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Sediment Transport Pattern Modelling in Bojong Salawe Coast Pangandaran using Mike 21

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Abstract

Bojong Salawe is a coastal area with unique characteristics due to a confluence of three rivers that flow through Cijulang, Cijalu, Cialit and into the Indian Ocean. With complex oceanographic conditions, the sediment transport patterns at Bojong Salawe needs to be contemplated, especially the coastal's utilization which is quite productive. This study aims to determine the sediment types, the sediment transport patterns and the effect of sediment transport on abrasion or accretion which are supported by hydrodynamic parameters modelling such as wind, currents and tides in the west and east monsoons using hydrodynamic modules and sediment transport in MIKE 21. The results showed that the sediments in this study is 80% sandy silt and 20% sand. The sediment transport pattern models in both the west and east monsoons tend to be influenced by tidal currents, sediment types and the season itself. West monsoon has a higher sediment concentration which ranges from 0 to 8.4 kg/m^3 compared to the East Monsoon with a range of 0-4 kg/m^3. The effect of sediment transport on the average bed level was 0.71861 m in the west monsoon and 0.37586 m in the east monsoon whereas in the estuary (research station), the average change in West Monsoon is 0.00861 m (ST 1) and 0.07107 m (ST 2) and in the East Monsoon, it is 0.01003 m (ST 1) and 0.01147 m (ST 2). This bed level change tends to increase, indicating that the Bojong Salawe coast has experienced sedimentation (accretion).

Keywords: Bojong Salawe. MIKE 21, Modelling, Sediment Transport

1. Introduction

Coastal regions are transitional areas between land and sea components on the earth's surface (Crossland et al., 2006). These areas are important but difficult for stakeholders and contributors to manage (Boudreau et al., 2013). Indonesia has a total coastline of 81,000 km and about 60% of ± 250 million people live in there (Siry, 2007). Bojong Salawe is one of the coastal areas in Indonesia where three rivers meet geographically and flow towards Pangandaran Bay into the Indian Ocean; Cijulang River, Cijalu River and Cialit River. Therefore, these locations are used as shipping routes by fishermen. The fishermen's activities along with the Fish Auction makes Bojong Salawe a strategic area for the communities. In addition, it has a port which is still under construction as well as several other coastal and marine resources such as culinary and tourism (Tresna & Nirmalasari, 2018). For the dynamics of

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marine waters, the wind is the main source of energy as the driving force for seawater and the sediment materials. This transfer of energy from the wind to the sea surface will cause waves and ocean surface currents. The currents generated by the wind have different speeds based on depth. However, the depth that is affected by current movement can be caused by the sedimentation process (Yang et al., 2013).

Sedimentation is the deposition of sedimentary materials transported by wind and water (Razjigaeva et al., 2013). It is the main process for removing particulate matter from the water column. The stability of aquatic ecosystems is largely determined by the materials transported during the sedimentation process (Ostrovsky et al., 2014) because high sediment concentrations will affect the level of dissolved oxygen in the waters (Talke et al., 2009). Sediment transport has the potential for land formation either due to erosion or sedimentation (Sherman et al., 2013).

Sedimentation will become a problem if it occurs in a coastal environment that is often used for human activities such as ports and shipping lanes because it can inhibit activities by siltation or erosion around the coast (Rijn, 2005). Therefore, as a preliminary study, a sediment transport model was created around the development site of Pangandaran Port in Bojong Salawe Coast using MIKE 21 based on the modules (DHI, 2014) and (DHI Software, 2012).

Based on location of Bojong Salawe Coast with strong oceanographic characteristics, the presence of a port and also a river estuary, this coast has its own sediment transport pattern. My team and I want to do research by modeling it using MIKE 21 software. The aim of this research is to obtain the sediment types, the sediment transport patterns and the effect of sediment transport on abrasion or accretion

2. Materials and Methods

2.1. Materials

This research will be carried out in Bojong Salawe Pangandaran Coast by modeling it using MIKE 21. The tools needed to support this research are Google Earth, Laptop, Ms. Office, Sieve Shaker, Kummod Sel, Arc GIS and MIKE. The materials used in modeling it is sediment, tides, wind and bathymetry. Sediment data retrieval was performed at 7°41'28.6" S, 108°32'20.6" E (ST1), and 7°42'55.2" S, 108°29'55.9" E (ST2) as shown in Figure 1.

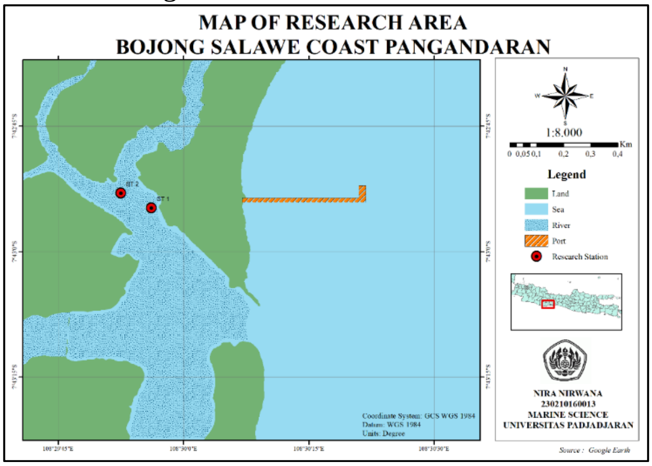

Figure 1. Map of Research Area

2.2. Methods

The method used in this research is observation and simulation; an examination of natural conditions by describing a parameter simply and systematically using hydrodynamic and sediment transport modelling in MIKE 21 (Lumborg & Pejrup, 2005). The model is run by the Hydrodynamic Module (HD) for flow modelling, and Mud Transport Module (MT) for sediment transport modeling and bed level change (DHI, 2012). This simulation uses a two-dimensional numerical method by inputting hydrodynamics (wind, bathymetry, tides) and sediment transport validated with field data (DHI, 2014). The results of the two-dimensional model of sediment transport will indicate abrasion or sedimentation by looking at the value of suspended sediment concentration and changes in bed level which occur due to sediment transport.

Hydrodynamic and Sediment transport is simulated over a period of three months during the West Monsoon (December, January, February) and the East Monsoon (June, July, and August) in 2017, 2018, and 2019 to determine the sediment transport patterns in the estuary and Bojong Salawe Beach by comparing it during high tide and low tide conditions (Husrin et al., 2014).

2.3 Model Validation

Insert common mathematical equiations or build up your own equations using a library of math symbols. Variables and parameters must be typed in italics, while symbols of vectors or matrices are typed upright and bolded. Validation is done to prove the model data with field data (Daud & Akhir, 2015) by validating the model simulation results with data from the IOC Sea Level Monitoring within the first 15 days in June 2019. This model analysis takes the form of a percentage error (Fattah et al., 2018). The equation to obtain the error value is:

$$Error = \frac{1}{N}\left[\sum_{i=1}^{N}\left|\frac{Xi-xi}{TP}\right|\right] \times 100\% \quad (1)$$

Notes:

N : Amount of data

Xi : Modeling result

xi : Field data

TP : The range of tide observation data

3. Results and Discussion

3.1 Sediment Identification

Based on the grain size category according to Shepard (1954) (Shepard, 1954), the sediment found in the research area at both ST 1 and ST 2 is categorized as sandy silt. The data is shown in Table 1:

Table 1. Identification Results of Sediment Types by KUMMOD-SEL

No	Code	Sediment Fraction (%)				Sediment Type
		Gravel.	Sand.	Silt.	Clay.	
1	ST 1	0	19.8	80.2	0	Sandy Silt
2	ST 2	0	18.3	81.7	0	Sandy Silt

From the table 1, both the sediments in ST 1 and ST 2 are dominantly silt. ST 1 has 80.2% silt and 19.8% sand. ST 2 has 81.7% silt and 18.3% sand. This is because the research stations are located at estuary and they are in a closed area, therefore the sediments deposited there are smoother as they have weaker currents. Currents greatly affect the movement of the sediments (van Rijn et al., 2007). In addition, sediments that contain sandy silt will affect the pattern of sediment transport because it is smooth and easily transported (Martinez-Mena et al., 2000). Strong currents will dominate sediment transport (Seifert et al., 2009). The smaller the sediment grains are, the easier they are to be transported. Conversely, the larger the sediment grains are, the harder it is for them to be transported (Boudet et al., 2017). Sediments with smaller grain sizes will be easily suspended in water and suspended sediments are more easily transported compared to sediments in the bottom waters (Butt et al., 2005).

