

Variation of beach sand in relation to littoral drift direction along the Kuala Terengganu coast

ROSNAN YAACOB¹, M.L. HUSSEIN¹ AND A. TAJUDDIN²

¹Fisheries and Marine Science Center, Universiti Pertanian Malaysia
Mengabang Telipot, 21030 Kuala Terengganu, Terengganu

²Department of Geology, University of Malaya
50603 Kuala Lumpur

Abstract: A knowledge of long shore variation in beach sediment and littoral drift direction is important for making decisions in coastal zone management and coastal engineering, especially in the construction of ports and breakwaters. This paper discusses a systematic analysis of the beach grain size variation along the north-western coast of Kuala Terengganu by applying a time series approach. The study area is located close to the city of Kuala Terengganu, extending from the beach at Tanjung Gelang to Kuala Ibai. The beach sediments in the study area are exclusively sandy with median diameter between coarse and fine grained sand. The median grain size, as well as sorting and skewness values show a spatial and temporal variation throughout the entire study area. The median grain-size generally decreases along the direction of the littoral drift with increasing distance from the sediment source. The beaches' morphologies vary throughout the area, with finer beach sediment causing a more gentle foreshore due to less erosion. The study shows that sediment grain-size gradation can be used as an indicator of net littoral drift direction.

INTRODUCTION

A knowledge of littoral processes is necessary for complete understanding of the depositional or erosional framework of a coastline. Littoral drift can be simply define as the movement of sand along the coast as a result of the breaking waves which stirred up the sand particles into suspension (Komar 1976). This sand move in a somewhat zig-zag pattern as it been carries along shore by the long shore current. Net littoral drift transcends seasonal variations in the littoral drift direction and can be defined as the overall long-term direction of sediment transport along shore. An understanding of the beach sediment transport, as well as identifying areas of erosion or accretion, is necessary in any rational coastal management or planning and coastal engineering endeavor. Furthermore, net littoral drift and sediment characteristics are important component for the environmental impact assessment study.

Lately, the study of sediment pattern has tended to become more applied. Taggart and Schwartz (1988) used geomorphic and sedimentological indicators to determine the direction of shore drift (long term sediment transport) along a coast line. This is a quick and accurate method to resolve the impact of coastal sediment transport regime on coastal zone management decisions, as well as the

construction of coastal structures. The nature and extend of coastal erosion and accretion at a local or regional scale can also be determined through the use of this indicator. Among the studies done that noted the important of a variety of sedimentological trends to interpret littoral drift direction are by Sunamura and Horikawa (1972), Self (1978), Engstrom (1978), Stanley (1986), Rosnan and Saadon (1989) and Noda (1971). However, previous study especially in Terengganu used limited amount of data and did not represent the seasonal trend and changes that took place throughout the year. The purpose of this study is to describe the long shore variation of beach sand in relation to the littoral drift direction along the coastline of Kuala Terengganu by applying a time series approach.

MATERIALS AND METHODS

Study Area

The study area is located on the east coast of Peninsular Malaysia (Fig. 1). Eight sampling stations were chosen in the beach area located along the coast near the mouth of Sungai Terengganu. The beach at the north-west region of Sungai Terengganu is relatively steep compared to the gradual profile south-east region of the river. Sungai Terengganu is one of the major source of

river sand. Eroding beaches and the other major source provide a significant volume of sediment to the long shore transport system (Stanley, 1986). The coastline is relatively straight and is aligned at about 315 degree. The sampling stations are selected based on the economical basis of the region. Kuala Terengganu Airport is located along the coast, five kilometers north of Sungai Terengganu. Access along the coastline is by a road located less than one kilometer inland from the coast. At the south-eastern of the river, the shoreline is aligned at about 350 degrees. The city of Kuala Terengganu is located along this coastline. There are various developments along the coast including school, hotel, residence, recreational area and the sultan's palace.

The study area lies in the wet topics, where high rainfall is recorded during the monsoon season. The northeast monsoon prevails between November and March, and the rest of the years is the transition and south-west monsoon period. The mean annual temperature lies in the range of 25.6°C and 27.8°C. The temperatures of surface water are typical of tropical type, being 27°C to 28°C. The water off east coast belongs to the surface type as described

by Leong (1974); having warm temperature of more than 25°C and low salinity of less than 34 ppt. The most prominent winds come from NNE-NE directions and SES Winds (Dale, 1956).

