

## The Amplitudes and Phases of Tidal Constituents from Harmonic Analysis at Two Stations in The Gaspar Strait of Bangka Belitung

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### ABSTRACT

The waters of the Bangka Belitung islands are shallow waters that are affected by tides. The tides in these waters originate from the propagation of the South China Sea and the Java Sea so they have unique characteristics. This study aims to analyze the amplitude and phase difference at 2 stations representing Bangka and Belitung Islands with the final output of LAT and HAT information as safe depths for ports in NFP Sungailiat and NFP Tanjung Pandan. Tidal data for 1 year with time intervals of 1 hour in 2015 were used to extract the harmonic components to determine the type of tide and calculate the tidal level at each station. The results obtained are 19 harmonic components with a diurnal tide type. The water level at Tanjung Pesona was higher than Tanjung Tinggi which is described by tidal levels with HAT 2.64 and LAT 1.72 m. Safe depth for anchored in the LAT condition (lowest recess), the water level at Tanjung Pesona station was above the maximum depth of the Sungailiat NFP pool, on the other hand, the Tanjung Pandan NFP LAT is 0.44 m below the maximum depth of the port pool.

**Keywords:** Bangka Belitung Waters, chart datum, HAT, LAT, tidal level

### ABSTRAK

Perairan kepulauan Bangka Belitung merupakan perairan dangkal yang dipengaruhi oleh pasang surut air laut. Pasang surut di perairan ini berasal dari perambatan Laut Cina Selatan dan Laut Jawa sehingga memiliki karakteristik yang unik. Penelitian ini bertujuan untuk menganalisis amplitudo dan beda fasa pada 2 stasiun yang mewakili Kepulauan Bangka dan Belitung dengan keluaran akhir berupa informasi LAT dan HAT sebagai kedalaman aman untuk Pelabuhan Perikanan Nusantara (PPN) Sungailiat dan Tanjung Pandan. Data pasang surut selama 1 tahun dengan interval waktu 1 jam pada tahun 2015 digunakan untuk mengekstrak komponen harmonik untuk menentukan jenis pasang surut dan menghitung tinggi pasang surut di setiap stasiun. Hasil yang diperoleh adalah 19 komponen harmonik dengan tipe pasang surut diurnal. Ketinggian air di Tanjung Pesona lebih tinggi dari Tanjung Tinggi yang digambarkan oleh pasang surut dengan HAT 2,64 dan LAT 1,72 m. Kedalaman aman untuk berlabuh pada kondisi LAT (reses terendah), tinggi muka air di stasiun Tanjung Pesona berada di atas kedalaman maksimum kolam PPN Sungailiat, sebaliknya LAT PPN Tanjung Pandan berada 0,44 m di bawah kedalaman maksimum kolam pelabuhan.

**Kata kunci:** Perairan Bangka Belitung, chart datum, HAT, LAT, level pasut

### 1. Introduction

The water level in the ocean fluctuations is caused by the interaction of celestial bodies, namely the moon, earth, and sun, as well as the shape of the coastline and the topography of an

area's waters (Supangat 2003; Stewart, 2008). The attraction of these astronomical factors causes tidal and ebb patterns. The position of celestial bodies that is sun, moon, and earth are in alignment (at the time of the new and full moon) creating extra-high tides and very low tide

due to the additive effect of the solar tide on the lunar tide called a spring tide. When the sun and moon are at right angles to each other, the solar tide partially cancels out the lunar tide and produces moderate tides known as neap tides (Sumich, 1966).

The tidal period's length can be determined based on the amplitude dominance value of the main components, namely the K1, O1, M2, and S2 components (Marchuk and Kagan, 1983). The main component is also used to determine the time of daily tides by using the Fomzhal number with the tidal type output (Widyantoro, 2014). The different phases produced in each component can show tidal propagation from one region to another (Pugh, 1971). Therefore, information about tides is vital, especially in coastal areas, because it directly affects the lives of organisms and domestic and industrial activities around them.

The Bangka Belitung Islands are located in the east of Sumatra's island, whose land is surrounded by the sea. These waters are shallow waters affected by tidal propagation from the South China Sea Basin in the North and Java Sea in the South (Fatoni, 2011). This strategic location makes fisheries one of the potential commodities. Support for fisheries potential has been supported by Nusantara Fisheries Port (NFP) construction at two locations, namely NFP Sungailiat on Bangka Island and NFP Tanjung Pandan on Belitung Island. NFP, based on ministerial decree ministry of marine affairs and fisheries republic of Indonesia Number 6 / Kepmen-KP / 2018, is a place for government activities and fishery business activities used as a place for fishing boats to dock and load unloads fish equipped with shipping safety facilities and fishery support activities.

