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Modeling sea currents in working environment area of Parit Rempak Karimun port

Eny Budi Sri Haryani[1,*], Syofyan Hasan[2], Andika Bayu Candra[2]

[1]Marine Engineering Study Program, Faculty of Transportation and Logistics Engineering, Trisakti Institute of Transportation and Logistics, Jakarta 13410, Indonesia.
[2]Directorate General of Marine Spatial Planning Management, Ministry of Marine Affairs and Fisheries, Jakarta 10110, Indonesia

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ABSTRACT

Sea currents is an important indicator, especially if permanent infrastructure to be built in waters area. Based on Government Regulation No. 21/2O21 Regarding the Implementation of Spatial Planning, it is mandatory to have licensing for Sustainability of Marine Spatial Utilization Activities (SMSUA). Therefore, Karya Karimun Mandiri Company collaborated with authors to conduct this research at Parit Rempak port. This research only focus to sea current and aims to determine the existing conditions of sea currents and their modeling in planned location for construction of LPG-GFS jetty pier. The analysis includes surface current conditions, sea currents based on NOAA data, sea current rose directions, sea current modeling, bathymetry maps and sediment condition, which use primary and secondary data. Primary data was measured at 6 research stations, which were then analyzed using Mike 21 software. The research results showed that: (a) existing conditions surface current speed at high tide ranges from 0.0 to 0.83 m/s towards the east, at low tide it ranges from between 0.07 to 0.64 m/s towards the west; (b) based on NOAA data, sea currents at research location move relatively regularly and in a direction towards southeast, which were speed of sea currents varies according to season, with a range of 0.0 m/s to 0.125 m/s, non-tidal so it is relatively not turbulent; (c) sea current modeling that maximum current speed is 0.25 m/s and minimum current speed occurs at highest tides and lowest low tides, with direction of current movement to southwest and northeast; (d) bathymetric conditions with a depth between 0-5 meters, constitute shallow water and sediment consist of mud, muddy sand and gravelly sand, are safe for building a LPG-GFS jetty pier. Based on the conditions of sea currents and data above, SMSUA permits is eligible to be granted and must be issue

Introduction

Karimun is one of the regency in the Riau Islands Province of Indonesia. This regency has an area of 7,984 km², with a land area of 1,524 km² and sea area of 6,460 km², so the area is dominated by the sea, because the area is an archipelago. There are 198 islands in Karimun Regency, of which 67 are inhabited. In year of 2020, the total population is 257,297 people, with a population density of 281.81 people/km² (Wikipedia, 2024).

The population of Karimun Regency is increasing and with the government's policy to shift the use of gas fuel, the price of LPG gas is getting more expensive. So that the retail price becomes high, which is due to the transportation of LPG gas to Karimun Regency using sea transportation is very far, because LPG gas filling stations are not yet available in Karimun Regency. So it is planned to build an LPG gas filling station (LPG-GFS) in the working areas of Parit Rempak port of Karimun (Karya Karimun Mandiri Company, 2022).

The construction is in the form of a mooring pier and berthing for ships carrying LPG gas, with a dolphin pier type, which is located in the Parit Rempak port area on sloping coastal waters. The length of the pier to be built is ± 40 meters, from the beach with a width of ± 26 meters. The construction uses a mooring dolphin, which functions as a ships mooring anchored to the pier so that they do not move far from port when receiving forces (Simamora, 2023).

Furthermore, for the construction of the pier, hydro-oceanographic data is required. This data is used to prepare a proposal of a licensing for

* Corresponding author.
Email address: eny.bs_haryani@yahoo.com

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Suitability of Marine Spatial Utilization Activities (SMSUA) to the Ministry of Maritime Affairs and Fisheries of Indonesia. Some of the data used for the permit process is sea current (Ministry of Marine Affairs and Fisheries, 2021).

As is known, currently the Ministry of Marine Affairs and Fisheries is very orderly in providing permits for the use of marine space (SMSUA) with quite strict requirements. Therefore, the LPG-GFS development plan must obtain this permit and of course must be carried out with caution. Moreover, the Karimun area is also inhabited by fishermen, there are fishing areas in the waters. As is the experience of managing the Gulf of Northern California, Mexico, the application of marine spatial and non-spatial is combined. Two spatial management tools, using a spatial priority approach, combined with a permit regularization process, non-spatial quota prioritization, and trade-off analysis in a new way, were found to be very effective in being implemented there (Morzaria-Luna et al., 2020). Things like this are also being implemented in Indonesia currently, through the granting of permits SMSUA for marine spatial utilization (Goverment of Indonesia, 2021).

