Hydrodynamics of Bontang Seawaters: Its Effects on the Distribution of Water Quality Parameters

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Abstract

Bontang is filled with residential and industrial activities which produce heat waste into surrounding waters. This condition may cause environmental problems, and changes in water condition. Understanding on the dynamics of physical and chemical waters conditions in Bontang city is very important as an effort to address environmental issues as part of coastal zone management and protection. The aim of this research is to understand hydrodynamic characteristics (tide and current) and the influence to distribution of physics and chemical in Bontang waters base on primary data (current and tide during one month, physics and chemicals waters data taken by in situ) and secondary data (bathymetry and tide forecasting). Hydrodynamic simulation is based on MIKE 21 and supported by CD-Oceanography and WR plot. The results show that the current is dominant move toward the Southwest and Northeast with current speed ranged from 0-0.22 m.s^{-1}. The results of hydrodynamic simulation in the surface water show that the current move base on tide movement with current speed ranged from 0-0.24 m.s^{-1}. The results of physic and chemical concentration is analysed by ArcGIS 10 to know spatial distribution of all parameters. Surface temperature ranged from 29-31.8^{o}C, surface density ranged from 20-20.6 ppm, salinity ranged from 33.1-33.5 ppm, dissolve oxygen concentration ranged from 0.078-0.11 ppm. Distribution of all physic and chemical parameters is influenced by current and tide movement.

Keywords: *current, numerical model, water quality, Bontang waters*

Introduction

Bontang geographically located between 117 ° 23' and 117^{o} 38' E and 0° 01' and 0° 12' N, and is located between the Mahakam Delta and Sangkulirang Bay, East Kalimantan. Industrial activities and community settlements in Bontang produce waste and can lead to a decrease in water quality. These pollutants if it is above the threshold in a body of water can cause an ecological imbalance (Zainuri and Evi, 2011).

Some coastal areas in Bontang contaminated heat pollution released from cooling water system of several chemical companies. Exhaust hot water brings a lot of heat energy a large impact on the physical, chemical and biological waters parameters. Hot water flowing from the outlets is a major factor leading to rising sea surface temperatures and potentially interfere biological ecosystems in the region (Suyatna dan Ahmad, 2013).

Bontang waters has a complex ecosystem conditions, the pattern of current flow between islands dynamic and activity in the region has an influence on transport and dynamics of physical and chemical conditions of the waters. According to Ritonga (2013a) Bontang waters is a dumping ground for chemical waste and physics, where the distribution of waste materials is influenced by the pattern of current that moves around Makassar Strait.

An understanding of the condition of waters is very important to reduce the negative impacts that occur in planning for the development of coastal and marine areas. Currents is one component of oceanography, the current measurement is one of the initial steps of monitoring the condition of waters, movement patterns within the scope of the current comprehensive study is to do a collection of field data and using mathematical approach. Modeling their natural state is another alternative that is cheaper and easier to obtain a picture of the distribution both in the present and predictions in the future (Sugianto dan Anugroho, 2007). The purpose of this study is to determine the pattern of ocean currents in the Bontang waters using

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hydrodynamic simulations which were validated with field data for 1 month, and to know how much the dynamics of currents affect the distribution of physical and chemical factors in Bontang waters.

Materials and Methods

Current and tide data were collected in one observation station using Euler method with consideration of the location is not disturbed by the activities of fishermen or vessel. Oceanographic parameters were studied in the form of currents, and tides without regard to the effect of the wind. Measurement of surface current data is performed by the Euler method using the tool ADCP (Aquadopp Profiler - NORTEK) (Table 1) as a tool to gain speed and direction of currents, as well as other parameters such as temperature and tides. The measurement results will be shown in three depths is 5m; 10m; and 15m, this is a practical tool that will easily obtained the data for one month in Bontang

Table 1. Acoustic Doppler Current Profiler Specification

Acoustic frquency	0,6 MHz
Max profil range	30-40 m
Cell zise	1-4 m
Minimum blanking	0.50 m
Max cell	128
Velocity range	± 10 m.s-1
Accuracy	1 % of measured value ± 0,5 cm.s-1
Max sampling range	1 Hz

waters and have Blanking Distance of 0.5 m. ADCP planting sites were in the western part of Bontang waters with a depth of about 20 meters (Figure 1).

Determination of sampling stations based on purposive sampling method which is a method of determining the sampling / data source with a certain consideration (Sugiyono, 2012). There were 5 sampling stations located in the waters around Bontang (Figure 1).

The results of field data collection in the form of currents data were processed using Microsoft Excel software, CD-Oceanography, WR plots and Mike 21 to see the dominance of the direction and speed of currents in the study area. Processing of the data obtained from the survey results in the form of bathymetric data and coastline were plotted using MIKE 21. Set-up of hydrodynamic modeling can be seen in Table 2. Boundary condition was data tidal forecasting results with NAOtide (Figure 2).

Water quality data were collected in situ by by using DKK TOA Water Quality Checker. The parameters were temperature, salinity, density, and DO (dissolve oxygen).

The parameter data retrieval was done on tidal conditions towards Neap Tide without repetitions at each station. The data obtained were processed using software ArcGIS 10 to determine the distribution pattern of each physical and chemical parameters of water.