Tides are one of the factors that influence port buildings and anchored ships (Trihadmojo, 2009). Tides are also essential to determine building dimensions, namely breakwaters, docks, buoy guide, channel depth, and harbor waters. Chart datum is a reference plane of water level reference used on navigation charts which are generally connected to the lowest water level (Suyarso, in Ongkosongo, 1989). The data chart is used to determine the reference for the port pool depth obtained from calculating the tidal harmonic components. LAT (HAT) is defined as the lowest (highest) tidal level that can be predicted from average meteorological conditions and a combination of astronomical conditions. LAT and HAT are calculated from observations of at least one year or over a period of at least 19 years using harmonic constants (International Hydrographic Organization, 2010). The data chart values, namely LAT and HAT, can be used to make marine

cadastre. Marine cadastre is an administrative system in the 3D marine sector by considers legal and systematic technical arrangements of marine spatial rights, boundaries, and responsibilities for marine spatial activities (Ashraf et al., 2013).

This study aims to analyze the amplitude and phase difference on Bangka Island (Tanjung Pesona Station) and Belitung Island (Tanjung Tinggi Station). Furthermore, the data obtained is used to show the littoral zone, namely LAT and HAT, as a reference for marine cadastre and describe the tidal level in the port pool near each station to show a safe reference depth for anchorage.

## 2. Material and methods

The data used in this study is the water level observed using kalesto (water level measurement using radar wave) at hourly intervals at Tanjung Pesona on Bangka Island and Tanjung Tinggi on Belitung Island. The observation period for one year from 1-Jan-2015 to 31-Dec-2015. The duration of the observation period of one year (365 days) is sufficient to perform harmonic analysis and obtain the main components (Madah, 2020). Time-series of data elevation is obtained from BOOST (Babel Ocean Observation and Technologies). The geographic position of the tide measurement station and fishing port is shown in Figure 1. Hourly time series inspections and quality checks were carried out, including checking gaps and spikes and preparing the data into a suitable analysis format. The data used for harmonic analysis in Tanjung Pesona and Tanjung Tinggi does not have a data gap.

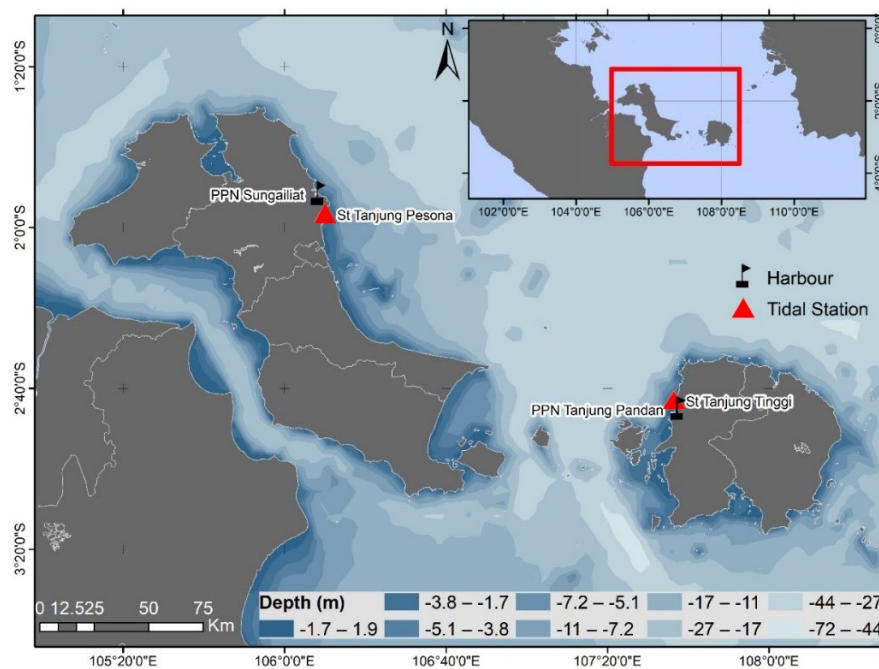
The basic assumption of applying the time domain harmonic analysis method is that the tidal variation can be represented by the finite number N (Godin, 1972):

$$\xi(t) = \sum_{i=1}^N H_i \cos(\omega_i t - G_i); n = 1, \dots, N \dots (1)$$

$H_i$  is the amplitude,  $\omega_i$  is the angular velocity, and  $G_i$  is the lag phase. The lag phase is conventionally expressed relative to the Greenwich meridian. Typically, angular velocity is expressed in degrees per hour and phase lag in degrees. Algorithms used to estimate phase and amplitude by Godin (1972) and Foreman (1997). At fixed locations, the variation in water level caused by tides can be expressed as a series of cosine functions (Pugh, 1987):

$$Z(t) = Z_0 + \sum_{i=1}^N f_i H_i \cos[\omega_i t + (V_0 + u)i - G_i] \dots (2)$$