Winds stronger than 20 km/h are mainly from NE-ENE directions. NEE wind occupy about 70% of the wind frequency from the sea (Shiozawa, 1984). Raj (1982) states that there are two net directions of present-day beach sediment transport by the littoral drift along the Terengganu state coastline; a north-westward transport, and southward transport, to the north-west, and south of Kuala Terengganu respectively. The average rate of sediment transport for the coast is about 250 cm/day (Phillips, 1985). Other studies using sediment grain-size indicates that sediment on the north western part of the river is moving to the north-west and sediment on the south-eastern part of the estuary is moving to the southeast (Rosnan and Saadon, 1989; Stanley, 1986).

Sampling and Analytical Technique

A total number of 124 beach samples was collected from the foreshore and backshore area at

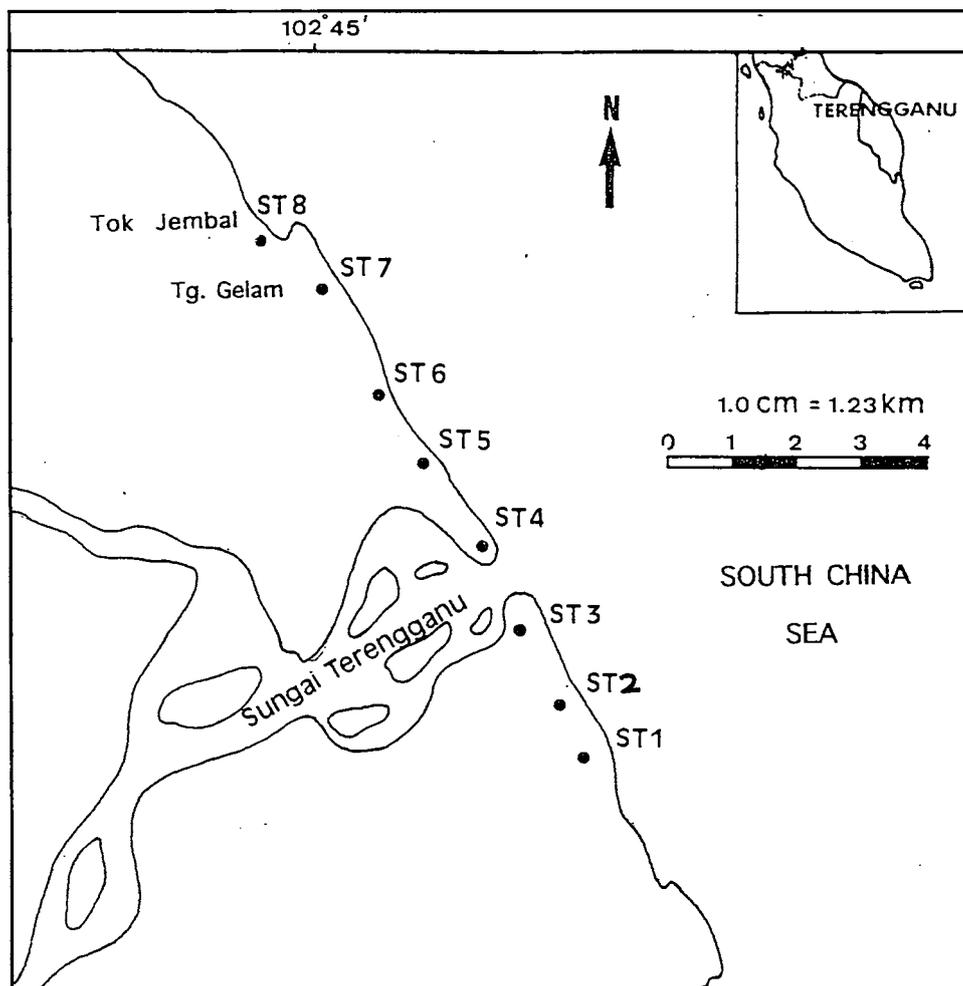


Figure 1. Map of the study area showing the sampling stations.

each station from January 1989 to December 1991. The samples were placed in plastic bags and stored for further laboratory analysis. Profile surveys were carried out monthly by using level and staff method. The data on littoral environment collected during the survey, followed the method of Littoral Environment Observation Program of the United States Coastal Engineering Research Center, 1977. Measurements were made on wave period, wind speed, wind direction, long shore current velocity and beach slope.

