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Quay Layout Planning Of Beaco Port Viqueque District, Timor-Leste

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Abstract

Timor-Leste shares the island of Timor with Indonesia and is strategically located near Australia, giving it significant maritime potential for both domestic connectivity and international shipping logistics. To support maritime transportation and national economic growth, the Government of Timor-Leste, through the Ministry of Transport and Communications, plans to develop and upgrade several port facilities, including Beaco Port. Therefore, a jetty layout plan that meets technical planning standards and operational requirements is required. This study focuses on the planning and design of a jetty structure for vessels with a capacity of 1000 DWT. The planning process includes site selection, determination of quay type and dimensions, quay basin, navigation channel, turning basin, causeway dimensions, fender and bollard specifications, as well as the spacing between fenders and bollards. The analysis was conducted using several software packages, including Microsoft Excel, WR Plot, ODV (Ocean Data View), MIKE Zero, and AutoCAD. The results indicate that Site 2, located at coordinates 8°56'53.43" S and 126°28'2.08" E, was selected as the optimal location. The proposed design consists of a jetty-type quay with dimensions of 122.6 m in length and 32.5 m in width, a one-way navigation channel with a depth of 10 m, width of 46.4 m, and length of 200 m, a turning basin with a diameter of 201 m, and a jetty basin with a depth of 6 m, length of 100.5 m, and width of 20 m. The selected fender type is V-SAN 800H × 1000L with 10 m spacing between fenders and WF500 fender piles, while the bollard system uses TEE BOLLARD with a capacity of 100 kN and 15 m spacing between bollards.

Keywords: Beaco Port, jetty design, port planning, maritime transportation, Timor-Leste.

1. Introduction

The territory of Timor-Leste is located on the same landmass as Timor Island, neighboring Indonesia and Australia. The maritime potential of Timor-Leste not only serves to connect its regions but also facilitates international maritime transport and logistics. The government, through the Ministry of Transport and Communications, plans to construct and improve port facilities in Timor-Leste, including the Beaco Port, to enhance sea transportation access and boost the national economy. The development of Beaco Port necessitates a quay layout plan that meets planning standards and criteria. The objective of this study is to assess hydro-oceanographic parameters for planning the Beaco Port facilities for RO-RO vessels and to determine the most suitable quay construction type among several alternatives, considering the physical environmental conditions, land availability, and accessibility around the Beaco Port area.

Timor-Leste occupies part of the Timor Island landmass and shares maritime frontiers with Indonesia and Australia, situating its port planning within a complex regional geopolitics and a dynamic maritime economy. The government's transport and communications agenda identifies Beaco Port as a strategic node to improve regional access, support RO-RO operations, and stimulate national growth through enhanced sea transport and logistics networks. In this context, a rigorous quay layout planning exercise is essential to ensure that the port configuration complies with planning standards while optimizing safety, efficiency, and environmental resilience for RO-RO vessels (Silva et al., 2022).

Hydro-oceanographic assessment is a necessary precursor to quay geometry selection, as sea-state, tides, currents, wave climate, and sediment dynamics directly influence breakwater design, berth length, dredging requirements, and channel navigation depth and width (Silva et al., 2022; Nasution, 2018). Beaco's coastal setting, land availability constraints, and accessibility considerations require an integrated hydrodynamic and geotechnical evaluation to identify the most suitable quay construction type among alternatives, balancing capital outlay with long-term operability under climate variability and potential sea-level rise (Silva et al., 2022; Nasution, 2018). The Beaco case thus aligns with broader regional port planning practices that combine hydrographic data, RO-RO operational requirements, and land-use planning to inform quay depth, berth spacing, and associated shore protection measures "Trade and Maritime Transport Trends in the Pacific", 2020 (Nasution, 2018).

