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# THE MAPPING OF SHORELINE CHANGE CAUSED BY ACCRETION AND ABRATION AS AN IMPACT OF TIN MINNING IN PANGKALPINANG

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**ABSTRACT**

*Bangka Island is the biggest tin producer in Indonesia. Pangkalpinang is the capital city of Bangka Belitung Archipelago which has 36 km$^2$ shoreline and is one of the areas affected by anthropogenic activities especially tin minning activities. This study aims to determine the changes of position and rate of shoreline change in 2000 – 2022 using multitemporal imagery in Pangkalpinang. This study used remote sensing method (Algorhytm of Normalized Difference Water Index) and geographic information system with on screen digitation approach using DSAS (Digital Shoreline Analysis). Shoreline position measurement using the NSM analysis and rate of shoreline change using the EPR analysis. Digital image processing result showed that shoreline position at coastal region in Pangkalpinang has changed in 22 years. At sector A (Pasir Padi area), The land mass accretion/ maximum accretion occurred at Serata, Pasir Padi Beach adjacent to Batu Rusa estuary which was 63,6 m with shoreline rate change was approximately 2.89 m/year, while the land mass decreasement/ highest abration occurred in Pasir Padi Beach was 164,5 m with the shoreline rate change was approximately 7.48 m/ year. At sector B (Tanjung Bunga Area) abration occurred was -124.6 m with the shoreline rate change was approximately 5.66 m/year. At sector C (Sampur Beach Area) abration occurred was 81 m with shoreline rate change was 3.68 m/tahun. The average of shoreline change rate in Pangkalpinang affected by abration was 2.5 m/year while the average of shoreline change affected due to accretion was 2.89 m/year whereas there were 2 beaches in Pangkalpinang which did not experience the accretion, namely Tanjung Bunga Beach and Sampur Beach.*

***Keywords**: Shoreline, Pangkalpinang, Accretion, Abration, Tin Minning*

## INTRODUCTION

Shoreline is defined as the border between the land and water level. Shoreline is the interaction between sea areas and land areas and has dynamic character (Hermanto, 1986). The dynamic shoreline change is not only affected by physical factor but also affected by anthropogenic factor which have a crucial impact to environment (Cui, 2011). Anthropogenic activities are the destructing phenomenon or pollution that unnaturaly occurred caused by the human activites (Akhrianti *et al*., 2019). Shoreline changes could happen because of physical process such as tides changing process, sediment lift brought by tributary, sea wave and currents move following or downing the coast. The shoreline changes such as abration or accretion is one of examples of physical process occurred (Wibowo and Yudha (2012). Abration is a shoreline change phenomenon caused by seashore erotion by the wave or erotion by the wind (Tarigan, 2007). Sea wave scrapes the bottom base (interaction area) then construct basins that affect on displacement of sand structure or downward of rock structure (Wirahadi, *et al.* 2015). Accretion is a shoreline change process caused by the land increasement due to sediment deposition process brought by the river or sea (Tarigan, 2007).

Bangka Island and Belitung Island are two biggest tin producers in Indonesia and second after Malaysia. The minning permit of PT. Timah, Tbk in Bangka Belitung Archipelago Province is 330.664,09 ha and PT. Koba Tin is

41.680,30 ha, while the rest are owned by private company and people`s mine (Yuliana, 2016 *in* Akhrianti 2020). Since the freedom of minning was applied to BABEL society in 2000, the waters tin minning (Floating Tin Mine) was massively occurred as a result of the difficulty in finding the mining location on land (Syari, 2008). One of areas in Bangka Belitung Archipelago province with the anthropogenic activities and offshore tin minning activies is Pangkalpinang coastline.

The existence of wave breaker at Pasir Padi Beach and massive human activites (Industrial activities, warehousing, tourism from settlements, fisheries, shrimp aquaculture, thermal power station, port, and ship traffic) and also anthropogenic activities (domestic waste) in the area around Batu Rusa estuary, Tanjung Bunga and Sampur Beach in Pangkalpinang either directly or undirectly were suspected as the caused of sedimentation and land mass decreasement and land shallowment that come from land or sea sedimentation. Additionally, based on the research result of Akhrianti and Gustomi (2019) proved that there was mangrove degradation on coastal area in Pangkalpinang with the mangrove species composition found were ± 22 dominated by *Rhizophora apiculata*. Mangrove condition in Pangkalpinang coastal area on 2020 was on quite apprehensive condition and was classified as varied from damaged-good category. Based on the extreme phenomenon in Pangkalpinang, it was assumed that there was an abration and accretion on beach and also there was a significant coastal dynamic as a resut of anthropogenic activities especially tin minning activities (Akhrianti dan Gustomi, 2020).

