

# Coastal Erosion Monitoring Along the Coast of Negeri Sembilan, Malaysia

**M.A. Zaidi<sup>1,2</sup>, M.R.M. Adib<sup>1\*</sup>, I.B. Isha<sup>2</sup>, Mo Wang<sup>3</sup>, N.F.M. Zulkifli<sup>1</sup>**

<sup>1</sup> Faculty of Civil Engineering and Built Environment,  
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

<sup>2</sup> Department of Civil Engineering,  
Politeknik Port Dickson, KM. 14 Jalan Pantai, 71050 Si Rusa, Negeri Sembilan, MALAYSIA

<sup>3</sup> College of Architecture and Urban Planning,  
Guangzhou University, Guangzhou 510006, CHINA

\*Corresponding Author: [adib@uthm.edu.my](mailto:adib@uthm.edu.my)

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## Abstract

Coastal monitoring, mapping and analysis are comprehensive for various coastal studies, such as advancement of regression planning, geohazard identification, decomposition-enhancing research, and theoretical or predictive modelling or coastal characterization. The objectives of this research were to identify the overview of coastal erosion monitoring along the coast of Negeri Sembilan, Malaysia. The coastal erosion assessment approach includes the creation of sediment cells for the coastal area, as well as the collecting and examination of secondary data related to the research areas. Categorization of erosion has been concluded based on locations of study area. Category 1 erosion was discovered along the coastline at the PD Waterfront, Batu 1, Jalan Pantai Port Dickson, The Regency Tanjung Tuan Beach Resort (Batu 5), Tanjung Gemok, Kampung Gelam, and Pantai Teluk Kemang (Batu 8). Pantai Tanjung Gemok, a prominent recreational beach, is currently experiencing groyne erosion downdrift. Apart from that, a groyne is being eroded downdrift in Pantai Regency Batu 5, Negeri Sembilan.

## 1. Introduction

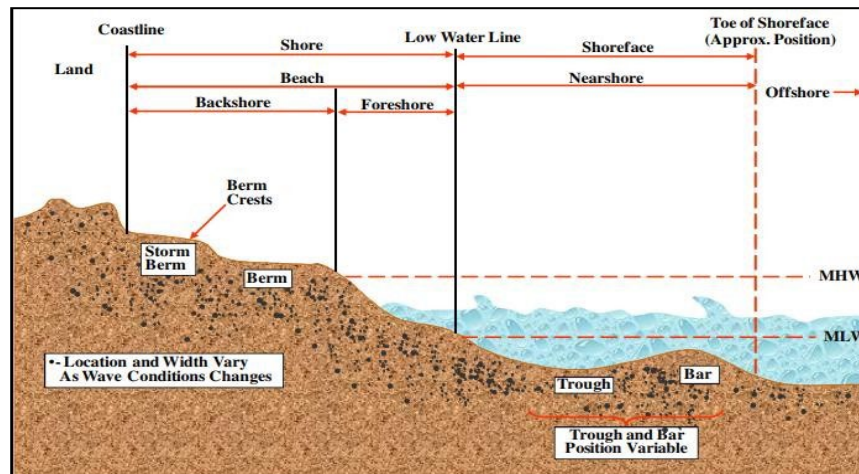
Coastal erosion is a major environmental issue that affects not only Malaysia but the entire world. The coastal zone is one of the most extensive coastal networks, with a wide variety of non-living and living components [1,2]. Over time, natural processes and human-made activities have played a significant role in altering the environment of coastal areas. A limited stretch of land and wetland immediately adjacent to the shoreline is characterised as a coastal zone; a line where the sea and the land meet. Shoreline lines are the land-sea interface that shifts unpredictably in reaction to one or more causes in nature, such as morphological, climatic, or geological factors [3]. The DID Manual defines the coast as the strip of land that extends inland from the beach to the first significant change in the terrain features that are unaffected by coastal processes [4]. As instance, coastline extraction gives critical information on the land-water border, allowing for the detection and monitoring of symptoms of coastal erosion or accretion. Backshore, foreshore, nearshore, offshore, beach, and berm are some of the landscape units that make up the coastal area. Consequently, coastal changes are predominantly driven by a variety of elements, including tides, winds, waves, water currents, sediments, and oceanic temperatures, among others, all of which are classified as constantly evolving processes and are responsible for the changes in the environment [5]. Several variables influence shoreline changes, including hydrodynamic changes like river cycles and sea level rises,

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geomorphological changes like barrier island formation and split growth, and other factors including sudden and rapid earthquake activity and storms. Thus, coastal monitoring is necessary to give critical information about the current state of a country's coastal areas by studying changes occurring along its boundaries.

