



Shoreline Change Analysis of Pontang Cape of Serang Regency of Banten Province

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ABSTRACT

Coastal areas, being vulnerable to environmental problems, have one of the most frequent problems which are the change in the shorelines. Shoreline changes, namely abrasions, can cause problems such as land degradations or loss of land in a coastal zone. This problem occurs in many areas, one of which is Pontang Cape. This study aims to determine the distance and rate of shoreline changes that occurred in the Cape and its surroundings, as well as explaining the analysis points based on similar studies that had been conducted. This research used ArcMap software and Digital Shoreline Analysis System (DSAS) toolset to determine the distance and rate of shoreline changes for 19 years (1999-2018). Based on the results, there were two shoreline segments where different phenomena of shoreline change took place, namely Banten Bay (accretion) and Pontang Cape-Lontar (abrasion). The most likely causes of changes in the shorelines are sediment runoffs from rivers that lead to bay and sediment transports that affect Banten Bay accretions, while sea sand mining and conversions of mangrove swamps into fishery ponds are factors affecting abrasions in Pontang Cape.

Keywords: Abrasion, Accretion, Pontang Cape, Banten Bay, DSAS

ABSTRAK

Wilayah pesisir, yang rentan terhadap permasalahan lingkungan, memiliki salah satu masalah yang paling sering terjadi yaitu perubahan garis pantai. Perubahan garis pantai seperti abrasi dapat menimbulkan masalah seperti penurunan fungsi lahan atau hilangnya lahan yang ada pada suatu area pesisir. Penelitian ini bertujuan untuk mengetahui jarak dan laju perubahan garis pantai yang terjadi di Tanjung Pontang dan sekitarnya, serta memaparkan poin-poin analisis berdasarkan penelitian serupa yang pernah dilakukan. Penelitian ini menggunakan software ArcMap dan toolset Digital Shoreline Analysis System untuk mengetahui jarak dan laju perubahan garis pantai selama 19 tahun (1999-2018). Berdasarkan hasil penelitian, terdapat dua segmen garis pantai yang mengalami fenomena perubahan garis pantai yang berbeda, yaitu Teluk Banten (akresi) dan Tanjung Pontang-Lontar (abrasi). Penyebab yang paling mungkin dari perubahan garis pantai adalah sedimentasi dari sungai yang bermuara di teluk dan transpor sedimen yang mempengaruhi akresi Teluk Banten, sedangkan penambangan pasir laut dan konversi rawa mangrove menjadi lahan tambak adalah faktor-faktor yang mempengaruhi abrasi di Tanjung Pontang.

Kata kunci: Abrasi, Akresi, Tanjung Pontang, Teluk Banten, DSAS

1. Introduction

Shorelines can be defined as the water's edges or lines dividing the oceans and lands, lying between the lowest tide level and the highest elevation on land that is affected by

storm waves (Trujillo & Thurman, 2016). Shoreline changes are indicated by positional changes, depending on the interactions between topography, sediments and their properties with waves, tides, and winds. (Opa, 2011).

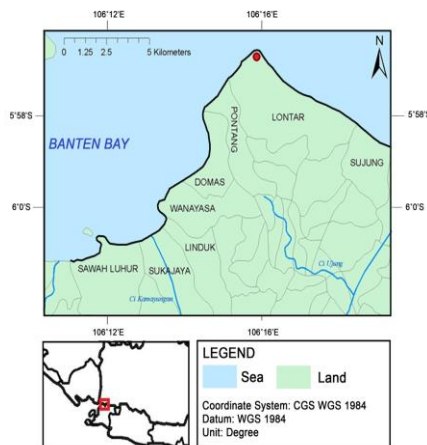


Figure 1. Area of interest, shoreline cast (shown in bold black line) from Sawah Luhur to Sujung (Pontang Cape shown in red dot)

Pontang Cape was chosen as the object of research based on scientific studies that had been carried out in the same area. Research using remote sensing shows that abrasions are prominent phenomena in Pontang Cape (Rahmawan et al., 2017; Husrin & Prihantono, 2014; P3SDLP, 2014). Research in 1995-2001 shows that the average erosion in Pontang Cape had caused the loss of beach width of up to 3 km as well as high turbidity in Banten Bay (Hoitink & Hoekstra, 2003). In addition, Pontang Cape as part of the north coast of Banten is directly connected to the Java Sea, making it prone to coastal damages due to continuous large waves from the direction of the sea or perpendicular to the coast (Tarigan, 2007).