Although in fact there are many things that need to be considered in applying marine spatial considerations in integrated coastal and ocean management, such as how the multi-dimensional social sustainability interacts with each other, as well as with economic and environmental aspects of planning and managing marine areas. There needs to be an emphasis on how developing marine spatial planning can also be carried out in a socially sustainable manner (Flannery *et al*., 2020; Gilek *et al*., 2021). Based on statutory regulations related to marine spatial planning, fortunately in Indonesia, social sustainability has also been taken into consideration in granting permits for marine spatial utilization (Ministry of Marine Affairs and Fisheries, 2021).

Next, to fulfill the licensing process (SMSUA), let's look at the important data that must be provided. According to Haryani *et al* (2021) that currents and waves are important aspects for coastal area management. Irawan (2018), sea currents and waves are important parameters in water dynamics that influence changes in coastal and marine areas. Those parameters also important for determining whether a water location in the sea is suitable or not for LPG-GFS or permanent infrastructure to be built. Especially if it is to be built in a port environment where there is already existing infrastructure, then it is important to be careful so as not to affect port performance (Zhuang *et al*., 2022). Therefore, permanent infrastructure development, by utilizing sea space, will affect current and wave patterns, which if not adjusted will result in damage to surrounding buildings, or can even damage the balance of the surrounding environment (Özkan, 2018).

This research focuses only on discussing sea currents around the research location. Sea currents are the flowing movement of a water mass caused by wind gusts, density differences, or the movement of long waves. Sea currents are widely used for various purposes that support human life. Various technologies have also been developed to detect sea currents, for example in the Persian Gulf in the Oman Sea, with technology combining satellite data and hydrographic observations. Currently this is often done in Indonesia by modeling using the Mike 21 application (Pirooznia *et al*., 2022). However, limited research on sea currents has been carried out, especially in Indonesian waters (Irawan, 2016).

Sea currents continue to change all the time, but their patterns and trends can be predicted using sea current modeling analysis methods (Morzaria-Luna *et al*., 2020). It is important to know the existing conditions of sea currents and their modeling, so this research was carried out. So the aim of this research is to determine the existing conditions of sea currents and their modeling in the planned location for the construction of the LPG-GFS jetty pier at Parit Rempak port. The results of the research will be used as material for submitting a proposal for the SMSUA licensing process so that the construction of the LPG-GFS jetty can be carried out.

Materials and Methods

Time and site

This research was conducted in November 2022 in the waters of Karimun Regency (Figure 1). These waters are within the working area of Parit Rempak Port, which serves the loading and unloading of goods for the economic needs of the people of Karimun Regency. This port will be developed for PLG-GFS in the eastern part, or the location marked with the yellow star in Figure 1.

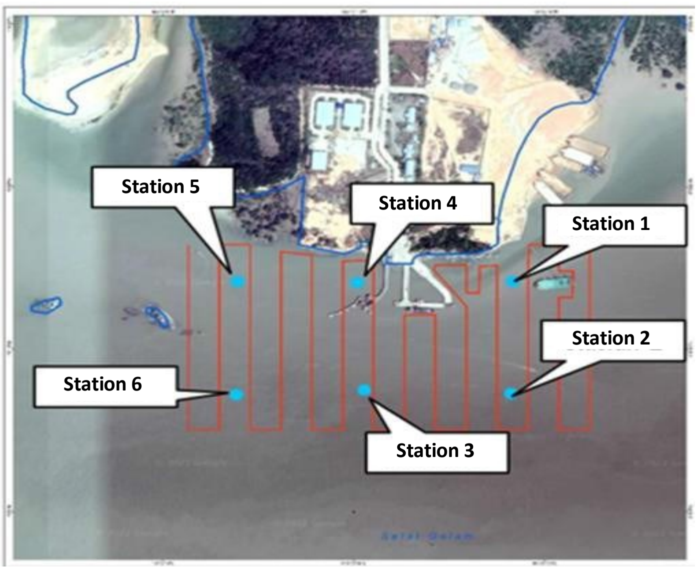
Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 39-47

Source: Karya Karimun Mandiri Company (2022)

Figure 1. Area of Parit Rempak port as research location (insert: visible near Singapore and Malaysia); the dotted box represents the survey area.

Data collection procedure

The data used is primary and secondary data. Primary data is collected directly through this research activity and secondary data is data from other parties (Sugiyono, 2020). Primary data collection was carried out by field survey in the sea space of research location, where the sea space will be used for the construction of the LPG-GFS jetty pier. Observations were made of sea current conditions at the research location. Observation stations are divided into Stations I, II, III, IV, V, VI (Figure 2).



Source: Research Analysis Results (2022)

Figure 2. The position of six survey stations.

The survey begins with a preliminary survey, by looking at the field conditions as a whole. Then determine the measurement technique and the position of the research stations, there are 6 research stations (Figure 2). After the preliminary survey was carried out, the research began with the main activity of collecting data as analyzed and presented in this writing. The data acquisition or collection process continues, using polygon points as a place for a tool that can target detailed points in all directions.

