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Utilization of the Hydrodynamic Model to Determine the Movement Characteristics of Marine Debris in Karimata Islands Compare to Data Collection from Citizen Science Research

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Abstract. Indonesia is an archipelagic country that has a large population. This high population has increased the amount of waste produced every year. Kalimantan is one of the regions in Indonesia that has a small population. However, large amounts of waste were found in the area around the coast of the Karimata Islands. This research goal is to figure out the source of the waste along with the characteristics of the sea current in the vicinity area of the research location. The methodology is carried out in 2 ways, including collecting primary data with the support of citizen science research within the transect method and a hydrodynamic numerical model. This research is on undergoing project, then the initial outcomes prove that hydrodynamic numerical modeling can be used as a tool to determine the source of marine debris and most of the marine debris stranded on Buluh Kecil Island and Genting Island at Karimata Islands. The characteristic marine debris movement is dominated by the north direction sea current, including waste from Vietnam, Malaysia, and Thailand.

INTRODUCTION

Entering the 4th industrial era, there are many problems faced by countries in the world, one of them is the waste problem. The increase in the volume of waste is related to rapid population growth. Marine debris, from both land-based and sea-based sources, has tangible and wide-reaching impacts, affecting marine areas all over the world [1]. Marine debris is aesthetically detrimental, a hazard to commercial shipping and fishing vessels, can facilitate the transport of organic and inorganic contaminants and is harmful to marine organisms and potentially also humans [2, 3]. Plastic debris is unsightly; it damages fisheries and tourism, kills and injuries a wide range of marine life, has the capacity to transport potentially harmful chemicals and invasive species and can represent a threat to human health [4]. In Indonesia, the Ministry of Environment and Forestry admits that in 2020 the total national waste production has reached 67.8 million tons. This means that around 185,753 tons of waste are produced by 270 million people every

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day or it can be said each resident produces about 0.68 kilograms of waste per day. Indonesia turns out to be a country with the world's second-largest marine plastic debris production after China. There are about 275 million tons of plastic debris produced from 192 coastal countries studied, and among this plastic debris, about 4.8 - 12.7 million tons enter the ocean [5].

Indonesia is an archipelagic country along with most of its territory is water, for centuries known as a maritime country. In this way, the maritime and marine sector becomes crucial in every aspect of Indonesia. Even so, those sectors have not received enough attention. One of the things that have received less attention is marine debris. Director of ASEAN Cooperation, Ministry of Foreign Affairs of Indonesia, Jose Tavares (2017) said that every year at least 12.7 million metric tons of plastic waste are produced on land. It is dumped into the ocean around the world. The amount of plastic waste originating from land is dumped into the sea reaches 80 percent of the total waste in the ocean [5].

Marine debris can also come from other countries carried away by sea current. As stated by the Greeneration Foundation (2021), most likely the waste did not come from the coastal area. It could be that debris came from countries across the ocean and had already been tossed around in the ocean for some time before finally being carried away by the waves and stranded on the beach. Citizen Science research was conducted in the Karimata Islands. Karimata Islands have a population of about 3273 people. The Citizen Science research was initiated by Balai Konservasi Sumber Daya Alam Kalimantan Barat (BKSDA Kalimantan Barat) along with the research team from Tanjungpura University (Untan). Then, this activity was followed by the Betok Jaya village community who are members of the Betok Jaya DESKAR research community group. Data shows that marine debris washed up on beaches in the Karimata Islands is dominated by plastic bottles that might come from other countries around Indonesia.

STUDY LITERATURE

Marine debris

According to Government Regulation No. 83 (Appendix Section) concerning the Handling of Marine Waste, marine debris is waste originating from land, water bodies, and coastal areas flowing into the sea or waste originating from activities at sea. While plastic waste is waste that contains polymer compounds. This plastic waste has become the largest component of marine debris. Marine debris is found in all marine habitats, from densely populated areas to remote locations untouched by humans.

Marine debris includes any form of manufactured or processed material discarded, disposed of or abandoned in the marine environment. It consists of items made or used by humans that enter the sea, whether deliberately or unintentionally, including transport of these materials to the ocean by rivers, drainage, sewage system or by wind [6].

Hydrodynamic model using Delft3D

In the past various kinds of numerical models were used in water research. Hydrodynamic models in 2D form were first used in the Zulawy region, Poland. The use of 2D models is quite useful and accurate in estimating water levels [7]. At this time hydrodynamic models can be created using the 3D method to simulate hydrodynamic modules based on the Delft3D modeling system [8].

