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PENENTUAN KEDALAMAN TUBAN PELABUHAN TPI PALANG MELALUI PERHITUNGAN KOMPONEN PASANG PASANG

THE DETERMINATION OF THE DEPTH OF TPI PALANG'S HARBOUR BASIN TUBAN THROUGH CALCULATION OF TIDE COMPONENT

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ABSTRAK

Penentuan grafik datum dengan menggunakan komponen pasang surut dapat digunakan untuk menentukan kedalaman kolam pelabuhan. Cekungan pelabuhan TPI Palang sering digunakan sebagai tempat tambat kapal nelayan, namun sering terjadi kapal-kapal tersebut tersangkut sebelum memasuki cekungan pelabuhan. Jenis kapal nelayan yang berada di alur pelabuhan TPI Palang adalah kapal payang dengan kedalaman draft 2 m. Kedalaman alur pelabuhan hasil pengukuran pada bulan Juli 2017 adalah 8 m, sedangkan berdasarkan peta batimetri adalah 12 m. Perairan Palang, di Kabupaten Tuban terletak di Laut Utara Jawa Timur yang bertipe perairan terbuka, oleh karena itu penentuan kedalaman kolam pelabuhan didasarkan pada keadaan perairan tersebut yaitu 1,2 x sarat kapal yaitu 2,4 m. Metode least square dan metode admiralty digunakan untuk membandingkan metode yang paling baik dalam menghitung komponen pasang surut. Peneliti menggunakan data pasang surut bulan Agustus 2016-Juli 2017 yang diperoleh dari BIG. Tipe pasang surut perairan Palang adalah diurnal, dengan nilai F untuk pengolahan admiralty sebesar 5,160 dan pengolahan least square sebesar 5,167. Koefisien korelasi komponen pasang surut dengan pengolahan admiralty terjadi pada K1-MS4 sebesar 0,792, sedangkan least square terjadi pada K1-M4 sebesar 1,6. Hasil perhitungan komponen pasut dari kuadrat terkecil digunakan untuk menentukan nilai grafik datum. Grafik datum IHO (International Hydrographic Organization) digunakan sebagai acuan dasar untuk menghitung kedalaman kolam pelabuhan TPI Palang. Hasil perhitungan menunjukkan bahwa kedalaman perairan Palang pada kondisi eksisting (8 m) masih memerlukan pengerukan antara 0,033 - 1,071 m. Namun, untuk memenuhi standar kolam pelabuhan, kedalaman yang dibutuhkan adalah 13,071 m (dari LWS) hingga 13,557 m (dari LLWS) yang berarti pengerukan kolam pelabuhan sekitar ± 4 m.

Kata Kunci: kuadrat terkecil, admiralty, datum bagan, pasang surut, perairan pesisir

ABSTRACT

Determination of the datum chart using the tide component can be used to determine the depth of the harbour basin. TPI Palang's harbour basin is often used as a place for mooring fishing boats, but it often happens that the ships get stuck before entering the haarbour basin. The type of fishing ship at the TPI Palang harbour basin is a *payang* boat with a draft depth of 2 m. The depth of the harbour basin measurement results in July 2017 was 8 m, while based on the bathymetric map is 12 m. Palang waters, in Tuban Regency is located in the North Sea of East Java, which is open water type, therefore the determination of the depth of the harbour basin is based on the state of the water, is 1.2 x ship draft, which is 2.4 m. The least square and the admiralty method were used to compare the best method in calculating the tidal component. Researchers used tidal data for August 2016-July 2017 obtained from BIG. The tidal type of the Palang waters is *diurnal*, with an F value for admiralty treatment of 5,160 with least square processing of 5,167. The correlation coefficient of the tidal component with admiralty processing occurs in K1-MS4 of 0.792, while the least square occurs in K1-M4 of 1.6. The result of the calculation of the tidal component of the least square is used to determine the value of the datum chart. The IHO (International Hydrographic Organization) datum chart is used as a basic reference for calculating the depth of the TPI Palang harbour basin. The results show that the required depth of Palang waters in the existing condition (8 m) still requires dredging between 0.033 - 1.071 m. However, to meet the standard of the harbour basin, the required depth is 13,071 m (from LWS) to 13,557 m (from LLWS) which means that the dredging of the harbour basin is about ± 4 m.

