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Past, present and future coastal changes at the Kuala Kemasin estuary, Kelantan State

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Abstract: The Kelantan State coast at Kuala Kemasin is fronted by sandy beaches that extend northwestward, and southeastward, from breakwaters constructed on both sides of the estuary between 1989 and 1991. Aerial photographs flown over the area in 1948, 1949, 1952, 1966, 1974, 1978 and 1983 show that there have been several pre-breakwater (past) coastal changes, mainly involving variations in the size of sand spits on both sides of the then unprotected estuary. These changes are due to the predominantly northwest directed littoral drift here which results from the oblique approach of swell and storm waves from the South China Sea. Satellite imagery between 1990 and 2005 as well as aerial photographs flown in 1995, and field surveys in May 2005 and March 2006 show that the northwest directed littoral drift has continued to impact the area; there being accretion of beach sediments (and shoreline advance) on the south side of the estuary, but erosion (and shoreline retreat) on the north side. Rates of shoreline advance and retreat are relatively low, in the order of a meter or so per year, though erosion already now threatens several wooden houses and agricultural land on the north side of Kuala Kemasin. In view of the continued prevailing northwest directed littoral drift, it is concluded that there will continue to be accretion of beach sediments on the south side of the Kuala Kemasin estuary, but erosion on its north side.

Abstrak: Pantai negeri Kelantan di kawasan Kuala Kemasin dibanjari oleh pantai berpasir yang menganjur ke timur laut dan tenggara dari benting pemecah ombak yang dibina di kedua belah bahagian muara di antara tahun 1989 sehingga 1991. Gambar-gambar foto udara kawasan ini bagi tahun 1948, 1949, 1952, 1966, 1974, 1978 dan 1983 menunjukkan terdapatnya beberapa perubahan pantai pra-benting pemecah ombak (lampau), terutamanya variasi dari segi saiz beting-beting pasir di kedua-dua belah muara sebelum ia dilindungi. Perubahan pantai ini adalah disebabkan oleh arus hanyutan pesisir yang menganjur terutamanya ke timur laut dan terhasil akibat hempapan «swell» dan ombak ribut secara menyilang dari Laut China Selatan. Imej satelit antara tahun 1980 dan 2005, serta gambar foto udara pada 1995 dan tinjauan lapangan pada bulan Mei 2005 dan Mac 2006 menunjukkan arus hanyutan pesisir timur laut terus menghempap kawasan ini, terbukti dengan penokokan sedimen pantai (dengan pengunjuran garis pantai) di kawasan selatan dari muara, manakala hakisan (dan pengunduran garis pantai) terjadi di kawasan utara. Kadar pengunjuran dan pengunduran garis pantai secara relatifnya adalah rendah di dalam skala satu meter setahun, walaubagaimanpun hakisan sedang mengancam beberapa rumah kayu dan tanah pertanian di utara Kuala Kemasin. Berdasarkan penerusan proses hanyutan pesisir dari timur laut ini, adalah dirumuskan bahawa akan terjadi penerusan penokokan sedimen pantai di bahagian selatan muara Kuala Kemasin dan penerusan hakisan di bahagian utara.

INTRODUCTION

Estuaries along the East Coast of Peninsular Malaysia are located at the mouths of the several small and large rivers that discharge into the South China Sea. These estuaries are geologically very young features for they (and their adjacent coastal plains) only developed during the Holocene global rise of sea-level that followed the last glacial maximum when much of the Sunda Shelf was sub-aerially exposed and sea-level was some 114 m below present level at about 19,000 years B.P. (Hanebuth *et al*., 2000). In tectonically stable Peninsular Malaysia, sea-level rose to a maximum height of about 5 m above mean sea-level in the mid-Holocene (approximately 5,000 years B.P.) and then receded to its present level through a series of fluctuations of progressively lower peaks and depressions (Tjia, 1992).

Most of the East Coast estuaries, particularly those in Terengganu and Kelantan, are flanked by narrow to broad stretches of sandy beach along which there is the lateral transport of sediments by littoral drift. This littoral drift results from the oblique approach of swell and storm waves from the South China Sea and gives rise to temporal variations in the morphology of the estuaries, not only through beach erosion and shoreline recession, but also through beach accretion and shoreline advance as well as the formation of sand spits and near-shore bars. Breakwaters, piers, jetties and other structures constructed at, or close, to the estuaries furthermore, have had a direct impact on the littoral drift; there occurring accretion of beach sediments (and shoreline advance) up-drift of the structures, but erosion (and shoreline recession) down-drift of them.

In this paper, the impacts of the construction of breakwaters at the Kuala Kemasin estuary in Kelantan State are discussed in terms of the past (pre-breakwater) and present (post-breakwater) coastal changes that have occurred, as well as future changes that will occur.