The state of Negeri Sembilan is divided into seven (7) districts, which are Seremban, Port Dickson, Tampin, Kuala Pilah, Rembau, Jelevu, and Jempol, with Seremban serving as the capital. The state has a total land area of 665,374.77 hectares and a coastline that stretches for 61.28 kilometres. According to the National Coastal Erosion Study (NCES) completed in 2015, some of the shoreline has been eroded. [6] concluded that the urbanisation of coastal areas is necessitated by the expansion of the coastal zone as a result of population increase and societal needs. The consequences of rising risk exposure and ecological decline, as well as being subjected to considerable anthropogenic pressures, are more likely to produce long-term modifications [7, 8].



**Fig. 1** Classification of coastal zone (USACE, 2002)

As shown in a study based on 25 years of National Aeronautics and Space Administration (NASA) and European satellite data using satellite altimeter measurements, global sea-level rise has been accelerating in recent decades, rather than rising steadily. This is primarily due to increased melting in Greenland and Antarctica, as well as increased melting in the Arctic and Antarctic. When compared to the constant rate of sea-level rise projections, this acceleration has the potential to more than double the overall sea-level rise expected by 2100. It was so estimated that sea level is anticipated to rise by around 65 cm by 2100, posing a major threat to coastal cities and their infrastructure [9]. Sea-level rise may increase the vulnerability of low-lying places to erosion, resulting in the loss of beaches and tidal habitats. As a result, coastal changes are crucial environmental indicators since they can have a big impact on the city's economic growth and land use planning. Subsequently, coastal monitoring is required in order to give valuable information about the current circumstances of a country's coastal areas by studying changes that are occurring along its boundaries. The present study aimed to review and identify coastal erosion problems including rate of erosion per year, coastal types and existing coastal defense along the Negeri Sembilan coastline.

## 2. Materials and Methods

The coastal erosion assessment approach includes the creation of sediment cells for the coastal area, as well as the collecting and examination of secondary data related to the research areas.

### 2.1 Data Collection

The Negeri Sembilan coast is divided into three sediment cells: A (Sg. Sepang – PD Headland), B (PD Headland – Tg. Tuan), and C (PD Headland – Tg. Tuan) (Tg. Tuan to Sg. Linggi). After reconnaissance of the entire Negeri Sembilan coast, topographic maps, aerial oblique, vertical aerial picture mosaics, and the most recent remote sensing data were used to divide the area into sub-cells and microcells. Some of the lines are clear, while others are more ambiguous. Some of the boundaries, particularly for the smaller sediment compartments (microcells), are subjective, and the problem of subdivision is exacerbated by coastal disturbance caused by land reclamation and coastal structure construction. Table 1 lists the detailed distinction of cells, sub-cells, and microcells, respectively.

**Table 1** List of sediment cells

Sediment Cell	Sub-Cell/Extent
Lukut (Sg. Sepang – P.D Headland)	A1: Sg. Sepang – Bt Keramat A2: Bt. Keramat – Tg. Gemok A3: Tg. Gemok – PD Headland
Port Dickson (P.D Headland – Tg. Tuan)	B1: PD Headland – Avillion Headland B2: Avillion Headland – Si Rusa Kecil Tombolo B3: Si Rusa Kecil Tombolo – Admiral Cove Breakwater B4: Admiral Cove Breakwater – Bt. Tg. Kemang B5: Bt. Tg. Kemang – Tg. Tanah Merah B6: Tg. Tanah Merah – Tg. Tuan (Pulau Intan)
Pasir Panjang (Tg. Tuan – Sg. Linggi)	C1: Tg. Tuan (Pulau Intan) – Tg. Menyala C2: Tg. Menyala – Tg. Selamat C3: Tg. Selamat – Sg. Linggi

