) can be seen in the following table:

**Table 5. Result of Calculation Basic sediment transport using Einstein equation**

| Hour | Q ($m^3$/Sec) | Ψ | Ø | $q^b$ (kg/sec/m) | Qb | |
|---|---|---|---|---|---|---|
| | | | | | kg/sec | ton/sec |
| 1 | 9.964 | 3.641 | 2.169 | 1.94 | 4.37 | 377.47 |
| 2 | 81.044 | 0.157 | 11.446 | 10.25 | 23.05 | 1991.83 |
| 3 | 295.745 | 0.023 | 11.804 | 10.57 | 23.77 | 2054.12 |
| 4 | 236.697 | 0.031 | 11.780 | 10.55 | 23.73 | 2049.98 |
| 5 | 132.179 | 0.075 | 11.663 | 10.44 | 23.49 | 2029.64 |
| 6 | 75.023 | 0.176 | 11.395 | 10.20 | 22.95 | 1982.90 |
| 7 | 53.907 | 0.289 | 11.093 | 9.93 | 22.34 | 1930.49 |
| 8 | 42.452 | 0.414 | 10.761 | 9.63 | 21.67 | 1872.71 |
| | | | | | | 14289.14 |

## 5. Conclussion

Based on the results of the discussion in the form of hydrological analysis, hydraulic analysis and characteristic analysis of sediment grains on Kamp River Wolker, the authors take some conclusions, namely:

1. The critical sediment shear rate velocity is 0.025 m / s, the critical voltage of 2.036 N / m² and based on the shield graph the relationship between critical shear rate and sedimentary diameter indicates that the bed load on the Wolker River river for flood conditions return period 5 , 10 and 25 years of moving.
2. The amount of bed sedimentation rate on Kamp River woker for flood discharge with 25 year return period according to Einstein equation is 14287.12 ton / day.

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