Keywords: least square, admiralty, chart datum, tides, coastal water

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PRELIMINARY

The design of the harbour basin can be determined from tidal data from the area where the harbour basin will be built (Annisa, 2017; Satriadi & Hariyadi, 2017; Simanjuntak et al., 2012).

High and low tides will affect design of the harbour basin. Several studies used tidal data from the mean of high water level (MHWL), the mean of sea level (MSL) and mean of lowest water level (MLWL). Several studies used tidal data from the mean high water level (MHWL), the average high water level (MSL) and the lowest low water level (MLWL). (Hanifah et al., 2016; Sasongko, 2014).

The length of the coast of Tuban Regency is about ± 65 km, it has a fishing port with 3 (three) fish landing sites (PPI) and 10 (ten) fish auction places (TPI), one of which is TPI in Palang village which is dominated by fishing boats of the type of fishing gear anchored in the harbour basin (Diskanak, 2017). However, some of these ships did not dare to enter the pier because they got stuck before entering the place. This condition certainly requires information about the Chart Datum. Therefore, it is necessary to conduct research to determine the depth of the TPI Palang's harbour bas through the determination of the Chart Datum from tidal component data. Forn this reason, this study aims to determine the accuracy of the value of the tidal component through the Least Square and Admiralty methods, then proceed to determine the Chart Datum value according to the Tuban waters area, especially the Palang waters so that it can determine the need for the depth of the dock pool at TPI Palang and, it can ensure the safety of the ship.

RESEARCH METHOD

The research location is in the TPI Palang's harbour basin in Tuban, which is geographically located at coordinates -6.898051° South Latitude and 112.144179° East Longitude. The research data are tidal data taken *in situ* with observations for 24 hours with an interval of 1 hour from July 1 to 31 using a tripod and measuring pipe installed at the TPI Palang pier, and also tidal data from the BIG (Badan Informasi Geospasial or Geospatial Information Agency) in August 2016 to July 2017.

Data processing

Tidal data from BIG which has been obtained during one year was processed using the least squares method and the admiralty method (Joesidawati, 2017; Supriyono et al., 2015), then the researchers determined the most accurate tidal component value analysis method from those two methods (Gracella, 2019; Ulum & Khomsin, 2013)

The tidal components obtained from the most accurate method are then analyzed to determine the type of tide and to test the quality of the data obtained.

a. Perform datum chart model calculations to find out which datum chart method is most suitable for the research location
b. Analyze the water depth in the harbour in several ways of determination of the depth of harbour water area.

The following is an outline of the data processing flow chart as shown in Figure 1

