Jurnal Miyang (J.Miy) : Ronggolawe Fisheries and Marine Science Journal
Vol.3 No.2 (2023), pp. 63-70 | http://journal.unirow.ac.id/index.php/miyang
ISSN: 2828-2582 (Online) | ISSN: 2828-3279 (Print)

Residual Analysis and Tidal Harmonic Components in Bangkalan Regency, East Java

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Diterima (*Received*): 4 November 2023 Direvisi (*Revised*): 9 November 2023 Diterima untuk Publikasi (*Accepted*): 10 November 2023

ABSTRACT

Bangkalan Regency is one of Madura, East Java, where some of its areas are located in a coastal environment. The coastal environment can experience economic development due to the transportation aspect so that many industries have been established in that environment. Studies on oceanographic parameters are essential because management of coastal environments can not be separated from oceanographic information: The tides information about the tidal characteristics can be obtained after performing a harmonic analysis, which produces the value of harmonic components. This study analyses the residue and tidal harmonic components using the LP-Tides Matlab software in the Sepulu district, Bangkalan Regency, East Java. The data used are January 2021 data from the Geospatial Information Agency. This research shows that the main harmonic components generated include K2, M4, MS4, M2, S2, N2, K1, O1, and P1. The tidal type shows that the Sepulu district is a semi-diurnal type with a Formzahl number = 0.08566. The maximum observation and prediction data values for January 2021 in the Sepulu district are 978 and 1273.64 mm. The MSL value is 434 mm, with an average tidal residue value between the observation and predictive data = 166.01 mm. Then the calculation of the RMSE value and standard deviations are 12.88 and 125.90 mm

Keywords: Tides, Harmonic Components, Residue, LP-Tides Matlab, Bangkalan

1. Introduction

Bangkalan Regency is one of the districts in Madura, East Java which has an area of approximately 1,260.14 km^2 (Pemerintah Kabupaten Bangkalan, 2019). This district is located in the west of Sampang Regency with a geographical position of 112° 40' 06"to 113° 08'44" Longitude and -6o51'39 "to -7° 11'39" Latitude (Pemerintah Kabupaten Bangkalan, 2019). Bangkalan Regency borders the Madura Strait (south and west), Sampang Regency (east), and the Java Sea (north) (Pemerintah Kabupaten Bangkalan, 2019). Bangkalan consists of around 281 villages and 18 districts with 2 to 100 meters above sea level. Several areas in Bangkalan are located on the coast, including the southern part, namely Kamal, Labang, Modung, and Kwanyar, and the northern part, including Sepulu and Tanjung Bumi. The coastal environment could experience economic development due to the transportation aspect, so that many industries have been established in the area.

It is crucial to study oceanographic parameters because the management of the coastal areas cannot be separated from various information. One of the critical oceanographic parameters to study is tides. Tides are phenomena of rising and falling sea levels caused by celestial bodies such as the moon, earth, and sun, which occur periodically (Ongkosongo, 1989). The calculation of tidal information can use the Least Square and Admiralty methods. Information obtained from tide processing includes tide types, elevation parameters, and tidal harmonic components. Richasari et al. (2019) stated that harmonic analysis could be carried out with a specific period that produces harmonic waves expressed in harmonic components (amplitude and phase of the wave).

Previous researchers have researched harmonic component analysis. Gumelar et al. (2016) conducted a study to study the tidal components in Java's southern waters using Sea Level Anomaly data from the Topex / Poseidon Satellite for 1992-2002 Jason-1 Satellite data from 2002-2011 using the Inverse Distance Weight (IDW) interpolation method. This study indicates that 21 components affect the formation of tides, including nine semidiurnal parts. This study shows four long-period components and eight diurnal components with diverse tidal types, which tend to be semidiurnal.

Siswanto & Nugraha (2014) also researched oceanographic characteristics, one of which was the tides in the Madura Strait, East Java using the Admiralty method. The primary data used in the study came from the Meteorology, Climatology, and Geophysics Agency. This research shows that the type of tides in the Madura Strait is mixed, leaning towards multiple dailies (semidiurnal). The study of Ningsih et al. (2012) used JASON satellite data and the least-squares method. These experiments indicate that altimetry data can determine tidal components, and the number of observations of 50 data results in nine optimal tidal parts characterized by a small standard deviation value.