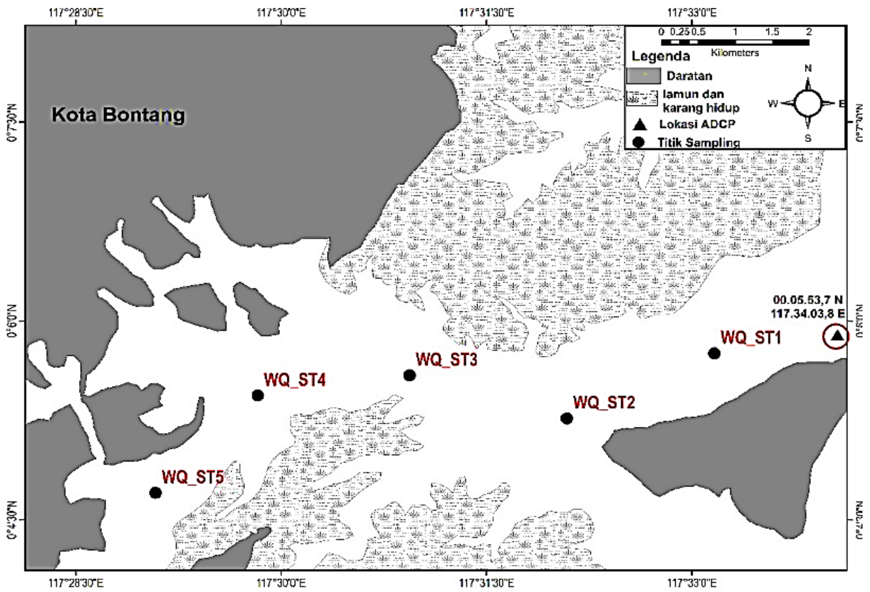


Figure 1. Location of planting ADCP and measurement of in situ data

Table 2. Set-up *software MIKE 21* for hydrodynamic models

Parameters	Applied in simulation
Time Simulation	Number of time step = 4464 Time step interval = 600 detik Start and stop simulation date = 27/06/2015; 09.00 – 27/07/2015; 09.00
Mesh Boundary	Bathymetry = Bathymetry of survey result combined by DISHIDROS Bathymetry data
Flood and Dry	Drying depth = 0,005 m Flooding depth = 0,05 m Wtting depth = 0,1 m
Boundary condition	Tide Forecasting with coordinates: 1. Long : 117.5194, Lat : 0.1149 2. Long : 117.5262, Lat : 0.0878 3. Long : 117.5060, Lat : 0.0601 4. Long : 117.4815, Lat : 0.0618

Results and Discussion

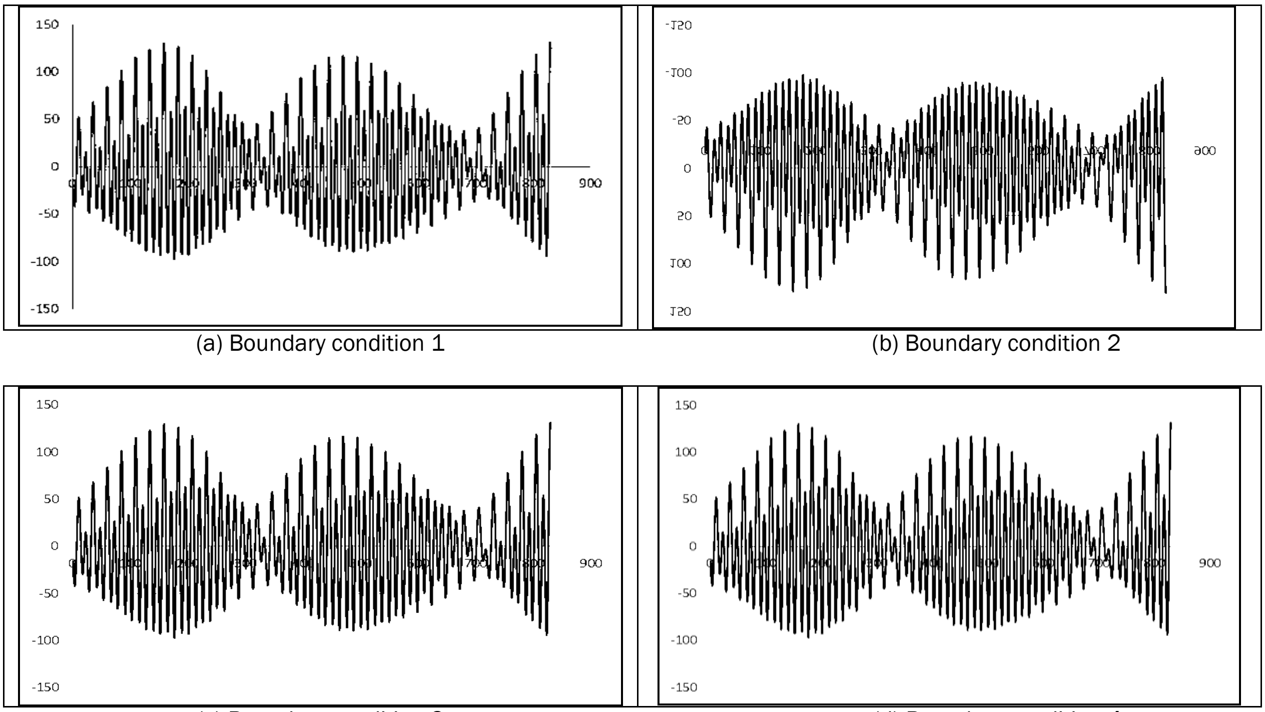
From the processing current data obtained some of the processing results in the form of a scatter plot, stick diagrams, flow velocity vertical profiles, as well as the results of simulation modeling MIKE 21, but in principle to the four types of analysis are the same, which illustrate the direction of the dominant currents in the waters. Bontang waters flow velocity in June-July 2015 ranged from 0 to 4.3 $m.s^{-1}$, the results are within their earlier research by Pranowo *et al*. (2012) which states that the current velocity ranges from 0.01 to 4.4 $m.s^{-1}$, the current conditions are generally caused by the dynamics of sea level elevation is formed and is also affected by the bathymetry conditions.

Results on a scatter plot and stick diagram (Figure 3,4,5) showed that currents in the Bontang waters move to any direction and the velocity decreasing with increasing depth, at any depth direction of current changes meet the rules Ekman spiral. The condition is also influenced by the topography bottom waters and coral and seagrass ecosystems in the waters around Bontang. According to Ritonga (2013b) the existence of a complex ecosystem in the waters, causing the pattern of current flow between islands to be dynamic and activity in the region has an influence on the content of dissolved substances as well as its distribution pattern.

