Multi-Response Model of Flooding in

Tondano Estuary

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Abstract

The river is a multi-resource functions that are vital to human life. The main functions of the river is a source of drinking water, power generation, irrigation fields / farms and aquaculture, transport, supply of building materials, tourism and so forth. In fact the condition of the river, discharge and water quality is even more alarming, as these resources are non-renewable. This research will be discussed further on physical variables such as changes in velocity, density, momentum and drag force, the social impact, attitudes and behavior are good in order to flood hazard mitigation and control, and the relationship between attitudes and behavior in order to mitigate hazard and flood control. Physical variable modeling analysis results showed that the increasing flood flooding the maximum velocity of the river flow will be shifted toward the surface, so with the momentum, but the density of the river water is almost evenly on all levels of the river water, but the drag force will be larger, because the drag force depends on the velocity of the river flow.

Keywords: physical properties, Spearman correlation, the social impacts of flooding
1. Introduction

The river is a multi-resource functions that are vital to human life. The main functions of the river is a source of drinking water, power generation, irrigation fields / farms and aquaculture, transport, supply of building materials, tourism and so forth. In fact the condition of the river, discharge and water quality is even more alarming, as these resources are non-renewable. In addition to the potential and benefits of a broad and vital, rivers often become a source of harm to humans. Floods that occurred in various places besides causing huge material losses also can cause casualties Euripidou (2004).

Objectives and policies of irrigation development in the long term development of the second (PJP II) are: (1) the provision of adequate water terjuwudnya and equitable for the entire life of the community and so on, (2) the establishment of the system of water allocation is efficient, effective, and fair and so, (3) preservation of water sources maintained and improved environmental quality. Further irrigation development policy specifically focuses on four issues: (1) strengthening the irrigation infrastructure, (2) an increase in the utilization of water resources, (3) environmental damage control, (4) strengthening the institutional development of irrigation in the irrigation field PJP II in North Sulawesi include : (1) the development of management systems, (2) information systems and water control, (3) utilization of water resources, (4) protection and preservation of water resources, and (5) penganggulangan natural disasters. One strategy for achieving development goals is the development of irrigation North Sulawesi River region (PWS), in which each PWS should have a Master Plan (Master Plan) River Basin Development, which periodically needs to be fixed / improved (Anonymous, 2003).

Watershed (Watershed), which is widely known as the DAS is basically an area of land which is an integral part of the river and its tributaries, which serves to accommodate, store, and drain water from rainfall to the lake or the sea natural, which is the limit of its land and maritime boundary topographical separation. Till the water area is still affected by land-based activities. One or more watersheds and / or small islands that luasanya ≤ 2000 km2 forming a unity of natural resources management area called River Basin / River Basins (Article 1 of Law no. 7/2004).

Problem of damage settlements, inundation, erosion of river banks, preventing erosion and destruction of levees, etc., are closely related to the physical style of water flow momentum. Both of these physical quantities, the quantity will be very big at the time of the flood, both due to the increase in the rate of flow and density (density) of water masses. Theoretically, increased flooding will increase the force caused by the flow of the floating charge (suspended
load), on the other hand, the impact of increasing erosion of the river bed due to increased momentum transport streams with base material (bed load transport). Measurements will be undertaken by the Centre for Environmental Management of the Ministry of Environment (2007) in the mouth of the river Tondano, concluded that the discharge of sediment transport increased significantly more than the increase in flow in the event of flooding. This fact in addition to indicators of erosion on the upstream, can also indicate the potential for environmental damage is quite high, especially because of the increased momentum and drag force in the event of flooding. Balasch, et al.'s (1992) stated that the availability of measurement data variable have the flow and sedimentation mechanisms of sediment source to outlet, is important information for land conservation in the uplands and also the information that forms the basis for society and governance in the context of natural resource management. So the data and information flow variables results in the area of the estuary, as well as provide an overview of the processes that occur in the uplands, among others, relating to the use of agricultural land. Another problem lies arising in connection with the provision of data and information on the condition of the river is the availability of funds, equipment, methods, research teams and so forth. Besides requiring expensive equipment, observation and data processing requires funding and expertise.

From the above explanation shows that the need for a physical variable modeling the flow of river water is the water mass density, velocity, momentum, and the drag force. By knowing the physical modeling of the four variables are expected to get an idea of the vertical profile of velocity, density, and momentum flow based on water depth variations.

