Gravitasi: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 11, No. 1, Feb 2025, Page 65-79

Identification of subsurface layers and shoreline shifts in abrasion-prone areas of the northern part of Bengkulu Province using multichannel analysis surface wave method and Google Earth Pro

Yuni Karisma Sinaga, Refrizon*, Muchammad Farid, Adinda Permata Putri, Muhammad Taufiqurrahman Syah, Naela Sahada Sasabela

Geophysics Study Program, Faculty of Mathematics and Natural Sciences, Bengkulu University, Indonesia

**Email: refrizon@unib.ac.id*

(Received: 14 Oktober 2024; Accepted: 08 March 2025; Published: 11 March 2025)

ABSTRACT

Shoreline change is a phenomenon that occurs due to land erosion or abrasion. This study aims to measure and analyze shoreline changes and determine rock stratigraphy based on the value of secondary wave propagation velocity (Vs) in the Northern Bengkulu Province. The research was conducted at 52 points along the coast with three main stages, namely seismic data acquisition in the field, dispersion analysis, and dispersion curve inversion. Observation of shoreline changes was conducted using quantitative methods with a geophysical approach, utilizing satellite data from Google Earth Pro. Meanwhile, stratigraphic acquisition was performed using the Multichannel Analysis of Surface Waves (MASW) method. The results showed that the soil layers in the Northern Bengkulu Province area include alluvium and poor consistency, soft layers. The second to fourth layer contains a medium-dense soil layer of coarse and fine-grain soil. The fifth layer comprises a soft rock layer consisting of coarse-grain and fine-grain soils. The Vs30 values obtained range from 115 m/s to 576 m/s, indicating that the Northern part Bengkulu Province area is dominated by Site Class SC (hard, highly compacted soil and soft rock) vulnerable to deformation, including abrasion. The research results obtained in the form of Vs30 values of 115 m/s to 576m/s are dominated by three rock formations: bintunan formation, lake deposits and andesite. Stratigraphic data and Vs30 values can be used for coastal infrastructure development, such as sea walls, breakwaters, and other protection structures to reduce abrasion.

Keywords: Abrasion, accretion, coastline changes, Google Earth Pro, MASW

DOI: 10.30870/gravity.v11i1.29134

INTRODUCTION

Bengkulu is geographically located on the west coast of Sumatra Island, directly facing the Indian Ocean. The province can be divided into three physiographic regions: lowlands along the west coast, hills in the central region, and mountains in the eastern region bordering Jambi and South Sumatra. Therefore, some coastal areas are exposed to strong ocean waves, which can cause coastal abrasion or sedimentation along the coastline (Kusmanto and Hasanudin, 2019). Coastal areas are also vulnerable and threatened by changes in hydro-oceanographic activities in ocean waters and human activities on land (Yulianti et al., 2022). Shoreline changes are caused by sediment movement, currents and waves approaching the shore (Raihansyah et al., 2016). Shoreline change is one of the events that occur continuously in coastal areas, which can be in the form of erosion of the coastal body (abrasion) or the addition of the coastal body (sedimentation or accretion) (Maulana et al., 2021). The coastline is the meeting point between land and ocean, not a static boundary. Its position constantly changes due to the tides and abrasion along the coastline (Nugraha et al., 2022). The structure and geological conditions of the earth's subsurface rocks affect abrasion around the coast (Apriansyah et al., 2019). The weak underground rock structure is considered one factor causing the high abrasion rate (Refrizon et al., 2019). Ocean waves cause energy flow along the coast and perpendicular to the coast that carries sand to the sea as beach material, resulting in erosion of material in the coastal area, which causes abrasion around the beach (Castelle and Masselink, 2023). This is reinforced by photogrammetric data showing that the coastline in Bengkulu has undergone significant changes, reaching 2.5 meters per year (Samdara, 2014).

According to previous research conducted based on research Putra and Santosa (2023), it is known that some areas of Bengkulu, namely North Bengkulu Regency, experience abrasion of 1.1 to 5.8 meters per year. Meanwhile, according to Farid et al. (2014), the speed of coastline change in Central Bengkulu Regency causes most of the coastline of Central Bengkulu Regency to experience erosion. Based on research using the active seismic method (MASW), the coastal area of Central Bengkulu Regency is included in the rigid soil category with Vs values ranging from 227 to 1235 meters per second. The structure and geological conditions of the earth's subsurface rocks affect the occurrence of abrasion around the coast. In general, abrasion-prone areas have weak rock structures and low cohesivity. Apart from that, according to a study conducted based on research by Supiyati et al. (2024), abrasion on the north coast of Bengkulu (from Bengkulu City to the north) is relatively faster than the coastal areas of Bengkulu City. The abrasion speed is exacerbated by the destruction of forests along the coast that have been turned into oil palm plantations by residents and unmonitored sand excavation that accelerates the abrasion rate.

Meanwhile, in a study conducted based on research by Lubis et al. (2022), based on the calculation of wave energy that has been carried out, it is found that the energy of sea waves in coastal areas ranges from 600-1800 J/m^2. Based on the results obtained, it can also be concluded that wave height and large sea wave energy are factors causing abrasion in the Serangai area of Batik Nau District, North Bengkulu. This is also confirmed by a study at Palik Beach in North Bengkulu conducted based on research by Putra (2023) that large coastal waves trigger sediment transport that can cause abrasion, accretion and shoreline changes that can disrupt fishing activities by fishermen and fish auction activities in the area.

In various places in coastal North Bengkulu, ports, transportation, industrial areas, tourism, fisheries, aquaculture, and settlements have been used by the community and government as livelihoods (Apriyanti, 2021). Shoreline changes that occur over a relatively long period can endanger coastal ecosystems and threaten the business continuity of local communities (Darmiati et al., 2020). Along the northern coast of Bengkulu, abrasion is severe and has caused damage to residential areas. Abrasion and accretion are the two main processes that cause shoreline changes. Transformed ocean waves approaching the coast generate coastal currents that transport sediment and cause abrasion in one area and accretion in another. Shoreline changes are influenced by currents and sediment transport patterns based on the seabed's shape, tidal currents, wind, and human activities (Huda et al., 2022). The level of vulnerability of abrasion areas needs to be known to minimize the damage caused by abrasion disasters. Weak geological conditions are some of the characteristics of geological conditions that are prone to deformation, landslides, and abrasion. There are eight types of beaches in North Bengkulu Regency. Four of the eight beach types are currently eroding and are composed of (1) coarse sandy beach tuff, (2) coarse sandy beach clay, (3) coarse sandy beach alluvial clay, and (4) coarse sandy beach cliffs (Farid et al., 2013).