Current measurement uses the Euler method with a Vale-port Type 106 Current Meter. Each measurement was carried out in three observations, namely at depths of 0.2d, 0.6d, and 0.8d where d is the water depth at the measurement position. The duration of each measurement is at least 24 hours per day, namely from low tide to the next low tide, or from high tide to the next high tide, or 1 tidal cycle. Wave, tidal and wind measurements were also carried out in this research, but the discussion focuses on sea currents, bathymetry and type of sediment only.

Next, collect bathymetric data by direct survey to the research location, to determine the condition of the seabed and depth using a GPS MAP tool (Nurkhayati, 2013). The sounding path was created previously using ArcGIS software, which is compatible with GPS Map sounder. Other tools use echosounder, notebook and boat. Bathymetric surveys were carried out along the research location corridor (Figure 2) with varying widths. Then also collect topographic data using a theodolite. Then, photos were taken of the seabed profile to determine the type of sediment on the seabed. Next, a sediment distribution map was created to describe the overall condition of the seabed at the research location.

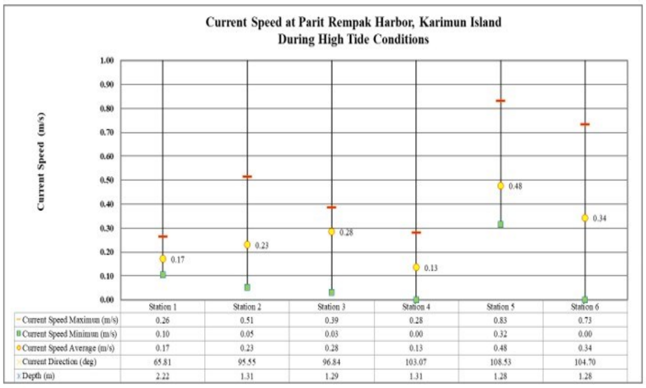
Analysis data

Data analysis began by using secondary data from National Oceanic and Atmospheric Administration (NOAA) of United State of America (US), for analysis of sea current direction, current rose direction and current speed. Then analyze the primary data to determine the bathymetry map, the speed and direction of sea currents as well as sea current modeling and also sediment condition. These data were analyzed using software Mike 21. Other secondary data, for example data from the Centre of Hydro-oceanographic Indonesian Navy Office, was analyzed to complete the data processing needs in question.

Results

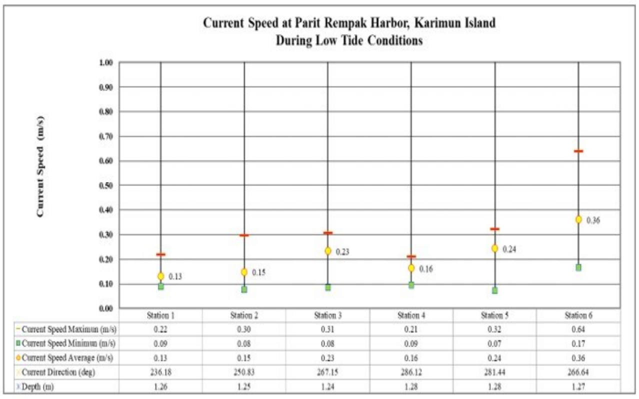
a. Sea current

Surface current measurements were carried out on 12 November 2022 at 6 research stations (Figure 2), at high tide and at low tide. Measurements for 15 minutes at intervals of every 10 seconds. The results of measuring current speed during high tide conditions can be seen in Figure 3 and during low tide conditions can be seen in Figure 4. The results of measuring current speed at station 5 which is close to the land location, at high and low tide are Figure 5. Then the sea current data station 5 in the form of a scatter plot as in Figure 6, can help in analyzing the results of the data distribution.



Source: Research Analysis Results (2022)

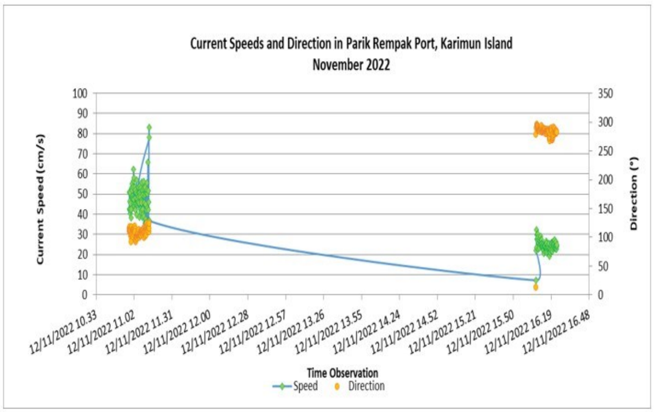
Figure 3. Results of measuring current speed during high tide conditions at the research location.



