ASSESSMENT OF THE DEVELOPMENT AND COASTAL EROSION ALONG THE SOUTHERN COASTLINE OF TERENGGANU

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Assessment of the Development and Coastal Erosion along the Southern Coastline of Terengganu

by

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the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by:

(Ahmad Mustafa bin Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD HAZWAN BI MOHMAD RAZALI

ABSTRACT

An understanding and knowledge of coastal environment and processes involved is necessary for any coastal management or planning and coastal engineering endeavour especially when dealing with the coastal erosion problem. The main objectives of this study are to carry out assessment on the current state of erosion, determine the causes of coastal erosion and evaluate the performance of existing protection measures. The study covers approximately 84 km long of shoreline in southern part of Terengganu. The erosion profile, coastal features and process, environmental data, causes of erosion, erosion control measures and some previous studies are discussed in the literature review part as a basis for the assessment of the current state of erosion in the study area. The data and information from local authority, journals, reports, text books and also local communities were collected throughout the year. Samples of beach sediment are collected during the site visit. The samples are then tested in the laboratory through dry sieve analysis. The test is conducted to determine the average size, type and particle size distribution of the beach sediment. The results are analyzed and combined with other data to classify the state of erosion into one of the erosion categories (critical, significant and acceptable). Possible longshore sediment transports are calculated at several locations where the erosion is critical and significant. From the trend in beach profile, particle size, beach width and beach slope, it can be concluded that many locations in southern coastline of Terengganu are still facing significant and critical erosion. The results of this study provide valuable data and information for further research and implementation.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

NCES : National Coastal Erosion Study

NRMS : National River Mouth Study

DID : Department of Irrigation and Drainage

TNB : Tenaga Nasional Berhad (National Electricity Corporation)

NCECC : National Coastal Erosion Control Council

CETC : Coastal Engineering Technical Centre

MMD : Malaysian Meteorological Department

Units of Measure

m : meter

km : kilometer

m^2 : square meter

m^3 : cubic meter

km^2 : square kilometer

yr : year

Malay Terms

Kg. : Kampung (= Village)

Kuala : (= River mouth)

Tg. : Tanjung (= Headland)

Pantai : (= Beach)

Teluk : (= Bay)

Pulau : (= Island)

Sungai : (=River)

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia relies heavily on the rich natural resources of its coastal areas. The coastal zone of Malaysia has a special socio-economic and environmental significance. Abdullah (1993) says that more than 70% of the population lives within the coastal area and a lot of economic activities such as urbanization, agriculture, recreation, eco-tourism, fisheries, aquaculture and oil and gas exploration are situated in this area. The coastal zone and its associated resources create a dynamic and sensitive natural environment that contributes significantly to the economic and social well being of the people of Malaysia.

Malaysia has about 4,809 km of coastline comprising two distinctly different physical formations, namely the mangrove fringed mud flats and sandy beaches. The east coast of Peninsular Malaysia consists of straight sandy formations in the north and a series of hook- or spiral-shaped bays to the south. The west coast of Peninsular Malaysia, however, comprises mainly muddy formations, with limited areas of pocket sandy beaches. In Sarawak and Sabah, the coastlines are about equally divided between sandy beaches and mud coast. The coastal zone is broadly defined as the areas where terrestrial and marine processes interact. This includes the coastal plains, deltaic areas, coastal wetlands, estuaries and lagoons.

1.2 Problem Statement

The effects of the increasing pressure in the coastal areas are degradation of the environment through pollution and unsustainable exploitation of coastal living and non-living resources. With 4,809 km of coastline and a large percentage of population living within 5 km from it, demands of developments and industrialization in these areas have made a very big impact on the resources and the coastline itself. "Erosion was identified as a national problem in the National Coastal Erosion Study (1986) with approximately 29% (1400 km) of Malaysia coastline was facing erosion" (Abdullah, 1993; Basiron, 1998 and Ghani Aziz and Mokhtar, 2003). Figure 1.1 illustrates the total length of shoreline and length of eroded shoreline of ach state in Malaysia.

According to Ghani Aziz and Mokhtar (2003) and Chonwattana, Naimsampao, and Saengsupavanich (2009), the coastal erosion is basically a natural phenomenon. However, apart from the hazards brought by natural phenomena, man-made activities have contributed significantly to the erosion of the coastlines. Activities and projects ranging from channel dredging, construction of harbor and dams, reclamation and sand mining have caused the alterations to the natural coastline, which in turn have severely affected the biophysical resources and the ecological functions of coastal areas. Development of coastal areas to serve important economic and social needs often interferes with coastal processes, causing the shoreline to respond differently and altering the natural erosion patterns.

Terengganu is also facing coastal erosion problem especially in the southern coastline. In some areas, the erosion has encroached and endangering the roads, infrastructure and other structures. On the other hand, the structures that were built on beach tend to increase the potential of coastal erosion. Another problem is that the existing coastal protection works such as the construction of engineering structures and beach nourishment are very costly and not always successful to deal with this situation. These problems require appropriate mitigation measures and related coastal protection works to reduce the effect and prevent the beach from erosion.

State	Length of Coastline	Length of Coastline Having Erosion			Total Length of Coastline	
		Category 1 CRITICAL EROSION	Category 2 SIGNIFICANT EROSION	Category 3 ACCEPTABLE EROSION	Having Erosion	
	(km)	(km)	(km)	(km)	(km)	(%)
State		Length Critically Eroded				
Perlis	20	4.4	3.7	6.4	14.5	72.50%
Kedah	148	31.4	2.2	9.9	43.5	29.40%
Pulau Pinang	152	42.4	19.7	1.1	63.2	41.60%
Perak	230	28.3	18.8	93.1	140.2	61.00%
Selangor	213	63.5	22.3	66.1	151.9	71.30%
N. Sembilan	58	3.9	7.7	12.9	24.5	42.20%
Melaka	73	15.6	15.1	6	36.7	50.30%
Johor	492	28.9	50.3	155.6	234.8	47.70%
Pahang	271	12.4	5.2	107.8	125.4	46.30%
Terengganu	244	20	10	122.4	152.4	62.50%
Kelantan	71	5	9.5	37.6	52.1	73.40%
W.P. Labuan	59	2.5	3	25.1	30.6	51.90%
Sarawak	1,035	17.3	22.3	9.6	49.2	4.80%
Sabah	1,743	12.8	3.5	279.2	295.5	17.00%
TOTAL:	4,809	288.4	193.3	932.8	1,415	29.41%
		6.0%	4.0%	19.4%		

Source : Department of Irrigation and Drainage of Malaysia

Figure 1.1: Total length of eroded shoreline of each state in Malaysia

1.3 Objectives of Study

The objectives of the study are:

(a) To assess the current state of erosion of the coastal areas.

(b) To observe the performance of the existing coastal erosion protection work.

(c) To assess the impact of the development of some protection work on the foreshore to the beach profile.

(d) To study the causes of coastal erosion as well as the effect to the structures, infrastructures and local communities.

(e) To provide recommendation for the improvement of the coastal areas.

1.4 Scope of Study

The scope of work for the study includes:

(a) Collection and review of available data and information from journals and previous studies related to the current study such as:

i. Meteorology and hydrology
ii. Coastal land use socioeconomic condition
iii. River mouth and shoreline condition
iv. Existing projects for river mouth improvement and coastal erosion protection

(b) Field Survey/Measurement and Analysis

i. Shoreline and river mouth surveys
ii. Socioeconomic survey
iii. Data and sample collection
iv. Shore material analysis (sieve analysis)

The study covers the area of approximately 83 km long of shoreline in southern part of Terengganu starting from Kg. Rantau Abang to Kg. Geliga Basar in Chukai. The whole area covers 6 major towns in Terengganu which are Dungun, Paka, Kerteh, Kemasik, Kijal and Chukai. Figure 1.2 shows the location of study area.

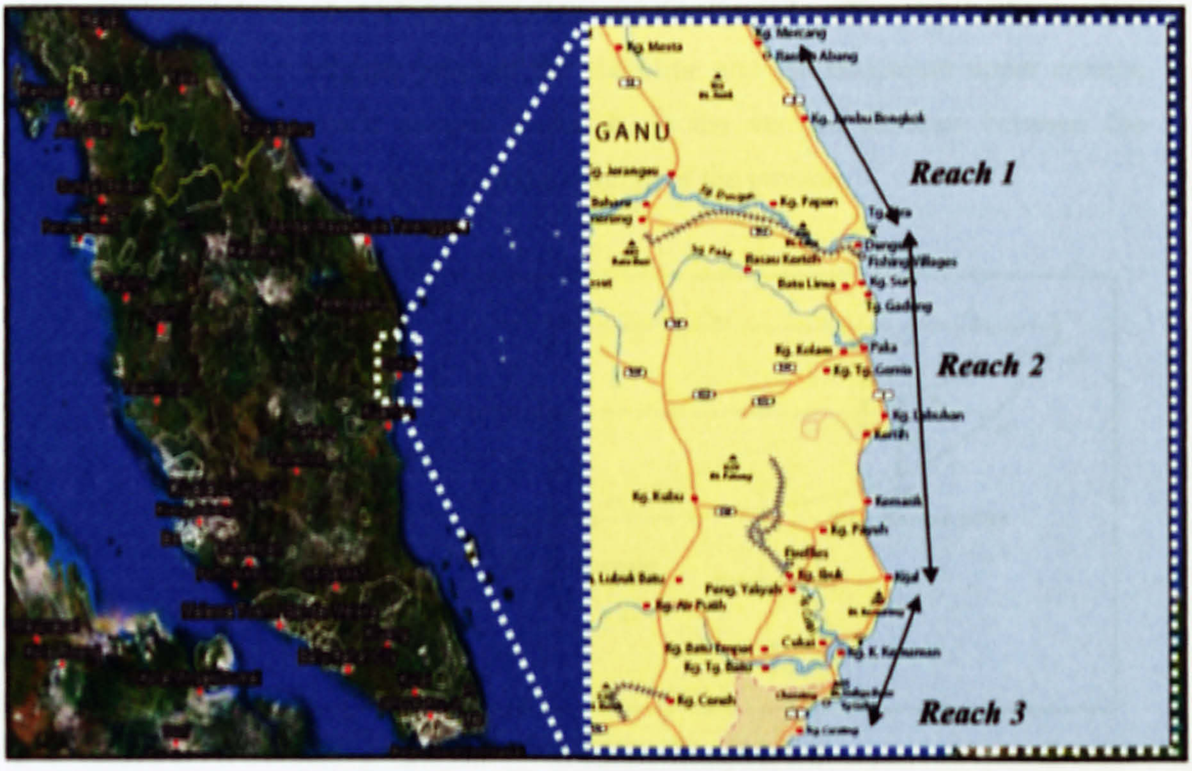


Figure 1.2: Location of study area

CHAPTER 2

LITERATURE REVIEW

2.1 Erosion Profile

Ozolcer (2008) explains that the beach profile is mainly affected by a number of parameters, such as wave height and period, beach slope, and the material properties of the bed. The characteristic of the typical beach erosion geometry is shown in Figure 2.1 below. As shown, $\mathbf{x_m}$ is the horizontal distance between the original point of the shoreline and the maximum upper erosion point, $\mathbf{x_e}$ is the horizontal distance between the original point of the shoreline and the equilibrium point, $\mathbf{x_s}$ is the horizontal distance between the original point of the shoreline and the final shoreline, $\mathbf{h_m}$ is the vertical distance between the original point of the shoreline and the maximum upper erosion point, $\mathbf{h_d}$ is the maximum erosion depth, $\mathbf{h_e}$ is the vertical distance between the equilibrium point and **SWL**, and **Ve** is the volume of the erosion.

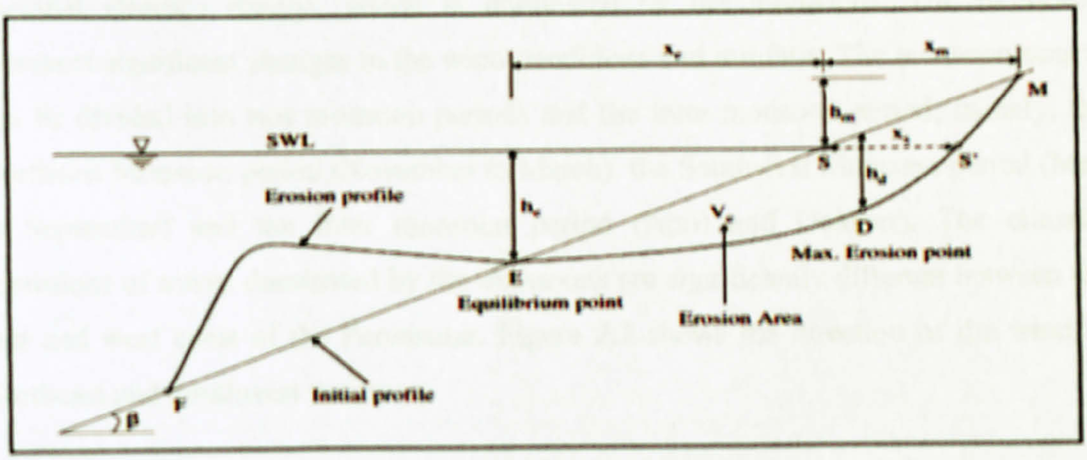


Figure 2.1: Beach erosion geometry

2.2 Transport Process

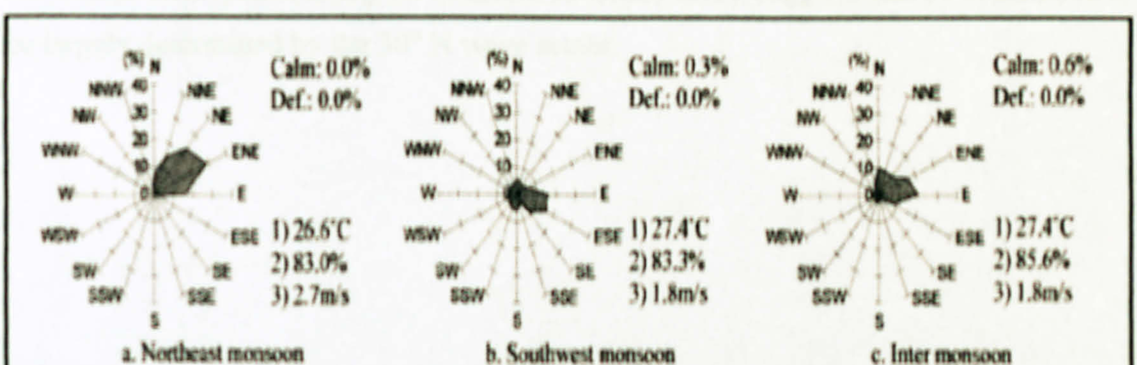
Rijn (1997) presented that mean currents such as tide-, wind- and density-driven currents carry the sediments in the direction of the main flow. This type of transport usually is termed the current-related transport. Besides, Vesterby has conducted study about the littoral transport and he says that littoral transport is divided into two general clauses which are transport parallel to the shore (longshore transport) and transport perpendicular to the shore (transversal transport). The material transported is called 'littoral drift'. Longshore transport results from the stirring of sediment by the breaking wave. The movement of this sediment is a function of the component of the wave energy in an alongshore direction, the longshore current generated by the breaking waves and the tidal variation. The direction of longshore transport is directly related to the direction of wave approach (the angle of the wave to the shore) and the tidal current. The rate of longshore transport is dependent on the generated longshore current, wave duration and energy. Transversal transport is determined primarily by wave steepness, sediment size, tidal variation, beach and sea bottom slope.