This research was conducted to identify changes in the coastline of the North Bengkulu Coast region, which is very vulnerable to abrasion. Abrasion is closely related to the process of shoreline change, where the impact of shoreline change on abrasion can reduce land area and even damage ecosystems. Abrasion occurs due to the force of ocean waves, which also affects the subsurface geological structure of the coastal area. Several previous studies have been carried out, but only on abrasion, so they do not focus on changes in the coastline due to abrasion. This research was conducted to see the subsurface geological structure of abrasion-prone areas and changes in the coastline due to abrasion. One of the Geophysical methods used in this research is the seismic method. Geophysical methods are used in this study because of the advantages of Geophysical methods compared to other conventional methods, which can describe subsurface conditions on a broad scale and are also environmentally friendly (Narotama Sarjan and Muchtaranda, 2023). This research uses the seismic method, which utilizes seismic waves that travel into the earth's crust. In principle, seismic waves are generated by an impulsive source or other mechanism that penetrates the soil layer in the area to be analyzed for its physical properties and produces refractive and reflective waves, which are then received by the geophone (Daud et al., 2021). The seismic method used in this study is MASW, a seismic survey that identifies near-surface geotechnical characteristics by utilizing Rayleigh surface waves as the main signal source (Rasimeng and Laksono, 2017). The MASW method is used because the MASW method is starting to become an alternative in analyzing soil layers. After all, the cost is relatively low, data acquisition and processing is easy, the size and weight of the equipment is not too large so it can be carried by human power, more environmentally friendly. In addition, this method is better used for geotechnical and abrasion problems (Hasya et al., 2021). When compared with previous research conducted based on research by Panjaitan et al. (2023), the MASW method is much better used to identify the abrasion area. This is because the MASW method uses surface wave data to obtain information about the distribution of vertical shear wave velocity (Vs) at a certain depth. These shear wave velocities are very useful for mapping soil layers and changes in geotechnical properties, which can indicate the impact of abrasion on subsurface soil structures, whereas using microtremor tends to be more sensitive to surface vibrations caused by external sources (e.g., human activity or wind). Results from microtremors are often more limited in terms of resolution depth and may not give a complete picture of the deepest soil layers affected by abrasion. This method uses the phenomenon of scattered surface waves to evaluate the character of a medium and the interpretation of measurement results from geophysical methods makes it possible to identify the nature and stratigraphic structure of rocks. Shear wave velocity profiles (Vs30) are calculated for each depth and rock layer. The MASW method can calculate the variation of surface wave velocity with depth. The MASW method is used for the measurement of subsurface soil medium heterogeneity that can vary laterally. The wavelength correlates with depth, with the wavelength decreasing with depth. Shear wave velocity depends on the type of rock material through which it passes, and the softness and hardness of the rock layer also affect the shear wave velocity. In this study, Vs30 values were obtained using the MASW method, which proved effective in describing the subsurface structure in detail with small misfit and standard deviation values. Through the Vs30 value, it is possible to know the characteristics of each depth as well as the type of material that makes up the rock. Shear wave velocity (Vs) values are an important reference for interpreting the distribution of Vs30, which is the shear wave velocity to a depth of 30 meters. The geologic map of Bengkulu's North coast provides a guiding picture to understand the soil characteristics and potential abrasion risk in the area. By integrating geological and Vs30 data, mapping the Vs30 distribution will provide a more accurate picture of soil strength and its response to potential abrasion. Observations of shoreline change can be made through satellite imagery using remote sensing technology or geographic information systems. Remote sensing data that is getting better and has a higher resolution from year to year can provide an optimal picture to study an area with a certain duration of time or multitemporal (Arwono, 2023). 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 Google Earth. Google Earth Pro is used to analyze shoreline shifts and identify patterns of shoreline change. By collecting satellite image data from Google Earth Pro, analyzing satellite image data to identify shoreline shifts and shoreline change patterns and measuring the distance and extent of shoreline shifts. This method is used because Google Earth Pro has a single band. Still, Google Earth satellite imagery has other advantages, such as easy access, free of charge and good enough resolution for detailed mapping (Zainul et al., 2021). Using Google Earth imagery as one of the most efficient data sources with a wide coverage of the research area requires very detailed accuracy (Desmayanti and Rahman Yudi Aulia, 2022). Analysis through image data from Google Earth Pro was used to show areas of abrasion and accretion. Google Earth Pro software can determine The research location based on the affected area (Masri et al., 2020). The data used in this research is very high spatial resolution satellite data provided by Google Earth. Analysis of shoreline changes was carried out with a visual interpretation approach through digitization on the screen using the Google Earth application (Suwandana, 2019). Determination of shoreline changes using Google Earth Pro, namely by monitoring shoreline changes can be done with a large area coverage by utilizing spatial analysis on satellite imagery, shoreline changes can be studied, providing information on coastal morphological conditions affected by abrasion and accretion (Darmiati et al., 2020). Integration of digitized shoreline data from various years allows identification of areas undergoing abrasion or accretion (Riyanti et al., 2018). Thus, shorline changes can be detected and estimated.

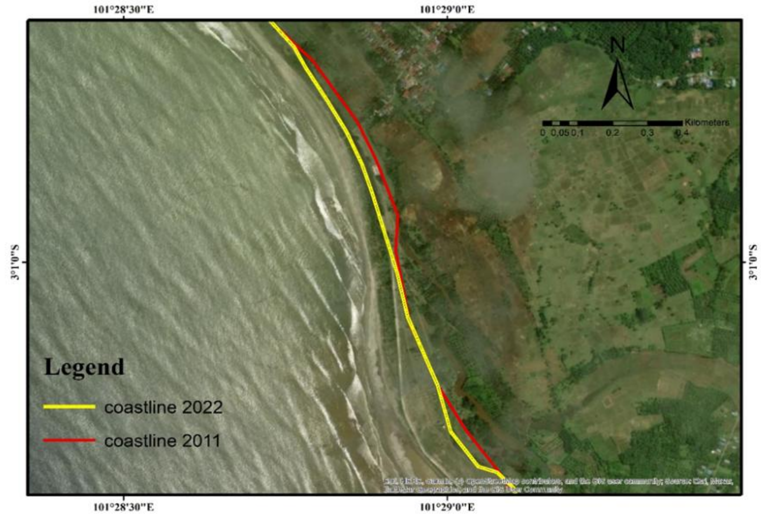


Figure 1. (a) accretion at Pasar Ipuh Beach (3°00'32 "S, 101°28'58 "E)

