Character Physical Variable Flow Distribution of Sediment Transport Impact Dry Season Upstream of Lake Sub Das Noongan Tondano

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Abstract: The objectives of the present paper are: to describe the flow velocity model map at the estuary of Noongan southern upper sub watersheds, Lake Tondano and to describe the map of sediment transport spreading model of Noongan southern upper sub watershed. The research methodology describes that the analysis of physical variable of estuarine flow of Noongan sub watersheds has met the steady, non-turbulent and homogenous assumptions, thereby the flow path at the measurement position and flow velocity data are subjected to four measurement segments according to the width of estuary and at the depth positions of \( v_{0.8h} \) and \( v_{0.2h} \) during dry season. The character of flow velocity along the estuary until the mouth of the lake towards the outlet shows the spread of material transport in the form of bed load and suspended load. Meanwhile, the suspended load in the form of wash load will spread on the mouth of the lake towards the lake outlet. The intensity of mass flow containing wash load spreads on the mouth of the lake until the outlet. The spreading analysis of sediment transport in the form of bed load and suspended load at the river estuary of Noongan watersheds at the mouth position towards the lake outlet does not occur. And it means the loading of material transport also does not happen. The position of transport and deposition of wash load will be pushed by flow momentum of the mass density of water carried by Noongan River flow towards the outlet of Lake Tondano. The shifting of suspension load spreading in the form of wash load is mainly controlled by the flow velocity physical variable and mass flow density containing bed load, suspended load and wash load. The shifting patterns of sediment transport and estuary bed erosion will occur during prolonged dry season or in the changes of season, from dry season into rainy season.

Key words: Character speed transport stream sediment deposition

INTRODUCTION

Lake Tondano is a natural reservoir storing water and the surrounding sediments which is located on Tondano upper watersheds. Bathimetry Map 1995 shows the silting process Lake Tondano occurred in the southern and northern regions. The southern region comes down to Noongan River and Panasen River which are the permanent southern rivers supplying water periodically. The maps of slope and land use show that Lake Tondano with its several tributaries are located at Noongan and Panasen sub watersheds with an area approximately of 3,234 ha and 5,402 ha, that is 25% of the whole Tondano upper watershed. These data suggest that Noongan and Panasen sub watersheds are areas supplying the largest sediments or contributing the largest silting to Lake Tondano [1].

The measurement result by Soeparto [2] suggests the lake covers an area of 4,472 ha with varying depths in particular spots. The southern region is in form of much shallower rice fields, i.e. from the lakeside until the depth of 20 meters reaching out from 2 to 2.5 km, whilst on the western and eastern regions at the equal depth only reaching out from 0.5 to 1 km. The southern upper sub watersheds of Lake Tondano show the areas having the highest level of erosion. As shown by the map of land use, areas having high level of erosion are found in rice fields, coconut and cloves plantations of upstream areas of Noongan River, [1,3]

The vast benefits of Lake Tondano with increasingly concerned condition and is not capable of functioning optimally creates extremely serious impacts. Such condition requires an integrated management. The results from several research conducted predict that the locations
feared to store huge potential of silting are yet supported by data, for instance, the sediment transport contribution towards the silting of the lake is not analyzed by the flow velocity pattern of Noongan estuaries. The sediment transport on the silting of the lake is thereby essential to be analyzed in order to find out the spreading and depositional patterns, whilst the flow velocity of Noongan estuaries become highly crucial to be analyzed for determining the spread/deposition of sediment transport in Lake Tondano, especially in the southern upstream areas of the estuary.

The focus of the research in general is to describe; firstly, to analyze the character of flow velocity of Noongan upper sub watershed; secondly, how the spreading process of sediment transport of Noongan upper sub watersheds is; thirdly, to provide an description of sediment transport deposition model as an impact of changes in a flow velocity variable of Noongan upper sub watersheds, Lake Tondano. The objectives of the present paper are: to describe the flow velocity model map at the estuary of Noongan southern upper sub watersheds, Lake Tondano and to describe the map of sediment transport spreading model of Noongan southern upper sub watershed. The results are expected to be significant in the decision making (decision support systems). The management of Lake Tondano utilization is for the purpose of estuary natural resources and environmental conservation and to be beneficial to the investigation of siltation and sediment transport deposition of southern upstream of Lake Tondano.

**Theoretical Background:** Steady flow is the flow in which each particle of fluid passing through the same point will have the same velocity. At some other points, fluid particles may have different velocity from that of fluid particles passing through the first point. Such condition can be achieved at low flow rates or calmly flowing water. Steady, non-whirling and non-compressed or homogenous assumption is commonly used for the field research related to the fluid movement.