The most recent research conducted by Prihantono et al., (2018) reviewed the processes of coastal abrasion and turbidity in Pontang Cape using numerical modeling of hydrodynamics and sediment transports, with measured parameters consisted of currents,

bed level changes, and water turbidity levels. The results state that there were indications of abrasions and sedimentations around Pontang Cape based on the numerical model, but this statement is only limited to the implications of the results of the study. This research was conducted to obtain quantitative values of the rate and distance of coastline changes caused by abrasion or sedimentation processes in Pontang Cape, as well as trying to find supporting evidence for the studies used as references.

2. Material and methods

2.1. Datasets

Datasets used in this research were Landsat 7 images (from 1999, 2000, 2001, 2002, 2003, 2005, 2007, 2010, and 2011), Landsat 8 images (from 2013 2014, 2017, and 2018). Landsat images were downloaded from the United States Geological Survey (USGS) Global Visualization Viewer (GloVIS, <https://glovis.usgs.gov/>). Landsat datasets were taken one from each year, with the low cloud cover value (<15 %). The research was conducted in the Pontang Cape coastal area, Serang Regency, Banten. This area was located in the Districts of Pontang and Tirtayasa, and consisted of villages Sukajaya, Linduk, Wanayasa, Domas, Pontang, Lontar, and Sujung. The coastline used as the object of research was Pontang Cape and its surrounding areas which were included in the Ciujung Drainage Basin. The area also included Serang City in the west, in the form of a coastline cast from Sawah Luhur village. The area of interest is shown in Figure 1.

2.2. Image processing

Landsat 7 SLC-off image data (images with black line slits due to non-functioning Scan

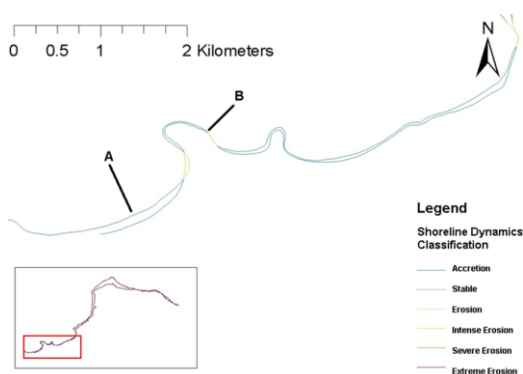


Figure 2. Visuaization of Study Area I

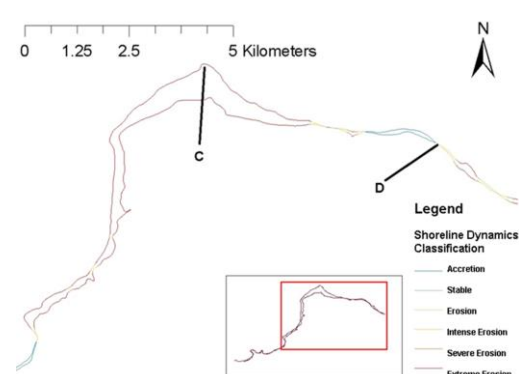


Figure 3. Visuaization of Study Area II

Line Corrector on Landsat sensors) in 2005, 2007, 2010, and 2011 were corrected first using the Frame and Fill software developed by Richard Irish (Viet et al., 2014). Landsat images still in the form of raster files were processed into shoreline polylines to match the format required by DSAS, using Landsat Toolbox for Shoreline Extraction toolset (Daniels, 2012). Image dataset with bands 1-7 was first clipped into the desired area boundaries, then band 3 and 4 of the image were processed using NDVI (Normalized Difference Vegetation Index tool, to quantify green vegetations in the image), then all the original bands (1-7) were processed by Tasseled Cap Analysis, which produced three new bands in the form of Brightness (representing natural structures, man-made structures, as well as barren or partially covered dry lands), Greenness (representing living vegetations), and Wetness (representing moist

soil, bodies of water and other aquatic features).

Bands from NDVI and Tasseled Cap were then processed using the Category Creation for Land and Sea tool, producing images with various categories marked with color. Values of different land categories were uniformly assigned to put together, the same was done for aquatic categories. Then the two main categories (land and water) were separated by the Classify Land and Sea tool and the line that borders these two categories is transformed into a coastline by the Create Shoreline Boundary tool.