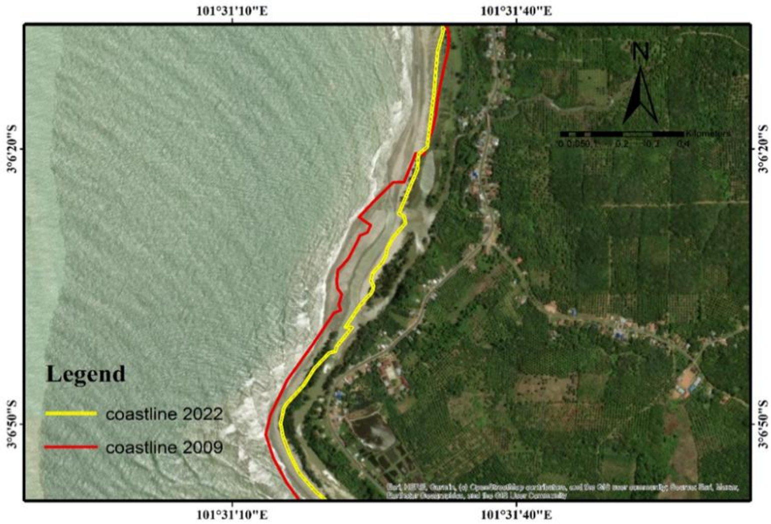


Figure 1. (b) abrasion at Air Rami Tourism Beach (3°06'14 "S, 101°31'38 "E)

RESEARCH METHOD

This research was conducted at 52 points along the coast of North part of Bengkulu Province (Figure 2). In this study, the method used was the MASW active seismic method. In principle, this method consists of three main steps: seismic data acquisition in the field, dispersion analysis, and finally, dispersion curve inversion. The tools used in seismic data acquisition in the field are a seismograph and 24 Geophones with a frequency of 10 Hz. Portable hammers and iron plates were also used as seismic vibration sources. 24 geophones recorded seismic surface waves with a distance of 4m between geophones. Then, the offset of the first geophone to the vibration source was also 4m long. Seismic wave vibration data was acquired 24 times for each source repetition to obtain the subsurface structure. Seismic measurement data is obtained in the field through parameter data such as frequency, receiver number, receiver distance, source offset and measurement direction. At the beginning of data processing, the geometry value is changed to determine the frequency limit with the phase velocity limit. Some of the main parameters in this method include seismic wave sources, the distance and number of each geophone, topographic and geological conditions in the field, and the most important output in the form of shear waves Vs. The things that can affect the results in the field are geological conditions in the field and environmental conditions, such as vibrations from traffic, machinery, or human activities that can contaminate surface wave data, strong winds, waves (in coastal areas), or other natural seismic activities and buildings around the measurement location can cause additional wave reflections.

The initial stage in processing Rayleigh wave recording data is data selection. Only Rayleigh waves were selected to eliminate the noise recorded in the data acquisition. Next is creating a dispersion curve, which plots data on the relationship between frequency and phase velocity and then selects the fundamental mode region. Then, the inversion process is carried out to obtain the shear wave velocity (Vs) in 1D, and the resulting shear wave velocity pattern is homogeneously flat on the surface to a depth of 30 meters. If the error is small or characterized by the intersection of the fitted model curve with the mean model and the standard deviation is small (<10%), then the 1D image can be used. However, suppose the fitted and average model curves do not coincide, and the standard deviation is still large (>10%). In that case, the data collection process is repeated until the error is small. Signal filtering techniques are essential to improve data quality and remove noise that can interfere with dispersion curve analysis. The signal filtering technique used in this study is a Bandpass Filter to maintain the relevant Rayleigh wave frequencies and remove high and low-frequency noise. This process involves converting the recorded data from the time domain to the frequency domain and then converting it to phase velocity at a specific frequency. The dispersion curve containing phase velocity and frequency information is input in the inversion process to obtain the subsurface structure profile through the Vs value. From the structure of the subsurface layer, the type of constituent rock and the thickness of soft sediments, as well as the classification of rock types, are then determined by calculating the Vs value to a depth of 30 m (Vs30) from the Vs30 value, the rock classification can be determined. The harder the soil material, the greater the shear wave velocity.

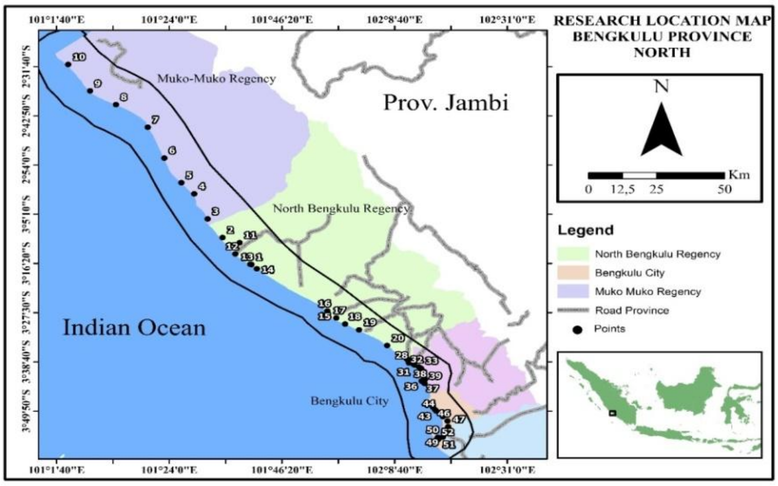


Figure 2. North part Bengkulu Province Study Area and 52 MASW data collection points

