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Research paper

The characteristics of current patterns in the waters of port of Tanjung Emas Semarang

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Abstract

The Port of Tanjung Emas Semarang is located in the northern of Java which is regarded as a strategic position to support sea transportation connectivity to Kalimantan. Conducted at the Port of Tanjung Emas Semarang, this research applied exploratory descriptive as the research methodology. Measurements of this research were made by using ADCP (Acoustic Doppler Current meter Profiler) type of Multi Cell Argounaut-XR. The research was carried out in 3 days (January 16th, 2016 – January 19th, 2016). Current velocity data were taken at ± 7 meters depth in five depth strata. The research was aimed to measure the current pattern and distribution of ballast water discharges from commercial vessels at the port. Based on the research, it was found that the current velocity of all water columns in the port varied ranging from 0.042-0.124 m/s with minimum current velocity of 0.0–0.003 m/s and maximum current velocity of 0.139-0.452 m/s. It was also found that the dominant current direction was north and south. It was predicted that the distribution of the ballast water discharges during falling tide (the tide went from high to low) moved from south to north, heading the port exit. In contrast, during rising tide (the tide went from low to high), the distribution of the ballast water discharges moved from north to south, heading the estuary of Baru river.

Keywords: *Port of Tanjung Emas Semarang; ADCP; Current Pattern; Ballast Water Discharges Distribution.*

1. Introduction

North Semarang is a coastal area in northern coast of Java in which an industrial development takes place. The development is supported by the presence of Port of Tanjung Emas in which cargo loading-unloading activities are carried out that the supply of goods hopefuly becomes faster and easier [1]. Located in Central Java Province, precisely at $6^{0}55'52.5''$– $6^{0}58'45''$ S and $110^{0}17'18''$ – $110^{0}29'25''$ E, this port has a strategic position to support sea transportation connectivity to Kalimantan region [2- 4].

Current is defined as water mass movement whose direction is horizontal or vertical. The presence itself is influenced by some factors including resistance, Coriolos force, and density difference [5]. Wind stress on sea surface will give pressure to the surface layer, leading to the condition where the surface layer's movement will push the layer underneath and so forth until surface currents are formed, reaching the depth of 100-300 m. There are three types of tidal currents. The first type is diurnal in which one high and low tide occur each day. The second type is semi-diurnal in which two high and low tides occur each day. The third type is mixed in which two high and low tides of different heights occur each day [6], [7].

Based on the previous studies, it was found that the currents of the port's waters tended to move from west to east with the maximum velocity of 0.3256 m/s [4]. Sea currents in the Port of Tanjung Emas Semarang were dominated by tidal currents whose directions were north and south, with minimum and maximum velocity of 0.016 m/s and 0.638 m/s and the average velocity of 0.279 m/s [3]. The waters of North Semarang are categoried as shallow waters which range between 0-5.147 m depth with a nearly flat bottom [1]. Based on the research, it was found that Genuk waters in North Semarang had tidal current of 88.84%, residual current of 11.16%, and the distribution pattern heading away from the coast. This condition more or less had affected the water quality in the Port of Tanjung Emas Semarang [8]. The abrasion occurred on the coast of Sayung and the accretion on the coast of Kendal which had showed the dynamics of sedimentation required attentive attention and solution from the authority of Port of Tanjung Emas Semarang [9]. Hydro-oceanographic conditions are importantly required in order to identify what effects they could possibly have on the vessels movement when entering the port waters [10].

Ballast water is defined as sea water which is used for the stability of commercial vessels when they are not loaded, which is then discharged in a loading port. Research conducted at the Jakarta Inaport 2nd port showed that the ballast water discharges reached 47,552.25 tons in 2016 [11].

Based on the above researches, a survey focusing on current pattern is needed in order to determine the direction of ballast water discharges of commercial vessels in the Port of Tanjung Emas Semarang.

