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The Estimation of Total Sediments Load in River Tributary for Sustainable Resources Management

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Abstract. One problem that disrupts the stability of the river is sedimentation. The impact caused by excessive sedimentation can cause an increase in riverbed elevation (siltation) and at the same time can cause an increase in water level so that it can increase losses when flooding occurs. For the purpose of sustainable water resource management, especially for river ecosystems, it is very important to be able to estimate the total amount of sediment loads a little more accurately according to the river's carrying capacity. This study aims to evaluate the method of estimating sediment transport that gives the best level of accuracy of existing sediment transport methods. The method is considered accurate if the percentage of compliance with the highest discrepancy ratio (r) ranges from the available data. This research methodology analyzes and compares several methods of estimating the total sediment load that are most suitable for the Cimanuk River tributary data. Sediment parameter data inventory is done by taking water samples to estimate the concentration of suspended sediment, bed load sediment samples and samples of the bed load material using the correct strander data retrieval. In addition, measurement of river hydraulic parameters is needed, including flow velocity and river water temperature. Based on the analysis, the method that works best to calculate the sediment transport values in sequence are the Van Rijn method, the Yang method, the Bagnold method, the Engelund-Hunsen method, the Karim-Kennedy method and the Toffaletti method which is close to 30% fulfilling the discrepancy ratio (r) ($0.5 \leq r \leq 2.0$).

1. Introduction

The river is a dynamic system that includes hydraulic processes and sediment transport. In a watershed, soil erosion due to rain causes ecological and environmental damage and decreases in agricultural production. The process of erosion of the river body and erosion of the catchment area in the upper reaches of the river along the surface flow will enter the river bodies and can cause sedimentation. Sediment deposits in this river channel will cause flood water levels to rise. On the other hand, the erosion of the river bed due to strong river currents can cause water levels to fall upstream and transport sediment particles downstream. Sediments in the water will also have a negative effect on water quality. Sediment and scouring generally occurs in the riverbed due to differences in sediment load and sediment transport capacity in the stream.

The water flow of the river is a fairly complex process. Water moves through the river body due to the influence of gravity. Flow velocities increase with increasing slope of the river bed. In natural rivers,



the flow is definitely not uniform even in a turbulent form. The stream energy will also increase in line with the increase in water volume and slope so as to bring the sediment load. The dynamics of turbulent flow causing sediment load value is non linear with respect to variables other rivers. Several important variables in the dynamics of river flow are: (1) gradient (2) velocity, (3) discharge and (4) sediment load [1].

The flow rate indicates the water supply coming into the main river body. With careful observation can be known the source of the arrival of the water whether from surface flow or seepage of ground water that enters the river body. The existence of ground water is very important because it ensures the existence of a river as a permanent streams throughout the year. Instead, if the river water supply depends on the season, the river is sometimes filled with water or dry or known as non-permanent rivers (intermittent streams).

Along the river body, the flow velocity is not the same, depending on the flow pattern, shape, and roughness of the river body. The largest velocity is located at the top of the deepest part of the canal which is far from frictional strings on the walls and bottom of the canal. In a winding river, the maximum velocity zone is on the outside of the bend and the minimum speed zone is in the interior of the bend. This causes a lateral erosion of the river body. The flow velocity flows proportionally to the slope of the riverbed. Rivers in mountainous areas that have a large slope, produce a faster flow. On a gentle slope, it produces slow velocity even close to zero. Flow velocity also depends on the volume of water, where if the volume of water gets bigger, the flow velocity will increase.

A number of researchers have developed various analytical procedures and theories to predict sediment load, but the implementation of most existing theories is only suitable for certain types of rivers. From various tests on sediment measurement data through laboratory experiments and data measurements on the river by various researchers, there are limitations in the application of existing theories. It is planned to validate the conversion functions using additional data from further sediment seasons [2]. This study aims to evaluate the best method of estimating sediment transport rates from a number of existing sediment transport methods for river conditions in Indonesia.

2. Method

2.1 Sediment Load Estimation Methods

Nowadays, there are many methods of estimation of sediment transport which includes basic sediment transport, suspended sediment transport and sediment transport in total. Based on the basic concept formulation, existing theories can be classified according to the basis of the critical shear stress or flow; statistics and probability; energy exchange; and other concepts.

Bed-Load	Suspended-Load	Total-Load
DuBoys ⁽¹⁾	Chang-Simon-Richardsons ⁽¹⁾	Einstein ⁽²⁾
Shield ⁽¹⁾	Einstein ⁽²⁾	Toffaleti ⁽²⁾
Schoklitsch ⁽¹⁾	Brooks ⁽²⁾	Shen-Hung ⁽²⁾
Meyer-Peter ⁽¹⁾	Lane-Kalinske ⁽⁵⁾	Colby ⁽²⁾
Meyer-Peter-Muller ⁽¹⁾	Leo van Rijn ⁽⁵⁾	Bagnold ⁽³⁾
Einstein ⁽²⁾		Engelund-Hansen ⁽³⁾
Vanoni-Brooks ⁽²⁾		Yang ⁽³⁾
Rottner ⁽⁴⁾		Karim-Kennedy ⁽⁴⁾
Leo van Rijn ⁽⁵⁾		Ackers-White ⁽⁴⁾
		Laursen ⁽⁵⁾
		Leo van Rijn ⁽⁵⁾

Figure 1. The classification of sedimen load method.