$Z(t)$  is the water level,  $H_i$  and  $G_i$  amplitude and lag phase of the constituent  $n=i$ , respectively;  $\omega_i$  is the angular velocity;  $N$  is the number of tidal constituents;  $Z_0$  is the average water level over a certain period; find  $(V_0 + u)$  is the nodal amplitude



**Figure 1.** Research locations on Bangka Island and Belitung Island. The red triangle is the position of the observation station and the black point of the fishing port.

factor and the astronomical factor. The formula shows that the variation in water level results from different periodic components according to the tidal constituents. Analysis of tidal constituents in the form of amplitude ( $H_i$ ) and phase ( $G_i$ ) used the least square harmonic method. Equation 2 is changed for this purpose to:

$$Z(t) = A_0 \sum_{i=1}^N A_i \cos \omega_i t + \sum_{i=1}^N B_i \sin \omega_i t \dots (3)$$

Where  $A_0$ ,  $A_i$ ,  $B_i$ , in equation 3 the unknown is obtained by solving the general matrix equation for the least-squares approximation:

$$[C] = [SXX]^{-1}[SXY] \dots (4)$$

Where  $[C]$  is a  $2N + 1 \times 1$  the unknown vector with  $[SXX] = [X]'[X]$  and  $[SXY] = [X]'[Y]$ . The Fourier transform of a continuous-time signal  $x(t)$  can be defined as:

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} dt \dots (5)$$

The Fourier transform is a function of spectral density. The spectral density function is integral at a given frequency interval, giving the variance in quantity contributed by the integration interval frequency.

In this study, the T-Tide harmonic analysis method (Pawlowicz et al., 2002) was used to extract harmonic constants, namely the

amplitude and phase-lag of the tidal constituents. One of the tidal characterizations can be obtained by calculating the main harmonic constituents' amplitude ratio,  $M_2$ ,  $S_2$ ,  $K_1$ , and  $O_1$ . This value is called the Formzahl number (Dietrich, 1963) and (Pugh, 1987) defined in formula 6, and the value obtained is used to determine the tide type as Table 1:

$$F = \left( \frac{K_1 + O_1}{M_2 + S_2} \right) \dots (6)$$

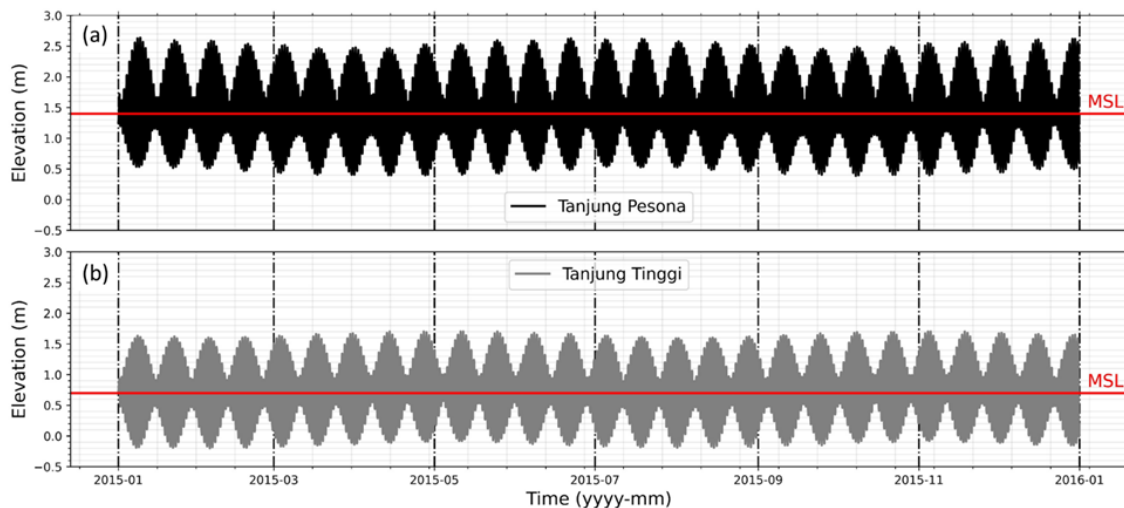
Time propagation of tidal component can be defined in formula 7 based on Fatoni (2011),  $g$  is the phase of tidal constituent ( $^\circ$ ) and  $n$  represent phase velocity of tidal constituent ( $^\circ/\text{hour}$ ).

$$t = g \times \frac{1}{n} \dots (7)$$

Time series data for sea level elevation at Tanjung Pesona and Tanjung Tinggi are shown in Figures 2a and 2b. Data regarding fishing port areas is obtained from DKP Bangka Belitung Province, which is then used to see the dynamics of high tides in the port's waters. Analysis, visualization, and computation using the Python 3.8 programming language with the Jupyter Notebook Integrated Development Environment (IDE).

