CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter described the study area and methodology used in this research. The island will be described in detail in terms of the different environmental settings. The methodologies used in this research are being described section by section.

3.2 Study Area

Pulau Pangkor is an island off the northwest coast of Peninsular Malaysia (Fig 3.1) and is located about 2.4 km off the southwestern coast of Perak (Fig 3.2). This island is renowned for its beaches and resorts and can be reached by ferry from Lumut (a small coastal town southwest of Ipoh, the capital of Perak) (Chan et al., 2010; Othman and Rosli, 2011). Pulau Pangkor is a relatively small island with a total area of about 32 km^2 (Chan et al., 2010). The island is about 2.5km wide at its southern end and it widens to about 5km in the central part of the island before tapering off to about 1.5km at its northern-most top. The entire length of the island measures 9.6km. In 2005, it had a population of approximately 25,000 inhabitants. This island lies in the central-eastern part of the Strait of Malacca (Fig 3.1). The beaches on which the tourism industry relies are exposed to pollution risks from potential oil spills originating in the Strait of Malacca as it is one of the busiest maritime thoroughfares in the world.

The 5 beaches analysed in this study include Teluk Dalam on the northeast coast, and Belanga Bay, Teluk Nipah, Tortoise Bay and Pasir Bogak on the west coast. The sandy beaches of the southern coast of Pulau Pangkor are not easily accessible and have not been analysed in this study.

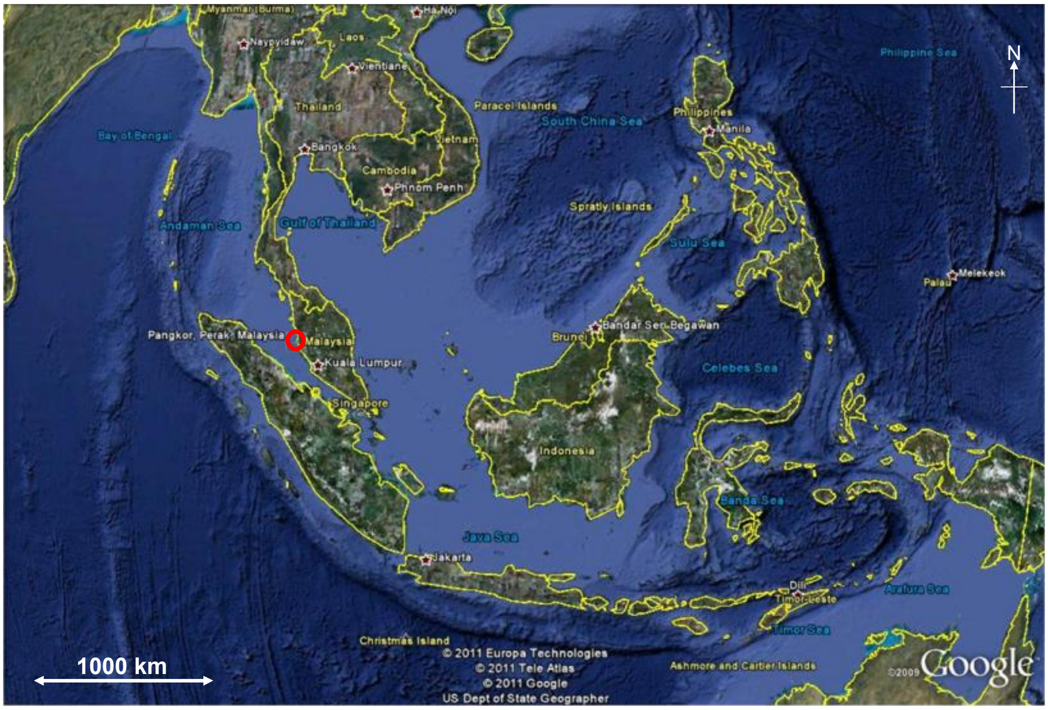

Figure 3.1: Pulau Pangkor in Southeast Asia circled in red, from Google Earth 2009.