Source: Research Analysis Results (2022)

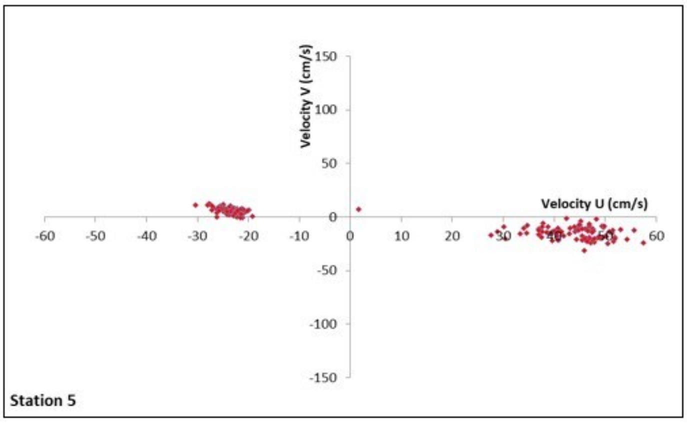
Figure 4. Results of measuring current speed during low tide conditions at the research location.

The results of surface current velocity measurements using vale-port show that surface current velocity at the research location during high tide conditions ranges from 0.0 to 0.83 m/s. The pattern of surface currents in these waters is dominant towards the east at high tide. Meanwhile, the speed of surface currents at low tide ranges from 0.07 to 0.64 m/s. The pattern of surface currents in these waters tends to the west at low tide.



Source: Research Analysis Results (2022)

Figure 5. Speed and direction of sea current at station 5.



Source: Research Analysis Results (2022)

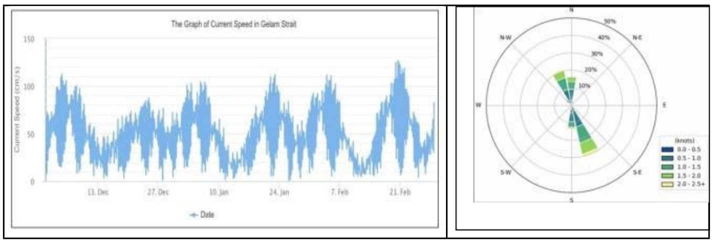
Figure 6. Sea current of station 5 in the form of a scatter plot.

Based on analysis of current data from NOAA for 1 year (December 2021–November 2022), which was processed in the form of graphs and current rose diagrams, from the current rose it can be seen the distribution of current speed and direction. The results of the analysis are divided into seasons, namely western season (December-February), transition season 1 (March-May), east season (June-August), transition season 2 (September-October). The following are the conditions of sea currents at the research location according to Figure 7, Figure 8, Figure 9, and Figure 10.

The results of analysis of NOAA current data at the research location are as follows: (a) in the west season, the dominant current direction is towards the southeast and the maximum speed is around 126.63 cm/s; (b) in the first transition season, the dominant current direction is towards the southeast and the maximum speed is around 127.69 cm/s; (c) in the east season, the dominant current direction is southeast and the maximum speed is around 112.76

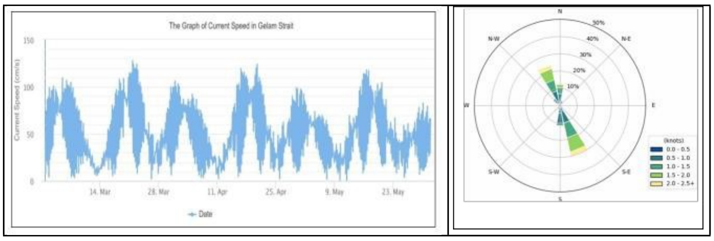
Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 39-47

cm/s; (d) in transition season II, the dominant current direction is southeast and the maximum speed is around 123.91 cm/s.



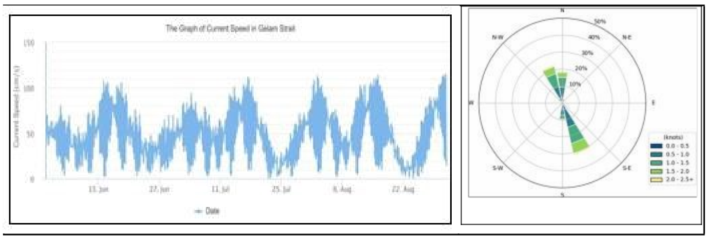
Source: Research Analysis Results (2022)

Figure 7. Graph of current speed and current rise in the West Season.