Synthesis of planning implications for Beaco Port quay layout indicates that (a) hydro-oceanographic parameters must be explicitly incorporated into quay type selection (e.g., open quay vs. shore-protected quay, with or without breakwaters) to accommodate RO-RO draft, maneuverability, berthing efficiency, and safety considerations; (b) land availability and port-access constraints require the quay plan to optimize footprint while ensuring hinterland connectivity and integration with the national transport network; and (c) international connectivity and regional maritime activity necessitate a design capable of handling domestic RO-RO services and potential future growth in both freight and passenger movements, underpinned by climate-informed resilience planning "Trade and Maritime Transport Trends in the Pacific", 2020 (Silva et al., 2022; Nasution, 2018). These integrated considerations provide a rigorous basis for advancing Beaco Port's quay layout in support of Timor-Leste's strategic development objectives, including economic diversification and enhanced regional linkages (Nasution, 2018).

2. Research Methodology

2.1 Materials and Methods

This study aims to design a quay facility using a jetty-type structure intended to accommodate vessels with a capacity of 1000 DWT. The planning process includes a comprehensive analysis of site selection based on oceanographic, meteorological, and bathymetric conditions, as well as the determination of the most suitable quay configuration and structural dimensions. The design parameters cover the quay length and width, harbor basin (quay pool), navigation channel, turning basin, and causeway dimensions to ensure safe and efficient vessel maneuvering and operational activities.

In addition, the study evaluates the appropriate types and arrangements of marine accessories, including fenders and bollards, along with the optimal spacing between these components to meet berthing safety standards. Hydrodynamic and environmental analyses were also conducted to assess wave characteristics, currents, and wind conditions affecting the port area.

The analysis and design processes were carried out using several engineering and visualization software packages, including Microsoft Excel for numerical calculations, WRPlot for wind rose analysis, Ocean Data View (ODV) for oceanographic data processing, MIKE Zero for hydrodynamic modeling, and AutoCAD for technical drawing and infrastructure layout design.

2.2 Data Collection Method

Data collection was conducted through a combination of field surveys, environmental analysis, and literature studies to evaluate the feasibility of the proposed port development site. The primary objective of the survey activities was to assess the suitability of the selected coastal area for the construction of a jetty-type quay and supporting maritime infrastructure.

Primary data were obtained directly from field measurements, including tidal observations, bathymetric surveys, and soil investigations to determine seabed characteristics and foundation conditions. Secondary data were collected from relevant institutions and previous studies, consisting of wind data, ocean currents, and wave characteristics used to support hydrodynamic and navigation analyses.

In addition, supporting references were gathered from scientific journals, previous related theses, technical standards, and port planning guidelines, including Port and Coastal Engineering by Bambang Triatmodjo (2010) and Harbour Approach Channels Design Guidelines published by PIANC (2014). These references were used as the basis for determining design criteria, navigation safety standards, and structural planning parameters.

The study employed a quantitative research approach, where numerical data obtained from field measurements and secondary sources were analyzed using engineering calculations, hydrodynamic modeling, and spatial interpretation techniques. The research was conducted from May to July 2024 in Beaco, Viqueque District, located at coordinates 8°56'53.43" S and 126°28'2.08" E.