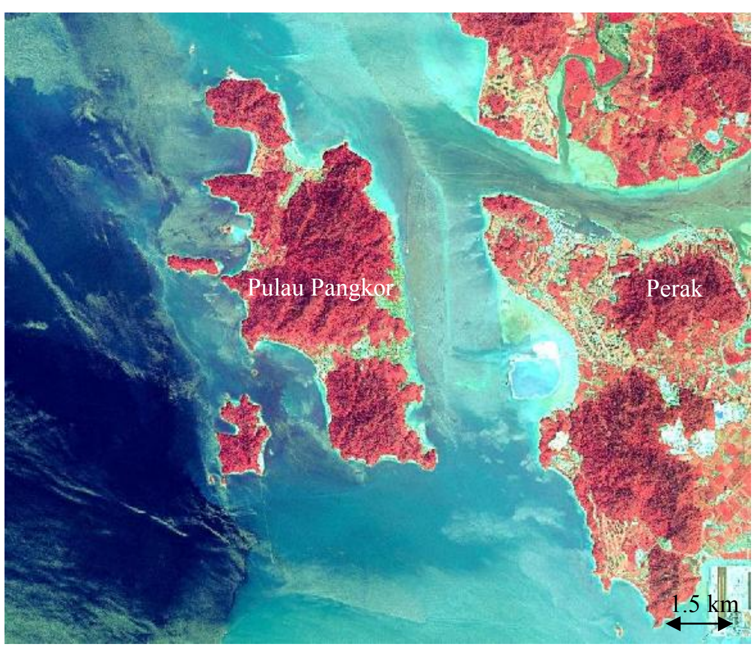

Figure 3.2: Satellite image of Pulau Pangkor taken on 14 December 2004, SPOT-5 Pansharp Supermode All Bands from the Malaysian Remote Sensing Agency.

3.2.1 Methodology of geomorphology and land use of Pulau Pangkor

3.2.1.1 Coastal geomorphology mapping

1. Satellite imagery was used to generate a coastal geomorphology map of Pulau Pangkor. The satellite image was classified into fixed numbers of classes based on the different tone, colour, structure and pattern on the satellite imagery by using Envi 4.7 software and then later narrowed down to only six classes based on field observation. The image was then edited by using ArcGIS 9.3 software into six classes.

3.2.1.2 Digital Elevation Model

1. Elevation data were extracted from Extract XYZ Grid of Topography (2009) website and were used in developing the Digital Elevation Model by using ArcGIS 9.3 software.
2. The Digital Elevation Model was then compared with the topography map (Sheet 83, 1998, Series DNMM 5101, Edition 1-PPNM) obtained from the Department of Survey and Mapping Malaysia, (Jabatan Ukur dan Pemetaan Malaysia, JUPEM) for confirmation of data.

3.2.1.3 Beach slope gradient calculation

1. The same elevation data used for the Digital Elevation Model were also used to calculate and produce the contour map by using ArcGIS 9.3 software. From the contour map (Fig 3.3), the slope gradient was calculated by measuring the width of beaches on the map as well as identifying the height of the slope and calculating them using the formula below.

   $$\text{Tan } \theta = \frac{\text{Sin } \theta}{\text{Cos } \theta} = \frac{\text{Height of beach (identify from contour map)}}{\text{Length of beach (measure from contour map)}}$$

   = slope gradient
2. Ground truthing was conducted by using clinometer. To use a clinometer, the reader had to lay flat at the edge of low tide line and aim the other end point to a fixed object, for example tree or pole, and the reading of the clinometer would show the slope gradient. Slope gradient for all beaches were recorded and compared to the calculated slope gradient from contour map.

