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Utilization of Hydrodynamic Models for Development of the Coastal Zone in Poso Regency

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Abstract. Indonesia is an archipelago country that has an abundance of marine resources. However, lack of measurement data, including bathymetry, topography, bed roughness, current velocity along with water level have identified the challenges due to marine development as well as Poso Regency. This regency is located in the coastal area, but the local communities are still unable to develop marine resources optimally. Thus, the goal of this research is to deliver information for managers about the potential area for various developments in the vicinity research area. By making the methodology concerning hydrodynamic numerical models in the waters or coastal areas of Poso Regency, then it complies with the criteria of suitable location for tourism, fish and seaweed cultivation. It is hoped that it can produce the basis for education, information, and applications in developing coastal areas. Then, it can advance the economy of the surrounding community. This research project is still underway due to the comprehensive aspect. After carrying out the calibration and verification, the initial research demonstrates that the model meets the accuracy within the value of root mean square error of about 0.106 m. Thus, the outcomes regarding the hydrodynamic model simulation can be used as elementary data for marine development at this location, including tourism, cultivation, or development in other fields.

INTRODUCTION

Indonesia is a vast archipelago and rich in marine resources. As the world's largest archipelagic state, the ocean plays an undeniably central role in Indonesia. With a water area that is nearly four times larger than its land area, the country derives pivotal benefits from the sea for its economy, geopolitics, culture, and natural environment [1]. Having a huge region, Indonesia has the economic potential of both biological and non-biological in the maritime sector. There is a dual role in marine resources including as a natural resource that supports human survival as well as supporting aquatic ecosystems and becomes an important economic development component. The management of marine resources is a politically and culturally driven process, shaped by human livelihoods and perceptions, where notions of both space and place shape policies and decision-making in fundamental ways [2-3]. Marine resources can be accessed and developed through coastal areas. Poso Regency is one of the regencies located in the coastal area of Indonesia. However, the marine resources in it and the marine tourism potential provided by nature, have not been developed optimally. As shown in Figure 1, an example of the great potential of the marine waters in the Poso Regency. However, it has not been fully utilized. Seaweeds have been an important part in Asian cuisine more so than in western cultures [4]. Global seaweed cultivation occupies approximately 20% of the total world marine aquaculture production by weight, with an annual value of US $6.7 billion in 2013 [5-6]. Seaweed cultivation based on residents' portraits was

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only a side income. Because the local communities in general still frequently go to the forest or hills to seek natural resources as their main income.

FIGURE 1. Seaweed Cultivation in the Coastal Areas of Poso Regency

Seaweed is only a side income for the local communities and many other potential marine resources. It has not been used optimally or even not been developed by the local communities, therefore this research project chose Poso Regency as our research location. Whilst, the objective of this research is the lack of measurement data, including bathymetry, topography, bed roughness, current velocity along with water level have been identified the challenges due to marine development as well as Poso Regency. Thus, the goal of this research is to deliver information for managers about the potential area for various developments in the vicinity research area.

To determine the oceanographic conditions in the Poso Regency area, this research will be conducted by creating a hydrodynamic model using the open-source Delft3D software, including water level and sea current conditions. Then from the simulation data can become a basic reference in the future to determine the hydrodynamic condition in the coastal area of Poso Regency, such as developing tourism, agriculture, or others. Determining the location for the development of tourism and cultivation areas generally only looks at the conditions in the field at the time of the observation. These observations ignore variations in the conditions of a location that will change over time. It can be seen that in the development of aquaculture in the sea were often wrong targets. The choosing and determining the location for cultivation has weak currents, so it was not suitable for aquaculture. Therefore, by carrying out this research, it is hoped that it will bring positive impacts such as information, education, and applications for the people around Poso Regency.

STUDY LITERATURE

The hydrodynamic model is a method for estimating the dynamic movement of water. The hydrodynamic model itself can be used as a basic reference in developing an area, especially those in the sea or coast. Like the research conducted by the researcher on the sea in the southern part of the Java sea by analyzing current velocity, wave height, and tidal range. It can be converted into electrical potential energy and was carried out by making hydrodynamic models using Delft3D softwar. Delft3D is a modelling package which consists of several modules to compute amongst other the flow (FLOW), wave (WAVE) and morphology (MOR, included in FLOW) in coastal waters [7].