From Sg. Sepang to the Port Dickson headland, Lukut Cell A is a narrow indented harbour that stretches for approximately 21 kilometres. In the Port Dickson area, Cell B stretches for approximately 21 kilometres from PD Headland to Tg. Tuan and is distinguished by submerged laterite beach platforms that extend from headlands and rugged shores. This Cell has been the focal point of tourism growth as well as government assistance in the areas of protection and preservation. The small bay that extends from Tg. Tuan to Tg. Serai in Melaka is a popular tourist destination. Pasir Panjang Cell C, on the other hand, is comprised of the Negeri Sembilan portion of the bay, which has a length of 19 kilometres.

In parallel with the site visits to the eroding sites, shoreline sediment samples were obtained at several locations along the coastline. These samples provide information about the type of in-situ shoreline material present, as well as the distribution of sediments in the shoreline. The samples were then transported to a soil testing facility where they were subjected to a Particle Size Distribution (PSD) analysis.

The use of secondary data is critical to the effective completion of this research. These data, including aerial photography of the coastline, satellite pictures from various years, met-ocean data, shoreline management plans, erosion control design plans and other associated papers have been determined as being of significant importance for this investigation. Site visits are an effective means of determining the current status of the coastline. In order to gain a first-hand description of the state of the shoreline, it is possible to hold discussions with local people and users of the beach. It is possible to make observations about the type of material, the gradient, and the erosion and accretion features along the coastline. Site inspections were conducted in regions that had been recognized as having a significant level of erosion. Aerial photography allows for a significant amount of ground to be covered in a short amount of time. It is possible to determine the land use features of the coastline and its backshore by taking oblique aerial images. These photographs serve as a complement to remote sensing images as well as photographs shot on site. Using unmanned aerial vehicles (UAVs), pilots can capture photographs of superior quality that are comparable to or even superior in detail to images captured using conventional aerial imagery. UAV surveys are perfect for monitoring the effects of coastal erosion at a considerably greater level of accuracy than traditional methods. In addition, engineers will be able to access the sort of changes that are occurring and, in turn, study the effects on the environment as a result of the high- quality imaging. This is accomplished through the use of remote sensing and geographic information system (GIS) techniques. It is possible to assess the movement of the shoreline by using satellite pictures of the area. Given that satellite photos are relatively new and have reasonable accuracy when compared to nautical charts and topographic maps, they are still deemed superior. Worldwide, there are many different types of satellites that can record photographs of the earth's surface, including the shoreline. These images can be used to help researchers to understand climate change.

## 2.2 Morphology

Based on the information gathered from the data collection, this part presents the morphological baseline conditions at regional scales. The Lukut Cell has a circular form that faces south to west clockwise. Wide mud flats areas stretch a few kilometres offshore, with sea depths ranging from -3 metres to 0 metres MSL. The area can be divided into three sections; mangrove forest and mud flats dominate the area west of Sg Lukut Besar. The Jimah power station, built on shallow mud flats to the east of the Sg Sepang entrance, is part of this section. Behind the reclamation, the primary mangrove line has been preserved. A mangrove area with mudflats and a number of aquaculture ponds lies east of Sg Lukut and extends up to Sg Lukut Kecil. The coastal portion to the east is more developed (power station, oil terminal, jetty facilities, tourist resorts and urban development). There are no mangroves visible, implying that they have been cleaned. A variety of protection structures, particularly seawalls,

are located here to guard against localised erosion. A few sandy pocket beaches can also be found along this stretch of coastline. Port Dickson Cell is a well-developed region with many tourist complexes and public beaches. Since the southern section of PD Township sits on the northern end of this cell, it is densely populated. The number of natural elements such as natural rocky headlands and protrusions, as well as man-made constructions (marinas, reclamation, coastal protection structures, and so on) that divide the cell into few compartments, make this stretch highly complex. Pasir Panjang Cell is a circular coastal cell that faces S on the northern end and SW adjacent to Sg Linggi on the southern end. The northern region has sandy beaches, while the area around the PD Sanctuary is known for its huge mud flats covered by mangrove forest. In the middle, there's a transition zone with pocket beaches made up of sand and fine particles. Sg Linggi produces huge amounts of suspended sediments, which settle in the calm areas around the river's mouth. The tidal flats are intermittently dry or submerged depending on tide levels, as is typical of the Negeri Sembilan coast. The water levels affect wave penetration since most of the beach profile is under water at high tide and dry at low tide. There are no big man-made constructions or projects in this cell; nevertheless, certain tourist sites may be found around Tg Tuan in Pantai Cermin and at the Palm Springs Resort near Sg Menyala. The native mangrove forest in this last section has been destroyed, and it is now prone to erosion and a source of fine sediments during rainstorms. Figures 2, 3, and 4 represent an overview of the selected sediment cells.