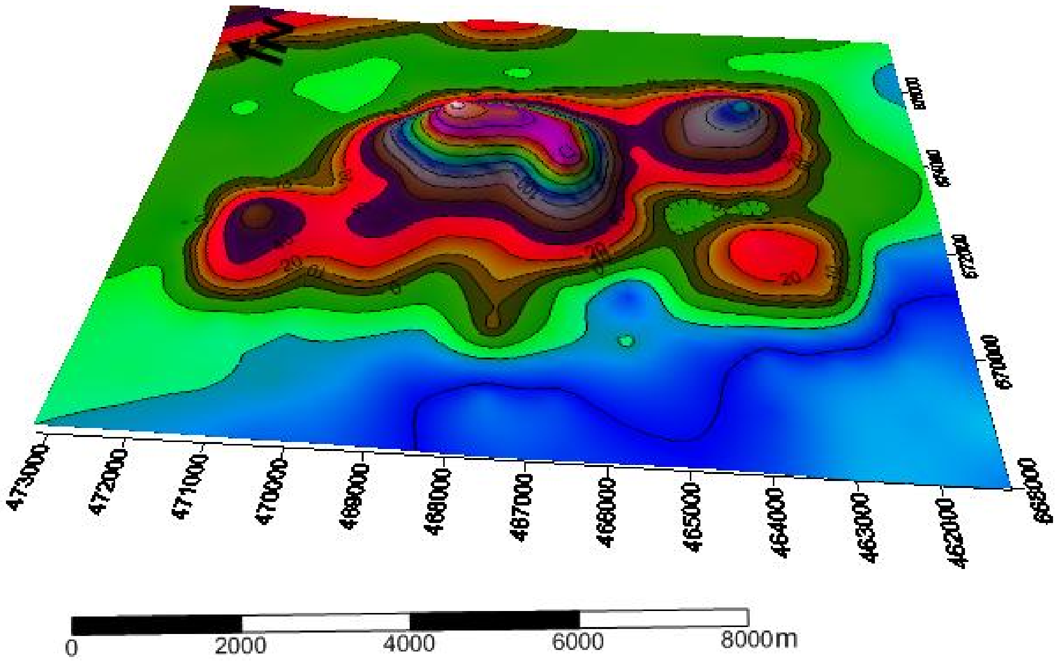

Figure 3.3: Contour map of Pulau Pangkor

3.2.1.4 Width and length of beaches calculation

1. The width and length of the five beaches studied in Pulau Pangkor were measured from the topography map (Fig 3.4) (Sheet 83, 1998, Series DNMM 5101, Edition 1-PPNM) obtained from the Department of Survey and Mapping Malaysia, (Jabatan Ukur dan Pemetaan Malaysia, JUPEM).

3.3 Methodology of wind and wave current

1. Satellite imagery was obtained from the Malaysia Remote Sensing Agency and meteorology data of 20 years were obtained from the Malaysian Meteorology Department (Chiang et al., 2003) (Appendix 1). The meteorology data were correlated with the satellite imagery to ascertain the wind and current directions along the Strait of Malacca in Pulau Pangkor area.
2. The wind and swell direction were presented in wind-rose diagram.
3. Additional data such as oceanography map and main shipping route along the Strait of Malacca were obtained through online websites, books and journals.

4. The dominant wind and current directions were overlapped with the shipping route along the Strait of Malacca to map out the zones of oil spills resulting from shipping accidents that would potentially affect Pulau Pangkor.