Scatter Plot and diagrams stick also illustrates that the currents in the waters Bontang moves erratically. The movement of currents at a depth of 15 meters (Figure 5) looks more stable due to the influence of friction base and no effects of wind, the depth of the water column is between a depth of 5-10 meters have been seen that the influence of the wind begin to make the current direction into a spread. It appears that the current spread over the Northeast and Southwest because it is influenced by wind and tidal. This is consistent with Wisha *et al.* (2015) who stated that the current movement vertically influenced by factors such as bed stress, wind, and tides.

From the results of measurements of ocean currents can also be seen how the movement vertically at any depth which represents the condition of ups and downs (Figure 6,7,8). Vertical current move is influenced by many factors, in the water column near the base of the movement of currents are not too significant this is caused by the friction base and also the effect of density on the basis of moving current will be limited both by their elementary particles waters, so the speed and energy getting stronger, other than that the density at the base of the higher waters make movement flow becomes blocked, it can be seen in Figure 6 that flows near the base has a weak pace and more regularly. The more upward movement of the starting current is influenced by other factors, such as wind and tide, so that the movement of the flow becomes faster at the surface and there are no more obstacles such as basic friction and density of sea water, this is in accordance with the revelation Wisha *et al.* (2015) that current scaling vertically and horizontally affected by several factors such as, wind, tides, density and resistance base. According to Hoekstra *et al.* (2002) that the drift current in the surface is affected by the monsoon conditions and causing transport of particles suspended high in the territorial waters.

Vertical profile current in the waters Bontang shows that the movement of currents in waters is influenced by many factors, the graph North velocity (Figure 6) shows that current movement is influenced by basic friction, density and wind on the surface, as well as East velocity vertical pattern currents influenced by density and the basic friction. But the speed in the direction V is more stable when compared to the current pattern in the direction U is more moving in all directions starting from the water



(a) Boundary condition 1 (b) Boundary condition 2

(c) Boundary condition 3 (d) Boundary condition 4

Figure 2. Graph of forecasting the ups and downs as a boundary condition modeling MIKE 21