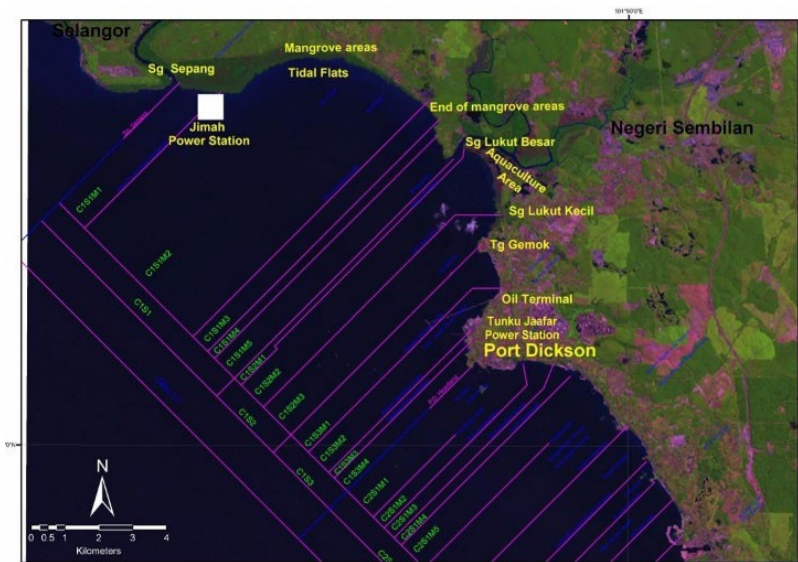


Fig. 2 Overview of Lukut Cell

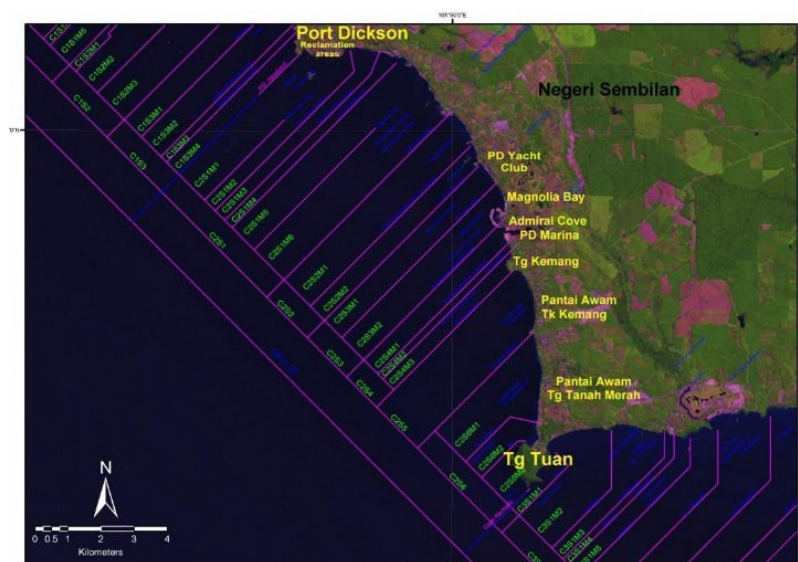
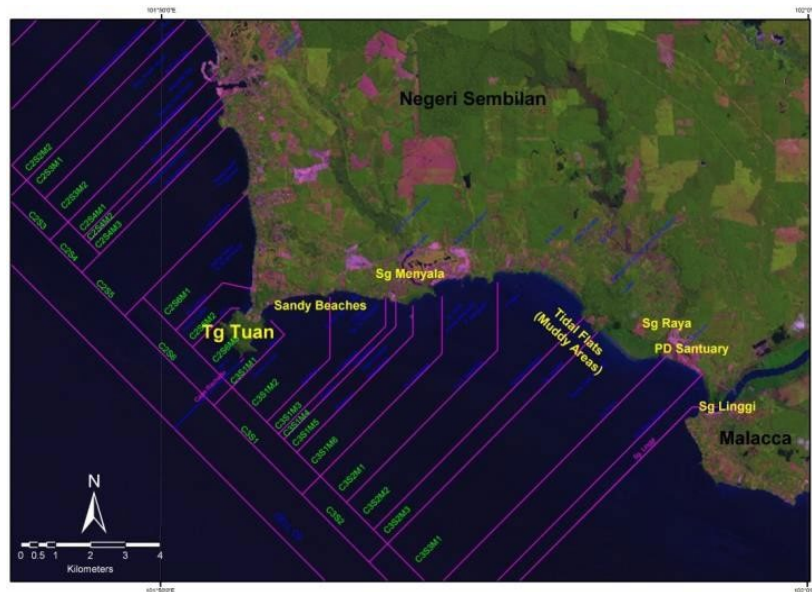