2. Theoretical

a. River flow Velocity

In fact, the variable of river flow velocity is very complex, as fluid flow characteristic as abovementioned. For instance, to fulfill soft characteristic, we do not get perfect solution other than just in the form of approach – approach (Hudson, 1992). The approach uses step analysis in such a way by limiting time interval in which the velocity is assumed very low and then it can apply an analysis in soft condition (Ven Te Chow, 1984). The method of flow velocity measurement consists of direct and indirect methods. The direct methods are: aravelocity method), dilution techniques, electromagnetic method, and ultrasonic method (Herschy, 1978). Indirect measurement method is based on hydrology structure and slope-area method (Subramanya, 1984, Hulsing, 1966 and Hulsing, 1967). The form, topography, and variance of river bed’s roughness, straightness and roughness of river edge, and so on., are factors influencing the characteristics of the flow, including flow velocity. Although the component of velocity in hori-
zonal direction is varied due to the factors abovementioned, but the variance in vertical direction (according to the depth or height of river bed), the velocity distribution follows the equation of $V = 5.75 \times \log \left( 30y / ks \right)$, with $v$ the velocity (cm.s$^{-1}$) in $y$ vertical distance (cm) above the river bed, $vs$ is drag velocity (cm.s$^{-1}$) and $ks$ roughness coefficient of river bed (cm$^{-1}$) (Subramanya, 1984).

b. Water mass density

Flow mass density shows sediment concentration transported through one longitudinal plane. The total materials transported by the water flow are total sediment load. The total sediment load consists of bed material load and wash load (Ven Te Chow, 1984). Bed material load consists of suspended load and bed load (Sumarto, 1987). a) wash load consists of smooth particles and colloid as the results of land surface erosion in upper course. This load settles very slow though in quiet water. The quantity of this load is very small compared to bed material load (Sumarto, 1987), so that in the momentum calculation and momentum change, the flow effect is not significant; b) suspended load is the load which does not directly touch to the river bed, but floating along the flow (for certain time) (Schwab et al., 1981; Sumarto, 1987). This suspended load drag velocity is equal to water flow velocity. Bartnik, Madeyski and Michalik (1992) conducting field measurement in the rivers in South Poland conclude that suspended material load consists of: very fine dusty soil, loam, and sand considered as the results of soil erosion. Part of suspended load is abrasion product of sand grain in the rivers but especially determined by the process occurs in catchment area. Schwab et al., 1981 state that the results of laboratory study show that critical threshold velocity needed to move particles in the bed river is stated in empiric equation of $v_t = 0.152 \times d^{4/9} (G − 1)^{1/2}$, where $v_t$ is threshold velocity (m.s$^{-1}$), $d$ is particle’s diameter (mm), and $G$ are specific gravity (mm.s$^{-2}$).

c. Flow Momentum

Basic and simple definition of momentum is multiplication of mass and velocity. General notation used is: $p$ for momentum (kg.m.s$^{-1}$), $m$ for mass (kg) and $v$ for velocity (m.s$^{-1}$). The mathematic correlation is $p = mv$ (Resnick & Halliday, 1985; Zafiratos, 1986). Momentum is a vector, the result of multiplication of mass (scalar) and velocity (vector) (Resnick & Halliday, 1985). The basic formulation can develop in the form of the more complex formulation, depending on velocity vector function.

In many senses, fluid mechanics problems are solved by implementing the principles of continuity, momentum and energy (Ven Te Chow, 1984). According to fluid characteristics, the implementation of momentum principle must certainly
consider that fluid mass can have form change, so that the momentum change approach must be applied per time unit.

d. Drag Force

In fluid dynamics, drag force (sometimes called fluid drag or fluid resistance) is the force resisting a solid object through fluid (liquid or gas). The most general form of drag force is arranged by some friction forces acting parallel with the object’s surface, plus pressure force acting toward vertical direction with the object’s surface. For solid object moving through a fluid, drag force is the component of aerodynamics of resultant force or fluid dynamics force working in line with the movement. The vertical component moving toward this direction is considered as lift force. Thus, drag force is opposed to the object’s movement. Drag force of wave lasts when a solid object moves passing through fluid or approaches sound velocity in the fluid or in the case where a fluid’s surface flow freely. For high velocity or in Reynold, the total drag force of an object is characterized by a non-dimensional number.

