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Hydro-oceanographic condition (Tide, Sea Current, and Waves) of Nongsa Batam Sea

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Abstract

Tanjung Bemban is one of the seas found in the Nongsa sub-district, Batam city which is currently developed as a tourist attraction. This research aims to find out the hydro-oceanographic component, which consists of tide and the current and wave pattern in the sea of Tanjung Bemban Nongsa. Tide Pole method (using measuring sign) is used to collect the data regarding tide. Float Tracking (Lagrangian) method is used to collect data of sea current (by measuring distance and displacement of floating object in the sea). Wave Pole method is used to collect the data of the wave (by measuring wave height). Based on the result of the research, it is clear that the tide of the sea is categorized as the semi diurnal, since there are two tides in one day with identical height, which occur sequentially and regularly. The highest tide reaches 260 cm and the lowest ebb 19 cm in the 4 days of observation, with 15 minutes interval. The measuring of ocean current is carried out for every 30-second intervals. Current velocity in Nongsa sea ranges from 0.02 m/s to 0.26 m/s. The current moves from east to southwest and west, even though some move northwest and north. Wave height is quite low, between 18 cm and 23 cm. Hydro-oceanographically, the Tanjung Bemban Nongsa area can be developed into a strategic tourism area.

Keywords: Hydro-oceanography, Tide, Sea current, Waves, Nongsa

1. Introduction

There are many seas in Batam island. One of them is Tanjung Bemban sea located in Nongsa sub-district, Batam city. From the perspective of economy, coastal and marine resources in Tanjung Bemban sea have the potential to be developed as a mean to improve welfare, for example, by constructing tourist attractions and fish and shrimp ponds. Furthermore, the development also has the potential to prevent coastal erosion and sedimentation. Tides, currents, and waves are important parameters in the dynamics of sea which influences changes in coastal and marine areas.

Irawan (2016), conducted a research by measuring and analyzing type of tides using measuring signs and current patterns using Lagrangian method on Batam Island, which will then be presented in a web. Five research locations were chosen based on purposive sampling method in one hour intervals, with a total measuring time of 24 hours. The results show that the type of tide in the Batam Island in general is the semidiurnal tide. The pattern of the sea current of the island of Batam ranges from 0.02 m/s to 0.1 m/s, moving from the north to the northeast. The drawback of this research is that the samples taken are too few, so that it does not describe the entire cities of Batam.

Hidayat, 2012 and Lubis *et al.,* 2017 conducted a literature review on hydro-oceanography and Longshore transport sediment. In the discussion regarding hydro-oceanography brief description and basic theory of wave, wind, current, tide, and coastal bathymetry condition analysis is provided. By conducting a hydro-oceanographic research on a coastal area, physical processes that may occur can be predicted. One of the physical processes usually found is damage to coastal areas due to change in coastline, in form of accretion and coastal erosion caused by longshore transport sediment.

Yuliasari, *et al.,* 2012 observed currents at Marina Beach, Ancol. The results show a complex pattern and they are more influenced by wind, although there are also influences from coastal buildings and reclamation. Overall, the formation of currents on Marina Beach, Ancol is resulted from several types of currents, such as those generated by tide, wind and longshore current. Simulation results for coastal reclamation plan current pattern model show that there is no significant change in the current pattern at Marina beach, Ancol compared to the pattern before coastal reclamation. Therefore, it can be concluded that the Beach reclamation plan in Ancol does not affect the flow pattern.

Al Tanto *et al.* 2016 conduct a physical oceanography research on the Bay of Bungus. Bathymetry data analyzed is obtained from the map released by Dishidros in the form of 2D and 3D map views. The data of tide are measured using ADCP, the main measuring instrument for ocean currents, and HOBO, which has a built-in pressure sensor. Wave data are obtained from ECMWF in the form of significant wave height. In addition, there is also significant wave height model/forecasting from BMKG. Teluk Bungus sea depth is shallow, reaching only 30 m.

Syahputra et al. 2014 measure current to calculate the renewable energy potential output. This research employs quantitative descriptive method and purposive sampling in determining the location. The research is divided into two major stages: field survey stage and numerical modeling stage with MIKE 21 flow model, flexible mesh, followed by calculation of the energy potential of sea currents. Based on the results, the intended potential location is located at -8o18'06.9";123^{o}01'20.1", with probability of potential of 94.85% in the east season is, 95.73% in the transition season II, 96.84% in the west season and 96.77% in the transition season I.

Purba, N. P, et al. 2014 conducted research to calculate the wind speed produced on Berhala Island, Anambas Island, and Biawak Island. The data are obtained from field and satellite observations. The averages of sea current velocity on these Islands are 0.135 m/s, 0,055 m/s, and 0,272 m/s respectively. The averages of wind speed on the sea surface are 0.220 m /s, 3,032 m/s.