The sediment samples were air dried and quartered by hand (Kruimbein and Pettijohn, 1988). In the laboratory, the sediments samples were washed carefully to remove salt. Some portion, approximately 100 to 250 grams of each sample was used for the textural analysis by dry sieving method as described by Buller and McManus (1979). Based on the data obtained, statistical measures were calculated according to the Folk and Ward's (1957) formula.

RESULT AND DISCUSSION

Tide, Currents and Waves

Phillips (1985) described the tides along the Terengganu as having mean spring tide in the range of 1.8 m. The tides is mixed, with a strong diurnal component beating with a smaller semidiurnal phase. These give rise to asymmetric tides near the spring where the tide may flood in 6 to 8 hours and ebb over as long as 18 hours. The diurnal component, giving one high water and one low water a day, is dominant during the usual day. The semidiurnal component becomes more dominant during the period of the equinoxes, resulting in two high water and two low water in a day. However the successive high and low waters are unequal in height and times.

The Royal Malaysian Navy has long term tidal records for Cendering that is near the study area. The mean sea level at Cendering (M.S.L) is 1.5 m while at Kuala Terengganu, the mean sea level is 1.0 m. The tidal range in the study area nowhere exceeds 2 m and the area may thus be described as low mesotidal, according to the classification of coastal types based on the tidal range (Hayes, 1979).

Current patterns in the South China Sea are monsoon-controlled flowing southeast during the Northeast Monsoon and northeast during Southeast Monsoon. The currents are a mixture of tidal current, wind and wave generated. During the Northeast Monsoon, the currents speed varies from 0.1 to 0.2 m/s and runs southward along the east coast of Peninsular Malaysia. During the Southwest Monsoon, the currents (0.1 to 0.2 m/s) are to the

north and may vary with variation in the wind direction. During the transition periods, the currents are similar in strength and run south for less than 50% of the time.

Generally, the coastal currents, flow parallel to the coastline. The flow is in the southerly direction during the Northeast Monsoon but is reversed for the other season. The change in drift direction occurs during the transitional months. The effect of tides on surface water movement near the coast of Kuala Terengganu (< 0.5 nautical mile) is significant (Saadon and Rosnan, 1989). At receding tide the surface water move northward but at rising tide the reverse is true. The tidal current will either inhibit or reinforce the wind driven current.

From the result of field survey in June 1989, the surface current velocity ranged from 0.022 to 0.280 m/s and the bottom current ranged from 0.057 to 0.320 m/s. The current direction recorded during the survey is mostly southerly. There are, however, a few readings that show northerly flow direction.

The long shore current differs from place to place depending on the coast geometry and angle of wave approach. The long shore current direction recorded is either northwesterly or southeasterly with southeasterly direction dominating during the northeast monsoon. Its velocity varies from 4 cm/s to 14 cm/s and increases slightly when the tide is going down. The wave height varies from a few meters to maximum of about 4 m. NNE-NE waves are predominant during NE monsoon seasons whereas NE-SSE waves during the other seasons. The most frequent wave height is between 1.0 to 1.5 m.

The wave period recorded is within 3 to 6 s. This is within the short wave period. By using the simple relationship between period and wavelength ($L = 5.12 T^2$), it is seen that the wavelength ranged from about 14.4 m to about 57.5 m. Waves approaching this coast generally break over a fairly wide zone forming both plunging and spilling breakers but during high tide and during the Northeast Monsoon plunging breakers predominate. Upon reaching the beach, converging waves at the water edge are sometimes observed especially at stations 3 and 4. Waves are generally higher and more turbulent at the central part compared to the other stations.