STUDY AREA - ENVIRONMENTAL SETTING

The Kelantan State coast at Kuala Kemasin is fronted by stretches of sandy beach, some 10 to 100 m wide, that extend northwestward, and southeastward, from breakwaters (groynes) located on both sides of the estuary there. These breakwaters were constructed between 1989 and 1991 as a part of the Semerak Rural Development Project to alleviate flooding of low-lying areas in the coastal areas of Kelantan State. These breakwaters are constructed of large granite blocks (>0.05 m^3 volume); the southern breakwater extending some 400 m in a general northeast direction, whilst the northern breakwater extends some 250 m in a more easterly direction. Revetments comprising inter-locking concrete blocks were also placed along the inner sides of the estuary.

There is a total absence of rocky headlands, near-shore and off-shore islands all along the Kelantan State coast which is thus directly exposed to swell and storm waves from the South China Sea. The near-shore sea bottom gradient is a gentle one with the 10 fathom line located some 5 to 15 km off-shore. Inland is found a broad, undulating to flat plain, underlain largely by alluvial deposits and locally covered by a series of beach ridges whose development is related to higher Holocene sea-levels (Figure 1).

The study area has a climatic regime that is primarily influenced by the Northeast Monsoon, blowing from November to March, and to a lesser extent by the Southwest Monsoon blowing from June to September. During the Northeast Monsoon, west to southwestward strong surface winds are present with heavy rainfall, whilst during the Southwest Monsoon, weak, east to northeastward surface winds are present with little rainfall. The inter-monsoon periods are also characterized by weak and variable surface winds and low rainfall. Marine influences on the study area are directly related to the Monsoons, with maximum sea and swell conditions during the Northeast Monsoon.

Surface drift currents in the South China Sea, close to the study area, are related to the Monsoons, with a southeast setting drift from November to May, but a generally northwest setting drift from June to October, except in July, when a northeast setting drift is present (Raj, 1985). Tides at Tumpat, some 30 km northwest of Kuala Kemasin, are mixed with the diurnal component dominant. The ratio between diurnal and semi-diurnal tides is 1.5:1; diurnal irregularity is high and often there is one high and one low water in a day. The maximum tidal range is 1.2 m and the mean spring tidal range of 0.6 m is the lowest recorded in Malaysia. Analyses of tidal records show that mean sea level is strongly influenced by the Monsoons, achieving its maximum height in November or December and dropping to its lowest level in June or July; the mean difference in sea levels being about 52 cm (Teh and Tengku Shamsul Bahrain, 1995).

PAST (PRE-BREAKWATER) COASTAL CHANGES

Aerial photographs of approximately 1:25,000 scale have been flown over the Kelantan State coast on 3rd November 1948, 17th September 1952, 4th August 1966 and in July 1974. Interpretation of the coastal features at the time of photography and the super-positioning of their corrected boundaries show that there have been some changes along the coastline between Kg. Beris Tok Pakeh and Kg. Kubang Golok (Figure 2). These changes have been mostly minor ones with different sites having experienced the erosion, or accretion, of beach sediments. At the Kuala Kemasin estuary, however, there have been several changes, involving variations in the size of the sand spits then present on both sides of the estuary. Between 1948 and 1952, as well as between 1952 and 1966, there was a northwestward extension of the sand spit on the south side, though between 1966 and 1974, there was a southeastward extension of the spit on the north side. As the extension of the sand spits is the direct result of littoral drift, it appears that the direction of the littoral drift has varied with time; being northwestward between 1949 and 1966, but southeastward between 1966 and 1974.

More detailed drawings of the coastal configuration at Kuala Kemasin as seen on 1:25,000 scale aerial photographs flown in 1949, 4th August 1966, 1978 and 23rd July 1983 better illustrate the impact of the variable littoral drift (Figure 3). In the drawings, the exposed beach at the time of photography was mapped; this exposed beach comprising sandy deposits that were not covered by a continuous vegetation cover. In the 1949 drawing, there is a wide area of exposed beach, though this has been reduced in the 4th August 1966 drawing. The aerial photographs of August 1966 also show that vegetation (shrubs and grasses as well as pine trees) had colonized much of the beach that was exposed in the 1949 photograph. The northwestward extension of the sand spit on the south side between 1949 and 1966 clearly shows that there is a predominantly northwest directed littoral drift. The coastal configurations of 1966 and 1978 also show the continued influence of the northwest directed littoral drift; there being a northwestward extension of the sand spit on the south side as well as an increase in the area covered by vegetation. The coastal configuration of 23rd July 1983, however, appears to indicate a southeast directed littoral drift for there is a southeastward extension of the spit on the north side as well as erosion of the spit on the south side.