2.3 Climate Condition in Malaysia

Ahmad and Kobuta (2006) have investigated the climate condition in Malaysia. Their findings show that most towns in the Peninsular Malaysia experience high temperature and humidity throughout the year without remarkable variations. However, there is a seasonal climatic change, which is dominated by the monsoons. The monsoons represent significant changes in the wind conditions and rainfalls. The monsoon season can be divided into two monsoon periods and the inter monsoon period; namely, the Northeast Monsoon period (November to March), the Southwest Monsoon period (May to September) and the inter monsoon period (April and October). The climatic conditions of towns dominated by the monsoons are significantly different between the east and west coast of the Peninsular. Figure 2.2 shows the direction of the wind in Northeast and Southwest monsoon.

Figure 2.2: Wind direction of each monsoon period

Figure 2.3 below indicates the wind roses and summary of climatic conditions in Terengganu over the past 15 years (1988-2002). The indicated climatic data was calculated by averaging hourly values observed by the Malaysian Metrological Department (MMD). As shown, both the mean temperature and the mean relative humidity varied minimally throughout the year. By contrast, the direction and mean wind velocity change according to the monsoon periods. The mean wind velocities in Terengganu indicate 1-3 m/s. Figure 2.3 also shows that values of mean wind velocity in the inter monsoon period are similar with those in the southwest monsoon period. On the east coast of the Peninsular, the wind direction of the daytime sea breeze corresponds to those during the northeast monsoon period. Thus, in Terengganu, the wind directions observed during the northeast monsoon period prevail. The mean wind velocity during the northeast monsoon period is 2.7 m/s (Ahmad and Kobuta, 2006).



Note : 1) Daily mean temperature, 2) Daily mean relative humidity, 3) Daily mean wind velocity

Figure 2.3: Wind rose and climate summary in Terengganu

2.4 Coastal Features

In southern coastline of Terengganu, there are many coastal features such as straight sandy beach, hook-shaped bay, rocky headland, river mouth and sand spit. The most special feature is the hook-shaped bay. Klomp, Tilmans, and Vroeg (1993) have studied the formation of hook-shaped bay especially in Kerteh Bay. They found that once the sediment is being transported alongshore on a coast with headlands, it will form a curve logarithmic-spiral segment in the center, and a near circular section in the lee of the upcoast headland. Such bay shapes have been formed over thousands of years ago but have been eroded, or more greatly indented in the past hundreds of years due to reduction in sediment supply to the coast from rivers. In terms of stability, hook-shaped bay maybe in dynamic equilibrium with continual sediment supply, or in static equilibrium when no further littoral drift is taking place. It is believed that most of the hook-shaped bays in Terengganu are in dynamic equilibrium.

Klomp, Tilmans, and Vroeg (1993) concluded that the shape of the bay beaches can be represented by a logarithmic spiral, as shown in the Figure 2.4. From Figure 2.4, it can be seen that Kerteh Bay configuration fits such a spiral shape. This crenulate-shaped landform has been shaped over centuries by monsoon wave action from the South China Sea, with predominant wave approach from 30° N and 60° N wave sectors. In this respect, it is interesting to note that the spiral shape of Figure 2.5 well delineates the static equilibrium shape in respect to the 60° N wave sector. This fact thus indicates that the littoral drift system along the southern coastline of Terengganu can be considered to be largely determined by the 30° N wave sector.

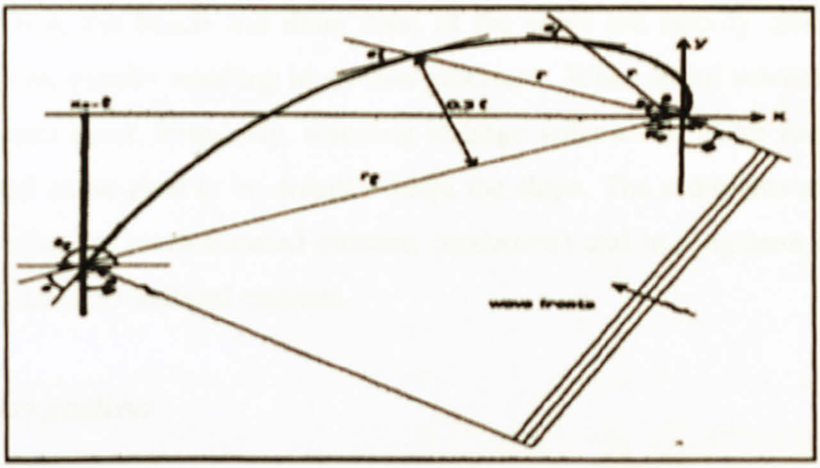


Figure 2.4: Spiral theory of a hook-shaped bay

Figure 2.5: Application of spiral theory in Kerteh Bay

2.5 Causes of Coastal Erosion

2.5.1 Natural Causes

Storm Wave

Rijn (2009) pointed out that one of the causes of erosion is storm waves which move the sediment towards offshore while fair-weather waves and swell return the sediments shoreward. Then, the beach and dune zone of the coast are heavily attacked by the incoming waves, usually resulting in erosion processes. When storm waves arrive at the beach, the crests break frequently, resulting in large volumes of water running up the beach face and cause sand to be dragged down the slope. The sediments are carried in seaward direction by wave-induced currents (undertow) and in longshore direction by wave-, wind- and tide-induced currents.

Transport gradient

Mangor (2002) also points out that the cause of natural coastal erosion is an increasing gradient in transport rate in the direction of the net transport. This can be due to gradients in the wave conditions at certain stretches, a curved coastline, or special bathymetric conditions.

Sea level rises

Prasetya (2006) found that the possible cause of coastal erosion is sea level rise. As the sea level rises, the water depth increases and the wave base becomes deeper; waves reaching the coast have more energy and therefore can erode and transport greater quantities of sediment. Thus, the coast starts to adjust to the new sea level to maintain a dynamic equilibrium.

Natural Variation

Besides, the natural variation in the supply of sand to a coastline from a river can contribute to erosion. Droughts in large river basins can result in long periods with decreasing supplies of sand to the shoreline, leading to shore erosion (Mangor, 2002).

2.5.2 Human Causes

Apart from the above natural causes, the erosion also can be caused by the development of coastal structures and sand mining work in the river mouth.

Interference by coastal structures

"The presence of the structure like groyne or other similar structure perpendicular to the shoreline has a series of effects such as trapping of sand on the upstream side of the structure and leaves the other side with insufficient sediment budget, thus causing shore erosion along adjacent shorelines. Trapping of sand in entrance channels and outer harbor also caused the erosion" (Leont'yev, 1997). Again, Mangor (2002) points out that seawalls and revetments also can cause erosion. He says that an eroding shore will continuously supply the material to the littoral transport budget if the erosion is allowed to continue. When the erosion is stopped at certain sections by the construction of seawalls or revetments, the supply of sand from this section of the shoreline to the sediment budget along the adjacent sections of shorelines will stop, whereby these adjacent shorelines will be exposed to increased erosion.

Leont'yev (1997) also studied about the effect of the construction of breakwater and jetties to the erosion. In order to maintain a navigation channel at the river mouth, breakwater and jetties are constructed. However, they will modify flow variation, drainage pattern, and water quality because of the change of the tidal exchange and flood flow. Sometimes, salt water intrusion into upper reaches of the river affects the existing use of water. The construction of breakwater at the river mouth also sometimes causes shoreline erosion and accretion nearby the river mouth because of the modification of the littoral sediment transport and sediment supply from the river. Nursery and breeding area may be destroyed directly or affected by the siltation. From an aesthetic point, the breakwater will modify landscape at the river mouth.

River Regulation Works and Sand Mining in Rivers

A decrease in the supply of sediments to a shoreline due to the regulation of rivers, which previously supplied material to the shoreline, is a very common cause of coastal erosion. The river regulation works can be the construction of dams for power production and irrigation purposes, or the deepening of navigation channels and sand mining, but all of them cause less supply of sediment to the shoreline. Sand mining in a river lowers its bottom, causes bank erosion and reduces the supply of sand to the coast (Mangor, 2002).

2.6 Previous Studies and Surveys

2.6.1 National Coastal Erosion Study (NCES)

As a subject of major national concern, the Malaysian government launched the National Coastal Erosion Study from November 1984 to January 1986. Depending on the economic and physical consequence of coastal erosion, these erosion sites were classified under three categories, namely critical, significant and acceptable (NCES, 1986). An eroding coastline is deemed critical if the infrastructure within the area is immediately threatened and if the erosion is going to threaten the infrastructure within 5 years without any coastal protection, it is classified as significant. Similarly, a severe eroding shoreline with uninhibited woodland in the backshore is classified as acceptable (NCES, 1986). The information and data collected from the NCES report are described as below.

Reach 1

Reach 1 covers the area from Kg. Rantau Abang to Tg. Dungun (Figure 1.2). This is an extremely straight shoreline with a steep foreshore (1 on 8) and a narrow beach approximately 50 m in width. This reach was relatively stable where shore retreat is noted about 1 m or less per year. Longshore transport was to the south. Quite likely, the net longshore transport rate was low, 10 000 to 30 000 m^3/yr. The direction of the wave is 63° to the north (NCES, 1986).

Reach 2

Reach 2 covers 58 km of areas starting from Tg. Dungun to Tg. Penunjok where most of beaches have a series of small and large hook-shaped bays and rocky headlands (Figure 1.2). The general trend of the coast was north-south. The general shoreline alignment of this reach is 340°. The shoreline in this area is exposed to waves from the South China Sea. The predominant direction of littoral transport along the shore is to the south. At each of the hook-shaped bays, there is a discrete submerged offshore bar extending from the updrift or north headland and returning to the shore approximately 1.0 to 2.5 km down coast. Common beach material in these areas is fine sand. However, in some areas there are a few piles of rocks which can reduce the wave energy from eroding the fine beach sediment (NCES, 1986).

Erosion areas in this reach were typically located in Dungun and Paka. 12 m to 15 m of the shore in Dungun eroded since the bar formed in 1978. In 1984, rocks were randomly dumped along the shoreline to prevent further erosion. Approximately 2 km south of Dungun, a 100 m to 120 m stretch of coastal roads leading to MARA Institute of Technology had been protected by rocks. However, both of these rock revetments did not appear to have a filter layer and subjected to damage during high wave attack (NCES, 1986).

Paka was also experiencing same problem. Local residents at Paka stated that the beach was about 18 m to 21 m wider about ten years ago before 1984. A steel sheet pile bulkhead was constructed to prevent the beach near the Paka Power Station from erosion. However, this sheet pile was temporary and had been removed following the completion of the offshore work. Paka bays experienced large movements of sand north and south along the coast even though the amount of sand entering and leaving the bay in an alongshore direction was probably small. Engineers interviewed at the site had noted that the beach between Paka and Tg. Batu Laut was relatively stable. The beaches between Kerteh and Kijal were also relatively stable. A few of the small streams located along this area were open indicating that the longshore littoral transport is small (NCES, 1986).

Reach 3

Reach 3 is 30 km long and extents from Tg. Penunjok south to Tg. Cherating (Figure 1.2). The general alignment of all the beaches in this reach is about 10°. The protection work like north and south breakwaters had been constructed to overcome the erosion along the shoreline especially in Kg. Kemaman. The turning basin and entrance channel had been dredged to -16 m below ACD with provision to deepen to -19 m ACD. This reach is directly exposed to the waves from South China Sea because there is no any island located offshore along the coast. Predominant wave energy approaches from the northeast, strong southerly winds during the southeast monsoon period can generate up to 2 m waves. The longshore transport is from north to south along this reach as evidenced by the large buildup of sand on the seaward side of the north breakwater, around the breakwater head and inside the turning basin against the wharf at Tg. Berhala. The area north of the harbor was considered as stable. South of the harbor, the area was relatively stable to slightly accretional, with the exception of Kg. Kemaman. The shoreline and erosion characteristics were similar to that at Paka and Dungun. However, 100 m of the beach immediately south of Sungai Kemaman was dredged and used as fill for the supply base at Tg. Berhala. Some residents have loosely constructed a bulkhead using sandbags and scarp wood to protect their homes during the monsoon. Vegetative cover along the coast in this bay consists of coconut trees, casuarinas trees and grassland. The hinterland is largely composed of swamp forest (NCES, 1986).

2.6.2 Coastal Erosion in Kerteh

This study was conducted by Klomp, Tilmans and Vroeg in July 1993 to determine the causes of coastal erosion and mitigation measures using dedicated mathematical model tools in Kerteh. They have found that the Kerteh Bay was suffering severe erosion and caused the sea to encroach the Rantau Petronas Complex. The results of the study in Kerteh Bay, with downcoast orientation of 70° N shows that the net longshore transport in North-East and South-West Monsoon are 175,000 m^3/year southward and 35,000 m^3/year southward respectively with the total of 210,000 m^3/year southward.

Klomp, Tilmans and Vroeg (1993) stated that one of the factors affecting the stability of coastal area within the Kerteh Bay is the supply of sand from Sungai Kerteh discharge. Evidence of the low river sand and water discharge may be found in the spit formation across the river entrance. A further factor that causes erosion along the Kerteh Bay is the changes imposed upon the coastal system by human action like the removal of the natural dune system and vegetation cover from the upper beach face and beach mining for building process. Such human interventions would reduce the natural resistance against erosion and yield the upper beach face more susceptible to the wave attack. They have also studied the erosion behavior at the Rantau Petronas Complex. This area was highly susceptible to any reduction of the volume of bar bypassing. The shoreline erosion mapping between 1966 and 1987 gives evidence of this susceptibility in restoring dynamic equilibrium of Kerteh Bar morphology (Figure 2.6).

