# Identification of Shoreline Shifts and Subsurface Layers using Google Earth Pro with the Multichannel Analysis of Surface Wave (MASW) Method in the Abrasion-Prone Areas of Central Bengkulu to Seluma

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**Abstract**: Central Bengkulu to Seluma is mostly abraded and slightly accreted. Shoreline changes occur as a result of sediment movement, wave action, ocean currents, and human activities. This study aims to determine, analyze changes in the coastline from Central Bengkulu to Seluma using Google Earth Pro and determine the value of rock stratigraphic layers using the Multichannel Analysis of Surface Wave (MASW) method. Field data collection was carried out using the Seismograph PASI 16S-24P seismic tool. The results of mapping and validation of primary data that has been inversed and then processed in surfer software, show that the beach with the largest abrasion value over a span of 16 years is Muara Dua beach in track 3, with a shoreline change of 6.7 m/year. Then based on the value of Vs the coastal area of Central Bengkulu to Seluma is divided into 3 class sites, namely class D stiff soil, C very dense soil and soft rock, and B medium rock.

Keywords: Abrasion; Accretion; Google Earth Pro; Multichannel Analysis of Surface Waves (MASW); Shorline Change

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## I. INTRODUCTION

Bengkulu Province has a coast that faces the Indian Ocean, causing large waves. Large waves or waves have the potential to cause abrasion [1]. Very often, the Indian Ocean experiences very large ocean waves, which cause erosion in many direct-facing coastal areas [2]. The coastal area is one of the areas of concern, so it is important to review from various planning and management perspectives, both in terms of quality and quantity [3]. Abrasion, also called coastal erosion, is a natural process in which the land around the coast is eroded by ocean waves and currents. In simple terms, abrasion is when waves and currents destroy or damage coastal areas. Erosion reduces coastal areas, especially those areas closest to the sea. As a result, shoreline erosion may continue and seawater may flood the area around the shoreline [4].

Shoreline change is a continuous process through various natural processes on the coast that include sediment movement, longshore currents, sea surface wave action and land use [5]. Shoreline changes can be in the form of land reduction (abrasion), or land gain (accretion) [6]. Factors that cause damage to coastal areas can be natural or anthropogenic. Natural factors come from the influence of hydro-oseanographic processes that occur in the sea that can cause wave heaving, changes in current patterns, tidal variations, and climate change while anthropogenic factors are caused by human activities, for example sand mining, coastal development [7].

According to Farid *et al.* [8] the speed of shoreline change in Central Bengkulu Regency causes most of the coastline of Central Bengkulu Regency to erode, based on research using the active seismic method (MASW) the coastal area of Central Bengkulu Regency is categorized as rigid soil with Vs values ranging from 227 to 1235 meters per second.

The structure and geological conditions of the earth's subsurface rocks affect abrasion around the coast [9]. The weak subsurface rock structure is thought to be one of the factors causing the high rate of abrasion [10]. Observation of shoreline changes can be observed through satellite imagery using Remote Sensing technology or Geographic Information Systems. One of the technologies that can be used in observing shoreline changes is the Google Earth Platform. The utilization of Google Earth imagery as a data source is very efficient with a large scope of research areas and requires very detailed accuracy [11]. Thus, shoreline changes can be detected and predicted.

## II. METHODOLOGY

This research method uses the multichannel analysis of surface wave MASW method. This research was conducted along the coast starting from the coast of Bengkulu Tengah Regency to Seluma Regency Beach. Then the primary data obtained from the results of field data is the shear wave velocity (Vs). The area used as a measurement point has an adequate area to conduct research and estimate the stretch of the seismic trajectory of the MASW method during data collection. At this stage, a location will be sought for the measurement track that is not far from the shoreline. The data collection point must be in a flat area. Fig. 1 shows the mea-

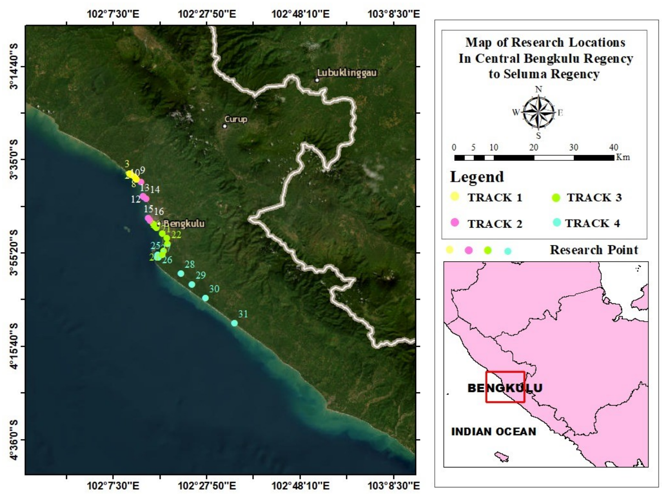


FIG. 1: Map of The Research Area.