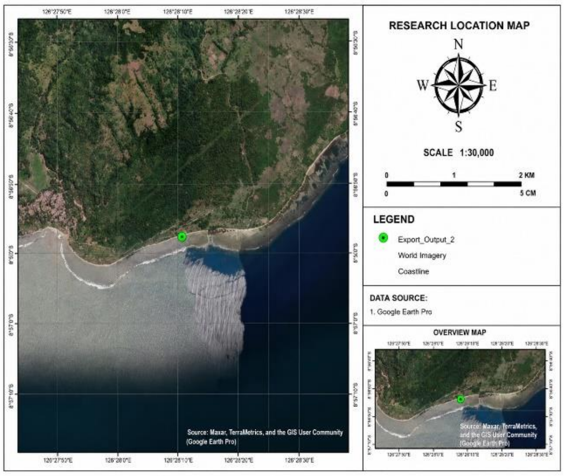


Fig 1. Research location

Fig 2. Location of Data Collection

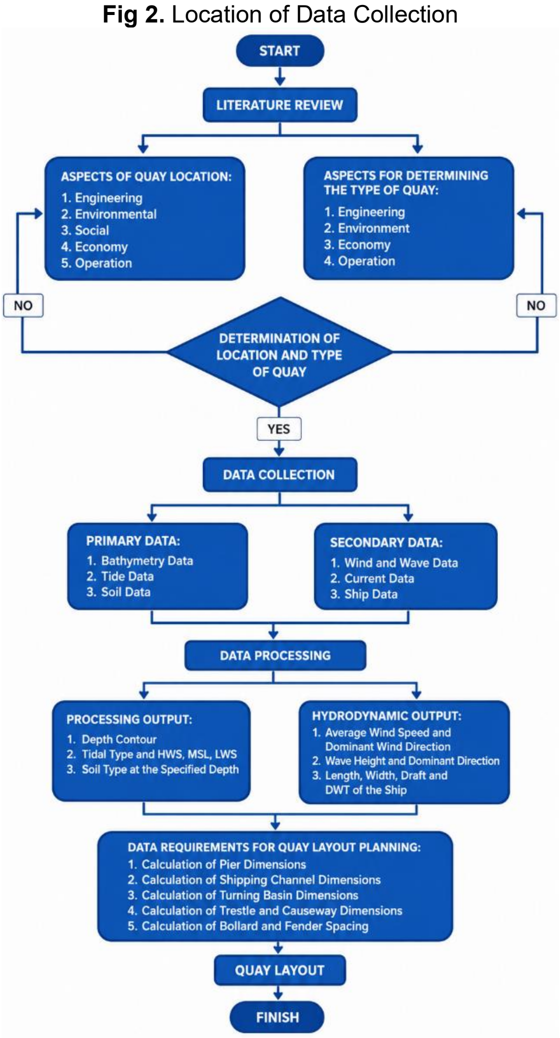


Fig 3. Research flow chart

2.3 Data Analysis

Planning the layout of the Beaco Port quay, the first step is to collect the data needed in planning the quay layout including wind data, currents, tides, bathymetry, ships and land data. Quay layout planning includes:

a. Quay location and type selection

Based on field data collection, site selection includes 4 aspects, namely: technical, environmental, social and economic aspects.

The selection of quay type is based on field data collection, including engineering, operation, environmental and economic aspects.

b. Quay Dimension Planning

Factors considered include:

Quay length: IMO (International Maritime Organization) provides an equation for determining the length of the quay as below:

$$Lp = n \times \mathrm{LOA}\,(n + 1) \times 10\% \times \mathrm{LOA} \qquad (1)$$

Where: Lp = quay length (m); n = number of moored ships and Loa = ship length (m)

Quay width: Tailored to operational needs, work areas, and goods distribution channels. Water depth: Should be deep enough to ensure vessels can berth without draft issues. Waves: Can cause movement of anchored vessels, increase the risk of damage to the quay structure, and disrupt the loading and unloading process. By considering wave characteristics, such as height and direction, planners can determine the optimal orientation of the quay, select appropriate materials, and design wave protection to reduce negative impacts.

c. Fender Planning

Most Quay will have fenders as a medium to absorb kinetic energy from berthing vessels. The calculation of berthing energy generally takes into account the worst-case combination of ship maneuvers, ship speed, berthing angle, and various coefficients (Trelleborg, 2007) Normal Berthing Energy (EN)

$$E_N = 0.5 \times M \times V_B^2 \times C_M \times C_E \times C_C \times C_S \qquad (2)$$

Description:EN = Normal energy to be absorbed by the fender (kNm); M = Mass of the ship (ton); V_B = Perpendicular speed of the ship when leaning (m/s); C_M = Additional mass; C_E = Eccentricity coefficient; C_C = Type of quay configuration and C_S = Density of fender type

Abnormal Berthing Energy (EA)

$$E_A = F_S \times E_N \qquad (3)$$

Description: EA = Abnormal heel value to be absorbed by the fender (kNm); F_S = Safety factor for abnormal heel and E_N = Normal Berthing Energy

Fender Distance

$$L = 2\sqrt{r^2 - (r-h)^2} \qquad (4)$$

Where: L= maximum distance between fenders (m); r = radius of curvature of the bow side of the ship (m) and h = fender height

$$\log r = -1{,}055 + 0{,}650 \log (DWT) \qquad (5)$$

Where:
DWT = deadweight tonnage

d. Bollard Distance

After determining the type of bollard to be used, the next thing needed is to estimate (approximate) the distance between bollards. This estimate is found in the book Port designer's handbook by Carl A Thoressen, 2018, that is:

Table 1. Bollard Load and Estimated Distance Between Bollards

DWT	Bollard Load (kN)	Estimated distance between bollards (m)
1.000	100	5-10
5.000	200	10-15
10.000	300	15
15.000	500	20
30.000	600	20
50.000	800	20-25
100.000	1.000	25
200.000	1.500	30

e. Shipping channel planning.