(1) based on the concept of critical shear stress.

- (2) based on the statistical-probabilistic concept.
- (3) based on the concept of energy exchange.
- (4) based on the concept of dimension analysis and regression.
- (5) others.

From the literature review it is explained that in general methods based on the concept of energy exchange are more accurate, reliable and simpler than other approaches [3]. Fig.1 shows the classification method for sediment transport calculation based on the type of load and the basic concept of the estimation formulation. To simplify the calculation, the procedure and the calculation process is programmed into Microsoft Excel, so as to save time in the estimation process. Table 1 describes the formula and parameter data requirements used for each calculation method.

Table 1. Parameter of total sediment load formulation.

No	Methods	Formulation	ν	ρ_w	γ_w	W	D	V	S	d_{50}	SG	ω	T
1.	Van Rijn	$q_b = C_b u_b \delta_b$ atau $q_b = 0.053 T^{2.1} \frac{[g(s-1)]^{0.5} d_{50}^{1.5}}{d_*^{0.3}}$ $q_s = F V D C_a \rightarrow F = \frac{\left[\left(\frac{a}{D} \right)^{Z'} - \left(\frac{a}{D} \right)^{1.2} \right]}{\left[\left(1 - \frac{a}{D} \right)^{Z'} (1.2 - Z') \right]}$	✓		✓	✓		✓		✓	✓		
2.	Einstein	$q_{bw} = \sum i_{BW} q_{bw} = i_{bw} \phi_s \rho_s g d_i^{3/2} (s-1)^{1/2}$ $q_t = \sum (i_{BW} q_{bw})_i (P_{\varepsilon} I_1 + I_2 + 1)_i$ $P_{\varepsilon} = 2.3 \log \frac{30.2R}{\Delta}$	✓	✓	✓	✓	✓	✓	✓		✓		
3.	Toffaleti	$q_t = \sum q_{Bi} + \sum q_{SLi} + \sum q_{smi} + \sum q_{sui}$ $q_{Bi} = M_i (2d_i)^{(\eta_3)_i}$ $q_{SLi} = M_i \frac{(D/11.24)^{(\eta_3)_i} - (2d_i)^{(\eta_3)_i}}{(\eta_3)_i}$ $q_{smi} = M_i \frac{(D/11.24)^{0.244Z_i} [(D/2.5)^{(\eta_2)_i} - (D/11.24)^{(\eta_2)_i}]}{(\eta_2)_i}$ $q_{sui} = M_i \frac{(D/11.24)^{0.244Z_i} (D/2.5)^{0.5Z_i} [D^{(\eta_1)_i} - (D/2.5)^{(\eta_1)_i}]}{(\eta_1)_i}$	✓	✓	✓		✓	✓	✓		✓	✓	✓
4.	Karim-Kennedy	$\log \left\{ \frac{q_s}{[g \Delta d_{50}^3]^{0.5}} \right\} = -2.279 + 2.972 \log \left\{ \frac{V}{[g \Delta d_{50}^3]^{0.5}} \right\}$ $+ 1.06 \log \left\{ \frac{V}{[g \Delta d_{50}^3]^{0.5}} \right\} \log \left\{ \frac{(u_* - u_{*c})}{[g \Delta d_{50}^3]^{0.5}} \right\}$ $+ 0.299 \log \left\{ \frac{D}{d_{50}} \right\} \log \left\{ \frac{(u_* - u_{*c})}{[g \Delta d_{50}^3]^{0.5}} \right\}$	✓	✓	✓	✓	✓	✓	✓	✓	✓		
5.	Yang	$\Delta = 1.65$ $\log C_i = 5.435 - 0.286 \log \frac{\omega d_{50}}{\nu} - 0.457 \log \frac{u_*}{\omega}$ $+ \left(1.799 - 0.409 \log \frac{\omega d_{50}}{\nu} - 0.314 \log \frac{u_*}{\omega} \right) \log \left(\frac{V \cdot S}{\omega} - \frac{V_{cr} \cdot S}{\omega} \right)$ $q_t = \gamma_w D V (C_s \times 10^{-6})$	✓		✓	✓	✓	✓	✓	✓		✓	