2. Materials and methods

In this research, exploratory descriptive research method was applied. This research method is intended to identify causes or factors which influence the occurrence of some phenomena [12]. This research belongs to a qualitative research which characterized by: (1) inductive reasoning (empirical-rational or bottom-up), (2) a developing research design, (3) researchers are are also positioned as data collectors, and (4) research findings are in the form of descriptions in the context of a certain time and situation [13]. In this research, measurements were made using ADCP (Acoustic Doppler Current meter Profiler) type of Multi Cell Argounaut-XR. The measurement was carried out in 3 days (January 16th, 2016 – January 19th, 2016). The measurements included current velocity, direction, and tides. The research was conducted at $6^0$55'54.1" S and $110^0$25'8.4" E. The current velocity measurements were carried out in ± 7 meters depth. The measurements were done at five depth strata: (1) 0.0-1.2 meters depth; (2) 1.2-2.4 meters depth; (3) 2.4-3.6 meters depth; (4) 3.6-4.8 meters depth, and (5) 4.8–6.0 meters depth. The measurements were proceeded in 3 x 24 hours at 10 minutes intervals. This measurement was done in concurrently with tidal measurements in order to determine the current depth.

According to the data on current velocity which were measured by ADCP, the average velocity at each measurement location was calculated [14]:

$$V_i = \sum_{j=1}^{3} \frac{1}{4} (V_{0.h} + 2V_{0.6h} + V_{0.8}) I \quad (1)$$

Where, $V_{0.2h}$, $V_{0.6h}$, and $V_{0.8h}$ were current at the surface, middle, and bottom depth. Current velocity and direction were presented in graphs, scatter plot, current rose, and current distribution.

In this research, data source used for modeling included: (a) bathymetry data taken from Hydro-oceanography service of Indonesian Navy in Tanjung Emas Semarang; (b) tidal observations during field survey; dan (c) tide data of Semarang waters obtained from Hydro-oceanography Service of Indonesian Navy in 2015.

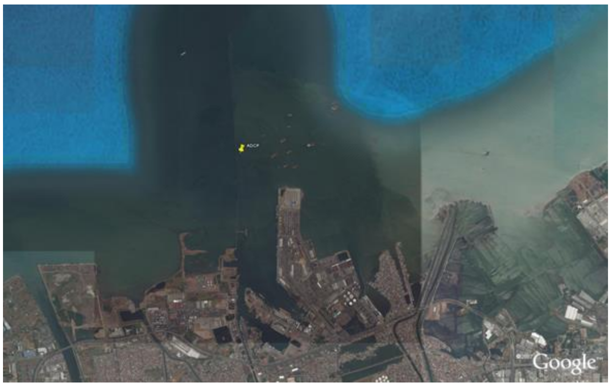

Fig. 1: Location of Measurements Process in the Port of Tanjung Emas Waters
(Source: Google Earth, 2016)

The software used in the current modeling was SMS (Surface–water Modeling System) 8.1 using ADCIRC module for hydrodynamics. The size of the modeling grid for the coastal area was 25 meters and the size of the modeling grid for the sea boundary was 500 meters. The depth of waters for the modeling area ranged from 0-12 meters. The modeling was done with a time step interval of 1 hour and a total time step of 360 hours or 15 days.

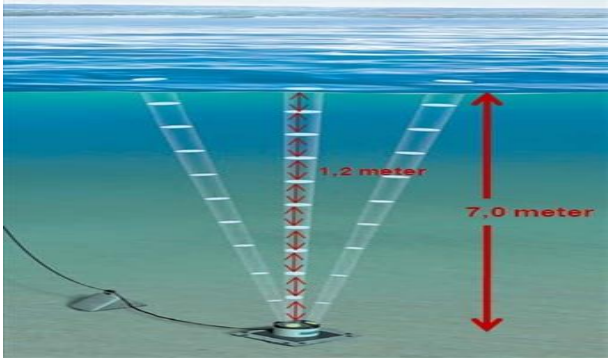

Fig. 2: Illustration of Data Recording on Current Velocity and Direction Using ADCP.

The distribution of ballast water discharges from commercial vessels was determined using Wolinsky formula [15]:

$$D = C \times Q \times z \quad (2)$$

Where, C = maximum current velocity in West Season, Q = multiplier factor based on tides (24/2 x 3600), z = drift constant.

3. Results and discussion

3.1. Results

Based on analysis, several findings were obtained. First, current velocity varied that the average velocity in all water columns ranged from 0.042-0.124 m/s with the minimum current velocity of 0.0–0.003 m/s and and the maximum current velocity of 0.139-0.452 m/s. The highest current velocity at the average depth was 0.118 m/s with an average velocity of 0.038 m/s. The highest current velocity at depth stratum1 (4.8-6.0 meters) was 0.188 m/s with an average velocity of 0.069 m/s. The highest current velocity at the depth stratum 2 (3.6-4.8 meters) was 0.182 m/s with an average velocity of 0.045 m/s. The highest current velocity at depth stratum 3 (2.4-3.6 meters) was 0.139 m/s with an average velocity of 0.042 m/s. The highest current velocity at depth stratum 4 (1.2-2.4 meters) was 0.291 m/s with an average velocity of0.05 m/s. The highest current velocity at depth stratum 5 (0.0-1.2 meters) was 0.452 m/s with an average velocity of 0.124 m/s (Fig.3).