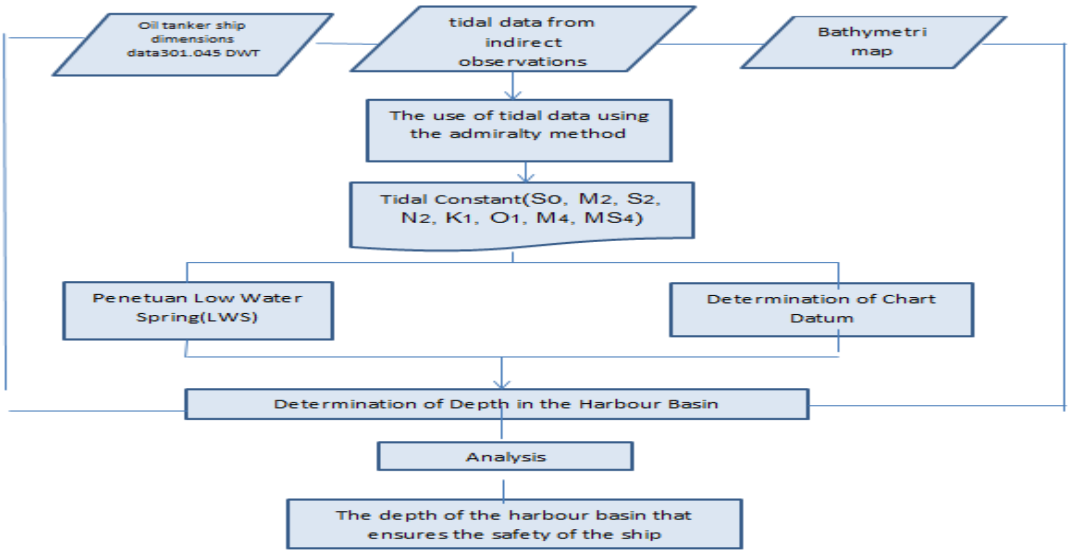

Figure 1. Data Processing Flow

Data analysis

a. Idal data is processed by 2 methods (admiralty and least square to obtain the value of the tidal component (So, M2, S2, N2, K1, O1, M4, MS4)
b. Determination of Tidal Type, refers to the equation of formzahl number
c. Determination of Chart Datum (Zo), (AL, n.d.; IHO, 2013; Susmoro, 2019)
America Zo= M2 (1)
UK Zo = 1.1 (M2+S2) (2)
IHO Zo $= \sum_{i=1}^{n} Ai$ (3)
d. Calculating *Low Water Spring* (LWS) (Benyamin, 2009)
LWS = So – Zo (4)
e. Calculating Lowest Low Water Spring (LLWL) (Benyamin, 2009)
LLWL = Z0–(M2+S2)–(O1+K1) (5)
f. The water depth in the harbour is calculated based on the state of the waters (open or closed water): (Anam, 2002; Anggraini, 2006)
closed waters (quiet) = 1.1 * ship draft
open water = 1.2 * ship draft
g. The water depth in the harbour if calculated based on the Lowest Low Water Level (LLWL) then it will be added by 5 feet (1 feet = 0.3048 m) (Kutz, 2004; Wright & Ashford, 1989)
h. The water depth in the harbour if calculated based on Chart Datum (Indonesia, 2010; Nugraha & Subiyanto, 2014)

RESULTS AND DISCUSSION

Tidal Component Analysis

Analysis of tidal components (M2, S2, N2, K1, O1, M4, MS4) using the Admiralty method (Table 1) and Least Square (Table 2). Table 3 shows statistical tests to determine the quality of the results of the analysis using different methods.

Table 3 shows that the quality of the tidal component analysis with a significance level of 95% (α = 0.05) has a t count value (0.209) < t table (2.365), this means both using the Least Square method and the Admiralty tidal data have the same good quality. The next step to determine the level of accuracy of the analysis results is to compare the rms error value. The rms error value of each method is shown in Table 4.

Table 1. Average Amplitude and Phase Values using the Admiralty method in August 2016-July 2017.

Component	S0	M2	S2	N2	K1	O1	M4	MS4	K2	P1
Amplitude	1.54	0.08	0.07	0.04	0.62	0.15	0.02	0.01	0.02	0.20
phase		85.10	359.70	85.57	122.53	158.81	52.30	253.19	359.70	122.53

Table 2. Average Amplitude and Phase Values using the Least Square method in August 2016-July 2017.

Components	So	M2	S2	N2	K1	O1	M4	MS4	K2	P1
Amplitude	1.75	0.05	0.07	0.03	0.39	0.13	0.01	0.01	0.07	0.26
phase		43.66	35.62	39.76	34.07	58.70	54.63	43.14	40.21	29.62

Table 3. Statistical Test Paired T Test to Compare Tidal Components using Admiralty and Least Square

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pair 1	Admiralty Method - Least Square Method	.022625	.305616	.108051	-.232876	.278126	.209	7	.840

Table 4. RMS error calculation results Admiralty Method - Least Square Method

Month	RMS error Admiralty Method	Least Square Method
August-2016	0,51	0,05
September-2016	0,55	0,07
October-2016	1,72	0.22
November-2016	1,75	0,32
December-2016	2,11	0,43
January-2017	2,02	0,40
February-2017	1,82	0,32
March-2107	0,72	0,18
April-2017	0,15	0,05
May-2017	0,21	0,06
June-2017	0,58	0,07
July-2017	1,58	0,10

Table 4 shows the level of accuracy using the least square method for tidal component analysis, the average value of the RMS error is smaller than the admiralty method. Therefore, to determine the next calculation, the least square method is used. According to (Ulum & Khomsin, 2013) using tidal prediction with the least square method is more accurate, while Rogesko et al., n.d. reveals the Least Square method is more accurate for long data. Therefore, this research to determine the depth of the harbour basin using tidal component data for 1 year uses the least square method.