No	Methods	Formulation	ν	ρ_w	γ_w	W	D	V	S	d_{50}	SG	ω	T
6.	Ackers-White	$C_t = \left[\frac{G_{gr} d_{50} \left(\frac{\gamma_s}{\gamma} \right)}{D \left(\frac{u_*}{V} \right)^n} \right] \cdot 10^6 \quad \rightarrow \quad G_{gr} = C \left(\frac{F_{gr}}{A_1} - 1 \right)^{m^{1-n}}$ $\rightarrow F_{gr} = \frac{u_*^n}{\left[\left(g d_{50} \left(\frac{\gamma_s}{\gamma} - 1 \right) \right) \right]^{1/2}} \left[\frac{V}{\sqrt{32} \log \left(\frac{\alpha D}{d_{50}} \right)} \right]$ $q_t = \gamma_w D V (C_s \times 10^{-6})$	✓		✓	✓	✓	✓	✓	✓			
7.	Engelund - Hansen	$q_t = 0.05 \gamma_s V^2 \left[\frac{d_{50}}{g(\gamma_s / \gamma - 1)} \right]^{1/2} \left[\frac{\tau_0}{(\gamma_s - \gamma) d_{50}} \right]^{3/2}$			✓	✓	✓	✓	✓	✓			
8.	Shen-Hung	$\log C_t = -107404.45938 + 324214.74734Y - 326309.58909Y^2 + 109503.87233Y^3$ $\rightarrow Y = \left(\frac{VS^{0.57}}{\omega^{0.32}} \right)^{0.007502}$ $q_t = \gamma_w D V (C_t \times 10^{-6})$			✓	✓	✓	✓	✓	✓		✓	
9.	Colby	$q_t = [1 + (k_1 \cdot k_2 - 1) 0.01 k_3] q_{ti}$			✓	✓	✓	✓	✓	✓			✓
10.	Bagnold	$q_t = \frac{\gamma}{(\gamma_s - \gamma)} \tau V \left(\frac{e_b}{\tan \alpha} + 0.01 \frac{V}{\omega} \right)$	✓		✓	✓	✓	✓	✓	✓		✓	
11.	Laursen	$q_t = C_t q \rightarrow C_t = 0.01 \gamma \left(\frac{d_{50}}{D} \right)^{7/6} \left(\frac{\tau'}{\tau_c} - 1 \right) f \left(\frac{u_*}{\omega_i} \right)$	✓	✓	✓	✓	✓	✓	✓	✓		✓	

Where :

Discharge (Q_w)	discharge of cubic meters per second, q = unit discharge [(m ³ / s) / m]
Wide (W)	width of river (m), measured from the width of the upper part of the river
Slope (S)	slope of the riverbed
d_{50}	average particle size of the base material in millimeters
Gradation	of basic particle size geometric deviations
Specific Gravity	Specific gravity basic particles
Concentration (C)	concentration of the load of basic material (not including wash load), in units of ppm by mass
Temperature (T)	temperature data in degrees Celsius

Ideally many factors (parameters) can be included for the formulation of the sediment transport rate calculation. There is a very significant effect and there is also a small influence. Accurate calculation of sediment transport rates depends on a combination of various complex factors including; depth, width, density, energy gradient, temperature, viscosity and turbulence of flowing water, size, shape, density, compactness and concentration of sediment particles and wide variations in longitudinal and lateral directions on river bodies. Real time measurements of suspended sediment concentration (SSC) and particle size distribution (PSD) measurements are very important for the investigation and management of fine sediment related processes in surface water systems and hydraulic schemes [2].

The factors that influence sedimentation in a watershed, include the amount and intensity of rainfall, geological formation and soil type, land use, topography, upstream erosion, sediment characteristics and river hydraulic characteristics. In the alluvial river, the flow erodes the material of the wall and bottom of the channel so that the flow is filled by sedimentary grains that are directly proportional to the amount of flow energy that can transport it [4]. The movement of sediment particles in the flow can be by rolling, sliding / hopping and floating. The load of bed transport material comes from the channel material itself

which consists of bed load and from suspended loads and determined by the basic conditions of the flow [5].

Almost all streams in the field are turbulent [6]. Contrary to this fact, almost all methods of sediment calculation are derived through the assumption of uniform, steady flow and other simpler conditions. This simplification assumption can be considered as a source of inaccuracy in predicting the sediment discharge [7].

Almost all researchers concentrate on calculating the transport capacity of riverbed materials. This means that the formula is developed with the assumption that the base material layer being reviewed always flows and the flow can bring as much sediment as it can get. Furthermore, the researchers can only calculate the components of basic material content and do not consider washload. To get the total sediment transport rate, washload should be analyzed separately and added to the basic material load of [8].

Sediment load can be predicted using several existing methods. From the results of the application and analysis of various types of rivers and compare them with the results of field measurements or experiments, it can be concluded that a method that initially gives good results that approach the measurement results for a particular area does not give same result for other river conditions [9 - 14].

Some researchers have developed the equation for transporting sediment loads. The sediment transport equation has derived based on the concept of energy [8]. Testing on a limited scope between the results of the prediction of sediment load and the results of measurements or experiments provide comparative results that are relatively good. There are various sediment transport theories, it is recommended to choose one that shows better consistency with sediment flow and conditions and available data [8].