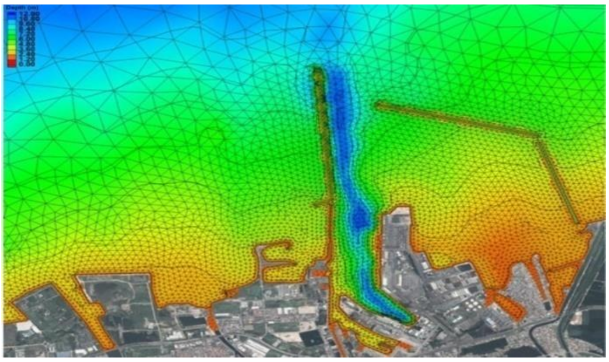

Fig. 3: Modeling Current Grid.

The direction of the dominant current at the observation point was north and south. The direction of dominant currents at the average depth was north and south with the frequency of occurrence reaching 26.68% and 24.83%. The dominant current velocity was > 0-0.05 m/s with an occurrence frequency of 81.67%. The maximum velocity which occurred reaching > 0.1-0.15 m/s with the occurance frequency of 1.39% (Fig.4).

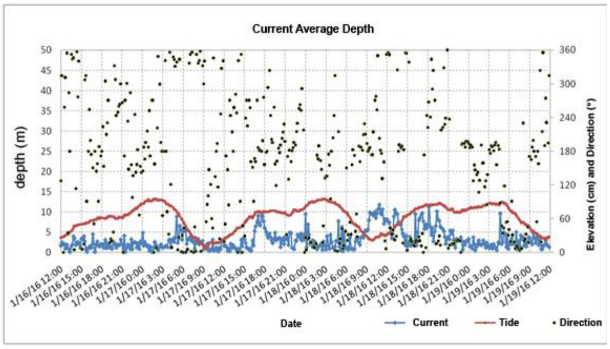

Fig. 4: Current Velocity at the Average Depth.

The direction of the dominant current at the depth stratum 1 (4.8-6.0 meters) was south with the occurance frequency of 24.59 %, the dominant current velocity of > 0–0.05 m/s and the occurrence frequency of 38.28 %. The maximum velocity was > 0.15-0.2 m/s with the frequency of 4.18% (Fig.5).

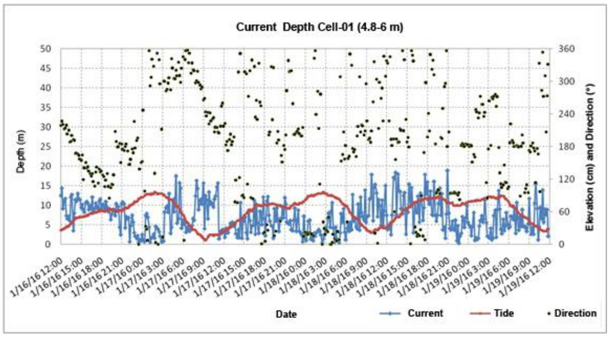

Fig. 5: Current Velocity at Depth Stratum 1 (4.8-6 m).

The direction of dominant currents at the depth stratum 2 (3.6-4.8 meters) was north and south with the frequency of occurrence reaching 28.77% and 27.15%. The dominant current velocity was > 0–0.0 5 m/s with the occurrence frequency of 65.20%. The maximum velocity was > 0.15-0.20 m/s with the occurance frequency of 0.46% (Fig. 6).

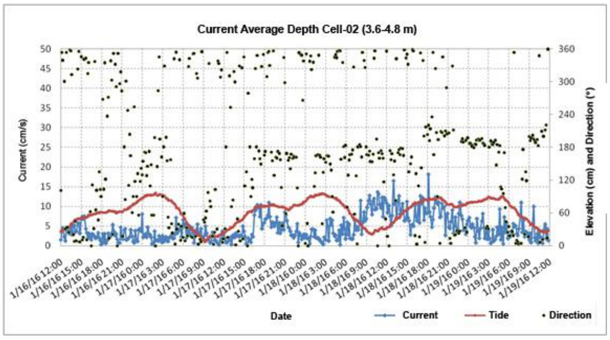

Fig. 6: Current Velocity at Depth Stratum 2 (3.6-4.8 m).

