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Hydrodynamic and Sediment Dynamics Study in the Coastal Area of Dobo Ferry Port, Aru Islands Regency, Indonesia

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ABSTRACT
Siltation in berth basins has become a major operational issue at the Dobo Ferry Port, Aru Islands Regency. This study aimed to analyze the hydrodynamic factors influencing sedimentation processes in the port basin and to propose effective mitigation strategies. Field surveys were conducted in July 2025, including topographic and bathymetric mapping, tidal observation, current and wave measurements, as well as sediment sampling. Data were analyzed using oceanographic survey techniques, numerical modeling, and laboratory analysis of sediment composition. The results revealed that tidal regimes in Dobo waters are of a mixed type predominantly semidiurnal, with an average tidal range of 94.1cm. This tidal condition strongly influences sediment transport into the berth basin. Significant wave heights during the southeast monsoon (1.2– 1.5m) contributed to sediment resuspension in shallow waters, while asymmetric tidal currents facilitated the trapping of fine-grained material inside the basin. Laboratory analysis indicated that silt and clay fractions dominated the sediments, accounting for more than 60% of the total composition. Numerical simulations showed that within a 15-day tidal cycle, sediment deposition reached 0.01– 0.07m in the old jetty and planned jetty areas. These findings suggest that siltation at Dobo Ferry Port is driven by a combination of hydrodynamic processes, sediment supply from terrestrial inputs, and anthropogenic activities in coastal settlements. Mitigation strategies should therefore integrate adaptive dredging practices, hydrodynamic engineering, ecological restoration of mangroves and seagrass beds, and the implementation of technology-based sediment monitoring systems. This integrated approach is expected to enhance the sustainability of port operations and maintain inter-island connectivity in the Aru Archipelago.

INTRODUCTION

Ferry ports play a strategic role in supporting interregional connectivity, particularly in archipelagic regions such as the Aru Islands, Maluku. The Dobo Ferry Port serves as one of the primary transportation infrastructures connecting Wamar Island with surrounding areas. However, in recent years, significant shoaling has been observed in the port's anchorage basin, which may hinder navigation activities and impact the local economy. This shoaling is generally driven by oceanographic dynamics that influence sedimentation processes, including tidal currents, waves, and sediment supply from both terrestrial and adjacent aquatic sources **(Bonesso *et al*., 2022)**.

Globally, sedimentation processes in coastal and port areas have become a key concern in oceanographic and coastal engineering studies. Previous research has demonstrated that alterations in current and wave patterns, whether driven by natural or anthropogenic factors, can accelerate sediment accumulation in port areas **(Van Rijn *et al.*, 2001; Van Rijn, 2009)**. Moreover, increasing development activities along coastlines often intensify erosion rates, thereby contributing to sedimentation in port basins **(Wang & Andutta, 2013)**. Despite this, studies on sedimentation dynamics at Dobo Ferry Port remain limited, necessitating further investigation to understand the causative factors of shoaling and potential mitigation strategies.

From an oceanographic perspective, port shoaling is influenced by a range of hydrodynamic factors, including tides, current patterns, and changes in seabed bathymetry **(Nielsen, 2009)**. Studies on sediment dynamics indicate that tidal currents play a crucial role in sediment transport within coastal environments, particularly in shallow waters such as deltas **(Syvitski & Saito, 2007)**. Additionally, alterations in hydrodynamic patterns due to human activities, such as dock construction and reclamation, can modify sediment distribution in waters surrounding ports **(Prumm & Iglesias, 2016; Hendriks *et al*., 2020)**. Therefore, a comprehensive analysis of the oceanographic factors contributing to shoaling at Dobo Ferry Port is essential.

Previous studies on port sedimentation have primarily focused on the effects of currents and waves on sediment distribution **(Pacific Coastal and Marine Science Centre – PCMSC, 2022)**. Recent research, however, has highlighted that the interaction between hydrodynamic processes and sediment characteristics also plays a significant role in determining the rate of shoaling **(Wang & Andutta, 2013)**. Accordingly, this study integrated analyses of currents, tides, and sediment characteristics to elucidate the sedimentation mechanisms in the Dobo Ferry Port anchorage basin. This integrated approach is anticipated to provide a more complete understanding of ongoing processes and to support the development of more effective mitigation strategies.

The novelty of this study lies in its comprehensive approach, combining physical oceanographic analysis with sediment characterization to identify the drivers of shoaling. Most previous studies have focused on individual aspects, such as current patterns or sediment properties, in isolation **(Van Rijn *et al*, 2001; Van Rijn, 2009)**. By employing bathymetric surveys, current modeling, and sediment composition analysis, this research aimed to provide a thorough understanding of sedimentation patterns at Dobo Ferry Port. Such insights are expected to contribute to more sustainable port management.

The findings of this study will not only provide scientific insights into the mechanisms of shoaling but also have practical implications for port planning and management in coastal regions. The obtained information can be used to design more targeted sediment mitigation strategies, such as hydrodynamic engineering, periodic dredging, or sediment control technologies. Furthermore, the study's outcomes can serve as a reference for policymakers in making informed decisions regarding port infrastructure development in areas susceptible to sedimentation.

In summary, this research aimed to analyze the oceanographic or hydrodynamic factors contributing to shoaling in the Dobo Ferry Port anchorage basin. The study is expected to address questions regarding the sources and mechanisms of sedimentation while providing strategic recommendations for sediment management at the port. Through a systematic, data-driven scientific approach, this research can make a significant contribution to the preservation and optimization of port functionality in Indonesia's coastal regions.

Specifically, this study was designed to achieve the following objectives: (1) to analyze the hydrodynamic factors (tides, currents, and waves) influencing sedimentation in the port basin; (2) to characterize sediment composition and identify the main sources of shoaling material; and (3) to propose effective mitigation strategies for sustainable port management on the Aru Islands.

MATERIALS AND METHODS

Research design

The study was conducted in the anchorage basin area of Dobo Ferry Port, Aru Islands Regency, in July 2025. Field surveys were carried out in several stages to obtain hydrodynamic and sedimentation data that reflect the actual conditions at the study site. The approach employed included field surveys and the processing of secondary data, encompassing aspects of topography, bathymetry, oceanography, sedimentation, and coastal land use.

Data sampling and analysis

Topographic survey

Topographic surveys were conducted using a theodolite and a water level (water pass) to obtain an overview of the land conditions surrounding the port. Measurements were focused on 14 observation points within a radius of approximately ±1 km from the pier location (Fig. 1). The data collected included land surface elevation, land and building boundaries, and other relevant physical elements. The survey results were presented in a topographic map at a scale of 1:1000, serving as the basis for analyzing the relationship between terrestrial features and water dynamics.