**Table 1.** Classification type of tide

No	Dietrich 1963		Pugh 1987	
	Type	Value	Type	Value
1	Semidiurnal	0 - 0.25	Semidiurnal	0 - 0.25
2	Mixed	0.25 - 3	Mixed, mainly semidiurnal	0.25 - 1.5
3	Diurnal	> 3	Mixed, mainly diurnal	1.5 - 3
4			Diurnal	> 3



**Figure 2.** Plot of sea level elevation against time at Tanjung Pesona (a) and Tanjung Tinggi (b)

### 3. Results and Discussion

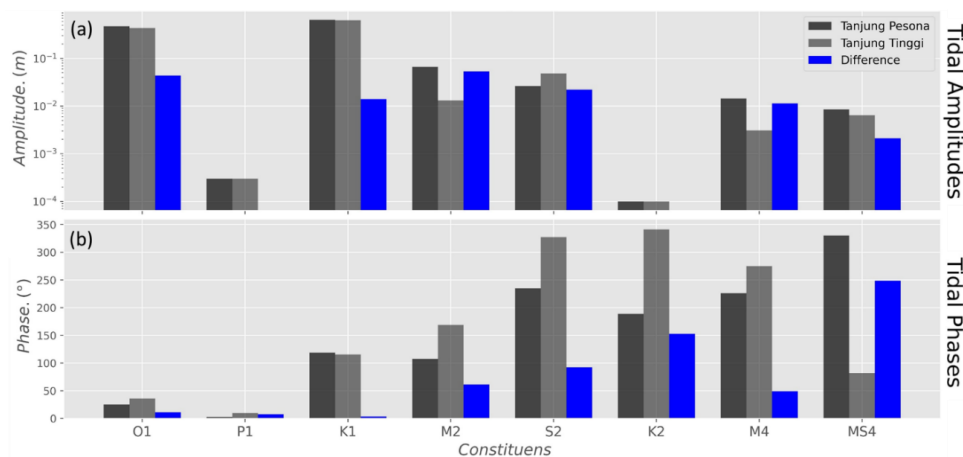
Several harmonic constituents can represent the observed water level data in amplitude and phase. The amplitude and phase of the tidal constituents from the harmonic analysis for tide gauges at Tanjung Pesona and Tanjung Tinggi can be seen in Table 2. Figure 3 shows the amplitude (a) and phase (b) values of the eight semidiurnal, diurnal, and shallow water constituents that are dominant for both stations. It can be seen clearly from Table 2 and Figure 3 that the tidal amplitude and phase have more or less the same value at both stations. Not many different values evidence this; even the constituents P1 and K2 have the same amplitude value. The results of the analysis show that the tidal constituents that have the largest amplitude

are diurnal (K1, O1, P1), semidiurnal constituents (M2, S2, K2), and shallow water constituents (M4 and MS4).

The main (dominant) constituent that propagates from the ocean when it reaches shallow waters has a nonlinear dynamic and a more complex spectrum. The nonlinear distortion that occurs causes constituents' appearance in the diurnal, semidiurnal, quarter diurnal, and even higher constituent bands (Aubrey and Spear, 1985). These constituents formed are called shallow-water tidal constituents because they are caused by the nonlinear distortion of the main astronomical tidal constituents (M2, S2, K1, O1) in shallow water. The term spatial advection yields constituents twice the interacting constituents' frequency; for example, M4 is generated from

**Table 2.** Amplitudes and phases of tidal constituents at Tanjung Pesona and Tanjung Tinggi

Parameter (Constituents)	Symbol	Frequency (hour <sup>-1</sup> )	Tanjung Pesona		Tanjung Tinggi	
			Amplitude (m)	Phase (deg)	Amplitude (m)	Phase (deg)
Diurnal	$O_1$	0.038731	0.4748	25.16	0.4308	36.25
	$P_1$	0.041553	0.0003	2.33	0.0003	9.77
	$K_1$	0.041781	0.6414	118.58	0.6274	115.16
	$UPS_1$	0.046343	0.0001	29.06	0.0001	296.22
	$2Q_1$	0.035706	0.0001	338.7	0.0001	111.48
Semi-diurnal	$MU_2$	0.07769	0.0001	23.2	0.0001	154.16
	$N_2$	0.078999	0.0118	148.26	0.0107	103.46
	$M_2$	0.080511	0.0666	107.53	0.0132	168.73
	$L_2$	0.082024	0.0005	326.01	0.0008	55.08
	$S_2$	0.083333	0.0261	235.15	0.0482	327.36
	$K_2$	0.083562	0.0001	188.62	0.0001	341.36
	$MSN_2$	0.084846	0.0002	152.33	0.0003	275.4
	$ETA_2$	0.085074	0.0001	88.76	0.0001	144.01
Third diurnal	$SK_3$	0.125114	0.0001	279.12	0.0001	306.12
Fourth diurnal	$M_4$	0.161023	0.0145	225.93	0.0031	275.09
	$MS_4$	0.163845	0.0085	330.47	0.0064	81.83
Fifth diurnal	$2SK_5$	0.208447	0.0001	27.91	0.0001	291.39
Eight diurnal	$M_8$	0.322046	0.0001	282.72	0.0001	318
Long periode	$MM$	0.001512	0.0001	339.5	0.0001	233.69



**Figure 3.** Values amplitude (a) and phase (b) of the diurnal, semidiurnal and fourth diurnal constituents obtained from harmonic analysis.