Beach Sediment and Profiles

The data obtained by dry sieving technique for all the composite beach sediments are summarized in Table 1. Average median diameter (Md) ranged from 0.73 to 2.12 phi. It was noted that stations that are near the estuary have larger grain size compared to all other stations. The average median diameters also indicate that most of the beach

sediments are composed Wentworth's (1972) classification. However, average median grain size values at stations 3 and 4 are in the coarse sand range and show relatively greater variation in either space or time (Fig. 2). Average median values for the south-eastern region (stations 7 and 8) are finer than the values obtained for the rest of the locations. Coarser sediments are found in the northwest of the river than to the south of it. The median diameter also indicates that the beach sediment decreased in size as it was moved along the shore away from the river mouth. On the whole, the erosion zones (at stations 3 and 4) are

composed of coarser sediment with smaller values of average median diameter and show great variation in either space or time. Visual examination of the samples shows that the central part is composed of angular or irregular particles while stations that are away from the river are dominated by sub-rounded or rounded particles.

The average sorting values display a pattern that is quite comparable to that of the average median diameters. The southeastern (stations 1 and 2) and the northwestern parts (stations 7 and 8) are either well sorted or moderately sorted and show relatively lesser temporal variation (Fig. 3).

Table 1. Statistical parameters for the beach sand of Kuala Terengganu coast.

Station	Number of samples	Av. Median diameter	Av. Sorting	Av. Skewness	Type	Type of Sorting
1	15	2.11	0.69	0.11	fine	moderately well sorted
2	15	1.75	0.72	0.41	medium	moderately sorted
3	16	1.65	0.71	-0.27	medium	moderately sorted
4	16	0.73	1.06	-0.37	coarse	poorly sorted
5	15	0.99	0.66	-0.16	coarse	moderately well sorted
6	15	1.09	0.56	-0.05	medium	moderately well sorted
7	16	1.87	0.52	0.02	medium	moderately well sorted
8	16	2.12	0.50	0.03	fine	well sorted

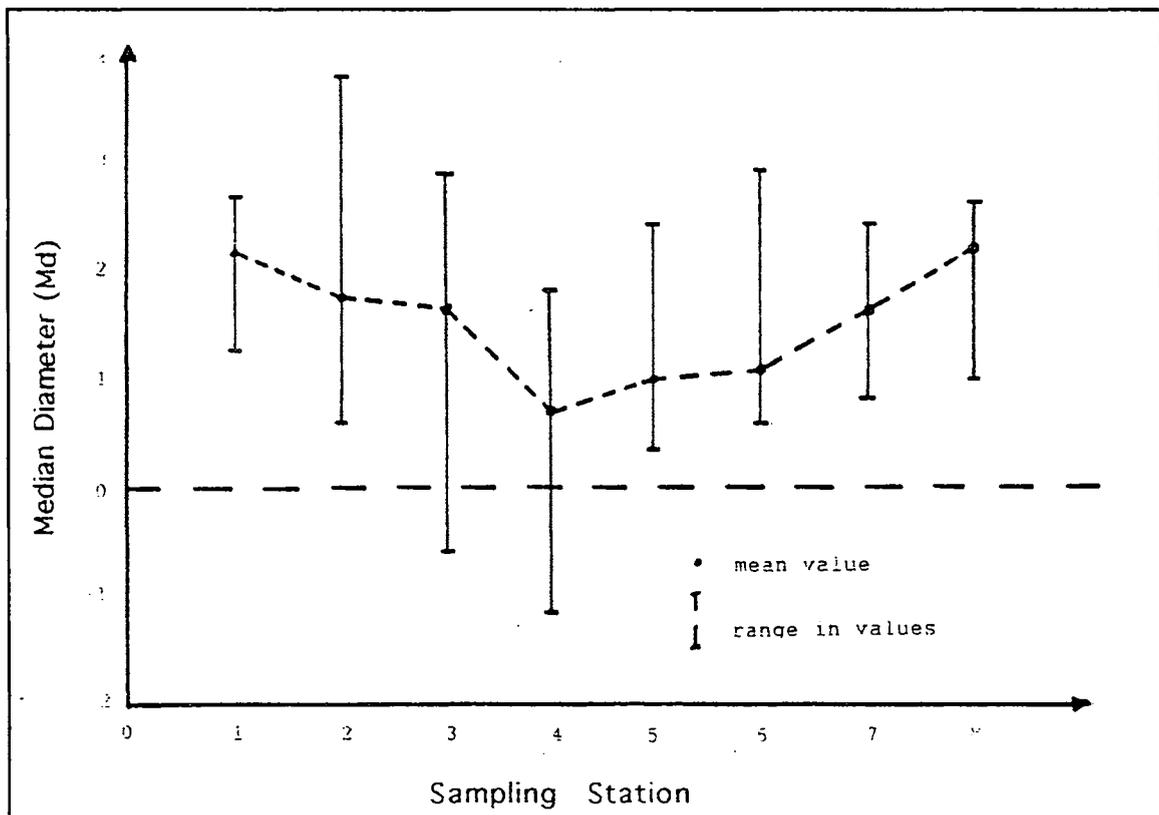


Figure 2. Range and mean values for the beach median grain size at each station.