Delft3D is an open-source software developed by Deltares. In its use, this application requires several other tools such as MATLAB and can be combined with ArcGIS: ArcMap and Global Mapper. According to Hafli, Delft3D is a multidimensional hydrodynamic modeling program that has functions to calculate waves, river flows, sediments, water quality, and ecological analysis in coastal areas.

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) [9].

Delft3D-FLOW

Delft3D-FLOW is a part of Delft3D which is used to determine the Shallow Water Equation (SWE) which can be presented in two or three dimensions depending on the model made [16]. Then the variable is projected on a line that has two directions (horizontal and vertical) or what is commonly called a grid. The determinant differential equation in combinations that match the initial settings can also be solved by the finite-difference grid equation to complete the modeling of currents and tides. The hydrodynamic and wave modules (Delft3D-FLOW and Delft3D-WAVE) may perform uncoupled simulations (offline) or interact with each other, coupled (online). The online feature may be characterized as a two-way exchange of data, in which the Delft3D-WAVE module recalculates wave conditions using hydrodynamic data from the Delft3D-FLOW module and the new wave field can hence be used as an input for the Delft3D-FLOW module [10]. The open-source Delft3D software system uses the Navier-Stokes equation in its calculations. According to Girault and Raviart the Navier Stokes equation is [11]:

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

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

The Root Mean Square Error (RMSE)

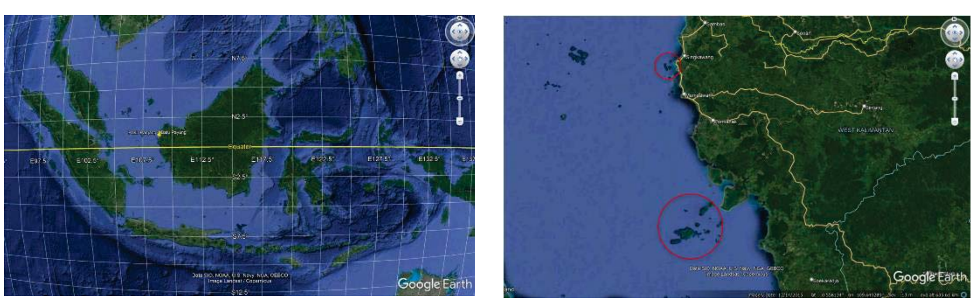
Several techniques for quantitative evaluation of a model's behaviour have been widely explored in atmospheric sciences [12]. The most used statistical parameter in model behavior analysis is the Root Mean Square Error (RMSE) [13]. The Root Mean Square Error (RMSE) is a method used as a standard statistical metric to measure the performance generated by models in several studies such as meteorology, air quality, and climate research. In geoscience activities, researchers use the RMSE method as a standard metric to assess how much error occurs in a model [14]. The validation or verification phase of a model is needed to check the model results. At this stage validation sources from secondary data will be used. Where the closer to 0 the prediction results will be more accurate. The RMSE value can be calculated by the following equation.

$$RMSE = \sqrt{\frac{\Sigma(X-Y)^2}{n}} \quad (2)$$

Where:
X = prediction value
Y = actual value
n = amount of data

METHODOLOGY

Considering that this research was conducted during the COVID-19 pandemic, every research activity related to model making was carried out online. This research begins by determining and preparing every observation point along the coast of West Kalimantan. An overview of the research site is shown in Figure 1 and for more detailed information, see Table 1.



(a) (b)

FIGURE 1. Research Site Location

TABLE 1. Observation Points Coordinates

No	Observation Points	Coordinate	
		Longitude	**Latitude**
1	Pasir Panjang	108.868774	0.709872
2	Genting Island	108.755278	-1.588333

Aside from using secondary data in the process of making hydrodynamic models, this research also uses other supporting primary field data sourced from public research activities which are also known as Citizen Science (CS) at Karimata Marine Reserve. As can be seen in Figure 2, this public research, monitoring, and data collection of marine debris washed up on beaches in Karimata Islands has been carried out. The result of the Citizen Science research is in the form of data on the amount, weight, and country origin based on the writing on the label of waste. This Citizen Science research uses the transect method to calculate the amount of marine debris scattered in coastal areas. This method is carried out by taking samples of waste that are found in the transect area. The transect was divided into 5 sections within the size of 5 x 5 m square. Furthermore, the waste was taken from 5 plots, with a plot size of 1 x 1 m in each square.