2.3. Shoreline change calculation

Based on the shoreline polylines, baselines were made manually and transects were automatically cast by the DSAS software. After the transect, baseline, and coastline layers

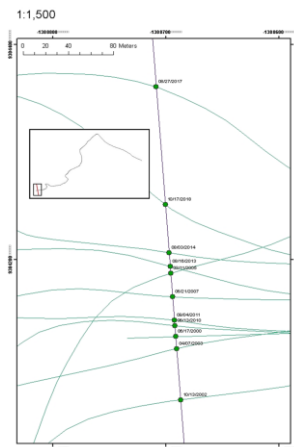


Figure 4. Transect A and its intersection points with the shorelines

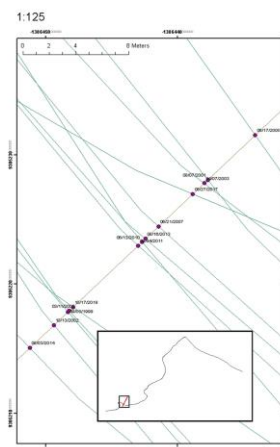


Figure 5. Transect B and its intersection points with the shorelines

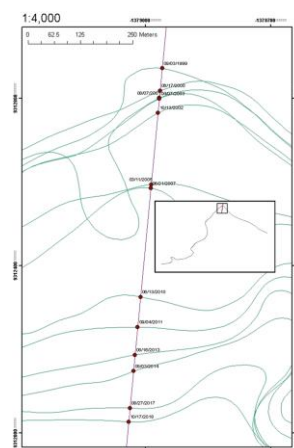


Figure 6. Transect C and its intersection points with the shorelines

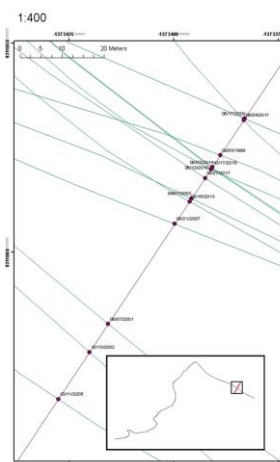


Figure 7. Transect D and its intersection points with the shorelines

were determined, the three layers were used in the calculation phase. After selecting the transect layer to be the target of the calculations, three calculation methods (Net Shoreline Movement, End Point Rate, and Linear Regression Rate) and the confidence interval (95 %) were set. Net Shoreline Movement (NSM) calculates the distance between the oldest and the newest shorelines; End Point Rate (EPR) is Net Shoreline Movement value divided by the number of elapsed years between the dates of the oldest and the newest shorelines; Linear Regression Rate (LRR) calculates rates of shoreline changes by plotting the distances between shorelines and baseline against the years of the shorelines, then fitting a least-squares regression line to it, the rate being the slope of the line.

The statistical calculation outputs were two tables, one table contained the calculation values of NSM, EPR, and LRR per transect and the other table contained the X and Y points of each crossing of the transects with the coastline and the distance of the cutoff points from the baseline (Thieler et al., 2009).

2.4. Analysis

Analysis of shoreline changes were derived from the magnitude of the correlations between changes in years and the process of abrasions or accretions that occurred in the region along with other statistical calculations

computed by DSAS, and also the observed levels of beach damage that was the object of research. The extent of the damages was assessed using the EPR-based beach erosion classification proposed by Esteves and Finkl (Luijendijk et al., 2018; Table 1). The points of analysis were summarized from various scientific studies related to shoreline changes that had been carried out before in Pontang Cape. The study reports were used as materials for analysis and comparison, by observing the consistency between the results of researches that had been done with the results of current research.

3. Results and Discussion

3.1. Shoreline change values

The research area was divided into two study areas, named Study Area I (Figure 2) and Study Area II (Figure 3). Separation into two study areas was done on the basis that in different parts of the coastline, there were differences in the dynamics of the coastline that became dominant. The dominant shoreline dynamics in Study Area I (including Sawah Luhur, Sukajaya, and Linduk villages) were accretions, while Study Area II (consisting of Wanayasa, Domas, Pontang, Lontar, Sujung, and Ciujung river estuaries) was dominated by abrasions.