This study aims to analyze the residual and tidal harmonic components in Sepulu District, Bangkalan Regency, East Java using the LP-Tides Matlab software from the above discussion results. The data used is January 2021 data from the Geospatial Information Agency (BIG). This study's results are expected to be useful to various parties, especially in conducting oceanographic studies in Bangkalan Regency, East Java.

2. Material and Method

2.1 Material and Research Location

The data used in this study is the tidal data for January 2021 from BIG. The research location is Sepulu district, Bangkalan Regency, East Java, with a geographical coordinate at -6.86008 Latitude, 112.94389 Longitude. The selection of research locations was based on considering that many people in the coastal environment use tidal information to carry out fishing by fishers and salt farmers who use the high tide to enter water into ponds. Figure 1 shows the research location in Sepulu District, Bangkalan Regency, East Java.

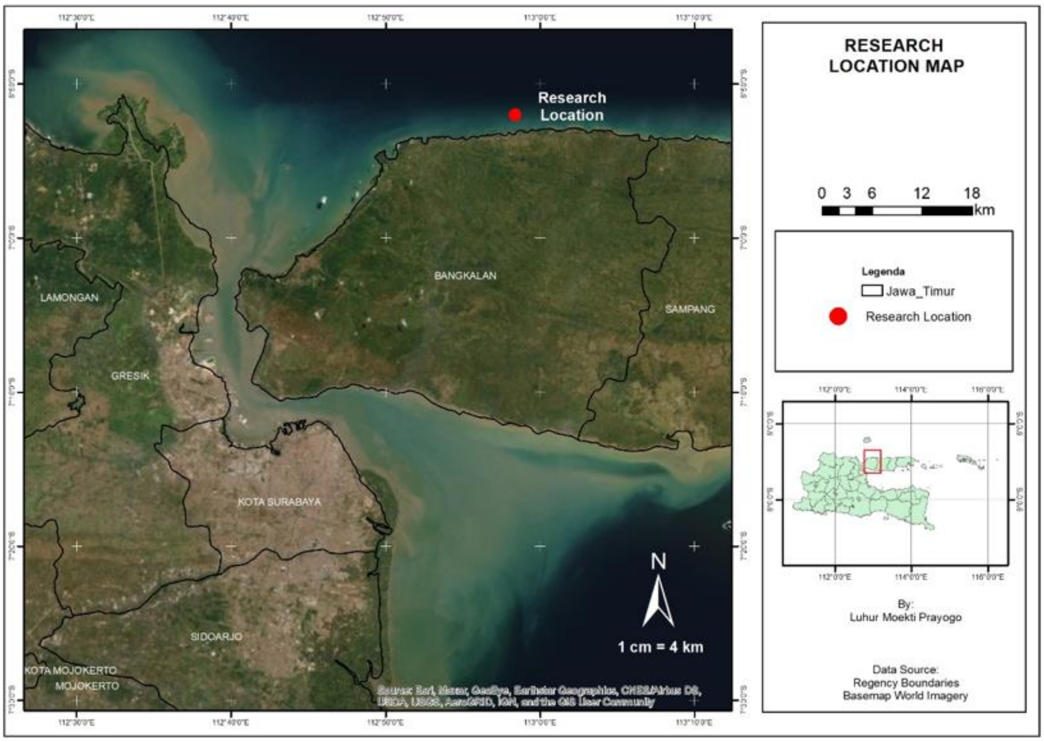

Figure 1. Research location in Sepulu District, Bangkalan Regency, East Java

2.2 LP-Tides Matlab Software

The LP-Tides software is a tidal processing program in the Matlab application (Geodesiana, 2021). This program was developed by Teguh Sulistian, a researcher at the BIG Centre for Marine and Coastal Environment. This program is designed like the T-Tide, which includes predictive analysis and tidal harmonic components (Geodesiana, 2021). Another feature of this software is a tide prediction tool and tide analysis presentation in graphical form and its reconstruction. There is also a blank data tracking operation and a Fill Gap feature that can be used to fill in empty tidal data (Geodesiana, 2021).