(a) (b)

FIGURE 2. Marine Debris at Buluh Kecil Island and Genting Island

Simulations in this research were carried out using the help of the Delft3D program. The research continued by collecting all supporting data in the process of making hydrodynamic models which will be called input data. These input data are land boundary files (.ldb) that were created manually with the help of Google Earth Pro, ArcGIS: ArcMap, and Global Mapper software; bathymetric data from General Bathymetric Chart of the Oceans (GEBCO), and other supporting data. After all, data has been collected, then proceed with processing all of the data collected so it can be used in the making of the hydrodynamic models.

After getting all the data, the research continued by creating a hydrodynamic model using Delft3D and Delft Dashboard software, inputting all the supporting model parameters such as land boundary files, grid files, bathymetry data, manning roughness, constituent harmonics, and wind data. The hydrodynamic model simulation was carried out and then the model was validated by taking data from Online Tide Prediction and comparing it with the simulation results, the Root Mean Square Error (RMSE) methods. The making of this hydrodynamic is trial and error to find the closest results to the actual conditions. From several trials and errors that were tested, finally found a model that was close to the simulation in the field [24]. If the verification of elevation and ocean current in a particular observed spot is accurate, then the model can represent the actual condition of Karimata Islands waters. Afterward, the result can be visualized using the Delft3D-QUICKPLOT module.

The area of observation of this research is bordered by the Java Sea, South China Sea, Sumatra Island, and Java Island. In this research, the simulation began on July 9th and ended on 18th July 2020. The time interval is 60 minutes, for more detailed information in Table 2.

TABLE 2. Simulation Parameter Setting

Parameter	Data
Grid number	214 x 192
Range for x-axis	5000 m
Range for y-axis	5000 m
Simulation time	9 days
Simulation start time	09 July 2020 (00.00)
Simulation end time	18 July 2020 (23.00)
Simulation time interval	60 minutes

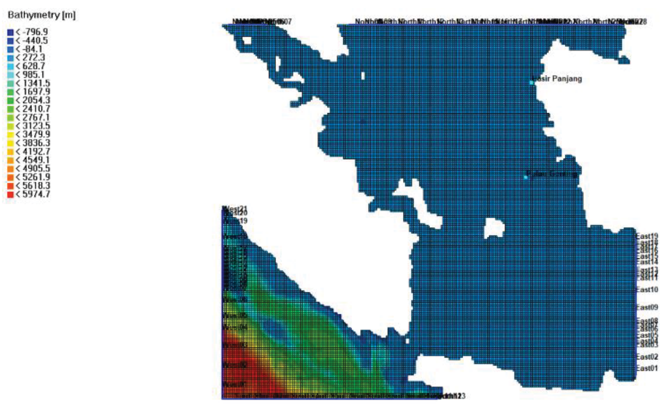


FIGURE 3. Visualization Area of Modeled Area

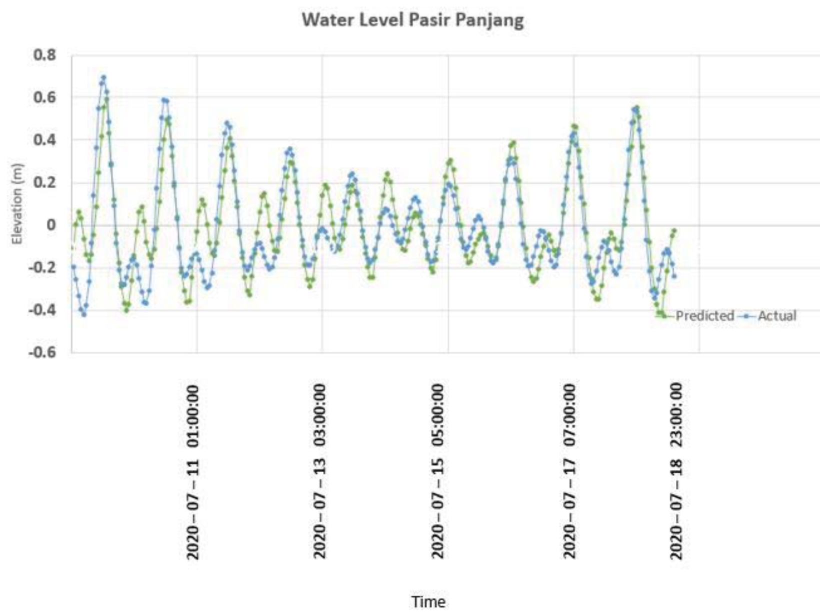
The verification stage is carried out to check the level of accuracy of the model that has been made. The data that was used to verify the model with the actual conditions was tide data. Tidal data is obtained from the Geodetic and Geodynamic Control Network Center (Pusat Jaring Kontrol Geodesi dan Geodinamika known as Online Tidal Prediction). For more detailed information can be seen in Table 3.