The appliance of remote sensing technique and Geographic Information System (GIS) plays a crucial role as the efficient method in providing the coastal area data and the dynamical area inside it. This ideal combination technique in mapping the land and water is needed to extract the coastline change area (Kasim, 2012). Thus, coastline information is needed because coastine is dynamic. Due to this dynamic characteristic, it is important to have a study on the mapping of coastline change regularly. On this research, ground check ad tide correction was conducted in analyse the dynamic of coastal area in Pangkalpinang.

## MATERIALS AND METHODS

### Research Design

This research used a descriptive method where research was carried out to present descriptive data with a systematic, factual, and accurate description of the facts, nature, and relationships in the phenomenon (Nazir, 2014). This research collected data based on surveys, interviews, spatial; analysis using remote sensing method and Geographic Information System (GIS).

### Research Sites

This research was carried out in Pangkalpinang City, Bangka Island, located in Pasir Padi Beach, Tanjung Bunga Beach, and Sampur Beach. Pangkalpinang City has total shoreline length of approximately 8.2 km, known as natural panoramas for quite long time.

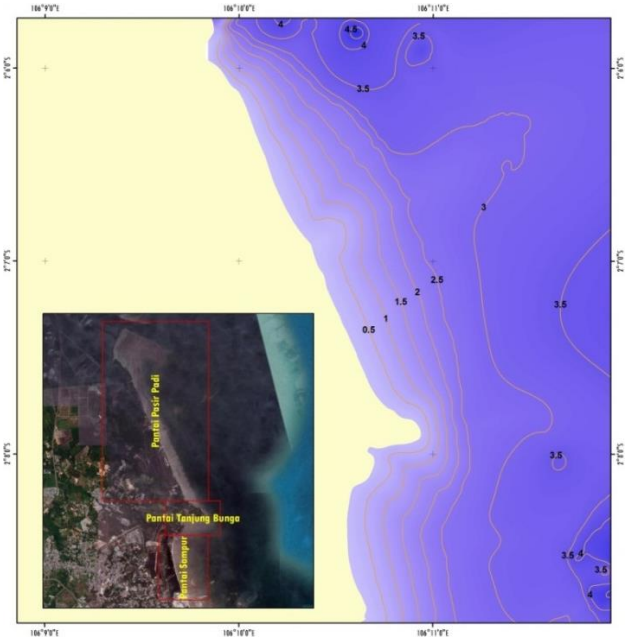


**Figure 1.** Batimetry Map and research locations in Pangkalpinang City

**Table 1.** Data collection tools and materials

| Tools | Materials |
|---|---|
| Stationary | Secondary and Primary data |
| Questionnaire | The questionnaire results related to the study |
| Digital Camera and drone | Shoreline View |
| Global Positioning System (GPS) | Ground Check |
| Laptop and Software Arc.Gis 10.3.1 | Shoreline Mapping |
| Geology Compass | Identifying Beach Elevation and Tide Corection |
| Multitemporal Imagery (Landsat TM and Sentinel 2A) | As Spatial Data |
| Ermapper 7.0 | Image Processing |

**Data collection**

Data used in this research was the satellite imagery data and tracking using GPS. Satelite imagery data was used as primary data in the process of resulting shoreline data, while tracking data with GPS was a ground check at the sites.

Satelite imagery data used were Landsat 5 TM Imagery and Sentinel 2A imagery. Landsat 5 TM imagery used was data on 2000 while Sentinel 2A imagery data was the data from 2022. Sentinel-2A Level 2A imagery was chosen because it has been systematically corrected in the form of Top of Atmosphere (TOA) reflectance values so that geometric and radiometric corrections are not necessary (Suhet, 2015). In addition, Sentinel-2A Level 2A imagery has a medium spatial resolution (10 meters) and can be obtained for free through the official website of the European Space Agency (ESA) at the link https://dataspace.copernicus.eu/ while Landsat 8 OLI/TIRS imagery has a spatial resolution of 30 meters and can be accessed for free through the website https://earthexplorer.usgs.gov/. Both data were accesed via earthexplorer.usgs.gov.