This planning can involve determining safe and efficient paths for vessels to enter and exit the harbor. The following is the formula for determining the Depth and Width of the Shipping Channel: based on the Harbor Approach Cahannels Design Guidlines PIANC, 2014.

Width of the shipping channel: Determined based on the size of the largest vessel that will pass through the channel.

$$\mathbf{W} = \mathbf{W_{BM}} + \sum \mathbf{W_i} + \mathbf{W_{BR}} + \mathbf{W_{BG}} \quad (6)$$

Where: W_{BM} = Basic Maneuvaring Lane; W_i = Environmental and Other Factors and W_{BR} & W_{BG} = Bank Clearance

Depth of the channel: Should be deep enough to ensure vessels can traverse the channel without draft issues.

$$\text{Channel Depth} = \text{Draft Load} + \text{Ship Related Factors} + \text{Add For Channel Bottom Type} \quad (7)$$

f. Turning basin planning

The diameter of the turning basin (Db) can be calculated using the following equation (Technical Standards and Commentaries for Port and Harbor Facilities in Japan, 2002):

Db = 2×LOA (ship maneuvering with the pilot boat assistance) (8)
Db = 3×LOA (ship maneuvering without pilot boat assistance) (9)

Depth of the turning basin: Should be deep enough to ensure the vessel can turn around without draft issues. Location of the turning basin: Should be strategically located and safe from harbor traffic interference.

g. Quay basin

Based on C. A. Thoresen, Port Designer's Handbook, 2014:
Length of quay basin
Length = 1.25 x LOA (When assisted by a pilot boat)
Length = 1.50 x LOA (When without the assistance of a pilot boat
Width of quay basin
Width = 4 x B + 50 m, > 1 quay facing
Width = 2 x B + 50 m, 1 quay facing
Width = 1.25 x B, free quay

The depth of the quay basin should be adequate for the draft of the largest vessel to be berthed, including a safety margin.

h. Planning causeway dimensions

Width of Causeway: Determined based on the number of vehicle lanes and pedestrian requirements.
Length of causeway: Depends on the distance that must be traveled to connect two land masses.
Height of causeway: Should be high enough to avoid waterlogging and waves.

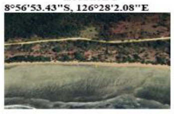
Structure and materials: Should be strong enough to withstand the traffic load and resistant to surrounding environmental conditions, such as erosion and abrasion.

3. Results and Discussion

3.1 Site Selection

Beaço is located on the South coast, Eastern part of Timor Leste ± 190 nautical miles from the capital city of Dili. This research provides two alternative locations in Beaco to be recommended to the government, namely Location 1 with coordinates 8°56' 42 "LS and 126°26' 54 'BT is an empty area that has never been developed before located in the middle of a residential area, and location 2 with coordinates 8°56'53.43 'LS and 126°28'2.08 "BT located on the edge of the paintai as far as 2.10 kilometers from location 1. Scoring Standards: Very unfavorable: 1 Not good: 2 Fairly good: 3 Good: 4 Very good: 5 (Table.2).

Table 2. Quay Site Selection Matrix

Aspect	Location 1 8° 56' 42"S, 126° 26' 54"E 	Scoring	Location 2 8°56'53.43"S, 126°28'2.08"E 	Scoring
Technical	Good access road and is the location of LNG terminal planning.	2	Good access road and is a vacant land (no development planning)	4
Operational	Land acquisition is required for parking vehicles before boarding the ship.	2	Land acquisition is not required for parking vehicles before boarding the ship.	4
Environmental	Near green areas, minimize pollution and access to water	2	Near green areas, minimize pollution and access to water	4
Social	In the middle of residential areas (33 meters from residential areas) and easy access to transportation	2	Far from residential areas (1.37 km from residential areas) and easy access to transportation	4
Economic	Near logistics area, easy logistics access, operational cost effective.	3	Near logistics area, easy logistics access, operational cost effective.	3
	Total	11		19

Based on the scoring, Site 2 is superior with a total score of 19 compared to Site 1 which scored only 12. Site 2 is preferred for development, mainly because it is not in the LNG planning location and has more favorable environmental and operating conditions.