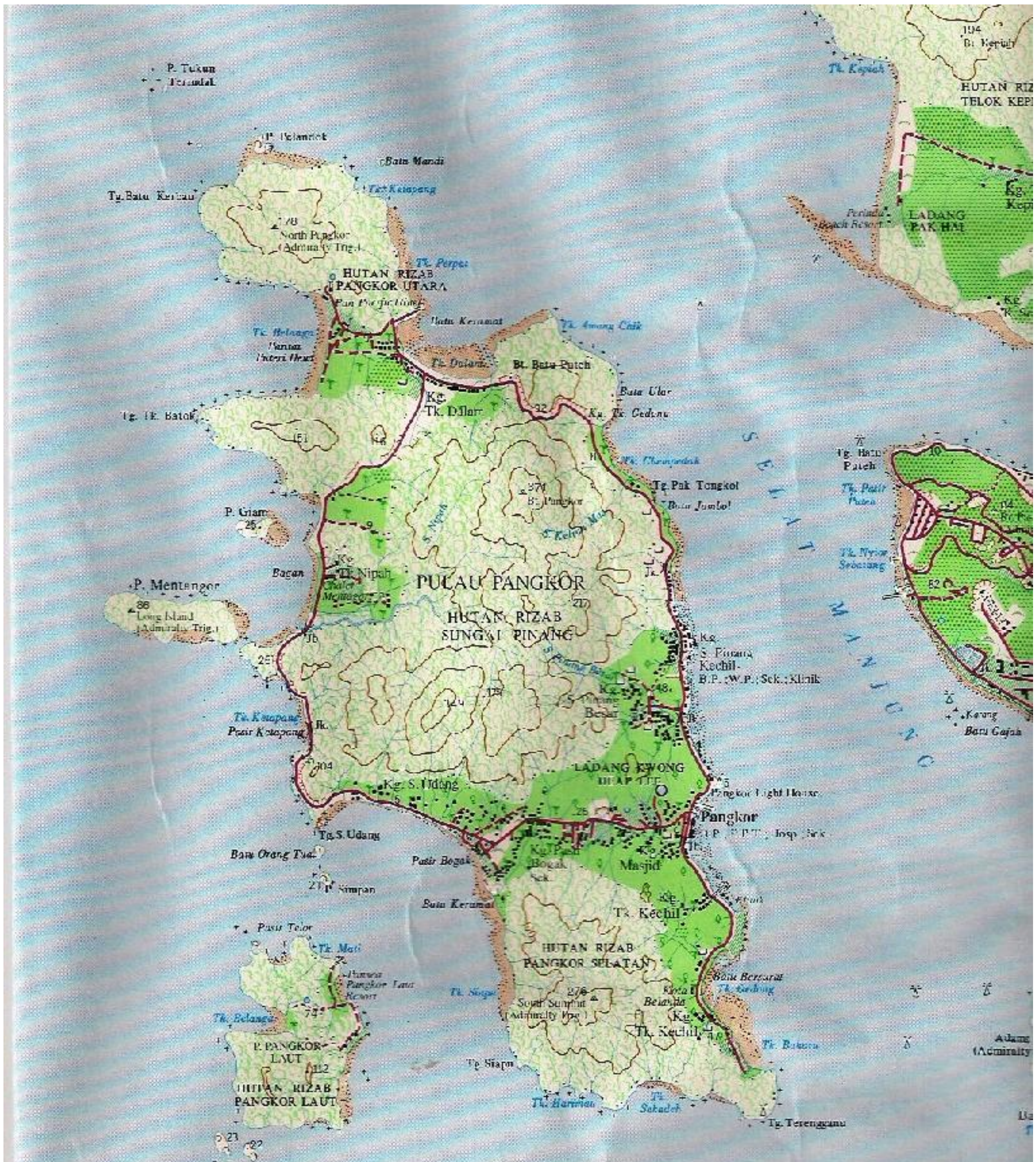

Figure 3.4: Topography map of Pulau Pangkor (Sheet 83, 1998, Series DNMM 5101, Edition 1-PPNM) obtained from Department of Survey and Mapping Malaysia, (Jabatan Ukur dan Pemetaan Malaysia, JUPEM)

3.4 Methodology of beach sediment analysis

Analyzing the type and composition of beach sediment is necessary to assess the impact of pollution by oil spills (Hii et al., 2009). Beach sediments in Pulau Pangkor were examined and this involved:

(i) Observations in the field

(ii) Visual analysis of beach sediment composition under the microscope.

(iii) Measurement of the proportion of carbonate sediments in beach samples through dissolution of the carbonate fragments using Hydrochloric Acid (HCl).

(iv) Grain size distribution determination by sieving beach sand samples.

3.4.1 Sand Composition

1. Beach sand samples were collected along five sandy beaches of Pulau Pangkor.

   Teluk Dalam

   Nine samples were collected from Teluk Dalam (Fig 3.5), two at the eastern end of the beach (named as Teluk Dalam Mangrove, samples D1 and D2) and the other 7 in the west (named as Teluk Dalam Beach, samples D3 to D9).

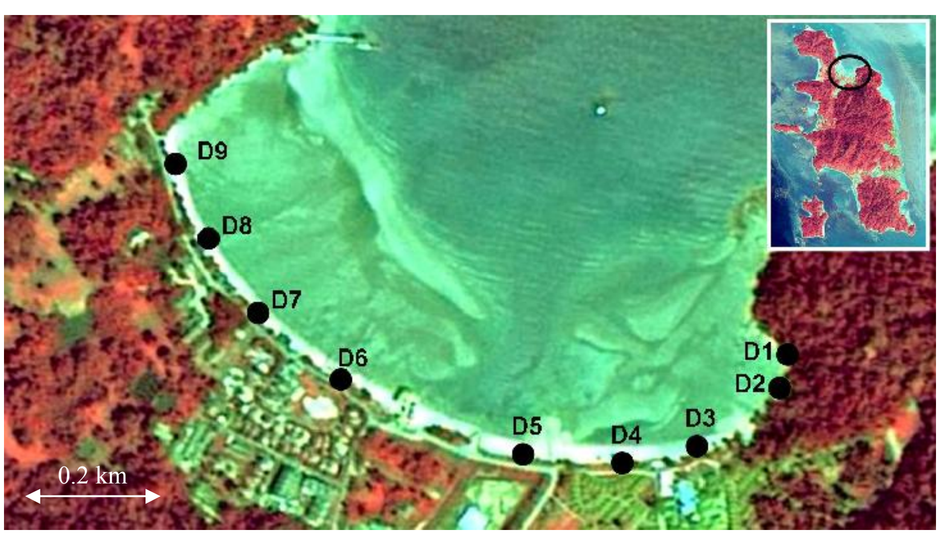

Figure 3.5: Sampling points of Teluk Dalam (white strip is the beach including the tidal zone).

Belanga Bay

Eleven samples were collected from Belanga Bay for sediment analysis (Fig 3.6).

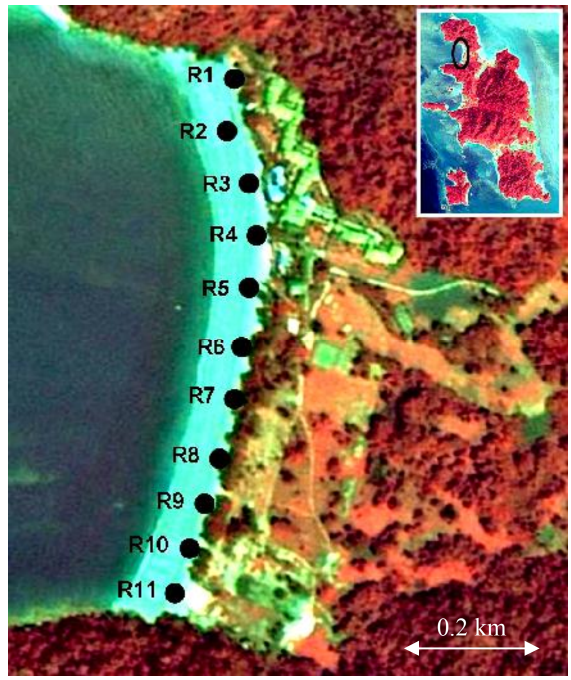

Figure 3.6: Sampling points of Belanga Bay (white strip is the beach including the tidal zone).