M2. The constituent of M4 has a time variation of twice the angular velocity of M2. The shallow-water constituents of MS4 result from the interaction between M2 and S2. This shallow water constituent has an angular velocity of M2 plus or minus an angular velocity of S2 (Amin, 1982). The other tidal components (third, fifth, eighth, and long-wave diurnal) have only small amplitudes. The analysis results show that the primary influenced by the diurnal constituents (K1) with 23.93 hours and (O1) with 25.8 hours with an amplitude of 0.6 m and 0.4 m, respectively, for each observation station.

Robertson and Ffield (2005) state that M2 (semidiurnal) tides generally dominate Indonesian waters with period 12.42 hours. Indonesian waters are also dominated by the K1 tides, with a period of 23.93 hours. The phase distribution shows that the tidal constituents of K1 around Indonesian waters are determined by the propagation of tidal waves from the Pacific Ocean and the Indian Ocean. This propagation is the same as in the tidal constituents of M2. The phase distribution between the K1 and M2 constituents shows some differences. The K1 constituents in the Makassar Strait, Maluku Sea, and the Halmahera Sea are more determined by propagating tidal waves propagating from the Pacific Ocean. The weak propagation of the K1 tidal wave from the Indian Ocean compared to the Pacific Ocean is one of the determining factors. The structure of the K1 constituent variations is more straightforward around Indonesian waters compared to M2 constituents. The K1 constituent has a small amplitude value in Indonesian waters. The amplitude value of K1 in Indonesian waters has a range between 10 and 30 cm. The exception is the Java Sea, where the amplitude reaches about 65 cm to the southwest of the island of Borneo around the

Bangka and Belitung Islands, which is the meeting place for K1 constituent propagation from the Pacific Ocean which propagates through the Java Sea and the South China Sea. (Hatayama, 1996).

### 3.1. Tide constituent propagation

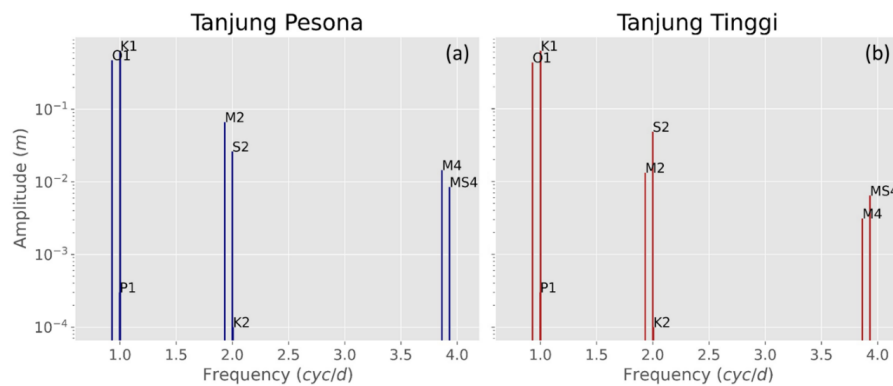
Tidal propagation in the waters of Bangka Belitung is influenced by the propagation of the waters of the Malacca Strait originating from the Indian Ocean. Furthermore, propagation from the Pacific Ocean also affects the tides in the Bangka Belitung waters that enter through the Java Sea from the Makassar Strait and the South China Sea (Hatayama, 1966; Pariwono, 1985). This condition causes differences in propagation time from one place to another. The propagation time is known from the value of the phase difference of each constituent.

The tidal wave propagation of the O1 constituent in the Bangka Belitung waters originates from the South China Sea (Fatoni, 2011), with tides formed earlier at Tanjung Pesona station than Tanjung Tinggi station with a time difference of 1 hour 11 minutes. Furthermore, Components M2 and S2 also show that the first tide occurs in Tanjung Pesona with a time difference of 2 hours 22 minutes and 3 hours 7 minutes. The propagation of the K1 component comes from the South China Sea and the Java Sea (Fatoni, 2011; Pariwono, 1985) which enters the waters of Bangka Belitung and shows the tide formed at Tanjung Tinggi is 3 minutes faster than Tanjung Pesona.