3.2 Model Validation

Tidal data needs to be validated. This is not the case for wind because the accuracy of wind data from the European Centre for Medium-Range Weather Forecasts (ECMWF) is very high, especially for tropical climate regions (Haiden et al., 2015). The same applies as well for bathymetric data from The

General Bathymetric Chart of the Oceans (GEBCO). Based on the evaluation, bathymetry data from GEBCO is the best choice for displaying 500 meters bathymetry contours (Marks & Smith, 2006).

Tidal data from IOC Sea Level Monitoring is real time data taken using radar to measure sea level elevation (UNESCO & IOC, 2020) at the Cilacap Observation Station. It is considered to have similar water level characteristics with the research area. The error value is 4% which means that the data model has a high accuracy and is sufficient to be considered suitable for use in this research. The following chart compares tidal data from IOC sea level monitoring and model results (Figure 2):

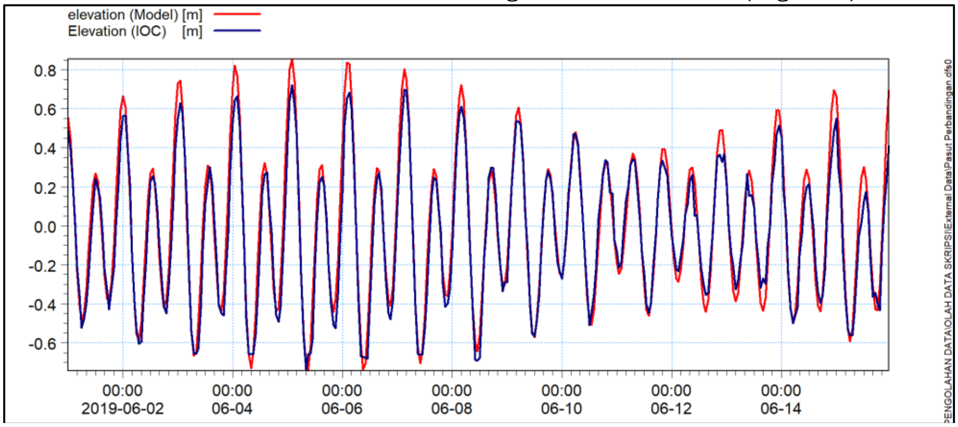

Figure 2. Comparison chart of sea level elevation data

3.3 Hydrodynamic Simulation

In general, the current speed in the research stations are smaller than in Bojong Salawe waters (Figure 3 - 6). This is because the position of the station at the estuary and riset location tends to be closed, resulting in a lesser influence of the ocean currents. The further away it is from the coast, the lower the effect. It can be seen in the average value of the current speed of ST 1 which tends to be greater than ST 2 (Table 2) because ST 1 is located closer to the beach. The difference in the current speed is also influenced by the tide conditions; higher during high tide and lower during low tide. Monsoons also have a role in the current movements, though the effect is not very significant (Supian et al., 2020).

Table 2. Current Speed Value at Research Station

No	Station	Period	Year	Current Speed (m/s)		
				Max	Min	Mean
1	ST 1	West Monsoon	2017	0.00694	0.00004	0.00230
			2018	0.01109	0.00002	0.00366
			2019	0.01024	0.00002	0.00352
2	ST 2		2017	0.00505	0.00004	0.00181
			2018	0.00512	0.00003	0.00176
			2019	0.00456	0.00001	0.00144
3	ST 1	East Monsoon	2017	0.01090	0.000003	0.00370
			2018	0.01288	0.00001	0.00347
			2019	0.02218	0.00045	0.00348
4	ST 2		2017	0.00399	000003	0.00150
			2018	0.00392	0.00001	0.00147
			2019	0.00954	0.00037	0.00172

Overall, when the data between 2017, 2018 and 2019 are compared, the highest average current speed in the West Monsoon is during the DJF 2018 period. This is in accordance with the average wind speed in the DJF 2018 period (Subiyanto et al., 2021). In the East Monsoon of the JJA period, the highest average current speed is at JJA 2019. The current speed during the East Monsoon is higher than the West Monsoon (Supian et al., 2020).

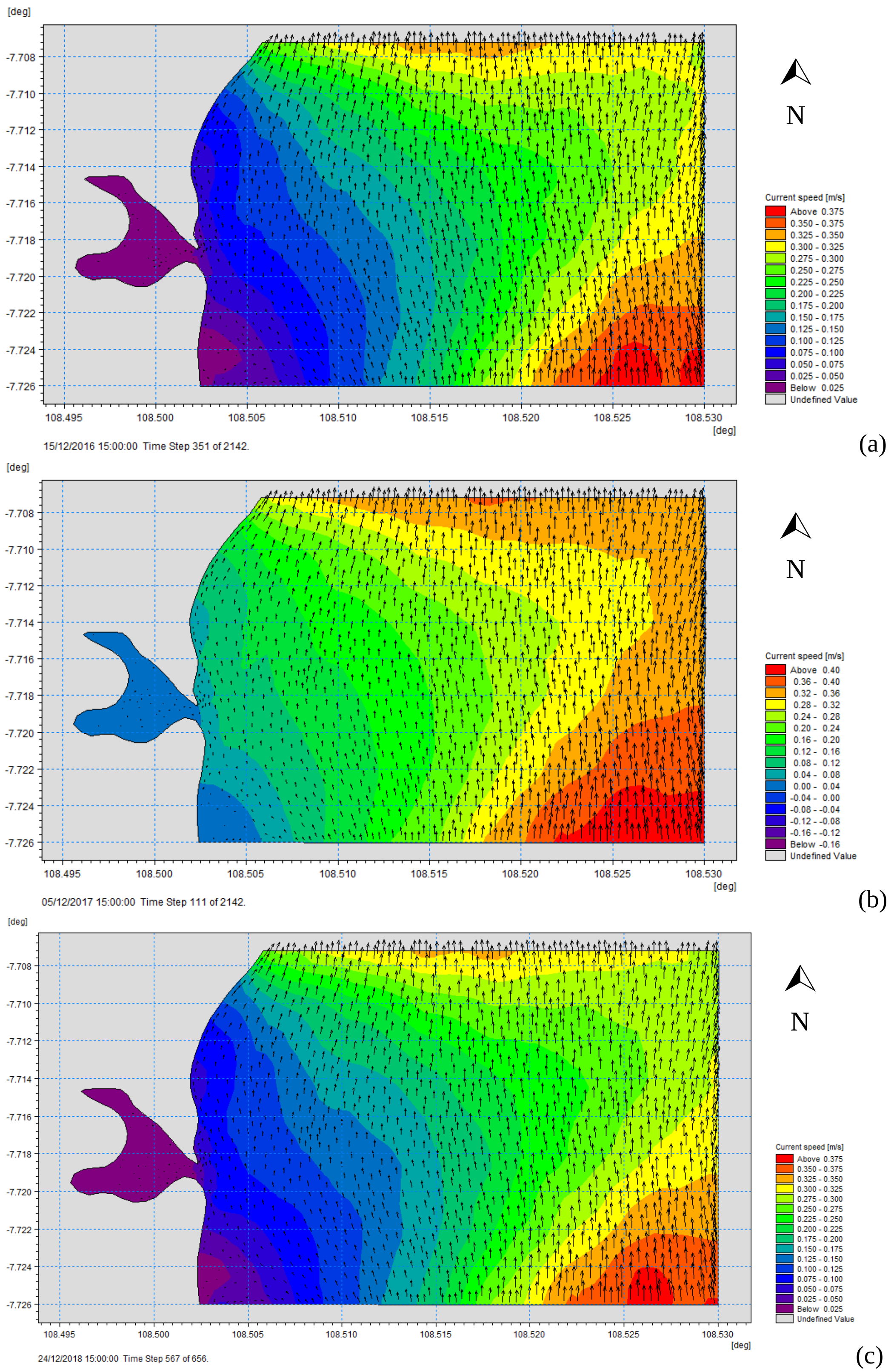

Figure 3. Current Speed in West Monsoon at Highest Tide (a) 2017 (b) 2018 (c) 2019