Tidal Data Analysis for 1 year

Tidal data used as primary data to determine the mean high water level (MHWL), mean water level (MSL), lowest low water level (MWL), was obtained from BIG (Geospatial Information Agency) in August 2016 to July 2017 through the results of automatic tide gauge measurements installed at coordinates -6.898051° South Latitude and 112.144179° East Longitude. , then analyzed by least Square method in Visual Fortran 6 . program

Direct tide measurements at the research site (TPI Palang) were also carried out to determine the type of tides (Figure 1) and also aimed to analyze the quality of the data obtained from BIG. Direct tidal measurements were carried out in July 2017 for 1 month and observed changes every 1 hour with a measuring device installed on the TPI Palang pier. Then the data obtained from this direct measurement is compared with the data obtained from the BIG. The results of the comparison of the data obtained were analyzed by paired - sample *t-test.*

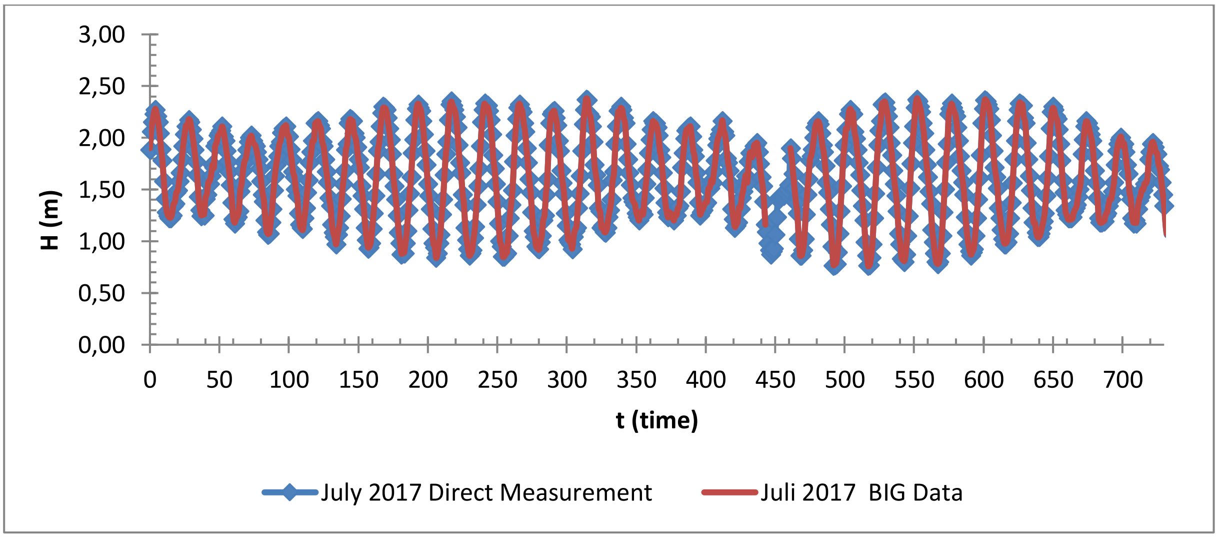

Figure 2. Tidal Types of Research Locations

Figure 1 reveals that the tidal type of the Palang Waters is *diurnal* tide, this is in accordance with research (Joesidawati & Suntoyo, 2017) where the Tuban waters have a diurnal tidal type.

Comparison of direct measurement data with BIG data shows that there is a difference of 0.02 cm (Table 5), while the error tolerance of the automatic tide gauge used (OTT AWLR) is 1.5 cm, so the difference can be said to have no effect because it is still below the specified tolerance limit (1.5 cm) so that it can be concluded that BIG data can be used to determine Mean High Water Level (MHWL), Mean Sea Level (MSL).