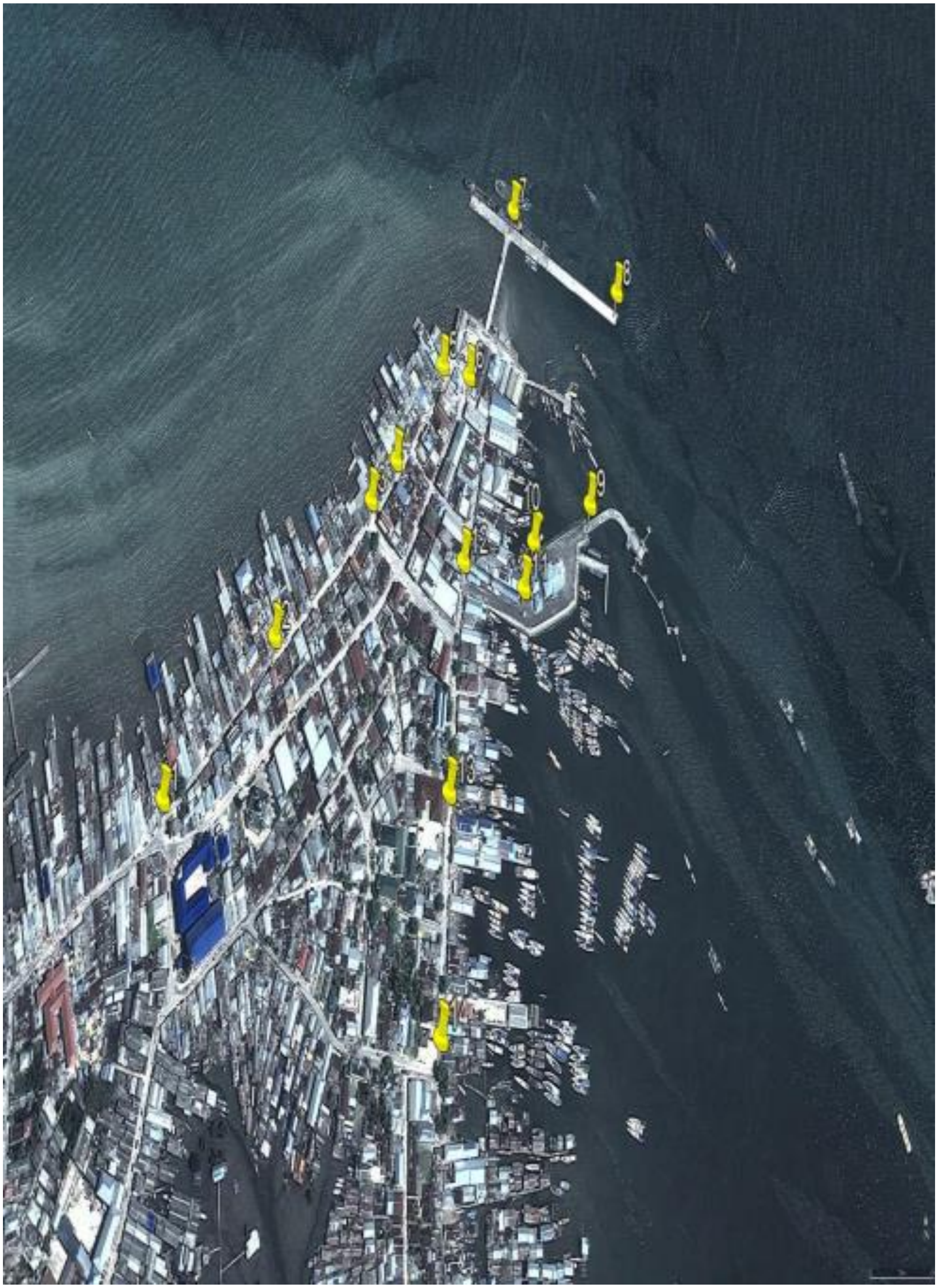

Fig. 1. Observation point of the topographic survey

Bathymetric survey

The water depth of the port anchorage basin was mapped using an echosounder integrated with GPS (Fig. 2). Measurements were conducted along a transect of approximately 18km, covering an area of over 45 ha. The bathymetric data were then corrected for tidal variations to obtain actual water depths (in meters). The resulting bathymetric map served as the primary reference for identifying areas prone to sedimentation and changes in seabed morphology.

Fig. 2. Bathymetric surveying instruments

Oceanographic survey

Tidal observations were conducted using a peilschaal over a 15-day period (9–23 July 2025), with measurements recorded at hourly intervals (Fig. 3). The data were processed using the Admiralty method to obtain tidal harmonic constants, amplitudes, phase differences, and the Mean Sea Level (MSL) values.

Fig. 3. Tide staff installation for measuring tidal fluctuations

Wind and wave conditions were obtained from Meteorology, Climatology, and Geophysics Agency (*Badan Meteorologi, Klimatologi, dan Geofisika /* BMKG) datasets

(2020–2024), with significant wave heights (Hs) expressed in meters (m). Currents were measured using a current meter installed 50– 60cm below the sea surface, with velocity data recorded in meters per second (m/s).

Sedimentation survey

Sedimentation was observed using sediment traps deployed at 10 observation points on the seabed, with a distance of over 50 meters between traps (Fig. 4). The number of traps was chosen to balance spatial coverage of the anchorage basin (2.8 ha) and operational feasibility, ensuring representative coverage of shoaling dynamics. After three days, sediments were collected and analyzed at the National Research and Innovation Agency (*Badan Riset dan Inovasi Nasional /* BRIN) Soil Testing Laboratory in Ambon to determine grain size fractions (μm) and sedimentation rates (g/m²/day).

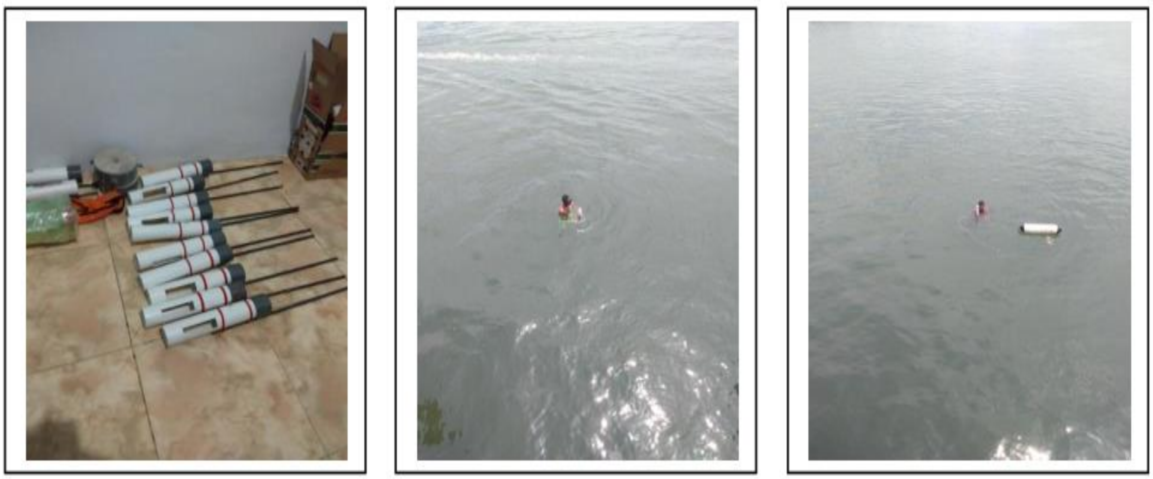

Fig. 4. Sediment trap installation at selected monitoring sites

Numerical modeling

Hydrodynamic and sediment transport modeling was performed using MIKE 21 (DHI Water & Environment), a widely applied coastal modeling software. The computational mesh was constructed based on field-derived bathymetry with a horizontal resolution of 20–40 m. Boundary conditions included tidal forcing from Admiralty tide tables at offshore nodes, wave forcing from BMKG wave data, and river discharge estimates based on local hydrological surveys. Calibration was carried out by adjusting Manning's roughness coefficients and time step until simulated water levels and current velocities closely matched field measurements, with RMSE values within acceptable limits (<0.05 m for tides, <0.05 m/s for currents). Model validation was performed by comparing simulated results against independent field datasets collected during the survey period.

RESULTS AND DISCUSSION

Topographic

The topographic survey in the Dobo Ferry Port area was conducted at 14 benchmark observation points, covering an area of approximately 150m². The results were visualized in a Topographic Map (Fig. 5), illustrating land elevation variations through contour lines and color gradients. Contour lines indicate uniform elevation along each line, with closely spaced lines representing steep slopes and widely spaced lines indicating gentle slopes. Meanwhile, the color gradients on the map enhance the distinction in elevation between observation points.

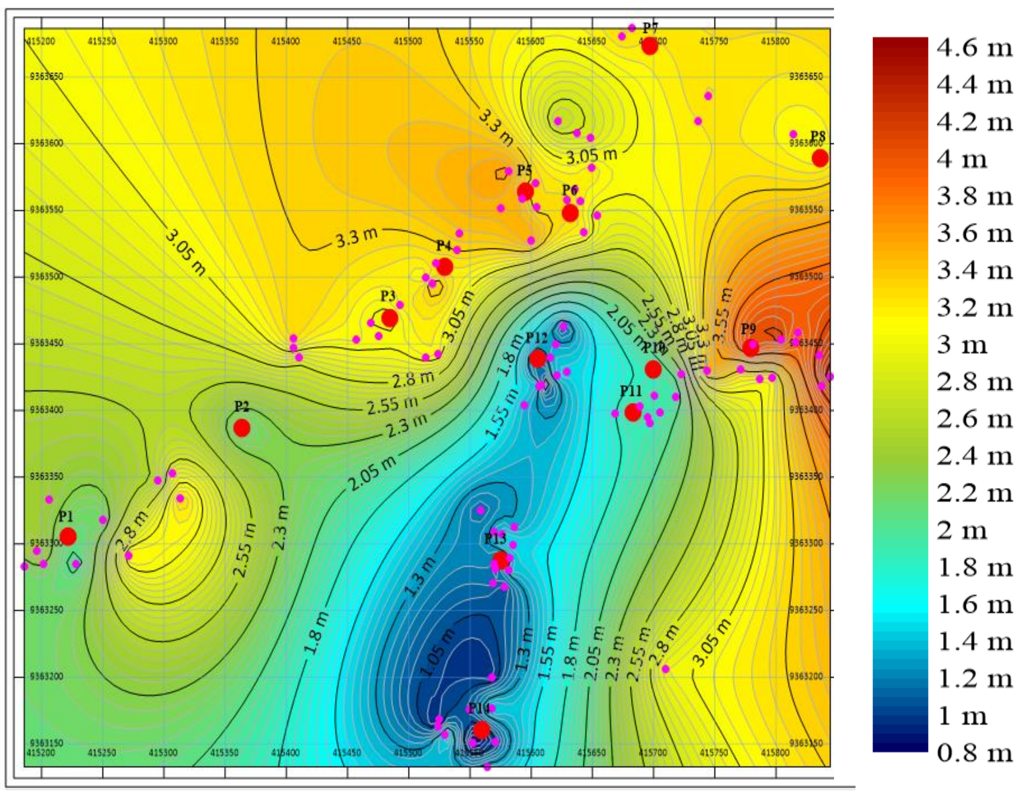

Fig. 5. Topographic map of the Dobo Ferry Port Area

The measurements indicated that Benchmark 9 (P9) was the point with the highest elevation at 4.05 m above chart datum, whereas Benchmark 1 (P1) had the lowest elevation at 0.936 m. The elevation differences among the benchmark points suggest that the land surrounding the port exhibits relatively low topography and is potentially prone to inundation during high tides. These findings are consistent with geomorphometric principles, which emphasize how DEM resolution and measurement methods determine the detail of elevation patterns and the interpretation of flood vulnerability in coastal areas **(Xiong *et al*., 2022)**.