3. Result and Discussion

The physical properties of flooding in estuary has several response variables as velocity \((y_1)\), density \((y_2)\), momentum \((y_3)\), and drag force \((y_4)\) and each variables are correlated. These variables depend on the distance from the bottom of river \((x)\). To describe the relationship between velocity \((y_1)\), density \((y_2)\), momentum \((y_3)\), and drag force \((y_4)\) depend on the distance from the bottom of river \((x)\) is using the multi-response model develop from the Theorem:

Theorem: If given the data pairs of \((x_i, y_{1i}, y_{2i}, ..., y_{ni})\), describe the relationship between velocity \((y_1)\), density \((y_2)\), momentum \((y_3)\), and drag force \((y_4)\) depend on the distance from the bottom of river \((x)\), then the multi-response of flooding model are \((i=1,2,\ldots, n \text{ with } n = \text{number of observation})\)

\[
Y_{ni} = X_{ni}\beta_{3x4} + e_{ni}
\]

The parameter estimate of this model is \(\hat{\beta} = (X'WX)^{-1}X'WY\).

Proof: The relationship between velocity \((y_1)\), density \((y_2)\), momentum \((y_3)\), and drag force \((y_4)\) depend on the distance from the bottom of river \((x)\), then the multi-response of flooding model are \((i=1,2,\ldots, n \text{ with } n = \text{number of observation})\)
The matrix representation of this multi-response model is given:

\[ \mathbf{Y}_{\text{mod}} = \mathbf{X}_{\text{mod}} \mathbf{\beta}_{3 \times 4} + \mathbf{\epsilon}_{\text{mod}} \]

\[ \begin{bmatrix} y_{11} & y_{21} & y_{31} & y_{41} \\ y_{12} & y_{22} & y_{32} & y_{42} \\ \vdots & \vdots & \vdots & \vdots \\ y_{1n} & y_{2n} & y_{3n} & y_{4n} \end{bmatrix} = \begin{bmatrix} 1 & x_1 & x_1^2 \\ 1 & x_2 & x_2^2 \\ \vdots & \vdots & \vdots \\ 1 & x_n & x_n^2 \end{bmatrix} \begin{bmatrix} \beta_{01} & \beta_{02} & \beta_{03} & \beta_{04} \\ \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} \end{bmatrix} + \begin{bmatrix} \epsilon_{11} & \epsilon_{21} & \epsilon_{31} & \epsilon_{41} \\ \epsilon_{12} & \epsilon_{22} & \epsilon_{32} & \epsilon_{42} \\ \vdots & \vdots & \vdots & \vdots \\ \epsilon_{1n} & \epsilon_{2n} & \epsilon_{3n} & \epsilon_{4n} \end{bmatrix} \]

\[ \mathbf{\epsilon}_{\text{mod}} \] has the variance matrix \( \mathbf{W}_{\text{mod}}^{-1} \). The error associated with different responses on the same sample unit may have different variances and may be correlated. It accommodates the correlation between the responses. Actually in physical theoretical, the response variables as velocity \((y_1)\), density \((y_2)\), momentum \((y_3)\), and drag force \((y_4)\) and each variable are correlated. To obtain the estimate of parameter estimation \( \mathbf{\beta}_{3 \times 4} \) using Weighted Least Square (WLS) as follow:

\[
\begin{align*}
\text{Min} \left\{ \mathbf{\epsilon}' \mathbf{W} \mathbf{\epsilon} \right\} &= \text{Min} \left\{ \left( \mathbf{Y} - \mathbf{X} \mathbf{\beta} \right)' \mathbf{W} \left( \mathbf{Y} - \mathbf{X} \mathbf{\beta} \right) \right\} \\
&= \text{Min} \left\{ \mathbf{Y}' \mathbf{W} \mathbf{Y} - \mathbf{Y}' \mathbf{W} \mathbf{X} \mathbf{\beta} - \mathbf{\beta}' \mathbf{X}' \mathbf{W} \mathbf{Y} + \mathbf{\beta}' \mathbf{X}' \mathbf{W} \mathbf{X} \mathbf{\beta} \right\}
\end{align*}
\]

The completion of this optimization, was obtained by derivating \( \mathbf{\epsilon}' \mathbf{W} \mathbf{\epsilon} \) against \( \mathbf{\beta}_{3 \times 4} \) the the result was equated to zero, and gave the result:

\[
\frac{\partial (\mathbf{\epsilon}' \mathbf{W} \mathbf{\epsilon})}{\partial (\mathbf{\beta})} = -2 \mathbf{X}' \mathbf{W} \mathbf{Y} + 2 \mathbf{X}' \mathbf{X} \mathbf{\beta} = 0
\]

\[ \mathbf{X}' \mathbf{W} \mathbf{X} \mathbf{\beta} = \mathbf{X}' \mathbf{W} \mathbf{Y} \]

Based on the equation above, it was obtained the estimator for multi-responses of flooding model is

\[ \hat{\mathbf{\beta}} = \left( \mathbf{X}' \mathbf{W} \mathbf{X} \right)^{-1} \mathbf{X}' \mathbf{W} \mathbf{Y} \]
Application to the data as implementation of multi-response phisical properties model of flooding in estuary has several response variables as velocity ($y_1$), density ($y_2$), momentum ($y_3$), and drag force ($y_4$) and each variables are correlated. These variables depend on the distance from the bottom of river ($x$).