**Image Processing**

Image processing was started by geometric and radiometric correction using QGIS on Landsat 5 TM imagery on 2000 while Sentinel 2A imagery was not corrected geometrically and radiometrically. Datum used on this research was UTM WGS 1985 zone 48S. The image processing was done using digitation (On screen digiitazing) on each image in ArcGis software. (Suharyo, 2019). One of the factors that influences changes in the coastline is the height of sea waves during the west wind season (Hidayat et al. 2023). High waves will erode the coastline. The highest waves occur during the west and east seasons on the East Coast of Bangka Waters. Waves originating from the Natuna Sea will spread to the East Coast of Bangka Waters during the west season, while waves originating from Java Waters will spread during the east season (Pamungkas, 2018). Waves that hit the coast intensively because the coast is open and perpendicular to the direction of the incoming waves. Digitazing and sharpening result will result the border between sea and land clearly (Purwadhi dan Sanjoto, 2008). Those borders were used in deciding shoreline change. These boundaries are used in determining changes in the coastline. After the shoreline layers were obtained, the analyses were continued using overlay process to calculate the changes (Suniada 2015).

The steps done to annallyse imagery data to determine shoreline are stated as follow:

1. Geometric and Radiometric Correction

Geometric correction was conducted to equate the geographic on image and base map. This process needs four points of GCP (*Ground Control Points*) pointed on every corner of image and then rectficated (Hidayah, 2020). The aim of radiometric correction was to fix pixel value so it will fit as what it should considering the atmospheric disturbance factor (Lukiawan 2019).

2. Image Cropping

The process of image cropping was obtained to get coverage area of study locations based on specific sites.

3. Band Combination

Band combinationing/ canaling was the merger of bands needed to clear up border between water and land, so it would ease the digitation process (Sutikno 2014). Band combination used on Landsat 5 TM imagery was 432, while on Sentinel 2A imagery was 842.

4. Digitation

After image was corrected and cut, the next step was process on scree digitation. Digitation

was obtained to change the raster format daya to vector data. All digitation process using image analysis on ArcGIS software that can show vector data and raster data together. Shoreline was digitated visually by showing the border between sea and land (Yulius dan Ramadhan, 2013).

5. Tide Correction

Tide correction was conducted to eliminate standing water causd by the tide on imagery record. Tide correction on shoreline was conducted by determining the slope of the bech surface base (β) (Darmiati *et al*. 2020). Beaach slope in Pangkalpinang was obtained from the research of Dewi *et al*. (2017) which was 4,67°. To determine the water level difference (η) when image was recorded to LML, shoreline from imagery result need to be corrected to minimum ride on the month of image recorded, so the shift distanc (r) was obtained using the formula:

$$r = \frac{(\eta)}{\tan \beta}$$

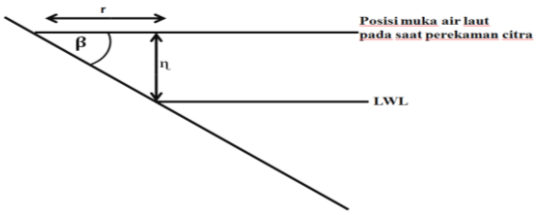


**Figure 2.** Schematic image of high sea level position when satellite during the satleite image acquisition.

If the image recording was done at low tide, so the shoreline was shifted to the land as far as r, and if it was on high tide so it was shhifted to the sea as far as r (Darmiati *et al*. 2020).

6. *Groud check*

*Ground check* was conducted to verify the accuracy of classification result based on digital image processing (Akhrianti *et al*. 2018). The geographic position during the shoreline data collection was started on the coordinate point -1°47'57,221" S, 106°7'9,256" E to -1°46'17,248" S, 106°5'29,648" E.

7. *Overlay Image*

Process of putting two or more than two image at once is called overlay. Overlay process was conducted from the result of polyline production on Landsat 5 TM image on 2000 and Sentinel 2A image on 2022. This step will show the shoreline change caused by abration and accretion on that exact year.