TABLE 3. Tidal Verification Setting

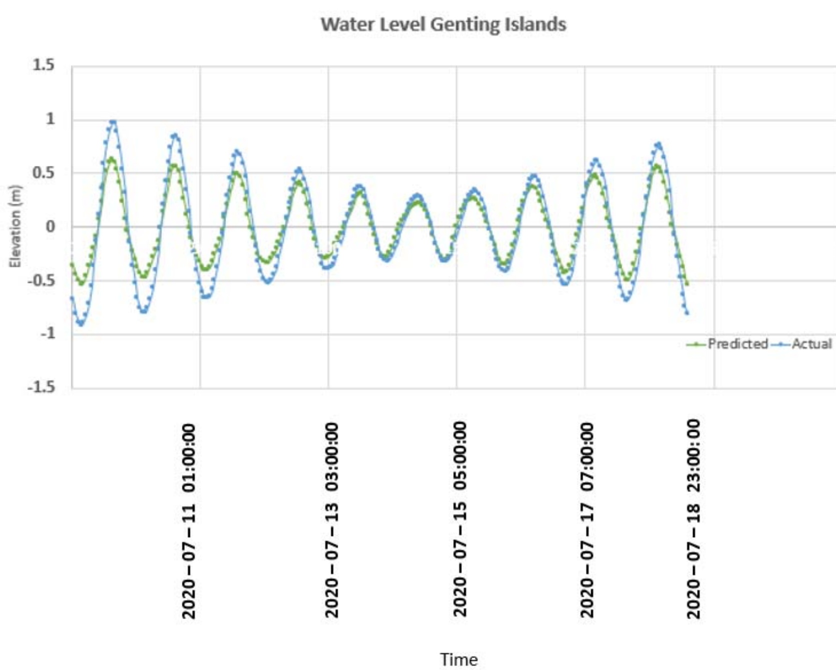
Location	Parameter	Data
Pasir Panjang	Coordinate	0.709872° ; 108.868774°
	Observed time	09 - 18 July 2020
	Data length	9 days
	Data interval storage	60 minutes
Genting Island	Coordinate	-1.588333° ; 108.755278°
	Observed time	09 - 18 July 2020
	Data length	9 days
	Data interval storage	60 minutes

RESULTS AND DISCUSSION

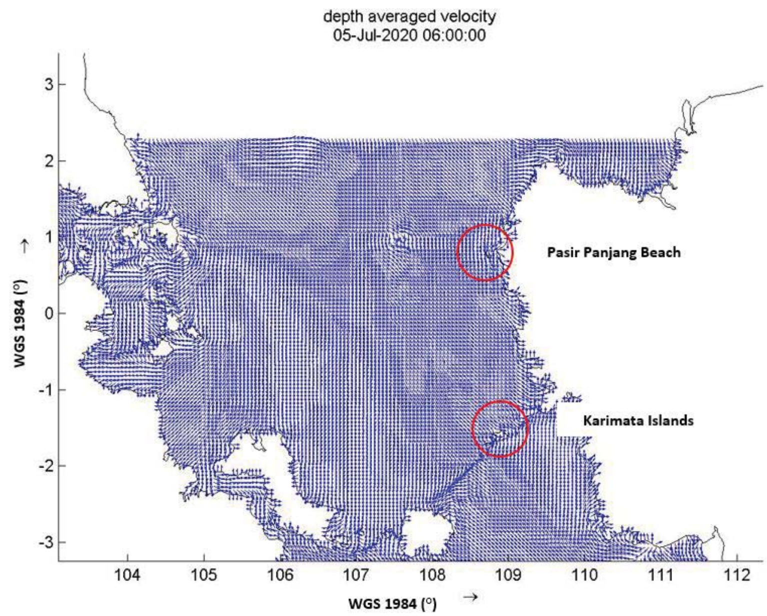
The outcomes of this research are in the form of current directions obtained from the hydrodynamic model itself. After being analyzed, the simulation of the hydrodynamic model of Karimata Island meets the agreement to original conditions. Thus, it can be used as an interpretation of the hydrodynamics of the area within a certain time. From this model, several main outputs will be obtained, such as the direction of ocean currents and changes in water level as can be seen in Figure 4.