In reality, the variable of river flow velocity is highly complex. We do not have a perfect solution other than some approaches to meet the steady property, for instance, the fluid flow characteristics as mentioned above. The approaches in question include using step analysis in such by limiting time interval, where changes in velocity are assumed extremely small. Further, an analysis can be applied for steady-state [4-7].

The topography and the variety of riverbed’s surface roughness, river banks’ straightness and surface roughness are the factors significantly influencing the flow properties, including the flow velocity. Meanwhile the velocity components in the horizontal direction may vary due to the factors above, nonetheless, based on laboratory studies, the variation in the vertical direction (in accordance with the depth or height above the riverbed) indicates that the critical threshold velocity required to drive (transport) the particles on the riverbed are expressed in an empirical equation, for example, \( v = 0.152 d^{0.9} (G - 1)^{0.2} \), where \( v \) is the critical threshold speed \((m.s^{-1})\); \( d \) is the diameter of particles \((mm)\) and \( G \) is the specific gravity between particles \((mm.s^{-2})\), [8]. By obtaining the data \( D \) and \( G \), the transporting/erosion of the riverbed can be predicted once the measurement of flow velocity when approaching the riverbed has been performed.

Sediment transport (bed material transport and wash load) can be defined as the mass density of the flow indicating the concentration of sediments being transported in a cross section. The overall material transported by water stream is called total sediment load. The total sediment load includes bed load, suspended load and wash load, [4, 6, 9, 10]. The wash load comprises of fine particles and colloids resulted from land surface erosion on the upstream region. Such load precipitates extremely slowly in calm water. The load quantity is very small compared to the bed material load, thus in momentum calculation and flow momentum modification, the effect is insignificant. A basic and simple definition of momentum is the multiplication of mass and velocity. The general notation used for momentum \((kg.ms^{-1})\), for mass \((kg)\) and for speed \((ms^{-1})\). The mathematical relation is \( p = m.v \). The basic formulation can be developed to more complex formulation, depending on the velocity vector function [11].

The speed shift of sedimentation transport equals to the water flow velocity. Bartnik, Madesyski and Michalik [12], B. Chen and K. Wang [13], L. L. Brothers, D.F. Belknap, J.T. Kelley and C.D. Janzen [14], who conducted field measurements in a number of rivers conclude that transport material consisting of bed load, suspended load and the wash load which are deemed as the results of soil erosion, in which a partial of material transports are the products of sand grains abrasion on the river is mainly determined by the processes occurring in the catchment area. A typical relationship of the velocity distribution,
Fig. 1: River Estuary of Noongan subwatersheds

sediment concentration and sediment transport, according to depth variation are capable of showing lower flow velocity at the riverbed, whilst for the sediment concentration getting denser downward the riverbed, such material movement occurs due to collision and bounces between the material transports.

The transportation by river is the transport of rock particles that have been eroded, whether by traction, rolling, sliding suspended matter or dissolve matter. This process does not stand alone. The material appears as bed material load in a certain places might be suspended loads at some other places [9, 15, 16]. The progressively accumulated sediment being transported, whether at the riverbed, floodplains or water body where the river is suspended highly depends on the sediment discharge and the extent to which the sediment velocity carried away by river flow. Therefore, sedimentation occurs as a result of river gradient or small surface slope and small river flow discharge. Thus the force to load is no longer able to transport the sediment transports. [6, 15, 10].

Methodology: The flow velocity is measured using a digital current meter. The position of velocity measurement according to depth is done at two points, i.e. at the layer close to the surface of the riverbed, $v_{0.3h}$ and $v_{0.2h}$, the depth of the riverbed. The method commonly used is dividing the cross-sectional into area segments where each segment is assumed to have met the flow requirements. Bogen [16] and Kumajas [7], Tendean [18] state that the number of measurement segments at the cross-sectional direction to ensure the flow requirements can be set by observing the flow condition at the research site and basic measurements, such as depth and slope. Segments with homogenous flow conditions, equal depth and slope are determined as measurement segments.

The measurement on the positions $v_{0.3h}$ approaching the riverbed is conducted to determine the distribution/spread of bed load and suspended load, whilst the measurement at the depth $v_{0.2h}$ according to the depth of the river is performed to find out the distribution of wash load. The suspension sampling is done simultaneously with the measurement of velocity and river flow discharge on measurement segments. The measurement of mass flow density (mass of water samples containing sediments per sample volume) uses a suspended sampler.

The speed required to precipitate bed load particles or bed load deposition velocity will use the formula: $v = \gamma RS$, where $\gamma$ = water density of 1000 kg.m$^{-3}$, R= sliding force (Newton) and S= riverbed’s slope [8]. Another formula usable to evaluate the potential deposition of bed load is proposed by Kennedy [7, 18]: $v_{c}= 0.55 \ m \ \sqrt{\gamma^{0.64}}$ where $v_{c}$ is the critical velocity, m is the price of critical value ratio (cvr) that depends on the type of material sediment and $\gamma$ is the depth of water. The depth measurement is performed on cross sections and is intended to assess changes in the depth based on previous bathymetric map and measurement using boats and depth measuring device.