Meanwhile, based on the statistical test with paired - sample t-test using SPSS 16 with a significance level of 95% (α = 0.05, the data obtained were Tcount (3.416) > t-table (1.647) which means that the data obtained from BIG with direct measurements in The research location has the same quality.Then the analysis of the value of the tidal component using the least square method for 1 (one) year from the BIG data can be shown in Table 6.

Table 6 explain that MHWL, MSL, MWL are at the research site as shown in Table 7 and Figure 2.

Table 5. Comparison of High and Low Tide Data from Direct Measurements at The Atudy Site with BIG Data in July 2017

No	Date	Time	Observation data (cm)		Difference
			BIG	Direct	
1	7/1/2017	0:00:00	190	188	-2
2	7/1/2017	1:00:00	208	206	-2
3	7/1/2017	2:00:00	217	215	-2
4	7/1/2017	3:00:00	225	223	-2
5	7/1/2017	4:00:00	228	227	-1
6	7/1/2017	5:00:00	222	221	-1
7	7/1/2017	6:00:00	215	215	0
8	7/1/2017	7:00:00	204	204	0
9	7/1/2017	8:00:00	189	189	0
10	7/1/2017	9:00:00	178	178	0
.	.	.	.	.	.
744	7/31/2017	23:00:00	178	177	-1
Amounth			117857	119625	1768
Mean			158.4099	160.78629	2.37634
Standard deviation			42.88397	42.944062	18.9762

Table 6. The value of the tidal component (August 2016 – July 2017) using the Least Square Method

No	Months	S0(m)	M2	S2	K1	O1	N2	K2	P1	M4	MS4
1	August-2016	1.759	0.08	0.03	0.45	0.19	0.02	0.01	0.07	0	0.01
2	September-2016	1.782	0.07	0.05	0.44	0.18	0.02	0.06	0.11	0.01	0.01
3	October-2016	1.757	0.04	0.07	0.73	0.1	0.03	0.09	0.54	0.01	0
4	November-2016	1.775	0.03	0.08	0.26	0.18	0.01	0.08	0.31	0.01	0.01
5	December-2016	1.766	0.01	0.12	0.33	0.01	0.01	0.11	0.28	0.01	0.02
6	January-2017	1.781	0.02	0.12	0.3	0.02	0.04	0.09	0.26	0.01	0.02
7	February-2017	1.813	0.02	0.24	0.05	0.01	0.05	0.25	0.03	0.01	0
8	March- 2107	1.759	0.03	0.08	0.56	0.12	0.03	0.05	0.58	0.01	0
9	April-2017	1.737	0.07	0.03	0.45	0.19	0.02	0.01	0.19	0.01	0
10	May-2017	1.77	0.07	0.02	0.41	0.19	0.03	0.01	0.23	0.01	0
11	June-2017	1.735	0.07	0.03	0.32	0.19	0.03	0.02	0.29	0.01	0.01
12	July-2017	1.606	0.08	0.02	0.34	0.18	0.03	0.03	0.24	0.01	0
	Rata-rata	1.75	0.05	0.07	0.39	0.13	0.03	0.07	0.26	0.01	0.01

Table 7 . Tidal Elevation for 1 year (August 2016 – July 2017)

Months	Tidal Elevation Parameters (m)							
	S0	HHWL	MHWS	MHWL	MSL	MLWL	MLWS	LLWL
August-2016	1,759	2,55	2,41	2,06	1,76	1,45	1,06	1
September-2016	1,782	2,56	2,3	2,07	1,78	1,47	1,21	0,96
October-2016	1,757	3,29	2,09	2,3	1,76	1,23	1,39	0,34

November-2016	1,775	2,69	2,33	2,05	1,77	1,52	1,35	0,91
December-2016	1,766	2,45	1,93	2,01	1,77	1,47	1,57	0,91
January-2017	1,781	2,59	1,91	2,02	1,78	1,53	1,68	1,05
February-2017	1,813	2,42	1,93	2,02	1,81	1,61	1,69	1,18
March-2107	1,759	3,06	2,06	2,21	1,76	1,27	1,48	0,36
April-2017	1,737	2,65	2,32	2,06	1,74	1,43	1,32	0,9
May-2017	1,77	2,67	2,48	2,08	1,77	1,47	1,09	0,91
June-2017	1,735	2,59	2,51	2,02	1,73	1,46	0,97	0,89
July-2017	1,606	2,44	2,36	1,88	1,61	1,34	0,83	0,79
Rata-rata	1,75	2,66	2,22	2,07	1,75	1,44	1,30	0,85

