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Study of Coral Reef Ecosystem Vulnerability using Sediment Transport Modeling in Bungus Bay, West Sumatera

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Abstract: ***Bungus Bay has many functions such as harbour, tourism, jetty, local fisheries, and power plant. One of the effect of many functions of Bungus Bay is sedimentation. Sedimentation in Bungus Bay distruption its Ecosystem, Coral Reef Ecosystem. Sedimentation Modelling is using to find out how much sediment concentration (SSC) and sediment transport happens in Bungus Bay. Using sedimentation data, Vurneralbility of Coral Reef Ecosystem in Bungus Bay can be determined. The Result is from 1404.27 ha area of Bungus Bay, 164.73ha is categorized suitable for Coral Reef Ecosystem, 809.55 ha moderate, and 429.99 ha not suitable.***

Keywords: sediment, modelling, vulnerability, coral reefs**.**

1. Introduction

Bungus Bay is located on 100.367 – 100.433 E, -1.015 - -1.078 S. It has 21, 050 meters coastline, 5, 418 length of bay and 1383.86 Ha of area [1]. Bungus Bay is one of bay in West Sumatra Province who has many functions. Fisheries Industries, Harbour, Pertamina Jetty, Tourism, and Power Plants located in this area. Many important functions and potential of the Gulf Bungus will bring a lot of problems as well, including alleged high sedimentation, especially in the area around the power plant [2].

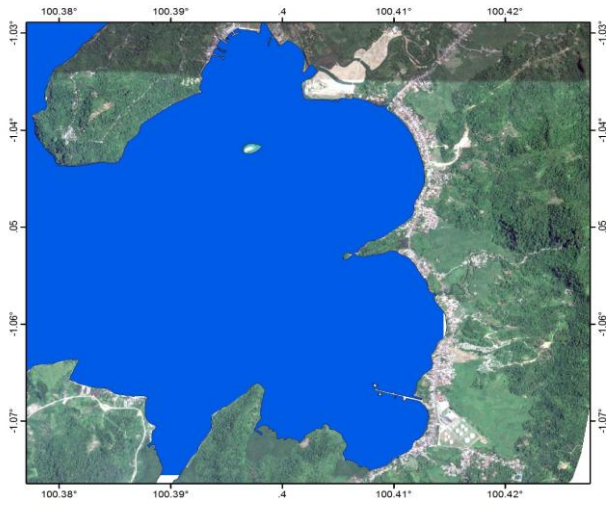

Figure 1: Bungus Bay

The rapid development of Bungus Bay is not balanced with ecosystem conservation in this area. Based on report in 2012, there has been contamination in this area effected by massive construction of power plant. High sedimentation in this area killed most marine life such as corals and benthos.

Research in Bungus Bay is important to find out vulnerability of ecosystem around bay. Coral Reef as one of ecosystem in Bungus Bay has boundary condition to keep functional. One of the factors is sedimentation. Sedimentation can be determined using modelling to find out how much concentration and transport of sediment in Bungus Bay.

2. Methodology

There are three stages in this research: early, core and final stage. Early Stage consists of a formulation of the problem, the study of literature and secondary data collection, in this stage of the study of literature related to research-related problems associated or software to be used after it conducted a secondary data collection is needed in research.

The core stage includes secondary data processing, modeling, analysis and solutions. The data that have been collected are used for modeling, in this study modeling using MIKE 21 software which is software that can model simulation of hydrodynamics and sedimentation. The module used in this study is Hydrodinamic module (HD) and Mud Transport (MT). The results of the modeling that has been calibrated then analyzed the concentration (SSC) and the sedimentation transport which would then be used for multiple regression analysis to see the effects of sedimentation on the coral reef.

Final stage in the form of conclusions and suggestions. A summary of the results obtained from this study are translated and also elaborated recommendations or directions for further research of the existing problems. Research Procedure can be seen in Figure 2.