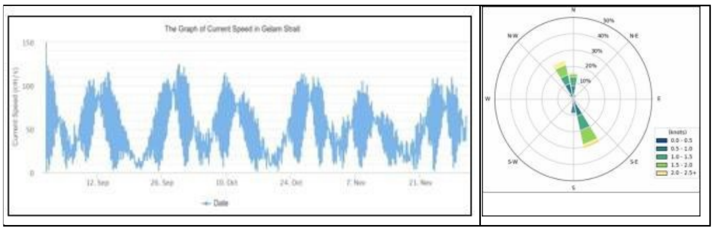
Source: Research Analysis Results (2022)

Figure 8. Graph of current speed and current flow in Transition Season I.



Source: Research Analysis Results (2022)

Figure 9. Graph of current speed and rise of the East Monsoon current.



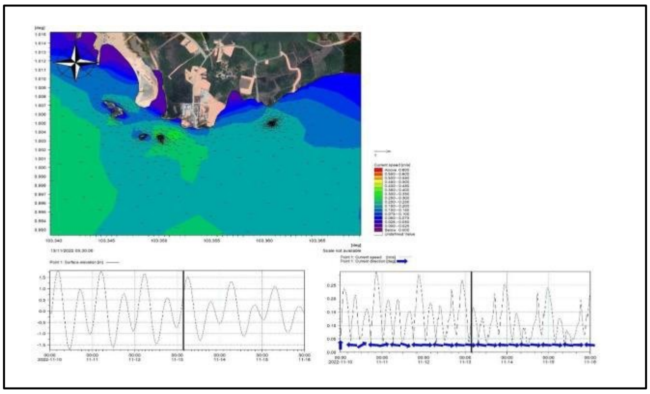
Source: Research Analysis Results (2022)

Figure 10. Graph of current speed and current surge for Transition Season II.

b. Current simulation

Current simulation or modeling is intended to determine the distribution and movement patterns of currents under existing conditions. The size of the grid or mesh used in modeling varies from 10 meters to 500 meters, with a smaller density level located in areas close to the coastline or coastal buildings. The bathymetry used in current modeling comes from the results of field measurements and bathymetry maps issued by the Centre of Hydro-oceanographic of Indonesian Navy Office. The results of the hydrodynamic simulation (current patterns) are not presented in their entirety during the simulation, but the presentation is only in the form of currents sampled at four tidal conditions (near high tide, at high tide, before low tide and at low tide).

The results of sea current modeling from existing data are as follows: (a) conditions from low tide to high tide (Figure 11), current speed varies between 0.0 m/s to 0.15 m/s, with the current direction to the east. The current speed around the Gelam Strait (in the surrounding area but outside the research area) ranges from 0.1 m/s to 0.32 m/s. The dominant current movement is towards the east; (b) highest tide conditions (Figure 12), current speed varies between 0.0 m/s to 0.11 m/s with the current direction to the east. The current speed around the Gelam Strait ranges from 0.1 m/s to 0.4 m/s. The dominant current movement is towards the east; (c) tidal to low tide conditions (Figure 13), current speed varies between 0.0 m/s to 0.125 m/s with the current direction to the west. The current speed around the Gelam Strait ranges from 0.05 cm/s to 0.25 m/s. The dominant current movement is towards the west-northwest; (d) lowest ebb conditions (Figure 14), current speed varies between 0.0 m/s to 0.05 m/s with the direction of current movement to the south. The current speed around the Gelam Strait ranges from 0.05 m/s to 0.2 m/s. The dominant current movement is towards the west.



Source: Research Analysis Results (2022)

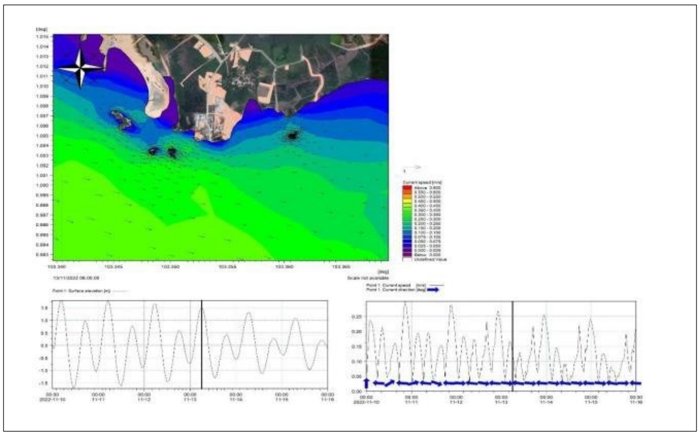
Figure 11. Current pattern from low tide to high tide.

c. Bathymetry

Bathymetric measurements, or commonly known as sounding, are depth measurement activities aimed at obtaining depth data so that a picture of the seabed profile or seabed surface model can be created (Kusumawati, 2015). Processing bathymetric data with Arcgis 10.3 software to create bathymetric