The implementation of the Decision Support System (DSS) for the development sustainable mariculture industry in Indonesia has been carried out for years. Initially, the DSS utilized the outcomes of hydrodynamic numerical models, including water level, sea current magnitude, wavc height, and depth information for site selection process as physical requirement. Then along with chemistry and biology requirements for another step to select the best location for further development of this culture.

Other research was also carried out by another author, using 3-dimensional hydrodynamic modeling to determine the optimal location for the placement of MCT (Marine Current Turbine) on the South Coast of Java [8]. The results of the data from the models that have been created through Delft3D software will be validated and their accuracy verified by the RMSE (The Root Mean Square Error) method. The data to be compared was the data from the modeling results using Delft3D software with data from local observation stations. Station observation data is obtained from data provided by the IHO (International Hydrographic Organization). The IHO is an intergovernmental consultative and technical organization. The IHO coordinates on a worldwide basis the setting of standards for hydrographic services in support of safety of navigation and the protection and sustainable use of the marine environment [9].

METHODOLOGY

Delft3D

A hydrodynamic model has been achieved with a 3D method to simulate a hydrodynamic module based on the Delft3D modeling system [18]. This application requires several other tools such as MATLAB and can be combined with ArcGIS. Delft3D is a multi-dimensional hydrodynamic simulation or modeling program that has a function to calculate waves, river flow, sediment, water quality, and ecological analysis in coastal areas [10].

Delft3D is a computational suite developed for a multi-disciplinary approach to nearshore wave and morphodynamic modelling. For this reason, this suite is composed of several modules which allow any user to carry out simulations of flow (Delft3D-FLOW), sediment transport (Delft3D-SED), waves (Delft3D-WAVE), water quality (Delft3D-WAQ and Delft3D-PART) and ecology (Delft3D-ECO) [11].

The finite-difference grid equation can also solve the determinant differential equations in the combination corresponding to the initial settings. To complete current and tidal modeling. The open-source Delft3D software system uses the Navier-Stokes equation in its calculations. According to Girault and Raviart Navier Stokes' formula is [12] :

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\rho x} + \frac{\partial(\rho v)}{\rho y} + \frac{\partial(\rho w)}{\rho z} = 0 \quad (1)$$

Where :
x, y, z = coordinates
ρ = density
u, v, w = velocity component

The Root Mean Square Error (RMSE)

Several techniques for quantitative evaluation of a model's behavior have been widely explored in atmospheric sciences **[13]**. The most used statistical parameter in model behavior analysis is the Root Mean Square Error (RMSE) **[14]**. Root mean square error (RMSE) is a standard statistical metric used to measure the performance produced by models in several studies such as meteorology, air quality, and climate research. In activities in geoscience, many researchers use the RMSE method as a standard metric to assess how much error a model is made of. So it can be said that RMSE is a measurement method that measures the difference in value between a model's predicted data compared to the original data resulting from an observation. Therefore, through the RMSE method, the resulting hydrodynamic model can be estimated the error rate through the RMSE formula :

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(\mathrm{Predicted}_i - \mathrm{Actual}_i)^2}{N}} \quad (2)$$

Where :
Predicted = Value of Simulation Prediction Data
Actual = Value of Observation Data
N = Total Data Used

Models created with open-source Delft3D require the input of 2 primary data. As can be seen in Figure 2, the Land Boundary (.LDB) and Bathymetry (.xyz) are inputted into the Delft3D software. Then in Delft3D, some data needs to be entered, namely tidal component data and 10-year wind data. All data that has been entered into the Delft3D application, then determines the specified simulation time in a certain time according to the time to be simulated and run by trial and error method. A stable simulation model is formed and can be used as an interpretation of the original conditions of the seawater changes in a certain period in Poso District. The stable model results will be reanalyzed and compared with the original conditions that occurred in the waters of Poso Regency using the RMSE method. The

RMSE method is carried out by comparing the stable water level data simulated with the data at the station owned by IHO. If the RMSE value is close to 0,1 it can be said that the model that has been created can be used as an interpretation of the original conditions of the coastal area of Poso Regency.