**Data analysis.**

Image data analysis was conducted using transformation of *Normalized Difference Water Index* (NDWI). NDWI transformation was used to sharpening water coloumn information and differentiate the water and land area. NDWI alghorytm used green band and near infrared band. Green band was used to optimalize reflection from water coloumn, while *Near Infrared* minimize water coloumn reflection. Thus, the water coloumn absorbstion on near infrared band was very strong, while on green band, the reflection value is bigger and if the NDWI value is more than zero so it was assumed represented watercoloumn and if the value were smaller so it is assumed as not water (McFeeters 2013). NDWI formula is stated as follow.

$$\text{NDWI} = \frac{\text{Green Band} - \text{Near Infrared Band}}{\text{Green Band} + \text{Near Infrared Band}}$$

The result of image data was digitated to produce shoreline datta. Digital Shoreline Analisis System (DSAS) is an additional software in ArcGis that can be used to calculate shoreline rate change automatically using a point as the measurement reference, whereas point was obtained from the intersection of transectline made by the user with shoreline based on time (Himmeltoss *et al*. 2009). Parameter used in DSAS consists of baseline as line reference, shoreline whose changes will be measured, and transects as perpendiculat line with baseline which divided eac sector on shoreline (Hasan 2019). DSAS method used on this research was *Net Shoreline Movement* (NSM) dan *End Point Rate* (EPR). The illustration of DSAS parameter is showed below.

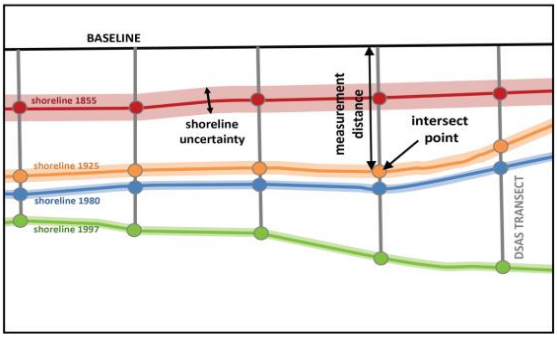


**Figure 3.** Components of DSAS Parameter.

## RESULTS AND DISCUSSION

### Shoreline Changes of Pangkalpinang City

The shoreline changes in the coastal area of Pangkalpinang City from 2000 to 2022 revealed significant patterns of accretion and abrasion. Notably, Pangkalpinang City is bordered by several beaches that stretch from east to west, serving as markers of its diverse shoreline. These beaches include Sampur Beach, Tanjung Bunga Beach, and Pasir Padi Beach.

The shoreline position analysis highlighted that the most significant land accretion occurred in the Pasir Padi area, particularly on transect 2, where the maximum accretion reached 63.59 meters, with a shoreline rate change of 2.89 m/year. In contrast, the Pasir Padi coastal area also recorded the highest abrasion, notably around Pasir Padi Beach, where the abrasion was approximately -164.47 meters, with a shoreline rate change of 7.48 m/year. Tanjung Bunga Beach showed similar patterns of abrasion. On transect 34, the recorded abrasion was -124.6 meters, with a shoreline rate change of 5.66 m/year. Additionally, transect 39 experienced an abrasion value of -81 meters, with a shoreline rate change of 3.68 m/year.

The average abration rate change in coastal area Pangkalpinang in the all sector A (Pasir Padi Beach), sector B (Tanjung Bunga Beach), sector C (Sampur Beach) was 2.5 m/year while the accretion value was 2.89 m/year. The shoreline position change in Pangkalpinang was suspected exist after the local regulation was applied where tin minning activity (Inconventional tin minning) was massively open either legal or illegal with the operation areas were on land and on Bangka Island Sea (Floating Tin minning, suction vessel, and dredger vessel) especially in Pangkalpinang. This statement was supported by ground check result that found out inconventional tin minning were assively found close to the research locations. The existence of this inconventional tin minning will likely harm the environment in that area.

Tarigan (2007) stated that human activities such as mangrove deforestation, sea sand minning and coral minning in some locations had contributed to beach abration because there was coastal protection from sea wave and storm. In this research abration and accretion were caused by the lack of protection on mangrove ecosystem in Pangkalpinang coastal area which shift into aquaculture area, street or public settlement.

Besides that, the high coastal dynamic in Pangkalpinang was suspected due to the existence of wave breaker and mangrove degradation in Pangkalpinang coastal area (Akhrianti and Gustomi, 2019). Wiratama *et al.* (2014) added, there were some factors that cause shoreline change, one of them was west season wave. High sea wave occurred continuously on west season would slowly scrape coastal land in Pangkalpinang. As the result, it would cause abration. Prameswari *et al.* (2014) explained that wave as hydro oceanography parameter was also contributed in shoreline change. When the waves occurred, sediment material will bring materials from the bottom of the sea and resulting sedimentation, besides that the coastal area in Pangkalpinang especially Pasir Padi beach area, and Sampur Beach has sandy type whereas sand scraped by waves will be brought by currents to the coast and then resulted in decomposition as the process of sedimentation. The sedimentation stacked for months even years will cause land mass and area increasement which called as accretion.