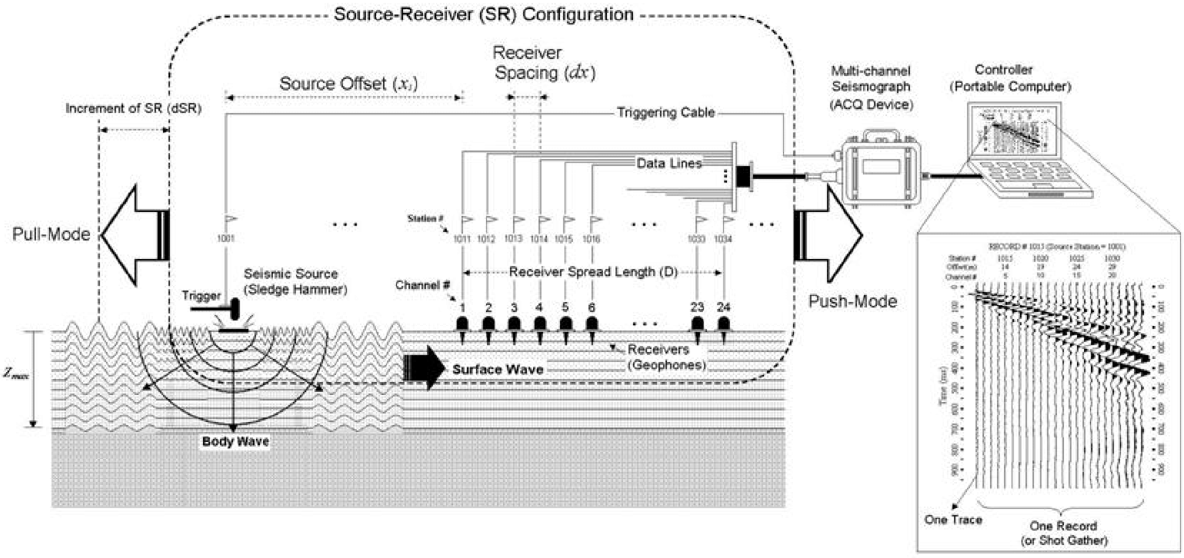


Figure 3. Active MASW field survey scheme (Taipodia and Dey, 2015)

Figure 3 visually represents the stages involved in a geophysical survey using the MASW method at the study site. 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 52 measurement points were sufficient. The relationship between 52 measurement points and 24 geophones is more about using geophones to collect seismic data that will be used to analyze the subsoil. The number of geophones used generally determines the key measurement points generated from the measurements. Satellite images displayed from Google Earth Pro were used to determine the shoreline changes from the observation time span. Google Earth Pro can display images for a long time, so it can be one of the factors in analyzing shoreline changes. Google Earth Pro is an online mapping and imaging program that provides high-resolution satellite imagery. This image was used to extract the instantaneous shoreline from 2009 to 2022 and then to estimate shoreline change. In estimating shoreline changes, validation is carried out between geological data during field surveys and shoreline change data obtained from satellite image data. This data validation is carried out to produce data by field conditions and data received from the data acquisition results.

The boundary between land and water is viewed as a coastline in image interpretation. The lines were digitized based on visual interpretation of the image layers after georeferencing all image layers. Data from each shoreline layer was digitized by date and year and entered into the corresponding attribute table. Analysis was conducted by marking reference points to determine the dynamics of shoreline change. MASW data obtained from the field is used as stratigraphic data to see the subsurface geological structure of the northern Bengkulu coastal area, which is an abrasion-prone area. From the subsurface geological structure data obtained, analysis is carried out on shoreline change data obtained from satellite image data. This is because the level of shoreline change is strongly influenced by the region's subsurface geological structure, especially regarding rock density in the North Bengkulu Coast region.

RESULTS AND DISCUSSION

In this study, the results are obtained as a Vs30 distribution map based on geological formations in Northern Bengkulu Province as support for knowing the characteristics of rock formations found in the research area, as shown in Figure 4. The distribution of Vs30 values from the research area is in the value range of 140-575 m/s, then categorized into three categories: low category for Vs30 values 140-305, interpreted in green. Then, the medium category with Vs30 values of 305-394 m/s is interpreted in yellow. Finally, the high category with a Vs30 value range of 394-575 is interpreted in red. In general, the soil footprint classification or soil footprint class based on the Vs30 value in the Northern Province area is divided into three types of footprint classification, namely soft soil types in the bintunan formation with constituent rocks in the form of tuffaceous mudstone, tuffaceous sandstone, tuff, reef limestone, and pumice. Then, medium soil types in lake deposits, including mudstone, siltstone, sandstone, swamp soil, and peat soil. And hard soil types with andesite rock types. Based on the different types of rocks in the area this is what makes the Vs30 value different in each region of the North part of Bengkulu Coast.

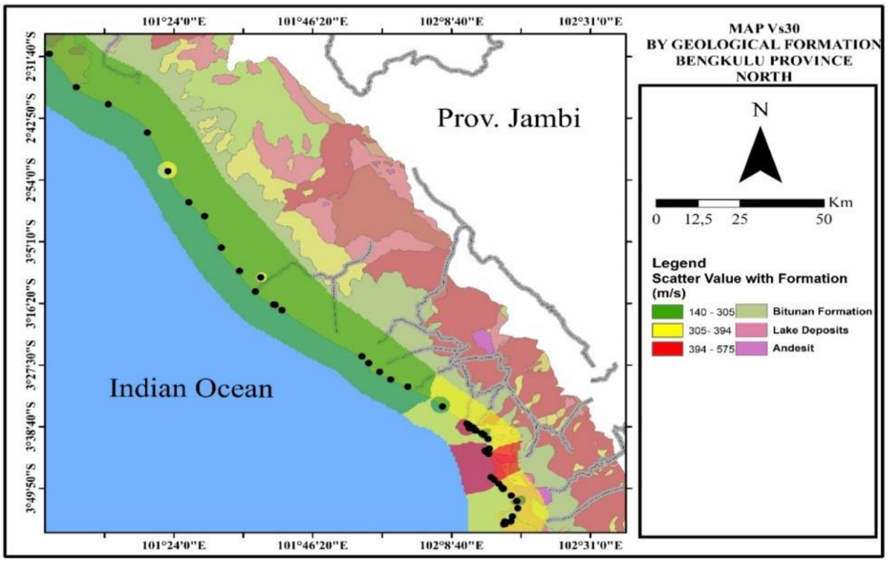


Figure 4. Vs30 distribution map and geological formations of the North part of Bengkulu Province.

Table 1. Classification of Soil Site Classes based on SNI 1726 - 2019 (BSN, 2019)

Site Class	General description	*Vs*30 (m/s)
SA	Hard rock	$Vs30 > 1500$
SB	Medium rock	$750 \leq Vs30 \leq 1500$
SC	Hard, highly compacted soil and soft rock	$350 \leq Vs30 \leq 750$
SD	Medium soil	$175 \leq Vs30 \leq 350$
SE	Soft soil	$Vs30 < 175$

Based on SNI 1726 - 2019 on the classification of soil site classes in Table 1, there are five site classes: A to E with hard rock to soft soil structures. This soil site class is based on the Vs30 value parameter. The Vs30 values obtained range from 115 m/s to 576 m/s, indicating that the Northern part Bengkulu Province area is dominantly Site Class SC (Hard, highly compacted soil and soft rock), susceptible to deformation, including abrasion.