Fig. 3 Overview of Port Dickson Cell



**Fig. 4** Overview of Pasir Panjang Cell

### 3. Results and Analysis

#### 3.1 Beach Profile

Tidal levels are important in Lukut Cell because the wide mud flat areas dry out and flood as the tides rise and fall. At high tide, the majority of the beach profile is submerged, whereas at low tide, it is dry. Wave penetration into the beach is influenced by water levels, with waves only being able to propagate to the beach at high water and breaking offshore in the steeper part of the profile during low water. The northern parts of Port Dickson Cell's beach profiles are flat and wide, whereas the southern stretches are narrower and steeper. During high and low water levels, the beach in the northern section is subject to flooding and drying. As with Cell, wave penetration is heavily influenced by water levels, with waves only being able to propagate into nearshore locations at high water levels. Waves break offshore on the steeper area of the profile at low tide. The beach profile is steeper in the southern regions; therefore, it is less affected by tide changes. As a result, flooding and drying are less of a concern in this area.

#### 3.2 Erosion Categorization

It is a public policy problem to address coastal erosion, as it has been shown that shoreline retreat will result in economic losses of varied magnitudes. According to the findings of this study, the erosion categorization system presented should consider not only the physical severity of erosion, but also its economic relevance as the coastline retreats. As a result, the approach that has been adopted is a composite measure that accounts for both the physical rate of coastal erosion and the economic impact of coastal erosion. Table 2 below shows the erosion categorization along Negeri Sembilan coastline.

**Table 2** Erosion categorisation for Negeri Sembilan

Location	Length of eroded shoreline (m)	Erosion rate (m/yr)	Physical erosion score	Erosion category
Pantai Teluk Kemang, Batu 8	2314.7	10.2	5.00	1
Tanjung Gemok	1621.8	21.9	5.00	1
The Regency Tanjung Tuan Beach Resort, Batu 5	459.1	3.9	4.00	1
Kampung Gelam	264.0	4.7	5.00	1
PD Waterfront	131.9	3.7	4.00	1
Batu 1, Jalan Pantai Port Dickson (east)	734.4	3.7	4.00	1
Taman Pantai Mas	958.8	31.3	5.00	2
PD Sanctuary Apartment and Training Camp	848.8	3.6	4.00	2
Pantai Cahaya Negeri, Batu 4	196.8	2.1	3.00	2
Sunshine Bay Resort	123.5	2.2	3.00	2
Batu 1, Jalan Pantai Port Dickson (west)	478.1	3.3	4.00	2
Shell Staff Club House & Conference Centre	199.4	2.0	3.00	2
Pantai Bagan Pinang	439.7	2.0	2.00	2
Pantai Saujana	796.7	1.3	2.00	2
Batu Melintang	201.6	3.8	4.00	3