Shoreline change physically was indicated by abration and accretion (Putra *et al.* 2015). Similar study was conducted by Setiabudi and Maryanto (2018) in Karawang regency coastal areas using DSAS showed average abration in

1990 – 2018 was -101.28 m with shoreline rate was 3.64 m/year while the accretion value was 195.63 m with the change rate was 7.04 m/year. Study by Hasan *et al.* (2019) in Jembrana regency, Bali showed the highest abration in 1997 – 2008 occurred at Delodberawah village with the value was 132.94 m and the highest abration rate was 12.085 m/year. Coastal area in Pangkalpinang has diurnal tide type which only occurred once a day with one highest tide and one lowest tide with the currents speed was approximately 0.094 m/s – 0.307 m/s (average currents speed was 0.221 m/s) with varied direction but dominantly moved from the north to south on June. Based on that data, compared to shoreline change data which was fluctuative, it showed that coastal area in Pangkalpinang was classified as the coastal susceptible area. The susceptible condition can be assessed by two factors such as beach physical indication and beach oceanography. Beach physical indication is the form of indication occurred on earth surface, such as geomorphology, beach, beach typology, and other factors. While oceanography indications are all indications occurred in the beach such as tide, current, wave, and others (Huda *et al*. 2019). Sea sirculation system, current and waveoccurred in coastal area, is effective to move the sedimentation materials. Beach with big wave and current generally has rough sediment materials. Mangrove lived in the shoreline is also play a crucial role in turn down current speed and wave so it can minimize sediment transport in the beach and resulting mangrove will grow in the shoreline area (Hendomi *et al*. 2015). Sediment transportation process in the beach will give the bad impact on beach slope change, evenmore, it will disturb the beach dynamic system. If the dynamic were disturbed, it will result on adding more beach area and beach erotion and immulsive sedimentation will occur (Degen *et al*. 2018).

a. Pasir Padi Beach

Pangkalpinang City is a city that has a coastal area on the Bangka Belitung Islands. Pangkalpinang City has several beaches, including Pasir Padi Beach, Tanjung Bunga Beach, and Sampur Beach. Pasir Padi Beach experiences changes every year. Based on research results, Padi Sand Beach experiences an average abrasion of 2.24 m/year. This occurs due to natural and human factors. Naturally, the abrasion that occurs on Pasir Padi Beach is caused by the erosion of sea water, while what is caused by humans is development in areas along the coast. According to Rijn (1993), sediment transport in coastal areas is influenced by a combination of hydrodynamic factors, while Triatmodjo's opinion (1999) is that physical sediment transport is influenced by interactions between tides, wind, waves, currents, type and size of sediment, and the presence of buildings in coastal areas. . The dominant changes occur in the river estuary area, at Pasir Padi Beach there is a fairly large river, precisely on the border between Pangkalpinag and Bangka Regency and also the entry and exit point for ships to anchor. Sediment transport that occurs in riverbeds is closely related to surface soil erosion caused by rain. Landslides caused by water seeping into the ground can enter rivers and have a big influence on the amount of sediment transported in rivers. This process is a cycle related to soil erosion, namely sediment transport and then settling. This sedimentation will result in shallowing which can disrupt transportation channels and make waters difficult to navigate due to changes in water depth and changes in shoreline configuration (Munandar 2014).

b. Tanjung Bunga Beach

Every year, abration occurred in Tanjung Bunga Beach. Based on figure 6, abration average arroud Tanjung Bunga Beach area was 3.37 m/year. This abration occurred because this area had strong current pressure so the sediment transport was massive and mangrove deforestation was also widely occurred to open the access for fishermen`s vessel anchored. Pond and Pickard (1983), stated that moving water mass from one place to another place either verticaly or horizontally will move to south, this was happened due to Coriolis law. Current movement in Bangka Island moved from north to south (Pamungkas 2018). Based on that theory, current pressure occurred will result on parallel current on the beach and the highest pressure will be be on the bay because that position was the highest parallel position in line with the beach. Mangrove deforestation was also impact the change of dynamic in coastal area, because mangrove can diminish the wave energy so materials on the beach was not scrapped by sea water. Current from the tide was not give a significant impact on beach morphology change, However, it can bring the sediment along the beach area that play a role in construct the topography (Akbar *et al*. 2017).