The Study Area I had a total length of 7047.97 meters, dominated by accretions of

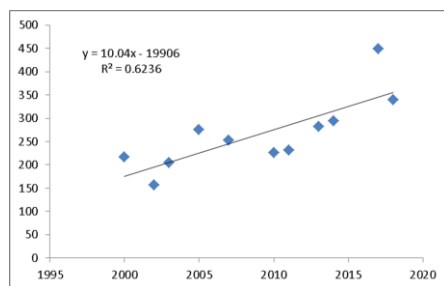


Figure 8. Linear regression of Transect A

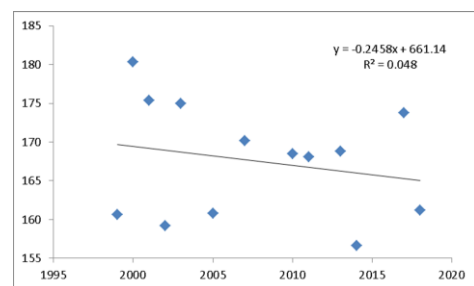


Figure 9. Linear regression of Transect B

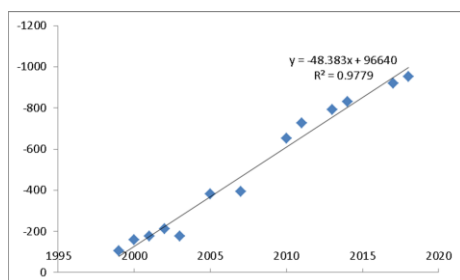


Figure 10. Linear regression of Transect C

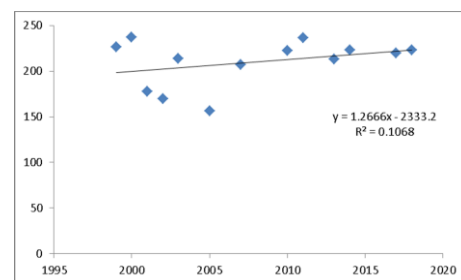


Figure 11. Linear regression of Transect D

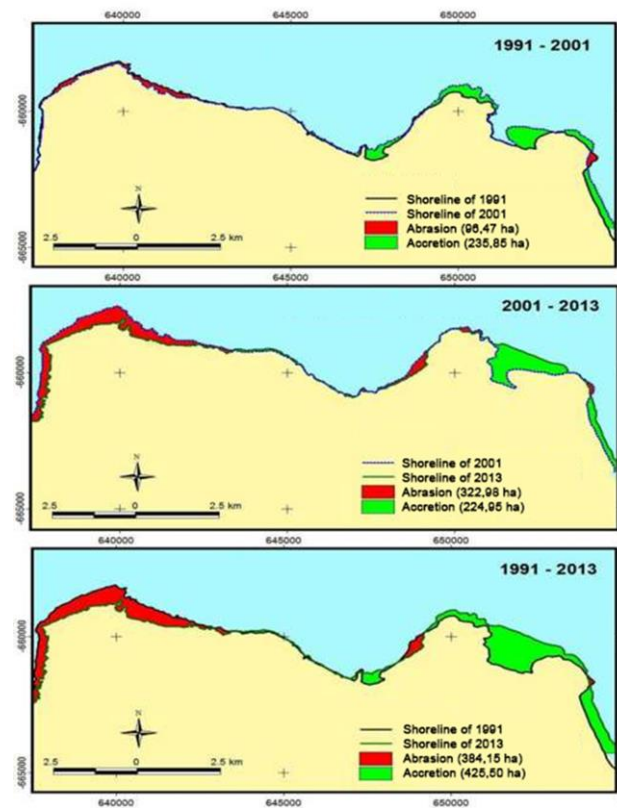


Figure 12. Results from Prihantono and Hadiwijaya's research
(Source: Prihantono and Hadiwijaya, 2014)

6541.93 meters (92.82 %). The Study Area II had a total length of 17545.6 meters, with most of the coastline were damaged by extreme erosions (coastal erosion more than 5 meters per year), being 11938.67 meters (68.05 %). The total length of the observed coastline was 24593.57 meters. Percentages of coastline lengths based on changes that occurred are tabulated in Table 2.

From the calculated transects in Study Area I, the greatest accretion occurred in transect A (Figure 4). The smallest accretion distance over 19 years was observed in transect B (Figure 5). Both transects A and B were on the coast of Sawah Luhur village. In Study Area II, the largest abrasion was recorded in Transect C (Figure 6). The smallest

abrasion was measured in Transect D (Figure 7). Transects C and D were respectively in Pontang Cape and east of Lontar Village. The results of the calculation of distance, rate, and coefficient of determination of the transects were tabulated in Table 3.