Teluk Nipah

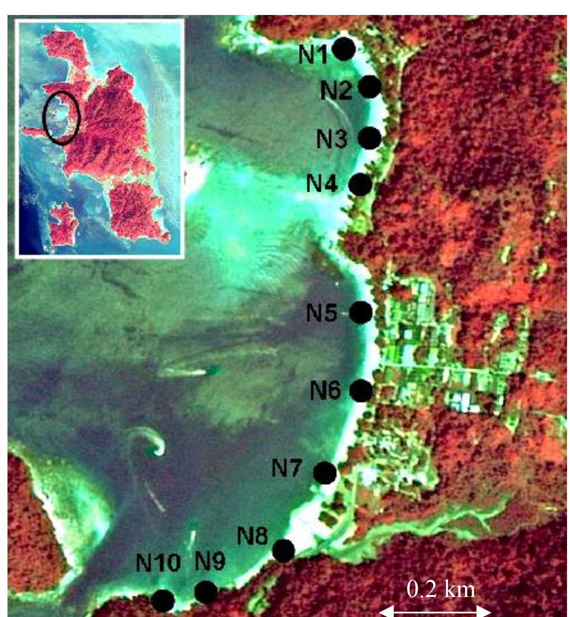

Figure 3.7: Sampling points of Teluk Nipah (white strip is the beach including the tidal zone).

Ten sediments were collected from Teluk Nipah (Fig 3.7), of which four (N1 to N4) were from Teluk Nipah North and another six (N5 to N10) were from Teluk Nipah South.

Tortoise Bay

Four samples, T1 to T5, were collected from Tortoise Bay (Fig 3.8).

Figure 3.8: Sampling points of Tortoise Bay (white strip is the beach including the tidal zone).

Pasir Bogak

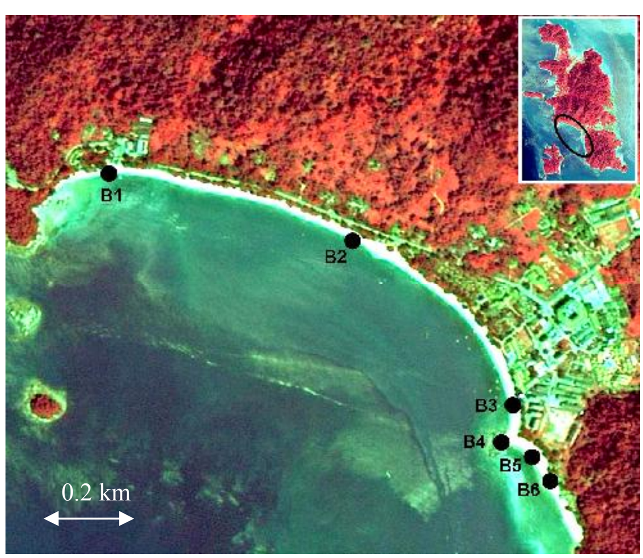

Figure 3.9: Sampling points of Pasir Bogak (white strip is the beach including the tidal zone).

Three samples (B1 to B3) were collected from the northern end of Pasir Bogak beach, one sample from the rocky outcrop in the middle (B4) and another two (B5 and B6) from the southern end of Pasir Bogak beach (Fig 3.9).

2. Representative samples (Fig 3.8, Fig 3.9, Fig 3.10, Fig 3.11 and Fig 3.12) were selected from each beach and were placed in rectangular picking trays divided in 7x6 squares (each square is 1cm x 1cm) and analysed under an Olympus SZX16 binocular microscope through visual observation to determine the sediment composition.
3. Sand components were identified and their proportion was estimated in each square. Average proportions were calculated for the whole sample.
4. Photos of the samples were taken with an Olympus DP72 microscope camera.

3.4.2 Proportion of Carbonate Fraction

Samples were analysed to determine the proportion of soluble fraction in hydrochloric acid. The soluble fraction of the beach samples consists mainly of carbonate grains (Appendix 2).