The direction of dominant current at depth stratum 3 (2.4-3.6 meters) was north and south with the frequency of occurrence reaching 29.47% and 21.58%. The dominant current velocity was > 0 – 0.05 m/s with the occurrence frequency of 68.91%. The maximum velocity was > 0.1-0.15 m/s with the occurance frequency of 8.12% (Fig. 7).

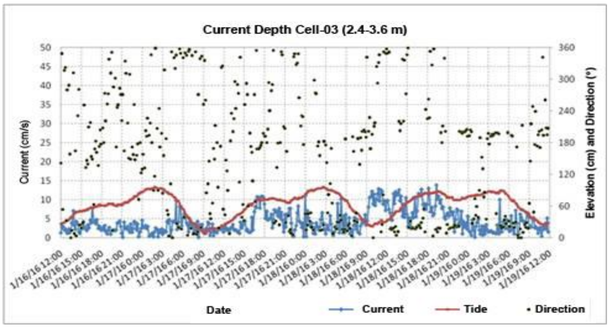

Fig. 7: Current Velocity at Depth Stratum 3 (2.4-3.6 m).

The direction of the dominant currents at depth stratum 4 (1.2-2.4 meters) was north and south with the frequency of occurrence of 24.59% and 18.33%. The dominant current velocity was > 0 – 0.05 m/s with the occurrence frequency of 64.50%. The maximum velocity was > 0.25-0.3 m/s with the occurance frequency of 23% (Fig.8).

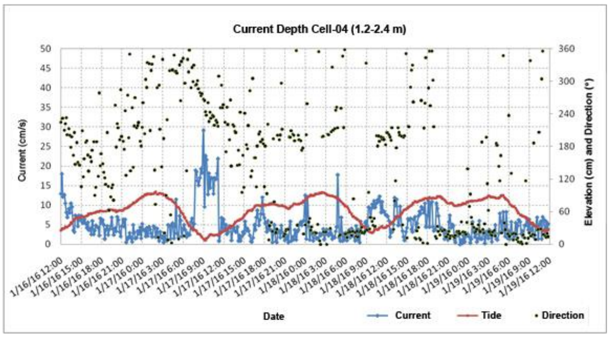

Fig. 8: Current Velocity at Depth Stratum 4 (1.2-2.4 m).

The direction of the dominant currents at depth stratum 5 (0.0-1.2 meters) was north and south with the frequency of occurrence of 16.24% and 32.48%. The dominant current velocity was > 0 – 0.05 m/s with the occurrence frequency of 35.96%. The maximum velocity was > 0.3 m/s with the occurance frequency of 12.76% (Fig.9).

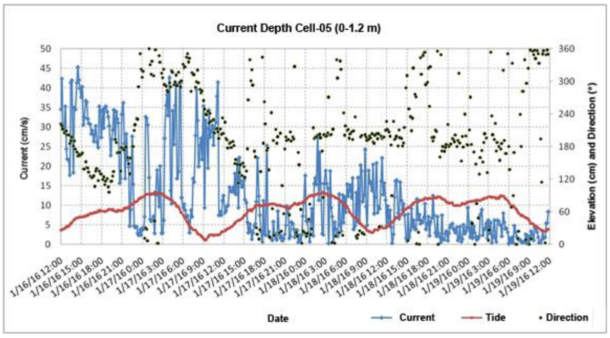

Fig.9: Current Velocity at Depth Stratum 5 (0.0-1.2 m).

Based on the findings presented on the scatter plots, the current direction moved to all directions with north and south as the more dominant directions. The movement of the current occured at all depth strata. Thus, it can be said that the velocity and direction of the current was dominated by tidal factors. Moreover, the velocity at the depth stratum 5 (0.0-1.2 meters) was influenced by non-tidal factors, one of which was wind (Fig.10).