Furthermore, analyses of topographic profiles in diagonal, vertical, and horizontal directions (Fig. 6), along with a three-dimensional model (Fig. 7), provide a more detailed visual understanding of land contours. Overlaying the contour map with a Geographic Information System (GIS) using ArcGIS software (Fig. 8) illustrates the relationship between land elevation and coastal conditions. Overall, the results confirm that the land surrounding the port is relatively low, making it susceptible to marine dynamics and sedimentation processes. Topographic mapping and terrain analysis studies have shown that topographic indices such as slope, aspect, and Topographic Position Index (TPI) can explain patterns of material accumulation and deposition at the local scale **(Szász *et al*., 2024)**. Therefore, the profile interpretations and GIS overlays in this study provide a solid basis for linking terrestrial conditions with observed sedimentation patterns.

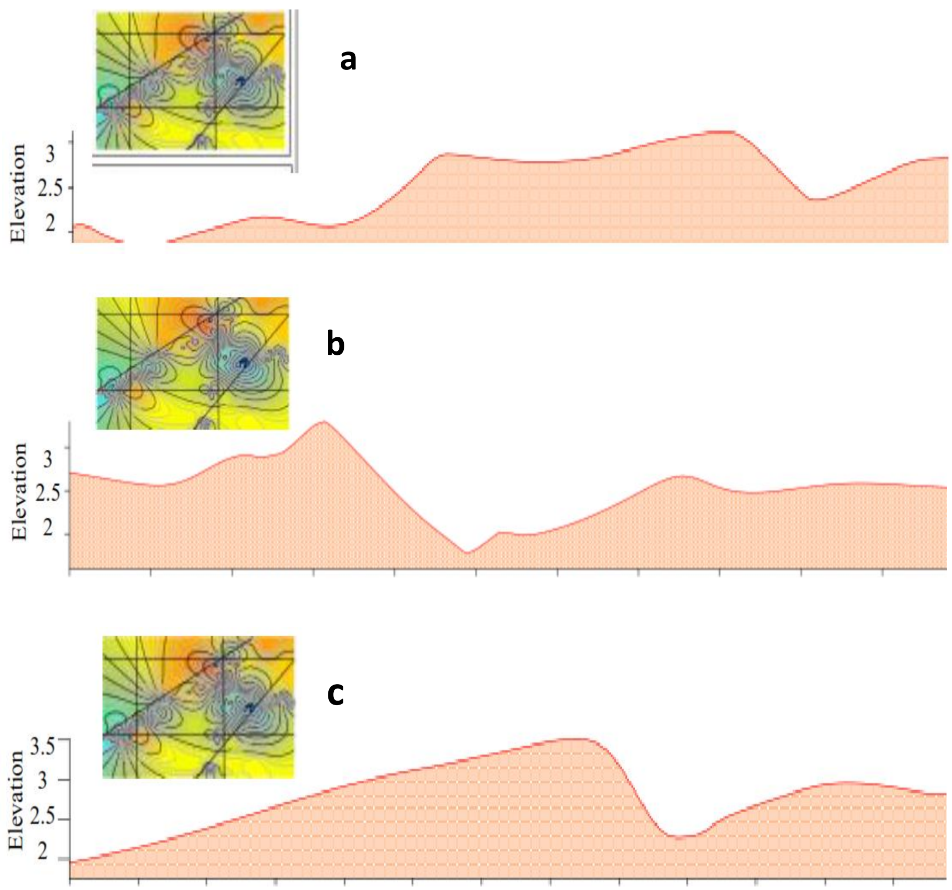

Fig. 6. Topographic Profiles of the Dobo Ferry Port Area: (a) diagonal profile; (b) vertical profile; (c) horizontal profile

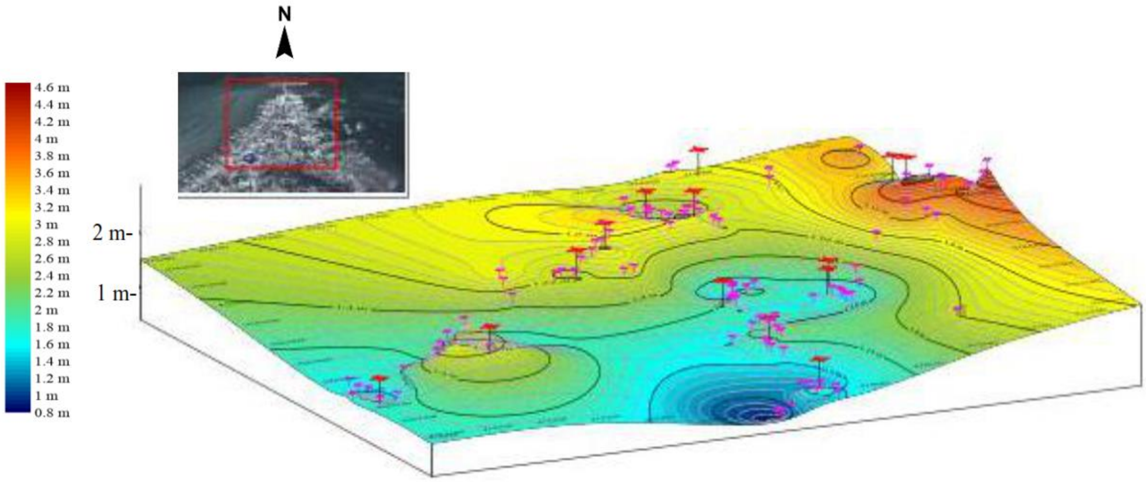

Fig. 7. Three-dimensional topographic profile of the Dobo Ferry Port Area

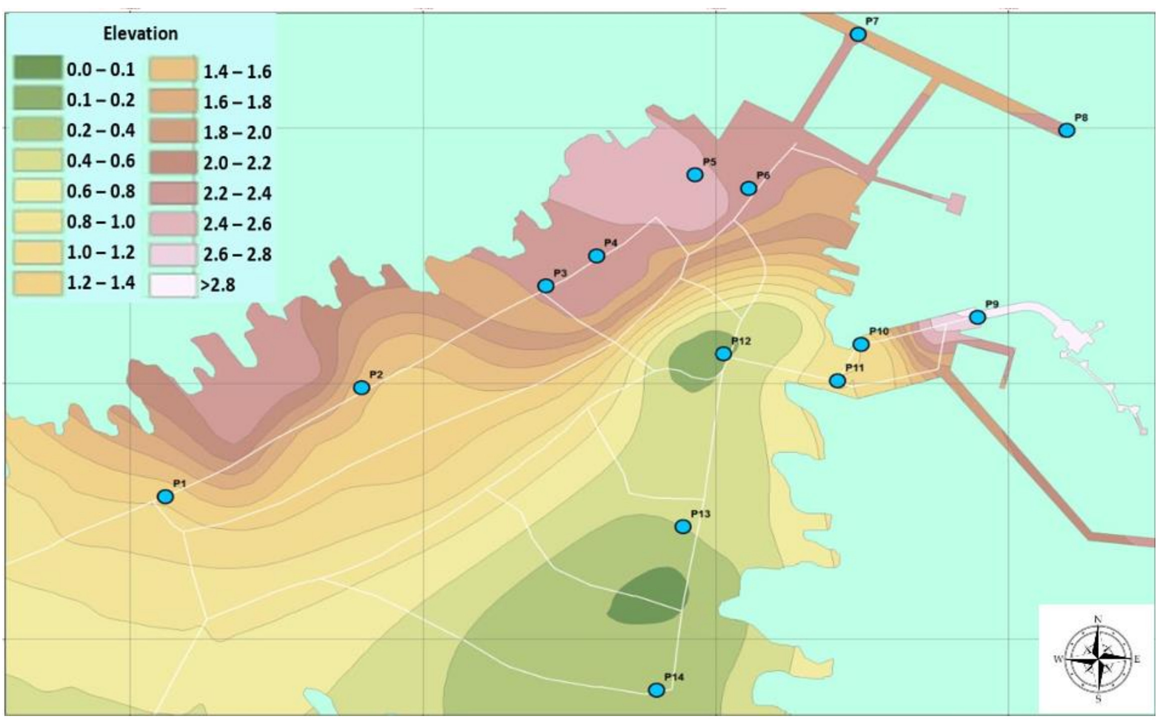

Fig. 8. Topographic map resulting from GIS Overlay

Bathymetric

Bathymetric mapping was conducted over an area of approximately 82.7 ha, with depths ranging from 0 to 34.8 meters. The survey results revealed the presence of an elongated trench at depths of 10–25 meters, directly connected to the anchorage basin. At depths of 1–6 meters, the seabed was dominated by mud substrates and extensive seagrass beds, as shown in the Bathymetric Map (Fig. 9). These conditions indicate that the shallow areas function as significant sediment accumulation zones, consistent with the findings of **Beselly *et al*. (2021)**, who reported that mudflats and seagrass beds in coastal regions act as natural sediment traps and experience long-term dynamics due to material supply from terrestrial sources.