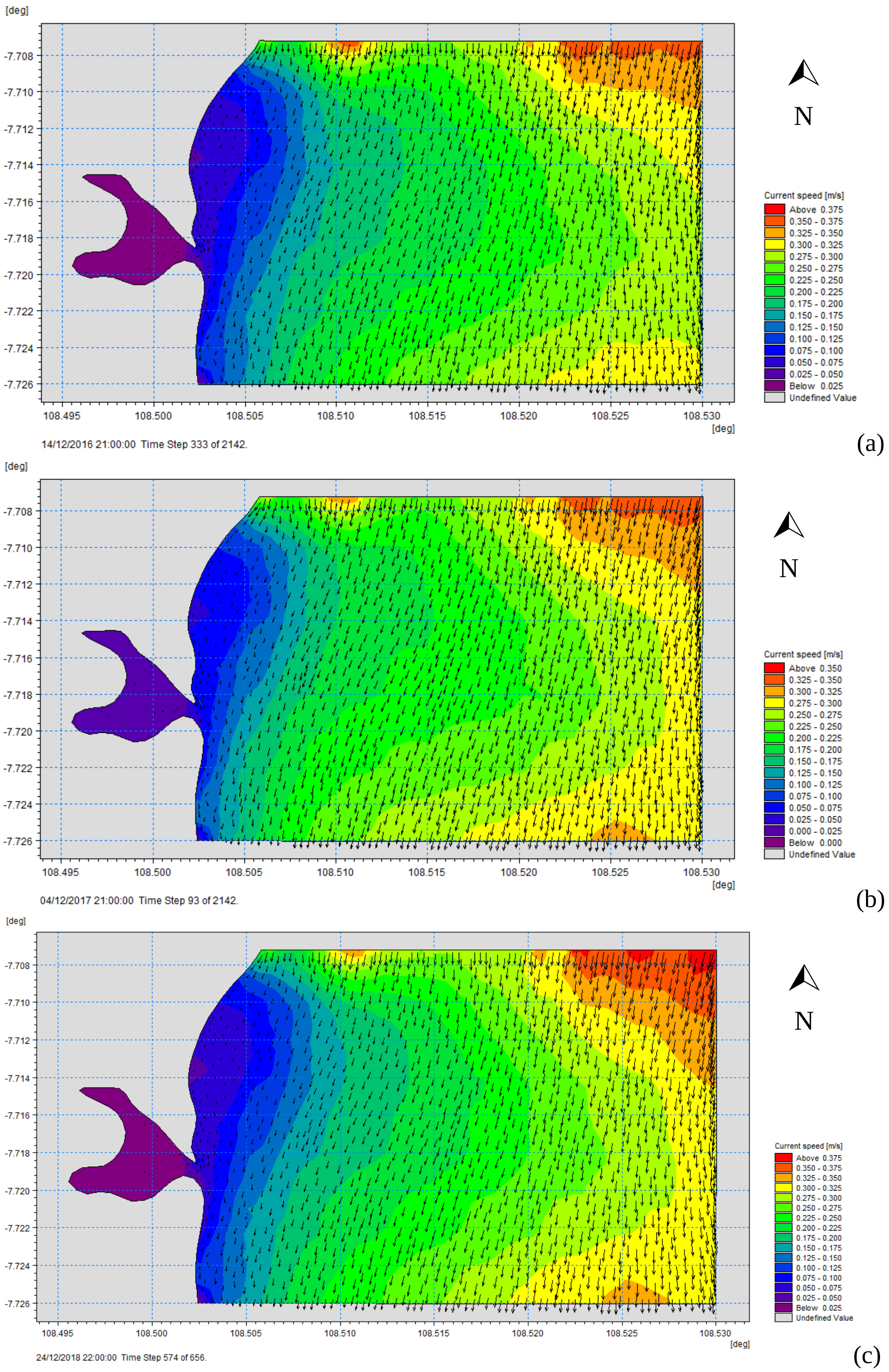

Figure 4. Current Speed in West Monsoon at Lowest Tide (a) 2017 (b) 2018 (c) 2019

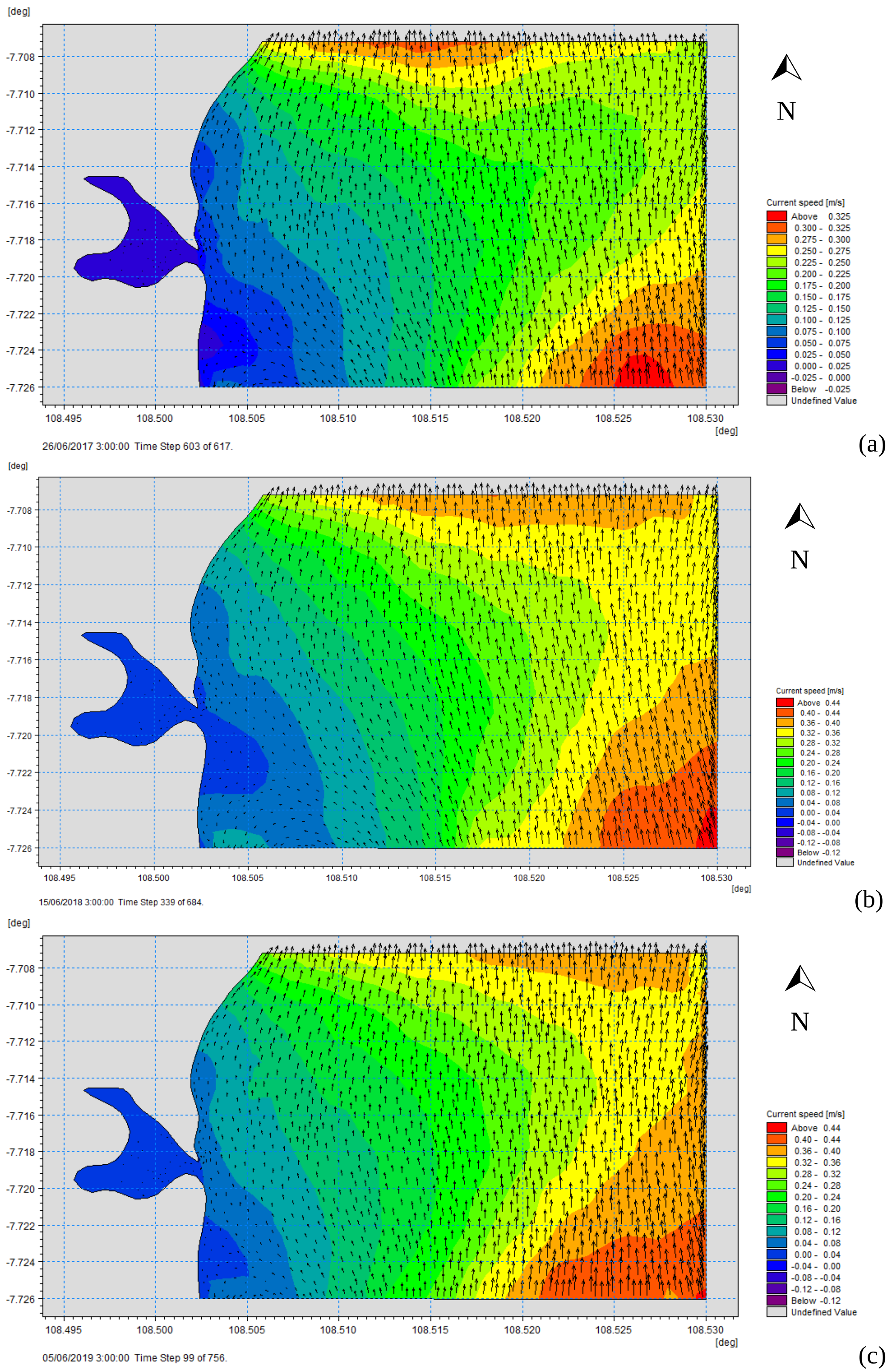

Figure 5. Current Speed in East Monsoon at Highest Tide (a) 2017 (b) 2018 (c) 2019