Nugrahadi, M. S, et al. 2013 use the Lagrangian hydrodynamic 3D model method to determine the function of tide elevations in the north and east of Madura Strait. The results show that the tides in Madura Strait are influenced by river discharge and direction of monsoon wind.

Tide is the recurring movement of receding and rising of water in a certain period due to the gravitational pull of celestial bodies, especially the sun and moon, to the water mass on earth. They are the result of gravitational pull and centrifugal effects. Centrifugal force pushes an object out of the center of rotation. Gravity is directly proportional to mass but inversely proportional to distance. Regarding tide, although the size of the moon is smaller than the sun, the gravitational pull is twice as large as the gravitational pull of the sun because the distance from earth to moon is shorter than the distance from earth to sun. Gravitational pull of earth pulls sea water toward sun and moon produces two gravitational bulges in tide in the sea. The latitude of the bulges is determined by declination, the angle between the axis of rotation of earth and the plane of the orbitals of sun and moon.

Sea current is the flow of water masses due to wind movements, differences in density, or long wave motions. Ocean currents are influenced by several factors, including wind direction, difference in water pressure, difference in water density, surface currents, upwelling and downwelling. Changes in current patterns in Tanjung Bemban sea are influenced by these factors. To find out the flow pattern in Tanjung Bemban sea, research on current pattern mapping in Tanjung Bemban sea needs to be done. Wave can generate energy that causes formation of beach, emergence of currents and sediment transport in perpendicular directions and along the coast, as well as the occurrence of forces that work on coastal buildings. Even now, the notion of wave is still not clear and accurate because sea surface is complex with a pattern that is ever-changing and unstable. Sea wave is the periodic movement of receding and rising of sea surface caused by tide.

Research by Denny Nugroho Sugianto in 2008 was conducted in the sea of Grati Pasuruan, East Java. The purpose of this research was to find out the hydrodynamic conditions in the sea, which includes currents, waves, and tides. The results of this research show that the type of tide around the Grati sea, in Pasuruan, is the mixed type with a tendency toward the preavaling semi diurnal tide. When the sea surface recede or close to ebb, the current speed reaches higher or even the maximum value and some of the current move east-southeast (750 – 1200). Surface current velocities ranged from 0.013 to 0.77 m/s, middle depth currents from 0.001 to 0.32 m/s, and base depths from 0.00 to 0.29 m/s. Based on the measuring results, the height and period of the wave in Grati sea are relatively moderate. The average height of the wave is 0.11 cm and the average period is 4.76 seconds. The highest height of the wave is 0,21 meter with the period of 5,5 seconds. Based on the results of forecasting, the height of the wave reaches 1.9-2.1 m in the west season and 2.0-2.3 m in the east season. Based on its depth, the wave is classified as transitional sea wave, with vertical profile of wave orbital velocity at the peak of the wave of 0.13 m/s, wave valley of -0.13 m/s, and it still affects the bottom of the sea.

Lolong, et al, 2011, conduct research related to information on hydro-oceanographic characteristics in the sea of Inobonto, North Sulawesi. Based on the results of the research, the tide type in Inobonto beach is the mixed preavaling semi diurnal tide type 0.44 (0,25 < F < 1.5), with the constants of M2 = 0,52 m, S2 = 0,42 m, N2 = 0,11 m K2 = 0.11m, K1 = 0,20 m, O1 = 0,22 m, P1 = 0,07 m, M4 = 0,01 m, MS4 = 0,01 m. The difference in tide is 2.0 meters with the highest flow of 2.5 meters and the lowest ebb of 0.5 meters, based on the datum. Maximum Wave Height occurs around October to March every year. Wave height reaches 2.5-4.27 meters with wave periods ranging from 5.5 to 7.5 seconds. Repeated wave height on H10 = 4,4192m, H20 = 4.5636 m, H30 = 4.6842m, with wave periods of T10 = 7.8119 seconds, T20 = 8,0479 seconds and T30 = 8.2433 seconds. The maximum current velocity in the Inobonto coast is 0.406 m/s, with the average speed of 0,237 m/s.

Prasita, V. D., et al, 2012 conducted a research of tide and current in the sea of Lamongan, East Java. From the results of observations and calculations it can be concluded that in the sea of Lamongan the type of tide are the single daily type with Formzhal value of 9. The Mean Sea Level or Mid Seat or Average Water Surface is 100 m, measured from 0 palm. The highest tide peak occurred on May 9th 2012 at 11.00 a.m. WIB, with a water level of 189 cm above 0 palm. The lowest ebb occurred on May 8th, 2012 at 10:00 p.m. WIB, with a height of 12 cm above 0 palm. The sea water height during observation is 177 cm. When the height reaches the peak, the flow velocity is relatively similar to the velocity in the time of ebb. The increase in the velocity occurs about 4-6 hours after the highest tide. When the flow occurs, sea water flows towards the beach.