Several computer programs such as SWAT, SOBEK-RE, HEC-RAS and StratSedOC has been used to compare the results of quantitative calculations and qualitative sediment transport rate [14 - 16]. However, because there are several parameters that cannot be entered directly into the program, there is a difference in the final result. Calculation of the sediment transport rate of the basic material for a single fraction size based on the concept of transport capacity fraction (TCF) and compared the results with the measurement results has been developed [17]. The results of the study deduced that the calculation of the transport rate for a single fraction size showed a small difference between the results of the calculation and the measurement results until the size of the fraction approached d_{50} . A mathematical model can be used to simulate the movement of water and sediment [18]. Regarding the results of the study, the peak of the water level will increase as the excess sediment increases.

The application of artificial neural network methods can also be used to calculate sediment load [19]. Based on the study it can be concluded that the backpropagation neural network (BPNN) model can be used in estimating sediment load in rivers. The BPNN model results are quite satisfactory. Better outcome will be obtained by increasing the number of hidden layers and calculation variation parameters found in the MATLAB model. This model estimates about 61% to 64% data accuracy for 2 to 8 hidden layers. This is a model advantage for use in predicting sediments for rivers with different hydraulic and sedimentary characteristics. The weakness of this model is that it cannot distinguish between valid and invalid data.

2.2 Methodology

The methodology of this research is to analyze and compare several methods of estimating the total sediment load that are most suitable for the Cimanuk tributary data set. The research phase carried out in this study can be described as follows:

- 1) Selection of methods based on the criteria of the basic concept of formulation to get the best method. Further testing of a number of secondary data sets. The method of estimating the total sediment load analyzed are the Van Rijn, Einstein, Toffaleti, Karim-Kennedy, Shen-Hung, Engelund-Hansen, Yang, Ackers-White, Colby, Bagnold and Laursen methods.
- 2) Based on the analysis of the results of the calculation there are probably 3 types:
 - a. The method is not suitable where the comparison of estimation results with measurement data (discrepancy ratio (r) is worth between 0 to 0.1 or discrepancy ratio (r) of more than 100).

- b. The method that results is close enough to the measurement results with the comparison of estimation results with measurement data between 0.1 to 100. This method is then analyzed and reliability is improved by estimation by regression or optimization so that there is a part of the formulation modified. This modified formulation is tried again with the same data until the results can be considered quite accurate.
- c. The method is appropriate and the results are accurate

To predict sediment transport rates in a river segment, knowledge of the nature and characteristics of the river is needed through basic sediment sampling using special nets, a sample of sediment using a USDH 48 sediment sampling tool and a sample of basic materials using the Ekman Grab tool. The sampling of these samples coincides with the measurement time of speed (V) and water temperature (T). These samples then go through a laboratory inspection process, where from the basic sediment sample measured the weight of the basic sediment particles in units of kg / s / m 'and from the floating sediment is known the concentration of elevated sediment (C) in units of mg / liter. The basic material sample will go through a sieve test and the percentage of average diameter (d_{50}) and gradation value, specific gravity (SG) particle sediment examination.

The data used in this study are primary data for the Cimanuk tributaries: the Cikamiri and Cibuah Rivers for 3 years ie. 2012, 2013 and 2014. Data recapitulation of the Cibuah River and Cikamiri River can be seen in Table 2. From the results of the PUSAIR laboratory Bandung, it is obtained data on concentration of basic sediment load and suspend sediment and properties data. Furthermore, obtained instantaneous discharge and flow velocity data as well as measurement data including transverse profile and profile measurement data extending each river segment where river water samples were taken for study.

The measurement of elevated sediment discharge is carried out by measuring the river water discharge and taking samples of suspend sediments simultaneously. Sediment debit at measuring time or (volume of suspend sediment per unit time (Q_s) can be calculated by the formula.