PRESENT (POST- BREAKWATER) COASTAL CHANGES

Aerial photographs of about 1:20,000 scale have been flown over the study area on 5th June 1995 whilst satellite imagery dating from 1990 covers the area at various

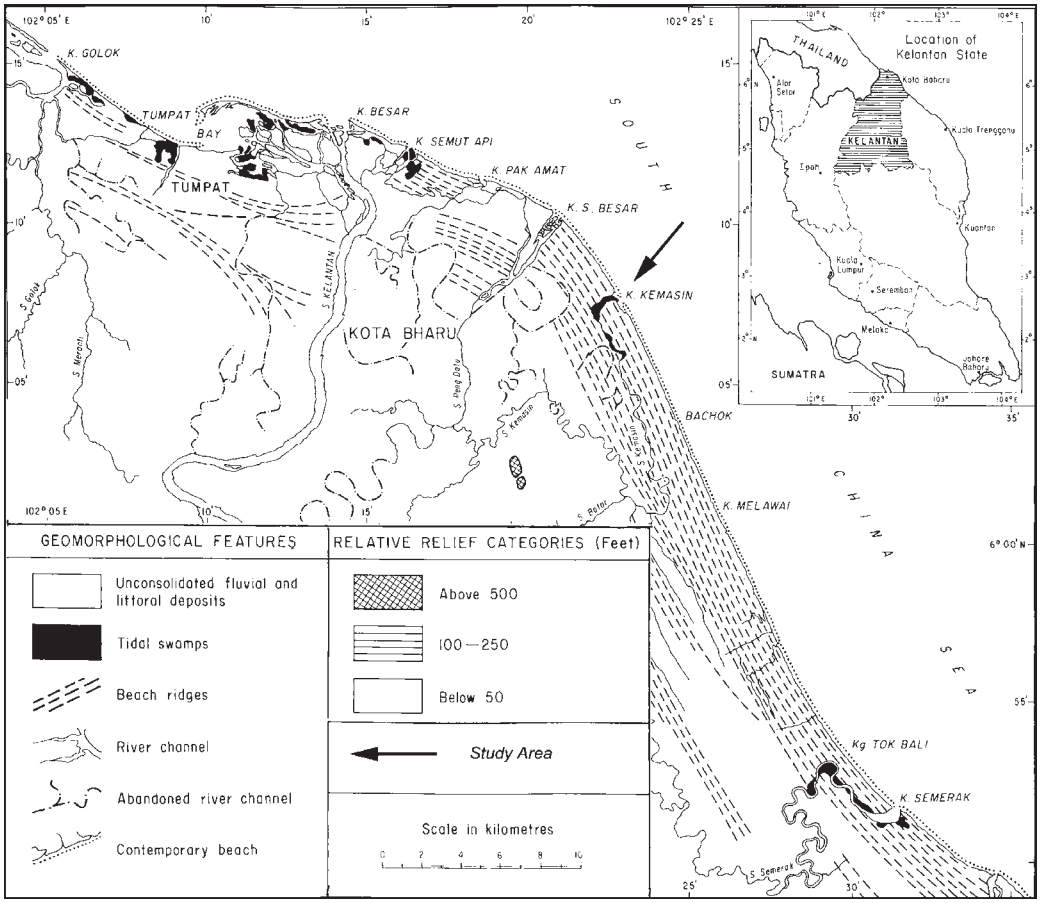

Figure 1: Location map.