2.3 Harmonic Components and Formzahl Numbers

The analysis of harmonic components in tidal measurements is essential because it will show the precision of a model (Budiman et al., 2015). In this study, the analysis of ocean tides with tidal harmonic components

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in this study is limited to the main features, which include (a) soli-lunar constituents (K1), (b) main lunar constituents (O1), (c) major solar constituents (P1), (d) Main lunar constituent (M2), (e) Sun principal constituent (S2), (f) Moon constituent (N2), (g) Soli-lunar constituent (K2), (h) Main lunar constituent (M4) and (i) Soli-lunar constituents (MS4) (Bosch et al., 2009). Then determine the type of tide by looking at the resulting Formzahl number. The determination of the Formzahl number is based on the harmonic components that have been obtained from previous calculations. The equation in calculating Formzahl numbers is as follows (Triatmodjo, 2009):

$F=((O1+K1))/((M2+S2))$………(1)

Where:

F = Formzahl number

O1 = Constant affected by moon declination

K1 = constant, which is influenced by the declination of the moon and sun

M2 = constant, which is affected by the position of the moon

S2 = constant, which is influenced by the position of the sun

Then the value of the Formzahl number can be classified as follows (Triatmodjo, 2009):

(a) F 0,25 with the Semidiurnal type,

(b) 0,25 < F 1,5 with Mixed type, tends to be Semidiurnal,

(c) 1,50 < F 3,0 with Mixed type, tends to Diurnal and

(d) F > 3,0 with a diurnal type.

3. RESULTS AND DISCUSSION

3.1 Tidal Harmonic Components

The tidal data input, which is processed using the LP-Tides software, is divided into three columns: the date, time, and tide value in millimetres (mm). The tidal analysis is then followed by checking the data intervals. The data used in this study used one-hour intervals to select data that did not match these intervals. Then the analysis is continued by checking the blank data. The results of this study indicate that there is no empty data or inappropriate intervals. All input data for January 2021 have been validated using the LP-Tides Matlab software.

Then the analysis is continued by looking for tidal harmonic components. This research only calculates the main harmonic components, including K2, M4, MS4, M2, S2, N2, K1, O1 and P1. The semi-diurnal tidal type's main features include M2, S2, N2 and K2, marked with code number two. The diurnal tidal type components include K1, O1 and P1, marked with code number one. Furthermore, M4 and MS4, which form the Quarterly tidal type, are marked with code number four. The calculation results are shown in Table 1 that the resulting harmonic constant values vary, including the importance of Frequency, Amplitude and Phase.

The calculation results show that the semi-diurnal tidal type, M2, S2, N2, and K2 components produce frequency values of 0.080511, 0.083333, 0.078999 and 0.083562. Furthermore, the harmonic components forming the diurnal tidal type, K1, O1, and P1 components produce frequency values of 0.041781, 0.038731 and 0.041553. Finally, the resulting frequency values for the M4 and MS4 details are 0.161023 and 0.163845.

The amplitude value, the components forming the semi-diurnal tidal type, components M2, S2, N2, and K2, produce values of 91.2236, 200.5868, 26.011 and 15.5615. Furthermore, the harmonic components forming the diurnal tidal type, K1, O1, and P1 components, produce amplitude values of 15,9374, 9,058 and 15,0272. Finally, the resulting amplitude values for the M4 and MS4 components are 10.7761 and 42.3025.

Furthermore, seen from the phase value, the components forming the semi-diurnal tidal type, components M2, S2, N2, and K2, resulted in 88.11, 54.57, 135.2 307.49. Furthermore, the harmonic components forming the diurnal tidal type, K1, O1 and P1 details, produce phase values of 228.93, 325.72 and 2.1. Finally, the resulting phase values for the M4 and MS4 components are 7.17 and 313.56. Table 1 shows the calculation of tidal harmonic components in Sepulu District, Bangkalan Regency, East Java.

Table 1. Tidal harmonic components in Sepulu District, Bangkalan Regency

No	Constituents	Symbol	Description	Const	Freq	Ampl	Phase (g°)
1.	Main lunar constituent	M_2	Semi Diurnal		0.080511	91.2236	88.11
2.	Main solar constituent	S_2			0.083333	200.5868	54.57
3.	Lunar constituent, due to Earth-Moon distance	N_2			0.078999	26.011	135.2
4.	Soli-lunar constituent, due to the change of declination	K_2			0.083562	15.5615	307.49
5.	Soli-lunar constituent	K_1	Diurnal		0.041781	15.9374	228.93
6.	Main lunar constituent	O_1			0.038731	9.058	325.72
7.	Main solar constituent	P_1			0.041553	15.0272	2.1
8.	Main lunar constituent	M_4	Quarterly		0.161023	10.7761	7.17
9.	Soli-lunar constituent	MS_4			0.163845	42.3025	313.56

Then the calculation is continued by determining the type of tide by looking at the results of the Formzahl number. The Formzahl number value is obtained by dividing the leading daily constant amplitude constant by the leading multiple constant. Experiments that have been carried out show that the tidal type in Sepulu District, Bangkalan Regency, is semi-diurnal with Formzahl number 0.08566. Figure 2 is a graph of tidal fluctuations in Sepulu District, Bangkalan Regency, East Java. Musrifin (2011) explained that the water level condition in the area (semi-

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diurnal tides) would experience double daily waves where there are two high tides and two low tides in a day.