$$Q_s = k \cdot C \cdot Q_w \quad (1)$$

Table 2. Data recapitulation on Cibuah and Cikamiri River

No	Data Code	Discharge (Q)	Width (B)	Depth (h)	Slope (S)	D35	D50	D65	Gradation	Specific Gravity (GS)	Concentration	TEMP.
		[m ³ /s]	[m]	[m]	[dimensionless]	[mm]	[mm]	[mm]			[ppm]	[°C]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		
1	Cibuah-06-2010-2	0.156	2	0.11	0.0008	0.31931869	0.38371	0.48762	1.61384377	2.65	14088.33867	23
2	Cibuah-03-2012-1	0.21312	2	0.36	0.0008	0.28391397	0.45604	1.6473	6.92102057	2.795953	60.755692	23
3	Cibuah-03-2012-2	0.0984	2	0.24	0.0008	0.28641302	0.34834	0.45205	1.67489526	2.776078	61.57837756	23
4	Cibuah-03-2012-3	0.0544	2	0.16	0.0008	0.28717549	0.35237	0.46466	1.72228764	2.770978	313.6360809	23
5	Cibuah-06-2012-1	0.248976	1.9	0.36	0.00268908	0.57862425	0.98401	7.10837	15.1074337	2.658408	59.22514587	23
6	Cibuah-06-2012-2	0.12312	1.9	0.36	0.00268908	0.31282625	0.39446	0.54821	1.88350821	2.724226	99.4824836	23
7	Cibuah-06-2012-3	0.08075	1.9	0.25	0.00268908	0.25758314	0.41305	1.47161	6.80904282	2.752676	70.6428853	23
8	Cibuah-07-2012-1	0.04551	1.85	0.3	0.00409483	0.33230132	0.4256	0.61104	1.98761671	2.714453	42.22471806	23
9	Cibuah-07-2012-2	0.2116215	1.85	0.41	0.00409483	0.34767724	0.55081	1.78877	6.09444391	2.686973	54.25576024	23
10	Cibuah-07-2012-3	0.127687	1.85	0.34	0.00409483	0.30132295	0.38815	0.56429	2.02857326	2.759285	36.30609981	23
11	Cibuah-11-2012-1	0.1291983	1.75	0.22	0.00163551	0.27976292	0.44566	1.50741	6.40022225	2.6832	135.6522307	23
12	Cibuah-11-2012-2	0.129371025	1.75	0.21	0.00163551	0.2045754	0.26242	0.37803	1.99859406	2.5935	106.5358567	23
13	Cibuah-11-2012-3	0.06114465	1.75	0.18	0.00163551	0.02269531	0.0399	0.80319	44.3587449	2.3241	112.7440599	23
14	Cibuah-12-2012-1	0.161975	1.9	0.25	0.0019469	0.732895	1.16681	3.92938	6.36662201	2.744165	522.0285548	23
15	Cibuah-12-2012-2	0.201628	1.9	0.28	0.0019469	0.31623694	0.39628	0.54391	1.84442708	2.698685	1112.880566	23
16	Cibuah-12-2012-3	0.174496	1.9	0.28	0.0019469	0.15790112	0.87902	6.12754	14.5339365	2.755518	2416.223184	23
17	Cibuah-02-2013-1	0.27432	1.8	0.3	0.00052419	0.38990553	0.48084	0.64	1.75027163	2.587132	88.80092753	23
18	Cibuah-02-2013-2	0.16344	1.8	0.2	0.00052419	0.41477287	0.69343	3.81941	11.2182148	2.525795	58.94401203	23
19	Cibuah-02-2013-3	0.042624	1.8	0.08	0.00052419	0.47611309	0.77804	3.28568	8.30554958	2.667045	54.25576024	23
20	Cibuah-03-2013-1	0.21645	1.5	0.39	0.00032	0.14856531	0.25003	1.51619	12.4782481	2.651626	33.74883043	23
21	Cibuah-03-2013-2	0.14268	1.5	0.29	0.00032	4.70853132	7.92501	48.1108	12.4936989	2.737715	34.47276043	23
22	Cibuah-03-2013-3	0.0684	1.5	0.2	0.00032	15.4014038	26.9153	406.198	32.9411196	2.734761	36.30368857	23
23	Cibuah-04-2013-1	0.385664	1.6	0.46	0.00262136	0.57999738	0.9506	4.13708	8.59798594	2.713182	1043.144887	23
24	Cibuah-04-2013-2	0.26368	1.6	0.4	0.00262136	0.32224229	0.54075	3.13997	11.8950682	2.704603	1014.231236	23
25	Cibuah-04-2013-3	0.10912	1.6	0.2	0.00262136	6.9389656	11.8304	89.7185	15.9230869	2.743495	1160.337751	23
26	Cibuah-02-2014-1	0.02226	1.5	0.14	0.00255556	0.25912292	0.31333	0.4025	1.64509392	2.8365	35.93484419	23
27	Cibuah-02-2014-2	0.15555	1.5	0.34	0.00255556	0.43747477	0.5188	0.64495	1.55114444	3.0638	40.72273824	23
28	Cibuah-02-2014-3	0.04572	1.5	0.12	0.00255556	0.40463537	0.49317	0.64246	1.68614109	2.9854	22.29376494	23
29	Cibuah-04-2014-1	0.13545	1.75	0.36	0.00092742	0.40808497	0.66222	2.61488	7.68366119	2.875	30.03092997	23
30	Cibuah-04-2014-2	0.38892	1.75	0.48	0.00092742	0.52070758	0.82035	2.56175	5.81156097	2.8159	37.03287843	23
31	Cibuah-04-2014-3	0.1911	1.75	0.28	0.00092742	0.69900961	1.06662	3.57559	6.05710961	2.8613	26.90960919	23
32	Cibuah-08-2014-1	0.016065	1.75	0.2	0.00110577	0.29859999	0.4121	0.71417	2.66150181	2.764762	30.77761161	23
33	Cibuah-08-2014-2	0.10316075	1.75	0.46	0.00110577	0.37265002	0.47424	0.67172	1.94387873	2.895226	70.61466792	23
34	Cibuah-08-2014-3	0.471057125	1.75	0.55	0.00110577	0.44831216	0.56105	0.76808	1.83641008	2.935278	21.35640054	23
35	Cibuah-10-2014-1	0.144144	1.8	0.22	0.00091304	0.59526225	0.91201	2.40071	4.69993922	2.7108	31.76515707	23