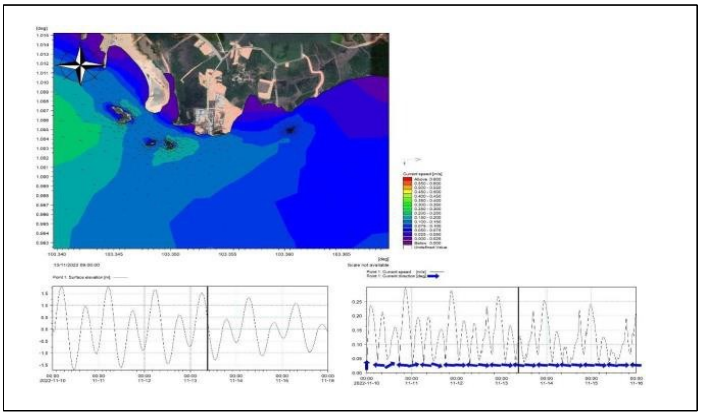
Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 39-47

contour lines produces a bathymetric map for the research location with depths ranging from 0–5 meters as shown in Figure 15.



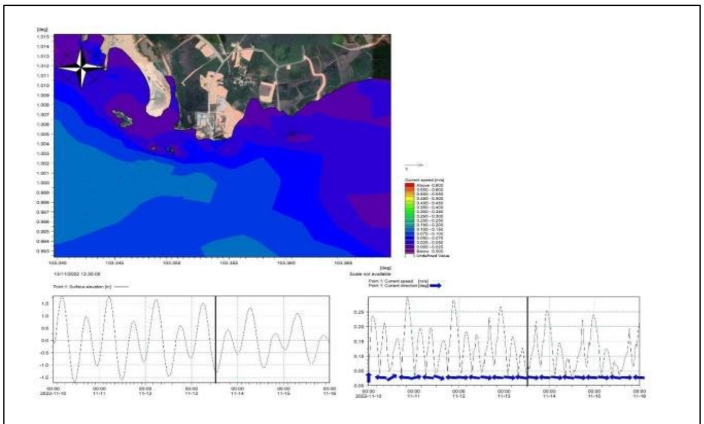
Source: Research Analysis Results (2022)

Figure 12. Current pattern at highest tide conditions.



Source: Research Analysis Results (2022)

Figure 13. Current pattern at tidal to low tide conditions.

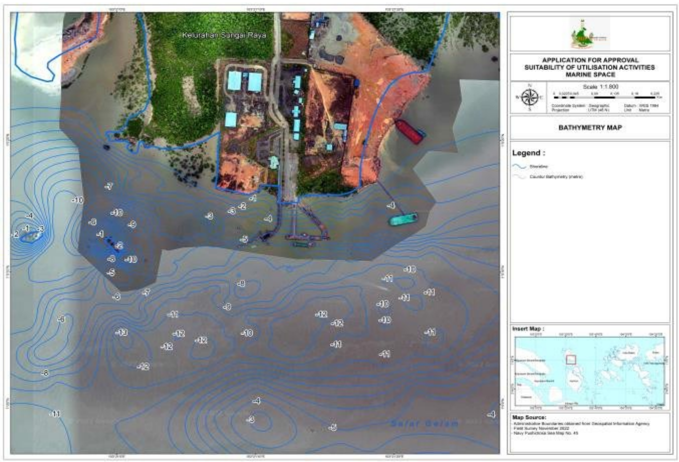


Source: Research Analysis Results (2022)

Figure 14. Current pattern at lowest ebb conditions.

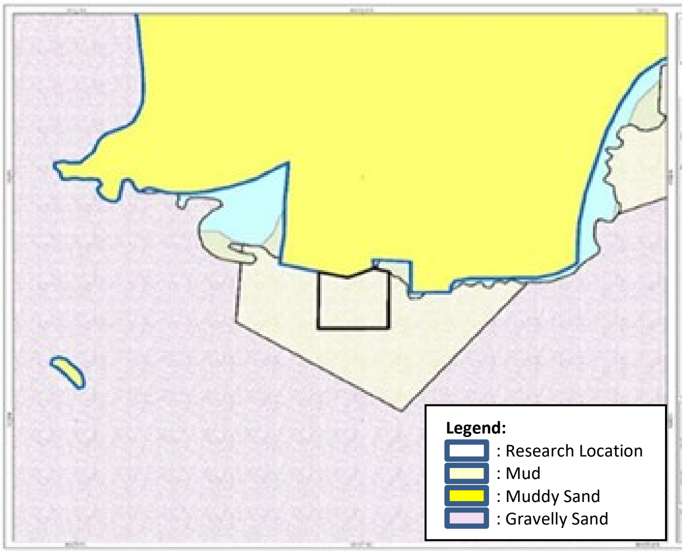
d. Sedimentation

On the other hand, the results of observations of the sediment type or seabed substrate type at the research location, namely the marine space location requested by SMSUA, are in the form of mud (station 1 and station 4), muddy sand (station 2) and gravelly sand (station 3). Then a wider map of the distribution of seabed sediment around the location requested by SMSUA is shown in Figure 16.