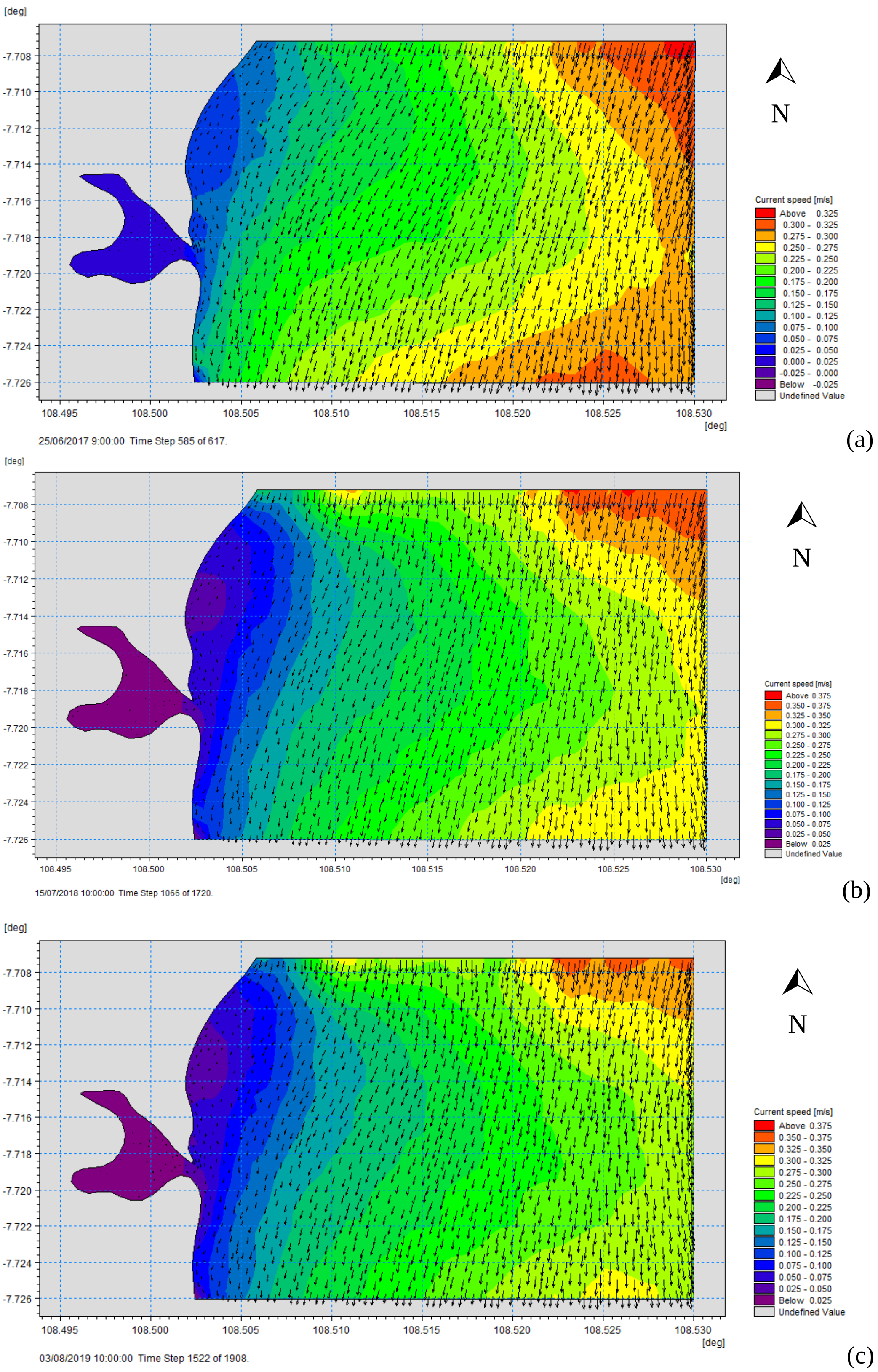

Figure 6. Current Speed in East Monsoon at Lowest Tide (a) 2017 (b) 2018 (c) 2019

3.4 Sediment Transport Simulation

The pattern of sediment distribution in the research area is observed by looking at the Suspended Sediment Concentration (SSC) and its bed level change which help to identify whether the area tends to experience abrasion or sedimentation (accretion) (Butt et al., 2005). Figures 7 - 10 show that SSC in Bojong Salawe waters during the West Monsoon in 2017, 2018 and 2019 has a range of 0 - 8.4 kg/m^3 while during the East Monsoon, the SSC has a lower range of 0 - 4 kg/m^3.

SSC values at the research station also tend to be lower than the sediment concentration in Bojong Salawe waters (Table 3). With water conditions that are more closed and its location being in the estuary, there are fewer currents which carry sediment materials from the sea. This indicates that the pattern of sediment transport in Bojong Salawe waters is influenced by currents generated by tidal and wind power (Wright et al., 2001). Tidal currents affect the direction and broad distribution (Anthony, 2000) while the wind season affects the concentration of suspended sediments carried by the current itself (Supian et al., 2020).

In high tide conditions, sediments with higher concentrations come from the south (offshore) which will decrease in SSC value when approaching the coast. Conversely, in low tide conditions, sediments with higher concentrations originate from the north (coastal areas) and progressively lower concentration levels. This means that the conditions of the tidal currents greatly affect the movement of the suspended sediment (Christiansen et al., 2000).

Table 3. Suspended Sediment Concentration in Research Station

No	Station	Period	Year	Suspended Sediment Concentration (SSC kg/m^3)		
				Max	Min	Mean
1	ST 1	West Monsoon	2017	0.01984	0	0.01204
			2018	0.02572	0	0.00999
			2019	0.01758	0	0.00822
2	ST 2		2017	0.03710	0	0.02152
			2018	0.03665	0	0.02145
			2019	0.03497	0	0.01705
3	ST 1	East Monsoon	2017	0.01774	0	0.00940
			2018	0.01799	0	0.00917
			2019	0.01801	0	0.01059
4	ST 2		2017	0.01121	0	0.00706
			2018	0.00953	0	0.00616
			2019	0.02814	0	0.01483

To see the effect of sediment transport on abrasion or accretion phenomena, changes in bed level which occur due to the presence of sediment transport need to be analysed (Yang et al., 2013). When the value of the bed level goes to the positive direction or there has been an increase in the bed level, then the location is indicated to have experienced sedimentation (accretion). Conversely, when the value of the bed level is getting away from the positive sign or there has been a decrease in bed level, the location is indicated to have experience abrasion (Yang et al., 2013).