3.2 Site Selection

The selection of the type of dock refers to several aspects, namely, technical, operational, environmental and economic aspects. With the general conditions in Beaco where, the contours of the seabed are relatively steep, the seabed consists of a layer of coral 3 to 7.5 m below the seabed, the tidal difference is quite high, the sea waves are relatively high, also an important aspect that can be considered in determining the type of dock.The following is a scoring matrix description of the type of Beaco quay recommended to the government. Scoring Description: Very Bad = 1 Bad = 2 Fair = 3 Good = 4 Very Good = 5

Table 3. Beaco Quay Type Selection Matrix

NO.	Aspect		Criteria	Quay type: WHARF	Scoring	PIER	Scoring	JETTY	Scoring
1	Technical	a	Dredging	Dredging required due to flat seabed contours	1	Dredging required due to flat seabed contours	1	No dredging required	5
		b	Proposed Quay Structure	Caisson, due to hard seabed soil structure	3	Caisson, due to hard seabed soil structure	3	Deck on Pile	2
		c	Sedimentation potential	High, due to dredging	2	High, due to dredging	2	Low, as there is no dredging	4
		d	Abrasion Protection Structure	May be required	2	Breakwater required	2	Not required	4
		e	Ease of Implementation	Difficult, dredging requires clamshell equipment (corresponding to seabed soil layer consisting of coral layer)	4	Very Difficult, dredging requires clamshell equipment (in accordance with the seabed soil layer consisting of coral layer)	4	Easy, as there is no dredging	5
		f	Construction Period	Longer	2	Longer	2	Faster	5
2	Environmental	a	Distance from the environment	High, dredging requires special environmental handling, disposal area for dredged material required	3	Very High, dredging and reclamation require special environmental handling	3	Very Low, no special environmental treatment	5
		b	Distance to Marine Biota	High	2	Very High, due to reclamation	2	Very Low	5
		c	Abrasion	Likely Very High, Much interference with seabed contours	2	Likely Very High, Much disturbance to seabed contours	2	Very low, no disturbance to seabed	5
3	Economic	a	Construction Cost	More expensive	2	More expensive, need additional protection structures	2	Cheaper	5
		b	Maintenance Cost	High, due to sedimentation	2	High, due to sedimentation	2	Low	4
4	Operational	a	Dock ramp for ups and downs of vehicles	Not recommended due to considerable depth from land	4	Not recommended as only one jetty is needed	4	Recommended because the direction can be adjusted to be in line with the waves and can be equipped with a ramp	3
			TOTAL		29		29		52

The selection of quay types that refer to several important aspects of consideration according to the table above, Jetty has the highest total score and is considered the most superior type of quay.

3.3 Bathymetry

For the creation of bathymetric maps, measurement data were transferred to a computer via Garmin Mapsource software. Autocad/Civil 3D was used to process the XYZ data from the Ms. Excel program and create contour lines by interpolating adjacent depth values. This map, which is based on the Ministry of Transportation and Communications in 2023, is used primarily for dock planning.

In the underwater topography (bathymetry) measurements, the lowest low tide boundary topography (reef) up to 120 meters to the south was found to be -17 m elevation. A stretch of elevation between -17 and -18 m was found in the area of the planned end of the quay.

3.4 Tidal

Tidal observations for 15 days (March 1-15, 2023) were made at one-hour intervals, with water level values determined using the zero tide mark position as a reference (peilschaal).

Admiralty method for harmonic analysis was used to calculate the tidal constant. Admiralty method was used to analyze the data and obtain the tidal constants at the study site. Table 4 contains these constants.