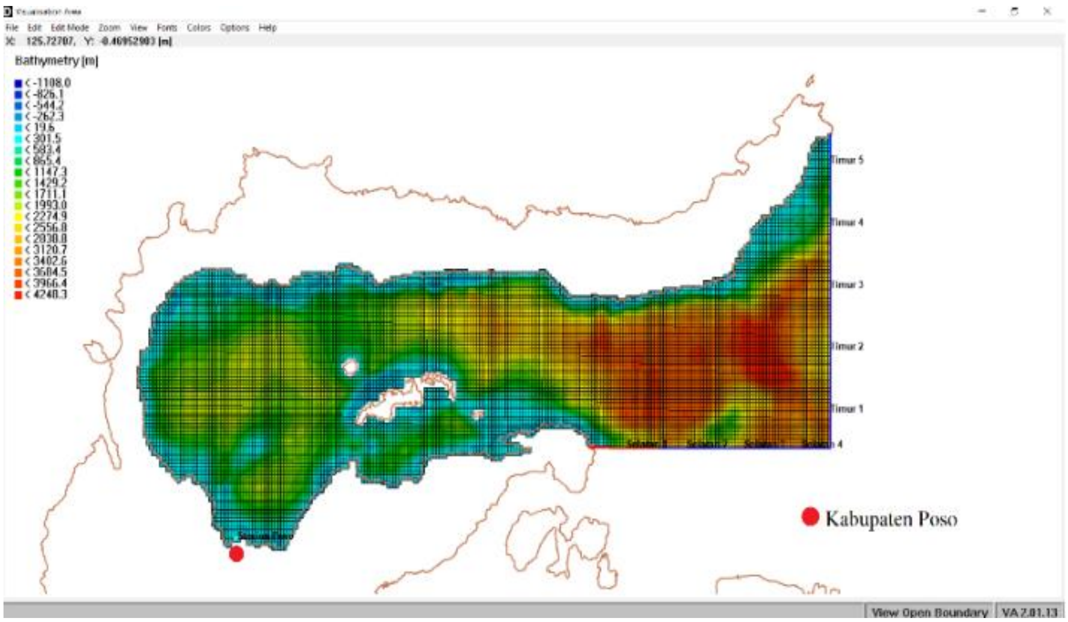

FIGURE 2. Visualization of the Water Depth Conditions

RESULT AND DISCUSSION

Simulation data were carried out for two weeks, starting on February 14, 2021, to February 28, 2021. During the initial step, the simulation carries out about 50 simulations. Then, as can be seen in Table 1, the best of 4 simulation model experiments are presented. Thus, model D is simulated with a grid size of 2,400 meters, a time step of 5 minutes, manning roughness of 0.05, a smoothing time of 30 minutes to provide the best result. The outcomes demonstrate that the simulation of the hydrodynamic model of the waters of the Poso Regency is stable for interpreting the area's hydrodynamics within a specific time.

TABLE 1. Results of Simulation

RESULTS OF SIMULATION						
MODEL	**Grid Size (m)**	**Time Step (Min)**	**Manning Roughness**	**Smoothing Time (Min)**	**Duration (Days)**	**RMSE**
A	2400	30	0.025	30	14	0.174
B	2400	10	0.05	10	14	0.153
C	2400	10	0.05	30	14	0.129
D	2400	5	0.05	30	14	0.106

As can be seen in Figure 3, the simulation results demonstrate that the seawater level reaches 0.6 m high along with a low water level of 0.4 m. Comparing with the measured data from the stations in Poso which is obtained from the International Hydrographic Organization (IHO) can be seen in Figure 4. It shows that the characteristic of the seawater level is fit with simulation data.