In addition to natural factors, the high sediment supply is influenced by river flows passing through mangrove forests south of the port. These flows transport muddy materials into the waters, contributing to sedimentation in the anchorage basin. This aligns with the study by **Setyadi *et al*. (2021)**, which found that mangrove ecosystems in Papua estuaries play a crucial role in sediment accretion and organic carbon storage, primarily due to high riverine material input.

Coastal community activities, particularly fishing settlements consisting of stilt houses extending 50–150 meters into the sea, also increase sediment input through domestic waste and localized micro-hydrodynamic changes around built structures. These factors demonstrate a close interaction between terrestrial and aquatic systems in shaping the bathymetric conditions around the port. **Mora-Uribe *et al*. (2025)** emphasized that river flow, tidal dynamics, and anthropogenic activities are primary determinants of estuarine bathymetric changes.

The planned anchorage basin, covering 2.8 ha, is flanked by two other ports: the main port (16.8 ha) and a community port (1.75 ha), as shown in the Anchorage Basin Map (Fig. 10). The proposed pier orientation is toward the northeast (45°–60°) with a depth of 7–10 meters at a distance of 75–100 meters from the shoreline (Fig. 11). These findings provide an important basis for pier placement, ensuring minimal disruption to vessel mobility and reducing the risk of shoaling—a critical consideration in the management of estuarine and port systems in tropical coastal areas **(Beselly *et al*., 2021; Mora-Uribe *et al*., 2025)**.