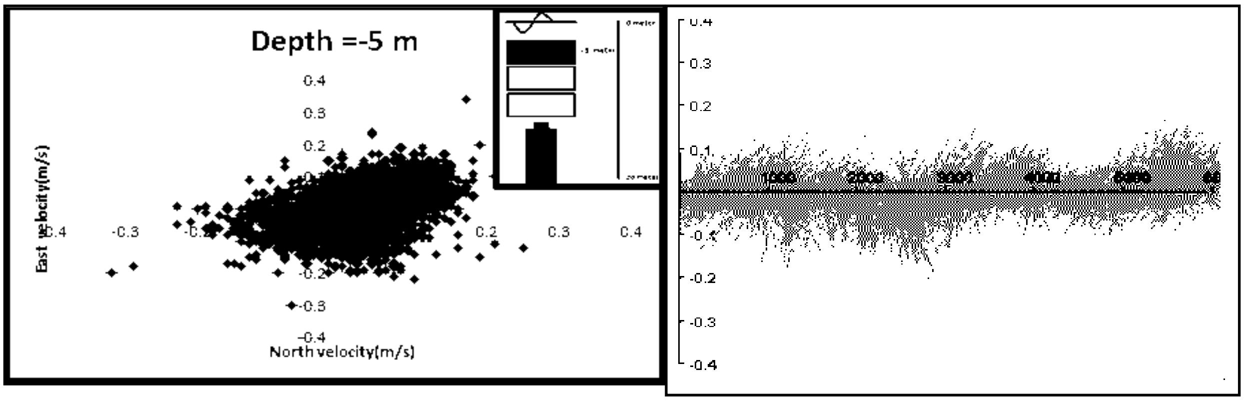


Figure 3. Current profiles in 5 m depth

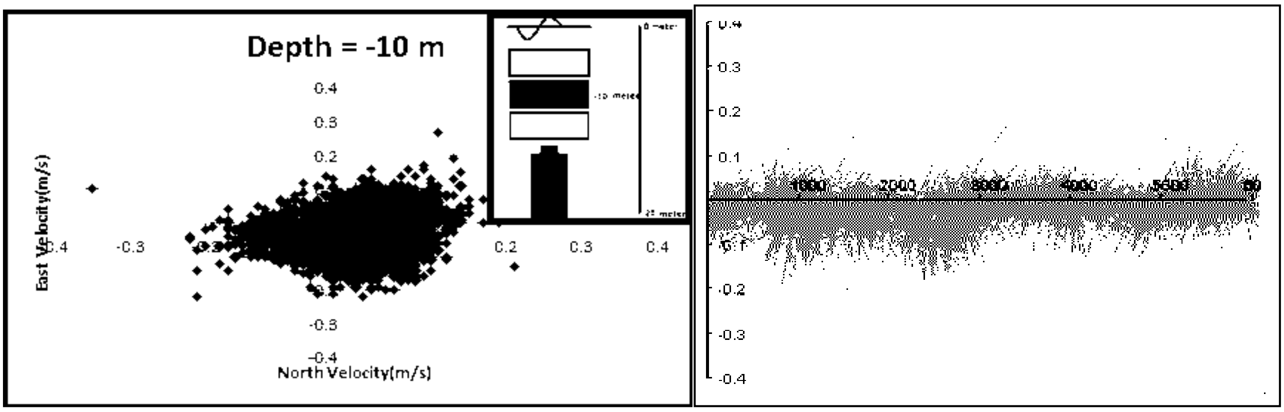


Figure 4. Current profiles in 10 m depth

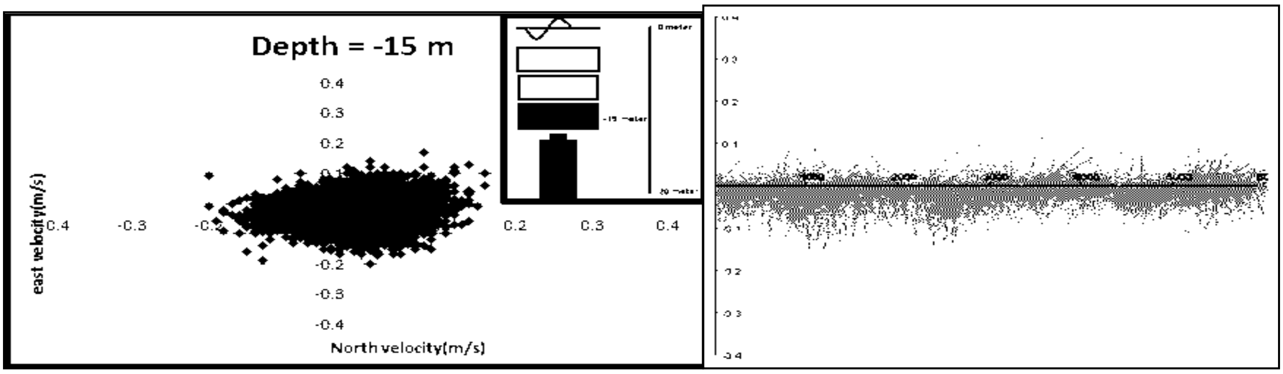


Figure 5. Current profiles in 15 m depth

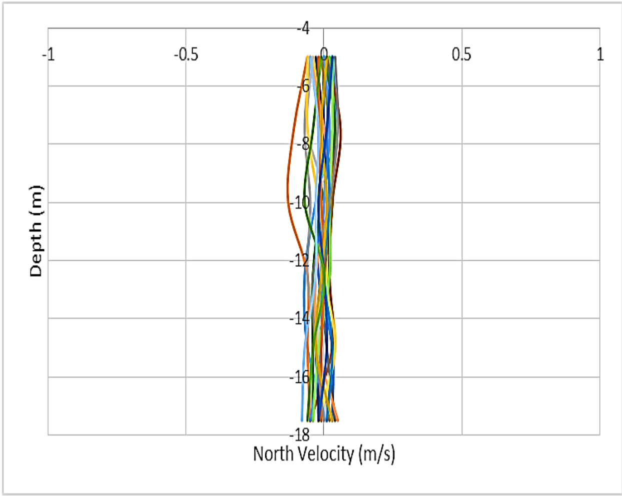


Figure 6. Vertical current profiles in U velocity

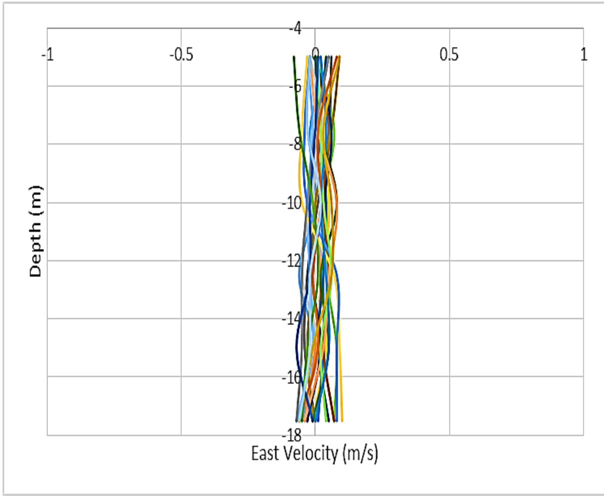


Figure 7. Vertical current profiles in V velocity

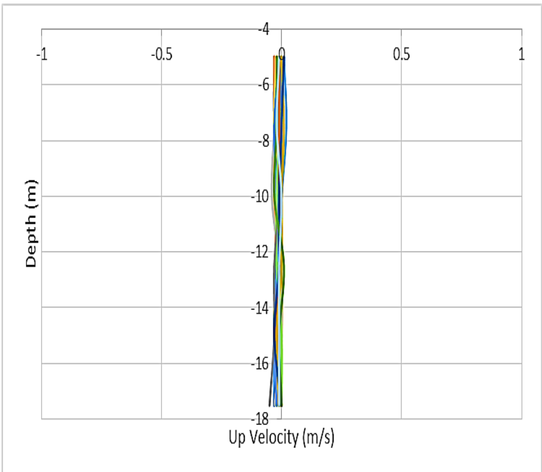


Figure 8. Vertical current profiles in Up velocity

column to the surface, is very different from the graph Up velocity (Figure 8) visible flow velocity at the base is very weak and then move up to the surface with an increasing pace steady, up velocity is influential in the process of upwelling (Hatayama *et al.,* 1996). ADCP currents data are also processed using software WR plot to determine the direction and speed of dominant currents when the survey took place. The dominant current moving towards the Northeast and Southwest with speeds between 0-0.4 m.s^{-1} (Figure 9).

From the results of the hydrodynamic modeling using MIKE 21, the output of the data obtained and the current speed Surface elevation where the data will be verified with measurement data is the data ADCP currents and tides. From the results of the verification shows that the speed graph flow model results and field data are almost identical (Figure 10) and the phase of ups and downs between the data results from modeling and field data is almost the same but at the end of the simulation there is anomaly phase tides for research data in the field, tidal range tend to be more fluctuative, this was due to the influence of wave (Figure 11), according to Triatmodjo (2011) states that the tides coincided with a wave and cause the sea level is going to be relatively unconstant. Error value calculation obtained RMSE values (%) of 11.99%.

The results of the hydrodynamic modeling using Mike 21 shown represent four conditions, namely spring high tide conditions (Figure 12), neap high tide (Figure 13), spring low tide (Figure 14) and neap low tide (Figure 15). All of the modeling results to show the dynamics of ocean currents horizontally to be analyzed influence on the distribution of physical and chemical parameters of waters.

The simulation results when the spring high tide, current direction moving toward to Makassar Strait, and away from the mainland, it is the same as the simulation results during neap high tide, only the speed of the current is just different. At the time of spring high tide flow velocity ranged from 0 to 4.3 m.s^{-1} whereas during the spring high tide flow velocity ranged from 0 to 1.7 ms^{-1}. This is because the conditions at the time of the full forces of attraction between the earth, sun and moon which are in one line straight so that the generation of tidal force becomes bigger and directly affect the speed of the current to be increased in these conditions (Qarnain *et al.,* 2014).