36	Cibuah-10-2014-2	0.148608	1.8	0.24	0.00091304	0.31544253	0.45499	0.9128	3.28073323	2.6675	39.44140055	23
37	Cibuah-10-2014-3	0.02052	1.8	0.15	0.00091304	0.27236236	0.37154	0.62263	2.53187005	2.6775	46.47684507	23
38	Cikamiri-06-2010-2	1.889	8	0.41	0.0005	0.40258823	5.14044	12.5767	4.27901255	2.65	40.14707024	23
39	Cikamiri-06-2010-3	1.889	8	0.61	0.0005	0.6665841	0.85507	1.23176	1.99856906	2.65	50.37480712	23
40	Cikamiri-03-2012-1	2.31336	8.4	0.68	0.0005	0.59186546	0.87902	1.98547	3.8531111	2.746305	52.92604758	23
41	Cikamiri-03-2012-2	2.744616	8.4	0.62	0.0005	0.6592401	0.97499	2.16228	3.7602186	2.765709	52.80913536	23
42	Cikamiri-03-2012-3	1.570464	8.4	0.57	0.0005	0.30758916	0.38107	0.51159	1.77637571	2.716344	51.2103907	23
43	Cikamiri-06-2012-1	1.6903152	8.18	0.84	0.0005	1.68006936	2.51768	5.92395	4.06667398	2.645347	44.40166956	23
44	Cikamiri-06-2012-2	1.3016016	8.18	0.68	0.0005	0.35683955	0.47643	0.75388	2.32001274	2.646963	46.2853706	23
45	Cikamiri-06-2012-3	0.5066692	8.18	0.38	0.0005	0.15087826	0.1977	0.29877	2.15886308	2.613527	248.3968015	23
46	Cikamiri-07-2012-1	0.304381	7.37	0.7	0.00031915	0.20167203	0.28184	0.50749	2.81477759	2.41413	25.17440474	23
47	Cikamiri-07-2012-2	0.194568	7.37	0.8	0.00031915	1.42746817	2.1677	5.44352	4.42536711	2.45214	17.8576768	23
48	Cikamiri-07-2012-3	0.2805759	7.37	0.27	0.00031915	0.21274935	0.26546	0.36131	1.81844935	2.659778	16.18104383	23
49	Cikamiri-11-2012-1	0.27846	3	0.26	0.00175676	0.49330585	0.80538	3.36967	8.21698206	2.627321	39.22592445	23
50	Cikamiri-11-2012-2	0.14274	3	0.26	0.00175676	0.22818046	0.37757	1.82571	9.69353485	2.673652	110.4888426	23
51	Cikamiri-11-2012-3	0.05208	3	0.04	0.00175676	6.45192218	10.8393	63.9969	12.1161134	2.692953	58.61176881	23
52	Cikamiri-12-2012-1	0.84069041	7.1	1.18	0.00073171	2.92877256	5.06991	55.171	23.3993376	2.746918	877.3461973	23
53	Cikamiri-12-2012-2	0.37351041	7.1	0.82	0.00073171	0.21067086	0.27353	0.40472	2.08714315	2.741882	10275.22746	23
54	Cikamiri-12-2012-3	0.10651704	7.1	0.38	0.00073171	0.04611268	0.07413	0.26966	6.97849014	2.719457	1227.928501	23
55	Cikamiri-02-2013-1	5.3312	8	0.7	0.00230263	8.51721006	10.3992	13.5901	1.69551629	2.746825	351.5940227	23
56	Cikamiri-02-2013-2	4.6464	8	0.6	0.00230263	1.01858439	1.48936	3.14982	3.52705805	2.75173	303.2904844	23
57	Cikamiri-02-2013-3	3.4776	8	0.7	0.00230263	63.8612518	72.277	83.7102	1.35855592	2.73708	248.1721091	23
58	Cikamiri-03-2013-1	4.8920976	8.06	0.72	0.00429293	0.37476395	0.45604	0.59239	1.67772765	2.7202	551.292129	23
59	Cikamiri-03-2013-2	4.9249824	8.06	0.76	0.00429293	0.38022841	0.46238	0.59993	1.67427185	2.71	503.9215192	23
60	Cikamiri-03-2013-3	3.4354944	8.06	0.64	0.00429293	0.43463169	0.57544	0.89161	2.24540394	2.7378	539.8580609	23
61	Cikamiri-04-2013-1	3.587172	8.2	0.69	0.00316832	0.83842785	1.24451	2.80409	3.84048661	2.712165	71.5603373	23
62	Cikamiri-04-2013-2	3.743546	8.2	0.71	0.00316832	0.50671563	0.60534	0.76171	1.58553226	2.695051	65.0388711	23
63	Cikamiri-04-2013-3	2.35094	8.2	0.61	0.00316832	0.25545578	0.31623	0.4239	1.77180321	2.686585	61.12813187	23
64	Cikamiri-02-2014-1	1.7472	8	0.78	0.00064516	0.52408062	0.78343	1.82234	4.00584051	2.820972	39.99601905	23
65	Cikamiri-02-2014-2	1.144	8	0.5	0.00064516	12.3335824	20.0447	80.2782	7.81123051	2.893384	52.35489527	23
66	Cikamiri-02-2014-3	0.936	8	0.5	0.00064516	0.47292381	0.80353	5.70831	14.8359137	2.876428	39.037692	23
67	Cikamiri-04-2014-1	5.66595	8.1	0.5	0.0005	3.72049701	5.5335	12.5785	3.88581691	2.796921	564.754828	23
68	Cikamiri-04-2014-2	4.867128	8.1	0.58	0.0005	2.39190197	3.43558	6.78692	3.21109068	2.666763	593.0293304	23
69	Cikamiri-04-2014-3	5.90733	8.1	0.78	0.0005	0.77826998	1.12202	2.24696	3.27257203	2.65131	654.8691091	23
70	Cikamiri-08-2014-1	1.0572807	7.9	0.42	0.00095506	6.62653151	9.01571	14.9987	2.50419941	2.742461	602.6361169	23
71	Cikamiri-08-2014-2	1.16369528	7.9	0.44	0.00095506	1.62878938	2.69153	12.8117	9.52266285	2.713319	367.6978955	23
72	Cikamiri-08-2014-3	0.828315	7.9	0.5	0.00095506	0.48828432	0.82985	5.92479	14.9163875	2.739339	142.8038677	23
73	Cikamiri-10-2014-1	0.438741	6.15	0.3	0.00281215	0.21483824	0.36644	2.80159	16.0630716	2.7098	40.1095181	23
74	Cikamiri-10-2014-2	0.644028	6.15									