### 3.3 Criteria for Determining Erosion Category

On a scale of 1 to 3, this study suggests a three-category erosion classification. The category, intuitively, corresponds to the severity and result of erosion. As a result, the categorization method assigns a greater severity grade to a rapidly eroding densely populated coastal stretch than to a slowly eroding sparsely populated area. In general, when the rate of coastline retreat accelerates and economic significance grows, the coastal length under consideration moves up the erosion hierarchy. On the other hand, a slow rate of coastline retreat and a little economic impact result in a lower erosion category. Other combinations of shoreline retreat rate and economic significance are classified as intermediate erosion categories. The proposed range of values for each erosion category is based on a series of iterations of probable ranges of values for a small sample of coastal segments. Because there is no widely defined erosion category used by countries around the world, the iterative procedure is used. This is understandable given that, due to differences in pricing, productivity, expenses, and property values, the severity of erosion and its economic repercussions can vary greatly around the world. The purpose of the iteration process is to make sure that the categories that emerge provide a reasonable and practical indication of erosion severity. The iteration procedure entails evaluating various end values for each range until the ranges are selected to represent the "Low" to "High" classification. The practice of changing end values is repeated until such abnormalities are eliminated. Table 2 presents the recommended category of erosion, which is based on the iterative process described above. In addition, a representative description of typical locations classified under each category is supplied to assist in understanding the intuitive meaning of the classification system. However, the representative description is not intended to be a definitive and limiting definition of what is indicated by the various erosion categories. Its purpose is to evoke imagery of each erosion category.

**Table 3** Description of erosion

Category	Score Range	Representative Description of Typical Areas
1 (High)	Greater than 12 points	Fast retreating coastline at the rate of more than 4 m/year with fairly dense human settlement, some commercial/ industrial activities and served by significant public infrastructure and facilities.
2 (Medium)	Greater than 5 points and lower or equal to 12 points	Retreating coastline at the rate of between 1 and 3.9 m/year with sparsely-populated area, some agricultural activities and served by relatively minor public infrastructure and facilities.
3 (Low)	Lower than or equal to 5 points	Slowly retreating coastline of less than 1 m/year with no human settlement, minimal agricultural activities and not served by public infrastructure and facilities.

### 3.4 Physical Parameter

In order to classify each site that has been recognised as being in a condition of erosion according to its erosion category, the rate of shoreline retreat is the most important physical criterion to consider. The pace of shoreline retreat was classified into three groups, which were labelled "Low," "Medium," and "High," according to the scoring system. The rate of coastline retreat was determined by analysing satellite photos of the same area taken during two consecutive events. The rate of coastline retreat was calculated by calculating the difference between the two occurrences. It is regarded to be experiencing high rate of erosion when a shoreline's erosion rate exceeds 4 metres per year. A coastline receiving 5 points is deemed to be experiencing high rate of erosion. Therefore, swift or immediate action must be made in order to guarantee that there is sufficient time to put in place appropriate mitigation measures in order to stop the erosion from progressing. This is particularly applicable in circumstances when the land immediately behind the eroding shoreline is densely populated, productively farmed, or where critical infrastructure is present and/or of significant economic worth. Any site with an erosion rate of less than 1 m/year is referred to as having a low erosion rate, and it is assigned a score equal to the rate of erosion that really occurs on the site. According to the assumption that the area behind the coastline is experiencing a low rate of coastline retreat, there is plenty of time to ameliorate the erosion of these eroding sites while valuable time and resources can be diverted to intervene in the high rate of coastal retreat locations. The erosion rates in areas with a medium pace of retreat range between 1 and 3.9 m per year. As shown in the table below, the scoring is divided into three bands: 1 to 1.9 m/year, 2 to 2.9 m/year, and 3 to 3.9 m/year.

**Table 4** Scoring for rate of coastline retreat

Physical parameter	Description	Erosion rate (m/year)	Score
Rate of coastline retreat	Low	< 1	Actual erosion rate (m/year)
	Medium	1 to 1.9	2 points
		2 to 2.9	3 points
		3 to 3.9	4 points
High	> 4	5 points	