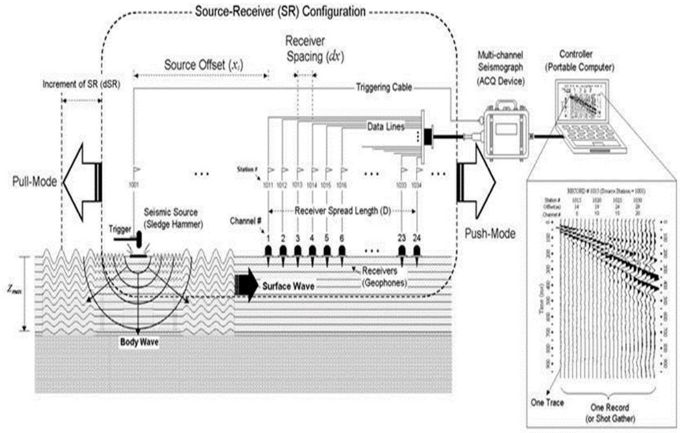


FIG. 2: Schematic of active MASW Field Survey (Park, 1999).

surement points in the field, which are 31 points, which are divided into 4 tracks. Track 1 starts from points 1-8 located at Nangai Beach to Padang Betuah Beach, Central Bengkulu. Then track 2 starts from points 9-16 in the Danau Gedang area to the Ratu Samban sub-district of Bengkulu City. Next, track 3 starts from points 17-25 in Ratu Agung sub-district, Bengkulu City to Pulau Bai. The last track points 26-31 are in Kampung Melayu sub-district to Ilir Talo sub-district, Seluma Regency.

The shear wave velocity (Vs) value is obtained after processing using winMASW 5.0 Professional Software by converting the recorded data obtained by geophones from the time domain to the frequency domain. Then, it turns into a phase velocity at frequency. The first process of processing Rayleigh wave (MASW) recording data is to select data where only Rayleigh waves are used and eliminate noise recorded in data acquisition. Next is the process of making a dispersion curve, which is a data plot of the relationship between frequency and phase velocity, then picking the fundamental mode region. Fig. 2 presents a visual representation of the steps conducted in the geophysical survey using the MASW method at the study site. Geophones (24 pieces) are placed in a straight line. Then, a connecting cable is installed for all geophones to the recording device so that the geophone position is stable on the ground. The wave source (hammer) is used by swinging it vertically to produce seismic waves (R waves). After applying the wave source, the wave data recorded by the geophone will be transmitted to the seismic recording device. Each geophone will record the wave travel time and vibration amplitude.

This study used the PASI 16S-24P Seismograph tool which is a seismic tool set. The number of measurement points was 31 investigation locations. The number of research points was determined based on field conditions, including the suitability of the site surface and existing noise levels. Based on the field conditions in this study, it was decided that 31 measurement points were sufficient. The relationship between 31 measurement points and 24 geophones is actually more about using geophones to collect seismic data that will be used to analyze the subsoil. The total number of geophones used is generally 24 which determines the number of main measurement points that can be generated from the measurement.

The wave data acquisition stage (receiver) uses 24 geophone sources and vertically uses a frequency of 4.5 Hz and uses a source of blows from a 5 kg sledge hammer as a source. The source of vibration used to generate waves comes from a large hammer that is hit on an iron plate as its base. One hammer blow obtained 1 wave data in the form of 24 vibrations recorded by 24 geophones. The distance between each geophone is 2 m and the distance between the first geophone and the source is 4 meters.

The inversion process is then carried out to obtain the 1D shear wave velocity (Vs) and the resulting average shear wave velocity pattern from the surface to a depth of 30 meters (Vs30). If the error is small or characterized by the convergence of the model fittes curve and the mean model and the standard deviation is small ($<$10%), then the 1D Vs representation can be used. However, if the fittes model and mean model curves do not coincide and the standard deviation value is still large ($>$10%), the picking process is repeated until a small error is obtained. After obtaining the 1D Vs profile against depth and interpolating it to 2 dimensions using Surfer, the results of data processing will be displayed in the form of contour maps. The contour map will provide information on the formation of subsurface structures or constituent rock types so that it can be used for abrasion interpretation along the coast of Central Bengkulu to Seluma Regency.