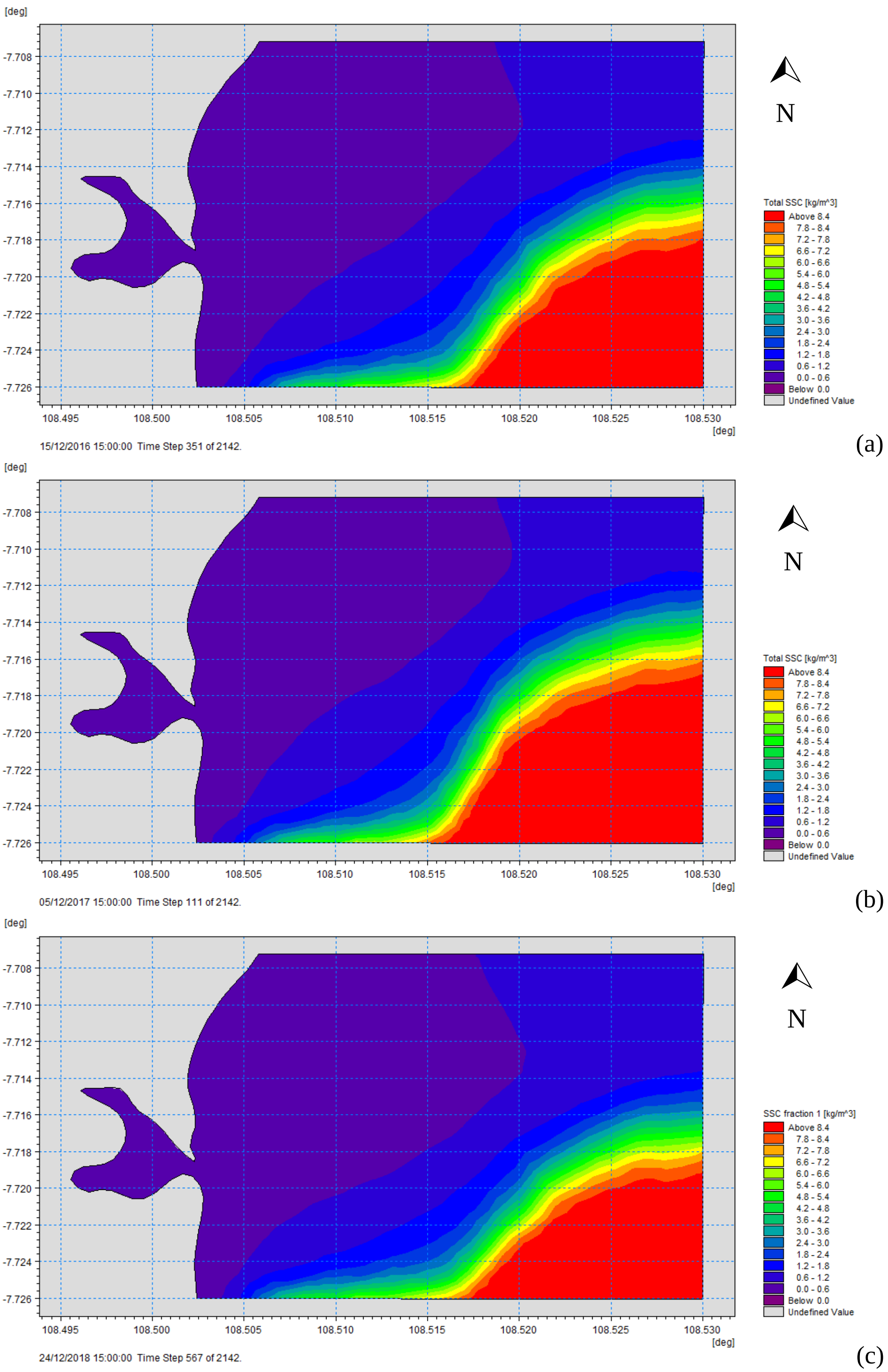

Figure 7. SSC in West Monsoon at Highest Tide (a) 2017 (b) 2018 (c) 2019

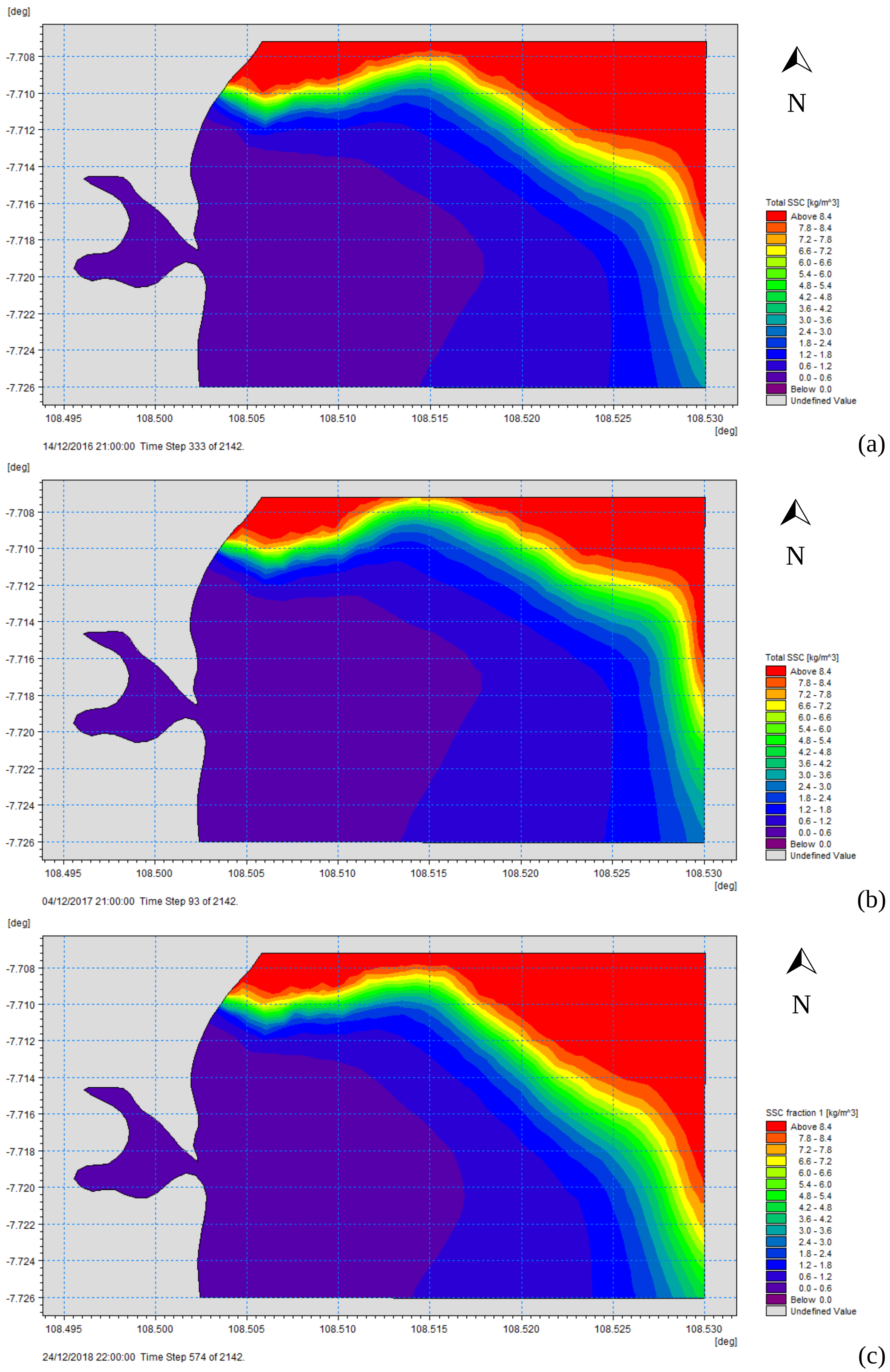

Figure 8. SSC in West Monsoon at Lowest Tide (a) 2017 (b) 2018 (c) 2019

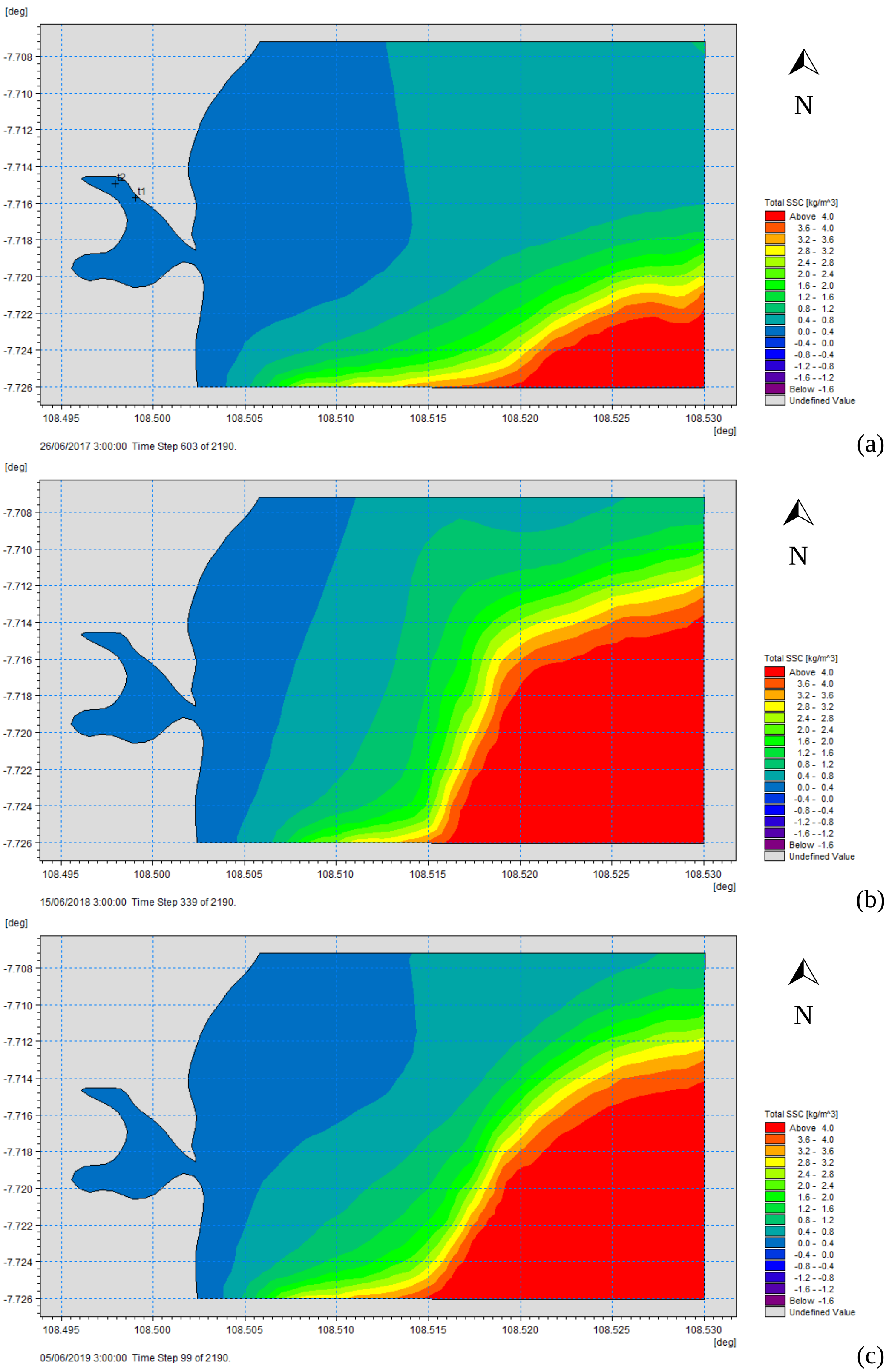

Figure 9. SSC in East Monsoon at Highest Tide (a) 2017 (b) 2018 (c) 2019