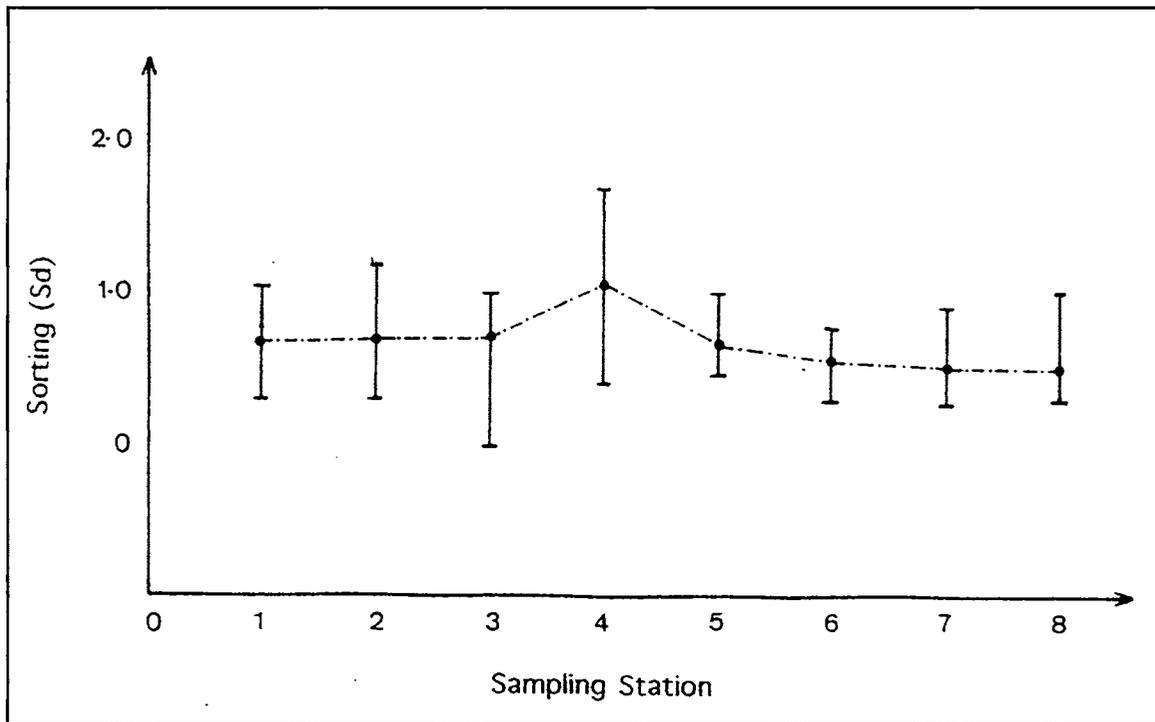


Figure 3. Range mean values for the sediment sorting at each station.