According to previous studies, the coastline in Central Bengkulu Regency, Bengkulu province, has undergone significant changes in recent years. This is caused by both nature and human actions [12]. Google Earth Pro is a great medium to learn more about the earth. The way to use the application is simple, namely by searching for an address or entering coordinates in its operation [13]. Changes in the coastline studied in the period 2006 to 2022 with an interval of 16 years covers along the coast of Central Bengkulu to Seluma. Shoreline

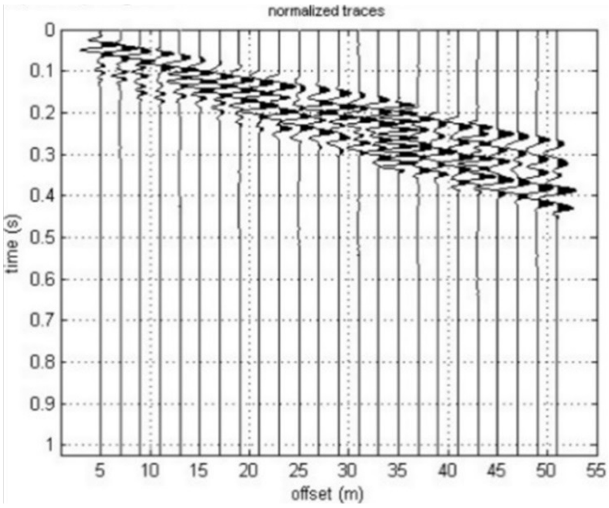


FIG. 3: Example of Seismic Wave Recording.

data processing can use ArcGis software. The coastline per year that has been generated previously is overlaid and displayed so that changes that occur in the research area can be seen.

## III. RESULT AND DISCUSSION

The research location was along the coast of Central Bengkulu Regency to Seluma Regency. The initial stage to start the research was to visit the point to be studied according to the initial plan and confirm the location. Then, data collection was carried out by stretching the geophone and hitting the hammer on the iron plate as the wave source. The distance between each geophone is 2 meters and the distance between the first geophone and the source is 4 meters. This study was divided into 4 tracks. Track 1 is at Nangai Beach to Padang Betuah Beach, Central Bengkulu. Track 2 is in the Danau Gedang area to the Ratu Samban sub-district of Bengkulu City. Furthermore, track 3 is in Ratu Agung District, Bengkulu City to Pulau Bai. The last track, namely Track 4, is in Kampung Melayu District to Ilir Talo District, Seluma Regency. Fig. 3 shows an example of seismic wave recordings at 3 measurement points located on track 1. This graph shows how the waves propagate with various offsets (distances) within a certain time span, measured in seconds (s). Each wave trace displays the characteristics of seismic wave propagation at various measurement points, with amplitude variations indicating subsurface conditions.

Seismic signals from Rayleigh waves that have been recorded signals that have been generated by geophones will automatically be stored in the seismograph in the form of DAT format. Then the data obtained is still mixed with noise, to remove noise by filtering. After the noise is removed, the waves taken are large amplitudes where these large waves are assumed to be surface waves. The results of data recordings that have been selected can be seen in Fig. 4.

Based on Fig. 4 and Fig. 5, the data is converted from

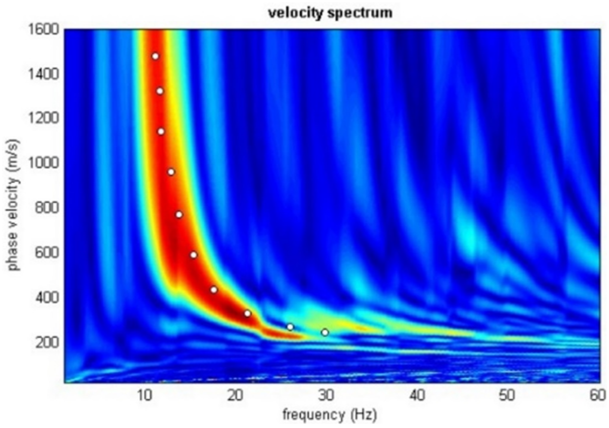


FIG. 4: Examples of dispersion curves that have been obtained from recording.