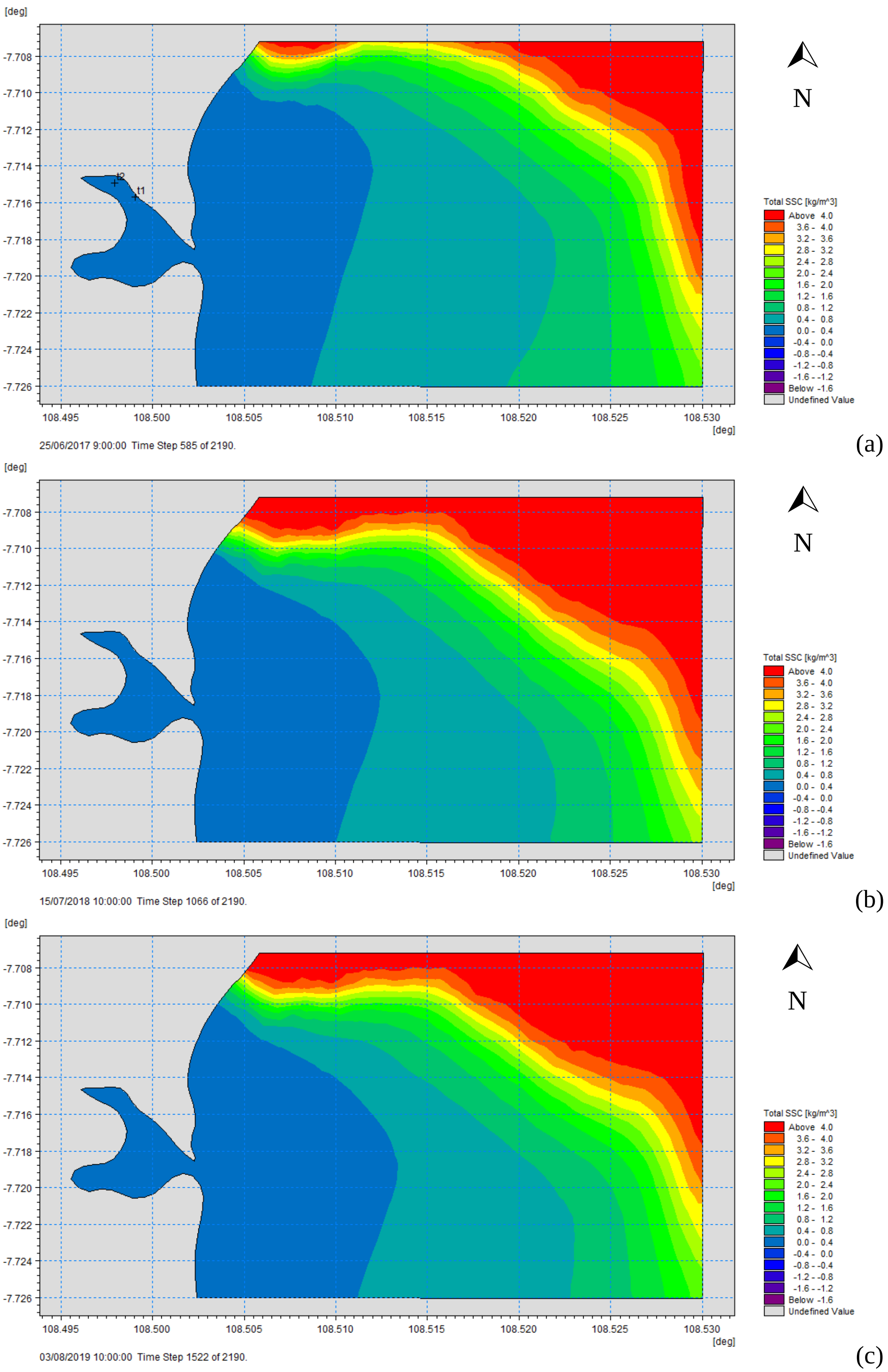

Figure 10. SSC in East Monsoon at Lowest Tide (a) 2017 (b) 2018 (c) 2019

Figures 11 – 14 is a chart of bed level changes taken in the West Monsoon and eat season in 2017, 2018 and 2019 at the research station and around Bojong Salawe Beach by taking one point 108.502125° E dan 7.714238° S as samples representing bed level conditions.