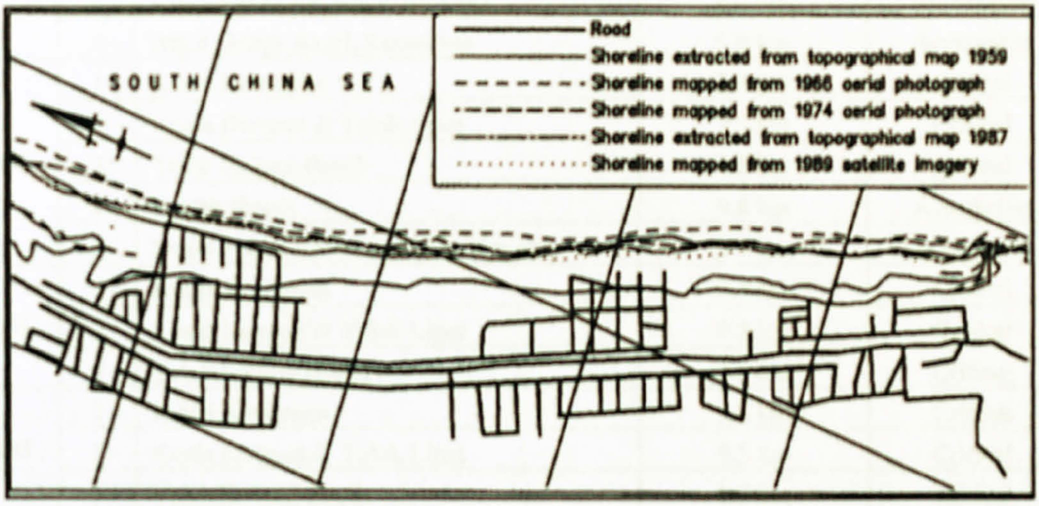


Figure 2.6: Kerteh shoreline variation from 1959 - 1989

The average erosion volume at Rantau Petronas Complex from 1966 – 1987 is around 40,000 m^3/year which would equal to the reduction of upcoast sediment supply over a similar period. Klomp, Tilmans and Vroeg (1993) have determined several possible mitigation measures to protect the beach from erosion. This includes artificial supply of sand (beach nourishment), bulkhead, revetment, seawall, breakwater, groyne and offshore.

2.6.3 Previous Surveys

The National Coastal Erosion Study was completed in 1986. The surveys then continued by the Department of Irrigation and Drainage (DID) to assess the state of erosion of certain shoreline in Terengganu. The information and database gathered from DID during site visit is presented in Table 2.1.

Table 2.1: Result from surveys from 1986 to 2005

Year	No	Location	Eroded Shore Length	Erosion Category
1986	1	Kuala Kemaman	2.5 km	Critical
	2	Kuala Dungun & Teluk Lipat	9.5 km	Critical
	3	Teluk Kalung Beach	0.4 km	Critical
	4	Kuala Paka (Kg. Bukit Tengah)	6.0 km	Acceptable
	5	Bukit Geliga Kecil, Kemaman	6.0 km	Acceptable
1990	1	Kuala Kemaman	2.4 km	Critical
	2	Kuala Dungun & Teluk Lipat	9.5 km	Critical
	3	Teluk Kalung Beach	0.6 km	Critical
	4	Kerteh Beach	9.8 km	Acceptable
	5	Kuala Paka (Kampung Bukit Tengah)	2.5 km	Acceptable
2001	1	Kuala Kemaman	2.4 km	Critical
	2	Kuala Dungun & Teluk Lipat	9.5 km	Critical
	3	Teluk Kalung Beach	0.6 km	Critical
2005	1	Kuala Kemaman	2.4 km	Critical
	2	Kuala Dungun & Teluk Lipat	9.5 km	Critical
	3	Teluk Kalung Beach	0.6 km	Critical
2009	1	Kuala Abang Beach, Dungun	2.0 km	Significant
	2	Kuala Dungun & Teluk Lipat	9.4 km	Critical
	3	Paka Beach	2.5 km	Significant
	4	Kerteh Beach	5.0 km	Critical
	5	Kuala Kemaman	2.3 km	Critical
	6	Teluk Kalung Beach	0.4 km	Critical

A report from DID of Terengganu stated that on 9 January 2009, Teluk Lipat Beach faced serious erosion due to the effect of strong wave especially during high tide. From the site investigation, it was found that the erosion has caused serious problem where the beach has eroded 5 m in width and 1m in depth at the existing Flex-slab revetment. The effect can be found along 500 m of beach where the shoreline in Teluk Lipat Beach is just 2 m from coastal road. Besides, 50 m of the road was eroded and part of it was collapsed. The wave overtopping also caused damages to the wave screening structure, pedestrian walkway and road surface. Realizing that problem, a meeting was conducted by the Local Authority on 10 January 2009 and chaired by the District Officer to take immediate action to avoid from more serious problem. From the local residents' feedback, they claimed that this year's incident is the worst erosion ever happened.

From the previous site investigation, it was found that the main cause of erosion here is the big wave carrying large energy coming from the South China Sea especially during North-East Monsoon. In 1991, a detail study was conducted by DID with Ranhill Bersekutu Sdn. Bhd. in order to find the solution to the erosion problem. This study covered 9.8 km of shoreline from Tg. Dungun (north) to Tg. Gadung (south). The result of the study showed that 5 km of shoreline from Dungun river mouth to Teluk Lipat Beach and in front of Dungun Golf Course. Nevertheless, the erosion has shifted to the unprotected area adjacent to the protected area (DID, 2009).

2.7 Erosion Control Measures

The consequences of coastal erosion can be limited by controlling erosion of coastal land or by controlling the usage of coastal land. There are two methods that can be applied which are hard engineering and soft engineering. Hard engineering is dealing with the structural solutions such as breakwater, groyne, revetment, beach drainage, concrete block and seawall or training wall. Soft engineering does not require structural member such as beach nourishment, mangrove replanting, sand-filled tube (NCES, 1986).

2.7.1 Breakwater

"Breakwaters are built to reduce wave action through a combination of reflection and dissipation of incoming wave energy. When used for harbors, breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbor facilities. Breakwaters also built to improve maneuvering conditions at river mouth entrances and to help regulate sedimentation by directing currents and by creating areas with different levels of wave disturbance" (Klomp, Tilmans, and Vroeg, 1993).

2.7.2 Groyne

"Groynes are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. Groynes function only when longshore transport is present. Groynes are narrow structures, usually straight and perpendicular to the pre-project shoreline (Klomp, Tilmans, and Vroeg, 1993).

2.7.3 Revetment

"Revetments are onshore structures with the principal function of protecting the shoreline from erosion. Revetment structures are flexible and typically consist of armor rock or cast concrete blocks. Revetments rest on the surface being protected and depend on it for support. They are relatively light structures and are well suited to locations free of heavy wave attack" (Klomp, Tilmans, and Vroeg, 1993).

2.7.4 Beach Drainage

"Beach drains comprise perforated land drain pipes buried below the upper beach surface, and connected to a pump and discharge. The concept is based on the principle that sand will tend to accrete if the beach surface is permeable due to an artificially lowered water table. The system is largely buried and therefore has no visual impact. The system actively lowers the water table in the swash zone, thereby enhancing the wave absorption capacity of the beach, reducing sand fluidization and encouraging sand deposition. The deposited sand will form an upper beach berm to protect the dune face from being eroded especially during storm events" (Klomp, Tilmans, and Vroeg, 1993).

2.7.5 Concrete Block

"The main purpose of the concrete block is to provide medium term (3-15 years) protection to the backshore area by absorbing wave energy along the dune face. Their application is restricted to the upper part of sandy beaches since they are not sufficiently durable to withstand regular direct wave action" (Klomp, Tilmans, and Vroeg, 1993).

2.7.6 Beach Nourishment

"Beach nourishment is also known as beach replenishment, beach feeding or beach recharge. Beach nourishment is a soft structure solution used for prevention of shoreline erosion. Material of preferably the same, or larger, grain size and density as the natural beach material is artificially placed on the eroded part of the beach to compensate for the lack of natural supply of beach material. The beach fill might protect not only the beach where it is placed, but also down drift stretches by providing an up drift point source of sand" (Klomp, Tilmans, and Vroeg, 1993).

2.7.7 Mangrove Replanting

"Wave energy reaching typically flat mangrove-fringed coasts is usually low allowing silt sized material to remain at or near the shore. Short fetches and depth limited wave approach directions of mangrove-fringed coasts limit wave energy from reaching the shore and thus prevent the shore from erosion" (Kamaruzzaman and Ong, 2008).

CHAPTER 3

METHODOLOGY

3.1 Gantt Chart

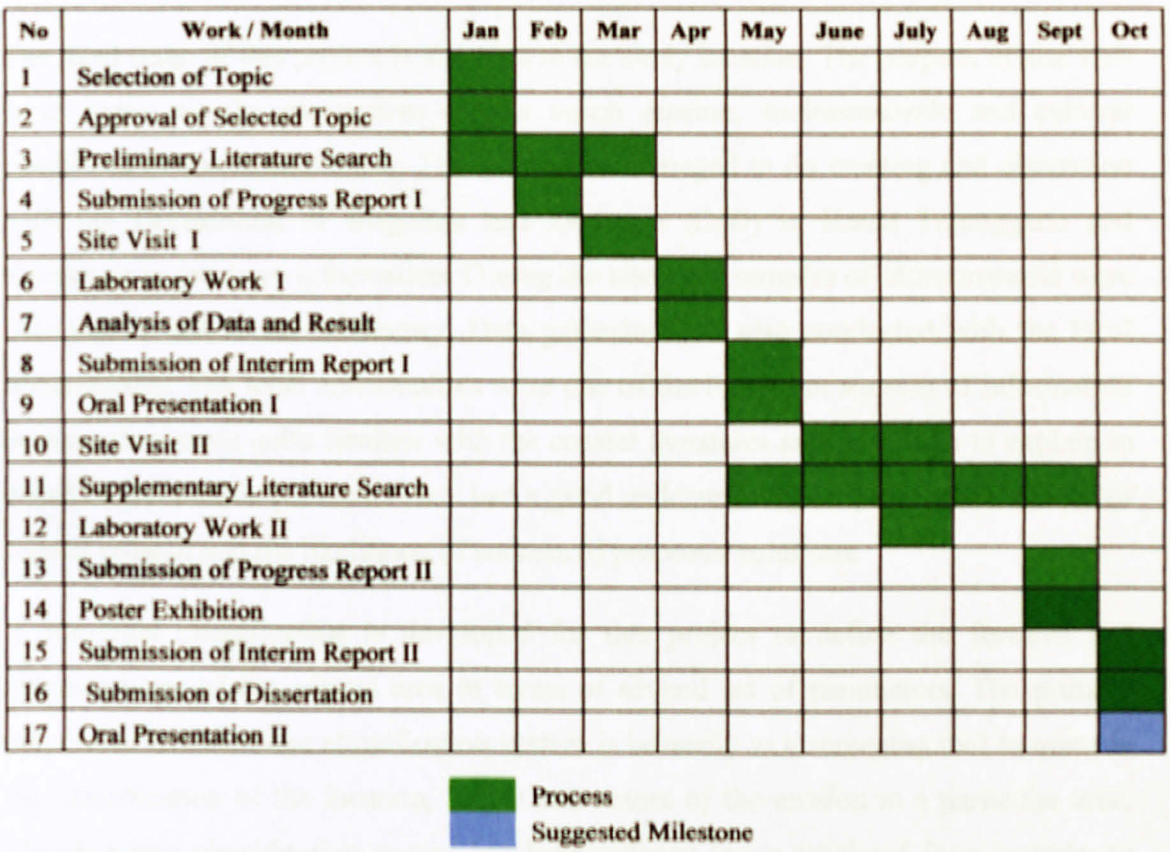


Figure 3.1: Project Gantt Chart

3.2 Research

The study was started by discussing with the Student Supervisor to get basic ideas of the project. The preliminary and supplementary literature research was then conducted through the internet, journal, textbook, article, report and some other papers to collect all the related information regarding to the coastal erosion. One of the most useful sources of information is the report of National Coastal Erosion Study (NCES). The study was conducted in 1986 by the consultants appointed by the government which contains all the valuable data and information about the condition of coastal area, causes and effect of erosion as well as the solutions to this problem.

3.3 Site Visit

The third stage of this project is site visit to the study location. The purpose of site visit is to carry out the assessment on the beach erosion, socioeconomic and cultural conditions of the coastal areas. The author has managed to do meeting and discussion with the Department of Irrigation and Drainage (DID) in Kuala Terengganu and Kemaman to get more information. During the site visit, samples of shore material were collected to test in the laboratory. Data gathering was also conducted with the local communities. The local communities were one of the important sources of information because they were quite familiar with the coastal dynamics and were able to explain in detail on the erosion problem. They had a good understanding of the potential causes of coastal erosion and the likelihood of success of proposed solutions.

A shoreline classification is developed for this project to define the features and characteristics of the coastal area in terms of several set of parameters. The primary purpose of the shoreline classification system is basically as a screening tool to assist in the identification of the location, length and nature of the erosion at a particular area. The shoreline classification system has been reduced into a tabulated form in order to make it easier to understand. The author has set several parameters to describe the shore such as oceanography/meteorology, coastal land use, local community/activity, shoreline condition, shoreline material, shoreline vegetation cover and coastal protection structure.

3.4 Laboratory Work

Sieve analysis was conducted to determine the particle size distribution of the samples of beach material by using Sieve analysis apparatus. After the sieve analysis completed, graphs of particle size distribution were plotted on the semi-log graph paper in order to calculate the Coefficient of Uniformity and Coefficient of Curvature.

Figure 3.2: Sieve analysis apparatus

CHAPTER 4

RESULT AND DISCUSSION

4.1 Environmental Data

It is very important to know the key parameters in conducting this study such as wave properties, wind, longshore transport and tide variations. Among those parameters, the most important environmental data is the wave properties. The wave data were collected from the Malaysian Meteorological Department (MMD). Figure 4.1 below shows the significant wave height and the mean wave period of South-East Asia region. It is noted that the significant wave height in southern coastline of Terengganu is about 0.3 to 0.6 m and the mean wave period is 5 seconds.

