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Constructing total suspended solid modelling on Agathis Lake by employing resource modelling associates program

R M S Prastica[*]**, H Soeryantono and D R Marthanty**

Civil Engineering Department, University of Indonesia, Jl. Margonda Raya, Pondok Cina, Beji, Depok 16424, Indonesia

E-mail: rian.mantasa@ui.ac.id

Abstract. This research uses Resource Modelling Associate (RMA) program to conduct a two-dimension model of Agathis Lake to analyse velocity and sediment transport distribution. The main programs are RMA-10 for velocity distribution and RMA-11 for the pollutant distribution. The sediment transport focuses on total suspended solids (TSS) pollutant. The research aims to construct total suspended solid model. Firstly, RMA Generation produces mesh of Agathis Lake. Next, RMA-10 and RMA-11 would perform both velocity and TSS simulation model to represent the actual condition. This research still gives temporary result due to limited sampling data. Calibration analysis of the model is needed to make the result of the program more accurate and more representative to the real condition.

1. Introduction

A phenomenon of landfilling the lake in urban cities have been discussed by Prastica [1]. The research shows that society chooses this decision due to the economic value of lakes. The society has paradigm that lakes have less opportunity to increase the prosperity of society in urban cities. According to Prastica [1], the paradigm grows in the large scale due to the decreasing of water quality of urban lakes. The most critical indicator for environment is the water quality [2, 3]. Bad water quality of lakes triggers several bad impacts that disturb people's activities. One of the worst scenarios of this problem is the death of people because of diseases that triggered by the lakes' environment. *Aedes aegypti* and *Salmonella typhosa*, which survive at lakes, are examples of triggering factors of the worst scenario.

This research is the development of the previous researches [1, 4] about developing the sediment transport modelling on urban lakes. The main pollutant that would be simulated is total suspended solid (TSS). This simulation will be done if the advection process on the lake can be run. The advection process is influenced by the velocity [4]. According to Ji [5], the mass balance of lake is affected by both advection and dispersion that accommodate by the following equation.

$$\frac{\partial C}{\partial t} = -U\frac{\partial C}{\partial x} + \frac{\partial}{\partial x}(D\frac{\partial C}{\partial x}) + S + R + Q \tag{1}$$

This process could be represented also in the following sediment transport equation [5].

$$\partial_t(HS) + \partial_x(HuS) + \partial_y(HvS) + \partial_z(w_sS) = \partial_x(HA_H\partial_xS) + \partial_y(HA_H\partial_yS) + \partial_z\left(\frac{A_v}{H}\partial_zS\right) + Q_s \tag{2}$$

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[*] To whom any correspondence should be addressed.

RMA program [6] basically uses finite element method to reach the solution [4]. Prastica [1] identified the step of the Equation 2 to be a linear matrix equation by employing the Galerkin method. RMA program has two main functions: RMA-10 for velocity distribution and RMA-11 for pollutant distribution.

This research aims to construct the velocity and TSS models by employing RMA program, so the models could represent the actual data by conducting field sampling result. The field sampling activities are proposed by Prastica.

2. Research Method
This research is the development of the previous research about developing a sediment transport model in two-dimension form at Agathis Lake that is situated in Universitas Indonesia. Models are developed by employing Resource Modelling Associate (RMA) program that could accommodate both velocity and TSS distribution on lakes. Sampling data was conducted on March 13 – 14, 2018.

3. Results and Discussion
3.1 RMA-GEN for Agathis Lake
The first step to model hydraulic and TSS constituent is constructing mesh in RMA-GEN. There are several data that are needed to complete the step. They are Agathis Lake map (Auto-CAD based), sediment trap design, and bathymetry map. After these data are completed, RMA-GEN is ready to construct. For RMA-GEN inputs, the x, y, and z coordinate maps of AutoCAD are required as base maps in the .map format. In addition, a bathymetry map is required to provide elevation for each node that will be created at the discretization stage. In the process of discretization, the Agathis Lake map is divided into several elements that have nodal. In the process of finite element method, the element is formed into a triangle. The velocity and the concentration in each node are the variables that become the review in this research.