3. Results and Discussion

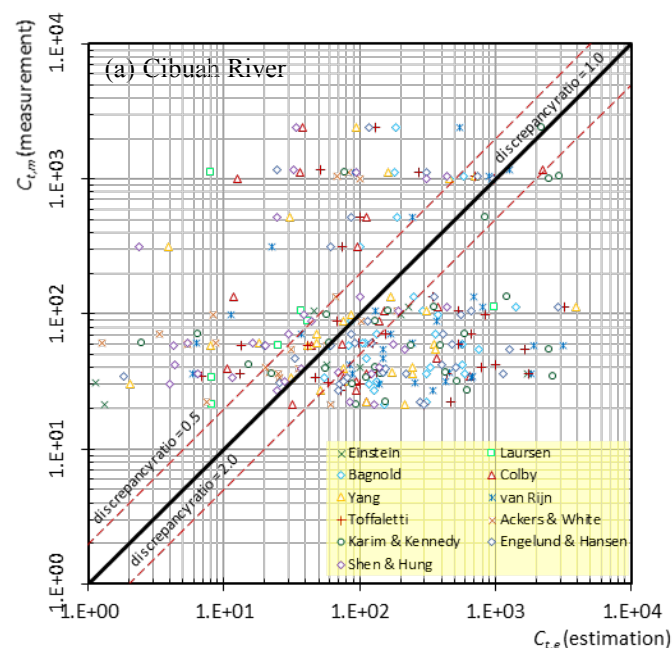
The application of the total sediment transport estimation method using the data from the Cibuah River and Cikamiri River has not provided satisfactory results. The highest percentage of data included in the range of $0.5 < r < 2$ discrepancy ratio is the van Rijn method and the Yang method which is 28% respectively. Next in a row are the Bagnold method, the Engelund-Hunsen method and the Karim-Kennedy method and the Toffaletti method. In more detail the recapitulation of the results of the analysis of the fulfillment of the discrepancy ratio of $0.5 < r < 2$ can be seen in Table 3.

Table 3. Discrepancy ratio (r) from sediment load calculation for Cibuah and Cikamiri River.

No.	Recap	Discrepancy ratio $r = q_{sc} / q_{sm}$, rerata, standar deviasi dan persentase nilai r diantara range 0.5 - 2 (score)										
		van Rijn	Einstein	Toffaletti	Karim &	Yang	Ackers & White	Engelund &	Shen &	Colby	Bagnold	Laursen
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Computed	75	75	75	75	54	75	75	75	75	75	75
2	(0.5 - 2.0)	21	1	18	18	15	14	19	10	13	20	2
3	Average	6.10	3.22	331.51	36.30	3.74	1.E+04	5.13	1.51	0.90	3.48	0.19
4	Stdev	11.62	15.08	2398.65	216.90	5.87	9.E+04	9.06	2.76	2.49	4.10	1.00
5	Score	28%	1%	24%	24%	28%	19%	25%	13%	17%	27%	3%

Figure. 2 (a) and (b) below present a comparison of the comparison of total sediment concentration data between the measurement data and the estimation results using the selected method 11 for the Cibuah River and Cikamiri River. From the figure (a) and (b) it can be seen that the data points are spread out beyond the range of the discrepancy ratio of $0.5 < r < 2$.

With consideration in addition to the eleven methods that have not been calibrated, these data also contain an error procedures during sampling and processing in the laboratory. The results of the calculation of the critical shear stress of the Shield show a lot of data that does not meet the requirements of the magnitude. The most data incompatibility lies in the data of the average diameter of sediment particles, d_{50} and gradation values. Methods that require fulfillment of shear stress conditions is the Karim-Kennedy method which only fulfill 18% of the data.