The results of the calculations of linear regressions between year increments with changes in coastline distances from the baseline for the maximum and minimum accretions respectively showed moderate and weak correlations (R^2 values = 0.6236 and 0.048, Figure 8 and 9). The value of R^2 of Transect B which was almost zero showed that there were no relations between the increase of years with the progress of the coastline, or the accretion had no effect on the Transect B. The regression results between the decline of the coastline to the year change for the largest abrasion distance and the smallest (Transects C and D) had R-squared values of 0.9779 and 0.1068, respectively (Figure 10 and 11); indicated a very strong correlation and a weak correlation between abrasion and changes in years in each place. Correlation of abrasion with a change in years was greater than the correlation between accretion with a change in

Table 1. Beach erosion classification
(Source: Lujendijk et al., 2018)

Erosion type	EPR value
Accretion	> 0,5 m/yr
Stable	-0,5 to 0,5 m/yr
Erosion	-1 to -0,5 m/yr
Intense Erosion	-3 to -1 m/yr
Severe Erosion	-5 to -3 m/yr
Extreme Erosion	< -5 m/yr

Table 2. Percentages of coastline length based on occurred changes

Coastline change classification	Study Area I		Study Area II	
	Coastline length	Percentage	Coastline length	Percentage
Accretion (>0,5 m/year)	6541,93 m	92,82 %	1768,85 m	10,08 %
Stable (-0,5 s/d 0,5 m/year)	-	-	153,49 m	0,87 %
Erosion (-1 s/d -0,5 m/year)	181,96 m	2,58 %	800,40 m	4,57 %
Intense Erosion (-3 s/d -1 m/year)	324,08 m	4,6 %	1955,16 m	11,14 %
Severe Erosion (-5 s/d -3 m/year)	-	-	929,03 m	5,29 %
Extreme Erosion (<-5 m/year)	-	-	11938,67 m	68,05 %
Total	7047,97 m	100 %	17545,6 m	100 %

Table 3. Shoreline change calculation results

DSAS calculation value	Study Area I			Study Area II		
	Transect A (Greatest Accretion)	Transect B (Smallest Accretion)	Average	Transect C (Greatest Abrasion)	Transect D (Smallest Abrasion)	Average
NSM (Net Shoreline Movement)	123,15 m	0,53 m	32,33 m	-848,01 m	-3,66 m	-184,03 m
EPR (End Point Rate)	6,72 m/yr	0,03 m/yr	1,7 m/yr	-44,35 m/y	-0,19 m/yr	-9,72 m/yr
LRR (Linear Regression Rate)	10,04 m/yr	-0,25 m/yr	-	-48,38 m/yr	1,26 m/yr	-
R^2 (Coefficient of determination)	0,6236	0,048	-	0,9779	0,1068	-

years. This implied that in the Pontang Cape and surrounding areas, changes in coastline tended to abrasions.

3.2. Accretions

Almost all of the coastlines in Study Area I experienced accretions, with the exceptions of the east and west sides of Pulau Dua, the largest cape in Sawah Luhur (intense erosion on the west, and erosion on the east).

Accretions were strongly suspected to occur due to the accumulation of sediment that came out of the rivers which emptied into the bay. At least 11 streams and small rivers flowed into the study area, namely Ci Banten, Kali Daun, Perumpung River, Kepuh River, Kramat River, Weraga River, Ci Kemayungan, Daon River, Jaro River, Kali Pudar, and Ci Anyar. While the erosion that occurred on the west and

east sides of Pulau Dua was thought to have been caused by the absence of water flow in the area, such as rivers and streams being the one which triggered sedimentation on the other parts of the coast.

3.3. Abrasions

Study Area II was dominated by the phenomenon of abrasions, with the exception of accretions on the east of Lontar Village. The most frequent were extreme erosions on the coast of the Cape and the western part of the Cape. Several other locations were damaged by multiple types of abrasions, from erosions to intense erosions, namely on the coast of Pontang Cape and Lontar Village and the coast north of Sujung. Abrasions were thought to occur due to offshore sand mining activities (Husrin et al., 2016), conversion of mangrove



Figure 13. Brackish water ponds on the coast of Serang



Figure 14. A narrow strip of land separating a pond and the sea



Figure 15. Abrasions left a tree immersed in the sea



Figure 16. Steep layers of soil indicates eroded land

lands into fishery ponds (Setyawan, 2010) and natural causes.