Currents moving northward and moving southward meet in the middle of the waters Bontang this is caused by the presence of horizontal pressure gradients and the influence of the Coriolis force that makes the current direction is deflected to the right in the northern hemisphere. According to Marpaung and Teguh (2014) current movement is

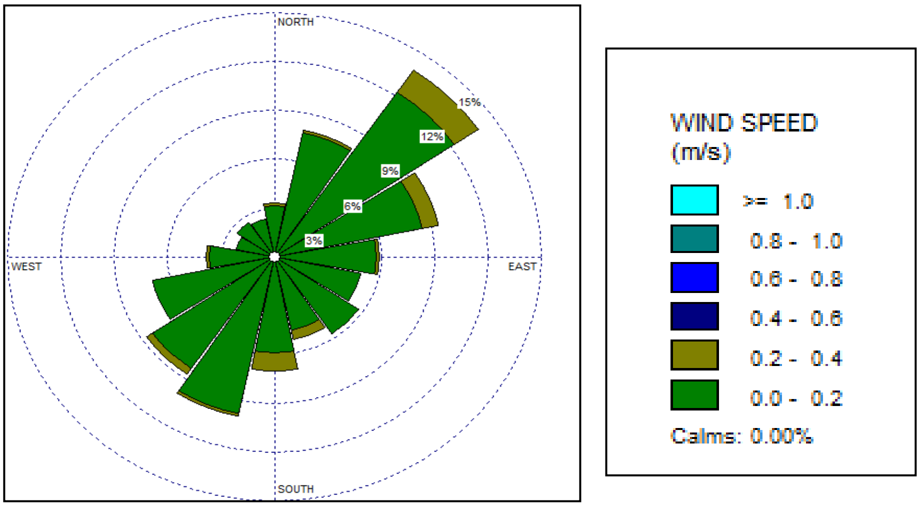


Figure 9. Current speed and direction dominations

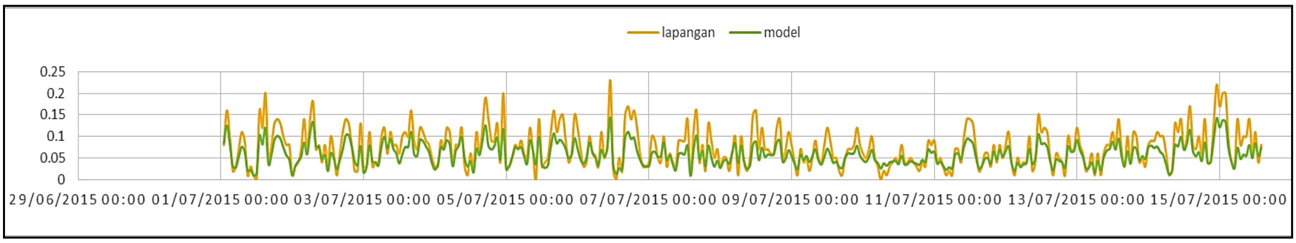


Figure 10. Model Result verifications using sea currents data

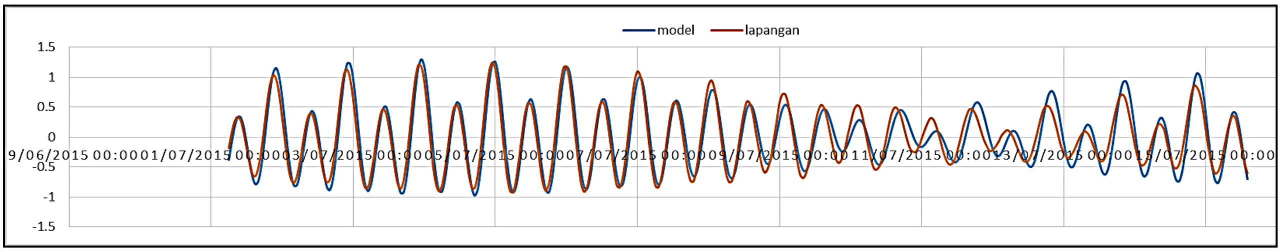


Figure 11. Model result verifications using tides data

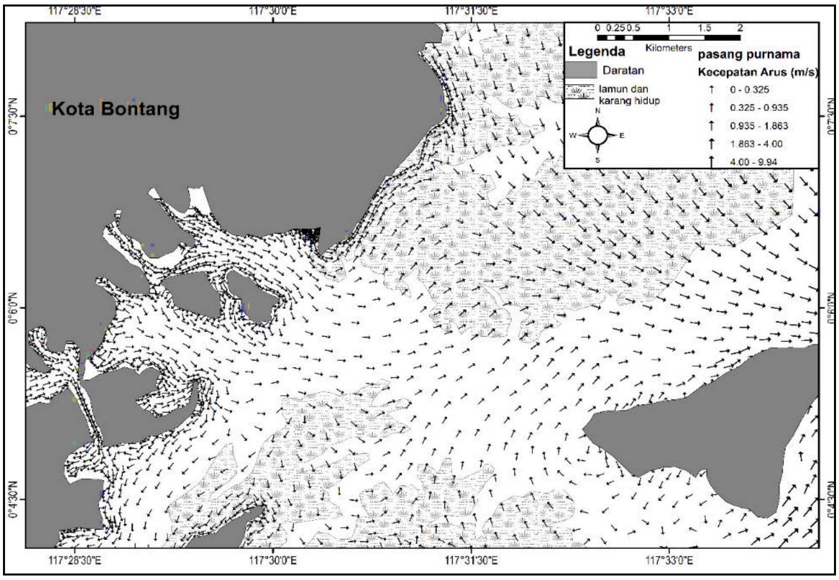


Figure 12. Current dynamics in spring high tide conditions

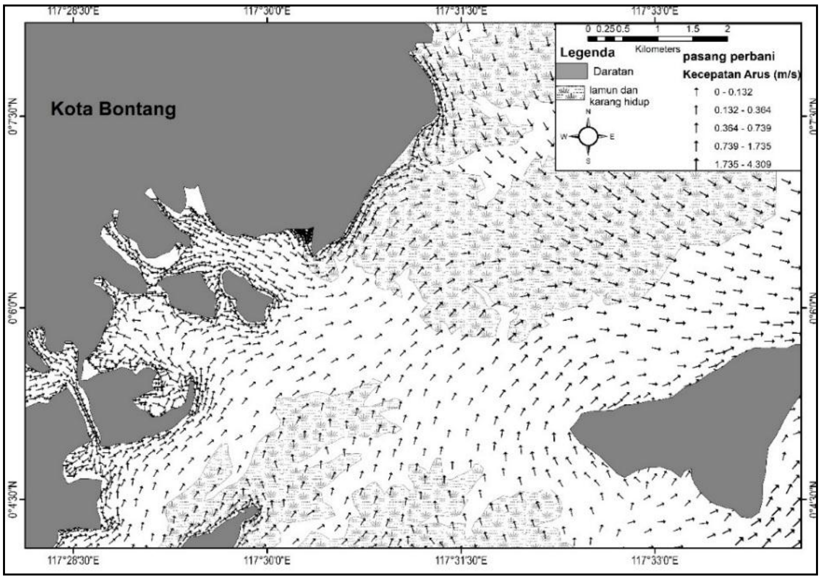


Figure 13. Current dynamics in neap high tide conditons

influenced by the horizontal pressure gradient and direction is influenced by the Coriolis force. The simulation results on the condition of spring low tide is seen that the current direction to move to the mainland, the flow coming from the Makassar Strait, and turn on when it approached the coastal area, where the movements more dominant towards to Southwest. Simulation at spring low tide is not much different, also the dominant current direction towards the Southwest, but