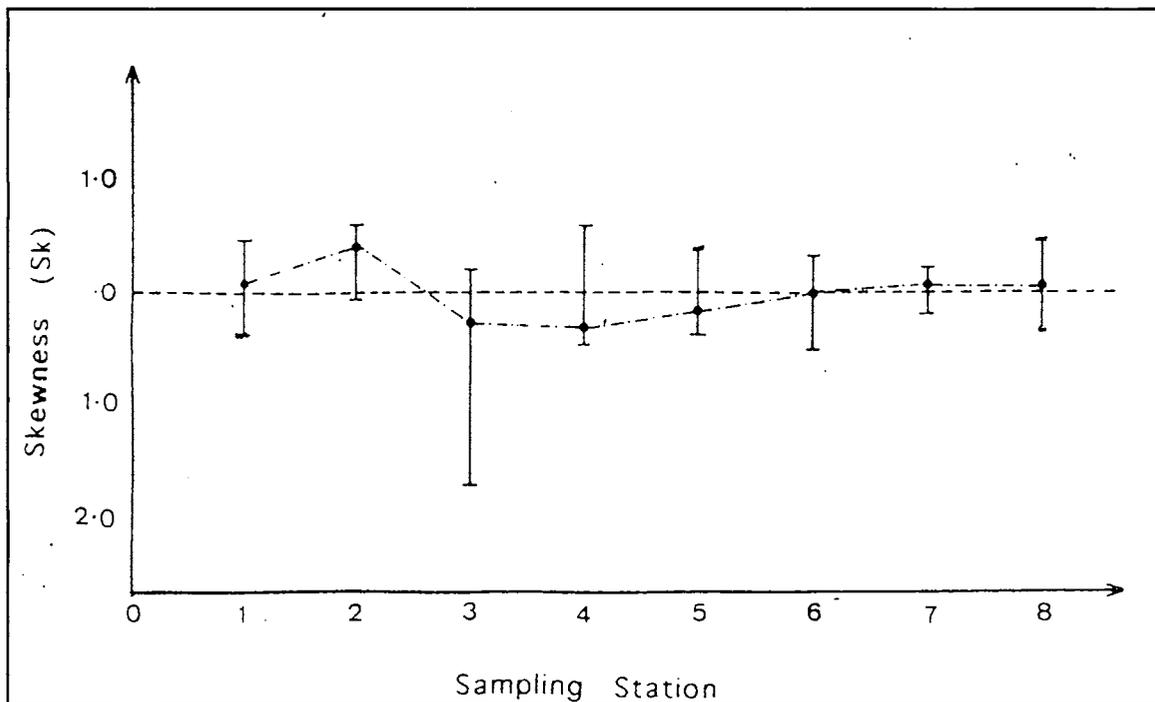


Figure 4. Range and mean values for the sediment skewness at each station.

Stations 2, 5, 6 and 7 have standard deviations in the moderately sorted to moderately well sorted categories but show some temporal variation. As station 4 is located in the higher wave energy and nearer to the sediment source, it is mostly dominated by poorly sorted sediment and shows greater temporal variation. In general, it can be said that sorting of the beach sediments are getting better as the distance from the source increases or as the grain size decreased. These indicate that the degree of sorting is not only dependent on the effect of wave energy reaching the coast, but also the source from which the sediments were derived.

Skewness indicates whether the sediments consist of excess of fine or coarse fractions. Positive values of skewness indicate that normal size

distribution is influenced by finer sizes. Average skewness values in the study area ranged from -0.37 to 0.41. Skewness values shows slightly different fashion than that shown for median diameter and sorting parameter. Almost all of the stations show a rather narrow variation in the skewness values throughout study (Fig. 4). In general, size frequency distributions of beach sediments tend to be symmetrical, negatively or slightly positively skewed due to back and forth motion of waves (Friedman, 1961). This trend is also noted during the study as shown in Figure 4. Stations 1, 6, 7 and 8 show near-symmetrical values, station 2 is fine-skewed and the stations 3, 4 and 5 are coarse-skewed. The negatively skewed sediments are probably due the presence of coarse