Surveys on wave are used to find out the forces acting on the port building and the amount of current and sediment caused by waves so that it can be anticipated. Wave is the main factor in determining industry and terminal port layout, shipping lines, coastal building planning and so on (Sutirto, 2014). Tide is used to determine water level elevation which will be used to design the dimensions of port facilities, to complete the need for depicting bathymetry (sea depth contour) maps, to determine the tide pattern during observation. The highest (flow) and lowest (ebb) water level data are also used to plan dock buildings, for example the elevation of peak breakwater buildings, docks, and so on (Diposaptono, 2007). The observation on sea current aims to obtain the direction and velocity data of the current in the sea construction plan area so that a description of the direction of the dominant current and the magnitude at any time is available (Triatmodjo, 2003).

2. Research Method

The design of this survey activity is presented in Figure 1. This activity begins with a preliminary survey. The preliminary survey is a field review which was done done previously to see the terrain conditions thoroughly, to determine measuring techniques and positioning of representative map frame points. The following criteria must be met: it is evenly distributed, the interval is uniform, free from interference, easy to set up measuring instruments, facilitates detailed measuring, visible to both preceding and following points, etc.

After the field conditions are known through preliminary surveys, the acquisition process or data collection is carried out. Topographic measurements are carried out by radial method, using the polygon point as the place for the device that can shoot detailed points in all directions. A topographic survey was conducted regarding natural and man-made detailed coordinates (X, Y, Z), as well as coastlines. Topographic data processing includes calculation of map framework (X, Y, Z) and detailed calculation of (X, Y, Z), or only calculation of direction/azimuth angle, flat distance, and height difference from the binding point, followed by plotting or drawing. The main tool used is theodolite.

Wave measurement can be carried out for 16 days continuously which includes measurement of wave height, wave period, and direction of wave arrival. The measuring are done by reading sea level elevations caused by waves recorded in a wave recorder which has been installed at a certain place periodically every 20-60 minutes. Wind surveys are carried out for the wave analysis, to find out the distribution of wind direction and velocity right in the planned port location, and to plan the load on the ship. Wind measurements are carried out using anemometer which is installed 10 meters above the surface of the water, while the recorder is on the land.

Tide observation is carried out for a minimum of 16 days to determine the elevation of the planned water level. This 16-day observation is carried out to get one tide cycle, comprising the spring tide and neap tide. As soon as possible after the installation, tide gauge/staff is tied vertically (as a waterpass), using leveling method, to the nearest control point on the land, before and at the end of the survey. Data obtained from the acquisition are coordinates of location, time of measurement, and water level. The stages in the field measuring are carried out accordance to SNI 7646 year 2010 (SNI, 2010).

The Euler method is used in current measurement, using Currentmeter. Data collection is carried out, at least, at three points simultaneously, so that every current pattern can be represented. Each measurement is carried out in the three observations: at the depth of 0.2d, 0.6d, and 0.8d, with d as the depth of the water in the measurement position (Basuki, 2006). Each measurement has a period of at least 24 hours per day, from the moment of receding until the next ebb or from a flow to the next one. This period is called the tide phase.