with a weaker current velocity. According to Ahmad *et al*. (1995) the current is moving to the West and the currents of the Pacific Ocean to the Straits of Makassar who helped influence on the flow in the waters around Bontang (Rizal *et al*., 2009).

At spring low tide conditions, flow speed range between 0 to 2.9 ms^{-1}, while at neap low tide conditions, current velocity ranged from 0 to 0.8 ms^{-1}, this is happened because at the time of spring low tide occurred highest low water level and influence tidal force so that the tidal range increases and affect the faster flow speed. According to Gordon and Fine (1996) water elevation reached its lowest water level at low tide neap conditions. Current condition (speed and direction) due to tidal condition changes influences distribution and sediment process inside the bay. According to Gordon and Fine (1996), magnitude and direction of tidal residual current flow will determine spread and

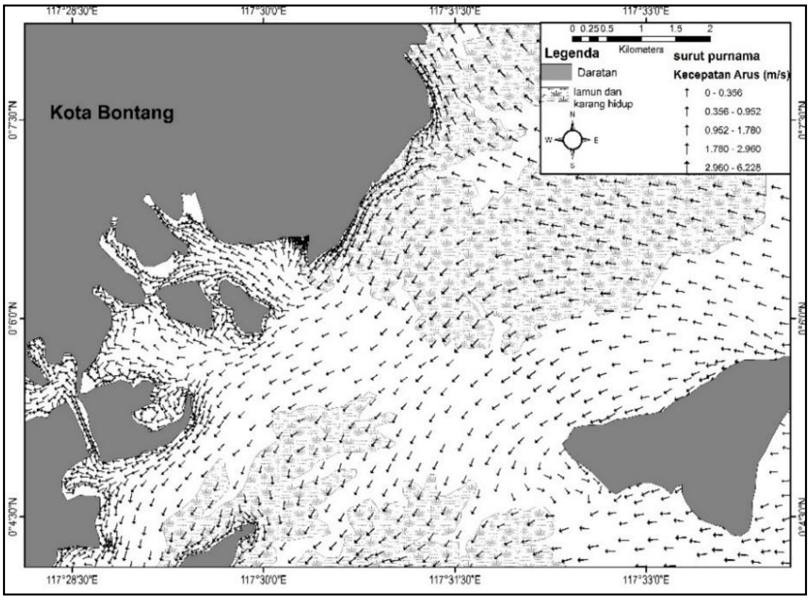


Figure 14. Current dynamics in Spring low tide conditions

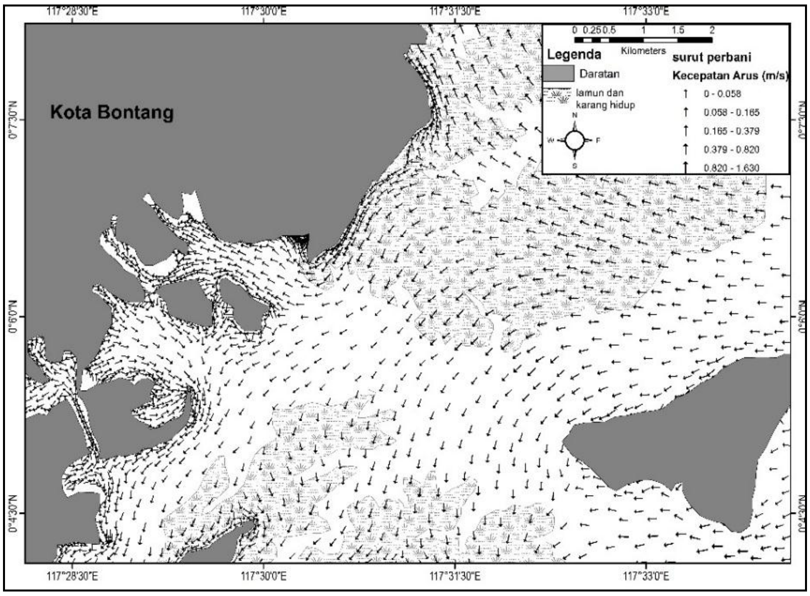


Figure 15. Current dynamics in neap low tide conditions

deposition process of various sediment and fluctuations (high to low water level and vive versa) will be followed by water mass movement (Hatayama *et al.*, 1996).