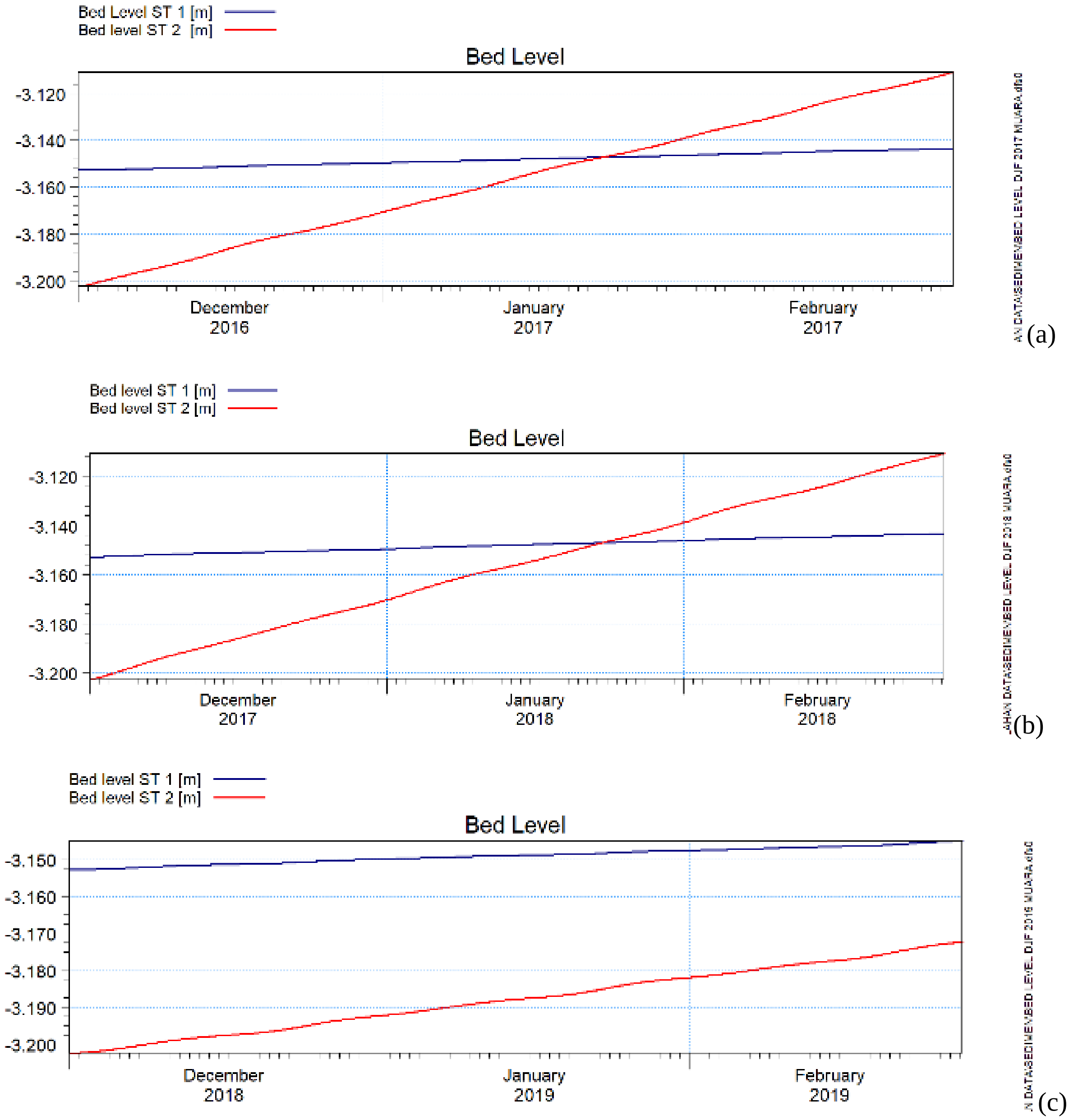

Figure 11. Bed Level Change in West Monsoon at Research Station (a) 2017 (b) 2018 (c) 2019

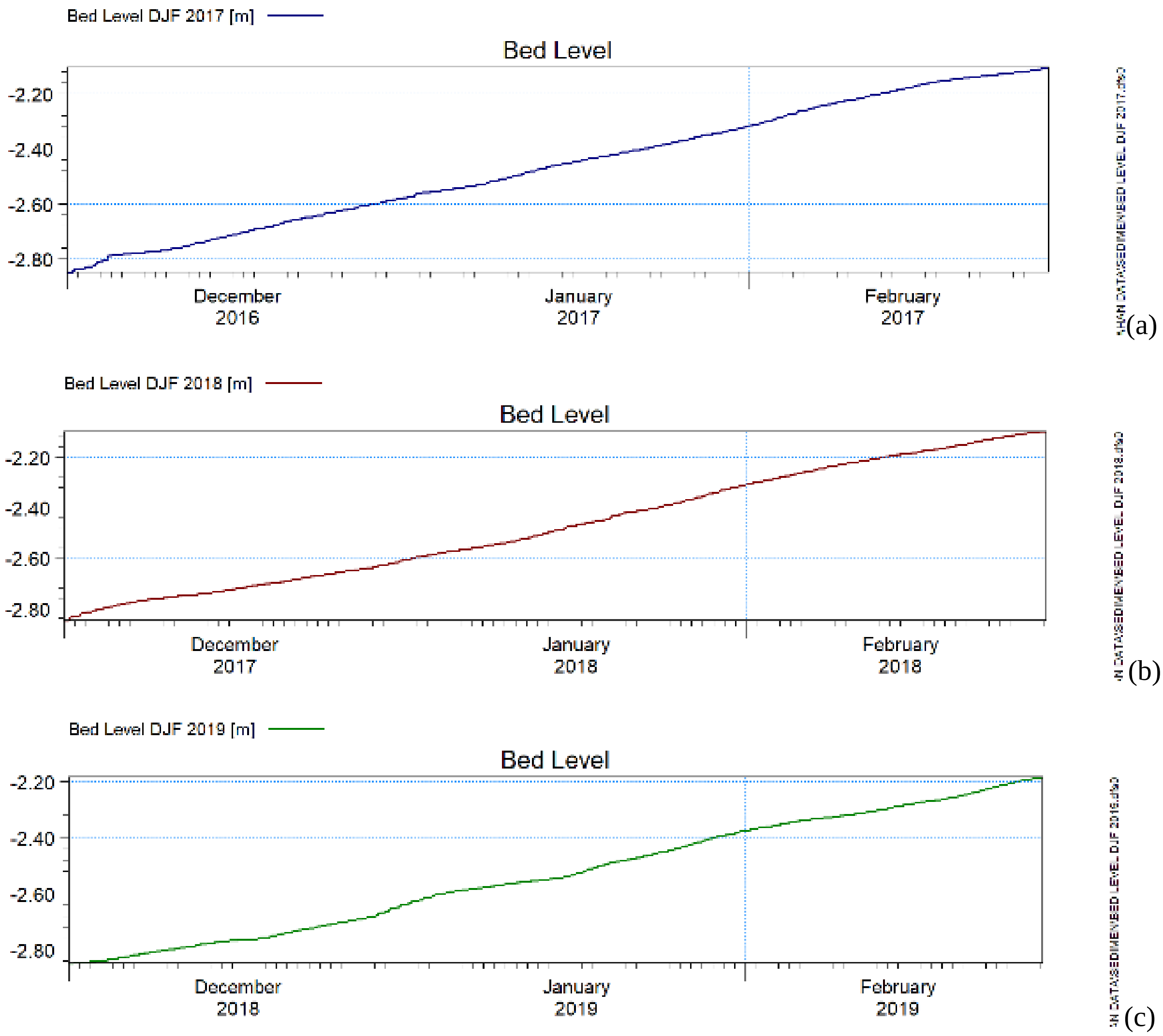

Figure 12. Bed Level Change in West Monsoon at the Beach (a) 2017 (b) 2018 (c) 2019