TABLE I: Rock Type Classification based on Uniform Building Code (UBC).

| Rock type | Rock Type Profile | Vs30 |
|---|---|---|
| A | Hard rock | $>$ 1,500 m/s |
| B | Rock | 760 1,500 m/s |
| C | Very Dense soil and soft rock | 360 760 m/s |
| D | Stiff Soil | 180 360 m/s |
| E | Soft Soil | $<$ 180 m/s |

time domain to frequency domain. Where the velocity spectrum graph and dispersion curve will be displayed. Then the picking process is carried out in the area that has a high value. Fig. 5 is the misfit evolution and Vs profile, which is a visual representation of the inversion result of the surface wave dispersion curve that produces a subsurface profile based on the shear wave velocity (Vs). From 31 points of coastal research locations ranging from Central Bengkulu Regency to Seluma Regency, which are divided into 4 tracks. The distribution of the value (Vs) of the inversion results using WinMASW 5.0 Professional software is then interpreted by drawing a contour map of the Vs value to depth using Surfer software. The greater the Vs value, the higher the rock stiffness level and vice versa, the smaller the Vs value, the lower the rock stiffness level [14].

The interpretation results on Track 1 starting from points 1-8 which are in the area of Nangai Beach to Padang Betuah Beach, Central Bengkulu. From the 2D profile in Fig. 6, it is indicated that the subsurface structure of the blue-colored contour at a depth of 0 - 10 m is a type of medium soil (stiff soil) with a Vs value of 200 m/s, then at a depth of 10-30 m the yellowish green contour with vs values of 300, 400, and 600 m/s is a type of very dense soil and soft rock.

On Track 2 starting from point 9-16 in the Danau Gedang area to Ratu Samban sub-district, Bengkulu City. Fig. 7 shows that at depths of 10-20 with Vs values of 500, 600 and 700 m/s green contours are indicated as having very dense soil and soft rock. The types of very dense soil and soft rock in this track

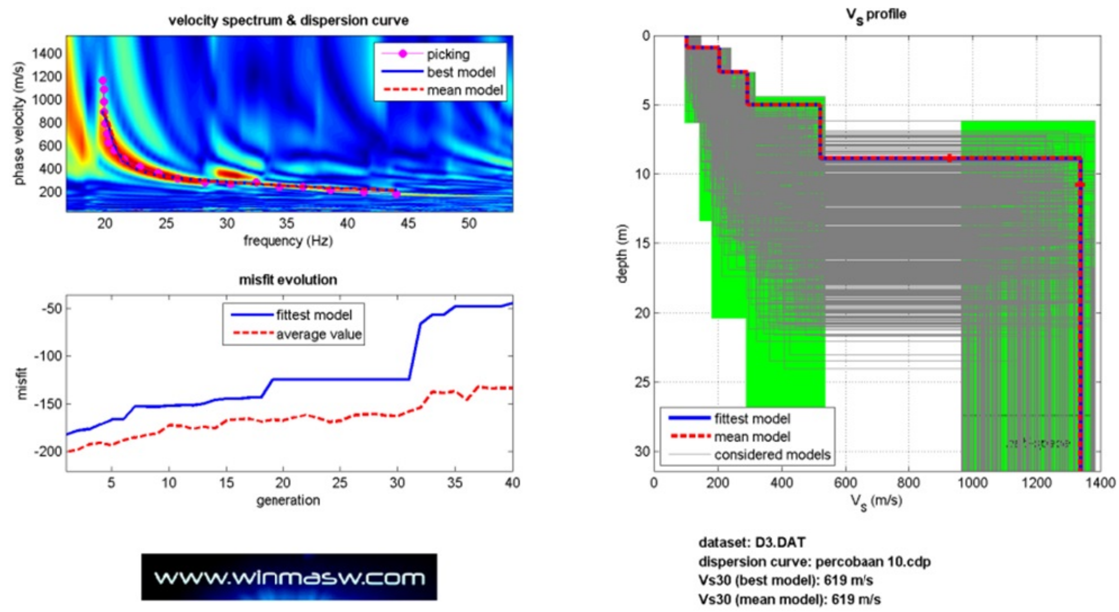


FIG. 5: Vs Profile.