The 1D profile displays several colours representing different layers, and the 1D profile image consists of 5 layers. Each soil layer has a different Vs value up to a depth of 30 meters.

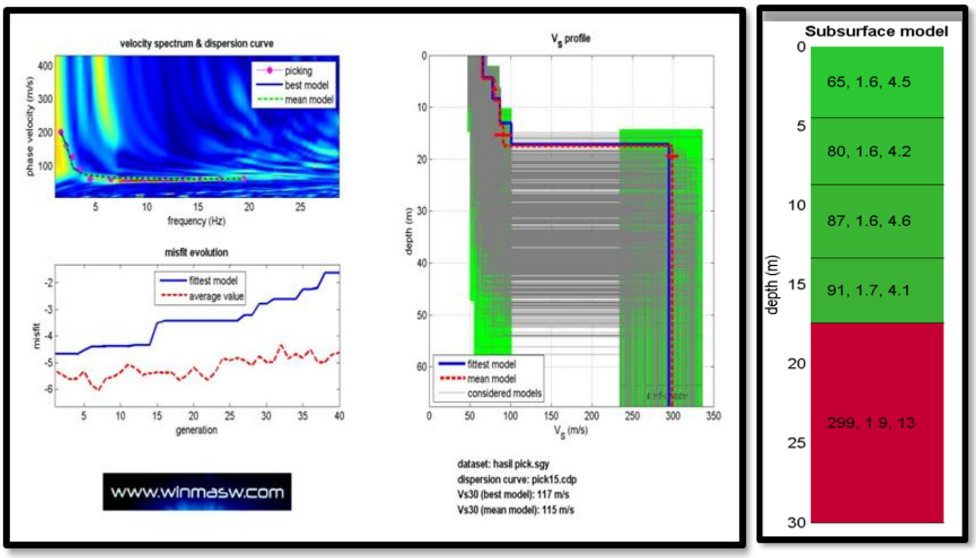


Figure 5(a) smallest Vs30 value.

The smallest Vs30 value of 115 m/s is found in soil types with a cohesion value of <180. This type of soil includes sedimentary soil with low to medium cohesion values. These deposits can be coarse-grained soil with poor concentricity or fine-grained soil with poor concentricity. However, in this area, the Vs30 value of 115 m/s indicates a fairly low shear wave velocity, which suggests that the type of material found in the top soil layer (up to a depth of 30 meters) is clay or soft, fine-grained soil.

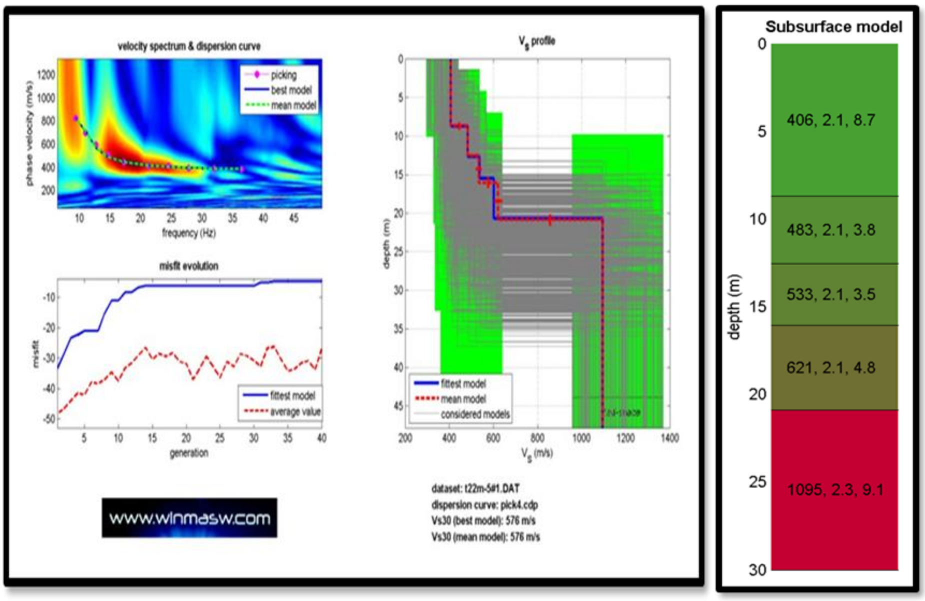


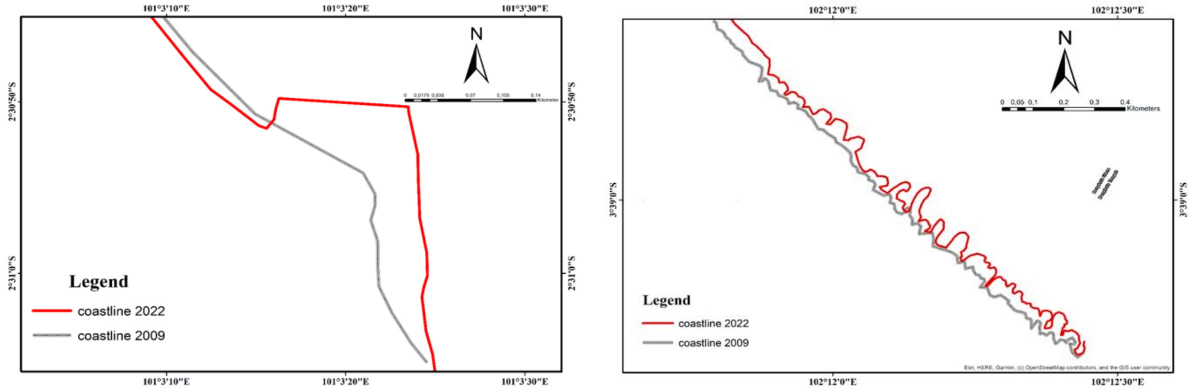
Figure 5(b) largest Vs30 value.

The largest Vs30 value is 576 m/s at 360-800, a soil type with very dense sand or clay deposits and gravel several tens of meters thick, indicating increased mechanical properties as depth increases. The Vs30 value of 576 m/s indicates a higher shear wave velocity, indicating that the material in the topsoil (up to 30 meters deep) belongs to the category of hard soil or soft rock. This material could be gravel, very dense sand or consolidated sediment. The density of the material greatly affects the shear wave speed. The thicker and more consolidated the soil or rock, the faster seismic waves can propagate, resulting in higher Vs30 values. Putri et al. (2024) show that the North Bengkulu to Seluma region is divided into three soil classes, namely class D (180-360 m/s, medium soil), class C (360-760 m/s, hard soil and soft rock), and class B (760-1,500 m/s, medium rock).