Table 4 Tidal Constant at Beaco

TIDAL CONSTANT	S0	M2	S2	N2	K1	O1	M4	MS4	K2	P1
A (cm)	220.84	68.38	38.03	12.37	35.93	23.11	2.39	1.30	10.27	11.86
g˚		60.80	35.87	107.37	265.80	33.32	161.58	253.15	35.87	265.80

= (K1+O1)/(M2+S2)

= (35.93+23.11)/ (68.38+38.03)

$$F = \frac{A(K_1) + A(O_1)}{A(M_2) + A(S_2)}$$

F= 59.04/106.41 = **0.5548**

Based on the Formzhal value, the tidal criteria are: Mixed Tide Prevailing Semi diurnal. Analysis of tides at Beaco from 15 days of measurements (March 1-15, 2023), it can be seen that some important tidal elevations at Beaco are:HHWL= +3,76 m; HWL= +2,72 m; MSL= +1,65 m; LLWL= +0,61 m; LWL= +1,61 m; HWS = +3,30 m; LWS = 0,00 m.

3.5 Wind

Beaco is located in the southern region of Timor Leste, facing the continent of Australia. Waves can be generated by winds coming from the east, southeast and south. At this facility, researchers process wave plans using wind data from ECMWF Era 5. The wind data is based on the Eastern Season (June - August 2023), Transitional Season 2 (September - November 2023), Western Season (December 2023 - February 2024), and Transitional Season 1 (March - May 2024). From the measured wind data obtained in nc format, data analysis is then taken from ECMWF Era5 in OCD (Ocean data view) and processed in excel to adjust the direction and speed, then input into the wrplot application to get a windrose.

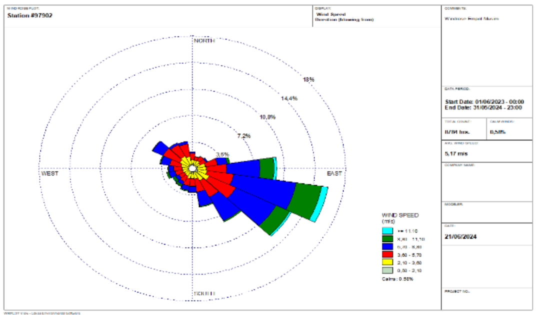


Fig. 1 Wind Rose combined four seasons (June 2023 - May 2024)

The above-mentioned data shows that when the largest or more frequent wind events occur in the four seasons are winds blowing from the TTG (East southeast) direction with 16.1%, and an average wind speed of 5.17 m/s.

3.6 Fetch

The study site recorded an average wind speed of 5.17 m/s during the observation period. Fetch, defined as the uninterrupted distance over water that wind blows in a single direction, is a critical parameter in wave generation as it determines the amount of energy transferred from wind to the water surface.

Based on the geographical location of the study site at 8°57'11.70"S and 126°28'14.71"E, the surrounding coastal morphology and land-sea distribution create specific constraints on wave generation. Analysis of the wind rose diagram and site orientation reveals that winds originating from the east (Figure 5), southeast (Figure 6), and south (Figure 7) have unobstructed paths over open water toward the study location, giving them the potential to generate significant waves.

In contrast, winds from other directions (north, northwest, west, and southwest) are either blocked by landmasses or have insufficient fetch length to develop substantial wave energy before reaching the study site. Therefore, only the easterly, southeasterly, and southerly wind directions were considered in calculating the effective fetch.

The effective fetch for each of these three dominant wind directions was determined using the radial method, which accounts for the angular spread of wind energy. Table 5 presents the calculated effective fetch values for each relevant wind direction, which were subsequently used in wave height and period estimations.