Sampling physical and chemical parameters of waters carried out during neap low tide water conditions, it can be seen towards the distribution of these parameters are influenced by the current during neap low tide (Wisha and Heriati, 2016). Physical parameters consist of temperature, salinity density, while chemical parameters are the DO concentration that results are displayed in Table 3.

The highest temperature value is in an industrial area close to the port, and the temperature decreases the value of the station away from the mainland. Neap low tide conditions make transport of high temperature becomes blocked, so that sewage residual heat cooling machine will accumulate in the area of disposal, it will affect the biological ecosystems in the region, and can cause coral bleaching due to sea water temperature is too high (Pastorok and Bilyard, 1985). Bontang temperature conditions in waters ranging from 29.5 to 31.8^{o} C. According Zainuri and Evi (2011) temperatures in Bontang waters are generally worth 28 ^{o}C at all locations. These results are very different from the results of a survey that has been done, an increase in water temperature in Bontang, when an increase in temperature of sea water due to the waste industry continues, it can be bad for biological ecosystems in the region (Nurjaya and Surbakti, 2009).

Values measured salinity ranged from 33.2 to 33.5 $^{o}/_{oo}$. The highest salinity value is in Station 1 and 5. It can be seen that the station is near the mainland, so the influence of community activities and also industrial waste disposal of residual heat also affect salinity, rising temperature will lower the salt content in the water. However, the salinity value is decreased when compared to previous studies by Suyatna and Ahmad (2013) which states that the maximum value of salinity in the waters of Bontang is 33.86$^{o}/_{oo}$. According to Supriharyono (2004) the salinity in the waters Bontang ranged from 29.5 to 32.8$^{o}/_{oo}$. This indicates that the salinity concentration increased along with the increase in other physical parameters.

The highest density values were in areas far from the land where the waste exhaust heat industry, because the density values are inversely related to temperature. At station 5 value is the lowest density (Figure 18) while at the same station value is the highest temperature (Figure 16). Density values ranged from 20 to 20.6 kg.m^{-3} and is quite low for a waters, especially in the area of industrial waste.

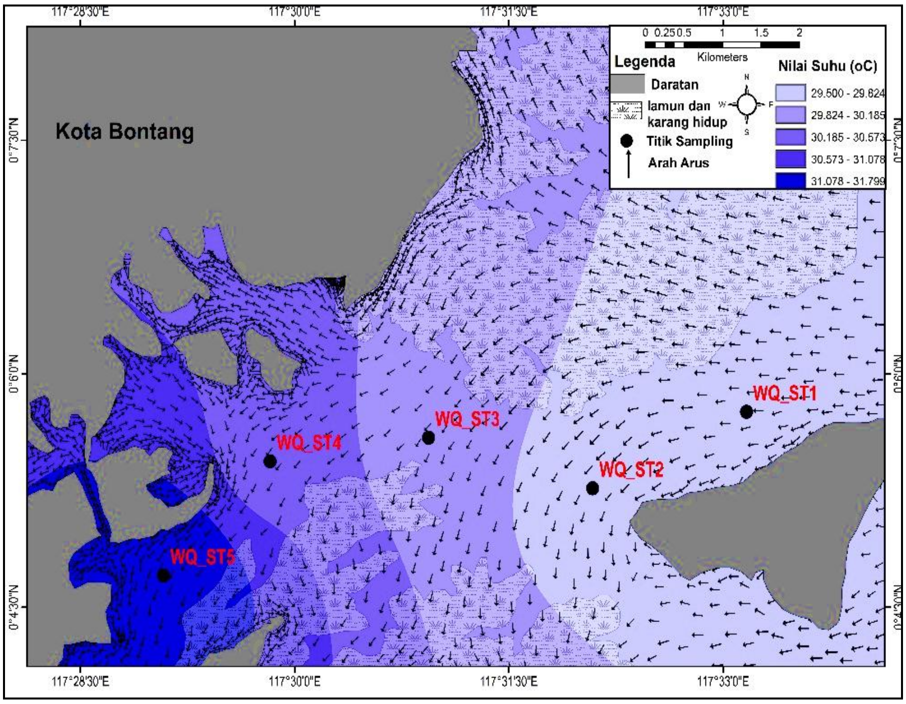


Figure 16. Sea surface temperature distribution in Bontang waters

Table 3. Physical and chemical parameters in each station

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	29.5	29.6	30	30.4	31.8
Salinity (%)	33.4	33.3	33.2	33.3	33.5
Density (kg.m^{-3})	20.6	20.5	20.3	20.3	20
DO (ppm)	7.35	14.8	5.6	8.18	7.92