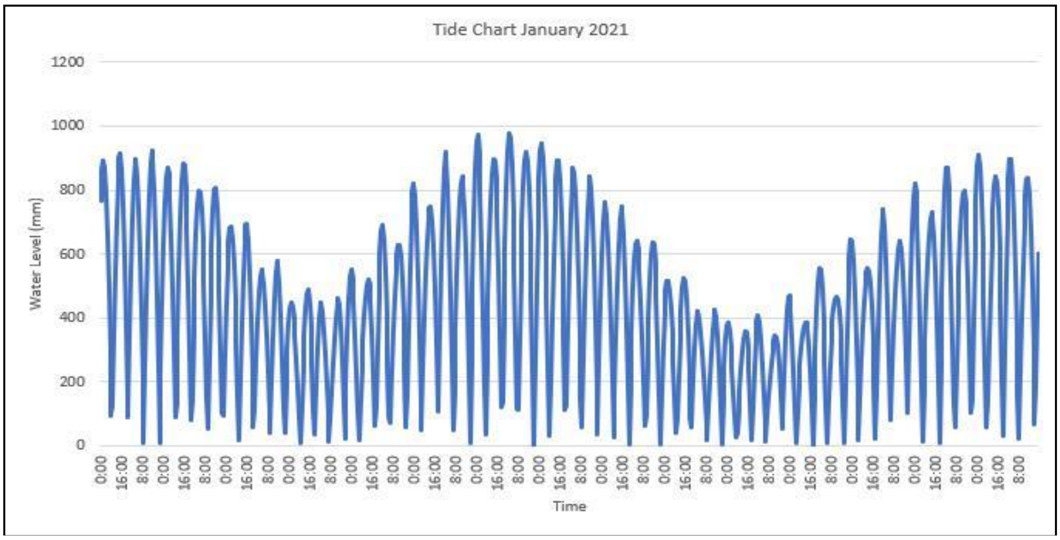

Figure 2. Graph of tidal fluctuation in Sepulu District, Bangkalan Regency, East Java

Figure two illustrates the dynamics of falling and rising tidal water levels recorded on the tide gauge at the station point, Sepulu District, Bangkalan Regency. The highest peak of the sea level is more than 990 (mm). The highest tidal peak occurred three times in the period of the study. The graph above represents that in one day, there can be double-ups and downs.

3.2 Prediction and Residual Tide Data

LP tides software provides tools for a user in predicting tide values. In this research, tide value prediction is carried out on January 1-30, 2021. It is done to compare observation data with predicting data. The observation dan predicting data results in maximum value (978 and 1273.64 mm). Then, Mean Sea Level (MSL) in the observation dan predicting data results 434 mm. Residual assumption testing is carried out if the best model has been obtained (Izzah & Budiantara, 2020). Following the constituents' use to predict the tide at the point and find the difference between the observed and predicted data, the residue is obtained (Kendartiwastra et al., 2018). The residual calculation is continued by finding the mean, root mean square error (RMSE), and standard deviation. The results showed the average value of the tidal residue between the observation data and predictive data was 166.01 mm. Then the calculation is continued by finding the RMSE value and standard deviation. From the experiments that have been carried out, the RMSE values and standard deviations are 12.88 and 125.90 mm, respectively. Figures 3, 4, 5 and 6 show a graph of observations, predictions and residues in January 2021 in Bangkalan Regency, East Java.