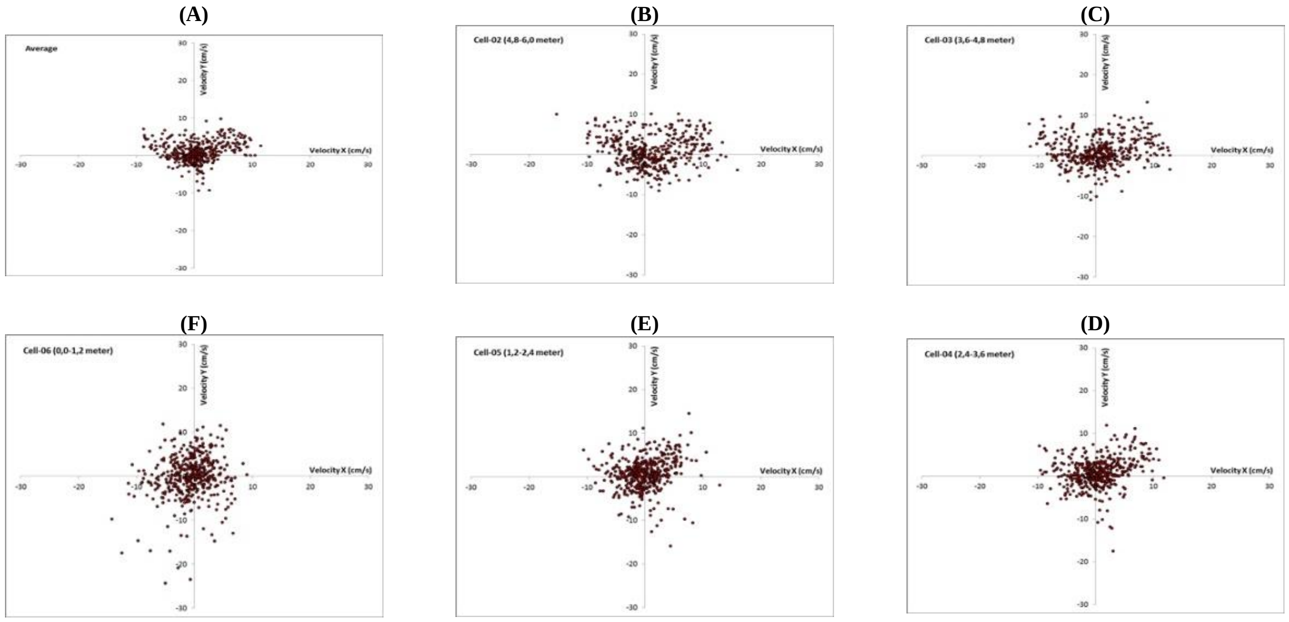

Fig. 10: Scatter Plot of Current Velocity: A) Average Depth, B) Depth Stratum 1 (4.8-6.0 m), C) Depth Stratum 2 (3.6-4.8 m), D) Depth Stratum 3 (2.4-3.6 m), E) Depth Stratum 4 (1.2-2.4 m), F) Depth Stratum 5 (0.0-1.2 m) (Clockwise, from Top Left to Bottom Left).