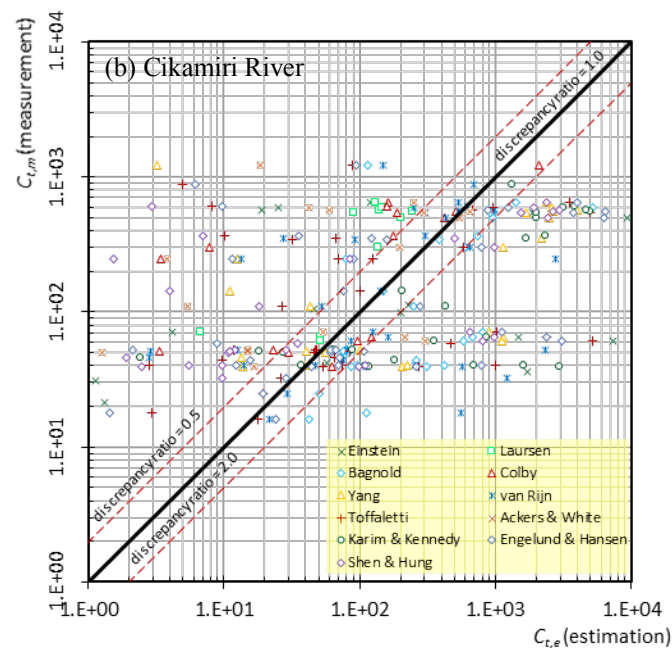


Figure 2. Comparison of total sediment concentration between measurement data and estimation results using the selected method 11 for (a) Cibuah River; (b) Cikamiri River

There are several reasons that cause inaccuracies in the estimation results of sediment loads, including the phenomena associated with quite complex sediment discharge. Sediment transport rates involve a number of flow types and parameters, including; depth, width, density, energy gradient, temperature, viscosity, and turbulence, as well as the size, shape, density, compactness and concentration of moving particles. Conversely, almost all sediment calculation methods and formulas are derived through the assumption that uniform flow conditions, steady flow and other conditions are simpler.

Accordingly, other thing that affects the calculation of the estimated sediment load is due to inaccuracies and limited amounts of available data. Data inaccuracy can be caused by the limitations of measuring devices and a large enough spatial and temporal variation of the concentration and rate of sediment transport. The limited number and site selection data collection in the field that do not represent the entire river locations.

Weaknesses of several existing procedures, such as Einstein's bed load function [20], and Samaga's method [21, 22] are less simple and often use various correction factors that must be read from a series of tables and graphics. The procedure not only makes calculations complicated and is not suitable for engineering applications, it can also result in loss of accuracy at each stage of the calculation.

4. Conclusions

Based on the analysis, some conclusions could be drawn as follows:

1. The method range of discrepancy ratio (r) ($0.5 \leq r \leq 2.0$) method can be used to compare the accuracy of various sediment load calculation methods.
2. The best method for calculating the total sediment load is the Van Rijn method, the Yang method, the Bagnold method, the Engelund-Hunsen method, the Karim-Kennedy method and the Toffaletti method which is close to 30% fulfilling the discrepancy ratio (r) ($0.5 \leq r \leq 2.0$).
3. Although all calculations of the sediment transport method have been carried out carefully, there has not been a single formulation that is generally applicable to all existing sediment data. There is still a gap that proves that not all sediment transport methods include an applicable modified version of a particular river case, even though it has been developed through an empirical approach to laboratory and field data.

4. The most sensitive parameters of the estimation method sequentially are sediment particle size (d_{50}), base channel slope (S), sediment particle falling speed (jatuh) and flow velocity (V).

The characteristics of rivers in Indonesia are very different when compared to rivers where the theory of estimation of sediment load is developed. Therefore, it is necessary to study and modify several equations to be developed into suitable methods for rivers in Indonesia.

Selecting a suitable method for estimating sediment load, beside based on the data, should also pay attention to the basic concept of deriving the formulation. The first step that can be done is to study carefully the information related to the location of the study including:

1. Information about the characteristic of river and the type of river flow
2. Climatic and geographical conditions of the study location
3. Range, type, variation and completeness of secondary data that can be collected
4. Parameters that can be generated from data
5. previous studies related to additional secondary information that can be obtained to compare with existing data

Knowing the strengths, weaknesses and limitations of the method chosen serves as a guide to developing more accurate procedures and modifying existing theories. In this case it is necessary to conduct a critical study of the selected calculation methods. For each method will be analyzed based on the concepts used, techniques, and calculation procedures used.

Considering Indonesia is still in dire need of studies on estimating transport of sediment loads because the impact of sedimentation is quite alarming. The disadvantages encountered in this study are the limitations of the data, especially those related to river sedimentation. For this reason, a large series of sediment data is needed with a good level of validity, so the guidelines procedures are needed regarding the measurement of hydraulic parameters and sediment sampling including the processing of the data in the laboratory. Related to this, it is time for the government through competent agencies as well as the private sector and educational institutions to pay attention and financial support.

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