c. Sampur Beach

Sampur Beach had also experienced change every single year, either abration or accretion. Abration in Sampur Beach was more dominant,

while the accretion occurred on the border of estuary between Pangkalpinang city and Bangka Tengah regency. Based on figure 6, it can be seen that on 2000 to 2022, the abration average in Sampur Beach was 2.28 m/year. Shoreline change in Sampur Beach occurred because of tin minning activity (Inconventional tin minning) in coastal areas, river, and estuary. Because of this activitiy, the base of Sampur Beach has changed either in accretion or abration. This process will impact beach areas because if the surface is deeper, the beach material will transport to the beach which supported byb current tide or abration. Syari (2008) explained that almost all riber, estuary, and coastal areas in Bangka Island has shifted to waste container from tin minning. The sedimentation occurred in the waters can impact the abration and accretion on seabed and beach. Sedmentation was occurred due to the tin mining at the upstream and along the beach in Bangka Island. Due to the massive minning activity along the beach has caused the deepening process in some parts of the beach due to the removal of seabed soil and accumulation of soil grains in some part (Prianto and Husnah 2009).

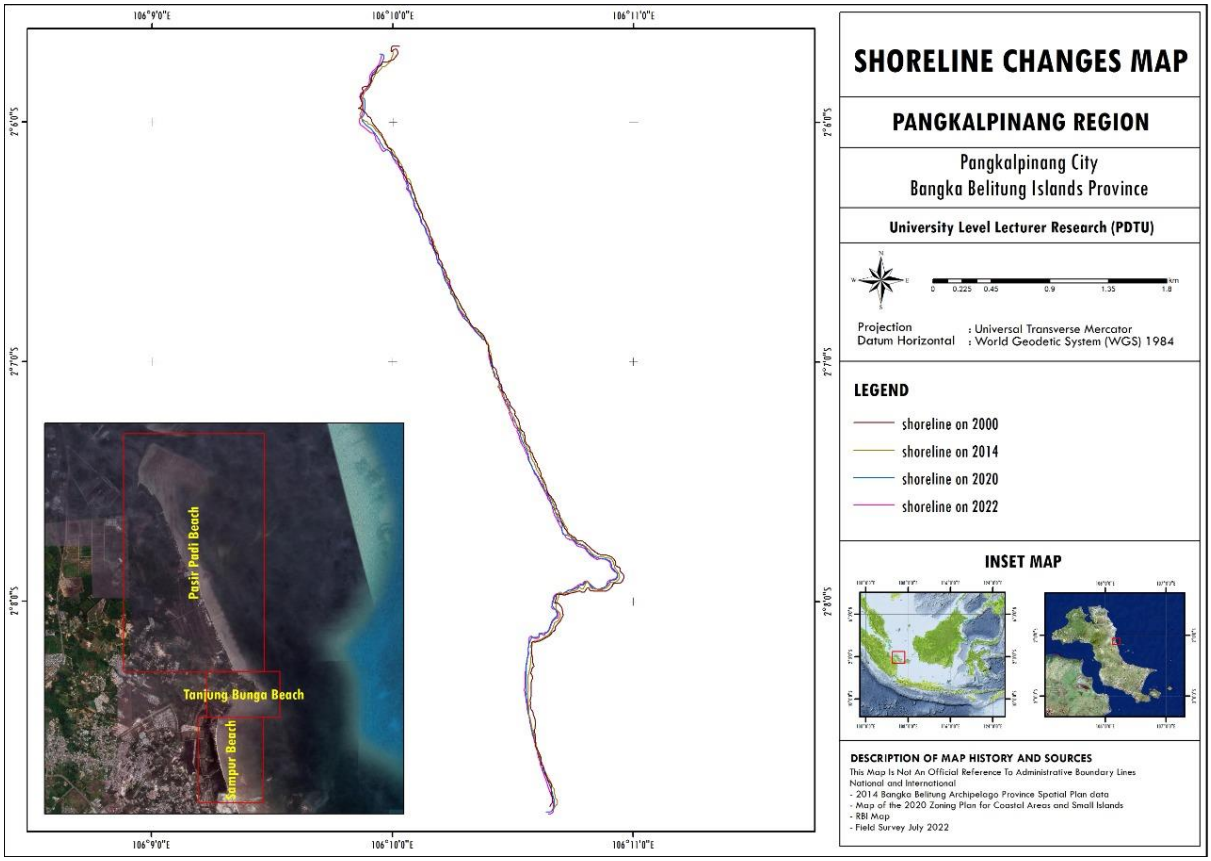


**Figure 5.** Mapping of Coastalline at Pangkalpinang City in 2000 – 2022

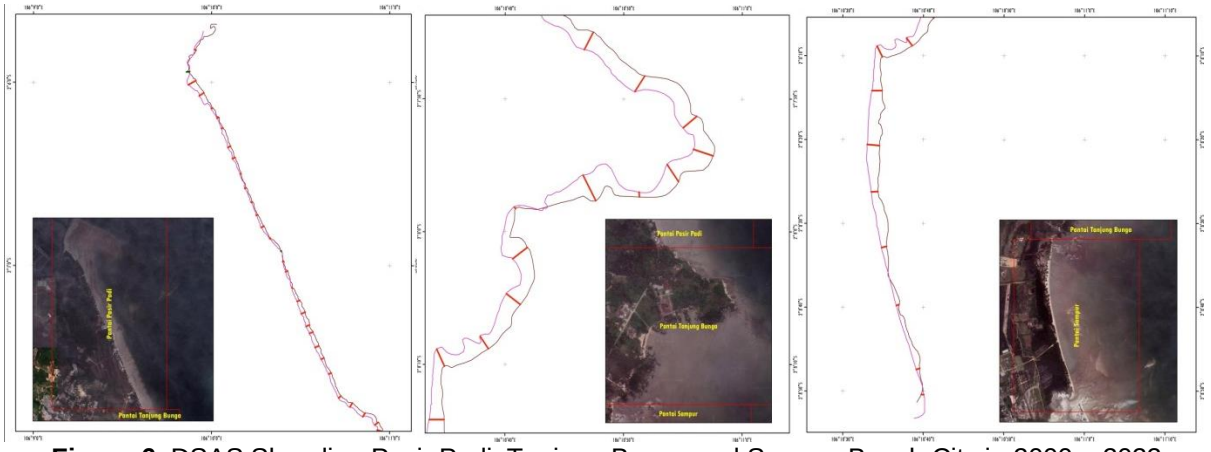

**Figure 6.** DSAS Shoreline Pasir Padi, Tanjung Bunga and Sampur Beach City in 2000 – 2022

**Table 2.** Abration and Accretion in Pangkalpinang Coastline

| Years | Abration (m/year) | | | Accretion (m/year) | | |