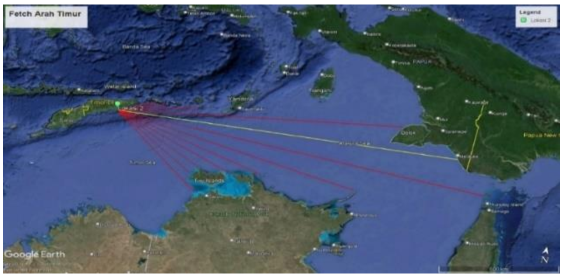


Fig. 5 Fetch map from East

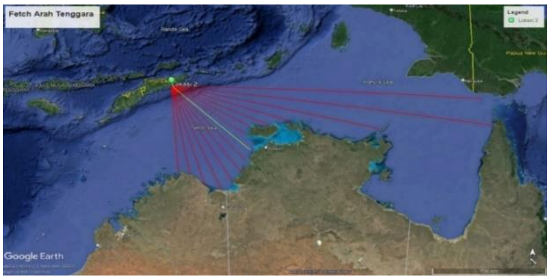


Fig. 6 Fetch map from the Southeast

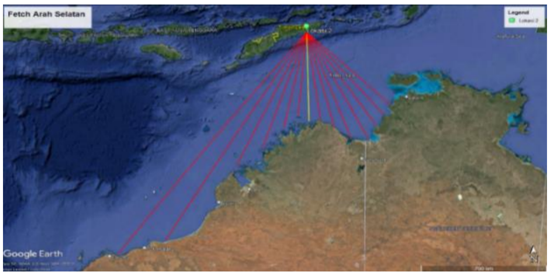


Fig. 7 Fetch map from the South

Table 5 Fetch effective Beaco beach

no	α	Cos α	Xi (Km)			Xi. Cos α (Km)		
			East	Southeast	South	East	Southeast	South
1	42	0,74	0	1654	593	0	1229	441
2	36	0,81	0	1720	618	0	1392	500
3	30	0,87	0	1118	651	0	968	564
4	24	0,91	186	663	707	170	606	646
5	18	0,95	228	566	670	217	538	637
6	12	0,98	372	486	581	364	475	568
7	6	0,99	1276	496	527	1269	493	524
8	0	1,00	1546	571	535	1546	571	535
9	6	0,99	1714	599	506	1705	596	503
10	12	0,98	1145	641	583	1120	627	570
11	18	0,95	728	674	724	692	641	689
12	24	0,91	632	687	863	577	628	788
13	30	0,87	481	638	1416	417	553	1226
14	36	0,81	479	542	1621	388	438	1311
15	42	0,74	569	529	1720	423	393	1278
		13,51				8887	10148	10781
		Fetch Effective				**658**	**751**	**798**

3.7 Waves

The wind speed values, which will be used to forecast future wave height and duration, were obtained from the collected field data on wind speed. The hindcasting results show that the dominating waves, with a maximum wave height of 6.5 m and a maximum period of 16.2 s, originate from the east-southeast direction.

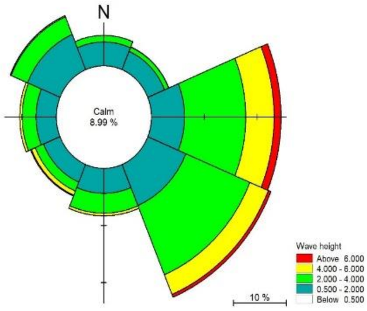


Fig. 8 WaveRose hindcasting results, four seasons combined

3.8 Current

Ocean current data at the study site were collected over a one-year period from May 2023 to April 2024, obtained from [insert data source] (Service, 2024). The raw data in NetCDF format were processed through a two-stage analysis: (1) exploratory visualization and statistical analysis using Ocean Data View (ODV) to characterize the spatio-temporal patterns of currents, and (2) numerical modeling using MIKE Zero to simulate current velocity and direction in greater detail.

As illustrated in Figure 4.18, the dominant current pattern flows from the southwest, with a maximum recorded velocity of 0.63 m/s. The relatively high current velocity at the planning site is attributed to its location in open water, where minimal topographic obstruction allows water masses to move more freely and energetically compared to semi-enclosed or nearshore environments

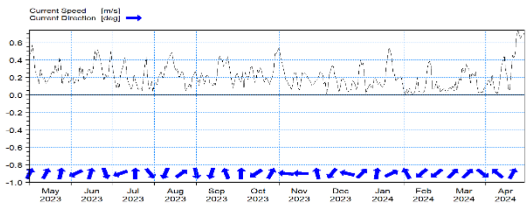


Fig. 9 Flow Direction and Velocity

3.9 Soil

The soil data used was obtained from soil work at the quay planning site. The data used is data at point BH 01 with a geographical coordinate system of -8.94787711° N and 126.46694463° E, where at this location it is dominated by sandstone which is very massive until the planned depth.