Source: Research Analysis Results (2022)

Figure 15. Bathymetry map at the research location.



Source: Research Analysis Results (2022)

Figure 16. Map of Seabed Sediment Distribution.

Discussion

Sea currents occur due to differences in sunlight on the ocean, which causes changes in temperature and salt content, causing sea water bodies to have different properties. The direction and magnitude of sea currents can be constant or change and are generally difficult to study, because they overlap with the ocean circulation of the local sea (Pamungkas & Farhaby, 2019). Sea currents are an important parameter when sea space will be used for infrastructure development (Wardoyo, 2020). Therefore, sea currents must remain controlled, so that the balance of the ecosystem is maintained, and the use of marine space is planned and sustainable, so that marine spatial planning regulations must be clear (Griggs, 2015).

An example of regulations on the island of Barbuda in the Caribbean implementing comprehensive marine spatial planning regulations, which have been implemented and as a result of Hurricane Irma which devastated Barbuda in September 2017, these regulations are functioning well and creating major challenges for the use of marine space there (Johnson *et al*., 2020). So that sea current is an environmental consideration and as a blue economy issues that are often taken into consideration in analyzes of marine space utilization. However there are still very few uses of marine space that take into account social sustainability (Escandón-Panchana *et al*., 2022; Akbar and Rahayu, 2023).

Based on the results of sea current analysis, specifically for station 5 in the form of a scatter plot presented in Figure 6, it can help in analyzing the results of the distribution of sea currents at the research location. If the current pattern moves elliptical (back and forth), the current in these waters is dominated by tidal currents, while the current pattern moves regularly in these waters is dominated by non-tidal currents (Pamungkas & Farhaby, 2019). So this condition is quite favorable for the construction of new infrastructure at this location, because the pattern of sea currents does not fluctuate greatly.

Then the speed of surface currents at the research location during high tide conditions ranges from 0.0 to 0.83 m/s towards the east at high tide. Meanwhile, the speed of surface currents at low tide ranges from 0.07 to 0.64 m/s towards the west at low tide. This condition is relatively calm so it will not be difficult if permanent infrastructure is to be built at the research location. So that according to Haryani and Simanjuntak (2023) and Haryani *et al* (2023) future management will be relatively easy to control, including developing port management that is balanced and environmentally friendly.

The results of the analysis of sea currents are in accordance with data from NOAA, that sea currents do not occur back and forth but move regularly, namely in a direction towards the southeast, only the speed varies. The maximum current speed ranges from 112.76 cm/s to 127.69 cm/s which is differentiated into the west season, transition season I, east season and transition season II. It can be clearly seen in Figure 7, Figure 8, Figure 9 and Figure 10, which show graphs of current speed and direction of the current rose.

According to the results of analysis of current data using NOAA data sources, the highest sea current speed occurred in transition season I, namely a maximum of around 127.69 cm/s. Meanwhile, the speed of sea currents is smallest in the east season, namely the maximum speed is around 112.76 cm/s. This difference is not too big, so it can be said that at the research location, sea current conditions are relatively stable, meaning that if permanent infrastructure is planned to be built, such as the LPG-GFS jetty, it is predicted that it will not be dangerous (Flannery *et al*., 2020). Although the current fluctuates greatly due to the effects of large waves and the periodicity of tidal phenomena (Zhou *et al*., 2013). However, the sea currents at the research location are different in the Arafura-Timor waters, in that the dynamics of surface geostrophic currents in the Arafura-Timor waters occur due to changes in absolute dynamic topography (sea level height) due to changes in monsoon winds each season (Ramadyan & Radjawane, 2013). If this infrastructure is built in this location (Arafura- Timor waters) it will have a difficult impact.

Then, to see the current speed in the surrounding waters, the research location includes the Gelam Strait waters in the Riau Islands Province, in the Gelam Strait the current speed is between 0.05 m/s to 0.25 m/s. The dominant current movement is towards the east, west and northwest. Meanwhile, according to Irawan *et al.* (2018) when compared with the sea current pattern on Batam Island, it ranges from 0.02 m/s to 0.1 m/s from the north to the northeast. This means that the current speed in the Gelam Strait is relatively higher than in Batam waters . Although at the research location the range is not as high as the Gelam Strait, namely around 0.05 m/s to 0.125 m/s. Then according to Saputro *et al.* (2023), for example in the west Surabaya-East Java waterway, which is one of the busiest sea transportation areas in Indonesia, that in these waters the results of sea current simulations explain patterns that are also different between the transition season 1 and the east season and the transition season 2 and the west season.