Results and Recommendations: The research methodology describes that the analysis of physical variable of estuarine flow of Noongan sub watersheds has met the steady, non-turbulent and homogenous assumptions, thereby the flow path at the measurement position and flow velocity data are subjected to four
measurement segments according to the width of estuary and at the depth positions of \( v_{0.2b} \) and \( v_{0.2h} \) during dry season.

The pattern of flow velocity along Noongan estuary and the mouth of estuary during dry season at the measurement positions \( v_{0.2b} \) and \( v_{0.2h} \) indicates the function of the flow velocity up to the mouth of the lake is at the amount 0.795 m.sec\(^{-1}\), while at the position along the river estuary, the flow velocity is thought exceeding the magnitude measured at the mouth of the lake. The magnitude of the flow velocity slightly changes at the eastern and western positions of the mouth of the lake, viz, at position of 10 meters with a range from 0139 m.sec\(^{-1}\) to 0.751 m.sec\(^{-1}\). The flow velocity drastically decreases in position of 40 meters from the mouth of the lake at the range of 0.120 m.sec\(^{-1}\) and at a position above 40 meters from the mouth of the lake, the changes in velocity at the depths \( v_{0.2b} \) and \( v_{0.2h} \) become zero. A range of estuarine flow velocity changes of Noongan sub watershed from the mouth of the lake towards the outlet decreases quadratic ally until 40 meters away from the mouth of the lake. And at the position above it, the flow velocity is zero.

The physical condition of the causes of changes in the estuarine flow velocity of Noongan sub watershed are mostly caused by the much greater lake water volume holding water flow from the river estuary, causing the flow velocity at the mouth of the lake suspended at the position of 40 meters away from the mouth of the lake to become zero, or mostly due to the calm mass layer of the lake water is greater than the volume of water carried away by the river flow. The result suggests the river flow velocity is suspended by mass layer of the lake water, then the flow velocity reduces and becomes zero. The condition of similar density type and the differences in water temperature being carried by river and lake water makes the mixing holding the river water flow velocity at the mouth of the lake decreases sharply.
Changes in flow velocity at the lake mouth of Noongan sub watershed at the position of 10 meters from eastward and westward of the lake mouth at the magnitude 0.139 m/sec$^{-1}$ and 0.751 m/sec$^{-1}$ are also mostly caused by calm mass layer of lake water that is larger than the water volume carried by river flow. And then flow velocity is suspended up to a magnitude immeasurable by current meter measuring device.

The differences in physical variable (mass flow density) leads the water mass carried away by the river push the lake water mass towards the middle of the lake, although not at a minimum critical erosion velocity condition to push the lake water which is visible in current meter. Material transport with a large water mass is carried away by the river flow having momentum (velocity and mass flow) will push lighter water mass. The character of Noongan River estuarine flow during dry season illustrate the spreading pattern of sediment transport in the estuary mouth area towards 150 meters heading to the lake outlet with the water level rise by±0.50 m. The flow rate at the mouth of the lake lies at the range of 0.0795 m.sec$^{-1}$. In the position of 30 meters from the mouth of the lake lies at the range of 0.021 m.sec$^{-1}$. The flow velocity condition in the mouth of the lake position reaching up to 20 meters towards the outlet indicates that the spread of material transport in the form of bed load and suspended load has precipitated whilst entering the mouth of the lake. Meanwhile, the suspended load in the form of wash load will spread in relatively large amount at the mouth of the lake towards the lake outlet. Mass flow density containing wash load at the mouth of the lake lies at the magnitude of 1,219 g/ L with a flow rate of 0.0795 m.sec$^{-1}$, while at position of 100 meters away from the mouth of the lake towards the mass flow density outlet in the form of wash load lies in the range of 0,648 g/ L at a zero flow velocity. The pattern of flow velocity at the mouth of the lake towards Noongan River upstream illustrates the mass flow density is nominated by bed load and suspended load up to the position of±10 meters from the mouth of the lake. Meanwhile, at the position±20 meters from the mouth of the lake towards the lake outlet, the mass flow density has been nominated by the suspended load in the form of wash load. Mass flow density nominated by the wash load at a position of 50 meters from mouth of the lake lies at the magnitude of 0,836gr/ L with zero flow velocity. Similarly, at a position 10 meters at the eastern and western mouth of the lake with flow velocity at the magnitude of 0,0751m/sec$^{-1}$ and 0.0831m.sec$^{-1}$, respectively, have a mass density of water of which largest concentration is the wash load. A small fraction contains bed load, suspended load, at the range of 1,185 g/ L and 1,165 g/ L, respectively. Positioned above 10 meters at the western and eastern areas, the concentration of mass density of the water is entirely wash load.