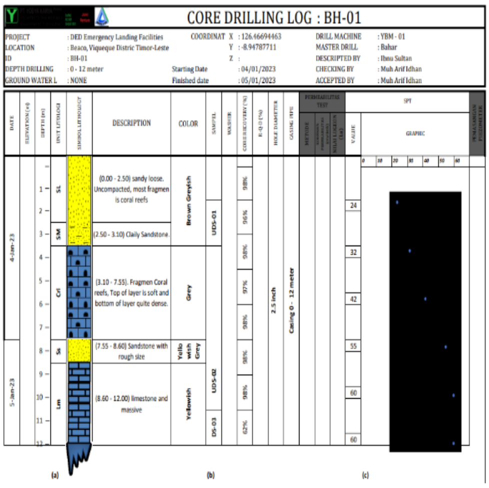


Fig. 10 Soil data

Table 7 Quay Layout Results

No.	Requirement		Dimensions
			Quay
1	Lenght		122,6 m
	Width		32,5 m
	Apron Elevation		+5,50 mLWS
			Causeway
2	Lenght		227,43 m
	Width		5,5 m
			Fender
3	Type		TIPE V-SAN 800H X 1000L
	Distance Fenders	between	10 m
			Fender Pile
4	Type		WF 500
			Bollard
	Type		*TEE BOLLARD*
5	capacity		100 kN
	Distance *bollard*	between	15 m

Table 8 The Result of Jetty Waterfront Layout

No.	Requirement	Dimensions
	Shipping channel	
	Type	*One way traffic*
1	Length	200 m
	Width	46,4m
	Depth	10 m
	Turning basin	
2	Diameter	201 m
	Depth	6 m
	Quay basin	
3	Lengt	100,5 m
	Widh	20 m
	Depth	6 m

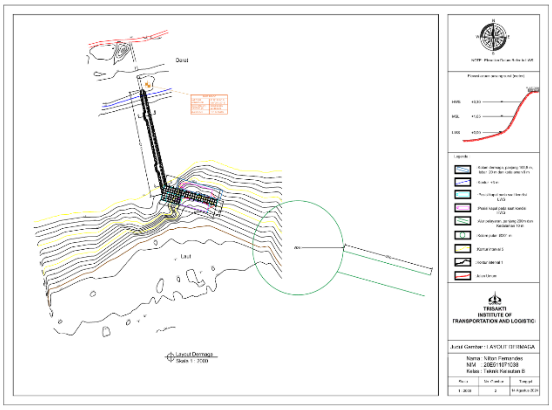


Fig. 11 Quay Layout

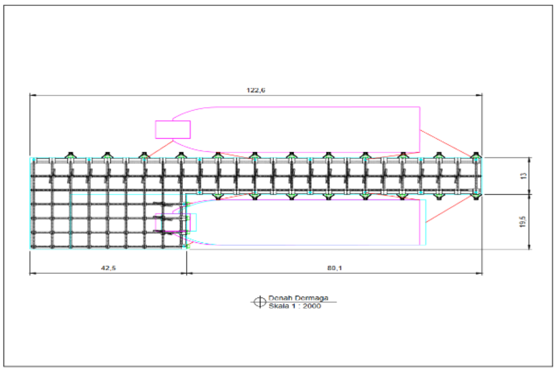


Fig. 12 Quay Plan

4. Conclusion

This study demonstrates that a location-specific, data-driven approach to quay design is essential for developing safe, efficient, and resilient port infrastructure in dynamic coastal environments. By integrating high-resolution environmental data—including tidal regimes, wave climate, wind patterns, current dynamics, and geotechnical conditions—the proposed jetty-type layout at Location 2 optimizes vessel operability while minimizing construction and maintenance costs. The design accommodates vessels with a maximum draft of 6.0 m and incorporates marine appurtenances calibrated to local hydrodynamic loads. Furthermore, the recommendation for a dedicated breakwater feasibility study in the Beaco area underscores the importance of proactive risk mitigation against seasonal water-level fluctuations of up to 4.0 m. Beyond the immediate site, the methodology and findings presented herein offer a scalable reference framework for port planning in comparable tropical, semi-exposed coastal settings, supporting evidence-based decision-making to enhance operational reliability and reduce vulnerability to extreme marine events.

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