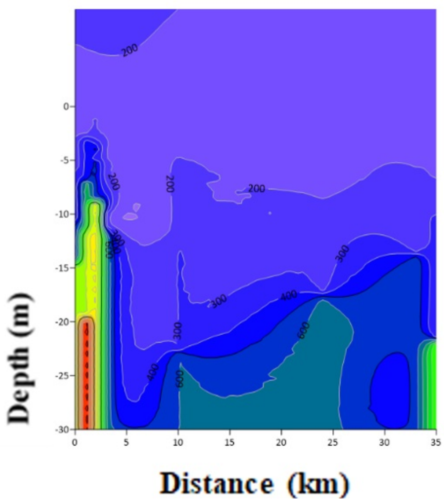


FIG. 6: Subsurface based on MASW survey on track 1.

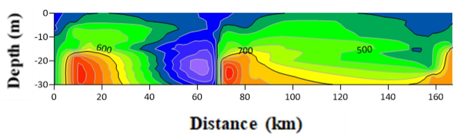


FIG. 7: Subsurface based on MASW survey on track 2.

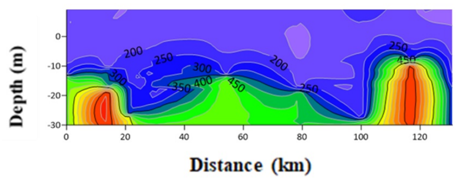


FIG. 8: Subsurface based on MASW survey on track 3.

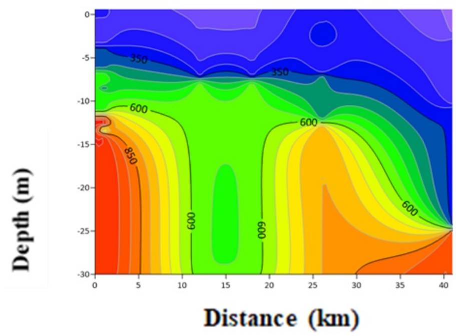


FIG. 9: Subsurface based on MASW survey on track 4.

are at a distance of 20 km, 80 km, and 130 km.

In Track 3 starting from point 17-25 which is located in Ratu Agung District, Bengkulu City to Pulau Bai. Fig. 8 can be seen, at a depth of 0 - 15 m on the blue contour with a Vs value of 200 - 350 m/s can be identified as a type of medium soil (stiff soil), while the Vs value of 400 - 450 m/s on the green contour is a type of very dense soil and soft rock.

The interpretation results on Track 4 starting from points 26-31 located in Kampung Melayu District to Ilir Talo District, Seluma Regency. From the 2D profile in Fig. 9, it is indicated that the subsurface structure with blue-colored contours at a depth of 0 - 5 m which has a Vs value of 350 m/s is a type of medium soil (stiff soil). Then at a depth of 10 m, the green contour with a Vs value of 600 m/s indicates a type of very dense soil and soft rock. Then, at a depth of 15 m with orange contours with a Vs value of 850 m/s, it is indicated as a type of medium rock.

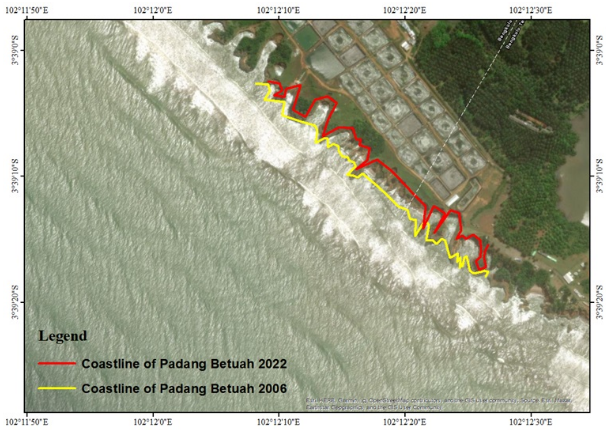


FIG. 10: Shoreline Change of Padang Betuah 2006-2022 track 1.


FIG. 11: Shoreline Change of Tanah Jenggalu 2006-2022 track 4.

According to the classification of soil sites based on the Vs30 value, the Central Bengkulu coastal area to the Seluma coastal area is divided into three categories of soil sites. They are site class D, site class C, and site class B. Site class D is a type of stiff soil, which means that the area has a relatively high level of vulnerability to the impact of earthquakes and abrasion with a range of values (Vs) of 180 - 360 m/s. Site class C includes very dense soil and soft rock with Vs30 values ranging from 360 - 760 m/s. Then site class B is a type of medium rock (rock) which has a Vs value range of 760 - 1,500 m/s.