Methodology of carbonate fraction analysis:

1. The samples were weighed.
2. Hydrochloric acid at 10% concentration was used to dissolve the carbonate fragments.
3. Samples were left overnight in the acid solution to ensure a complete dissolution of the carbonate fraction. The equation of the dissolution is:
   $4HCl + 2CaCO_3 \longrightarrow 2H_2O + 2CO_2 + 2CaCl_2$
4. The samples were then washed with distilled water over filter paper.
5. The samples were dried in an oven at low temperature, 45°Celcius, and the whole process was repeated to make sure all the carbonate fragments had been dissolved by acid.
6. Samples were weighed after complete carbonate dissolution and drying. The weight loss corresponds to the amount of soluble (carbonate) fraction in the samples (in weight %).

3.4.3 Grain Size Distribution

1. The sand samples were first weighed.
2. Sieves of 2mm, 1mm, 500 micron, 250 micron, 125 micron, 63 micron sizes and the pan were weighed individually.
3. The sieves were stacked with the largest sieve on top to the smallest at the bottom.
4. The sand samples were then poured onto the topmost sieve (2mm).
5. The sieves were stacked on to a sieve shaker and vibrated for 10 minutes.
6. The sieves were then removed from the shaker and weighed individually.

Weight of sieve with sediment – weight of sieve = weight of sediment retained in the particular sieve.

Sieve sizes used in this methodology follow Udden-Wentworth grain-size scale (Figure 3.10).

The amount of sediments retained in each sieve was measured and plotted against the sieve size (Appendix 3). From the graphs, the physical characteristics of the sediment such as mean, median, sorting and skewness were determined.

milimeters	Wentworth size class
	Gravel
2.00	Very coarse sand
1.00	Coarse sand
0.50	Medium sand
0.25	Fine sand
0.125	Very fine sand
0.625	Coarse silt

Figure 3.10: Udden-Wentworth grain-size scale for siliciclastic sediment (modified from Wentworth, 1922 in Tucker, 1988).

Mean

The mean is the average grain size of a sediment sample. The mean is calculated from the grain size distribution curves according to the formula (Appendix 4):

$$\text{Mean} = \frac{\varphi 16 + \varphi 50 + \varphi 84}{3}$$

$\varphi 16$ = value of 16 percent in the grain size distribution curve

$\varphi 50$ = value of 50 percent in the grain size distribution curve

$\varphi 84$ = value of 84 percent in the grain size distribution curve

Median

The median is the grain size at 50% of the grain size distribution curve. The median is calculated from grain size distribution curves according to the formula (Appendix 4):

Median = $\varphi 50$

$\varphi 50$ = value of 50 percent in the grain size distribution curve

Sorting

The sorting index is a measure of the standard deviation, i.e. spread of the grain-size distribution. It is one of the most useful parameters because it gives an indication of the effectiveness of the depositional medium in separating grains of different classes. Terms used to describe the sorting index values are:

Less than 0.35	very well sorted
0.35 – 0.50	well sorted
0.50 – 0.71	moderately well sorted
0.71 – 1.00	moderately sorted
1.00 – 2.00	poorly sorted
2.00 – 4.00	very poorly sorted
More than 4.00	extremely poorly sorted (Tucker 1988)

The sorting index is calculated from the grain size distribution curves according to the formula (Appendix 4):

Sorting, So = $\frac{(\varphi 84 - \varphi 16)}{4} + \frac{(\varphi 95 - \varphi 5)}{6.6}$

$\varphi 84$ = value of 84 percent in the grain size distribution curve

$\varphi 16$ = value of 16 percent in the grain size distribution curve

$\varphi 95$ = value of 95 percent in the grain size distribution curve

$\varphi 5$ = value of 5 percent in the grain size distribution curve

Skewness

The skewness index is a measure of the symmetry of the distribution and visually is best seen from a smoothed frequency curve. If the distribution has a coarse 'tail', i.e. an excess of coarse material, then the sediment is said to be negatively skewed; if there is a fine 'tail', then the skew is positive (Fig 3.11). If the distribution is symmetrical, then there is no skew. Terms for skewness (Sk) are:

+0.3 to +1.0	Very positively skewed
+0.1 to +0.3	Positively skewed
+0.1 to -0.1	Symmetrical
-0.1 to -0.3	Negatively skewed
-0.3 to -1.0	Very negatively skewed (Tucker, 1988)

Beach sands are generally well sorted and negatively skewed, whereas river sands are less well sorted and usually positively skewed (Tucker 1988). Skewness is calculated from grain size distribution curves according to the formula (Appendix 4):

Skewness (Sk) = $\frac{(\varphi 84 + \varphi 16 - 2\varphi 50)}{2(\varphi 84 - \varphi 16)} + \frac{(\varphi 5 + \varphi 95 - 2\varphi 50)}{2(\varphi 95 - \varphi 5)}$