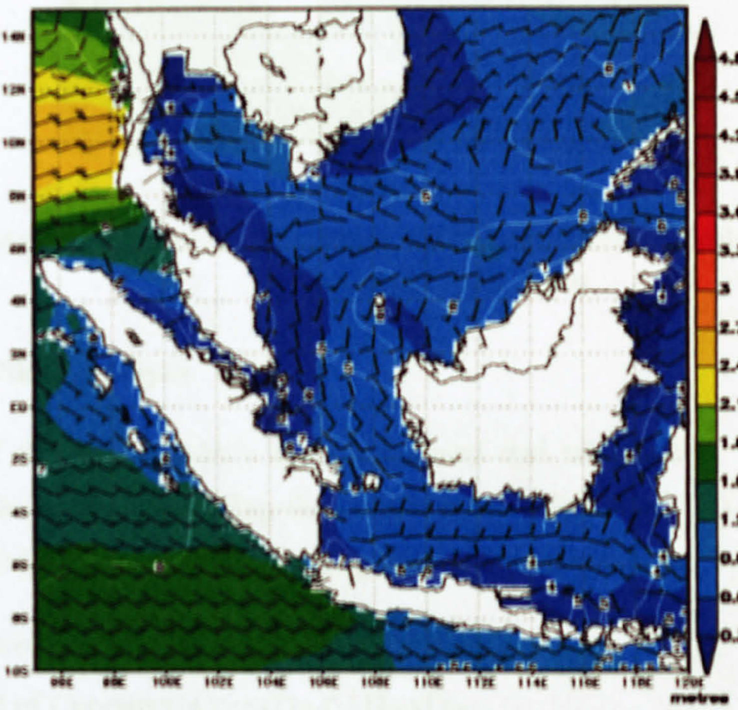


Figure 4.1: Significant wave height (meter, shaded contour) and mean wave period (seconds, white lines)

The information from MMD also indicated that the mean wind speed around the southern coastline of Terengganu is about 10 – 20 km/h. Other important parameters are the maximum wave height and peak wave period as shown in the Figure 4.2. It was predicted that the maximum wave height varies from 0.5 m up to 1 m especially in the Northeast Monsoon and the peak wave period is 5 seconds. These values are actually the estimated daily values and the maximum wave height might be larger up to 1.5 m as well as the peak wave period especially in North East Monsoon.

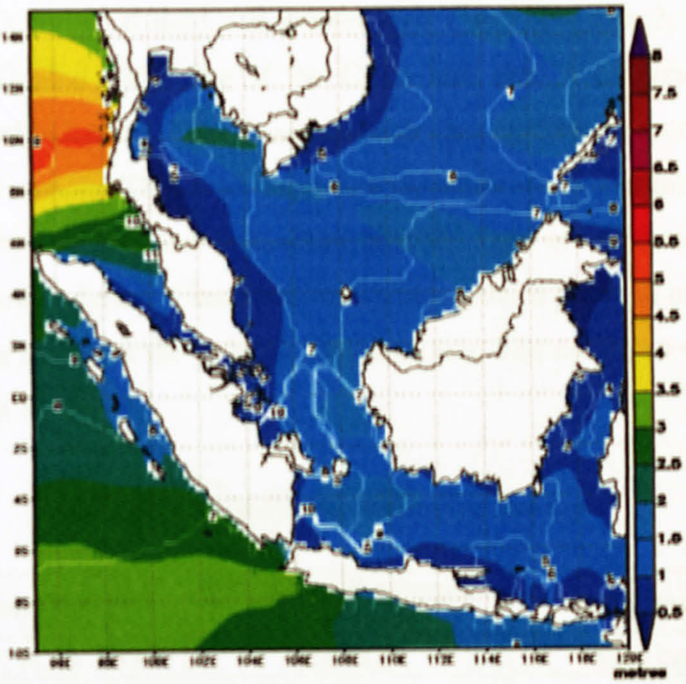


Figure 4.2: Maximum wave height (meters, shaded contours) and peak wave period (seconds, white lines)

4.2 Results of Sieve Analysis

The results of the sieve analysis are summarized and tabulated in Table 4.2. The calculation includes the determining the Coefficient if Uniformity (Cu) and Coefficient of Curvature (Cc). The equations governing these two parameters are:

(a) Coefficient of Uniformity, $Cu = D_{84}/D_{16}$

(b) Coefficient of Curvature, $Cc = (D_{30})^2 / D_{10} x D_{60}$

D_{10}, D_{16}, D_{30}, D_{50}, D_{60} and D_{84} are the particle sizes in diameter at 10, 16, 30, 50, 60 and 84 percent passing respectively. The relationship of the Cu and Cc values with the sediment group name is given by the Unified Soil Classification Chart. If the Cu value is equal or close to 1, the sediment is uniformly distributed and the Cu is much greater or less than 1, the sediment is not uniformly distributed. Uniformity here refers to the distribution of the particles having various sizes including fine and coarse materials.

The group name shows whether the sample is well graded or poorly graded which depends on the Cc value. If the Cc is greater than 1 and less than 3, it means that the sample is Well-Graded (WG) but if the Cc is less than 1 or greater than 3, it is classified as Poorly-Graded (PG). D_{50} represents the median size or average size of particle of a sand sample. This is an important parameter to determine the average size of sediment at any location and thus, determine the type of sediment. The American Geophysical Union Sediment Classification System gives a guide in order to determine the sediment type based on the average sediment size. The sediment size range and its type are shown in Table 4.1.

Table 4.1: Sediment size range and type

No	Sieve No.	Sediment Size Range (mm)	Sediment Type
1	10, 12, 14, 16 & 18	2.0 - 1.0	Very Coarse Sand
2	20, 25, 30 & 35	1.0 - 0.5	Coarse Sand
3	40, 45, 50 & 60	0.5 - 0.25	Medium Sand
4	70, 80, 100 & 120	0.25 - 0.125	Fine Sand
5	140, 170, 200 & 230	0.125 - 0.062	Very Fine Sand

Table 4.2: Sieve analysis results

No	Location	D_{50} (mm)	Cu	Cc	Uniformity	Group Name	Type of Sediment
1	Kg. Rantau Abang – Kg. Kuala Abang	0.600	2.391	0.773	Non Uniform	PG	Coarse Sand
2	Kg. Kuala Abang – Kg. Teluk Bidara	0.7	1.691	0.940	Uniform	PG	Coarse Sand

3	Tg. Dungun – Kg. Teluk Lipat	0.882	4.091	1.047	Non Uniform	WG	Coarse Sand
4	Kg. Sura Masjid - Kg. Sura Tengah	0.77	2.813	0.998	Non Uniform	WG	Coarse Sand
5	Kg. Sura Tengah - Kuala Sura	0.517	2.776	0.966	Non Uniform	PG	Medium Sand
6	Kuala Sura - Tg. Gadung	0.59	2.371	0.976	Non Uniform	PG	Coarse Sand
7	Kuala Paka – Tg. Labuhan	0.712	2.932	1.010	Non Uniform	WG	Medium Sand
8	Kuala Kerteh – Kg. Baharu	1.567	3.842	0.878	Non Uniform	PG	Very Coarse Sand
9	Kg. Baharu – Kemasik Beach	1.183	6.263	0.542	Non Uniform	PG	Very Coarse Sand
10	Kemasik Beach - Kuala Kemasik	0.909	3.604	0.829	Non Uniform	PG	Coarse Sand
11	Kuala Kemasik – Kuala Kijal	0.963	3.215	0.855	Non Uniform	PG	Coarse Sand
12	Kuala Kijal - Kg. Teluk Kalung	0.316	2.080	1.068	Non Uniform	WG	Fine and Medium Sand
13	Tg. Kalung – Tg. Sulung	0.420	1.962	1.206	Uniform	WG	Medium Sand
14	Kuala Kemaman – Kg. Geliga Baharu	0.731	4.435	1.126	Non Uniform	WG	Coarse Sand
15	Kg. Geliga Baharu – Kg. Geliga Basar	0.527	2.430	0.973	Non Uniform	PG	Medium Sand

4.3 Prediction of Longshore Sediment Transport

The longshore sediment transport rate can be expressed as the volume transport rate Q_l having units such as m^3/day or m^3/year. This total volume includes 40% void space between particles as well as the 60% solid grains. Another representation of the longshore sediment transport rate is an immersed weight transport rate I_l related to the volume transport rate by:

$$Q_l = I_l / [(\rho_s - \rho)\, g\, (1-n)] \quad \text{......Equation 1}$$

where ρ_s = mass density of the sediment grain
ρ = mass density of water
g = gravity acceleration
n = porosity

The volume of the transport rate Q_l also can be expressed as:

$$Q_l = K \times [(\rho\sqrt{g}) / 16k^{1/2}(\rho_s - \rho)(1-n)] \times H_b^{5/2} \times \sin(2\alpha_b)$$ ....Equation 2

where K = proportionality coefficient (dimensionless)
k = breaker index (H_b / d_b)
α_b = wave breaker angle relative to the shoreline

Recently, del Valle, Medina, and Losada (1993) have presented an empirically based relationship for the K parameter with the average sediment size as below:

$$K = 1.4\ e^{(-2.5D_{50})}$$ ....Equation 3

For this study, the calculation of possible longshore transport will be focused on the areas where the erosion is critical and significant. The net longshore sediment transport is assumed to be zero for the areas where the erosion is acceptable. Some assumptions have to be made because there are no exact environment data within the study areas. Therefore, the possible longshore transport will be calculated based on the estimated value of breaking wave height, breaker index, wave breaker angle, and porosity. Those estimated values are as below:

(a) Wave breaking height, H_b = 0.5m (take significant wave height from Figure 4.1)
(b) Breaker index, k = 1 (thus, d_b = 0.5m)
(c) Wave breaker angle = α_b (depends on the wave direction)
(d) Porosity, n = 0.4

Example of calculation:

Estimated net longshore transport in Kg. Teluk Lipat Beach;

Data:

- $\rho = 1025\ kg/m^3$
- $\rho_s = 2650\ kg/m^3$
- $g = 9.81\ m/s^2$
- $n = 0.4$
- $H_b = 0.5m$
- $\alpha_b = 20°$ (measured relative to shoreline)

- $k = 1$ ($d_b = 1$)
- $D_{50} = 0.882$ m

$$K = 1.4\, e^{(-2.5D_{50})} = 1.4\, e^{(-2.5 \times 0.882)} = 0.15$$

$$\begin{aligned} Q_l &= K \times [(\rho\sqrt{g}) / 16k^{1/2}(\rho_s - \rho)(1-n)] \times H_b^{5/2} \times \sin(2\alpha_b) \\ &= 0.15 \times [(1025\sqrt{9.81})/(16 \times (2650-1025)(1-0.4))] \times 0.5^{2.5} \times \sin(40°) \\ &= 0.15 \times (3210.39/15600) \times 0.132 \\ &= 0.0041\ m^3/s \\ &= 129{,}298\ m^3/yr\ \text{(southward)} \end{aligned}$$

Table 4.3 below shows the volume of the estimated net longshore sediment transport in the location of significant and critical erosion.

Table 4.3: Estimated net longshore sediment transport

No	Location	Erosion Category	D_{50} (mm)	α_b (°)	K	Longshore Transport, Q_l (m^3/yr)
1	Kuala Dungun - Kg. Teluk Lipat	Critical	0.882	20	0.150	129,298 (southward)
2	Kg. Sura Masjid – Tg. Gadung	Significant	0.626	4.5	0.290	137,292 (southward)
3	Kuala Paka - Tg. Labuhan	Significant	0.712	13	0.236	206,733 (northward)
4	Kuala Kerteh – Kg. Baharu	Significant	1.567	40	0.028	31,968 (northward)

4.4 Discussion

The whole study area is divided into 12 stretches which will be described in detail in this part of the report. All the data and information presented were collected from recent site assessment and measurement, DID and also from the sieve analysis results. Throughout the study period, two site visits were conducted during semester break. The first visit was conducted from 22nd March 2009 to 25th March 2009. Another visit was conducted in 15th June 2009 to 21st June 2009. Second visit was purposely conducted in order to update and assess the current condition of the shoreline. From both visit, it was found that there was no changes happen with respect to the shoreline condition in just 4 months time. Most of the wave data were actually taken based on observation at the site location in the morning and in some other areas, the wave height was taken in the afternoon. Overall, the wave height is small because this measurement was taken during calm sea condition. These values might change during monsoon periods either during North East or South West Monsoon.

4.4.1 Stretch 1 (Kg. Rantau Abang – Kg. Kuala Abang)

The shoreline from Kg. Rantau Abang to Kg. Kuala Abang is approximately 6.25 km in length (Figure 4.3). The shoreline is relatively straight and trends in a northwesterly direction. Kg. Rantau Abang is located in the district of Dungun with the coordinate of N 04° 51.572', E 103° 23.876'. No stream or river flow out to the sea along this shoreline. A coastal road runs parallel to the shoreline. The water quality is good as there is no interference by human activity along the shoreline. The beach is directly exposed to waves from the South China Sea. The observed dominant wave direction is from North 80° West with an average height of 0.2 m. Vegetation along this shoreline includes grasses on flat areas, casuarina trees and secondary forest. There is swamp land near to the shoreline which consists of mangrove and some tropical trees or shrub. Development along the shoreline includes residents' houses and a few chalets provided along the coastal road. The predominant beach material is fine sand on the backshore and coarse sand on the foreshore.

The Cu and Cc coefficient are 2.391 and 0.773 respectively and is considered as poorly graded sand. Overall, this area is stable where shore retreat is noted about 1 m or less per year but subject to seasonal changes. The transport in this area is nearly normal to the shoreline since the net movement of sediment from North and South is almost zero. The beach width is about 30 m and beach slope is 1:8 and the erosion category can be classified as acceptable since the erosion does not appear to be significant or threatening any structure.