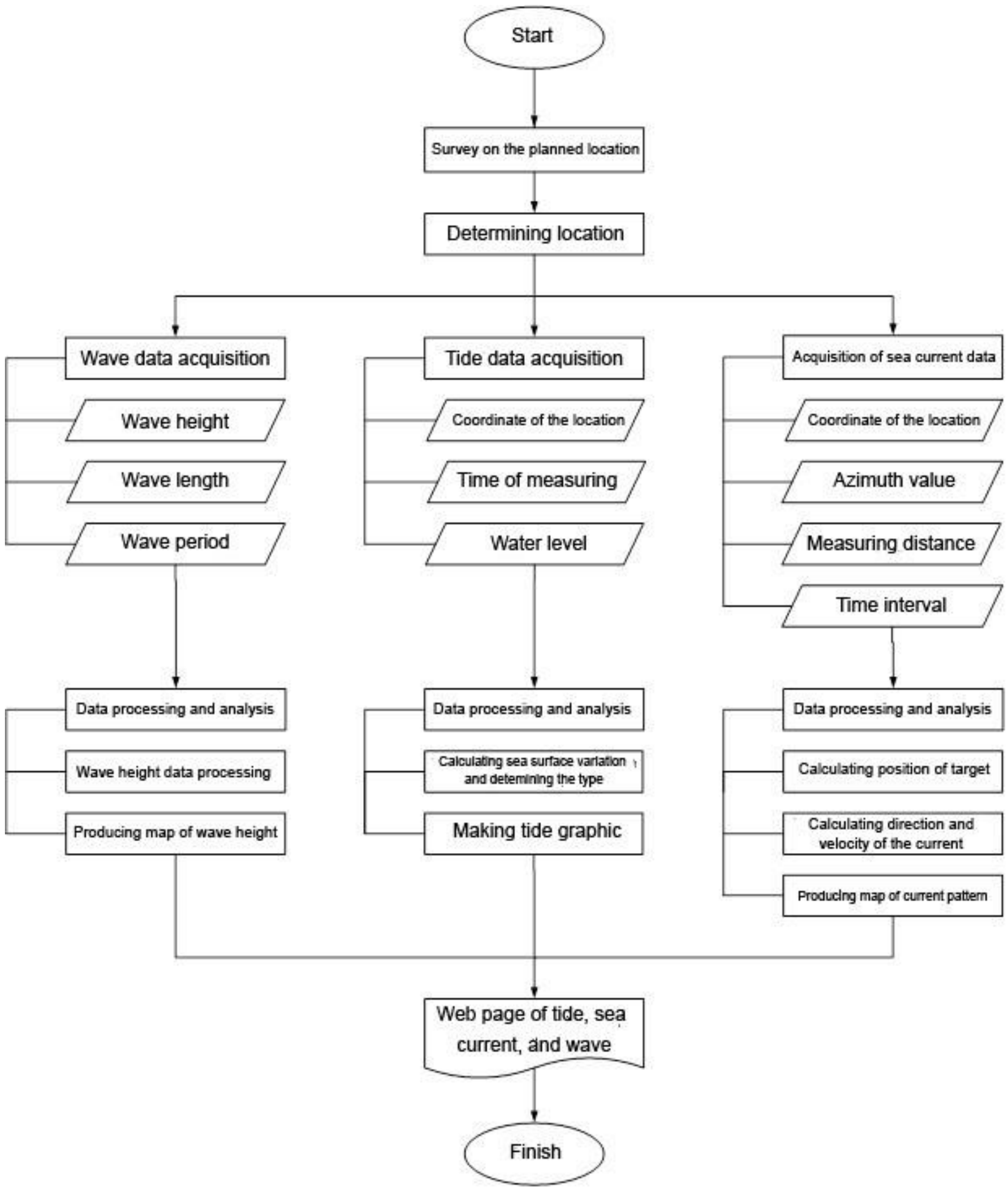

Figure 1. Research flow chart

3. Result and Discussion

Water level variation in the Nongsa region in one month can be seen in Table 1. The graph for tide can be seen in Figure 2. The measuring of tide at Tanjung Bemban were carried out on September 3rd-4th, 10th-11th, 17th-18th, and 24th-25th 2016. Based on the measuring made on September 3rd-4th 2016, two tides occur within 24 hours. The first highest flow occurred on September 4th 2016 at 00:00 a.m. with water level of 258 cm. The second highest flow occurred on September 4th 2016 at 12:45 p.m. with water level of 212 cm. The first lowest ebb occurred on September 4th 2016 at 7:00 p.m. with water level of 20 cm. The second lowest ebb occurred on September 4th 2016 at 9:00 a.m. with water level of 19 cm. Based on these results it can be concluded that in the first week of observation the semidiurnal or double daily type are identified; two tides occur in one day.

Based on Table 1, HW (Highest Water) value is 257.50 cm, MHHWL (Mean High Highest Water Level) value 218.49 cm, MHWL (Mean High Water Level) value 179.49 cm, MSL (Mean Sea Level) value 101.47 cm, MLWL (Mean Low Water Level) value 60.4 cm, MLLWL (Mean Low Lowest Water Level) value 39.62 cm, LW (Lowest Water) value 19.00 cm, Tide Range–the difference between the highest and the lowest water level–238.50 cm.

Table 1. Table of Variations in Sea Water Levels in the first to fourth week.

Variations in Sea Water Levels	Water level (cm)			
	Week 1	Week 2	Week 3	Week 4
HW	257,50	240,00	260,00	283,00
MHHWL	218,49	206,05	222,42	158,24
MHWL	179,49	172,09	184,83	133,49
MSL	101,47	104,18	109,66	83,98
MLWL	60,24	64,34	71,58	51,99
MLLWL	39,62	44,42	52,54	35,99
LW	19,00	24,50	33,50	20,00
Tide range	238,50	215,50	226,50	163,00

Based on the measuring conducted on September 10th-11th 2016, two tides were identified within 24 hours. The first highest flow occurred on September 11th 2016 at 1:00 a.m. with water level of 240 cm. The second highest flow occurred on September 11th 2016 at 1:30 p.m. with water level of 240 cm. The first lowest ebb occurred on September 10th 2016 at 7:30 p.m. with water level of 25 cm. The second lowest ebb occurred on September 11th 2016 at 08:00 with water level of 25 cm. Based on these results it can be concluded that in the first week of observation, the semidiurnal or double daily type are identified.