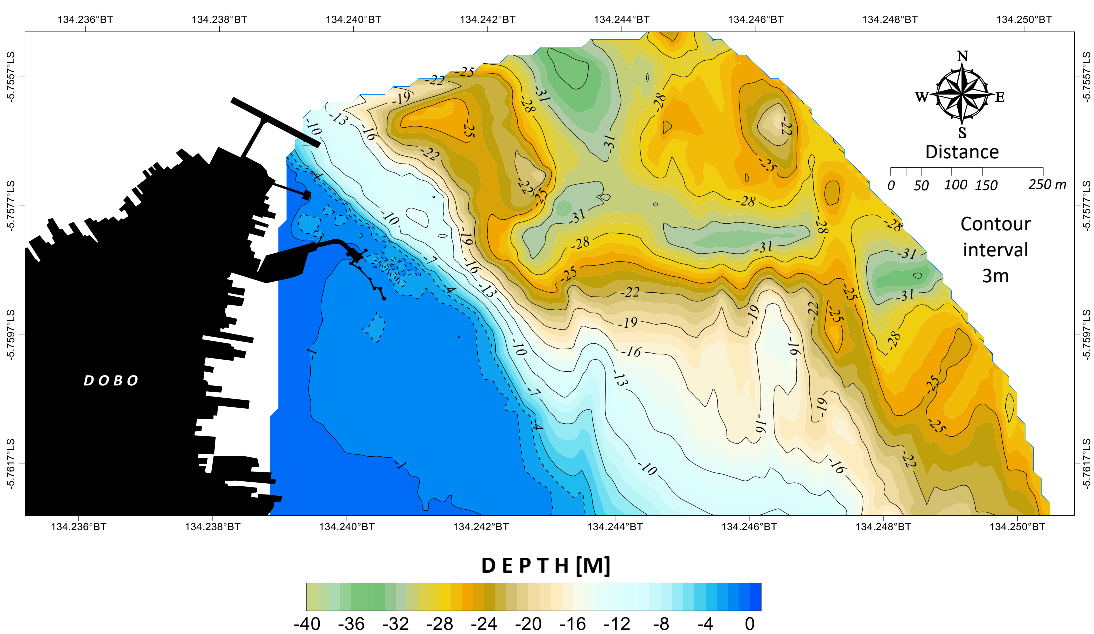

Fig. 9. Bathymetric map of Dobo Port

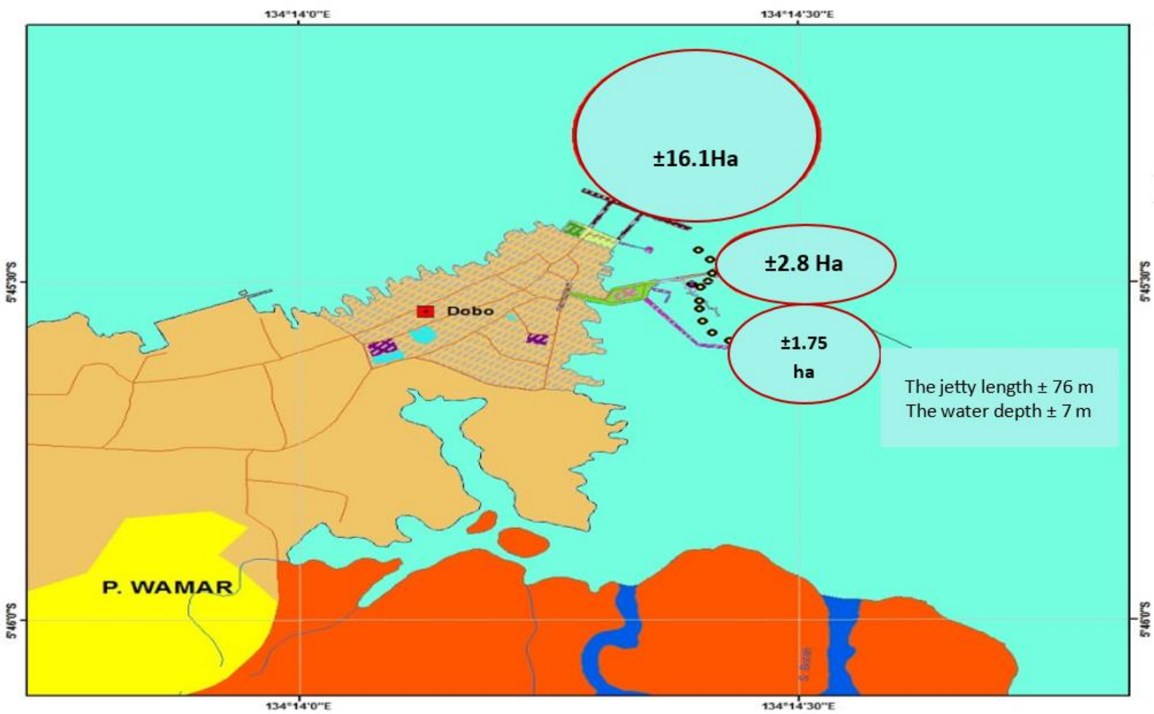

Fig. 10. Berth basin map of the Dobo Ferry Port Area

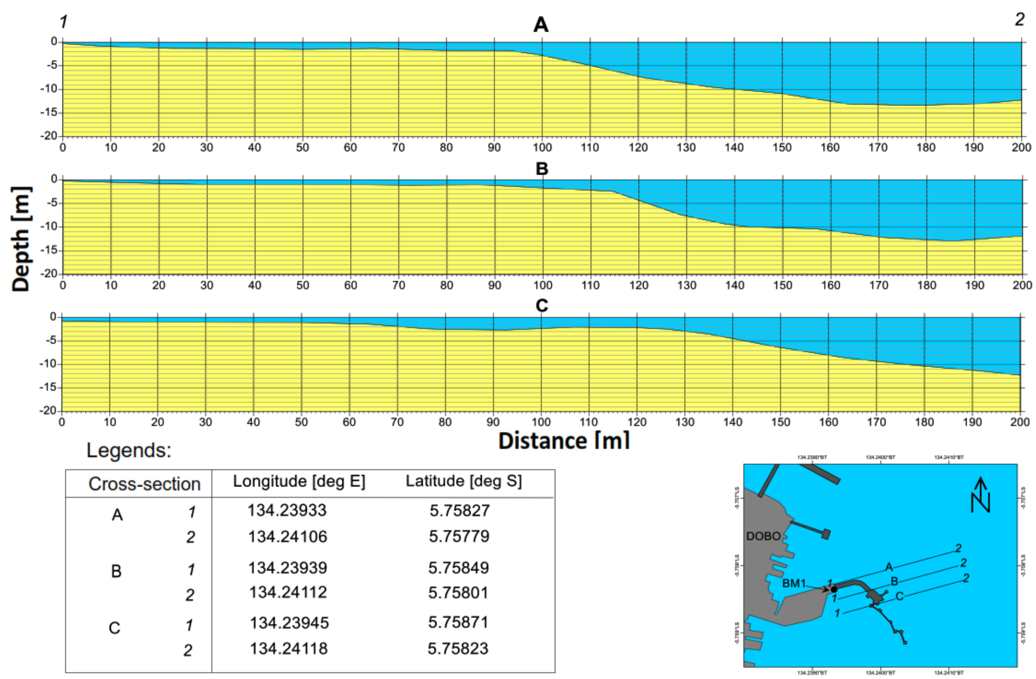

Fig. 11. Cross-sectional position port area

Parameter of oceanography

Tidal

Tidal observations over a 15-day period produced a semi-monthly tidal curve (Fig. 12). Harmonic constant analysis using the Admiralty method indicated that the tidal type in Dobo waters is mixed, predominantly semidiurnal, with two high tides and two low tides each day. The mean tidal range was 94.1 cm, and the MSL reached 162 cm.

The chart datum was determined using the Low Water Spring (LWS), calculated at 135.5 cm below MSL, with a Z_0 value of 26.5 cm (Fig. 13). These data were used as a reference to correct the bathymetric sounding results, ensuring that the measured depths more accurately reflect actual water conditions. Therefore, tidal analysis not only provides information on sea level dynamics but also serves as a key parameter in pier construction design.

The observations confirmed that tidal fluctuations significantly influence sediment mobilization in the port waters. During high tide, sediment materials tend to move into the anchorage basin, whereas during low tide, a portion of the material settles on the seabed. This demonstrates a direct link between tidal dynamics and the shoaling processes at Dobo Ferry Port.

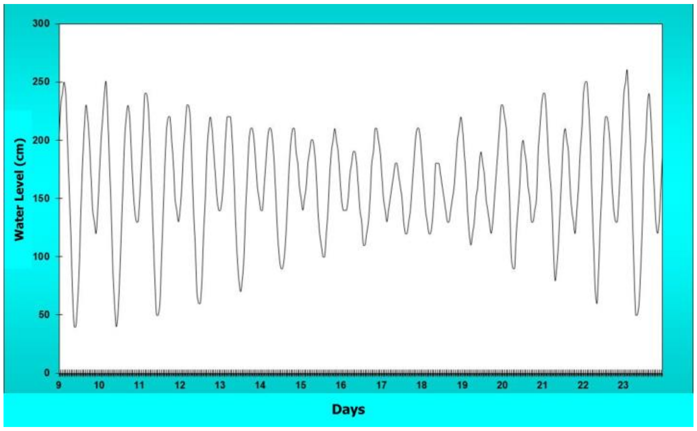

Fig. 12. Semi-monthly tidal curve in Dobo

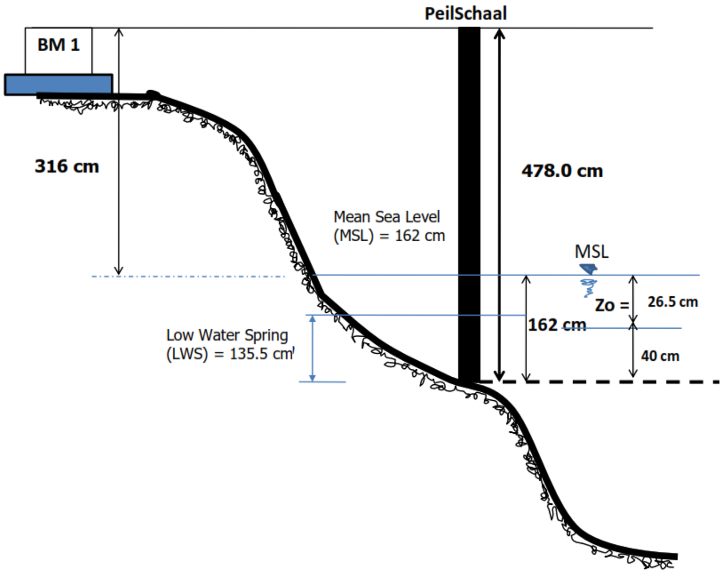

Fig. 13. Elevation of benchmark (BM) referenced to mean sea level (MSL)

Waves

Wind data analysis for the period 2020–2024 indicated that the dominant wind directions in the waters of Dobo Ferry Port originate from the northeast and southwest sectors. These data were processed to calculate the fetch length, defined as the effective sea surface distance influenced by wind. Based on these calculations, the significant wave height was determined showing seasonal variations. The results are visualized in Fig. (14), illustrating the correlation between dominant wind directions and wave generation in the port area.

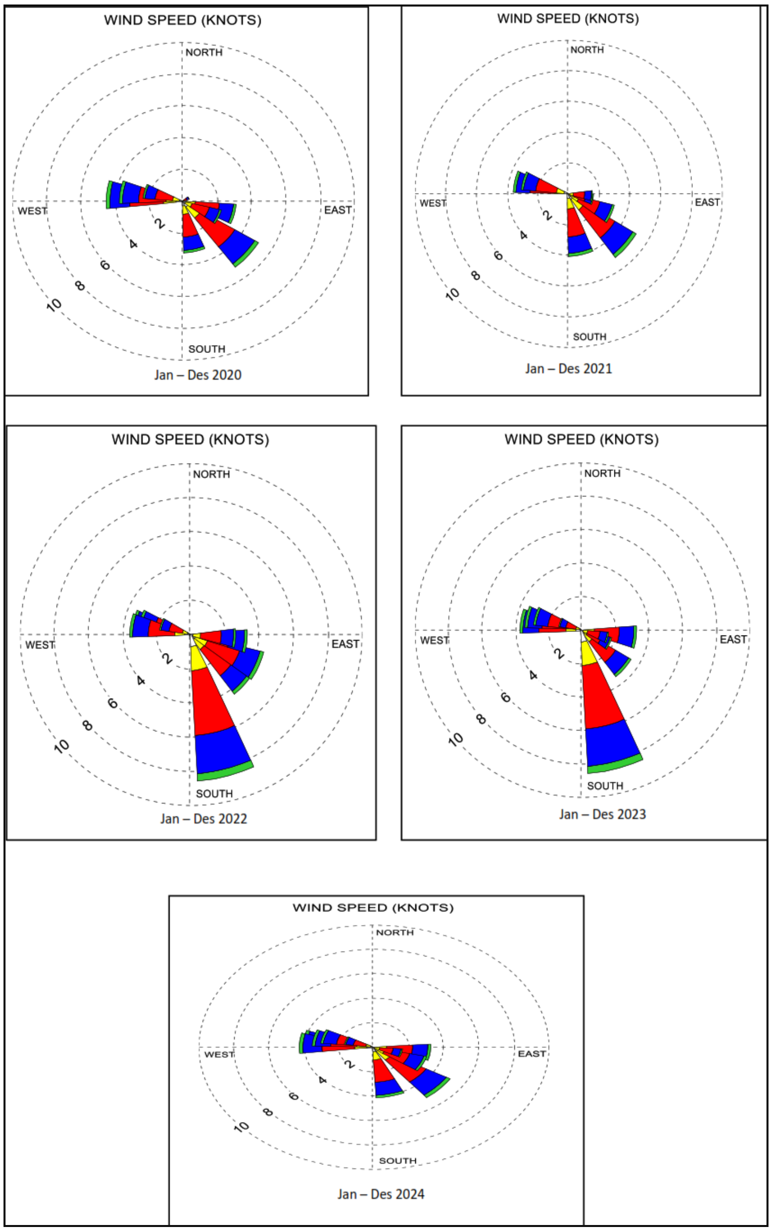

Fig. 14. Interannual variation of wind rose patterns in the Dobo coastal waters (2020–2024

Maximum wave conditions occur during the eastern season, with significant wave heights (Hs) of approximately 1.2–1.5 meters. Waves of this magnitude have the potential to increase sediment agitation in shallow waters and accelerate deposition in the anchorage basin. In contrast, during the western season, wave heights are relatively lower (0.5–0.8 meters), resulting in reduced energy transfer to the seabed. These fluctuations are important to consider in port facility planning, as they can influence sedimentation patterns throughout the year.