### 3.2. Frequency domain analysis

The main tidal constituent periodograms for Tanjung Pesona and Tanjung Tinggi observation stations are shown in Figures 4 (a) and 4 (b). It is clear that diurnal, semidiurnal, and shallow water cycles dominate. The amplitude (energy)





**Figure 4.** The amplitude periodogram of the main constituents at Tanjung Pesona (a) and Tanjung Tinggi (b)

of the daily cycle observed shows that the diurnal cycle is stronger than the semidiurnal and shallow water cycles. The study area located between islands creates a nonlinear distortion that forms the amplitude value of the fourth diurnal constituent, which also seems to dominate due to the interaction of M2 components (Crawford, 1982). The frequency-domain results obtained show a decrease in amplitude on all spectrums with increasing frequencies at Tanjung Pesona and Tanjung Tinggi observation stations. The peak of the substantial amplitude value is seen on the low and medium frequency bands. It is clear that all peak values are centered around 1 and 2 cycles per day (cpd), approximately 24 and 12 hours, corresponding to diurnal (K1) and semidiurnal (M2) tides.

The tidal observation stations at Tanjung Pesona and Tanjung Tinggi generally have tidal constituents with values that do not differ much. The diurnal constituents (O1, K1, and P1) at each observation station have the same pattern, K1 has the highest amplitude and P1 the lowest. The constituents K1 and O1 only have a slight difference in value. The difference is quite striking in the semi-diurnal constituents (M2, S2, and K2). The amplitude values of the M2 and S2 constituents of Tanjung Pesona and Tanjung Tinggi occupy the top position differently. Tanjung Pesona Station shows the M2 constituent value at the top position, while Tanjung Tinggi station is the S2 constituent. Besides, the constituent values of K2 have the same amplitude value. The difference in the amplitude peak value at each observation station impacts the amplitude of the shallow water constituents (fourth diurnal), namely M4 and MS4. This difference occurs because M4 and MS4 are formed due to interactions between constituents or the same constituents with different angular velocity variations. Tanjung Pesona Station has a higher M4 amplitude value

than MS4. The M4 tide component is an overtide component where the tide component whose angular speed (speed) is twice the rate of the M2 component, so the dominance of the M2 component will cause the value of M4 also to increase. Unlike Tanjung Pesona, Tanjung Tinggi has a higher MS4 constituent amplitude than M4. The MS4 component is a compound tide, a tide component formed from the interaction between several main tidal components (primary constituents, M2 and S2). The dominance of the S2 component at the Tanjung Tinggi station will cause the MS4 value also to increase. This pattern is similar to the research conducted by Andersen (1990).

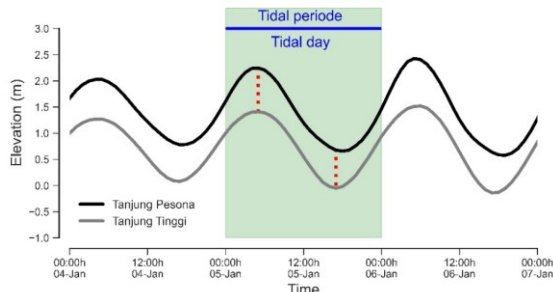
### 3.3. Tidal characteristics and dynamics

The type of tide in water can be determined by calculating the Formzahl Number (F) value based on the main components of astronomical tides (M2, S2, K1, and O1). Formzahl is a number to determine the type of tide based on a specific range of values (Dietrich, 1963; Pugh, 1987). The Formzahl number value at the Tanjung Pesona observation station is based on the calculation results of 12.04, and the Tanjung Tinggi observation station is 17.23. Based on the Pugh and Dietrich classification, the tide type at Tanjung Pesona and Tanjung Tinggi stations is classified as a single daily type (diurnal). A snapshot of the observation data at the two stations can be seen in Figure 5. The Tanjung Pesona and Tanjung Tinggi observation stations have tides of 2.25 m and 1.9 m, respectively. The results of determining the type of tide are following previous studies (Pamungkas, 2018; Radjawane et al., 2018; and Wiguna et al., 2020), which found a single daily (diurnal) tidal type pattern in the waters of Bangka and Belitung.

Mean Sea Level (MSL) is used as the reference level for various land development applications, while the low water level is the reference level. The vertical datum used as a

**Table 3.** Tidal values for Tanjung Pesona and Tanjung Tinggi levels

Station	Tidal Level						
	HAT	MHHWS	MLHWN	MSL	MLLWN	MLLWS	LAT
Tanjung Pesona	2.6462	2.5547	1.6083	1.4313	1.2543	0.3079	0.2164
Tanjung Tinggi	1.7206	1.6624	0.8642	0.6395	0.4148	-0.3834	-0.4416

**Figure 5.** The tidal levels of Tanjung Pesona and Tanjung Tinggi were sampled on 4 - 6 January 2015

reference level in the marine environment is called a graph datum. Graph datum is usually related to mean sea level, such as Highest Astronomical Tide (HAT), Mean Higher High Water Spring (MHHWS), Mean Lower High Water Spring (MLHWN), Mean Lower Low Water Neap (MLLWN), Mean Lower Low Water Spring (MLLWS) or Lowest Astronomical Tide (LAT). The critical tide levels at the observation stations are shown in Table 3.