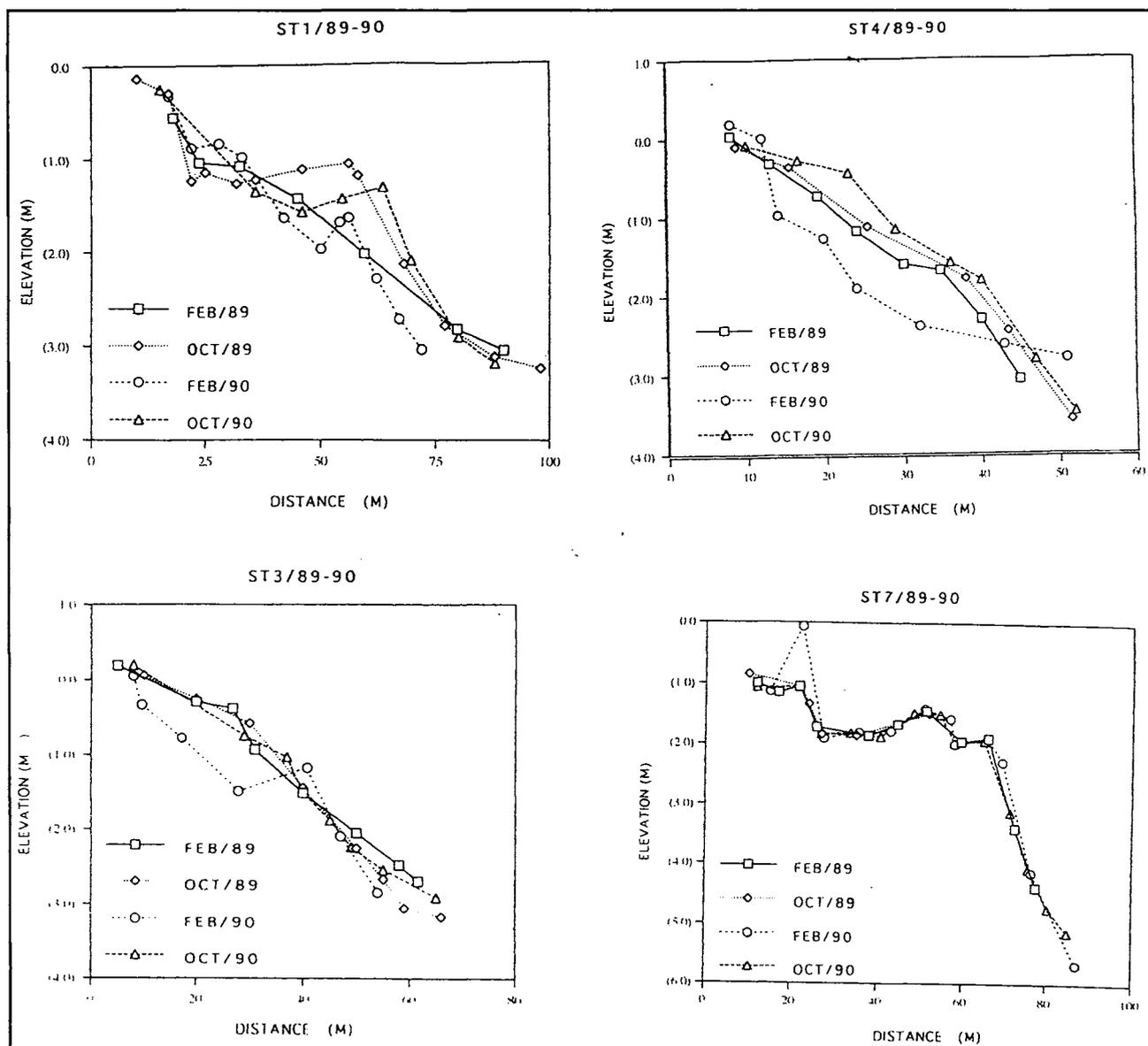


Figure 5. Beach profiles at selected stations.

sized sediment in greater percentage or due to mixing of sub equal proportion of the sediments and are subjected to variation of wave energy.

The profiles of the stations vary in character: the foreshore width can be less than 20 m to more than 40 m. Although apparently there are spatial variation in the beach morphology, there is still lack of quantitative data on the temporal variation. Profiles in the northwestern and southeastern end of the study area (stations 1 and 8) show a rather broad and gently sloping backshore area with a

relatively gentle slopping foreshore (Fig. 5). Some vegetation such as *Ipomea Pres Capre* and *Vitex Ovata* are found at the berm indicating a healthy state of accretion. Changes in the backshore portion of the profiles are minor and some are due to the wind action as it was observed that this portion is covered mostly by very fine sand. The foreshore area exhibited a moderate change of both erosional and accretional natures. Profiles near the river mouth (station 4) have steep foreshore. This steepness is due to higher energy wave energy on the beach which is turn causes coarser sediment to dominate this area. Erosion seems to occur more than accretion at station 4 throughout the year. There are no vegetation on the beach berm area to stabilize the area at station 4.