Overall, wave analysis indicates that, although significant wave heights in Dobo waters are moderate, the energy generated is sufficient to mobilize fine sediments at depths of 5–10 meters. This explains why the anchorage basin area at these depths experiences gradual shoaling. Therefore, wave dynamics constitute a key factor in accelerating material accumulation within the port area

Current

Current modeling in the waters of Dobo Ferry Port was conducted using survey-derived bathymetric data, which were subsequently constructed into a triangulated mesh grid. The model representation is shown in Fig. (15), with a color scheme indicating depth variations from shallow areas (red) to the deepest areas (dark blue). This triangulated mesh serves as the numerical domain for calculating current distribution according to tidal conditions and seabed morphological characteristics.

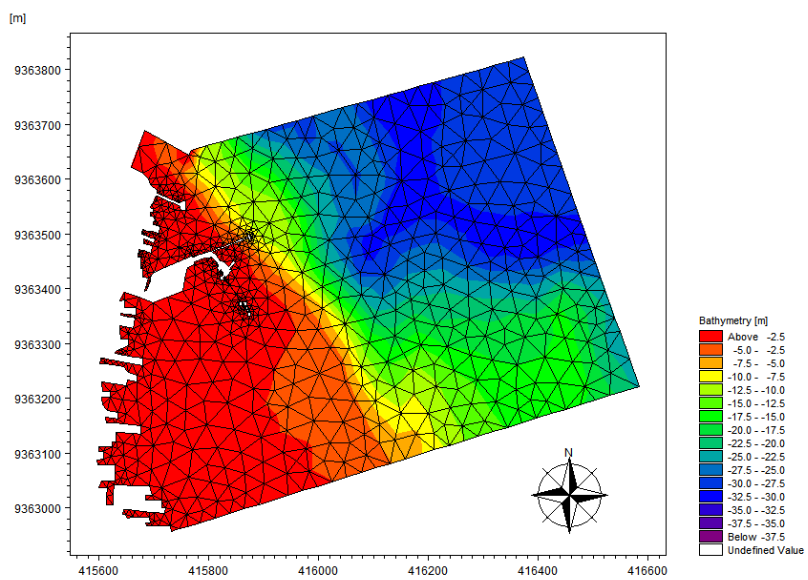

Fig. 15. Model domain and bathymetric grid for current analysis in Dobo Port waters

The modeling results indicate that currents tend to be influenced by depth patterns. In shallow areas around the anchorage basin (depths of 2.5– 7.5m), current velocities are relatively low, allowing fine sediment particles to settle. Conversely, in deeper areas (–15 to –30m), current energy is higher, keeping transported sediments in suspension and preventing deposition. This pattern highlights the role of bathymetry in shaping current dynamics, which in turn affects the shoaling process.

In addition to depth, tidal dynamics also influence current direction and velocity. During rising tides, currents flow toward the anchorage basin, transporting material from the open sea, whereas during ebb tides, part of the water mass flows outward but with weaker energy. This condition makes the anchorage basin a natural sediment trap. Thus, Fig. (15) not only represents bathymetric conditions but also illustrates the close relationship between seabed topography, current patterns, and potential sediment accumulation, which is the primary cause of shoaling at Dobo Ferry Port.

Beyond the bathymetric mesh domain (Fig. 15), the current simulation results are visualized as vector fields. Fig. 16 shows the distribution of current direction and velocity during the rising tide. In this phase, currents predominantly flow toward the northeast at relatively higher speeds (0.3– 0.6m/ s), particularly in deeper waters. This pattern indicates a significant inflow of water mass toward the anchorage basin area.

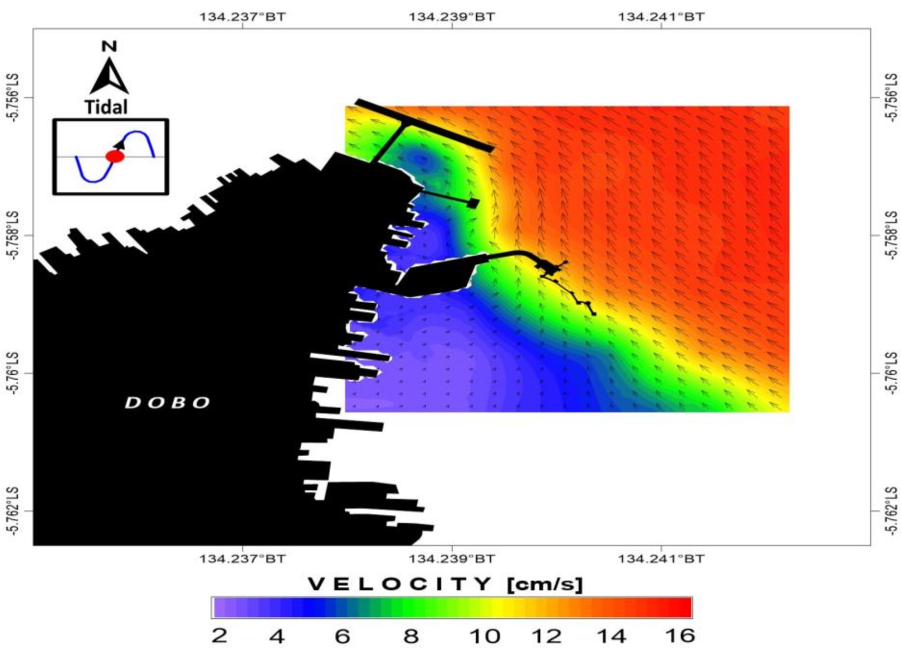

Fig. 16. Current velocity and direction during flood tide in Dobo Ferry Port waters

In contrast, Fig. (17) illustrates the current pattern during ebb tide conditions. The dominant current direction shifts toward the southwest, with lower velocities (0.1–0.3 m/s). This difference confirms that the current energy during ebb tide is insufficient to transport back the sediments that were carried into the basin during the rising tide. As a result, fine materials entering the anchorage basin tend to settle and accumulate on the seabed.

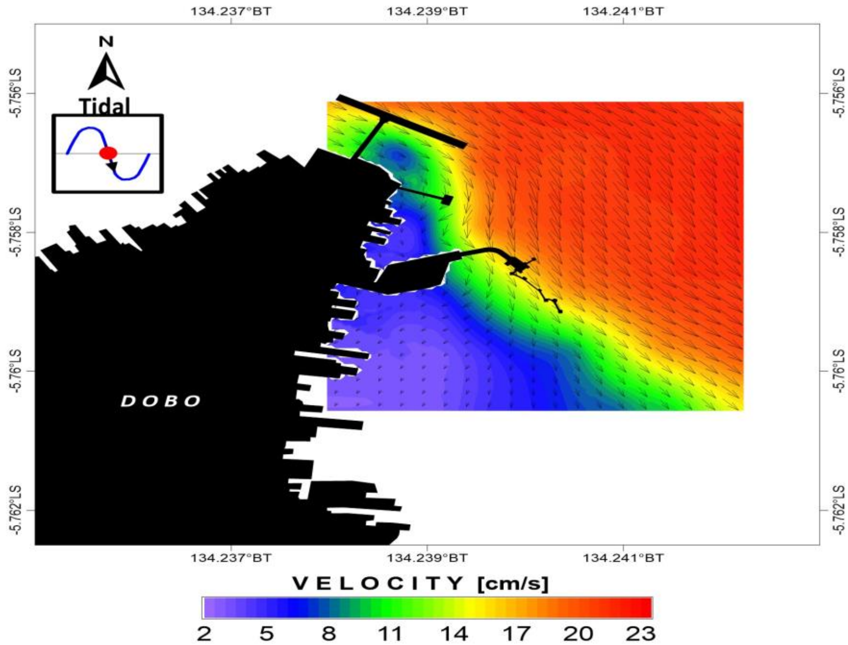

Fig. 17. Current velocity and direction during Ebb Tide in Dobo Ferry Port waters

This combination provides a clear illustration that the anchorage basin functions as a natural sediment trap. The asymmetric tidal current pattern—strong during flood tide and weak during ebb tide—serves as the primary mechanism explaining the accumulation of fine materials in the port area. Consequently, this current pattern directly contributes to the shoaling rate of the anchorage basin and should be considered in dredging planning and long-term port facility design.

Sedimentation

Laboratory analysis indicated that the trapped sediments were dominated by fine silt and clay fractions, with an average proportion exceeding 60% (Table 1). At several locations, fine sediments accounted for up to 70% of the total sample. This composition confirms that the primary source of shoaling materials consists of fine particles that are easily transported by currents and waves, subsequently settling in the anchorage basin. Coarse-grained sediments (medium to fine sand) were found only in limited amounts, indicating that sedimentation dynamics in this area are largely influenced by the supply of fine materials from terrestrial and coastal sources.

In addition to hydrodynamic factors, anthropogenic activities around the port area also contribute significantly. Small rivers flowing through mangrove areas transport organic and mineral materials into the waters, while coastal settlements with stilt houses extending into the sea add domestic waste particles. The combination of terrestrial sediment supply, tidal current dynamics, and wave energy makes the anchorage basin a natural sediment trap. This explains why the shoaling process occurs relatively rapidly, and without periodic dredging, the effective depth of the anchorage basin will continue to decrease, potentially disrupting ferry operations.