$\varphi 5$ = value of 5 percent in the grain size distribution curve

$\varphi 16$ = value of 16 percent in the grain size distribution curve

$\varphi 50$ = value of 50 percent in the grain size distribution curve

$\varphi 84$ = value of 84 percent in the grain size distribution curve

$\varphi 95$ = value of 95 percent in the grain size distribution curve

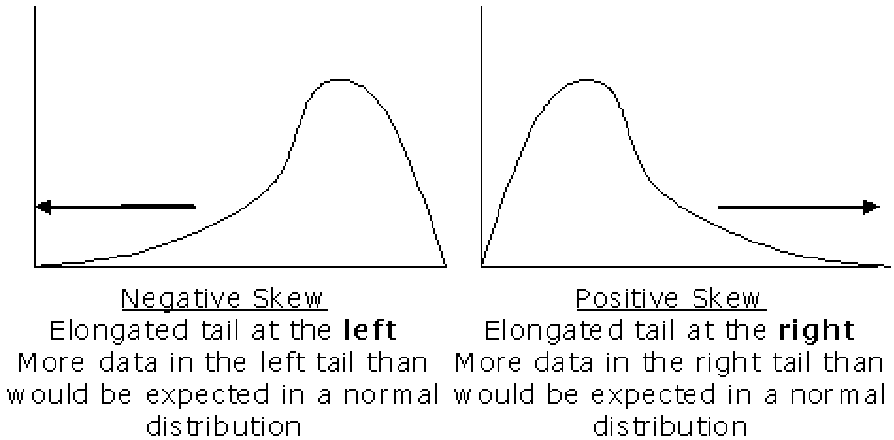

Figure 3.11: Example of negative and positive skewness graphs

3.5 Oil Penetration test

3.5.1 Sampling locations

To study oil penetration rates in the various coastal facies of Pulau Pangkor, cores of beach sediments were collected from the beaches and experiments were carried out in the laboratory. The locations of the sampling points are shown on Figure 3.12 and their coordinates are presented in Table 3.1. Selection of the sampling points of the beach sediment were based on the grain size distribution of the sediments in order to have a suite of samples representative of each beach or part of the beach.

One sample was taken from the mangrove swamp and another one from the clastic sediments in Teluk Dalam. Two samples were taken in Teluk Nipah as the northern and southern parts of the beach have different grain sizes. The cores were labeled as Teluk Nipah North and Teluk Nipah South. Only one core sample was taken in Belanga Bay and another in Tortoise Bay. These two beaches have a relatively homogenous grain size distribution. Three sediment core samples were taken along the northern section of the Pasir Bogak beach as the grain size distribution of the sediments changes from coarse in the north to fine in the south. The samples were labeled Pasir Bogak North-N, Pasir Bogak North-C and Pasir Bogak North-S.

Table 3.1: Coordinates of beach cores for oil penetration tests.

Place	Coordinates
Teluk Dalam Mangrove	N04°15.162’ E100°33.093’
Teluk Dalam Beach	N04°15.007’ E100°33.168’
Belanga Bay	N04°15.073’ E100°32.758’
Teluk Nipah North	N04°14.316’ E100°32.708’
Teluk Nipah South	N04°13.786’ E100°32.681’
Tortoise Bay	N04°13.154’ E100°32.663’
Pasir Bogak North-N	N04°12.838’ E100°32.901’
Pasir Bogak North-C	N04°12.732’ E100°33.271’
Pasir Bogak North-S	N04°12.502’ E100°33.514’

3.5.2 Sampling method

Cores of beach sediments were taken within the intertidal zone (Fig 3.13) as oil slicks reaching the coastal areas will be washed up to the highest reach of the intertidal zone and will cover beach sediments as the tide recedes (Jalali et al., 1998; DuTemple, 1999; Sagehashi et al., 2003; Al-Lihaidi, 2000; Payne et al., 2008). As seawater that saturates the beach sands lowers with the ebb tide, the oil slicks in contact with the beach sediments will start penetrating into the layers of beach sediments (Fig 1.3, Fig 1.4 and Fig 1.5).

Nine Perspex tubes, each measuring 50cm in length and 8 cm in diameter, were used to take samples of beach sediments (Grant, 1981). A Perspex tube was pushed into the beach sediments (Fig 3.14a) and extracted by removing sediments from around the Perspex tubes (Fig 3.14b). The compaction of the beach sediments around the edges of the Perspex tube was considered minor and thus not taken into account in the experiments.

Figure 3.12: Sampling points for beach sediment cores.