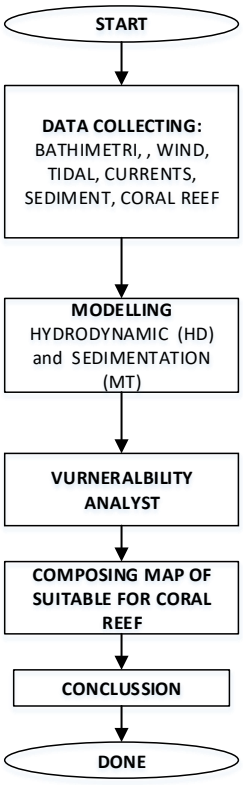

Figure 2: Research Flowchart

3. Result and Discussion

3.1 Calibration

Model calibration is need to be done to get modeling that close to real situations. Calibration is using comparison of tidal from model simulation and data field in same location. Model calibration done by change different chezy number (bed resistance) in model and smallest number error from chezy number is using for next simulation [3]. The equation for error rates shown in (1):

$$Error = \frac{1}{N}\left[\sum_{i=1}^{N}\left|\frac{Xi-X}{Tp}\right|\right] * 100\% \quad (1)$$

Table 1: Error Rates

Chezy Number	Error (%)
30	5.11
32	5.21
38	6.35
44	47.40
50	196.64

Based on error rates of five chezy number, chezy number 30 shown smallest error rates than other four. Thus, for sedimentation modelling, chezy number 30 is used.

3.2 High Tide Conditions

Simulation period is from 10 October 2013 until 11 November 2013 with time step interval 1 hour (3600 seconds). Hydrodynamics modelling shown condition of Sea Surface Height (SSH) and currents velocity and directions. This research focused on conditions during tide and neap condition to see the differences between two situations.

High tide conditions occur on 6 November 2013 in 1 PM. During these conditions, SSH on the east side of bay is higher than west side, thus current direction is moving to the west with average of velocity 1.13 – 2 m/s. As shown in Figure 3 and 4

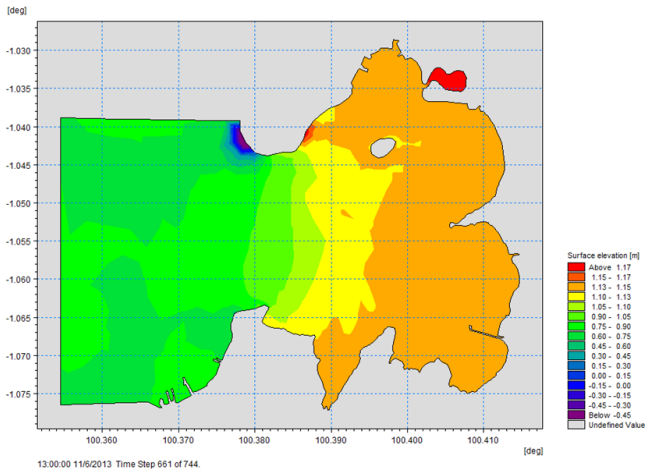

Figure 3: Sea Surface High during High Tide

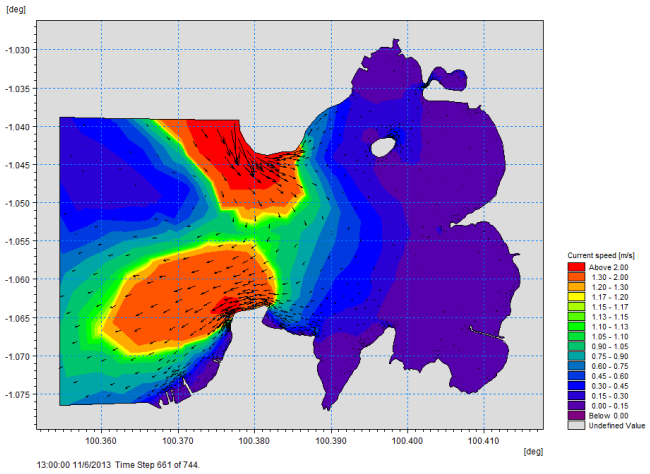

Figure 4: Currents Velocity and Directions during High Tide

The range of currents velocity around Bungus Bay around 0.015-2 m/s with currents directions come from north to west. Currents velocity tends to be high in the mouths of bays, but when it goes into the bay area, flow velocity tends to lower than outside the bay.