The coastline length of the Pontang Cape study in results from Prihantono and Hadiwijaya's research (2014; Figure 12) was approximately 19676.15 meters, with abrasion area from 2001 to 2013 recorded at 322.98 ha. From these two data, the average abrasion distance was 164.15 meters. While the results of NSM using DSAS analysis results for the same time range showed a figure of 162.3 meters. The percentage of errors obtained between the results of Prihantono and Hadiwijaya's research with the results of the DSAS analysis was 1.13%. The results obtained by Prihantono and Hadiwijaya matched with SIG analysis by Kusumawati (2008) who states that beach erosions occurred three times faster when sea sand mining was carried out (2003-2007) than before the mining began (1991-2002).

Based on field observations conducted in February 2020, the conversions of coastal lands into brackish fishery ponds (Figure 13) had an impact on the condition of the shorelines in the area. Ponds and seas were only separated by strips of land (Figure 14). If the barriers were broken, seawater would merge with the ponds,

making more salt-water flow landward and erode the landmass further. Conversions into fishponds involved a reduction in coastal vegetation, especially mangroves. The small number of mangrove trees and other vegetation, the majority of which are shrubs, aggravate abrasions, as shown in Figure 15 (the retreat of the coastline left land plants immersed in the sea) and Figure 16 (a steep layer of soil indicated remains of erosion). Lack of coastal vegetation and low bulk density of soil were also unable to withstand tidal waves, which cause tidal flooding in the lower coastal plains (Figure 17). This matched with the observations from Setyawan (2010) in the same area, who states that ponds built-in coastal lands and very close to the shorelines leaving little or no mangroves, causing the vegetations to lose their ability to inhibit coastal erosions.

The mangrove swamps as coastal wetlands functions to dissipate the energy from incoming waves and absorb excess water from the sea. Mangroves together with the sediment supply from rivers also compensate for land subsidence, the process by which soil is naturally compressed under its own weight. Removing mangroves to convert wetlands into ponds, as in the case of Pontang Cape, can



Figure 17. Tidal flooded coastal land

cause land subsidence to occur faster than the build-up of new soil layers by sediment deposits (Trujillo & Thurman, 2016). Land subsidence, absence of wave barriers, and sea-level rise (due to tides or due to climate change) are factors causing tidal flooding and retreating of the coastline, as observed at Pontang Cape.

4. Conclusions

There are two different phenomena in two different parts of the coastline, namely accretion that occurs in Study Area I (Banten Bay) and abrasion that occurs in Study Area II (Pontang Cape). Accretion occurs due to the accumulation of sediments from water flows that lead to the area, while abrasion is thought to occur due to offshore sand mining and conversion of mangrove lands into fishery ponds.

In study Area I from 1999 to 2018, the average accretion is 32.33 meters with an average annual change of 1.7 meters per year. The largest abrasion occurs in transect A which is located in Karangantu, amounting to 123.15 meters with a rate of change of 6.72 meters per year with a value of $R^2 = 0.6236$. The smallest measured accretion in transect B, located at Pulau Dua, is 0.53 meters with an accretion rate of 0.03 meters per year with a value of $R^2 = 0.048$. While the average abrasion distance in Study Area II is 184.03 meters, with an average setback rate of 9.72 meters per year. The largest abrasion is recorded in Transect C (Pontang Cape) as far as 848.01 meters with an abrasion rate of 44.35 meters per year with $R^2 = 0.9779$. The smallest abrasion is measured in Transect D, located east of Lontar Village, with a distance of 3.66 meters and a rate of change of 0.19 meters per year with a value of $R^2 = 0.1068$. The phenomenon of abrasion has a greater correlation implying that in the study

area the phenomenon of shoreline changes tends to lead to abrasion.

Overall, the phenomena in Study Area I is classified as accretions, with the exception of the east and west sides of Pulau Dua (intense erosions of 1 to 3 meters per year in the west, and erosions of 0.5 to 1 meter per year in the east). The Study Area II is dominated by extreme erosions (abrasions of more than 5 meters per year) on the coast of the Cape and the western part of the Cape. Several other locations experience dynamics from erosions to intense erosions, namely on the coast between Pontang Cape and Lontar Village, the eastern part of Lontar Village, and the coast north of Sujung. The accretions in Study Area II only appeared on the coast of Lontar Village.

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