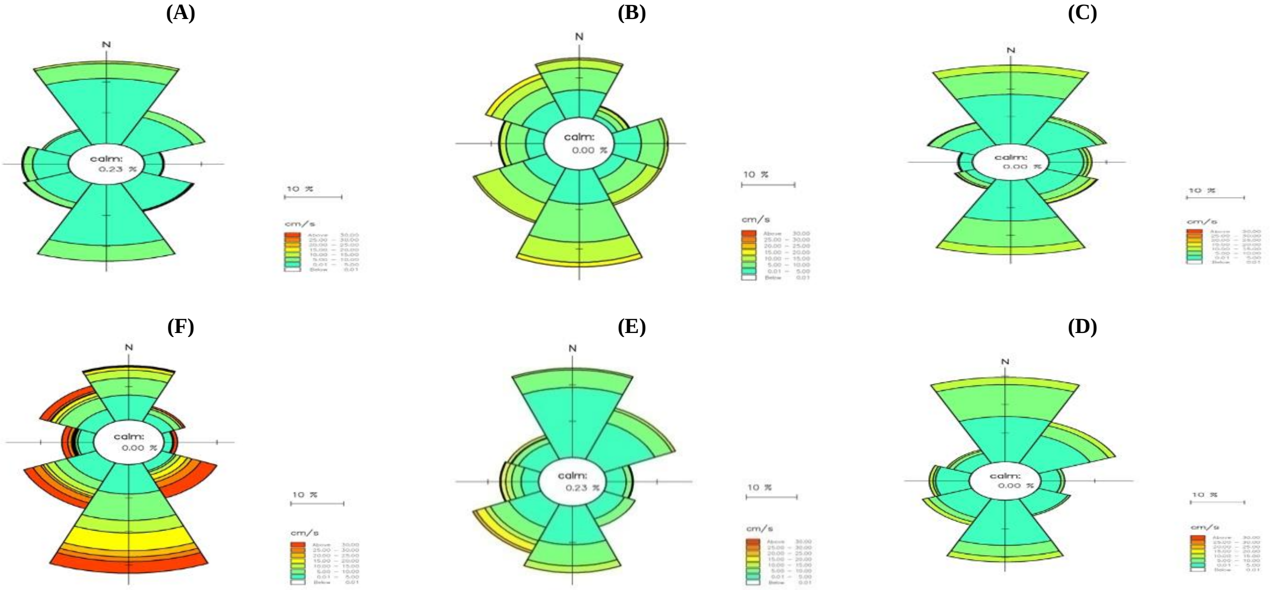

Fig. 11: Current Rose at: A) Average Depth, B) Depth Stratum 1 (4.8-6 m), C) Depth Stratum 2 (3.6-4.8 m), D) Depth Stratum 3 (2.4-3.6 m), E) Depth Stratum 4 (1.2-2.4 m), F) Depth Stratum 5 (0.0-1.2 m), (Clockwise, from Top Left to Bottom Left).

Based on the current modeling during falling tide (tide went from high to low), it was found that the current velocity ranged from 0.01-0.4 m/s. The frequency of the current direction was dominantly from east to west. Current velocity in Baru river ranged from 0.01-0.10 m/s heading north. Current velocity at outer port, inner port, and Nusantara pier ranged from 0.01-0.10 m/s heading southwest. Current velocity at Samudera pier and container pier ranged from 0.01-0.10 m/s whose direction heading north. Current velocity at the west of wave barrier area ranged from 0.08-0.30 m/s with movement heading west. Current velocity at the north of the wave barrier (port exit) ranged between 0.08-0.30 m/s whose direction varied from northwest to west (Fig.12).

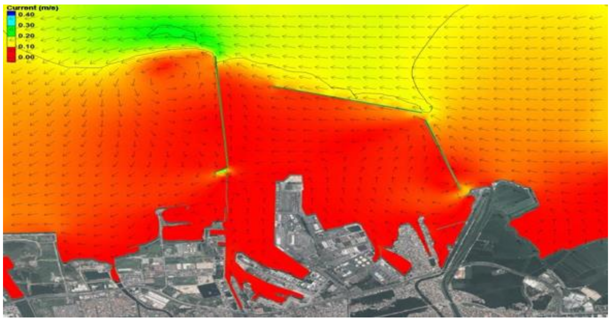

Fig. 12: Map of Current Patterns During Falling Tide at the Port of Tanjung Emas Semarang.

During the rising tide (the tide went from low to high), the current velocity in Semarang waters ranged from 0.01-0.4 m/s. The frequency of current direction in Semarang waters ranged from 0.1-0.4 m/s. The frequency of current direction during rising tide was dominantly from west to east. Current velocity at Baru river ranged from 0.01-0.1 m/s heading south. The current velocity at the outer port, inner port, and Nusantara pier ranged from 0.01-0.1 m/s heading southeast. The current velocity at Samudera pier and and container pier ranged from 0.01-0.1 m/s heading south. The current velocity at the west of wave barrier area ranged from 0.08-0.3 m/s whose direction heading east. The current velocity at the north of wave barrier area (port exit) ranged from 0.08-0.3 m/s with direction going to northeast and southeast (Fig.13). The direction of this current was in accordance with West Season which could be identified by the existance of water current heading from north through the northern of China Sea, Java Sea, and Flores Sea moving over Java island waters from west to east [16].

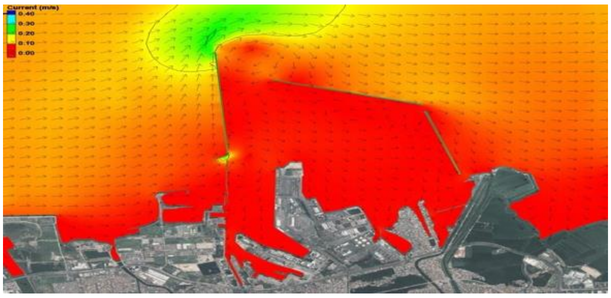

Fig. 13: Map of Current Pattern During Rising Tide at the Port of Tanjung Emas Semarang.