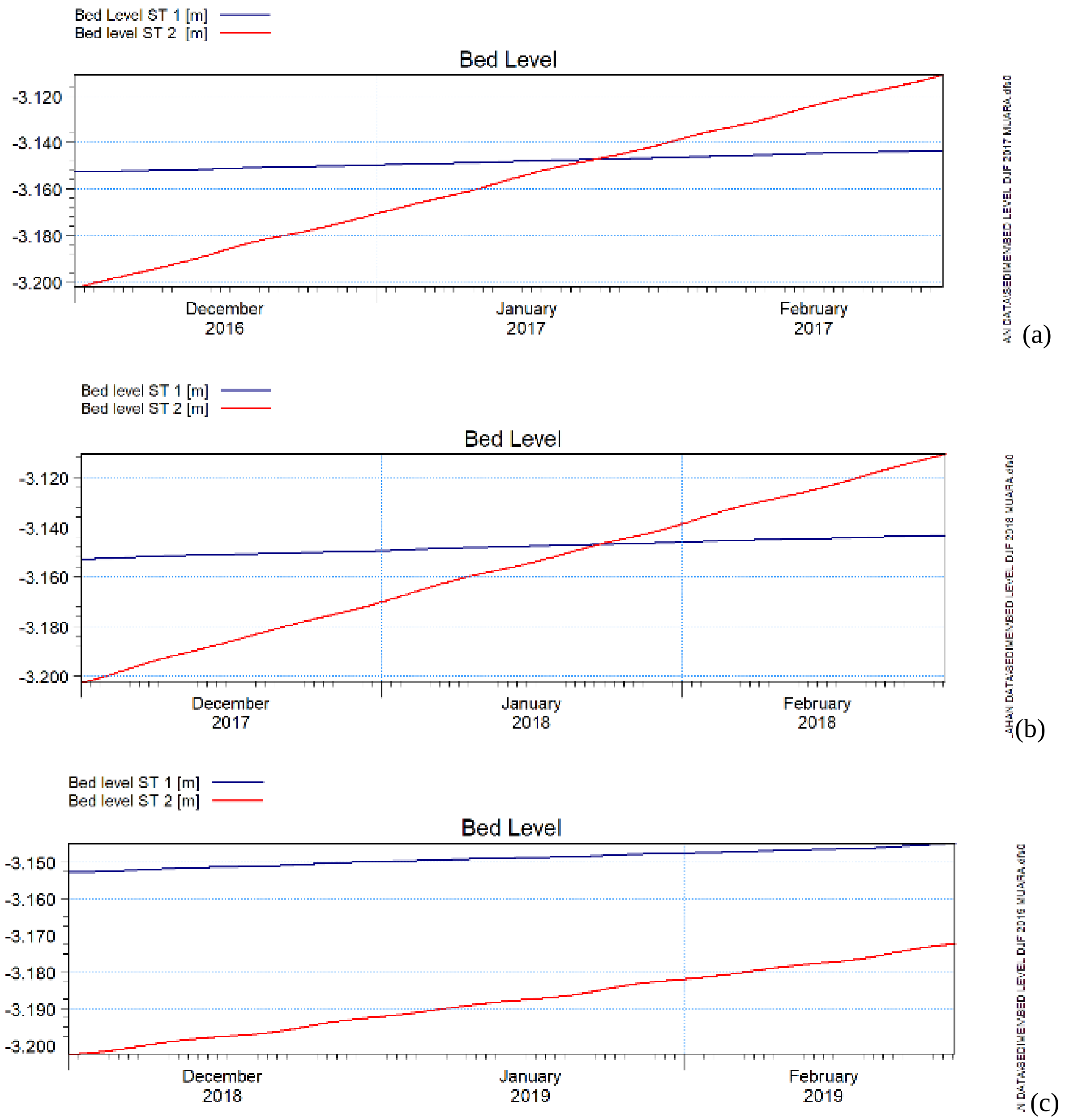

Figure 13. Bed Level Change in East Monsoon at Research Station (a) 2017 (b) 2018 (c) 2019

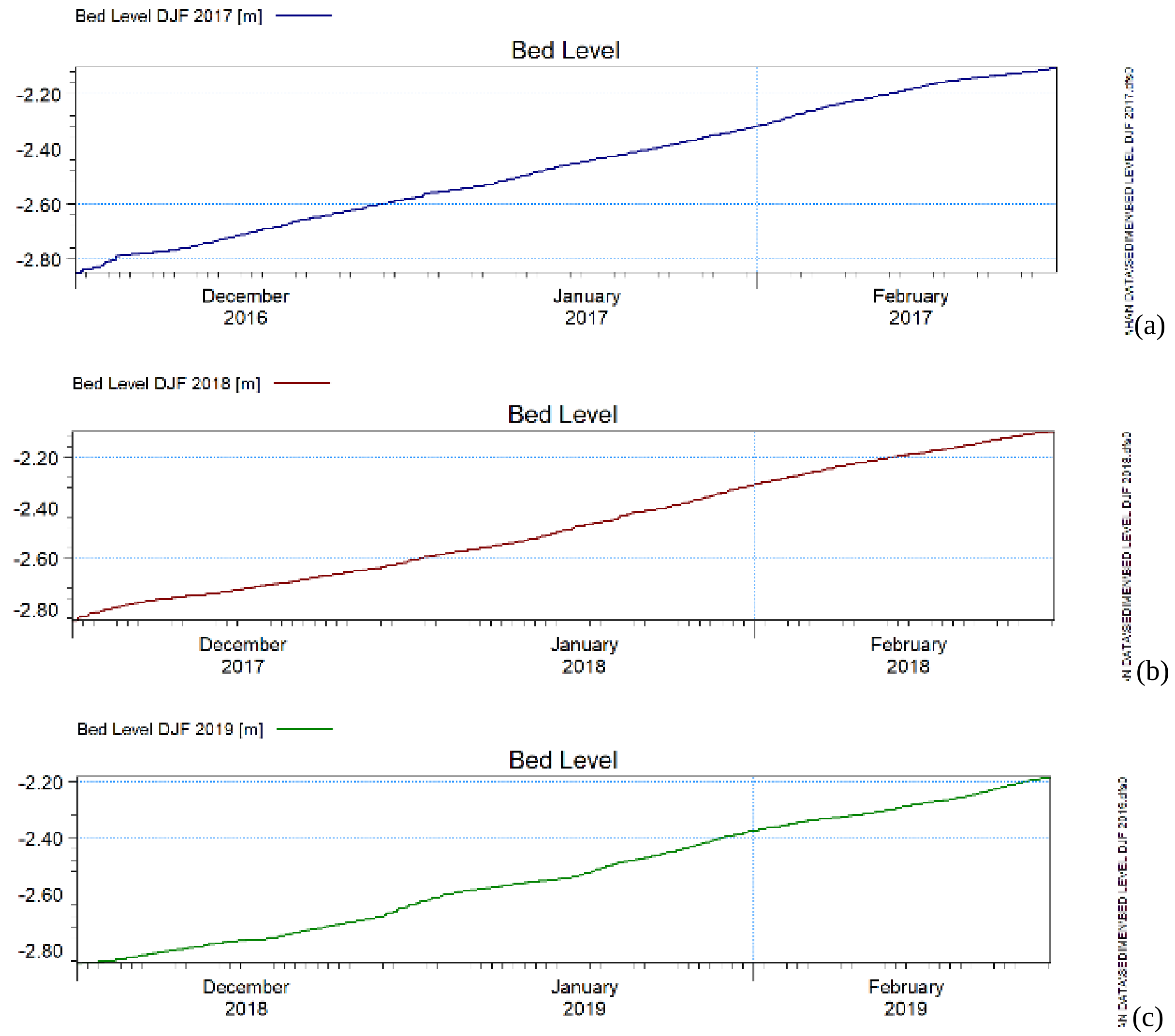

Figure 14. Bed Level Change in East Monsoon at the Beach (a) 2017 (b) 2018 (c) 2019

Based on the Figures 11 - 14, during the West Monsoon or East Monsoon in 2017 - 2019, the bed level at Bojong Salawe Beach tends to increase. The amount of additional bed levels at West Monsoon are as follows: 0.7433 m, 0.74844 m and 0.66409 m. In the East Monsoon, the additional bed levels are 0.37969 m, 0.37309 m and 0.3748 m. The same case occurred in the research station; the bed level tend to increase, though not as much as the ones on the beach. In the West Monsoon, the addition of bed levels at ST 1 are 0.00915 m, 0.00948 m and 0.0072 m whereas at ST 2, they are 0.09142 m, 0.09175 m and 0.03004 m. Even though the bed level in the East Monsoon is not too significant, the graph still shows an increase in bed level at both ST 1 and ST 2 in 2017, 2018 and 2019. The addition of bed level in ST 1 are 0.00961 m, 0.00939 m, and 0.01108 m, whereas at station 2, they are 0.00644 m, 0.00562 m and 0.02234 m. This is directly proportional to the hydrodynamic conditions where ST 2 gets less influence from sea water, therefore the currents are calmer than ST 1. The slower current conditions that cause sediment transport in these waters also slow down and over time will be deposited (van Rijn et al., 2007). The addition of bed levels that occur at both the research station and the coast indicate that the area is experiencing sedimentation (accretion) (Yang et al., 2013).

The sedimentation phenomenon will cause several problems, especially if it occurs continuously (Rijn, 2005). This can be a problem especially for fishermen who use Bojong Salawe (especially in estuary areas) as a transportation route when fishing into the sea. The Port is currently still under construction, and this pose another problem for the fishermen. Seeing this, it is necessary to take action and preventive measures in the future such as coastal engineering with coastal structures (long jetty, offshore break water, groins, revetments, etc.) (Rijn, 2005). The development must of course be adjusted to the conditions of the coastal waters in Bojong Salawe.

4. Conclusion

Based on the results and discussions above, it can be concluded that:

1. The sediment found in Bojong Salawe Coast is dominated by 'Sandy Silt'.
2. The sediment transport pattern models in Bojong Salawe Pangandaran Coast in the west and East Monsoon of 2017-2019 are influenced by sediment type, tidal current and wind season.
3. The sediment transport in 2017 - 2019 were affected by bed level change and tend to increase. It is indicated by sedimentation (accretion).

And for the next step of this research should be:

1. Measurements of water discharge and sediment concentration were carried out directly at the site so that the resulting modeling was more accurate
2. The addition of the research area coverage along Pangandaran Bay and slightly towards the river to see hydrodynamic conditions and sediment transport in a more complete and comprehensive manner.
3. To find out the source of sediment origin, Particle Tracking modeling is needed by taking samples of sources in the oceans and coasts.

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