Table 1. Grain size composition of bottom sediments in the waters of Dobo Ferry Port

No	Sample Code	Sand (Medium) 500 µm (%)	Sand (Fine) 250 µm (%)	Sand (Very Fine) 150 µm (%)	Silt (Coarse) 90 µm (%)	Silt 63 µm (%)	Clay <63 µm (%)	Total (%)
1	1A	–	–	0.56	8.81	0.99	89.64	100.00
2	1B	–	–	0.52	9.98	1.30	88.20	100.00
3	2A	–	–	–	2.27	25.00	72.73	100.00
4	3A	–	–	0.40	6.67	0.79	92.14	100.00
5	4A	1.23	4.99	0.13	0.53	3.22	89.90	100.00
6	4B	–	–	2.80	39.89	0.55	56.76	100.00
7	5B	–	–	–	1.94	34.22	63.84	100.00

In addition to the per-sample data, summary statistics (mean ± standard deviation) were calculated to provide a clearer overview of sediment composition across all stations (Table 2).

Table 2. Summary statistics of sediment fractions (mean ± SD) at Dobo Ferry Port

Sediment Fraction	Mean ± SD (%)
Sand (Medium, 500 µm)	0.18 ± 0.46
Sand (Fine, 250 µm)	0.71 ± 1.89
Sand (Very Fine, 150 µm)	0.63 ± 0.99
Silt (Coarse, 90 µm)	10.01 ± 13.66
Silt (63 µm)	9.44 ± 14.06
Clay (<63 µm)	79.60 ± 14.37

The grain size analysis revealed that sediments in the Dobo Ferry Port basin are dominated by fine fractions, particularly clay (< 63µm) and silt (90– 63µm). Clay accounted for an average of 79.60 ± 14.37%, while coarse and fine silt contributed 10.01 ± 13.66% and 9.44 ± 14.06%, respectively (Table 2). In contrast, sand fractions were negligible, averaging less than 1% of the total composition.

The high proportion of clay and silt indicates that the anchorage basin acts as a natural sediment trap for fine-grained material. Such particles are easily mobilized by tidal and wave dynamics but tend to settle under weak ebb currents, thereby accelerating shoaling in the port basin. This pattern is consistent with previous findings that fine-grained sediments dominate deposition in semi-enclosed coastal environments where hydrodynamic flushing is limited **(Van Rijn, 2009; Wang & Andutta, 2013)**.

The relatively large standard deviations, particularly for coarse silt and clay, reflect spatial heterogeneity in sedimentation across the basin. This variability is likely influenced by differences in local bathymetry, riverine inputs from mangrove areas, and anthropogenic activities around coastal settlements. Overall, the dominance of clay-rich sediments underscores the importance of adopting adaptive dredging and sediment monitoring strategies to maintain navigational depth at Dobo Ferry Port.

Sedimentation patterns during the rising tide phase showed a total sediment load (suspended load and bedload) of 3.10^{-27} – 5.10^{-26} m³/s/m (Fig. 18), whereas during high tide conditions, the total sediment load ranged from 2.10^{-28} – 3.10^{-27} m³/s/m (Fig. 19). When the current flowed toward ebb tide, sediment transport occurred at 5.10^{-22} – 3.10^{-21} m³/s/m (Fig. 20), and during peak ebb tide, sedimentation reached 5.10^{-24} – 3.10^{-23} m³/s/m (Fig. 21). Over the 15-day tidal simulation period, sedimentation changes ranged from 0.01 to 0.07m near the old pier, whereas around the planned pier area, sediment accumulation was approximately 0.01m.