Based on Table 1, HW (Highest Water) value is 240.00 cm, MHHWL (Mean High Highest Water Level) value 206.05 cm, MHWL (Mean High Water Level) value 172.09 cm, MSL (Mean Sea Level) value 104.18 cm, MLWL (Mean Low Water Level) value 64.34 cm, MLLWL (Mean Low Lowest Water Level) value 44.42 cm, LW (Lowest Water) 24.50 cm, Tide Range 215.50 cm.

During the measurement conducted on September 17th-18th 2016, two tides were identified within 24 hours. The first highest flow occurred on September 18th 2016 at 01:15 p.m. with water level of 260 cm. The second highest flow occurred on September 18th 2016 at 1:30 p.m. with water level of 210 cm. The first lowest ebb occurred on September 17th 2016 at 6:15 p.m. with water level of 34 cm. The first lowest ebb occurred on September 18th 2016 at 7:45 a.m. with water level of 42 cm. Based on these results it can be concluded that in the first week, semidiurnal or double daily types are identified.

Based on Table 1, HW (Highest Water) value is 260.00 cm, MHHWL (Mean High Highest Water Level) value 222.42 cm, MHWL (Mean High Water Level) value 184.83 cm, MSL (Mean Sea Level) value 109.66 cm, MLWL (Mean Low Water Level) value 71.58 cm, MLLWL (Mean Low Lowest Water Level) value 52.54 cm, LW (Lowest Water) value 33.50 cm, Tide Range 226.50 cm.

Based on the measuring on September 24th-25th 2016, two tides were identified within 24 hours. The first highest flow occurred on September 25th, 2016 at 1:30 a.m. with water level of 183 cm. The second highest flow occurred on September 25th 2016 at 2:00 p.m. with water level of 140 cm. The first lowest ebb occurred on September 24th 2016 at 7:30 p.m. with water level of 20 cm. The second lowest ebb occurred on September 25th 2016 at 10:00 with water level of 23 cm. Based on these results it can be concluded that in the first week semidiurnal or double daily type were identified; Based on Table 1, HW (Highest Water) value is 183.00 cm, MHHWL (Mean High Highest Water Level) value 158.24 cm, MHWL (Mean High Water Level) value 133.49 cm, MSL (Mean Sea Level) value 83.98 cm, MLWL (Mean Low Water Level) value 51.99 cm, MLLWL (Mean Low Lowest Water Level) value 35.99 cm, LW (Lowest Water) value 20.00 cm, Tide Range 163.0 cm.

The highest flow occurred in the third week, with a water level at about 260 cm, and the lowest ebb at about 19 cm. Observations are carried out every week. The type of tide from the first to the fourth week remains the same: the semi diurnal type, since there are two highest flows and two lowest ebbs in one day, even though the water level is always different every week.