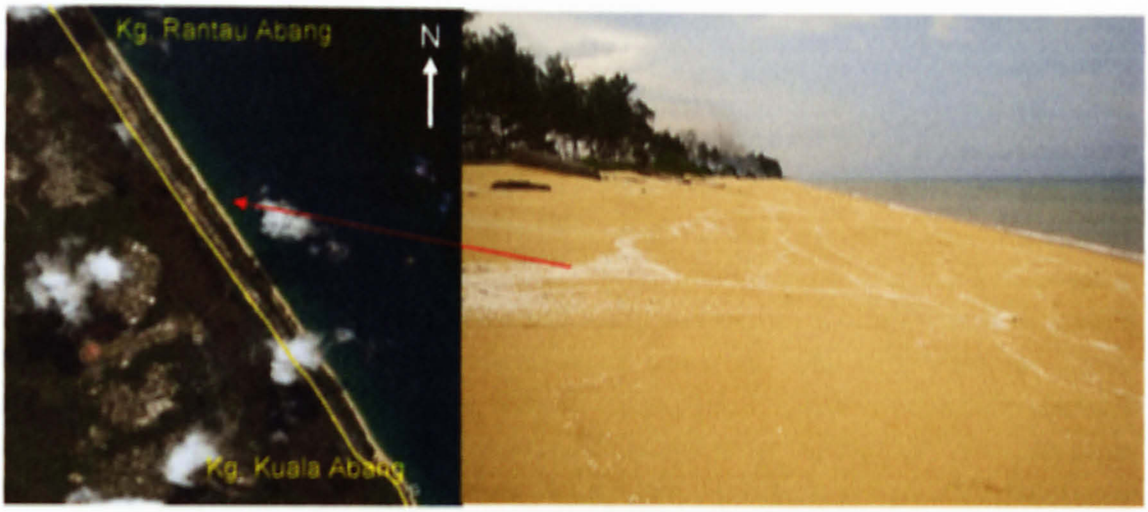


Figure 4.3: Map of Stretch 1 (left) and Rantau Abang Beach (right)

4.4.2 Stretch 2 (Kg. Kuala Abang – Kg. Teluk Bidara)

This area covers approximately 5.625 km long of shoreline where there are two headlands located between Kg. Kuala Abang and Kg. Teluk Bedara which are Tg. Jara and Tg. Dungun (Figure 4.4). The beach is exposed directly to the wave from the South China Sea with the direction from North 80° West. Two small islands like Pulau Tenggul and Pulau Nyireh which is located 28 km east of Kuala Dungun give little effect in reducing the wave energy from reaching the shoreline. In terms of coastal land use, some portion of the shoreline has been developed with the recreation place especially at Tg. Jara, but some areas are still undeveloped. The shoreline condition is stable with the beach width is 10 m and slope is about 1:10. The predominant beach material is poorly graded coarse sand. The wave is extreme only in the Northeast Monsoon season but throughout the year the wave action is very limited. This area is also relatively stable where shore retreat is about 1 m or less per year. The longshore transport is to the south. Quite likely, the net longshore transport rate was low, 10 000 to 30 000 m^3/year as stated in the NCES (1986). The erosion category along this shoreline is acceptable.

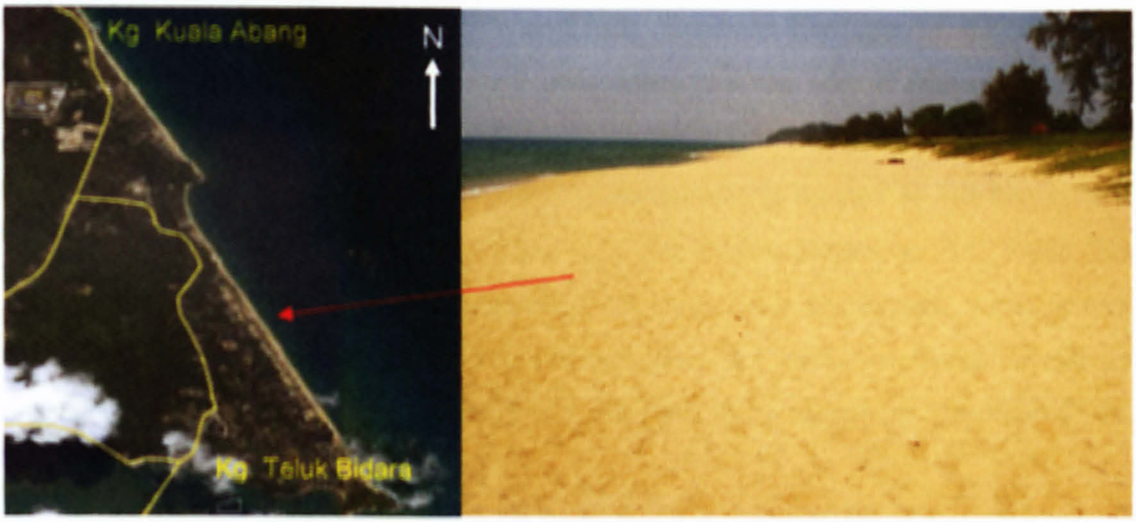


Figure 4.4: Map of Stretch 2 (left) and Kg. Temian Beach (right)

4.4.3 Stretch 3 (Kuala Dungun – Kg. Teluk Lipat)

This area is 3.45 km long and extends from Kuala Dungun to Kg. Teluk Lipat (Figure 4.5). This area is characterized by hook-shaped bay. The large river providing sediment is Sungai Dungun, located at the north end of the bay and immediately downdrift of the headland. The wave direction is to the west, opposite to the flow discharge of Sungai Dungun with the average height of 0.1 m. Common shoreline material is coarse sand in Kg. Teluk Lipat and very coarse sand at Kuala Dungun. The condition at the river mouth is unstable where significant erosion was found at the left bank of the river mouth. The local residents have taken the initiative by implementing gabion to protect the bank from continuous erosion.

In Kg. Teluk Lipat, the observed wave direction is from North 80° West with the average height is 0.3 m. However, during the Northeast Monsoon period, the wave height can reach up to 1 m. The development along the shoreline includes coastal road, houses, restaurants and recreational park. The category of erosion in this area can be classified as critical. Due to the extreme wave action, almost 1.5 km of the shoreline is facing critical erosion where the existing beach width is approximately 5 m and the slope is 2:5. Some protection works have been constructed along the shoreline such as Flex-slab, seawall, groynes, beach nourishment and sand bag.

Nevertheless, the construction of perpendicular structure like groyne causes more erosion at the downdrift of the structure and accretion at the updrift (Figure 4.6). The accretion and erosion at the groyne shows that the net longshore transport is to the south. In order to deal with this situation, beach nourishment is needed to fill the eroded shoreline so that the groyne will be effective for the erosion protection. It is found that some portions of the Flex-slab dislocated or dislodged due to extreme wave action. Therefore, the more reliable and effective structure like rock revetment should be considered because the rock can absorb and dissipate more energy as compared to the Flex-slab.

At the south end of the revetment, there is another protection work being constructed which is row of sand bags. The purpose of using sand bag is to protect the beach against the wave action. These sand bags are capable to dissipate the energy from the wave. Since the beach is always subject to sediment transport, the application of sand bags can prevent most of the beach material from being transported to the other location.

The dominant beach material in Kg. Teluk Lipat is coarse sand. The distribution of material is non uniform as some portion of fine sediment has been transported to the south, leaving some portion of coarser sediment. Based on the initial data, the estimated net longshore transport in this area is about 129,298 m^3/year (southward). The erosion and accretion will continue at the sides of the groyne as a result of this longshore transport. Therefore, beach nourishment is proposed to replenish the eroded beach at the downdrift of the groyne.

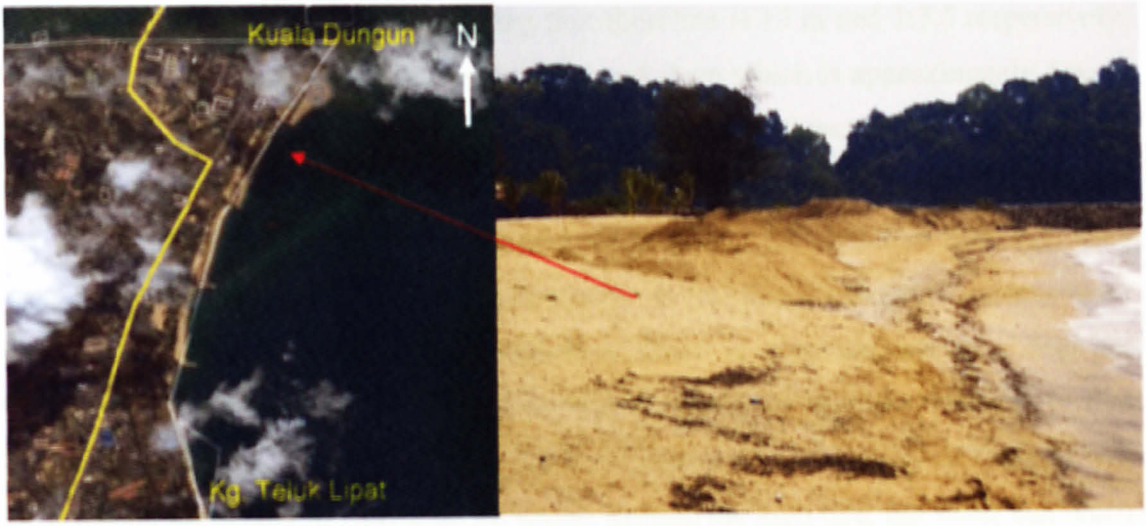


Figure 4.5: Map of Stretch 3 (left) and critical beach erosion near Dungun river mouth

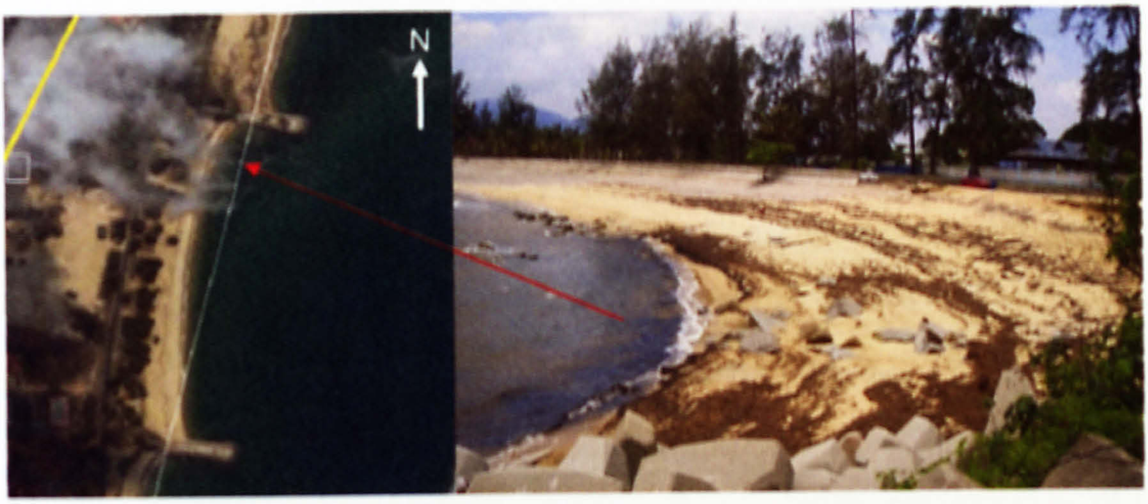


Figure 4.6: Groynes (left) and critical erosion at downdrift of the groyne (right)

4.4.4 Stretch 4 (Kg. Sura Masjid – Tg. Gadung)

The area from Kg. Sura Masjid to Tg. Gadung covers about 6.9 km of shoreline (Figure 4.7). There are three villages located in this area which are Kg. Sura Masjid, Kg. Sura Tengah and Kg. Beris Cerung including a small river mouth, bay and rocky headland namely Kuala Sura, Teluk Gadung and Tg. Gadung. From Kg. Sura Tengah to Kuala Sura and from Kuala Sura to Tg. Gadung, the average observed wave height is 0.2 m. The erosion state in this area is considered as significant.

The average beach width and slope along this shoreline is 15 m and 1:7.5 respectively. The beach in Kg. Sura Tengah is very narrow and steep which is approximately 5 m in width and 1/5 in slope. From Kg. Sura Masjid to Kg. Sura Tengah, there is no protection work be constructed. It was recorded in NCES (1986) that in 1984, 100 to 120 m of rock revetment had been constructed to protect the shoreline from Kg. Sura Tengah to Teluk Gadung. From the current study, it was found that this rock revetment has been extended about 2 km up to Kuala Sura. However, this rock revetment does not have filter layer and subject to damage especially during the high wave attack. In that case, the coastal road, houses and also MARA Institute of Technology of Dungun will be in danger especially in Northeast Monsoon. During the high tide, the water can reach up to the toe of the revetment. The main cause of erosion here is the strong wave and longshore transport which carry sediment to the south. Beach nourishment is also applied at the end of this area which is near to the river mouth of Sungai Sura. The beach nourishment was done in order to protect the recreation park and improve the beach appearance.

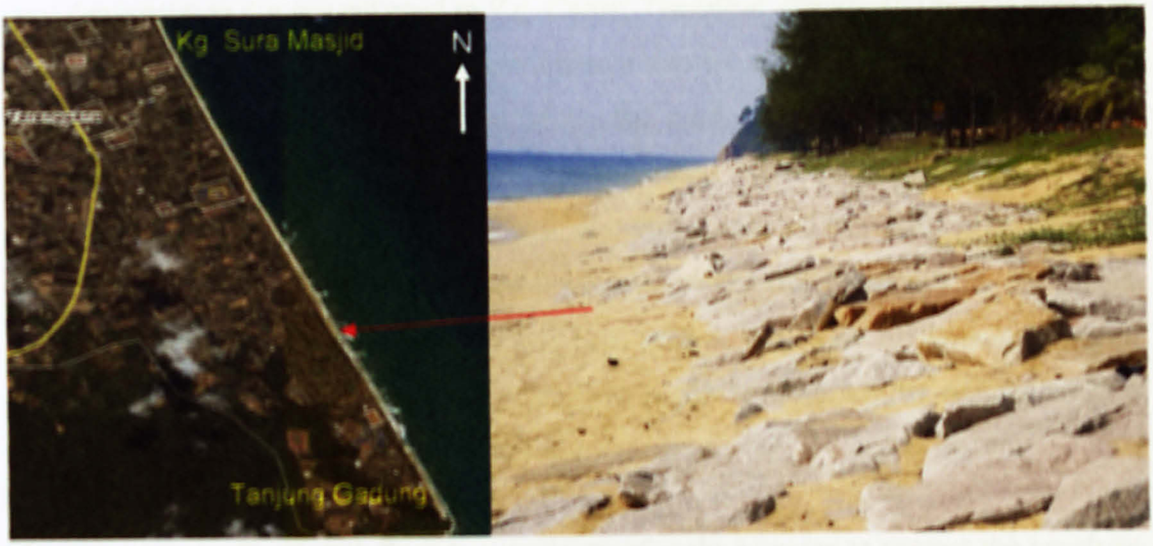


Figure 4.7: Map of Stretch 4 (left) rock revetment in Kg. Beris Cerung (right)

4.4.5 Stretch 5 (Kuala Paka – Tg. Labuhan)

This is a quite long stretch with the shoreline length of about 17.2 km (Figure 4.8). This area is characterized by a river mouth in Kuala Paka, straight sandy beach from Kg. Cacar to Kg. Seberang and headlands at Tg. Batu Lata and Tg. Labuhan. The special feature found in this area is the formation of sand spit near to the river mouth in Kuala Paka. The local residents reported that previously the discharge of Sungai Paka can flow out directly to the sea. They can easily drive their boats because the river mouth was big enough and the water was deep. Recently, they face difficulty to go out and come in because the access through this river mouth is getting narrower with decreasing of water depth. Along this shoreline from Kuala Paka to Tg. Labuhan, the average observed wave height during the site visit was 0.3 m with the direction of North 80° West. The beach width is about 15 m and the slope is 1:10. The beach material was well graded medium sand.