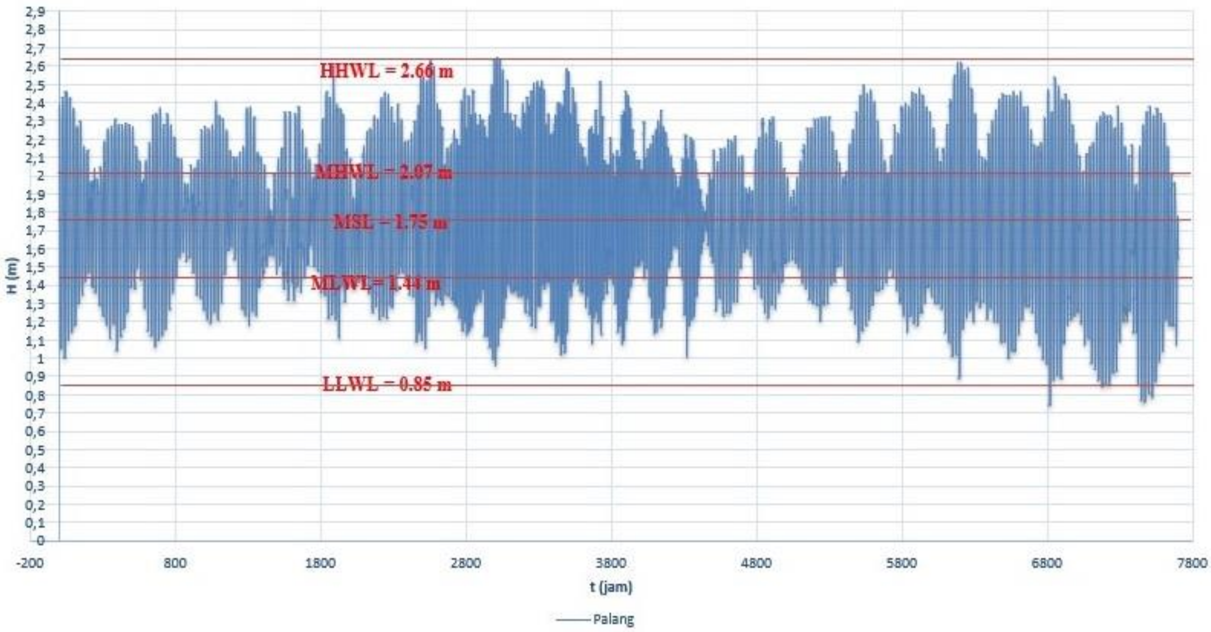

Figure 2. Tidal curve for 1 year (August 2016 – July 2017), with MHWL = 2.07 m, MSL = 1.75 m and MLWL = 1.44 m

Based on Figure 2, the tidal elevation of the Research Site (Palang Beach waters) is assumed to be + 0.00 from the Lowest low water level (LLWL), so that the elevation values are obtained as follows: HWL = + 2.66 m, MSL = + 1.75 m and LWL = +0.00 m (Figure 3)

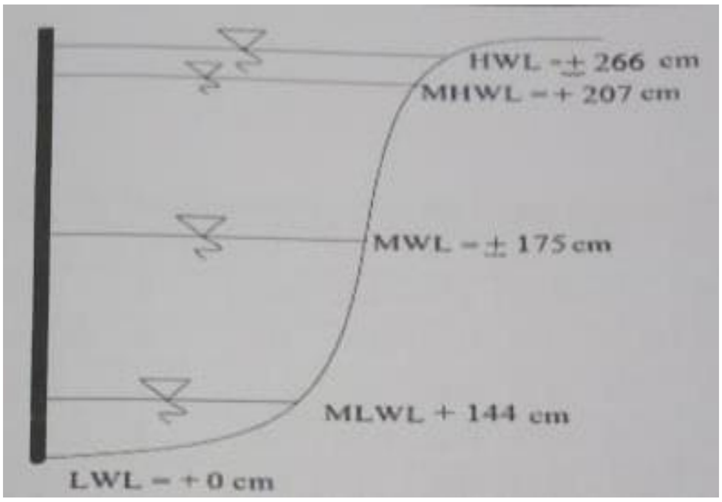

Figure 3. Tidal Elevation of Research Locations (waters of TPI Palang)