In general, small Vs30 values indicate that the rocks in the area are soft. Such soft stones are more easily eroded and tend to experience rapid abrasion. This rapid abrasion process can cause significant degradation of the coastal environment and affect the soil structure and surrounding vegetation. Conversely, large Vs30 values indicate that the rocks in the area are harder and stronger. Harder rocks have better abrasion resistance, so abrasion occurs slower. However, not all areas with small Vs30 values will always experience large abrasion. There are some areas that, despite having a low Vs30 value, still show a slow abrasion process. This phenomenon occurs because other factors, such as accretion dynamics, influence the process. According to a study made by Made et al (2024), accretion adds sediment to the beach, which can offset or even stop the abrasion process. Accretion is more dominant in some areas, so although the rock is soft, abrasion is not as rapid. Other factors, such as ocean currents, wind, and human activities, can also affect an area's abrasion rate and accretion. Based on the results obtained, there are different Vs30 values in each area of the North Bengkulu Coast. This is because the coastal area is formed from dynamic sedimentation processes such as erosion, sand deposition, and mud accumulation, which continue to change due to the influence of sea waves and river currents. Variations in the thickness and composition of these sedimentary layers cause differences in Vs30 values, especially in the rock types in this region. Another factor is that being close to the coastline, soils are often water-saturated, especially in tidal areas and coastal marshes. High water content can reduce the stiffness of the soil and lower the Vs30 value, making it lower and more susceptible to abrasion. Meanwhile, areas that are higher up and less affected by tides may be drier and denser, resulting in higher Vs30 values.

According to previous research, the North Bengkulu coast is dominated by very dense soil and soft rock. The material consists of sand, gravel, clay and alluvium deposits with low density and varies with depth. There is no indication of hard rock to a depth of 30 meters, only soft structured rock that is highly fractured and brittle. So, the results of this latest study are very accurate with previous research conducted by Refrizon et al., (2019). Based on the results of this study show that the subsurface rock structure in the abrasion-prone area of Northern Bengkulu is a weakly structured rock that is prone to deformation, such as cracks, settlement, and collapse, such as the abrasion phenomenon that has occurred so far.

To see changes in the coastline of North Bengkulu Province in 2009-2022, this study used Google Earth Pro to identify what happened after overlaying using ArcGIS. The results of data processing on the coast of North Bengkulu Mukomuko Regency are shown in Figure 6(a).

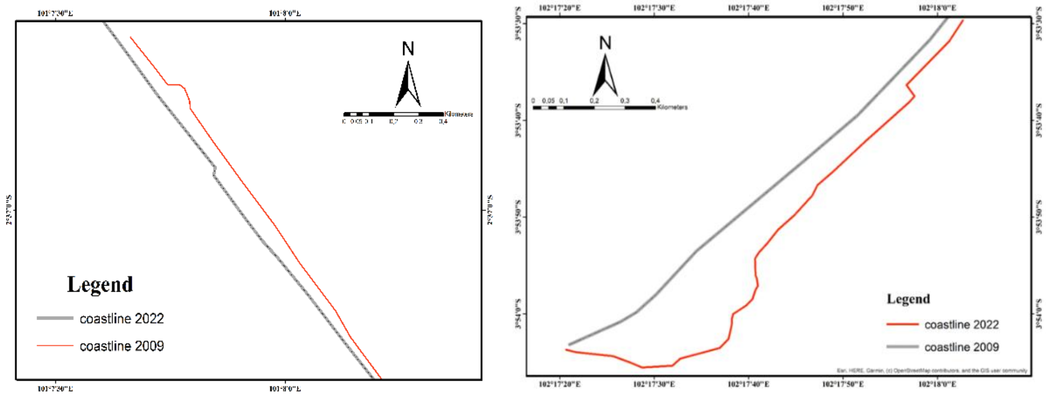


(A) (B)

Figure 6. (a) Distance: Coastline (2°31'9.37"S, 101° 3'59.47"T) in Mukomuko District, (b) Padang Betuah coastline (3°39'14.40"S, 102°12'26.32"T) in District of Central Bengkulu

Figure (a) shows the change in the abrasion coastline at the 10th measurement point, which is at Jarak Beach, Mukomuko District. The red line shows the coastline in 2022, while the grey line shows the coastline in 2009. In 2009-2022, the coastline changed 10.6 meters/year with a Vs30 value of 306 m/s. The soil site classification is site class D with moderate soil structure. The changes clearly show how much the coastline has shifted over time.

Meanwhile, the results of data acquisition in Figure 6 (b) Shoreline changes due to abrasion at the 29th measurement point at Padang Betuah Beach, Central Bengkulu Regency, are shown in the following figure. The red line shows the coastline in 2022, while the grey line shows the condition of the shoreline in 2009. During 2009-2022, coastline abrasion occurred at a rate of 6.06 meters/year, with a Vs30 value of 422 m/s. The soil site at this location is classified as class D with a medium soil structure. These changes provide a clear visual indication of the shoreline's shift over time. The shoreline changes in the North Bengkulu region caused by abrasion are very accurate with previous research that has been conducted (Lubis et al., 2022), which states that the phenomenon of abrasion causes changes in the coastline in the North Bengkulu region. Still, the incidence of abrasion in this region is relatively different every time. In this region, abrasion does not occur significantly every year. Accretion factors influence this and also rocks in the area.



(C) **(D)**

Figure 6. (c) Coastline (2°37'10.63"S, 101° 8'19.14"T) accretion in Mukomuko area
Figure 6. (d) Coastline (3°54'52.92"S, 102°18'28.44"T) in Bengkulu.

Figure (c) illustrates shoreline changes due to accretion at the 9th measurement point at Air Patah Beach, Mukomuko area. The red line shows the position of the coastline in 2022, while the grey line represents the coastline in 2009. During 2009-2022, the coastline experienced accretion at a rate of 2.1 meters per year, with a Vs30 value of 262 m/s. The soil site at this location is categorized as class D, with a medium soil structure. Accretion is the movement of sediment that causes the shoreline to advance towards the sea. Waves, ocean currents, tides and wind influence shoreline changes due to sediment movement.