To determine changes in coastline over time, satellite images displayed from Google Earth can be used to obtain coastline changes. Google earth can display images in the long term so it is suitable for analyzing coastline changes. For example, the use of google earth to observe coastline changes in Indonesia has been widely used [15]. Identification of abrasion coastline changes along the coast from Bengkulu Tengah to Seluma is obtained based on Google Earth images to see changes in the coastline from 2006 to 2022 can be seen in (Fig. 10 - 11). The red colored line shows the coastline in 2022, while the yellow colored line shows the coastline in 2006. Coastal abrasion in the research location occurs especially on the coast of Padang Betuah Beach, Sungai Suci Beach, Muara Dua Beach, and Seluma Beach. Fig. 10 shows the speed of change in the coastline of Padang Betuah which is on track 1 in a span of 16 years, namely 2006 to 2022. In Fig. 10 there are two yellow lines showing the coastline in 2006 and the red line showing the coastline in 2022, it can be seen that there is a change in the coastline along 5.1 m/yr due to abrasion which causes loss of land on the edge of the beach, which in this area based on the contour map is an area with a combination of two types of rock medium soil (stiff soil) and hard soil and soft rock (very dense soil and soft rock).

Fig. 13 shows the speed of change in the coastline of the Sungai Suci on track 2 over a 16-year period from 2006 to 2022. The yellow line shows the coastline in 2006 and the red line shows the year 2022. In this time span, there was a change in the coastline of the Suci River abrasion of 1.6 m/yr. Abrasion in this area is supported by the type of rock in the area which can be seen from the contour map is a type of very dense soil and soft rock.

Fig. 14 shows the speed of change of the Muara Dua coastline in track 3 over a 16-year span from 2006 to 2022. The yellow line shows the coastline in 2006 and the red line shows 2022. In that time span there was a change in the abrasion coastline in Muara Dua along 6.7 m/yr. Abrasion in this area is supported by a combination of dominating soil types, namely stiff soil and very dense soil and soft rock.

Fig. 11 shows the speed of shoreline change of Tanah Jenggalu in track 4 over a 16-year period from 2006 to 2022. The yellow line shows the shoreline change in 2006 and the blue line shows the year 2022. In the time span of 2006-2022 there was an accretion shoreline change on the coast of Tanah Jenggalu along 1.4 m/yr. The identification results of this area have a combination of stiff soil, very dense soil and soft rock, and rock.

Fig. 12 shows the changes in the accretion coastline at the 10th measurement point, which is on track 2. The red line shows the coastline in 2022 while the yellow line shows the coastline in 2006. In the time span 2006-2022 there was a change in the accretion coastline of 1.7 m/yr. Accretion is the movement of sediment that has an impact on the advancement of the coastline towards the sea. Shoreline changes due to sediment movement are influenced by wave activity, ocean currents, tides and wind [16]. It is known that track 2 is indicated to have very dense soil and soft rock. The combination of these soil types affects the pattern of accretion rates that occur. Hard soils tend to be more stable and less prone to erosion, while soft rock can be easily eroded or deposited, depending on environmental conditions.

Fig. 12 shows the changes in the accretion coastline at the 10th measurement point, which is on Track 2. The red line shows the coastline in 2022 while the yellow line shows the coastline in 2006. In the time span 2006-2022 there was a change in the accretion coastline of 1.7 m/yr. Accretion is the movement of sediment that has an impact on the advancement of the coastline towards the sea. Shoreline changes due

TABLE II: Shoreline Change Velocity 2006-2022.

| Point Measurement | Latitude (°) | Longitude (°) | Vs30 (m/s) | Distance (m) | Time Year) | Velocity (m/yr) | Description |
|---|---|---|---|---|---|---|---|
| 1 | -3.63417 | 102.18517 | 331 | 20.54 | 16 | 1.2 | Abrasion |
| 2 | -3.63467 | 102.18622 | 485 | 10.16 | 16 | 0.6 | Abrasion |
| 3 | -3.63514 | 102.18647 | 619 | 6.96 | 16 | 0.4 | Abrasion |
| 4 | -3.63578 | 102.18772 | 403 | 4.51 | 16 | 0.2 | Abrasion |
| 5 | -3.63925 | 102.19214 | 263 | 8.78 | 16 | 0.5 | Abrasion |
| 6 | -3.64611 | 102.20269 | 291 | 23.55 | 16 | 1.4 | Abrasion |
| 7 | -3.65400 | 102.20731 | 308 | 28.76 | 16 | 1.4 | Abrasion |
| 8 | -3.65519 | 102.20892 | 324 | 31.61 | 16 | 1.9 | Abrasion |
| 9 | -3.65561 | 102.21003 | 263 | 22.40 | 16 | 1.4 | Abrasion |
| 10 | -3.66361 | 102.22533 | 566 | 27.92 | 16 | 1.7 | Accression |


FIG. 12: Shoreline Change (Accretion) Point 10 2011-2022.