In the process of RMA-GEN construction, nodal density is required to compute with the following equation.

$$\Delta t < \frac{\Delta x}{U} \tag{3}$$

Where t is the time step for iteration, x is the distance of two nodes, and U is the velocity of the lake. In this study, mesh density can be seen from the simulation results that the speed of water in the lake ranges from 10-2 m/s magnitude. With the calculation of the Courant number and the step type of 0.1 hours, the minimum required nodes distance is 3.6 m. In making RMA-GEN Lake Agathis existing condition, nodes distance is made of 5 m. So, the mesh setting for Lake Agathis is appropriate.
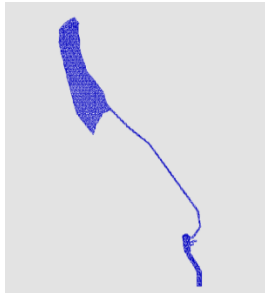
After making the discretization of Lake Agathis using RMA-GEN, the next step is to enter the basic elevation in each node. Elevations that can be read by RMA-10 and RMA-11 are relative elevations, which assume the water level elevation in the initial conditions is 0.00 m. The basic elevation for Lake Agathis is made in the minus form, signifying its position beneath the surface of the water. Contours are created and interpolated manually or automatically by RMA-GEN so that the contours make sense for water flowing from upstream to downstream. In this study, used contour and bathymetry maps in the form of secondary data that has been processed in 2017 by the University of Indonesia. Below is the result of discrimination of Lake Agathis on the existing condition. Figure 1-3 depict the construction process of RMA-GEN.

After RMA-GEN Lake Agathis is completed, next is to make ccline as an inflow and outflow of Lake Agathis. Inflow on a system made on RMA-GEN is a sediment trap inlet and outflow at RMA-GEN is an outlet of Agathis Lake. Figure 4-5 depict the inflow and outflow, respectively.
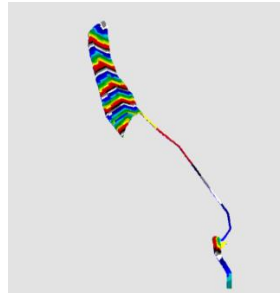
3.2 RMA-10 Construction
After RMA-GEN is completed, the next program to create is RMA-10. There are several data that are needed. They are sediment concentration at inflow, temperature at inflow, and debit at Inflow. These
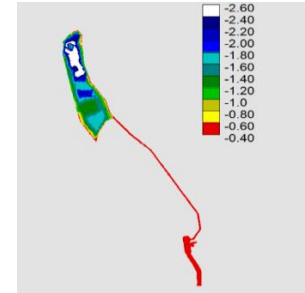
data are completed by field data sampling.

**Figure 1.** Discretization of Lake Agathis.

**Figure 2.** Ordering the Discretization of Lake Agathis.

Figure 3. Nodes with Relative Depth at Lake Agathis.

The data required for the RMA-10 program comes from the primary data. Sampling was conducted on March 13, 2018. This date is the starting date of the simulation of the RMA-10 program. Sediment concentrations in the inflow were analyzed using the Ackers and White Methods, in accordance with the methods recommended by the Guidance Manual RMA. Sediment collection is done at sediment trap inlet location as inflow system in RMA program. After the sediment samples were taken, an analysis of sediment grain distribution at the site was performed.

The temperature in the inflow is done on on-site sampling. Temperature is obtained when direct sampling using field thermometer. The temperature obtained is a range of 29° Celsius. Temperature collection in the inflow is done 5 times at different times between 09.00-09.45 a.m.
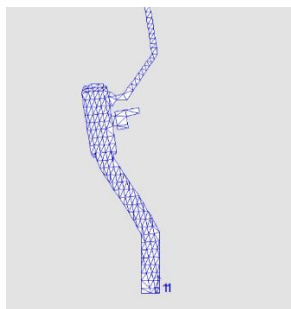

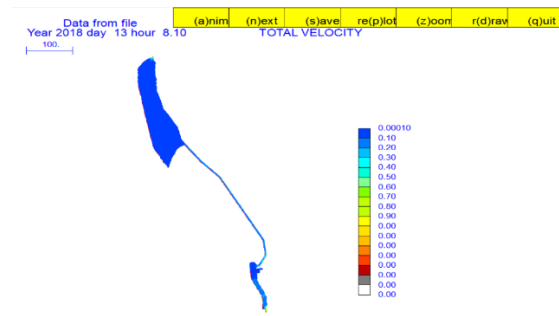**Figure 4.** Inflow of RMA-GEN for Agathis Lake at Existing Condition.
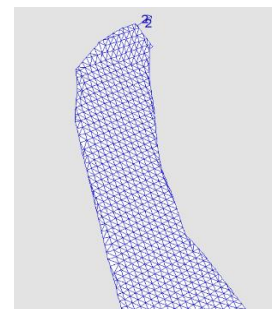
Figure 5. Outflow of RMA-GEN for Agathis Lake at Existing Condition.