3.3 Low Tide Conditions

High tide conditions occur on 5 November 2013 in 8 PM. During these conditions, SSH on the east side of bay is higher than west side, thus current direction is moving to the west with average of velocity is much lower than high tide condition which is 0.01 – 2 m/s. As shown in Figure 5 and 6.

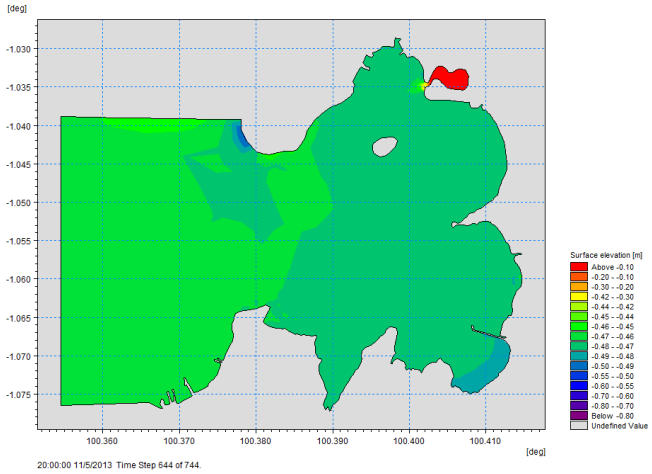

Figure 5: Sea Surface High during Low Tide

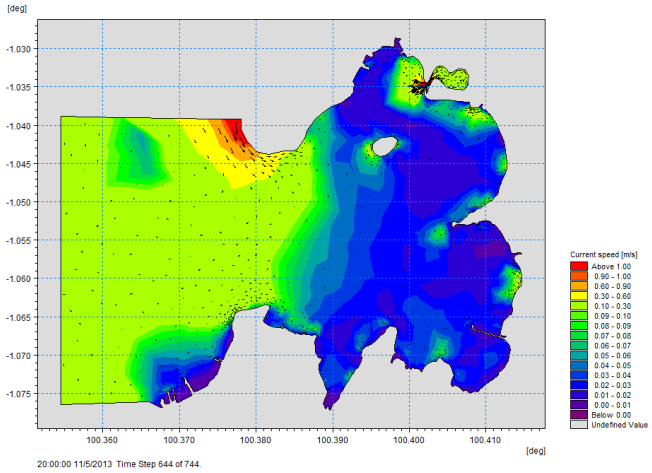

Figure 6: Currents Velocity and Directions during Low Tide

3.4 Suspended Sediment Concentrations (SSC)

Suspended Sediment Concentrations (SSC) taken at two points of the depth, 3 meters and 7 meters in 2 different locations. T1 is located in Bou Bay which is near of power plant locations and T2 is Kasiak Island which is an island in middle of Bungus Bay, shown in Figure 7.

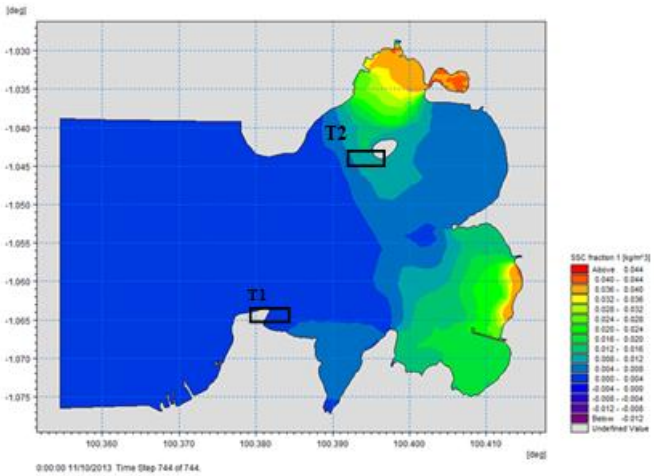

Figure 7: SSC Overall Map

SSC that occurred in T1 worth 12.2 - 12.3 mg /l with average of SSC 5.14 mg/l in 3 meters and 5.01 mg/l in 7 meters. In T2, SSC that occurred worth 0.22 mg/l with average of SSC in 3 meters is 11.89 mg/l and 11.46 mg/l in 7 meters. Graphics of SSC in T1 and T2 shown in Figure 8.