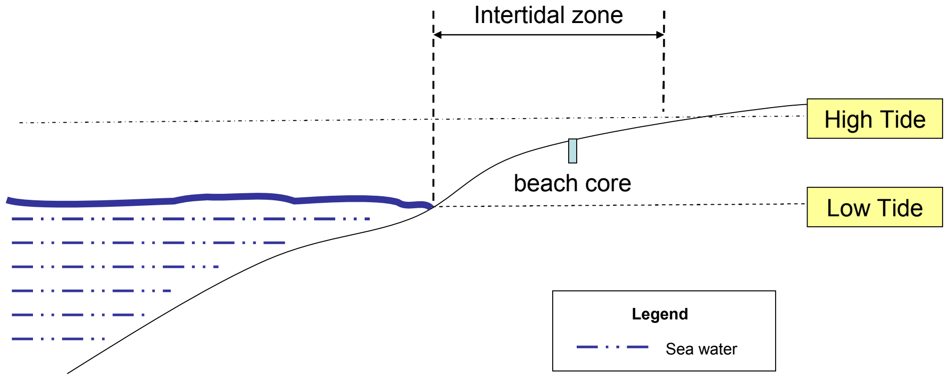

Figure 3.13: Beach sediment cores were taken in the intertidal zone.

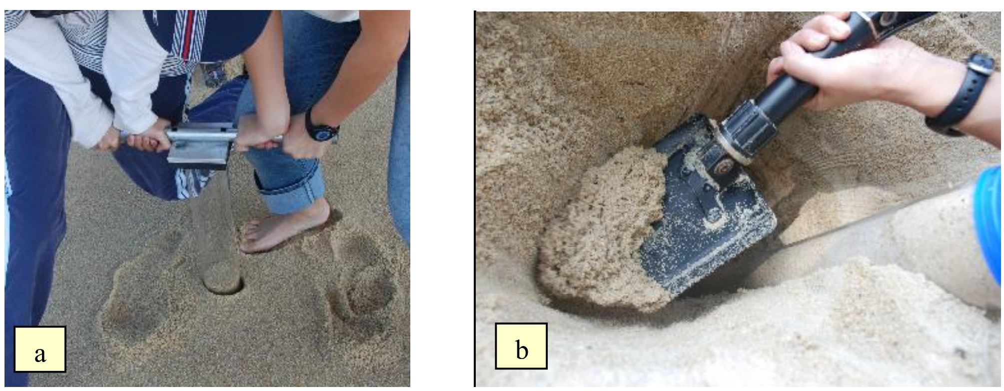

Figure 3.14: Perspex tubes were pushed into the beach sediments (a) and extracted by removing sediments from around the Perspex tubes (b).

3.5.3 Crude oil types for penetration experiment

The oil penetration tests were carried out with three grades of crude oil, i.e. light crude oil, medium crude oil and heavy crude oil. The crude oil used in these experiments was provided by PETRONAS Research Sdn Bhd and was collected from the Kekwa field. It had an original API gravity of 39 and a viscosity of 11 centipoises (cP). This crude oil was mixed with bitumen to obtain two additional oil samples of higher viscosities (medium and heavy crude oil) for this experiment.

The API gravity and viscosity in centipoise (cP) of the 3 grades of crude oil used in the oil penetration tests are

1. Light crude oil: API 39; 11cP
2. Medium crude oil: API 25; 588cP
3. Heavy crude oil: API 15; 44,375cP

3.5.4 Methodology of oil penetration experiment

Beach cores taken within the intertidal zone of five beaches in Pulau Pangkor were brought back to the laboratory for the oil penetration test. The bottom of each of the Perspex tube was covered with a plastic cover with holes to allow the passage of air and water. A filter paper was placed between the cover and the beach sand to prevent the beach sand from being washed away through the holes when saturating the beach sediment column with sea water. The top of the Perspex tube was left open and a gap of 5 cm was left above the top sediment level.

Oil penetration tests were conducted in the open to simulate a real beach environment. Beach cores were saturated with sea water before the commencement of the oil penetration experiment to simulate the nearest conditions to a real environment (beach sand are saturated with sea water during high tide). About 150 ml of crude oil was poured on top of the beach sediments (reaching a height of 3cm above the beach sediments). The seepage rate of the crude oil was monitored and recorded every minute for the first ten minutes, every 5 minutes for the next hour and subsequently every hour for the next 23 hours. The time interval between penetration measurements was initially shorter and then longer once the penetration rate stabilized. The maximum time taken for this experiment was 24 hours. The experiment was repeated for all three grades of crude oil (light crude oil, medium crude oil and heavy crude oil).

3.6 Methodology of effects of oil spills, mitigating and clean-up measures

1. Mitigating and clean-up measures were suggested based on impacts of oil spills caused on the various coastal facies of Pulau Pangkor.
2. Other researchers' published work have been compared and presented in this section which are similar to the research done in Pulau Pangkor.