Datum Chart Model Analysis

Chart Datum used is Lowest Low Water Level (LLWL) and Low Water Spring (LWS). The average value of the tidal component for one year can be used to determine the value of the datum chart (Zo). Some countries have a standard for determining Zo, this study uses 3 Chart Datum models, namely America, British and IHO (International Hydrographic Organization). After obtaining the Zo value, it is continued with the determination of the LWS Value and LLWL Value (Table 8).

Table 8. Zo values, LWS values and LLWL values based on American, British and IHO standards

Countries	Value Zo (m)	ValueLWS (m)	Value LLWL
East Coast America	0.049	1.704	-0.601
British	0.136	1.618	-0.514
IHO	0.683	1.071	0.033

Table 8 reveals that there are differences in values in determining the Chart Datum. According to (Pradipta et al., 2015; Susanto et al., 2017) the determination of the IHO datum chart is an international standard, therefore in this study the determination of the datum chart uses the IHO standard and formula.

Depth Analysis of the Harbour Basin
Depth of Water

Determination of the depth of the harbour basin must pay attention to the requirements to ensure the safety of the ship, including:

1. Ship dimension requirements
   The ships that are mostly found in TPI Palang are vessels with payang fishing gear with a weight of 20 GT. Length over all/ LOA 17 cm, Breadth/ ship length 9 m, Draft/ draft 2 m and Depth/ ship depth 7 m (Azis et al., 2017)

2. The States of Water
   The need for water depth depends on the type of water. The waters at the research location are the northern coast of East Java which has a maximum depth of 46 meters (Diskanak, 2017), while the results of measurements in the field have an average depth of 8 m. The North Coast of East Java is an open water type, so this is in accordance with (Anggraini, 2006) research's which determines the depth of the pier according to the water conditions, meaning the depth of the harbour basin waters when connected to the water states = 1.2 x ship draft (2 m) = 2, 4 meters. The depth of these waters is the minimum depth of the harbour

3. Depth of water in front of the harbour
   The depth of the harbour waters is calculated in 2 ways, namely based on bathymetry maps and existing conditions in the field. The initial depth of the harbour basin based on the bathymetric map is 12 m from the LWS. Meanwhile, the initial depth of the measurement results in 2017 was 8 m from the LWS, so that the required depth for the harbour basin around TPI Palang can be determined. (Table 9)

Table 9. Required harbour basin depth

Chart Datum	Depth Based on Bathymetry map			Depth Based on Existing Condition		
	Initial depth (m)	Depth according to Chart Datum	Required depth (m)	Initial depth (m)	Depth according to Chart Datum	Required depth (m)
LWS	-12	-13,071	-1,071	-8	-9,071	-1,071
LLWS +5 feet	-13,524	-13,557	-0,033	-9,524	-9,557	-0,033

Based on Table 8, it can be seen that the depth of the TPI Palang harbour basin still requires dredging between 0.033 - 1.071 m at the existing depth (8 m) measurement in July 2017. 13,071 (from LWS) to 13,557 (from LLWS) which means the dredging of the water basin is around ± 4 m

CONCLUSION

The tidal component used is the Least Square method, because the higher accuracy shown from the average RMS error value is smaller than the admiralty method.

Tidal measurements at the research location (TPI Palang harbour waters) conducted in July 2017, show the type of diurnal tide. Comparison of tidal measurement data directly with BIG data shows that there is a difference of 0.02 cm, so it can be concluded that BIG data can be used as a determination of Chart Datum Values
The depth of the TPI Palang harbour basin still requires dredging between 0.033 - 1.071 m if the existing depth data (in situ depth measurement) is used as a reference. However, based on the standard of the habour basin, the required depth in harbour basin waters is as deep as 13,071 (from LWS) to 13,557 (from LLWS) which means that the dredging of the harbour basin is around ± 4 m.

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