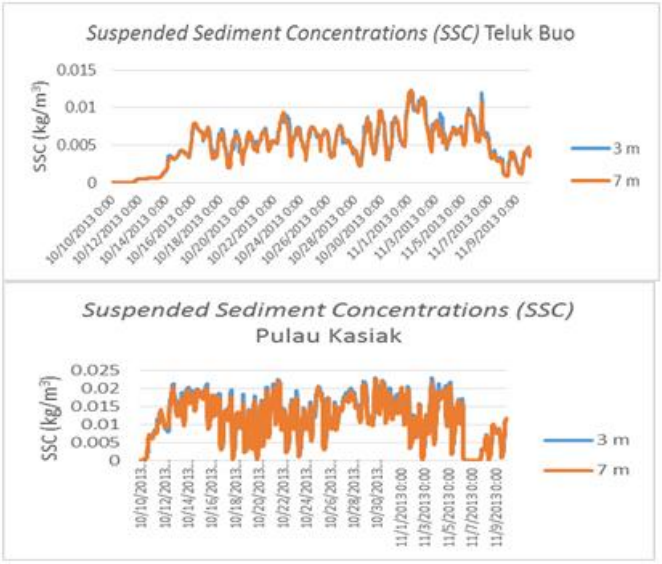

Figure 8: SSC in T1 and T2

3.5 Deposition

Deposition rate used to calculate sediment transport in Bungus Bay area. The average of deposition rate in T1 worth 0.003 mg/cm^2/day in 3 meters and 0.056 mg/cm^2/day in 7 meters. For T2, average of deposition rate worth 0.066 mg/cm^2/day in 3 meters and 0.049 mg/cm^2/day in 7 meters. Graphics of deposition in T1 and T2 shown in Figure 9.

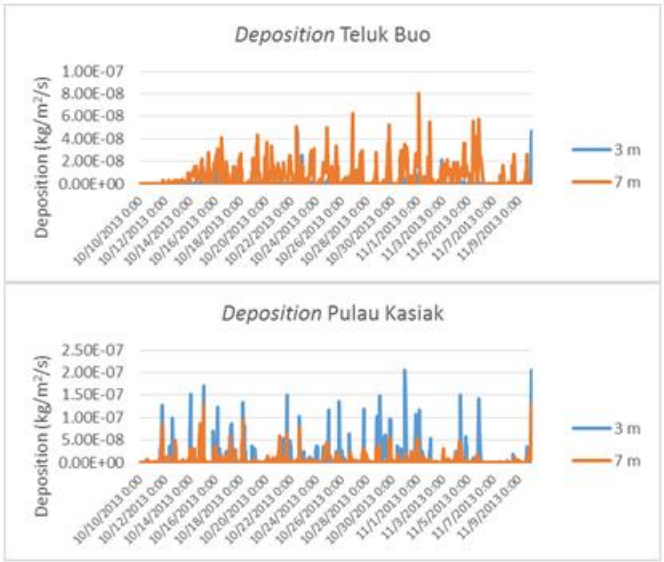

Figure 9: Deposition rate in T1 and T2

3.6 Multiple Regression

Multiple regression analysis is used to determine the effect of sedimentation to coral reefs conditions. Independent variables used in the regression analysis that SSC (X1), sedimentation rate (X2). While the dependent variable (Y) is Coral Cover. Equation of multiple regressions shown in (2):

$$Y = a + B_1X_1 + B_2X_2 + \dots B_nX_n \quad (2)$$

Table 2: Variables Use in Regression

No.	Coral Cover (%)	SSC (mg/l)	Deposition (mg/cm^2/day)
1	8.47	11.46	0.049
2	7.6	11.89	0.066
3	19	5.01	0.056
4	44.53	5.14	0.003
5	30.67	5.01	0.056
6	37.6	5.01	0.056
7	10.6	11.46	0.049