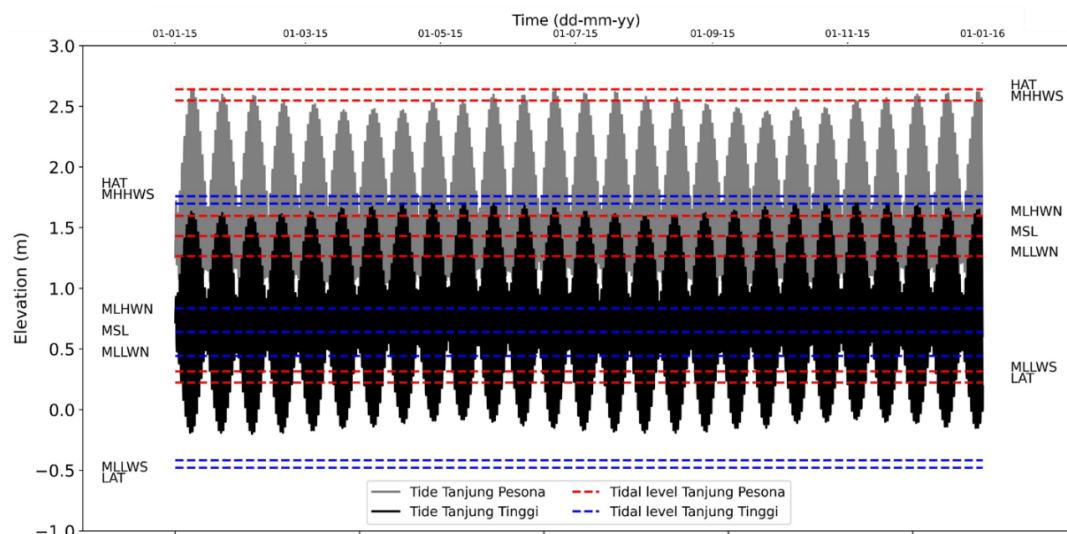
The tidal observation stations of Tanjung Pesona and Tanjung Tinggi have significant differences in tidal levels. The difference between the two observation stations can be seen clearly from each station's MSL depth. The Tanjung Pesona tide observation station has a higher MSL than the Tanjung Tinggi station, with a depth difference between the two ranging from 0.8 m. These values then serve as a reference for cadastral levels in certain waters. Tide datum

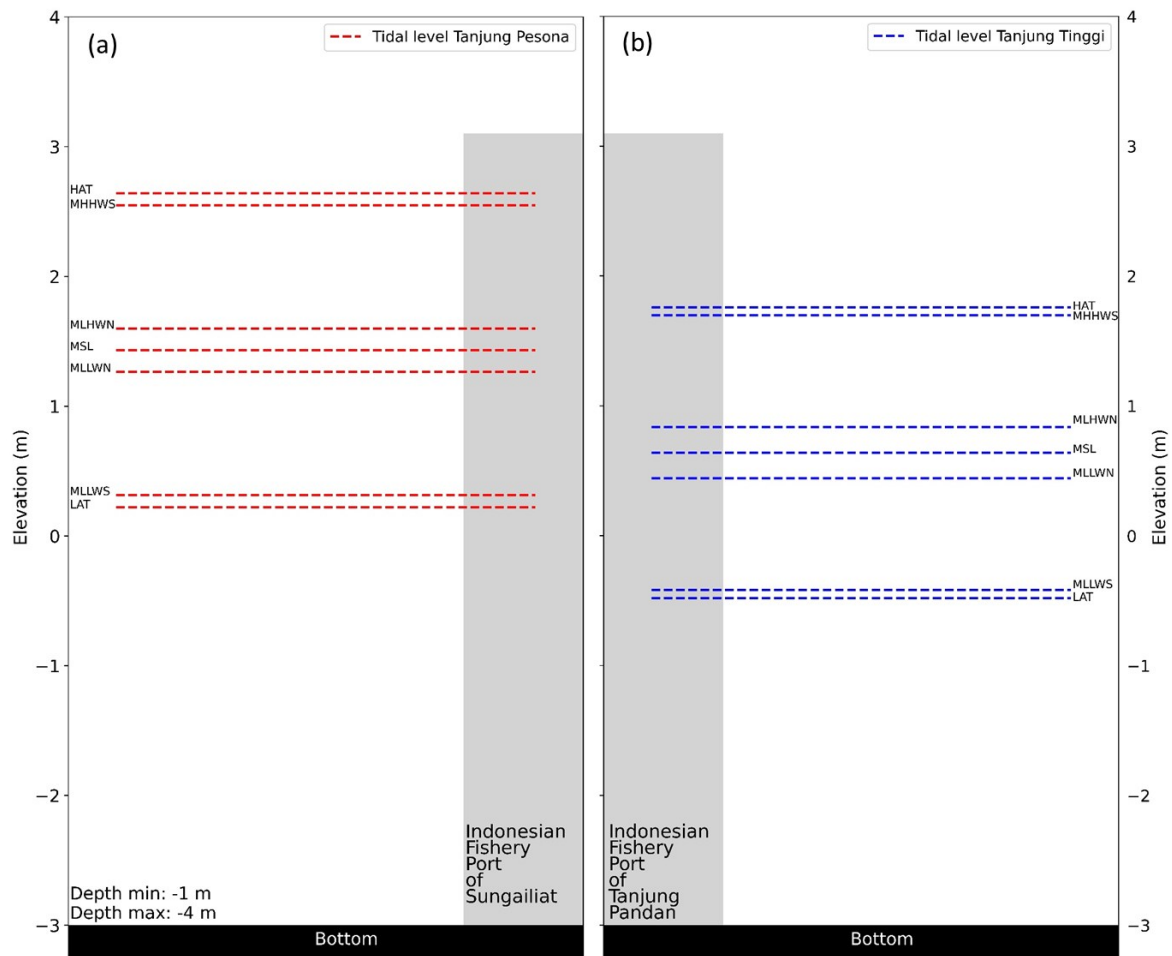
analysis to generate littoral zones for marine cadastre. The tidal levels of Tanjung Pesona and Tanjung Tinggi observation stations that have been overlaid with certain tidal levels can be seen in Figure 6.