|---|---|---|---|---|---|---|
| | Maks | Min | rata-rata | Maks | Min | rata-rata |
| 2000-2014 | 2.8050 | 0.0021 | 1.1485 | 3.0471 | 0.0414 | 1.0447 |
| 2014-2020 | 5.1271 | 0.1114 | 2.5972 | 3.3633 | 0.2339 | 1.9093 |
| 2020-2022 | 7.4279 | 0.1839 | 2.1738 | 3.7649 | 0.3470 | 1.5258 |
| 2000-2022 | 7.4763 | 0.3922 | 2.5577 | 2.8907 | 0.4791 | 1.6849 |

## CONCLUSION AND SUGGESTION

The conclusions that can be drawn from the research o\are, there were shoreline changes at Pangkalpinang City each year, either abration or acretion. Shoreline position change in coastal area in Pangkalpiang from 2000 – 2022 was the accretion with highest accretion was approximately 63.59 m and shoreline change rate was 2.89 m/year on transect 2 at Pasir Padi Beach area, while the highest land mass decreasement (abration) in coastal area in Pangkalpinang occurred around Pasir Padi Beach Area with -164.47 m abration with shoreline change rate was 7.48 m/year, followed by Tanjung Bunga Beach on transect 34 which was approximately – 124.6 m with shoreline change rate was 5.66 m/year, and -81 m on transect 39 in Tanjung Bunga with shoreline change rate was 3.68 m/year. Abration change rate average in coastal area in Pangkalpinang on the whole sector A (Pasir Padi Beach), sector B (Tanjung Bunga Beach), sector C (Sampur Beach) was 2.5 m/ year while the accretion was 2.89 m/ year. The increasment of shoreline change rate in Pangkalpinang was caused by sedimentation from wave breaker and the increasement of sea level.

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