According to Daruwedho *et al.* (2016), the sea current in Indonesia can be described that when the West Monsoon occurs, the wind blows from the West towards East, so the current also moves from the direction of the Asian Continent towards the Australian Continent. When the East Monsoon occurs, the wind blows from East to West, so the current also moves from the direction of the Australian Continent to the Asian Continent. Meanwhile, when the transition season occurs, both during the transition from the West monsoon to the East monsoon and during the transition from the East monsoon to the West monsoon, the current movement is irregular and tends to be divided into two directions, namely from the Asian Continent to the Australian Continent and from the Australian Continent to the Asian Continent but the speed Currents on average are weak in almost all waters in

Indonesia. So in Karimun waters the current speed is also weak, meaning it will make it easier to develop infrastructure in the marine space and is thought not to disturb the balance of the ecosystem.

In the other contents, according to Irawan (2016) that surveying sea currents is also one of the requirements for developing inter-island transportation in the Riau Islands region, whose area is dominated by water transportation. Currents are also very useful in designing port buildings, determining transportation routes, designing harbour pools, and planning breakwaters (Sadeghi, 2011). In this research, sea currents are closely related as a consideration for the use of marine space for the development of permanent infrastructure.

Hydrodynamic simulation results (current patterns) using software Mike 21, the dominant direction of current movement at the research location is to the southwest and northeast. The current speed is relatively greater during high tide conditions than during low tide conditions. In detail, the results of ocean current modelling: (a) low tide to high tide conditions, dominant current movement to the east; (b) tidal conditions dominant current movement to the east; (c) tidal conditions leading to low tide, dominant current movement to the west-northwest; (d) receding conditions, dominant current movement to the west (Figure 11, Figure 12, Figure 13 and Figure 14).

According to Kasim (2020), that the general current distribution obtained from simulations uses software Mike 21 in the Jeneberang estuary, South Sulawesi, the dominant sea current is towards the west, meanwhile the condition of the current itself is dominant towards the northeast and east. This shows that the results of the analysis with software Mike 21 quite clear and predictable. Then according to Amirullah *et al.* (2014), that the sea current pattern that occurs before the port development is predicted to not be much different from the sea current pattern that occurs after the port development is carried out. As happened in the development of the port in Tegal City, Central Java Province in the form of reclamation and breakwater buildings, the decrease in sea current speed was not significant. This means that at the research location where LPG-GFS will be built, changes in sea currents that will occur will not have a significant effect

Bathymetry is the measurement and mapping of seabed topography. Information on sea depth (bathymetry) in waters is very important in space utilization activities in coastal areas (Masrukhin *et al.*, 2014). The measurement results at the research location have varying depths between 0-5 meters with the bathymetry map shown in Figure 15. The research location is shallow water on the beach area and experiences an increase in depth towards the sea (Galceran & Carreras, 2013). This depth condition is relatively safe if a LPG-GFS is to be built at the research location, because the depth variations are not too varied or much different (Melina *et al.*, 2015).

The sediment type or seabed substrate type are in the form of mud, muddy sand and gravelly sand. This type of sediment is usually found in coastal waters or in shallow waters such as at the research location. As is known, sediment conditions will certainly change along with changes in the physical and aquatic environment, such as the impact of coastal buildings. According to Griggs (2015) that potential impacts of coastal buildings include visual effects, impoundment or placement losses, reduction of beach access, loss of sand supply, and passive and active erosion, which can change sediment conditions. Furthermore, in plans to build additional infrastructure at the research location, sediment conditions are relatively not a problem, but we must be aware of the potential for additional sediment with changes in physical and environmental conditions that will occur.

Conclusion

According to the description of the results and discussion, it is concluded that: (a) existing conditions surface current speed at high tide ranges from 0.0 to 0.83 m/s towards the east, at low tide it ranges from 0.07 to 0.64 m/s towards the west direction; (b) based on NOAA data, sea currents at the research location move relatively regularly and in a direction towards the southeast. The speed of sea currents varies according to the season, with a range of 0.0 m/s to 0.125 m/s, non-tidal so it is relatively not turbulent; (c) sea current modelling that the maximum current speed is 0.25 m/s and the minimum current speed occurs at the highest tides and lowest low tides, with the dominant direction of current movement to the southwest and northeast; (d) bathymetric conditions with a depth of between 0-5 meters, constitute shallow water and are safe for building a LPG-GFS jetty pier. The sediment type or seabed substrate type at the research location, are in the form of mud, muddy sand and gravelly sand. So based on the conditions of sea currents at the research location, SMSUA permits should be granted.

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