### 3.4. Vertical and Spatial Tidal Level Analysis

Tide data is one of the essential parameters in port construction, namely the elevation of the top of the building based on the tide level's elevation and the depth of the waters based on the low tide (Triadmojo, 2009). Determination of the safe depth of the pond for ships to lean on takes into account the value of LAT (Lowest Astronomical Tide), Which is the lowest low tide condition that can be achieved provided that the bathymetry value is known and also the size of the draft of the largest ship planned for the port (Asiseha and Apriansyah, 2016).

The Nusantara Sungailiat Fishery Port is located in Bangka Regency, Bangka Island, which has an area of 60,560 m<sup>2</sup> and has two port pools with a depth of -1 - -4 (DKP Prov. Kep. Babel, 2011). Observation data at Tanjung Pesona Station, which is 4.7 km from NFP Sungailiat, is used to reference tidal data to produce tidal levels. Figure 7 shows an illustration of the tidal level, which is corrected with the depth of the port column, which is 4 m below sea level. Based on the data analysis, the LAT and HAT values in the port column are 4.21 m and 6.64 m.

**Figure 6.** Tidal level at Tanjung Pesona (red line) and Tanjung Tinggi (blue line)



**Figure 7.** Tidal level towards the port pool (a) Sungailiat (Tanjung Pesona) and (b) Tanjung Pandan (Tanjung Tinggi)

Tanjung Pandan Nusantara Fishery Port in Belitung district, Belitung Island has an area of 33,900 m<sup>2</sup> with a port column depth of -3 m (DKP Prov. Kep. Babel, 2011). The tidal data at Tanjung Pandan Station is used to calculate the tidal level by correcting the depth column's depth. The results obtained are that the LAT and HAT values are 2.56 m and 4.72 m.

The tidal level in NFP Sungailiat is higher than that of NFP Tanjung Pandan, shown in Figure 7. The LAT value in NFP Sungailiat shows that the water level is higher than the total depth of the pool. Meanwhile, at the NFP Tanjung Pandan, during the lowest tide (LAT), it was found that the water level fell 0.44 m from the initial conditions, and in MLLWS conditions, the water level was at 0.38 m below the water level. Based on the tidal level analysis, it is recommended to increase the pond's depth at Tanjung Pandan NFP.

#### 4. Conclusions

The K1 and O1 components are the dominant components at Tanjung Tinggi and Tanjung Pesona stations with an amplitude range of 0.6 m and 0.4 m for each observation station, and it is known that the tidal type is diurnal. The tidal data's output components are 19 components consisting of eight semidiurnal, diurnal, and shallow water constituents, which are dominant for both stations. The frequency-domain results show a decrease in all spectrums' amplitude with increasing frequency at the two observation stations with a strong peak amplitude seen in the low and medium frequency bands. Its maximum peak values are centered around 1 and 2 cycles per day (cpd), approximately 24 and 12 hours, corresponding to diurnal (K1) and semidiurnal (M2) tides. The height of the tidal level, which is corrected by the depth of the port, shows that the NFP Sungailiat water level is higher than the NFP Tanjung Pandan, which is seen from the LAT and HAT values, namely 4.21 m and 6.64 m (NFP



Sungailiat) and 2.56 m and 4.72 m (NFP Tanjung Pandan). The littoral zone depicted with LAT and HAT values as a reference for marine cadastre shows water masses' propagation at Tanjung Tinggi station/coast approaching vegetation. This value is expected to be used as a reference for making decisions about coastal management in the future.

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