The result can be summarized diagrammatically as shown in Figure 6. On the whole, the beach sediment seems to decrease in size as the beach slope decreases. In a zone of erosion where the beach slope is steeper and there is a continuous influx of sediment in the system, for example at station 4, the beach usually consists of poorly-sorted sediment. As the sediment progress downdrift, it becomes increasingly better sorted until at the terminus of the drift, in the zone of accumulation (at stations 1, 7 and 8), the beaches consist of well-sorted sediment. From the trend of beach profiles, sediment size and beach slopes, it can be generally said that net littoral drift direction in the study area is from the Southeast to the Northwest at the northwestern sector of the river and is of opposite direction at the southeastern sector. The median grain size decreases in the direction of the littoral drift and as the distance from the river increases. This particular trend was also noted by Taggart and Schwartz (1988) in their study on shore drift directions.

Komar 1976, states that the diminution of sediment grain size in the direction of shore-drift is the result of lateral long shore variation in wave energy. This pattern is observed in the study area where coarser grained sediments at station 4 are transported by higher-energy waves. Finer grained sediment are move by lower-energy waves at stations 1, 2 and 8. This selective transport mechanism result in the finer sediments to moving further away from the source, while coarser sediments are being deposited. Thus it can be said that higher energy waves and coarser sediments at station 4 resulted in steep foreshore whereas lower-energy wave and finer sediments at stations 1, 2 and 8 cause a less-steep foreshore with relatively less erosion. This study shows that with sufficient data, sediment grain-size can be used as an indicator of the net littoral drift direction.

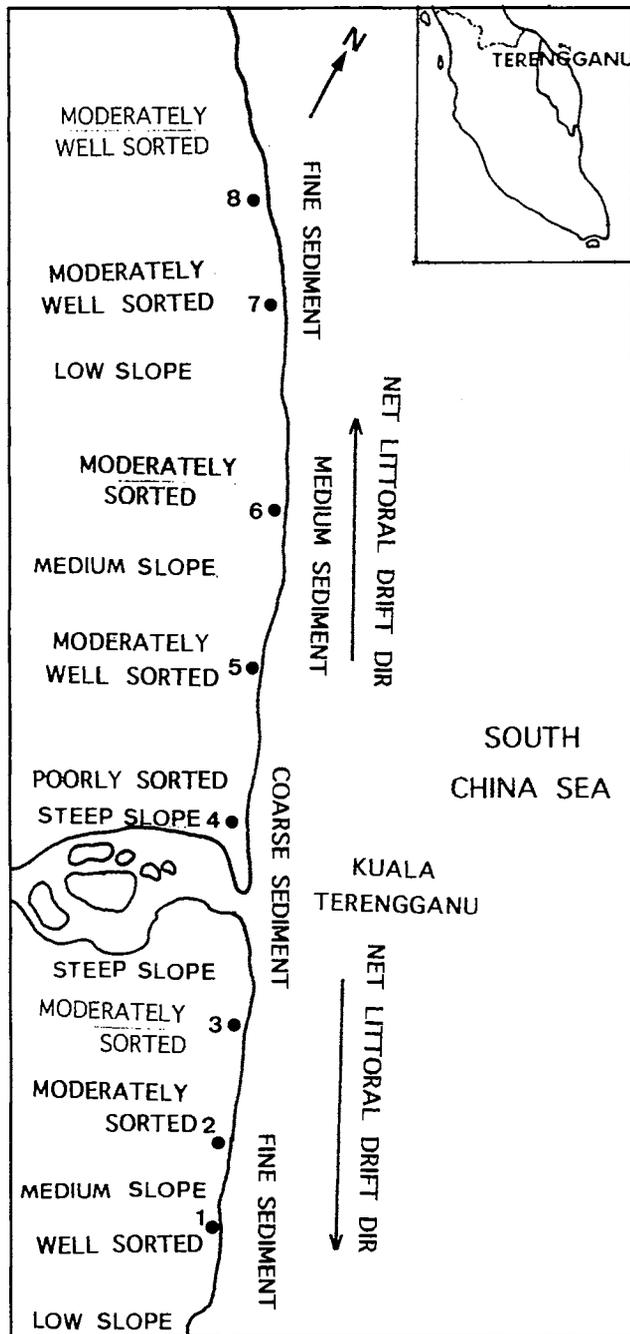


Figure 6. Relationships between sediment size, beach slope and shore-drift directions.

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