This area is always exposed to the wave attack from South China Sea and sometimes during the high tide, the water can cover half of the beach width. Once the water goes back to the sea, most of the fine sediments will be carried away towards the sea and cause erosion. The resident's houses are in danger especially during the Northeast Monsoon because sometimes the big wave can reach up to some level which might be very dangerous to the coastal road in Kg. Cacar. Therefore, the erosion in this area can be classified as significant. Much development can be seen from Kuala Paka to Tg. Batu Lata. This includes development of coastal road, town, housing, schools, TNB Power Station, oil and gas terminals and factories, Paka Port, and Petronas Gas Processing Complex, located on the left and right side of the road. The existing protection work includes 1.5 km of offshore breakwater and revetment at the Kerteh Port and also series of groynes in Tg. Batu Lata (Figure 4.9). This offshore breakwater is used to protect the port from the wave action and to improve the navigation and mooring condition for the oil and gas vessels.

The revetment at the Kerteh Port was made up of rocks in order to protect the beach as well as the facilities from the effect of erosion. The construction of this revetment is actually to replace the existing Flex-slab structure that was totally damaged and could not function anymore. The groyne was built to protect the beach from the erosion due to longshore transport. The accretion of the sediment at the updrift of the groyne shows that the net longshore transport is moving in south-north direction. Therefore, beach nourishment is needed to cover the eroded beach at the downdrift of the groyne so that the properties and structures can be protected.

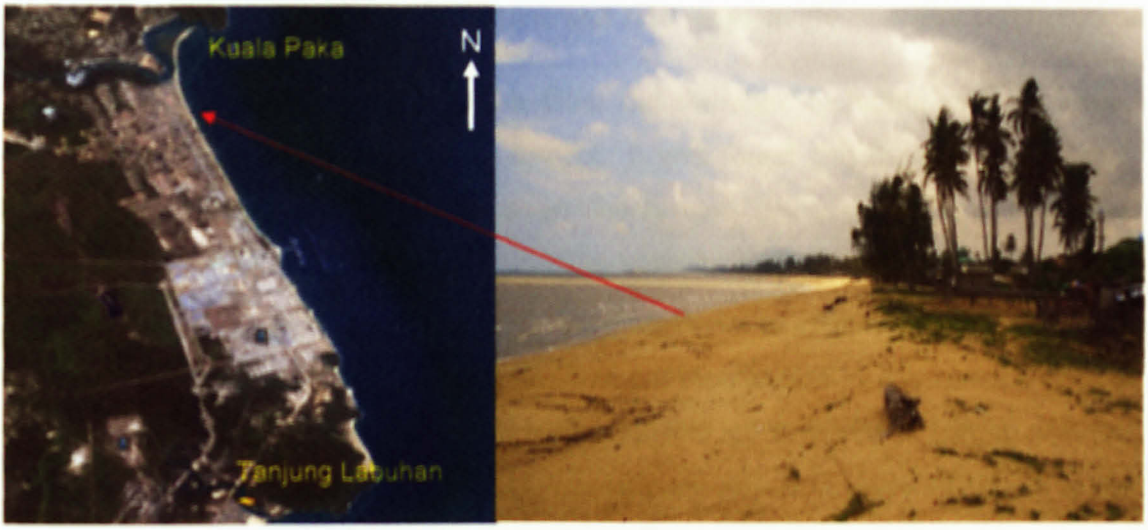


Figure 4.8: Map of Stretch 5 (left) and significant beach erosion near Kuala Paka (right)

Figure 4.9: Breakwater and groynes at Kerteh port (left) and rock revetment (right)

4.4.6 Stretch 6 (Kuala Kerteh – Kg. Baharu)

A special feature in this area is the hooked-shaped bay which was formed 100 of years ago. The only river that provides sediment to the shoreline is Sungai Kerteh. A study was conducted in 1997 showed that the Kerteh Bay was in dynamic equilibrium. The shoreline in this area is about 3.13 km (Figure 4.10). The average wave height is 0.2 m. Erosion in this area can be classified as significant. The common beach material is coarse sand. Beach width and slope is 10 m and 1:10 respectively.

The development was found at 400 m from the shoreline including road, housing, buildings and some jetties for fishing activity. It was found that the outlet of Sungai Kerteh is smaller than the width of the river. This is partly due to the effect of longshore transport which moves the sediment from south towards the river mouth. This longshore transport causes the erosion on the beach and contributes to sedimentation in the river mouth. The common problem in this area was the sedimentation in river mouth, not the erosion at the beach. Since most of the local residents are involved in fishing activity, they are very sensitive to the sedimentation or siltation problem. The water depth in the river mouth is getting shallower because the sediments are brought from the inlet of Sungai Kerteh and slightly from the littoral drift.

The sediments in the river mouth are recently dredged to allow access for the fisherman boats which is carried out by a contractor appointed by the DID namely MIKA GLOBAL Sdn. Bhd. (Figure 4.10). According to the Project Manager, the current depth of the water is less than 3.5 m and this river mouth should be maintained at least 4 m in depth so that the big boats can pass through the outlet of the river. He claimed that the dredging was once carried out in 2005 for the same purpose. Due to relatively high sediment accumulation rate, this problem occurs again in just 4 years time. In order to improve the navigation condition, a short detached breakwater was constructed at the south bank of river mouth to prevent the intrusion of sediments from the adjacent beach into the river mouth.

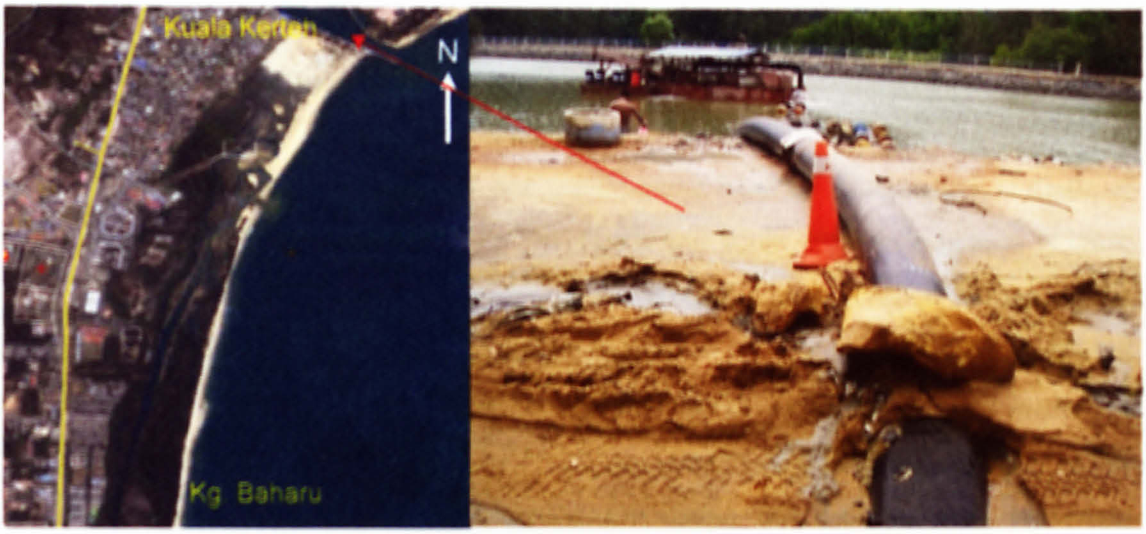


Figure 4.10: Map of Stretch 6 (left) and dredging work at Kuala Kerteh (right)

4.4.7 Stretch 7 (Kg. Baharu – Kuala Kemasik)

The 7.8 km shoreline in this area located at the south end of the hook-shaped bay (Figure 4.11). Almost 7 km of the shoreline is facing critical erosion caused by the wave attack from South China Sea. The observed average wave height was 0.4 m moving to the western which is approximately normal to the shoreline. The sediment transport in this area is much caused by cross-shore transport. The effect of this transport causes most of the beach materials to be very coarse sand because the finer portion of beach sediment was carried away towards the sea. About 1 km from Kuala Kemasik, the beach is consists of rock and medium sand. Overall, the beach width is about 15 m and the slope is 1:10.

In terms of the development, this area consists of Rantau Petronas Township, Rantau Petronas School, Petronas Carigali Complex, Mesra Mall Shopping Complex, houses, golf course and road. The beach near to the Rantau Petronas Township and Rantau Petronas School is very unstable and subject to extreme wave attack. The effect of erosion can be seen clearly at 500 m of shoreline behind the Rantau Petronas School where the erosion is approaching the school's gate and the remaining land is just 5 m from the shore (Figure 4.11). There is no any protection work carried out along the 6km of the shoreline. However, protection works such as groyne, gabion and also retaining wall are found at a distance of 1 km from Kuala Kemasik.

At 500 m from Kuala Kemasik, there are gabion and a huge structure which is made of concrete blocks, constructed to protect the beach and some resident's houses (Figure 4.12). At the back of the concrete blocks, rocks were randomly dumped to increase its stability and prevent from sliding during the high wave. A few local residents reported that before the construction of the revetment, the life of the residents was in danger because their houses are just very near to the sea. During the Southeast Monsoon, the erosion causes the beach to become narrower and steeper and sometimes the wave can reach up to their house. A few structures on the backshore were damaged as a result of the wave action (Figure 4.12). The possible protection measure that could be implemented is the rock revetment starting from the south end of concrete block to some length close to the river mouth.

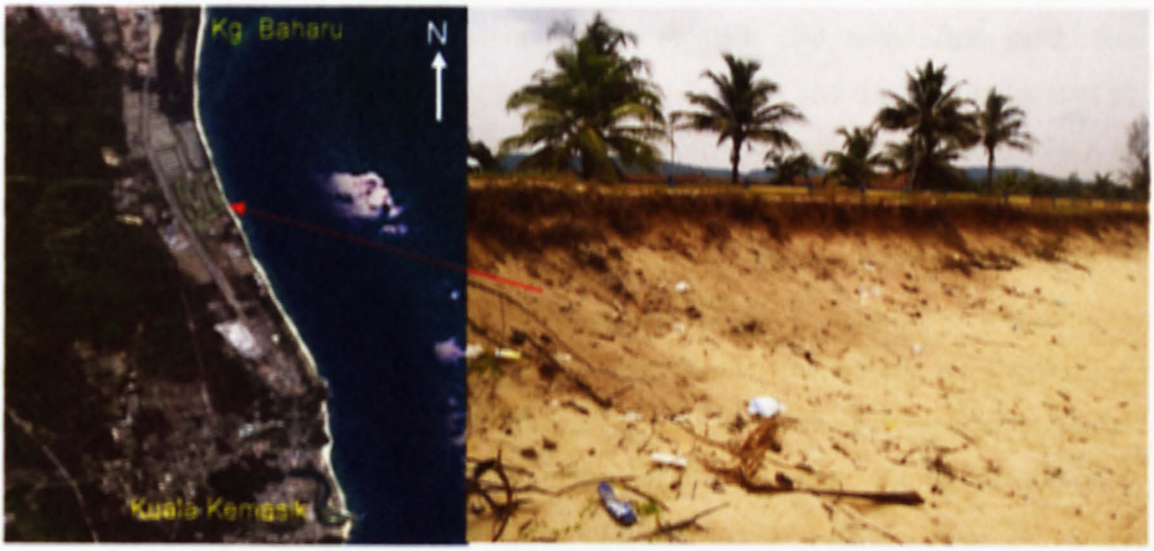


Figure 4.11: Map of Stretch 7 (left) and scarp near Rantau Petronas School (right)

Figure 4.12: Concrete block (left) and damage structure (right)

4.4.8 Stretch 8 (Kuala Kemasik – Kuala Kijal)

Stretch 8 covers about 5.9 km long from Kuala Kemasik and extends southward to Kuala Kijal (Figure 4.13). 2.4 km of shoreline from Kuala Kemasik is stable where the erosion is still acceptable. The beach along this shoreline is different from other places because most of the beach materials consist of rock and some fine sand. No development is found since this area is covered by forestry and the road is located at 700 m from the shoreline. As moving to the south, there is a recreational area which is Awana Kijal Golf Resort located along the 2 km of shoreline. At this particular area, the wave height is about 0.5 m moving to the west. Typically, the beach material consists of coarse sand. The beach is 20 m in width and 1:10 in slope. Vegetation in this area composed of casuarinas trees and grasses. The formation of scarp at the foreshore is the evidence of the significant erosion. The resort will be in danger especially in the Northeast Monsoon period because the big wave will cause more erosion and consequently threaten the facilities that were built near to the beach.

The area from Awana Kijal Golf Resort to Kuala Kijal, the shoreline is about 3.5 km. The dominant wave moves North 80 West with the average height of 0.2 m. The beach width is about 20 m and almost 30 m near the river mouth. The erosion in this area can be classified as acceptable since there is no development and no significant impact to the vegetation along the shoreline. However, the sedimentation does appear to be critical at the outlet of Sungai Kijal. The local residents reported that the configuration of the river mouth has changed as compared to 5 to 10 years ago. This is mainly due to the accumulation of the sand brought by the river flow during the flood season. The water depth is just about 1 m especially in the draught period. The south side of the river bank is strengthened by the crushed stones in order to protect the Kijal Earth Station (Celcom) (Figure 4.14).