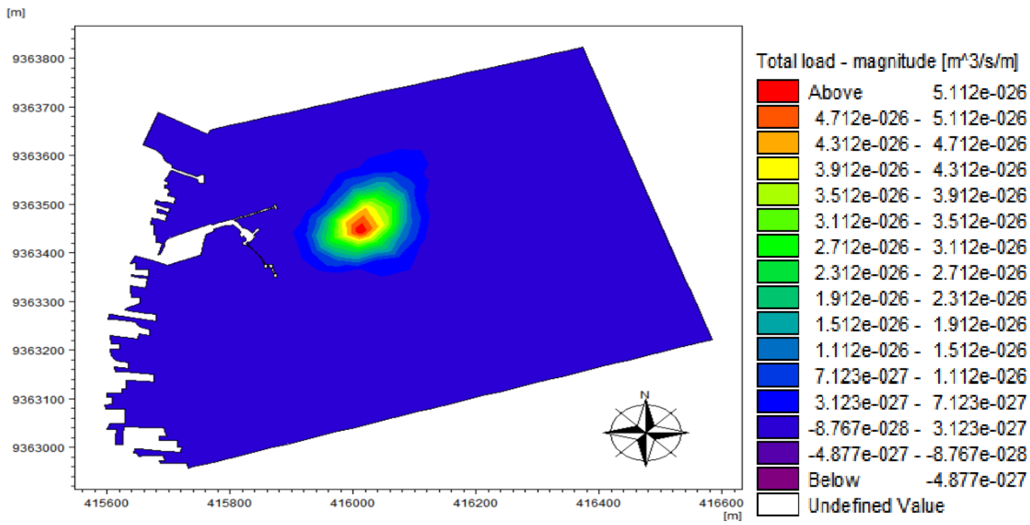

Fig. 18. Sedimentation pattern during flood tide

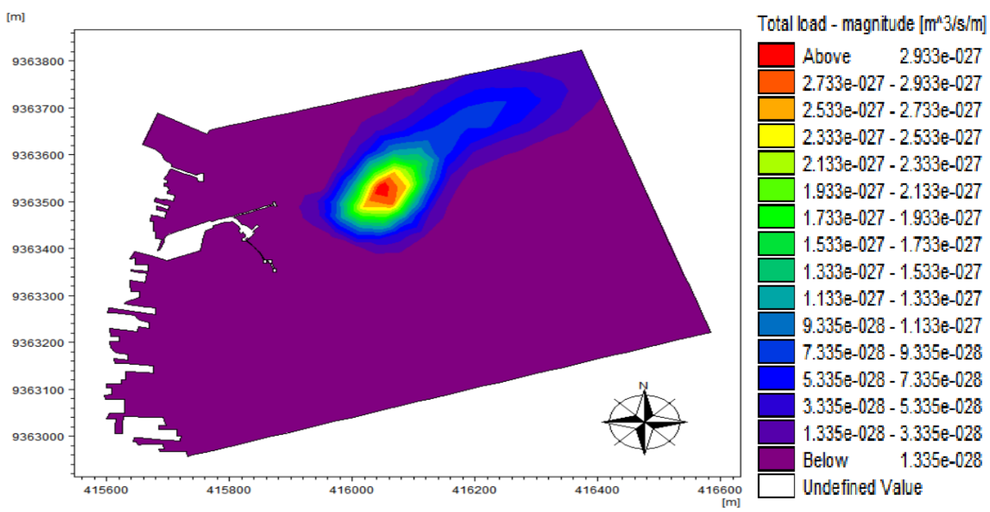

Fig. 19. Sedimentation dynamics at high water

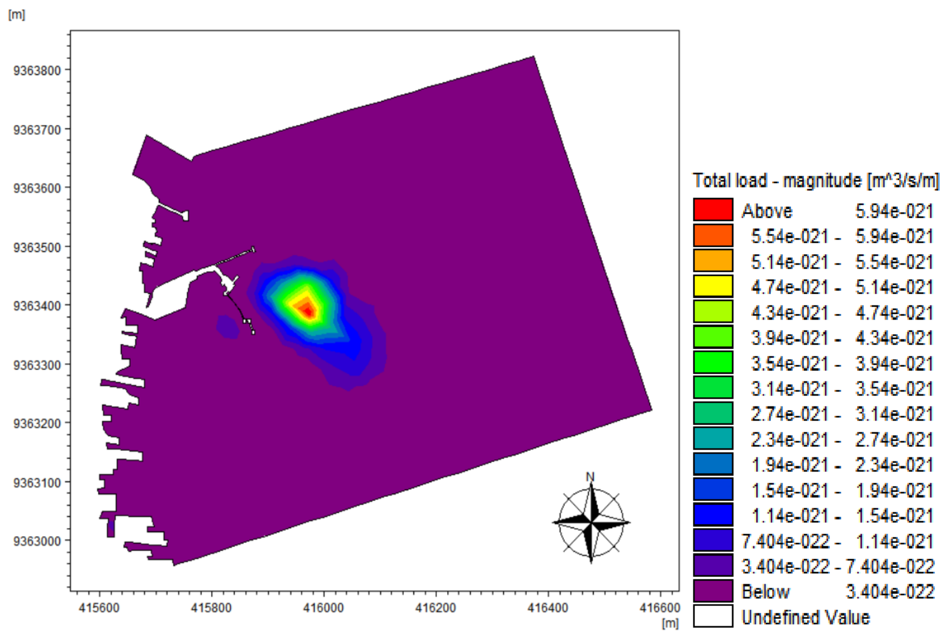

Fig. 20. Sedimentation pattern during Ebb tide

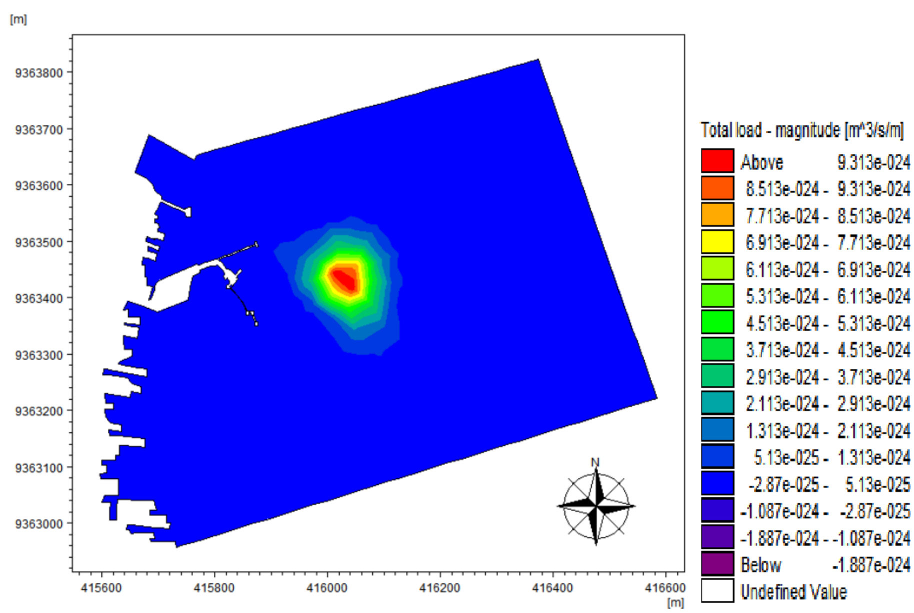

Fig. 21. Sedimentation pattern at low tide

Sedimentation processes observed at Dobo Ferry Port share similarities with several Indonesian ports where fine-grained materials dominate shoaling dynamics. For instance, studies in Tanjung Priok Port, Jakarta Bay, have shown that riverine inputs and high anthropogenic load significantly accelerate siltation in the basin, requiring frequent dredging to maintain navigable depths **(Wicaksono *et al.*, 2020)**. Similarly, Tanjung Emas Port in Semarang experiences persistent sedimentation due to combined effects of river discharge and tidal trapping mechanisms, which are comparable to the asymmetric tidal currents observed in Dobo **(Purnama & Adi, 2019)**. In eastern Indonesia, Makassar

Port has also been reported to face shoaling problems influenced by monsoonal wave forcing and sediment supply from adjacent rivers **(Halim *et al*., 2021)**.

In a broader Southeast Asian context, sedimentation challenges in Chao Phraya Port (Thailand) and Ho Chi Minh Port (Vietnam) highlight that estuarine and deltaic sediment loads play a major role in port shoaling **(Aksornkoae, 2017; Nguyen *et al*., 2018)**. Compared to these large ports, Dobo represents a small-scale archipelagic ferry port where hydrodynamic confinement rather than large riverine input is the dominant trapping mechanism. These comparisons suggest that while the magnitude of sediment supply may differ, the underlying processes of tidal asymmetry, wave resuspension, and fine-grained dominance are consistent across ports in Indonesia and Southeast Asia.

Managerial implications and sedimentation mitigation strategies

The results of this study indicate that shoaling in the anchorage basin of Dobo Ferry Port is the consequence of a complex interaction among current dynamics, tides, waves, and sediment supply from terrestrial sources. These conditions directly impact port operational efficiency, particularly in maintaining effective depths for ferry activities. If sedimentation is not properly managed, operational costs may increase due to more frequent dredging requirements, and the connectivity of inter-island transportation in the Aru Islands could be disrupted **(Xue *et al*., 2020)**.

From a managerial perspective, sedimentation mitigation strategies can be directed through two main approaches: technical engineering and ecological management. Technical engineering measures include periodic dredging, pier design modification, and the implementation of sediment flushing systems to reduce fine material accumulation in the anchorage basin. Studies at the port of Rotterdam have shown that a combination of adaptive dredging and current control systems can slow sedimentation rates by up to 30% **(Van Maren *et al*., 2015)**. These findings are relevant for application in Dobo, taking local hydrodynamic conditions into account.

In addition to technical interventions, ecological approaches also hold significant potential for reducing sediment input from terrestrial sources. Coastal mangrove ecosystem restoration has been proven effective in trapping sediments and reducing fine material influx into port waters **(Alongi, 2015; Rahman *et al.*, 2024; Tuahatu *et al.* 2025)**. Similarly, seagrass beds act as natural sediment traps while simultaneously reducing wave energy in coastal zones **(Potouroglou *et al*., 2017)**. Integrating technical and ecological solutions can provide a more sustainable mitigation strategy **(Berhitu *et al*., 2025)**.

Mitigation efforts must also consider the socio-economic aspects of local coastal communities. Settlement activities and infrastructure development around the port contribute to increased sediment loads. Therefore, involving local communities in coastal conservation programs and promoting environmentally friendly practices is essential to support the effectiveness of sediment control strategies **(Barbier, 2017)**. Such participatory approaches strengthen collective awareness in maintaining sustainable port functions.

Furthermore, the implementation of modern technology-based monitoring systems can enhance sediment management effectiveness. The use of current sensors, remote sensing, and numerical modeling allows for more accurate sediment accumulation predictions, enabling efficient “just-in-time” dredging **(Winterwerp *et al*., 2013)**. Integrating field data with predictive models minimizes operational costs while maintaining smooth navigation activities.

Moreover, vessel traffic dynamics should be considered as a managerial factor in sedimentation mitigation. A study by **Tukan *et al*. (2024)** on shipping patterns in Maluku showed that combining regular shipping routes with tramp shipping increases vessel utilization and strengthens inter-island connectivity. However, high vessel traffic intensity can also enhance sediment agitation in the anchorage basin. Therefore, integrating vessel scheduling, cargo load management, and hydrodynamic engineering is crucial in the sediment mitigation strategy for Dobo.

In conclusion, sedimentation mitigation strategies at Dobo Ferry Port should be formulated within an adaptive management framework that combines technical engineering, ecological approaches, community participation, technological support, and vessel traffic management. This holistic approach will not only maintain effective anchorage depths but also reinforce sustainable port operations while supporting maritime connectivity across the Aru Islands and the wider Maluku region.

Study limitations and future research

This study provides valuable insights into the hydrodynamics and sediment dynamics at Dobo Ferry Port; however, several limitations should be acknowledged. The field measurements were conducted over a limited seasonal period, which may not fully capture the variability of monsoonal hydrodynamics. In addition, the sediment data were obtained from a relatively small number of sampling points (14 topographic stations and 10 sediment traps), which may not entirely represent the spatial heterogeneity of the basin. Furthermore, the numerical modeling applied in this study was two-dimensional, thus not accounting for vertical stratification processes that may influence sediment transport.

Future research should address these limitations by conducting long-term monitoring that covers multiple monsoonal cycles to better capture temporal variability in sediment dynamics. Expanding the sampling design and employing three-dimensional sediment transport models would allow for a more detailed understanding of vertical mixing processes. Moreover, integrating hydrodynamic measurements with assessments of dredging efficiency and management strategies would provide practical insights for sustaining port operations in small archipelagic regions such as Dobo.

CONCLUSION

This study revealed that shoaling in the anchorage basin of Dobo Ferry Port results from a complex interaction between hydrodynamic factors and anthropogenic activities. Tidal analysis confirmed a mixed semidiurnal type, where tidal asymmetry plays a critical role in sediment transport. Significant waves during the eastern season resuspend fine sediments, while asymmetric tidal currents facilitate sediment deposition within the anchorage basin.

Sediment composition is dominated by fine silt and clay fractions (>60%), which are easily mobilized and accelerate shoaling. Additional contributions from river discharge and coastal settlement activities further increase sediment supply to the port waters. Sedimentation patterns observed during the 15-day tidal simulation indicated material accumulation ranging from 0.01 to 0.07 m around the anchorage basin. These findings confirm that the basin functions as a natural sediment trap and highlight the potential risk of navigational disruption if unmanaged.

Based on these results, mitigation strategies should be grounded in both engineering and ecological approaches. Adaptive dredging and pier design modification are necessary to address immediate shoaling, while mangrove and seagrass restoration are expected to reduce sediment inflow and stabilize the coastal zone in the longer term. The integration of these measures with technology-based monitoring will enhance the sustainability of port operations and maintain inter-island connectivity in the Aru Islands region.

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