The next data is the discharge data to run the RMA-10 program. The collection of debit samples is carried out using current meter and assistance from laboratory of Hydrology, Hydraulics and River Laboratory, Department of Civil Engineering Faculty of Engineering, University of Indonesia. Sampling is done at all points of the site with variations of different shipping times on the Lake Agathis system to be made in the RMA program. Figure 6 depicts an example of speed data retrieval activity in Agathis Lake water bodies. Results of field data related to water velocity at Lake Agathis will be used in the calibration step.
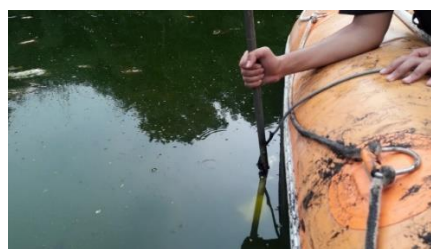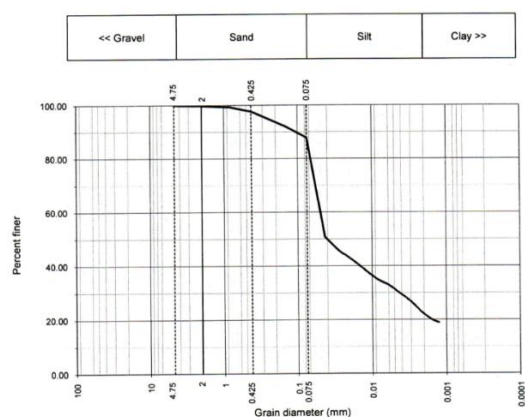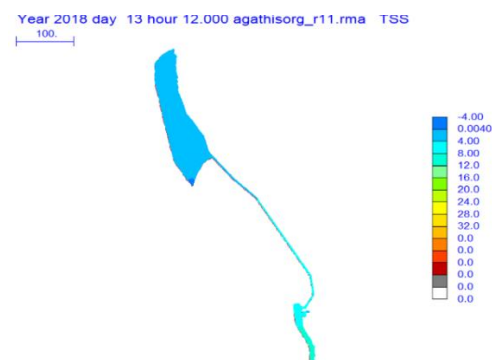
Figure 6. Velocity sampling at the water body.

The velocity distribution simulator on Agathis Lake was developed through RMA-10. Based on the required data and mesh construction results on RMA-GEN, then the result of running the existing condition of Agathis Lake using RMA-10 can be seen in Fig. 7 – 8.
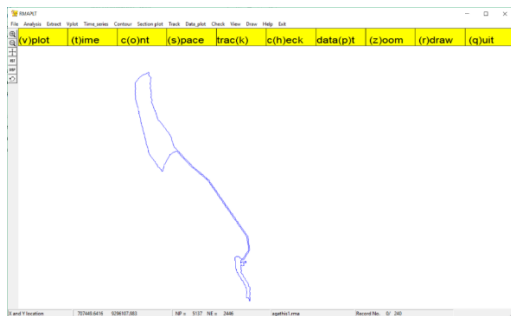
Figure 7. Initial Interface of RMA-10 Program.   **Figure 8.** Program Running Result at 8.00 a.m.

3.3 RMA-11 Generation

After RMA-GEN and RMA-10 are completed, the next program to create is RMA-11. The data that needed are temperature and settling velocity that could be found by field sampling activities. Sediment samples to be tested were taken at the site of the modelled Lake Agathis system inlet. Samples taken on March 13, 2018, at 10:00 am. Sediment collection was carried out using a sediment grabber as shown in Fig. 9.

Figure 9. Sediment Grabber.   **Figure 10.** Sediment Particle Distribution Analysis.
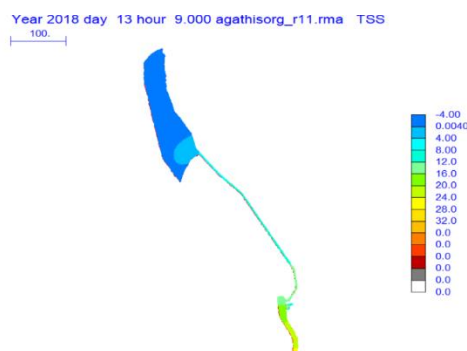
Figure 11. RMA-11 Program Running Result at   **Figure 12.** RMA-11 Program Running Result at

9.00 a.m.   12.00 a.m.