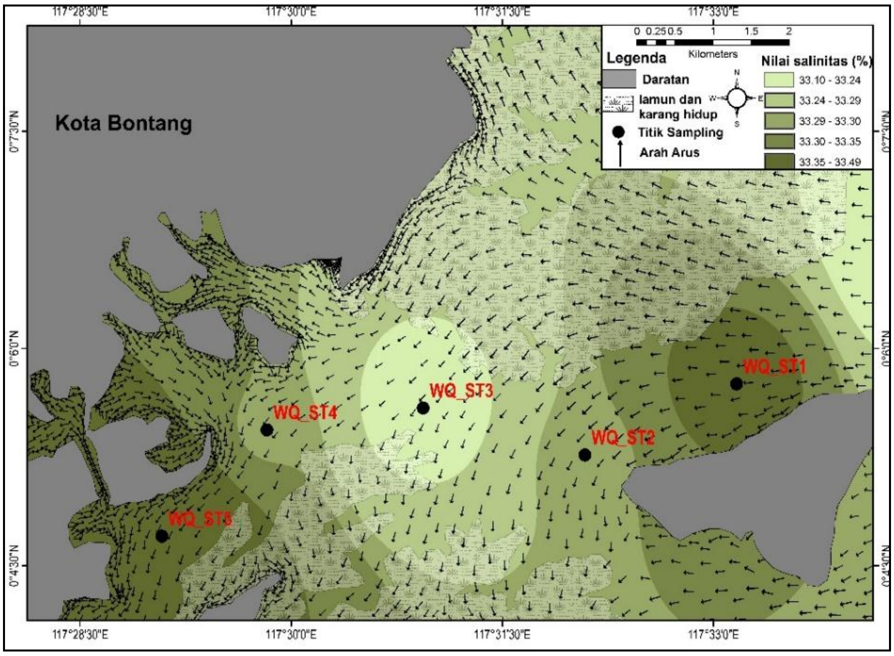


Figure 17. Sea surface salinity distribution in Bontang waters

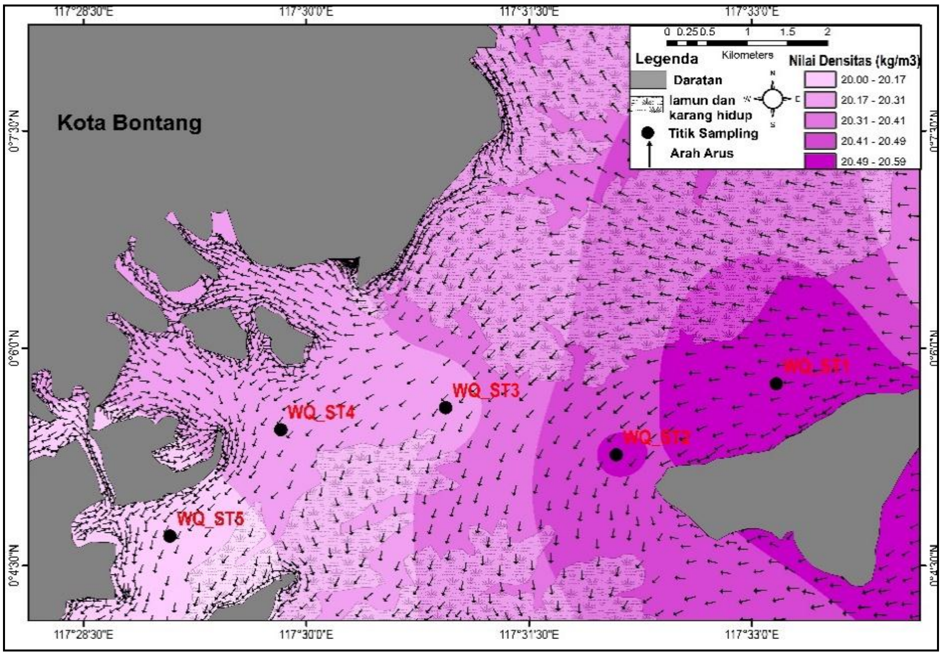


Figure 18. Sea surface density distribution in Bontang waters

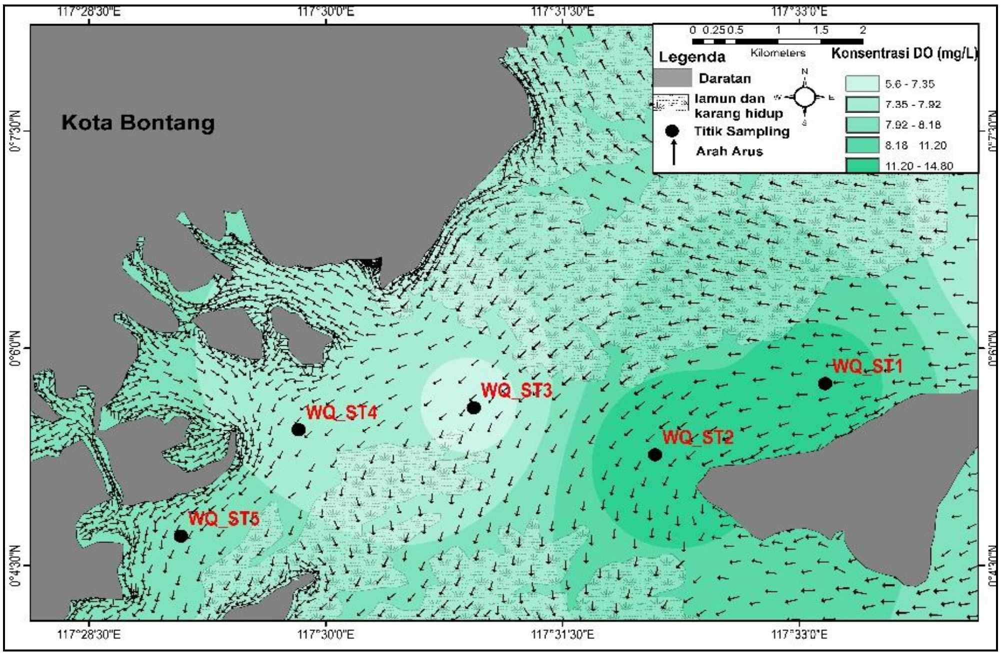


Figure 19. Dissolve oxygen distribution in Bontang waters

Dissolve oxygen concentrations (DO) is very fluktuative, especially at station 2 which has the highest concentration of DO and DO concentration values ranged from 5.6 to 14.8 ppm, the range in contrast to a previous study by Zainuri and Evi (2011) which states that in Bontang waters DO concentrations ranged from 6.10 to 7.67 ppm. An increase in the concentration of DO in the territory indicated that around the station 2 occurs algae blooms, this can lead to a condition anoxyde in the water column so that the water becomes less stable. Temperatures in the lower station 2 also support the condition. According Wisha *et al.* (2014) the effect of temperature, DO, and salinity is very important for the biological processes especially algae.

Conclusion

The dominant current direction in the waters of Bontang in June-July 2015 was vertical toward the Northeast and Southwest, with the speed inversely proportional to the depth of the water. Changes in flow velocity in each layer was caused by the density factor, basic friction, tidal, and surface winds. Hydrodynamic modeling shows that the current is moving back and forth in the waters of Bontang, with speeds ranging from 0.01-4.30 m.s^{-1}. This horizontal movement of the currents also affect physical and chemical conditions of the waters, especially for the parameters of temperature, salinity and density distribution is affected by horizontal flow pattern at neap low tide conditions.

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