Prediction of the distribution of ballas water discharges from commercial vessels during falling tide was as follows: the maximum velocity of 0.452 m/s, tidal pattern of Q = 12 x 3600, and the drift constant value (z) of 0.75 meant that D = 0.452 x 12 x 3600 x 0.75 = 12,960 meters or 12.96 km from the commercial vessels. The ballast water discharges moved from south to north heading the port exit. On the other hand, the distribution of the ballast water discharges during rising tide moved from north to south (heading the mainland) or towards Baru river estuary. If the commercial vessel discharged its ballast water 1.2-2.4 meters below the water surface, the distribution of would be 6285.6 meters or 6.286 km (Fig.14).

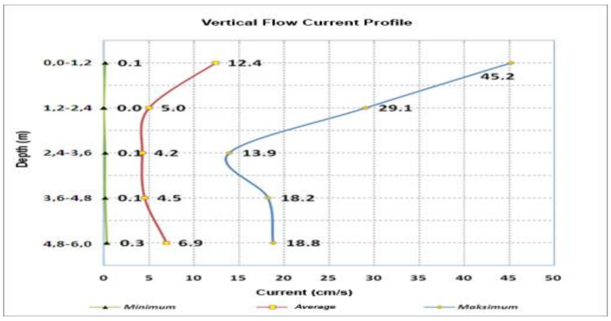

Fig. 14: Profile of Maximum, Minimum, and Average Current Velocity.

3.2. Discussion

The findings of this research were in accordance with the previous research which said that ocean currents were dominated by tides heading north and south whose lowest sea current velocity reached 0.016 m/s and the highest was 0.279 m/s. By the completion of the second phase development of the port, there will be an increase and change in the currents direction [3]. Current movements at the bottom of port waters dominantly headed east and west with the frequency of 18.4% and 18.2%. On the other hand, in the middle of the port waters, the currents headedwest and east with the frequency of 18.2% and velocity ranging from 0.003-0.112m/s [17].

It was also found that sediments at Semarang-Demak waters were dominated by sand with a concentration of 50% -95.55%. Thus, the distribution of sediment in the port ponds was dominated by silt reaching 70.74% which get in closer to the port [18,19]. The concentration of silicate at high tide was lower than the concentration at low tide [20]. This condition indicatesthat if ballast water discharges were found in port ponds, the concentration of discharges would be greater at low tide than at high tide.

The distribution of discharges was influenced by currents, water depths, and the wind direction [21]. Type of tide occurred in the port of Tanjung Emas Semarang was diurnal which would give no effect on the vessels. However, the current velocity was the one needed to be aware of. Thus, vessels of > 500 GT (Gross Tonnage) must be vigilant during low tide [22]. Sedimentation will occur at the west of breakwater base if reclamation is performed. Thus, the current becomes very slow to less than 0.1 m/s. However, 22 ha of the reclamation would not significantly affect the current pattern [23].

4. Conclusions

Based on the research, the current velocity varied. The average velocity at all water columns ranged from 0.042-0.124 m/s; the minimum current velocity was 0–0.003 m/s; and the maximum current velocity was 0.139-0.452 m/s. The current direction at the observation point was dominantly north and south. The current direction at the average depth was north and south with the frequency of occurrence of 26.68% and 24.83%. Based on the data analysis at all depths presented on scatter plots, the currents moved to all directions. However, the dominant movement was to north and south. The current movement occurred at all depths. Thus, it can be said that the velocity and direction of the current were dominantly affected by tidal factors. However, the condition at the depth stratum 5 (0.0-1.2 meters) was influenced by non-tidal factors, one of which was wind.

According to the analysis, the current modeling during falling tide indicated that the current velocity in Semarang waters ranged from 0.01-0.4 m/s. The current direction frequency was dominated by ones which moved from east to west. During rising tide, the current velocity in Semarang waters ranged from 0.01-0.40 m/s. The current direction frequency of this rising tide was dominantly from west to east. The distribution prediction of commercial vessels's ballast water discharges during falling tide moved from south to north heading the port exit. On the other hand, the distribution during rising tide moved from north to south (heading the mainland) or towards the estuary of Baru river.

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