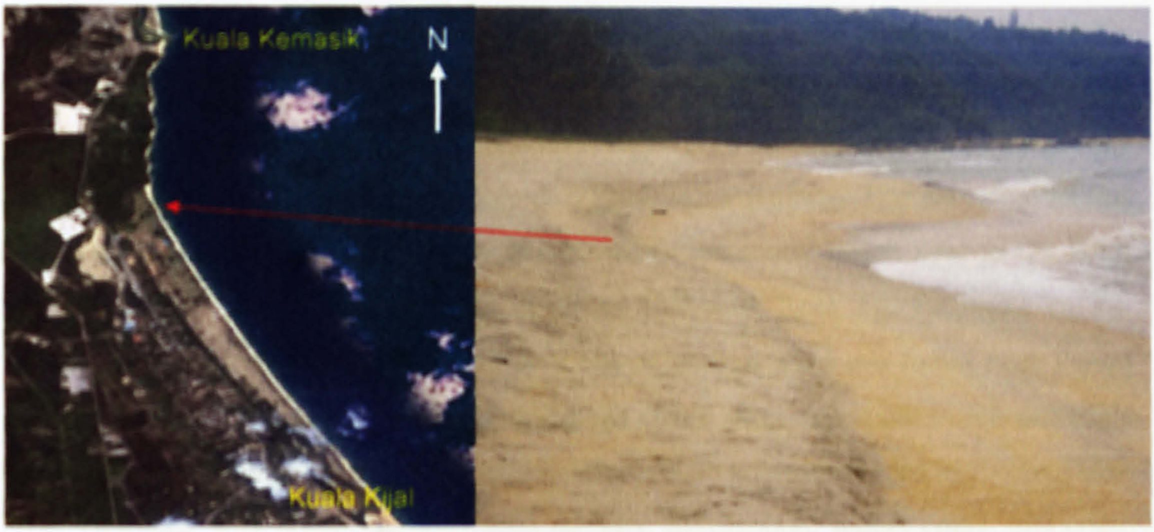


Figure 4.13: Map of Stretch 8 (left) and shoreline erosion in front of Awana Kijal Golf Resort (right)

Figure 4.14: Rock revetment at the bank of Kijal River Mouth in front of Kijal Earth Station (Celcom)

4.4.9 Stretch 9 (Kuala Kijal – Kg. Teluk Kalung)

This area is 3.0 km long extends from Kuala Kijal to Tg. Penunjuk and 5.7 km long from Tg. Penunjuk to Kg. Teluk Kalung (Figure 4.15). From the first 3 km of shoreline, the beach is made up of fine and medium sand with 25 m of width and 1:10 of slope. The average wave height is found to be 0.2 m and the direction is almost normal to the shore. There is no development found except the resident's houses which are quite far from the beach. The formation of small scarp at the foreshore shows that the state of erosion along this shoreline is acceptable. Although some part of shoreline is currently retreating, but the effect of erosion is not very significant to the properties of the residents. The shoreline from Tg. Penunjuk to Kg. Teluk Kalung consists of two rocky headlands and a small hook-shaped bay in Pantai Teluk Kalung. The shoreline in this area is mostly characterized by rocky beach except the sandy beach near to the Kijal Strawberry Park and in Pantai Teluk Kalung. This area from Tg. Penunjuk to Tg. Senajang is covered by the forest and in some casuarinas trees are found near Pantai Teluk Kalung. The beach along this shoreline is stable since dominant beach materials are rocks and insensitive to the wave attack. There is a recreational area in Pantai Teluk Lipat equipped with some facilities such as huts, playground, tennis court, groceries, football field, public toilets, and some benches. The beach is quite wide with the width is about 25 m and with mild slope of about 1:20. Common beach material consists of fine sand.

Figure 4.15: Map of Stretch 9 (left) and Teluk Kalung Beach (right)

4.4.10 Stretch 10 (Tg. Kalung – Tg. Sulung)

This 9.7 km long of shoreline consists of a series of rocky headlands which are Tg. Kalung, Tg. Berhala and Tg. Sulung (Figure 4.16). This rocky headland and rocky beach is in stable condition and erosion is very limited along this shoreline. Dominant shoreline vegetation cover from Tg. Kalung to Tg. Berhala is forestry. The shape of the shoreline from Tg. Berhala to Tg. Sulung is a kind of small hook-shaped bay. There is huge development area extended from the shoreline towards the inland including Kemaman Base Supply. The 800 m north and 2.0 km south breakwaters were constructed to protect the facilities on the land and as the same time to improve the navigation and mooring condition in the turning basin to allow access for the big vessels. The development project of Kemaman Port was started in 1981 and completed in 1985 with the total cost of RM 500 millions.

The project consisted of three main phases which the Phase I involved the design and construction of 800 m long breakwater to protect 360 m quaywall (5 berths) of reinforced concrete caissons, dredged basin and approach channel, reclamation and shore installation for service of the supply barges. Phase II development involved the design and construction of 648 m long east wharf (3 berths) constructed using R.C. caisson and subjected to loading from crane, HB loading, bollard pull and berthing load of 150,000 DWT vessels. Phase II also comprised of design and construction of LPG jetty (1 berth) to accommodate tankers between 1,000 and up to 40,000 DWT, and dredging work (11 million m^3) for east wharf, turning basin and channel and reclamation for east wharf and Telok Kalong Industrial Estate. Phase III involved the design and construction of East and South Breakwater (rubble mound type) of approximately 2,000 m to facilitate entrance of ship, protect LPG Basin. Apart from that, at the south of Kemaman Base Supply, there is a recreational area at the end of Tg. Sulung namely Telaga Simpul Recreational Area which facing the Kemaman River Mouth. A 60 m long gabion was placed to protect the beach in front of the recreational area.

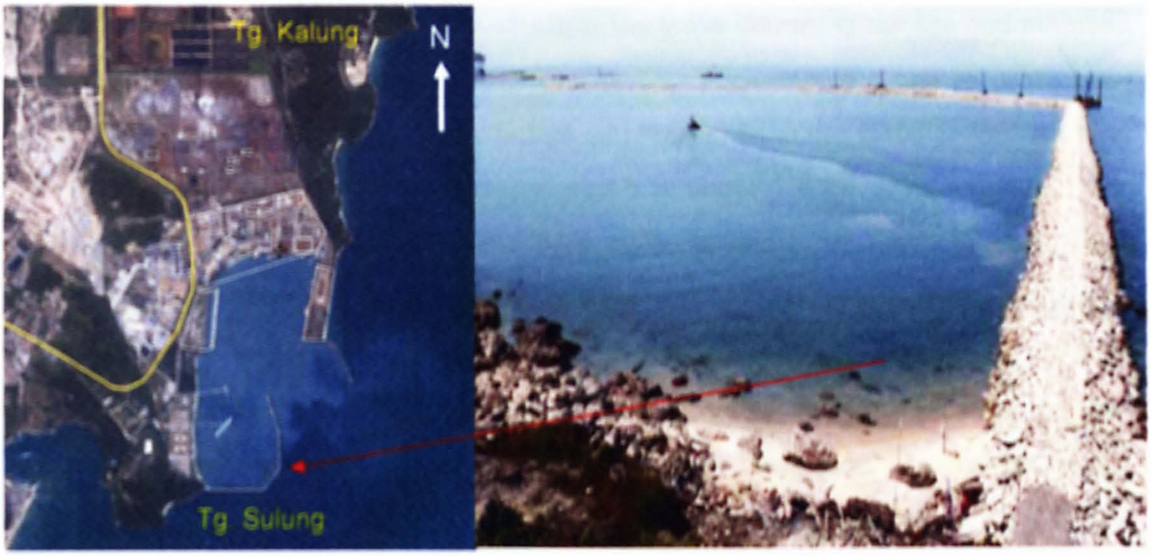


Figure 4.16: Map of Stretch 10 (left) and Kemaman south breakwater (right)

4.4.11 Stretch 11 (Kuala Kemaman – Kg. Geliga Baharu)

The area from Kuala Kemaman to Kg. Geliga covers about 2.5 km long of shoreline (Figure 4.17). The main river providing the sediment to the adjacent beach is Sungai Kemaman. Out of 6 main rivers in southern shoreline of Terengganu, Sungai Kemaman is the largest river where many economic activities are found at the river mouth. It serves as the main route for fishing and recreational boats and provides sediment supply to the shoreline. Most of the sediments are brought from two rivers which coming from north and south and meet at the outlet of Sungai Kemaman. The general alignment of the beach is North 10° East. There is no island located offshore along the shoreline and thus the shoreline is exposed directly to the wave from South China Sea. It was reported in NCES (1986) that about 2.5 km of shoreline in this area was facing critical erosion. The beach was very narrow due to severe erosion and sometimes the wave had reached to the residents' houses.

Recently, the condition along the shoreline is relatively stable. The erosion has changed from critical to acceptable. Many construction of protection works were applied such as offshore breakwater and groyne (Figure 4.18), gabion and beach nourishment (Figure 4.19). The construction of offshore breakwater at 800 m offshore from Kuala Kemaman has helped much in order to reduce and reflect the wave energy to the sea and maintain the calm condition in the river mouth. This is very important not just to protect the beach from erosion, but to protect the jetties and houses from the wave action. Another important structure is the rock revetment which is about 2.5 km long parallel to the shoreline (Figure 4.17). The revetment was designed and constructed to protect the beach along the shoreline from critical erosion as well as the resident's settlement because most of the houses are subject to direct wave attack because many of their houses are just close to the sea. Concurrently, the beach nourishment was also applied to recover the eroded beach behind the rock revetment. The effects of previous critical erosion are still there including the scarp formation and damaged structures.

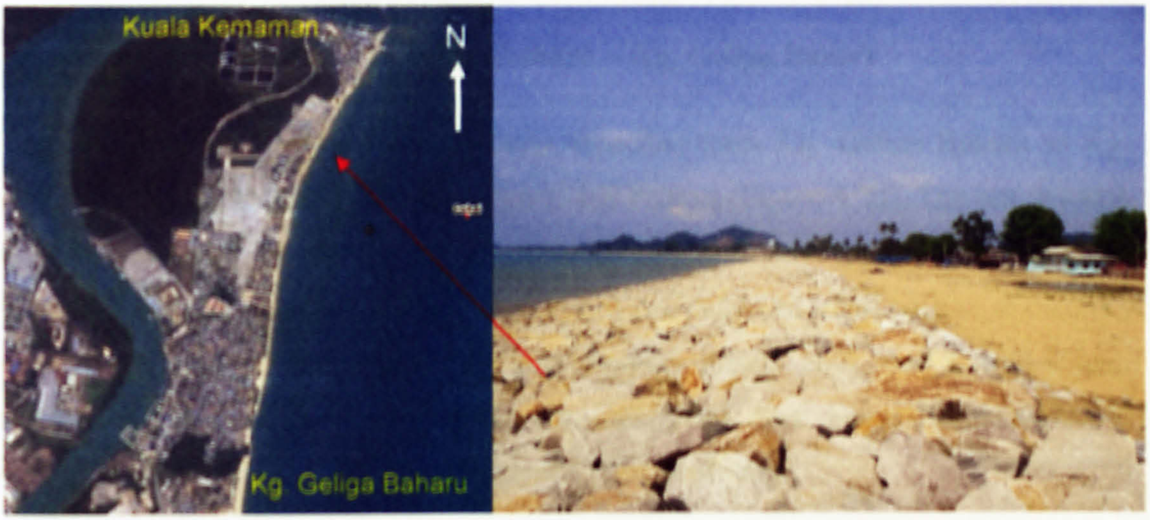


Figure 4.17: Map of Stretch 11(left) and rock revetment (right)

Figure 4.18: Groyne (left) and offshore breakwater (right)

Figure 4.19: Gabion (left) and beach nourishment (right)

4.4.12 Stretch 12 (Kg. Geliga Baharu – Kg. Geliga Basar)

The last reach covers about 3.3 km long shoreline from Kg. Geliga Baharu to Kg. Geliga Basar near the border of Terengganu and Pahang (Figure 4.20). The beach width is about 25 m and the slope is 1:10. Vegetation covers include grasses and casuarinas trees. Typically, the beach material composed of fine sand and small portion of medium sand. Development in this area includes housing, coastal road, and a well-known recreational area which is De Monica Bay or Pantai Mek Nik. This shoreline is currently stable and the erosion can be classified as acceptable.

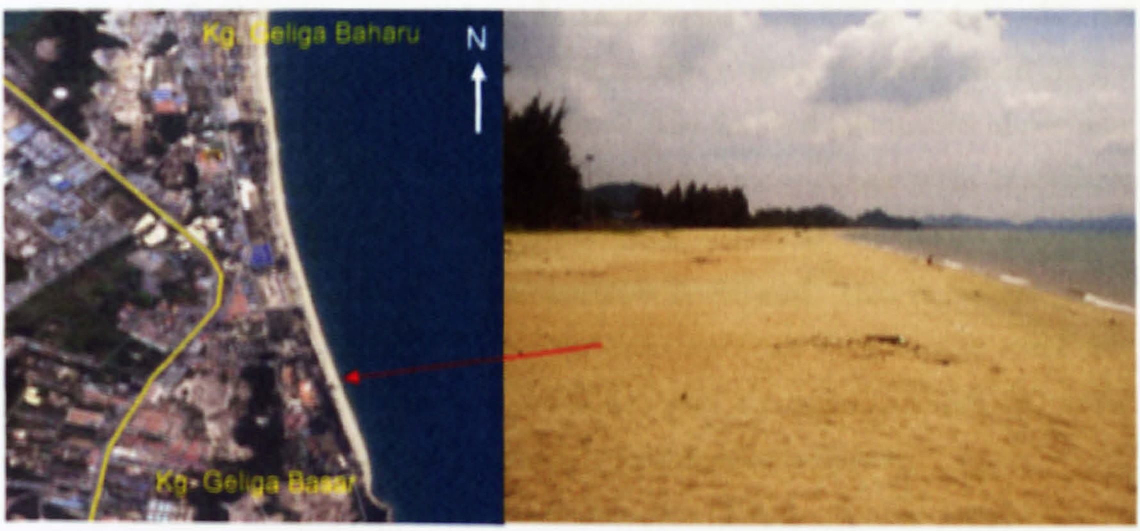


Figure 4.20: Map of Stretch 12 (left) and De Monica Bay (right)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The coastal zone is the major attraction pole for settlement and economic development. A lot of economic activities such as urbanization, agriculture, recreation, eco-tourism, fisheries, aquaculture and oil and gas exploration are situated in this area. The coastal zone and its associated resources contribute significantly to the economic and social well being of the people of Malaysia. Consequently, demands of developments and industrialization in this area had made a very big impact on the natural resources and alter the existing shoreline profile. About 29 % (1400 km) of the total length of shoreline in Malaysia and 62.5 % (122.4km) of total shoreline in Terengganu was facing serious erosion and this problem has been identified as national problem.