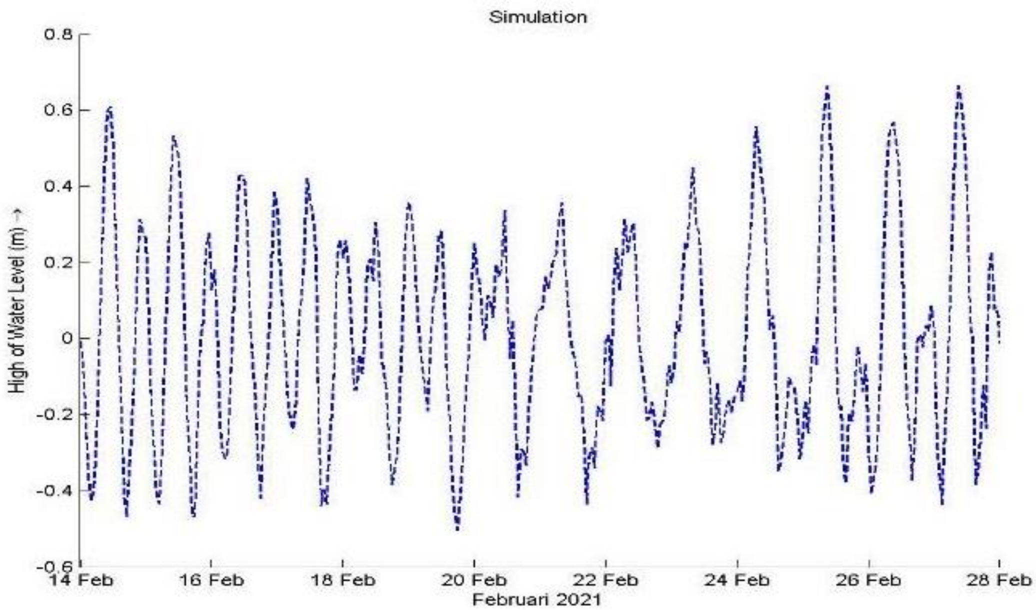

FIGURE 3. Simulated Water Level Data

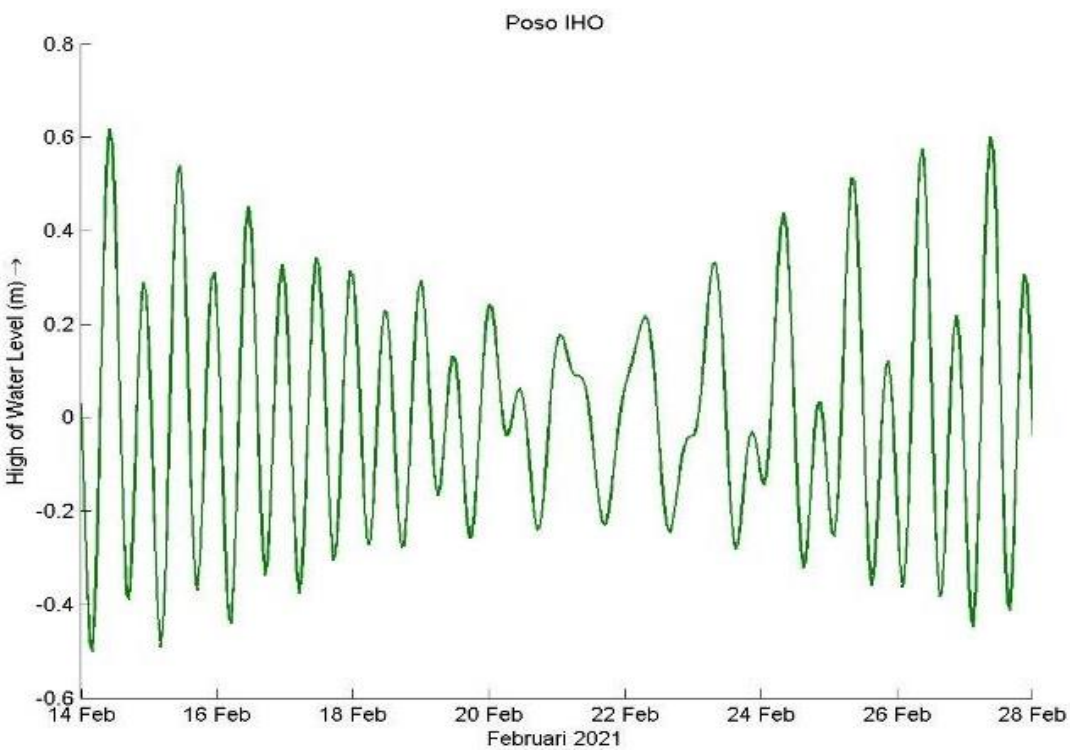

FIGURE 4. Station Water Level Data

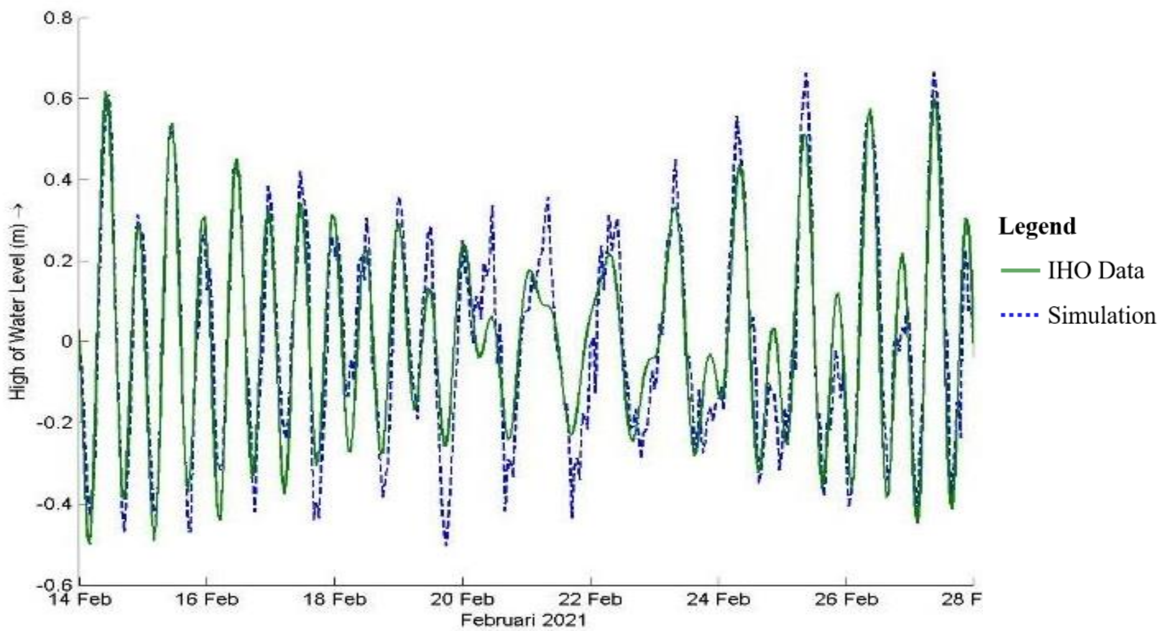

FIGURE 5. Validation of Simulation Results and Poso Station Water Level

To carry out the validation and verification results data, then the second graph in Figure 3 and Figure 4 are aligned into one (see Figure 5). The data from the two graphs are processed for reports and validated by the RMSE method. Then the result of the RMSE number is 0.106 which indicates that the model created can predict the data quite well. It can be used as a reference in determining the location for further development of marine resources including cultivation and tourism.

This finding meets the agreement with previous research which described that the RMSE value obtained is ± 0.1, reflecting the good performance of the model in predicting data accurately [13-14]. This finding also fits with another author who described at geoscience, a lot of researchers utilizing RMSE as a standard for assessing model simulation. In Indonesia, the utilization of hydrodynamic numerical models within the RMSE method for various purposes is made to increase human welfare along with environmental protection.

CONCLUSIONS

The simulation of the hydrodynamic model that has been made has a good RMSE value, which is equal to 0.106 because it is close to ± 0.1. The simulation can be used as a basic reference in estimating hydrodynamic conditions for the development of the coastal area of the Poso Regency including tourism, cultivation, and even other fields that can be useful in increasing economic progress for residents around the coastal area of Poso Regency. The recommendation for further research is to make a site selection in the decision support system for determining the suitable development areas in marine coastal water at Poso Regency.

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