Figure 1. The Relationship between Velocity ($y_1$) depend on distance from the bottom ($x$)

The figure shows the model of velocity change variable kecepatan, where the measurement is done in the height of water surface of 108-112 cm. The model obtained is in the form of quadratic equation. The highest velocity is on optimum point or dy/dx=0, so that by differentiating the equation above, it is obtained $x=\frac{-1.328/2^*(-0.008)}{2} = 82$ cm with velocity $y = 57.90$ cm.s$^{-1}$. Thus, maximum velocity of flood level 1 is at the position of 82 cm calculated from the bed river.

Figure 2. The Relationship between density ($y_2$) depend on distance from the bottom ($x$)
The test results show that at point x=10 cm, it is obtained that the y density = 1.08 kg.lt-1. At point x=110 cm, the y density = 1.00 kg.lt-1. Based on the results of the equation above, it is indicated that from the distance of 10 cm of the bed river to 110 cm of the bed river, the density decreases from 1.08 kg.lt-1 to 1.00 kg.lt-1. The density of flow mass shows the concentration of sediment transported through one longitudinal plane. The total materials transported by water flow are called as total sediment load. The total sediment load consists of bed material load and wash load (Ven Te Chow, 1984; Allen, 1990). The bed material load comprises suspended load and bed load (Sumarto, 1987).

![Figure 3. The Relationship between momentum (y3) depend on distance from the bottom (x)](image)

The test results show point x=10 cm, and y momentum = 17.52 gr.cm-2.s-1. At point x=110 cm, the y momentum = 51.59 gr.cm-2.s-1. At optimum point x=-1.343/2*(-0.008) = 80 cm, the momentum y = 58.93 gr.cm-2.s-1. Based on the result of equation above, it is indicated that the biggest momentum is in the position of 0.72 multiplied by the depth, calculated from the bed river, i.e. 58.93 gr.cm-2.s-1.
Figure 4. The Relationship between drag force (y4) depend on distance from the bottom (x)

Based on the test results of the equation above, it is obtained that: at point x=10 cm, the y drag force = 844.74 Newton. At point x=110 cm, the y drag force = 2804.00 Newton. At optimum point of x=-103.8/2*(-0.631) = 82 cm, the y drag force = 3290.81 Newton. The equation indicates that the biggest drag force is in the position of 0.74 multiplied by the depth, calculated from the bed river, i.e. 3290.81 Newton.

7. Summary and Conclusion

The results of analysis show that in general, physical form such as velocity, momentum, and drag force have quadratic pattern where there is an increase along with that of the distance from the bed river, but there is a decrease in the further distance from the bed river. It is different from the physical form, i.e. density, where the condition shows the decrease of density along with the further distance from the bed river. It seems that variable of physical determines or as the signal of the flood effects, i.e. velocity, density, momentum and drag force.

Based on the comparison of data and chart of density, velocity, momentum, and drag force, it can be concluded that flood increase can improve the materials transportation through longitudinal plane of the river in the research location. The results of evaluation show that in the condition of no flood or the
flood occurs around the measurement becoming sediment area; on the other hand the increase of big flood, density spread from the bed until the surface is almost even that can cause erosion of the bed river, erosion of the river (Ven Te Chow, 1984; Allen, 1990). It occurs due to the increase of momentum and drag force. It is indicated that the bed river in the research location is labil and easy to change due to flood. The sediment materials in the bed river can be easily brought by the flow; even when the big flood occurs, there is a displacement between shallow part and deeper part pursuant to the direction of river width.

The charts of velocity and momentum show that the increase of flood causes the increases of velocity and momentum of the flow, and the layer increasing bigger is the middle layer to near the surface. It can be concluded that flood increase has more potential of causing sloping riverbank erosion than bed river erosion. Physically, it can be seen that the erosion in sloping riverbank around the location of the research is high, even when the level of flood gets higher, landslide of the riverbank and construction destruction, including sloping riverbank, barbed wire, and construction buffer etc.

The correlation between drag force and momentum (distance) and velocity stated in the equation: \( F = p.v \) gives conclusion that if there is flood increase, total drag force increases and total work line move to the surface of the river (according to curve displacement of momentum chart, velocity and drag force). In such condition, drag force momentum toward construction or an object cultivated in the river increase sharply either due to the increase of force or force work line).

5. References


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