Specific gravity analysis and sediment particle size distribution were conducted at the Soil Mechanics Laboratory of Faculty of Engineering, University of Indonesia. Test performed using SNI 1965: 2008 standard. Fig. 12 shows the results of the sediment particle size distribution analysis. The specific gravity is 2.666 and 2.665 for two tested samples.

Based on Fig. 10, the composition for sand is 12%, silt is 65%, and clay is 23%. Based on soil classification of Unified Soil Classification, sediment sample has visual soil description as clayey silt. Prastica [7] processed data to obtain sediment transport concentrations through seven methods. The method that suits the field conditions in Indonesia is the Yang Method. However, based on the manual guide program of RMA, the method used there are 5 potential methods, namely Ackers and White Method, Van Rijn Method, Brownie Method, Van Rijn Method, and Van Rijn Method. The study will conduct an analysis using the Ackers and White Method. The formula used by this method is given in Eq. 4. From the results of field studies and laboratory test results, the grain number or Dgr has a value of 1.42.

$$D_{gr} = D_{50} g^{1/3} (S_{gs} - 1.0)^{1/3} v*^{-2/3} \tag{4}$$

Based on the D_{gr} number, there are conditions specified in this method. Here are the conditions required by Ackers and White to get the variables needed in the analysis. Based on the results of the analysis, then $D_{gr} > 60$. Therefore, the variable data analysis is further determined as: n = 0; A = 0.17; m = 1.5; and c = 0.025.

The next analysis is to calculate shear velocity ($u*$) using the Manning shear stress equation.

$$u* = \frac{M_n g^{0.5} v}{d^{1/6}} \tag{5}$$

Based on the results of analysis using RMA-10 program, then the number of Manning used is 0.04. While the speed of water in the inlet obtained from the results of field study activities. The amount of speed obtained is 0.47 m/s or 1.542 ft/s. Based on equation 3, the shear velocity value is 1.5 ft/s.

The next analysis is the number of sedimentary mobility that can be calculated using equation 6.

$$F_{gr} = u_*^n \left[gd \left(\frac{\gamma_s}{\gamma} - 1 \right) \right]^{-1/2} \left[\frac{v}{\sqrt{32} \log \left(\frac{\alpha D}{d} \right)} \right]^{1-n} \tag{6}$$

Where $u*$ is shear velocity, g is the acceleration of gravity, d is the diameter of the granules at 50% percent, v is the velocity in the inlet, D is the water depth of 0.2 m or 0.65617 ft, and α is 10. The mobility figure based on existing data is of 0.6367.

The final analysis of this method is to calculate the potential sediment concentration that goes into the inflow using equation 7.

$$C_{eq} = c S_{gs} \left(\frac{v}{u*} \right)^n \left(\frac{F_{gr}}{A} - 1.0 \right)^m \tag{7}$$

All parameters for calculating equation 7 are mentioned in the equations and the previous data. The amount of potential sediment concentration from the analysis of the equation is 303.22 mg/l. This data is the input to the RMA-11 program to model the distribution of TSS constituents.

The analysis of settling velocity could be derived from Equation 8.

$$V_s = \frac{g(\rho_p - \rho_w) D_{50}^2}{18\mu} \tag{8}$$

The amount of settling velocity is 0.026 m/s. This data is the input on RMA-11. This variable is used as a preliminary study of the analysis of the results of running the RMA-11 program. Based on the

results of the RMA-11 program running, the condition of TSS constituent distribution reaches steady after 5.7 hours or 20,520 seconds.

RMA-GEN and RMA-10 should be clear first before running this program. When both programs are running, then the next is the development of TSS distribution simulator on the existing condition of Lake Agathis. Fig. 11 and 12 figures the result of RMA-11 generation.

4. Conclusion and Suggestion

RMA program could accommodate the velocity and TSS distribution phenomena in Agathis Lake. This research concludes that the present model prediction of velocity and TSS distribution could not represent the actual data without conducting calibration analysis with SSE computation. This research suggests calibration analysis with more iterations to obtain the least percentage of SSE for RMA-10 and RMA-11 result.

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