Regression calculation is used to calculate the coefficient of determination (R^2) and also get value multiple regression model of the relationship of coral reefs with sedimentation. The results of multiple regression analysis is influence of the independent variables (SSC, Deposition rate) to affect the coral cover by 85% (R^2 = 0.859). Multiple Regression Model equations obtained are shown in (3):

$$\hat{y} = 4.48\,x\,10^{-17} - 0.735x_1 - 0.381x_2 \quad (3)$$

Information:

$\hat{y}$ = Coral Cover
X_1 = SSC
X_2 = Deposition Rate

3.7 Suitability Map of Coral Reefs

Suitability Map of Coral Reefs in Bungus Bay is based on the results of the calculation of SSC and deposition rate in Bungus Bay. Different parameters were used to classify areas including good-dangerous category. Parameter for SSC refers to the Ministerial of Environment and Foresty Decree No.51/2004 regarding water quality standards for oceans [4]. As for the deposition rate refers Pastorok & Billiard, 1985 regarding sedimentation rate vulnerable to coral reefs [5].

Table 3: Sediment Classification in Suitability Map

No.	SSC (mg/l)	Deposition (mg/cm^2/day)	Categorized
1	0-5	1-10	Suitable
2	6-20	10-50	Moderate
3	>20	>50	Not Suitable

SSC values in Bungus Bay obtained varied, with range 0.001 - 39.9 mg/l and deposition rate value obtained 1-10 mg/cm^2/day. Results of both parameters overlayed and categorized as an area eligible or not for the Coral Reef Ecosystem, which is in 3 categorized; High (suitable), Medium (moderate) and Low (not suitable). Overall width Bungus Bays amounted to 1404.27 ha, where 164.73 ha suitable, 809.55 ha moderated and 429.99 ha not suitable. Suitability Map of Coral Reefs in Bungus Bay in Figure 10.

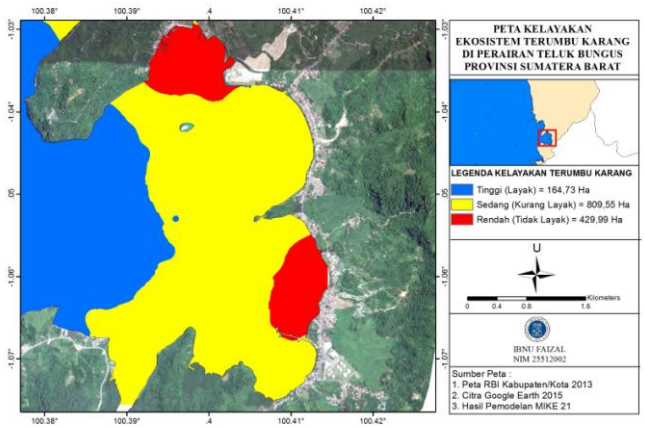

Figure 10: Suitability Map of Coral Reefs in Bungus Bay

4. Conclusion

Based on Suitability Map of Coral Reefs in Bungus Bay, there are only 11.73% of Bungus Bay area are categorized suitable. Moderate classification dominated in Bungus Bay area with 57.65% and not suitable with 30.62%.

5. Recommendation

Further studies regarding the layout and design of alternative solutions and sedimentation modeling can be continue to see the changes that occur through alternative solutions that given.

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Author Profile

Ibnu Faizal received his Bachelor degrees in Marine Science, Universitas Padjadjaran in 2012 and Master of Ocean Engineering, Institut Teknologi Bandung in 2015. His research focused on ecosystem and modelling. He is now a lecture in Marine Science Department, Faculty Fisheries and Marine Science, Universitas Padjadjaran

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