The assessment on the current state of erosion, identification of possible causes of coastal erosion and evaluation on the performance of the existing protection works are among of the main objectives of the study. Samples of beach sediment were collected and tested in the laboratory to analyze the particle size distribution and possible net longshore sediment transports have been calculated at some locations based on the current hydrological data and local sediment size. The data and information of previous studies and surveys from 1986 to 2008 have shown that many coastal areas in southern coastline of Terengganu were facing critical erosion. Overall, the results of current study show that the eroded length of shoreline is reduced. This is because some locations have changed from critical to significant and from significant to acceptable especially in Kemaman and Kemasik. However, there are some locations still under significant and critical erosion which need to be protected immediately.

Understanding the key processes of coastal dynamics and how coasts developed in the past and present, as well as over the short and long term, is very important for managing coastal erosion problems because coastal erosion may occur without cause for concern. This can be very complex and possibly controversial where many conflicts of interests exist within the coastal environment. In addition, coastal systems extend beyond jurisdictional boundaries and are affected by impacts of many local users and by decisions made by different levels of government. The management of coastal systems requires involvement of many agencies at different levels of government. To ensure this balance, rigorous planning must be enforced as it requires a multi- and interdisciplinary effort. It is recommended that such a concerted approach be organized to ensure minimal unfavourable impact. Planning strategies must be based on detailed area knowledge, mapping, zoning, analyses, evaluations and inventory taking. A co-ordinated policy of research, planning and management backed by public support will foster positive action. In a nutshell, it is highly recommended that the related government agencies and local authority to carry out a more detail and comprehensive research in order to develop better knowledge and understanding as well as providing the data and information related to this national problem for future action.

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APPENDIX

RESULTS OF SIEVE ANALYSIS

No	Location	D10 (mm)	D16 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	D84 (mm)	Cu	Cc	Uniformity	Group Name	Type of Sediment
1	Kg. Rantau Abang Beach	0.450	0.460	0.490	0.600	0.690	1.100	2.391	0.773	Non Uniform	PG	Coarse Sand
2	Kg. Kuala Abang - Temian (1)	0.580	0.600	0.650	0.710	0.790	0.980	1.633	0.922	Uniform	PG	Coarse Sand
3	Kg. Kuala Abang - Temian (2)	0.630	0.670	0.750	0.890	0.900	1.100	1.642	0.992	Uniform	PG	Coarse Sand
4	Temian - Kg. Teluk Bidara	0.600	0.640	0.700	0.850	0.900	1.150	1.797	0.907	Uniform	PG	Coarse Sand
5	Tanjung Dungun	0.490	0.530	0.700	1.100	1.400	2.200	4.151	0.714	Non Uniform	PG	Very Coarse Sand
6	Kuala Dungun - Teluk Lipat (1)	0.380	0.480	0.680	0.860	1.050	1.900	3.958	1.159	Non Uniform	WG	Coarse Sand
7	Kuala Dungun - Teluk Lipat (2)	0.240	0.300	0.550	0.800	1.000	1.900	6.333	1.260	Non Uniform	WG	Coarse Sand
8	Kuala Dungun - Teluk Lipat (3)	0.370	0.450	0.650	0.900	1.100	1.900	4.222	1.038	Non Uniform	WG	Coarse Sand
9	Kuala Dungun - Teluk Lipat (4)	0.390	0.485	0.690	0.950	1.170	1.950	4.021	1.043	Non Uniform	WG	Coarse Sand
10	Kg. Teluk Lipat Beach	0.460	0.490	0.590	0.680	0.710	0.910	1.857	1.066	Uniform	WG	Coarse Sand
11	Kg. Sura Masjid - Kg. Sura Tengah (1)	0.400	0.450	0.600	0.710	0.800	1.300	2.889	1.125	Non Uniform	WG	Coarse Sand
12	Kg. Sura Masjid - Kg. Sura Tengah (2)	0.450	0.510	0.610	0.800	0.950	1.450	2.843	0.870	Non Uniform	PG	Coarse Sand
13	Kg. Sura Masjid - Kg. Sura Tengah (3)	0.400	0.480	0.600	0.800	0.900	1.300	2.708	1.000	Non Uniform	WG	Coarse Sand
14	Kg. Sura Tengah - Kuala Sura (1km from UITM Dungun) (1)	0.280	0.350	0.400	0.520	0.600	0.950	2.714	0.952	Non Uniform	PG	Medium Sand
15	Kg. Sura Tengah - Kuala Sura (1km from UITM Dungun) (2)	0.280	0.340	0.410	0.520	0.610	0.950	2.794	0.984	Non Uniform	PG	Medium Sand
16	Kg. Sura Tengah - Kuala Sura (1km from UITM Dungun) (3)	0.280	0.330	0.400	0.510	0.595	0.930	2.818	0.960	Non Uniform	PG	Medium Sand

17	Kuala Sura - Teluk Gadung (UITM Dungun) (1)	0.360	0.395	0.490	0.590	0.640	0.930	2.354	1.042	Non Uniform	WG	Coarse Sand
18	Kuala Sura - Teluk Gadung (UITM Dungun) (2)	0.360	0.400	0.470	0.580	0.650	0.970	2.425	0.944	Non Uniform	PG	Coarse Sand
19	Kuala Sura - Teluk Gadung (UITM Dungun) (3)	0.370	0.420	0.490	0.600	0.690	0.980	2.333	0.940	Non Uniform	PG	Coarse Sand
20	Kuala Paka	0.650	0.750	0.950	1.300	1.600	2.400	3.200	0.868	Non Uniform	PG	Very Coarse Sand
21	Kuala Paka - Kg. Cacar (1)	0.270	0.330	0.425	0.550	0.610	0.950	2.879	1.097	Non Uniform	WG	Medium Sand
22	Kuala Paka - Kg. Cacar (2)	0.250	0.310	0.430	0.550	0.650	0.980	3.161	1.138	Non Uniform	WG	Medium Sand
23	Kuala Paka - Kg. Cacar (3)	0.285	0.330	0.400	0.540	0.640	1.000	3.030	0.877	Non Uniform	PG	Medium Sand
24	Kg. Cacar - Kg. Bukit Tengah (1)	0.285	0.330	0.410	0.500	0.590	0.850	2.576	1.000	Non Uniform	WG	Medium Sand
25	Kg. Cacar - Kg. Bukit Tengah (2)	0.280	0.350	0.410	0.520	0.590	0.960	2.743	1.018	Non Uniform	WG	Medium Sand
26	Kg. Cacar - Kg. Bukit Tengah (3)	0.290	0.350	0.425	0.520	0.600	0.900	2.571	1.038	Non Uniform	WG	Medium Sand
27	Kg. Bukit Tengah - Tanjung Batu Lata (1)	0.280	0.320	0.410	0.550	0.600	0.920	2.875	1.001	Non Uniform	WG	Medium Sand
28	Kg. Bukit Tengah - Tanjung Batu Lata (2)	0.280	0.340	0.450	0.590	0.630	0.950	2.794	1.148	Non Uniform	WG	Medium Sand
29	Kg. Bukit Tengah - Tanjung Batu Lata (3)	0.290	0.330	0.410	0.560	0.620	0.950	2.879	0.935	Non Uniform	PG	Medium Sand
30	Kg. Bukit Tengah - Tanjung Batu Lata (4)	0.670	0.790	1.150	1.650	2.000	2.800	3.544	0.987	Non Uniform	PG	Very Coarse Sand
31	Kuala Kertih - Kg. Baharu (1)	0.540	0.680	0.950	1.600	1.900	2.600	3.824	0.880	Non Uniform	PG	Very Coarse Sand
32	Kuala Kertih - Kg. Baharu (2)	0.530	0.680	0.900	1.500	1.900	2.700	3.971	0.804	Non Uniform	PG	Very Coarse Sand
33	Kuala Kertih - Kg. Baharu (3)	0.500	0.670	0.950	1.600	1.900	2.500	3.731	0.950	Non Uniform	PG	Very Coarse Sand
34	Petronas Complex - Kemasik Beach (1)	0.310	0.350	0.480	1.150	1.400	2.200	6.286	0.531	Non Uniform	PG	Very Coarse Sand
35	Petronas Complex - Kemasik Beach (2)	0.315	0.350	0.480	1.100	1.450	2.200	6.286	0.504	Non Uniform	PG	Very Coarse Sand
36	Petronas Complex - Kemasik Beach (3)	0.320	0.370	0.550	1.300	1.600	2.300	6.216	0.591	Non Uniform	PG	Very Coarse Sand

37	Kemasik Beach (1km from Kuala Kemasik) (1)	0.390	0.425	0.495	0.600	0.650	0.980	2.306	0.967	Non Uniform	PG	Coarse Sand
38	Kemasik Beach (1km from Kuala Kemasik) (2)	0.390	0.425	0.480	0.590	0.630	0.920	2.165	0.938	Non Uniform	PG	Coarse Sand
39	Kemasik Beach (1km from Kuala Kemasik) (3)	0.390	0.425	0.490	0.580	0.650	0.980	2.306	0.947	Non Uniform	PG	Coarse Sand
40	Kemasik Beach (500m from Kuala Kemasik) (1)	0.360	0.400	0.550	0.920	1.150	1.800	4.500	0.731	Non Uniform	PG	Coarse Sand
41	Kemasik Beach (500m from Kuala Kemasik) (2)	0.370	0.425	0.520	0.900	1.150	1.500	3.529	0.635	Non Uniform	PG	Coarse Sand
42	Kemasik Beach (500m from Kuala Kemasik) (3)	0.360	0.410	0.520	0.880	1.100	2.100	5.122	0.683	Non Uniform	PG	Coarse Sand
43	Kemasik Beach (500m from Kuala Kemasik) (4)	0.360	0.420	0.650	1.150	1.400	2.000	4.762	0.838	Non Uniform	PG	Very Coarse Sand
44	Kuala Kemasik	0.590	0.700	1.000	1.650	1.900	2.900	4.143	0.892	Non Uniform	PG	Very Coarse Sand
45	Awana Golf Kijal Resort (1)	0.425	0.480	0.630	0.900	1.100	1.650	3.438	0.849	Non Uniform	PG	Coarse Sand
46	Awana Golf Kijal Resort (2)	0.460	0.500	0.650	0.900	1.100	1.850	3.700	0.835	Non Uniform	PG	Coarse Sand
47	Awana Golf Kijal Resort (3)	0.450	0.500	0.650	0.950	1.160	1.700	3.400	0.809	Non Uniform	PG	Coarse Sand
48	Kuala Kijal	0.660	0.710	0.850	1.100	1.180	1.650	2.324	0.928	Non Uniform	PG	Very Coarse Sand
49	Kijal Beach (1km from Kuala Kijal) (1)	0.200	0.230	0.280	0.320	0.360	0.490	2.130	1.089	Non Uniform	WG	Fine and Medium Sand
50	Kijal Beach (1km from Kuala Kijal) (2)	0.200	0.240	0.280	0.320	0.370	0.495	2.063	1.059	Non Uniform	WG	Fine and Medium Sand
51	Kijal Beach (1km from Kuala Kijal) (3)	0.200	0.230	0.290	0.340	0.380	0.590	2.565	1.107	Non Uniform	WG	Fine and Medium Sand
52	Tanjung Penunjuk - Tanjung Senajang (1)	0.190	0.210	0.260	0.290	0.295	0.350	1.667	1.206	Uniform	WG	Fine Sand
53	Tanjung Penunjuk - Tanjung Senajang (2)	0.170	0.180	0.212	0.260	0.290	0.360	2.000	0.912	Non Uniform	PG	Fine Sand
54	Tanjung Penunjuk - Tanjung Senajang (3)	0.170	0.175	0.210	0.260	0.290	0.380	2.171	0.895	Non Uniform	PG	Fine Sand
55	Kg. Teluk Kalung Beach	0.213	0.260	0.340	0.420	0.450	0.510	1.962	1.206	Uniform	WG	Medium Sand

56	Kg. Kuala Kemaman (500m from Kuala Kemaman) (1)	0.212	0.290	0.500	0.750	0.950	1.700	5.862	1.241	Non Uniform	WG	Coarse Sand
57	Kg. Kuala Kemaman (500m from Kuala Kemaman) (2)	0.212	0.285	0.500	0.760	0.900	1.700	5.965	1.310	Non Uniform	WG	Coarse Sand
58	Kg. Kuala Kemaman (500m from Kuala Kemaman) (3)	0.200	0.280	0.460	0.710	0.880	1.600	5.714	1.202	Non Uniform	WG	Coarse Sand
59	Kampung Geliga	0.290	0.385	0.650	0.950	1.150	1.600	4.156	1.267	Non Uniform	WG	Coarse Sand
60	Kg. Geliga - Kg. Geliga Baharu (1)	0.320	0.360	0.480	0.650	0.750	1.150	3.194	0.960	Non Uniform	PG	Coarse Sand
61	Kg. Geliga - Kg. Geliga Baharu (2)	0.350	0.385	0.500	0.690	0.790	1.160	3.013	0.904	Non Uniform	PG	Coarse Sand
62	Kg. Geliga - Kg. Geliga Baharu (3)	0.290	0.350	0.450	0.610	0.700	1.100	3.143	0.998	Non Uniform	PG	Coarse Sand
63	Kg. Geliga Baharu - Kg. Geliga Basar (1)	0.320	0.340	0.400	0.510	0.600	0.800	2.353	0.833	Non Uniform	PG	Medium Sand
64	Kg. Geliga Baharu - Kg. Geliga Basar (2)	0.290	0.350	0.450	0.550	0.615	0.890	2.543	1.135	Non Uniform	WG	Medium Sand
65	Kg. Geliga Baharu - Kg. Geliga Basar (3)	0.285	0.330	0.400	0.520	0.590	0.790	2.394	0.952	Non Uniform	PG	Medium Sand

Notes:

1) Cu = Coefficient of Uniformity (**Cu = D84/D16**)

   Cu = 1 (uniform)
   1 >> Cu >> 1 (non uniform)

2) Cc = Coefficient of Curvature/Gradation (**Cc = D30 ^{2}/ D10xD60**)

   1 < Cc < 3 , well graded
   1 > Cc > 3 , poorly graded

1) WG = Well Graded
2) PG = Poorly Graded