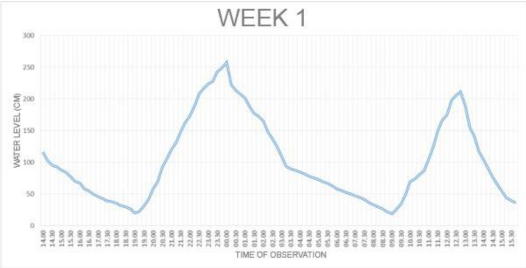

Figure 2a. Tide Chart for the First Week

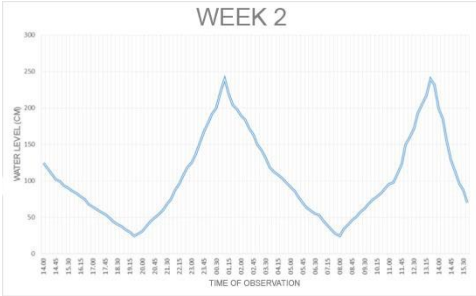

Figure 2b. Tide Chart for the Second Week

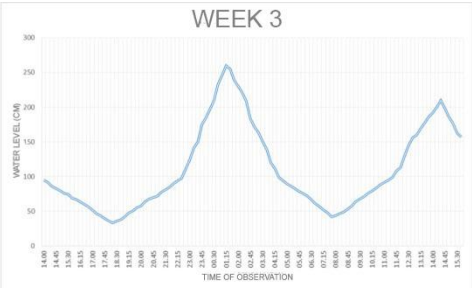

Figure 2c. Tide Chart for the Third Week

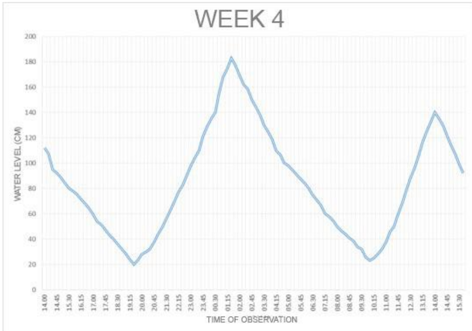

Figure 2d. Tide Chart for the Fourth Week

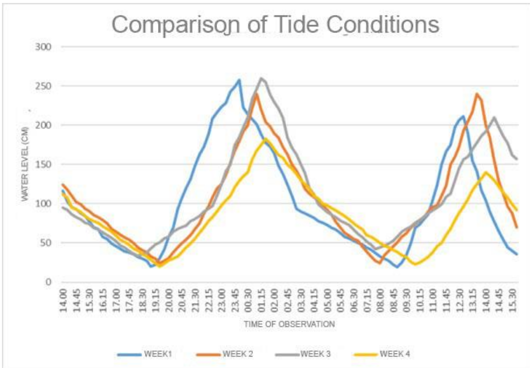

Figure 3. Comparison of Tide Conditions

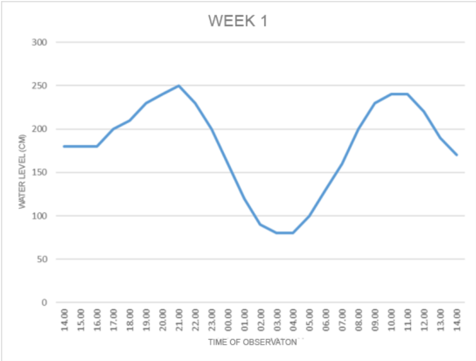

Figure 4a. Week 1 Tide Chart of The Dishidros TNI AL

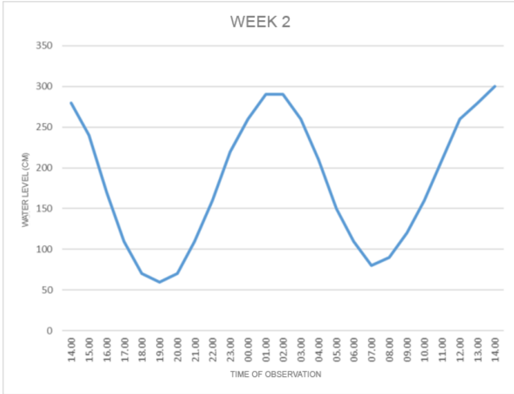

Figure 4b. Week 2 Tide Chart of The Dishidros TNI AL

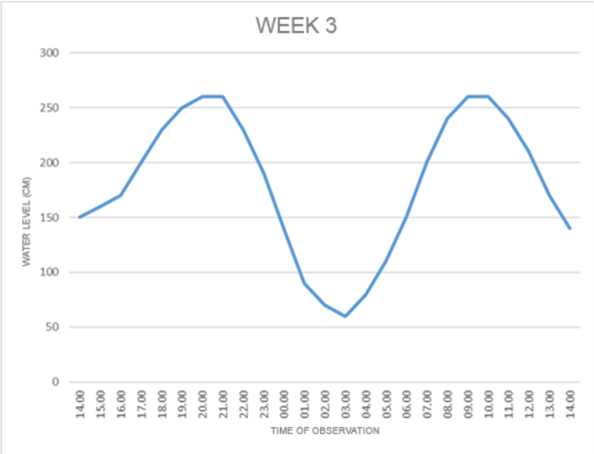

Figure 4c. Week 3 Tide Chart of The Dishidros TNI AL

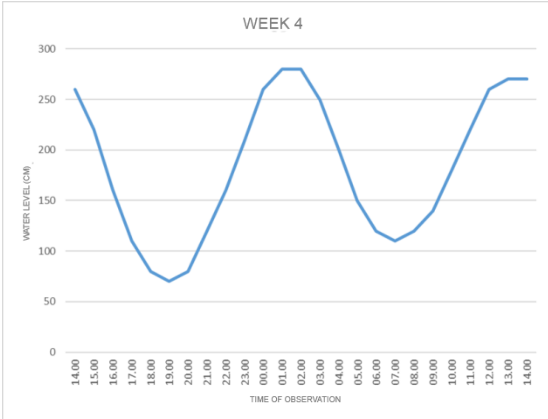

Figure 4d. Week 4 Tide Chart of The Dishidros TNI AL

As a field validation, comparison with the data from Dishidros TNI AL, which was obtained from observation at Batuampar on the same date and hour, can be seen in Figure 4. In the first week, the result of the observation at 2:00 p.m. WIB shows that the water level had receded until 7:00 p.m. WIB, followed by flow at 12:00 p.m. Based on the results of observation from Dihisdros TNI AL at 2:00 p.m., there was a flow until 9:00 p.m. and an ebb until 4:00 a.m. Based on these results, it can be concluded that in the first week of the observation conducted by Dishidros TNI AL, the semi diurnal or double daily type are identified, since there were two tides in one day. From the Anova test and the simple linear regression results above, with a 95% confidence interval and alpha of 5%, it can be seen that there is no similarity between the primary and secondary data at the first period, because the regression, which is multiple R, is 16.93% and R square 2,87 % and 0.0287 in simple linear regression, which is not close to 1, and the significance value > 0.05. It can be concluded that the regression relationship is incompatible since the water level in the primary and secondary data differs considerably.