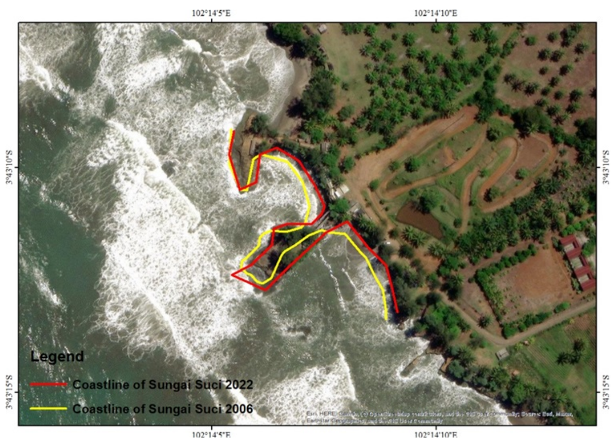


FIG. 13: Shoreline Change of Sungai Suci 2006-2022 track 2.

to sediment movement are influenced by wave activity, ocean currents, tides and wind [16]. It is known that Track 2 is indicated to have very dense soil and soft rock. The combination of these soil types affects the pattern of accretion rates that occur. Hard soils tend to be more stable and less susceptible to erosion, while soft rock can be easily eroded or deposited,


FIG. 14: Shoreline Change of Muara Dua 2006-2022 track 3.

depending on environmental conditions. The speed of shoreline change can be known by calculating the rate of shoreline change that occurs over a span of 16 years with the equation

$$v = \frac{s}{t} \qquad (1)$$

where $v$ : rate of shoreline change speed; $s$ : shoreline change that has occurred in meters; $t$ : time during which shoreline change occurs in units of years.

Table II shows the relationship between Vs (shear wave velocity) values and rock characteristics and abrasion rates, represented by 10 research points. In general, small Vs values indicate that the rocks in the area are relatively soft. These soft rocks are more easily eroded and thus tend to experience rapid abrasion. This rapid abrasion process can cause degradation.

The abrasion velocity varied from 0.2 to 1.9 m/yr, indicating differences in the severity of abrasion at various measurement points. Factors such as Vs30 and local conditions are likely to influence the abrasion rate. From the analysis conducted, there is no clear pattern between Vs30 and abrasion speed. For example, the point with the highest Vs30 (619 m/s) has a low abrasion speed (0.4 m/yr), while the point with lower Vs30 (324 m/s) has a high abrasion speed (1.9 m/yr). This suggests that other factors may be more dominant in determining abrasion velocity. abrasion and accretion phenomena can vary significantly along the coastline. High abrasion speed requires further attention and treatment to reduce negative impacts on the coastal environment. Accretion at some points also needs to be monitored to ensure the balance of the coastal ecosystem.

## IV. CONCLUSION

Based on the measurement and analysis results, it can be concluded that the Vs30 values obtained range from 200 m/s to 700 m/s. The Vs30 value is interpreted in the form of processing results from field data that are inversed using winMASW 5.0 Professional software which is then interpreted in 2D form with Surfer software. The results of the 2D interpretation show that the area from Bengkulu Utara to Seluma is divided into three soil class sites. Class D with Vs values ranging from 180 m/s - 360 m/s which indicates dominated by stiff soil, class C with Vs values ranging from 360 m/s - 760 m/s dominated by very dense soil and soft rock, then class B ranging from 760 m/s - 1.500 m/s dominated by rock. Abrasion shoreline changes that are very large in the period 2006 - 2022 are in the Muara Dua Beach area which in this study is on track 3, with a change value of 6.7 m/yr, and for beaches that experience accretion at measurement point 10 on track 2 with a shoreline change value of 1.7 m/yr. Shoreline changes that occur are influenced by the type of constituent rocks and other natural factors.

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