Figure (d) shows the change in the abrasion coastline at the 48th measurement point, which is located at Dock Beach in Bengkulu. The red line shows the coastline in 2022, while the grey line shows the coastline in 2009. In 2009-2022, there was a change in the shoreline of 20.7 meters/year with a Vs30 value of 297 m / s. The classification of the soil site includes site class D with moderate soil structure. It is clear that based on the acquisition of each year there is a very significant change in coastline caused by abrasion factors influenced by the type of rock in the area so that erosion occurs every year.

Oceanographic and geological factors influence abrasion or erosion events and coastal sedimentation processes. From the oceanographic side, currents move parallel to the coastline and the height of ocean waves. Meanwhile, geological factors include the morphological shape of the beach, beach slope, and subsurface structures. Variations in the speed of shoreline change at each location are caused by differences in local conditions, including the shape and geological structure of the coastal subsurface and differences in ocean currents and waves in each region. Beaches become more vulnerable to erosion when continuous ocean waves hit the cliffs accompanied by fragile cliff rock conditions. This is also supported by research conducted by Zuriyani et al. (2023), which states that simply shoreline change is caused by wind and water moving from one place, eroding sand and sediment, then moving and depositing it to another place continuously. Such conditions are strongly influenced by processes in the nearshore area (nearshore process) because the beach always adapts to various situations at that location. This process is very complex and is influenced by three main factors, namely the combination of waves and currents, sediment transport and coastal configuration that affect each other. Based on the research data obtained, this research can be used as an abrasion disaster mitigation plan in the North Bengkulu Coast area, especially in the regions that have a poor geological structure for coastal areas as indicated by the low Vs30 value, which is very vulnerable to sea waves that can create abrasion, so it is necessary to build embankments in the area or can also make a breakwater to minimize the abrasion area in the North Bengkulu Coast area.

CONCLUSION

This research differs from previous studies because it combines the surface wave analysis method (MASW) and Google Earth Pro to identify subsurface layers and shoreline shifts in North Bengkulu. The MASW method provides a more in-depth analysis of soil structure. At the same time, Google Earth Pro maps shoreline changes more accurately, thus providing more comprehensive results in identifying factors that cause abrasion. Based on the measurements and analysis results, it can be concluded that Vs30 values modelled in the form of 1D profiles illustrate the rock composition and type of material used at each layer depth. The results state that the underground stratigraphic value in the North Bengkulu Province area is divided into three rock layers: the initial part with a value of Vs < 115 m/s shows the dominance of soft soil, and the second layer with a value of 177 shows the supremacy of medium soil and the third layer shows the dominance of hard soil with a value of 360 < Vs < 576 m/s. The rock consists of sand, gravel and clay. The stones consist of sand, gravel, clay and alluvial deposits with low density and varying depths. Wear and changes in the coastline are influenced by the type of subsurface rocks that accelerate the abrasion process, so based on the data obtained, the abrasion process takes place quite significantly every year.

REFERENCE

Apriansyah, Apriansyah, Arie Antasari Kushadijayanto, and Risko Risko. (2019). The Influence of Waves on Shoreline Change in Batu Burung Waters of Singkawang, West Kalimantan. *Positron* 9(1), 1. doi: 10.26418/positron.v9i1.32632.

Apriyanti, Dessy. (2021). Impacts and Countermeasures of Abrasion Using Satellite Imagery Case Study in the Coastal Area of Tanjung Benoa Bali. *Geomatics Scientific Journal*. 1(1), 39–47. doi: 10.31315/imagi.v1i1.4732.

Arwono, Hadi. (2023). The Progress of Remote Sensing Technology for Land Mapping. *Gadjah Mada University Press* (September), 1–12.

Castelle, Bruno, and Masselink Gerd. (2023). Morphodynamics of Wave-Dominated Beaches. *Cambridge Prisms: Coastal Futures*. 1(West 2005). doi: 10.1017/cft.2022.2.

Darmiati, I. Wayan Nurjaya, and Agus S. Atmadipoera. (2020). Analysis of Shoreline Changes in the West Coast Region of Tanah Laut Regency, South Kalimantan. *Journal of Tropical Marine Science and Technology*. 12(1), 211–22. doi: 10.29244/jitkt.v12i1.22815.

Daud, Anye Gidalti, Piter, and Adrianus. (2021). Interpretation of Shear Wave Velocity (Vs) in the Subsurface Layer of Area 'X' by MASW (Multichannel Analysis of Surface Wave) Seismic Method. *Geosains Kutai Basin*, *Geofisika Fmipa Unmul*. 4(1), 1–6.

Desmayanti, and Aulia Rahman Yudi. (2022). Utilization of Google Earth Satellite Imagery for Shoreline Mapping in Padang City. *Journal of Geomatics and Natural Sciences*. 1(1), 22–26.

Farid, M., S. Brotopuspito Kirbani, Wahyudi. K., Sunarto., and Suryanto W. (2013). The Relationships Among Ground Shear Strain, Shore Characteristics And Abrasion On The West Coast Of Bengkulu Province, Indonesia. *Caspian Journal of Applied Sciences Research*. 2(2), 143–53.

Farid, Muhammad, Sri Brotopuspito Kirbani, Wahyudi, Sunarto, and Suryanto Wiwit. (2014). Ground Shear Strain and Rate of Erosion in the Coastal Area of North Bengkulu, Indonesia. *Advanced Materials Research*. 896, 521–24. doi: 10.4028/www.scientific.net/AMR.896.521.

Hasya, Cut Atika, Khaizal Khaizal, and Irwandi Irwandi. (2021). Comparison of Multichannel Analysis of Surface Wave Method and Cone Penetration Test Method for Soil Layer Analysis. *Journal of The Civil Engineering Student*. 3(1), 14. doi: 10.24815/journalces.v3i1.12265.

Huda, Abiyani Choirul, Pratikto Widi Agoes, Destyariani Liana Putri, Anggie Vibriyanti

Rossari Dewi, and Izdihar Amany Adha. (2022). Modeling of Beach Change and Total Suspended Solid Distribution Based on Remote Sensing Data Before and Post Reclamation in Lamong Bay Port. *Journal of Engineering Science and Technology* 17(2), 1328–45.

Kusmanto, Edi, and Hasanudin Muhammad. (2019). Presence of Solitary Wave and Instantaneous Transport of Suspended Sediment in Central Bengkulu Coastal Waters. *Oceanology and Limnology in Indonesia.* 4(3), 133. doi: 10.14203/oldi.2019.v4i3.262.