In the second week the result of observation at 2:00 p.m. WIB shows that the sea level had receded until 7:30 p.m. WIB, followed by flow at 1:00 a.m. Based on observation from Dishidros TNI AL at 2:00 p.m., sea level had receded until 7:00 p.m. and flow occurred at 1:00 a.m.. Based on these results, it can be concluded that in the second week of observation conducted by Dishidros TNI AL the semi diurnal or double daily type are identified, since there are two tides in one day. From the Anova test and the simple linear regression results above with a 95% confidence interval and alpha of 5%, it can be seen that there is no similarity between the primary and secondary data in the first period because the regression, which is multiple R, is 84.47 % and R square 71.35 % and simple linear regression of 0.7135, which is close to 1, and the significance value > 0,05. It can be concluded that the regression relationship is compatible since the water level of the primary and secondary data is identical.

Based on observation done by the researcher in the third week, at 2:00 p.m. WIB sea level had receded until 6:15 p.m. and then flow occurred at 1:15 a.m. Based on observation from Dishidros TNI AL at 14:00, flow had occurred until 9:00 p.m. and flow occured at 03:00. Based on these results, it can be concluded that in the third week of observation conducted by Dishidros TNI AL, the semi diurnal or double daily type are identified since there were two tides in one day. From the Anova test and the simple linear regression results above with a 95% confidence interval and alpha of 5% it can be seen that there is no similarity between the primary and secondary data in the first period, because the regression, which is multiple R, is 73.76 % and R square 54,40 %, and simple linear regression of 0,544, which is close to 1, and the significance value > 0,05. It can be concluded that the regression relationship is compatible, since the water level in the primary and secondary data is identical..

In the fourth week, observations by the researcher at 14:00 WIB shows that sea level had receded until 19:30 WIB and then experience flow at 1:30 a.m. Based on observations by Dihisdros TNI AL at 14:00, sea level had receded until 7:00 p.m., followed by flow at 03:00. Based on these results, it can be concluded that in the third week of observation conducted by Dihisdros TNI AL the semi diurnal or double daily type is identified, since there are two tides in one day. From the Anova test and the simple linear regression results above with a 95% confidence interval and alpha of 5%, it can be seen that there is no similarity between the primary and secondary data at the first period because the regression, which is multiple R, is 76.82 % and R square 59,02 %, and simple linear regression of 0,5902, which is close to 1 and the significance value > 0,05. It can be concluded that the regression relationship is compatible since the water level in the primary and secondary data is identical.

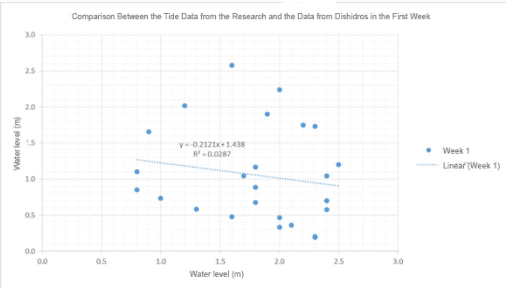

Figure 5a. Comparison between the tide data from the research and the data from Dishidros in the first week

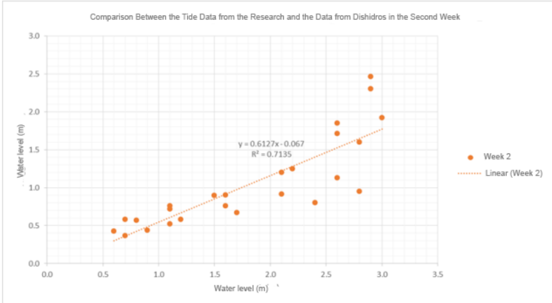

Figure 5b. Comparison between the tide data from the research and the data from Dishidros in the second week

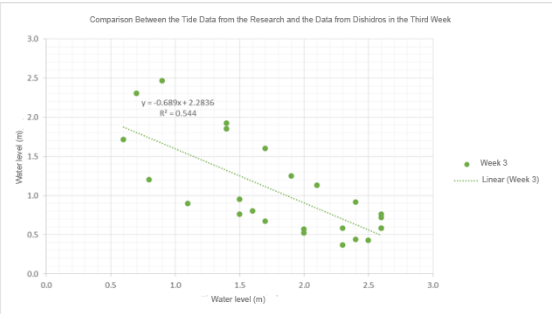

Figure 5c. Comparison between the tide data from the research and the data from Dishidros in the third week

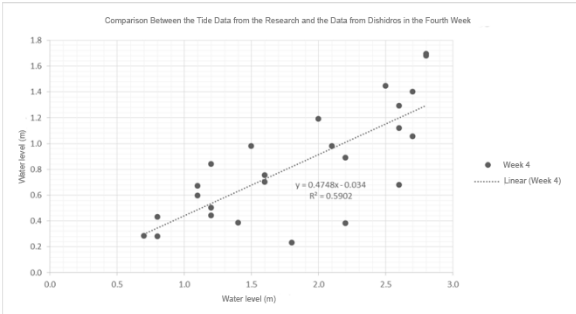

Figure 5d. Comparison between the tide data from the research and the data from Dishidros in the fourth week

Based on the results of measurements in the field, followed by data processing, a map of the ocean currents of Tanjung Bemban, Nongsa sea is produced, as shown in Figure 6. Based on Figure 6, it can be observed that in the sea of Tanjung Bemban, the highest current velocity is approximately 0.5 m/s and the lowest around 0.001 m/s. In Tanjung Bemban sea, the direction of the current moves from east to southwest and west, while some move northwest and north.