Water Level Pasir Panjang
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Elevation (m)
Predicted
Actual
2020 – 07 – 11 01:00:00
2020 – 07 – 13 03:00:00
2020 – 07 – 15 05:00:00
2020 – 07 – 17 07:00:00
2020 – 07 – 18 23:00:00
Time

(a)


Water Level Genting Islands
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
Predicted
Actual
2020 – 07 – 11 01:00:00
2020 – 07 – 13 03:00:00
2020 – 07 – 15 05:00:00
2020 – 07 – 17 07:00:00
2020 – 07 – 18 23:00:00
Time

(b)



(c)

FIGURE 4. Characteristic of Sea Current

Figure 4(a) and Figure 4(b) show the comparison between the tidal elevation from the model and observation data from Online Tidal Prediction for each observation point. From Figure 4(c) it can be concluded that the current model shows the dominant sea current coming from the north to the southern area where Karimata Islands are located.

The validation process is proceeded by using the Root Mean Square Error method (RMSE). It's used to measure the level of data accuracy from a hydrodynamic model that has been made previously with field data at each observation point. A model can be said to be similar to the original condition when its RMSE value is ≤ 0.1. Detailed information can be seen in Table 4.

TABLE 4. The Root Mean Square Error of Observation Points

No	Observation Point	Grid Size (m)	RMSE
1	Pasir Panjang	5000	0.129
2	Genting Island	5000	0.158

As can be seen in Table 4, each observation point produces an RMSE number close to 0.1. This is because the model used is one of the best results from the warming up model made to date. These outputs later will be used as an interpretation of the hydrodynamics of the area within a certain period.

The Citizen Science research provides several results, such as the weight percentage of marine debris and the percentage of waste based on the country on the waste's label. Detailed information can be seen in Figure 5. This figure shows that Malaysia, Vietnam, Thailand, and Tiongkok contribute the percentage of marine debris of 41%, 27%, 10%, and 7% from abroad, respectively.

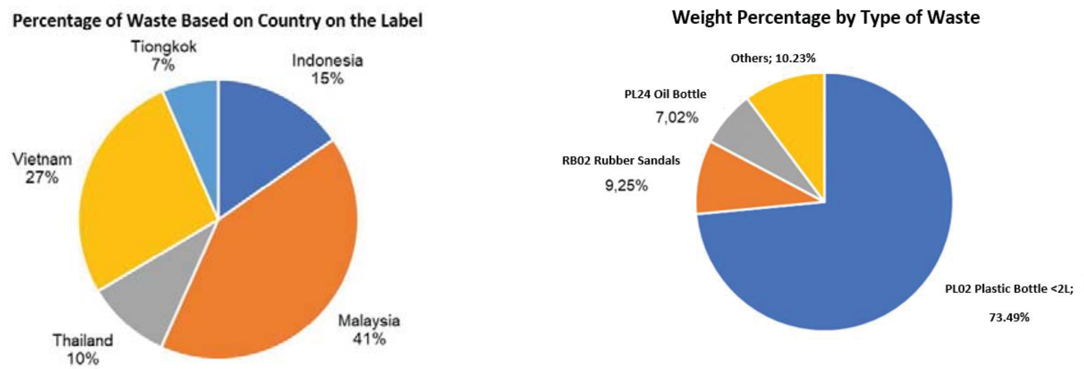


FIGURE 5. Marine Debris Data at Genting Island

Based on Figure 4(c), the current model shows the dominant sea current coming from the north. Marine debris data also demonstrates that the majority of the marine debris found was originally from Vietnam and Malaysia based on the brands listed on the waste. This hydrodynamic model with 5 km x 5 km grids illustrates that the current moves to hit the east coast of Malaysia and Vietnam before turning towards the Karimata Strait and weakening around the Karimata Islands. So there is a match between the model and the marine debris data. Due to the current passing through the west side of the Karimata Islands, it causes a lot of marine debris to be stranded on the northern and western parts of the islands. Marine debris data shows that plastic bottle waste is the most common type of waste stranded in the Genting Island area, with the amount of waste reaching 73.49% of the total stranded marine debris.

CONCLUSION AND RECOMMENDATION

Hydrodynamic numerical modeling can be used as a tool to determine the source of marine debris which is stranded on the coast. Although this research is undergoing research project, the initial outcomes prove that hydrodynamic numerical modeling can be used as a tool to determine the source of marine debris and most of the marine debris stranded on Buluh Kecil Island and Genting Island at Karimata Islands. The characteristic marine debris movement is dominated by the north direction sea current, including waste from Vietnam, Malaysia, and Thailand. Thus, this outcome also proves that the similarity found between gathering data from Citizen Science research and the hydrodynamic numerical model developed.

From the results of the research that has been done, some recommendations that can be given for future research are as follows : Using a server / supercomputer to complete the simulation faster, grid can be made with higher quality (tidiness, size, etc.) and using primary data that occurs at the research site for the validation process.

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