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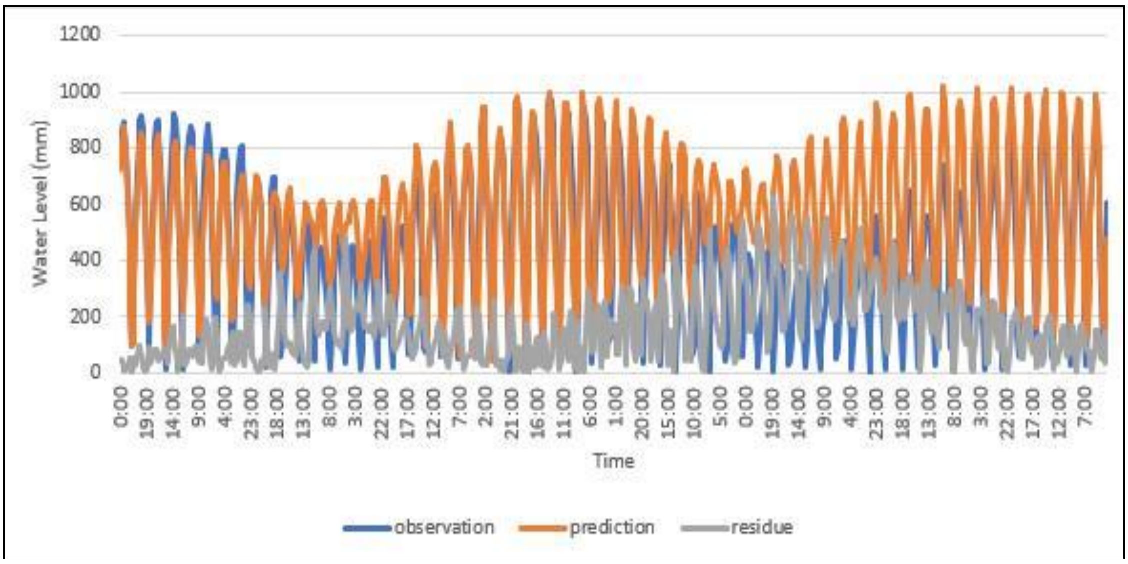

Figure 3. Graph of observations, predictions and tidal residues in Sepulu District, Bangkalan Regency, East Java

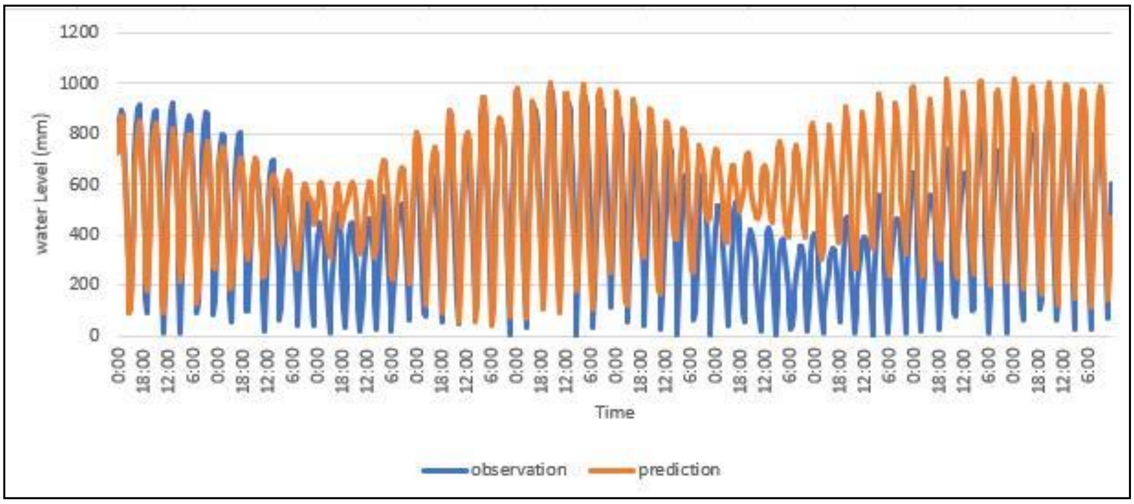

Figure 4. Graph of tide observations and predictions in Sepulu District, Bangkalan Regency, East Java