Lubis, Ashar Muda, Hanapi Rendi, Sinaga Juhendi, Samdara Rida, and Harlianto Budi. (2022). Estimating Shoreline Changes at Coastal Region of North Bengkulu Regency Using Unmanned Aerial Vehicle (UAV). *Globe Scientific Magazine.* 24(2), 81–90.

Made, Chandra, Putra Dewa, I. Gede Baskara, Ricko Ahmad, Septawan Kadek, Ida Putra, Putra Ramanda, and Aditya Muhamad. (2024). Mapping Coastal Abrasion And Accretion With Digital Shoreline Analysis System Method. Case Study: Kuta Beach Tourism Area. *Proceedings of the National Seminar on Engineering in the Vocational Fieldm XII.* 3, 821–28.

Masri, M, M, Andi, Rachman Taufiqur, and Chairul Paotonan. (2020). Identification Of Changes In The Coastline Of Mappakasunggu Sub-District, Takalar District Using Satellite Imagery. *Sensistek* 3. (November), 50–55.

Maulana, Fadli Arif, Amri Khairul, and Besperi Besperi. (2021). Prediction of Bengkulu Shoreline Change (Case Study of Zakat Beach, Bengkulu City). RADIAL: Journal of Civilization Science, Engineering and Technology. 9(1), 15–22. doi: 10.37971/radial.v9i1.216.

Narotama Sarjan, Achmad Fajar, and Muchtaranda Ismail Hoesain. (2023). Subsurface Geotechnical Assessment Using Geophysical Method Approach. Journal of Education, Science, Geology, and Geophysics (GeoScienceEd Journal). 4(1), 1–8. doi: 10.29303/goescienceedu.v4i1.217.

National Standardization Agency (BSN).(2019).Indonesian National Standard (SNI) 1726-2019 Earthquake Resistance Planning Procedure for Building and Non-Building Structures (Indonesian Seismic Building Code).Earthquake Resistance for Building and Non-Building Structures (Indonesia Seismic Building Code). Jakarta: Indonesia

Nugraha, Eki, Sudarsono Ignatius, and Mulyawati Fauzia. (2022). Handling Shoreline Changes on the Indramayu Coast (Muara Kali Eretan - Muara Sumber Mas). Journal of Infrastructure Engineering. 8(2), 8–19. doi: 10.31943/jri.v8i2.184.

Panjaitan, Ardika, Saragih Ronni, and Hutahuruk Anggiat. (2023). Microzoning of Landslide Potential Areas Using Microtremor Method in North Bengkulu-Lebong Regency. Scientific Journal of Physics FMIPA Lambung Mangkurat University. 20(2), 2541–1713.

Putra, Ihza Gian Fires, and Santosa Budi. (2023). Analysis of Shoreline Changes Using Empirical Methods at Palik Beach, North Bengkulu. Journal of Civil Engineering. 19(2), 246–64. doi: 10.28932/jts.v19i2.5953.

Putri, Adinda Permata, Hadi Arif Ismul, Sinaga Yuni Karisma, Jaya Shara Ashari Prana. (2024). 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. *Journal of Physics and its Applications.* 20(2), 53–59.

Raihansyah, Teuku, Ichsan Setiawan, Thaib Rizwan Marine Science Study Program, Faculty of Marine and Fisheries, Syiah Kuala University Darussalam, and Banda Aceh. (2016). Study of Shoreline Changes in the Coastal Area of Ujung Blang Waters, Banda Sakti District, Lhokseumawe. Scientific Journal of Marine and Fisheries Students Unsyiah. 1(1), 46–54.

Rasimeng, Syamsurijal, and Laksono Agung. (2017). Interpretation of Shear Wave Velocity Values (Vs 30) Using the Multichannel Analysis Of Surface Wave (MASW) Seismic Method to Map Earthquake Prone Areas in Bandar Lampung City. Journal of Exploration Geophysics *(JGE).* 3(No.3), 3–14.

Refrizon, Refrizon, Sugianto Nanang, and Purba Admo Bernard. (2019). Stratigraphic Determination of Shear Wave Velocity (Vs) in Abrasion Prone Areas of North Bengkulu Regency Using the Multichannel Analysis of Surface Wave (Masw) Method. Journal of Meteorology Climatology and Geophysics. 6(2), 15–20. doi: 10.36754/jmkg.v6i2.119.

Riyanti, Aulia Huda, Agung Suryanto, and Churun Ain. (2018). Dynamics of Coastal Line Changes in the Surodadi Village of Sayung Sub District by Using Satellite Imagery. *Management of Aquatic Resources Journal (MAQUARES).* 6(4), 433–41. doi: 10.14710/marj.v6i4.21333.

Samdara, Rida. (2014). Rate of Sea Level Change in Bengkulu Coastal Waters Using Satellite Altimetry. FLUX Physics Journal. 11(2), 197–203.

Supiyati, Supiyati, Johan Septi, Suwarsono Suwarsono, and Putri Hestyna Eka. (2024). Microzonation of Shoreline Changes Due to the Influence of Rip Current at Kota Bani Beach Bengkulu. Journal of Tropical Marine. 27(2), 236–46. doi: 10.14710/jkt.v27i2.22262.

Suwandana, Endan. (2019). Utilization of High Spatial Resolution Google Earth Data for Mapping Coastal Morphological Changes. *Depik.* 8(3), 193–206. doi: 10.13170/depik.8.3.14309.

Taipodia, Jumrik, and Arindam Dey. (2015). A Review of Active and Passive MASW Techniques A Review of Active and Passive MASW Techniques. *National Workshop Engineering Geophysics for Civil Engineering and Geo-Hazards (EGCEG).* 1–13.

Yulianti, Fitriani, Zulfan Zulfan, Zalmita Novia, Irawan Listyo Yudha, and Diah Husna. (2022). Community Preparedness to Face Beach Abrasion Disaster in Kedai Palak Kerambil Village. Geography Communication Media. 23(2), 227–35. doi: 10.23887/mkg.v23i2.53910.

Zainul, M. Arif, Kusuma Annisa, Hidayati Nurin. Besuki Pesisir, and Kecamatan Banyuglugur. (2021). Modeling and Analysis of Shoreline Change in Situbondo Regency, East Java. *JFMR-Journal of Fisheries and Marine Research.* 5(2). doi: 10.21776/ub.jfmr.2021.005.02.19.

Zuriyani, Elvi, Juita Erna, Zella Arie, Ulni Putra, and Despica Rika. (2023). Abrasion Disaster Mitigation Efforts at Naras Beach , North Pariaman District. 5(1), 37–44.