Based on the results of the measurements in the field, followed by data processing, a map of the distribution of sea wave height in Tanjung Bemban sea was produced and is presented on a map. Based on the map it can be observed that in the sea of Tanjung Bemban, the highest wave height is approximately 23 cm and the lowest around 18 cm. Wave height ranges from yellow to green, between 20 cm to 21 cm, when it reaches land.

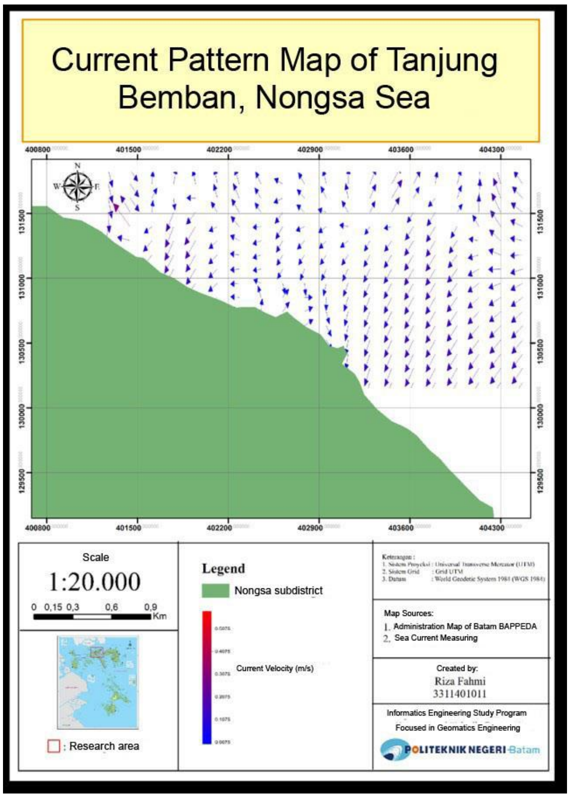

Figure 6. Tanjung Bemban Sea Current Pattern Map

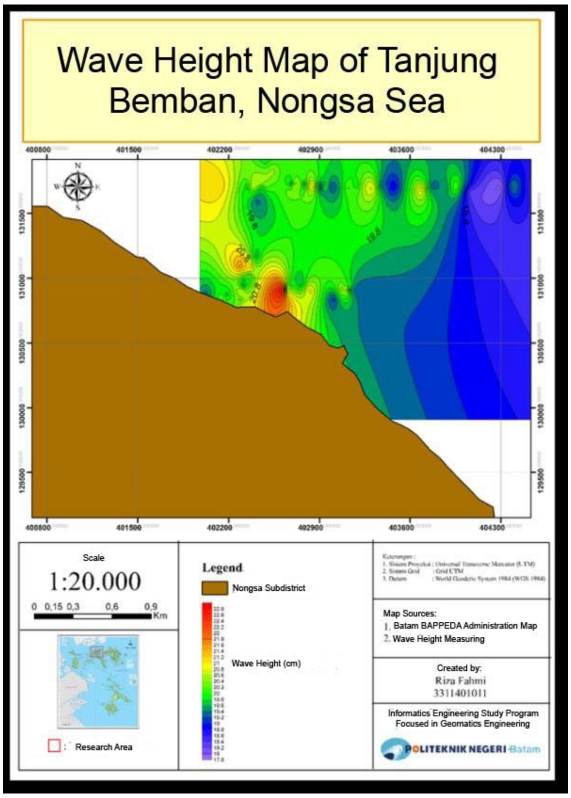

Figure 7. Tanjung Bemban Sea Wave Height Map

4. Conclusion

The height of the waves in Tanjung Bemban sea is relatively small because they are waves caused by wind. The tide in Tanjung Bemban sea is classified as the semi diurnal type. Compared to the data from Hidros TNI AL there are differences in some data, caused by difference in distance and location of data collection, hence, the different data, though only slightly. In Tanjung Bemban sea, the current moves slowly, moving from east to southwest and west, though some head northwest and north. This speed and direction map has provided information to the people of Tanjung Bemban sea, so that it can be used as a reference for fishermen in gathering fish or other marine products.

5. Reference

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