The analysis of the sediment transport spreading based on the flow velocity character during dry season upon estuary of Noongan watersheds illustrate that along the river estuary until the estuary mouth, huge amount of bed load and suspended load in large numbers are thought to happen. The position of the sediment transport spreading will change its position towards the lake outlet during prolonged dry season and ahead of rainy season or in the event of great flood at Noongan upper watersheds. The sediment transport in the form of
wash load will eventually spread in a relatively large amount at the mouth of the lake toward the lake outlet. The position of the suspension load in the form of wash load will move towards the outlet, whether in prolonged dry season, ahead of the rainy season, or during the rainy season shortly before the dry season comes. The spreading pattern of suspension load which is nominated by wash load at the mouth of the lake towards the outlet is mostly caused by differences in the flow physical variable, such as water mass momentum pushing the lake water mass towards the midst of the lake, although not in the minimum critical erosion velocity condition to load sediment materials of the lake flow. Such condition, i.e. the material transport containing bed load, suspended load and wash load with large water mass carried away by river flow has a flow momentum to push lighter water mass from the mouth of the lake towards the lake outlet.

The critical threshold velocity of the transport and erosion of estuary bed using Marvis equation requires the diameter measurement of particle grains of riverbed materials (d); the provision of measurement result from samples taken at points within±10 m from the mouth of the lake towards the river upstream; and the size of particles’ diameter (sand) with the smallest being 0.38mm and the largest being 0.82 mm. If the specific gravity price ranges from (G) 1.83 (mm.sec\(^{-2}\)) to 2.64 (mm.sec\(^{-2}\)) is used, thus the minimum critical erosion velocity price for particles with the size of d= 0.38mm is 0,0901 m. sec\(^{-1}\). For particles with the size of d= 0.82 mm, the minimum critical erosion velocity is 0.1268 m.sec\(^{-1}\). The flow velocity at the mouth of the lake position reaches up to±10 meters towards the lake outlet at the magnitude of 0.0795 m.sec\(^{-1}\) and 0.0789 m.sec\(^{-1}\). On the eastern and western mouth of the lake, the flow velocity is at the magnitude of 0.0752 m.sec\(^{-1}\) and 0.0759 m. sec\(^{-1}\), respectively. Therefore, in watersheds at the mouth position towards the lake outlet at the mouth of the lake position reaches up to±10 meters towards the midst of the lake, not occur. And it means the loading of sediment materials in the form of bed load and suspended load also does not occur. The flow velocity is at the range of 0.0795 m.sec\(^{-1}\). That is, only by slight increase in the flow velocity, the sediment transport deposition areas (bed load and suspended load) will shift from the mouth of the lake towards the lake outlet. The position of the loading and deposition of wash load will be pushed by the flow momentum with the mass density of water carried away by Noongan river flow towards Lake Tondano outlet. The shifting of spreading and loading of transport materials are mainly controlled by the flow velocity physical variable with the mass flow density containing bed load, suspended load and wash load.

Conclusions and Suggestions: The character of flow velocity along the estuary until the mouth of the lake towards the outlet shows the spread of material transport in the form of bed load and suspended load. Meanwhile, the suspended load in the form of wash load will spread on the mouth of the lake towards the lake outlet. The intensity of mass flow containing wash load spreads on the mouth of the lake until the outlet. The spreading analysis of sediment transport in the form of bed load and suspended load at the river estuary of Noongan watersheds at the mouth position towards the lake outlet does not occur. And it means the loading of material transport also does not happen. The position of transport and deposition of wash load will be pushed by flow momentum of the mass density of water carried by Noongan River flow towards the outlet of Lake Tondano. The shifting of suspension load spreading in the form of wash load is mainly controlled by the flow velocity physical variable and mass flow density containing bed load, suspended load and wash load. The shifting patterns of sediment transport and estuary bed erosion will occur during prolonged dry season or in the changes of season, from dry season into rainy season.
Recommendations from the results of this research are as follows: (1) In particular, sediment controlling should be conducted on the inlet of Lake Tondano, especially the deposition of material transports at Noongan watersheds during climate change, from dry season into rainy season and versa; (2) Technically, in order to control safe boundaries against precipitation by bed load and suspended load materials along the estuary in climate change, the government should build pockets of sediment container so as to prevent the deposition on the mouth of the lake towards the outlet and; (3) the results of this research should be developed by individuals or agencies, for the benefits of science, research methodology and the provision of more complete data in the interest of Lake Tondano’s inlet river estuary management. The data expansion includes measurements at different flow conditions, both at flood level and seasonal condition.

REFERENCES