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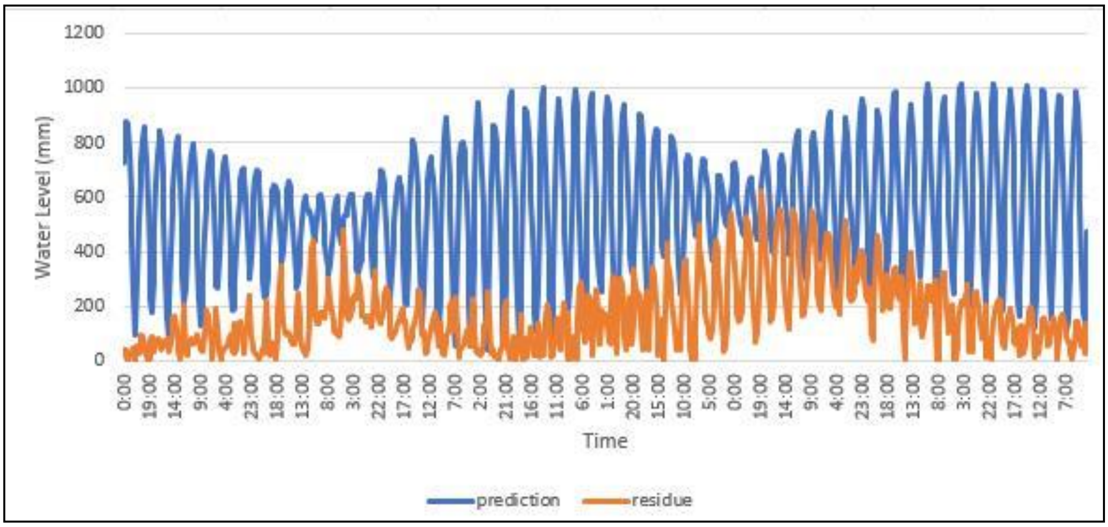

Figure 5. Prediction and residue graph in Sepulu District, Bangkalan Regency, East Java

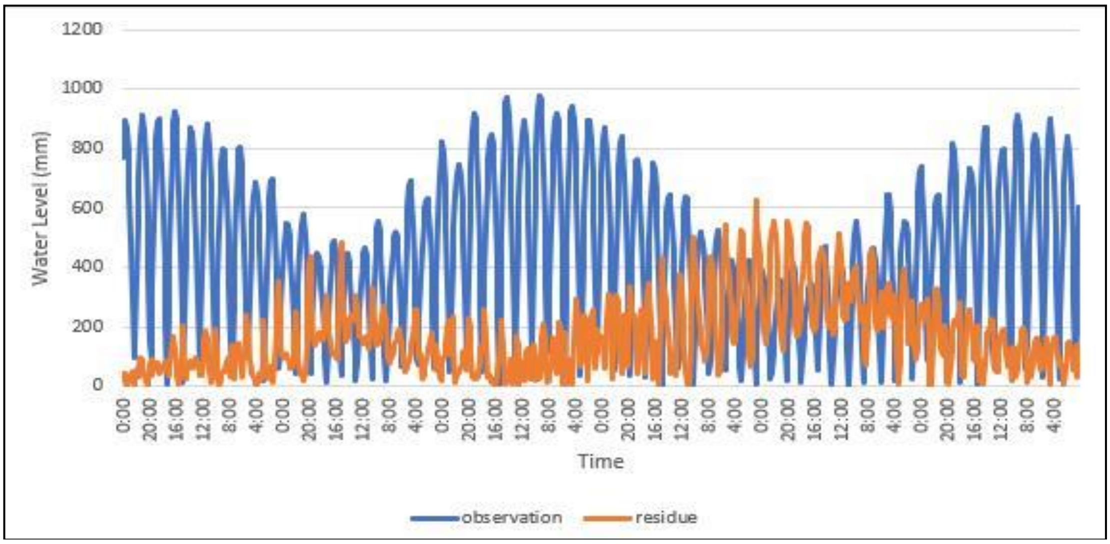

Figure 6. Graph of observations and residues in Sepulu District, Bangkalan Regency, East Java

Overall, the picture above compares the results of data observations in January 2021 with the results of tidal and residual predictions. The results of observation of field measurement data during January where the lowest point of seawater level was at 0 to 100 (mm). However, the modelling results with LP Tides software represented where the lowest level of seawater fluctuated, and even the lowest number reached 0 to 450 (mm). When overlaying the graph of the observation data and the model, there is a residual graph that is not too big of a difference.

CONCLUSIONS

From this research, it can be concluded that the main harmonic constants generated include K2, M4, MS4, M2, S2, N2, K1, O1 and P1. The tidal type shows that the Sepulu sub-district is a semi-diurnal type with a Formzahl number of 0.08566. The maximum values of observation and prediction data for January 2021 in Sepulu District, Bangkalan Regency are 978 and 1273.64 mm. The area's MSL value is 434 mm, with an average tidal residue value between the observation data and the predictive data of 166.01 mm. The calculation of the RMSE value and standard deviation are 12.88 and 125.90 mm.

ACKNOWLEDGMENTS

The author would like to thank the Indonesian Geospatial Information Agency for providing tidal data to be used in this research. Do not forget to thank Teguh Sulistian, a researcher at the Center for Marine and Coastal

Environment, the Geospatial Information Agency, who has developed the LP-Tides Matlab software.

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