### 4. Conclusion

The methodology for analysing shoreline changes within the research region makes use of cutting-edge technology, which is reflected in the results. It is proposed that the methodology for studying shoreline changes within the research region combines the use of remote sensing and geographic information systems (GIS) techniques, as well as other suitable thematic maps for the purpose of ground truthing. When mapping at different spatial resolutions, resampling techniques were used to ensure that the mapping could be carried out correctly. It was required to apply corrections to the satellite data while processing the data in order to remove data inaccuracies created by the sensor as well as the distorting effects of atmospheric conditions, which were both present at the time of collection. It was necessary to do geometric correction in order to remove distortion from an image, which was accomplished by bending the image to meet a map projection. When two photos of similar geometry and of the same geographic area are placed coincident to one another, related elements of the same ground area appear in the same location as they did in the registered photographs. During the rectification process, a map coordinate is assigned to each pixel. The geometrically corrected image can be used as a base map for on-screen digitising after it has been geometrically rectified. Comparing photos of the same site taken at multiple times

over a period of time can reveal changes in the coastline within the research region. The coastal polyline from a different time period can be placed over the base map to give a fresh perspective. After that, a pan-sharpening technique was used to improve the resolution of the image. Most of the time, this method results in a high-resolution photograph with natural coloration. This is a relatively time-consuming and demanding technique. Two photos are exhibited and overlaid together using ArcGIS software, allowing the shoreline position to be observed on each of the dates depicted. After that, each photograph was subjected to a meticulous on-screen digitization of the shoreline. The location of the shoreline was highlighted in order to determine whether there were any erosion or accretion regions along the coast. The difference in coastline displacement between two separate eras is calculated using the measurement tool in ArcGIS and is expressed in metres between the two periods.

This study acknowledges that there are certain to be some characteristics of worth that the rating system does not represent completely or sufficiently. This is understandable given the rarity of certain value dimensions and their occurrence under exceptional circumstances. Due to their rarity, including them in the rating system is inefficient. These unusual value dimensions can only be considered in exceptional circumstances, which is why they are referred to as special considerations. The erosion sites along the coastline of Negeri Sembilan were represented in Figure 2. Category 1 erosion was discovered along the coastline at the PD Waterfront, Batu 1, Jalan Pantai Port Dickson, The Regency Tanjung Tuan Beach Resort (Batu 5), Tanjung Gemok, Kampung Gelam, and Pantai Teluk Kemang (Batu 8). Pantai Tanjung Gemok, a prominent recreational beach, is currently experiencing groyne erosion down-drift. Apart from that, a groyne is being eroded down-drift in Pantai Regency Batu 5, Negeri Sembilan. Geobags were utilised to help with erosion control, but several of them were found to be perforated. Furthermore, near Kampung Gelam, Port Dickson, dying mangrove stands are interspersed throughout the developed shore.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.*

## References

- [1] Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B. & Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630), 253- 260.
- [2] Aedla, R., Dwarakish, G. S., & Reddy, D. V. (2015). Automatic shoreline detection and change detection analysis of Netravati-Gurpur rivermouth using histogram equalization and adaptive thresholding techniques. *Aquatic Procedia*, 4, 563-570.
- [3] Mujabar, P. S., & Chandrasekar, N. (2013). Shoreline change analysis along the coast between Kanyakumari and Tuticorin of India using remote sensing and GIS. *Arabian Journal of Geosciences*, 6(3), 647-664.
- [4] Department of Irrigation and Drainage Malaysia. (2009). Coastal Management. *DID Manual: Vol 3*.
- [5] USACE (United States Army Corps of Engineers). (2002). Coastal engineering manual. *Engineer Manual 1110-2- 1100*.
- [6] Balica, S. F., Wright, N. G., & Van der Meulen, F. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural hazards*, 64(1), 73-105.
- [7] Bagli, S., & Soille, P. (2003, October). Morphological automatic extraction of Pan-European coastline from Landsat ETM+ images. In *International symposium on GIS and computer cartography for coastal zone management* (pp. 256-269).
- [8] Mills, J. P., Buckley, S. J., Mitchell, H. L., Clarke, P. J., & Edwards, S. J. (2005). A geomatics data integration technique for coastal change monitoring. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group*, 30(6), 651-664.

- [9] Weeman, K., & Lynch, P. (2018). New study finds sea level rise accelerating. *NASA*, 13 02 2018. [Online]. Available:<https://climate.nasa.gov/news/2680/new-study-finds-sea-level-rise-accelerating/>. [Accessed 24 9 2018].