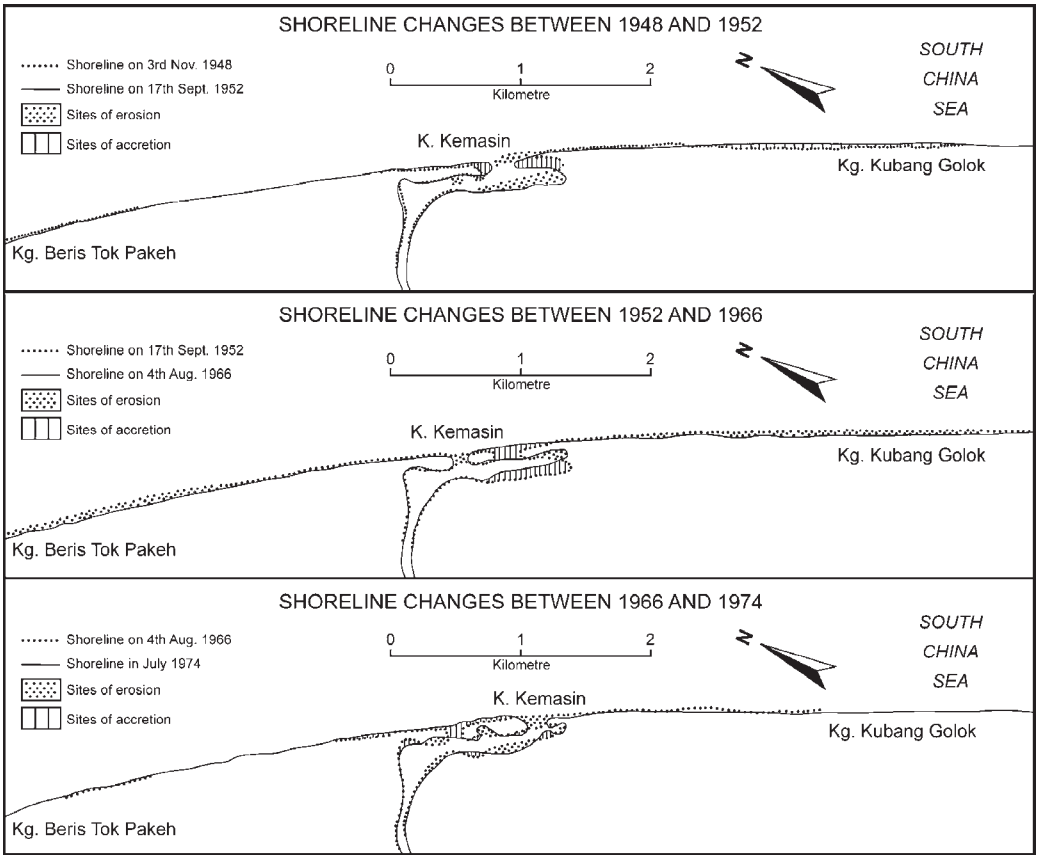

Figure 2: Coastal changes between 1948 and 1974

scales of resolution. The satellite images are of a rather small scale (<1:100,000), but can still be used to recognize some coastal changes that have occurred after construction of the breakwaters between 1989 and 1991. The drawing of the coastal configuration of June 1995 furthermore, clearly shows the impact of these breakwaters; there being a wide beach and the accretion of sediments on the south side of Kuala Kemasin, but a narrow beach and erosion on the north side (Figure 4).

A field survey on 2 March 2006 furthermore, shows the continued deposition of beach sediments on the south side of Kuala Kemasin, but erosion on the north side (Figure 4). Field evidence for accretion of beach sediments on the south side is also seen in their systematic colonization by vegetation; the youngest sediments close to the shoreline being bare, but those further inland (some 50m and more from the shoreline) being now covered by a continuous vegetation cover of creepers and grass tufts with several isolated young pine trees (>5 years of age). In between the two zones, there is a gradual change in vegetation cover, with the bare beach giving way to a zone with a discontinuous vegetation cover of creepers and grass tufts; this being replaced by a zone with a more continuous vegetation cover of creepers and grass tufts. On the north side of Kuala Kemasin, however, there is active erosion of beach sediments, marked by small wave cut notches and collapsed coconut tree trunks. Rates of accretion and erosion, however, appear to be quite low; there having occurred a maximum shoreline advance of about 10 m on the south side between 1995 and 2006, and a maximum shoreline recession of also about 10 m in the same period on the north side. Rates of accretion and erosion are this on the order of about one meter a year.

PROCESSES RESPONSIBLE FOR COASTAL CHANGES

The past and present coastal changes that have occurred, and occur, involve the transport of beach sediments by littoral (or beach) drift which results from the oblique approach of swell and storm waves from the South China Sea (Raj, 1985). These changes are dependent upon time of year for in the Sungai Kelantan delta, Koopmans (1972) has noted that high velocity, onshore blowing winds during the Northeast Monsoon result in plunging breakers that lead to erosion of the upper beach and deposition at off-shore bars. During the remainder of the year, however, the lower velocity and frequently off-shore blowing winds result in constructive breakers that lead to the deposition of sediments (from the off-shore bars) against the upper beach.

Superimposed upon the simple pattern of erosion during the Northeast Monsoon and deposition during the remainder of the year is the lateral transport of beach sediments by littoral drift (Raj, 1985). This littoral drift, however, is only important along coastal sectors that trend obliquely to the generally northwest-southeast to north-south trending wave fronts of sea waves and swell approaching from the South China Sea (Ritchie, 1968). This influence is clearly seen at Kuala Kemasin where the generally northwestward extension of sand spits indicates the presence of a dominantly northwest directed littoral drift.

FUTURE COASTAL CHANGES

In the Asian Bank Report (2001) on the Semerak Rural Development Project, it was noted that erosion had occurred at Kuala Kemasin, though this was not as serious as that further north at Kuala Pengkalan Datu where breakwaters had been constructed between mid-1986 and 1987. The coastal changes here have been discussed in detail by several workers, including Teh and Tengku Shamsul Bahrain (1995), who noted that following construction of the breakwaters, there resulted the classical pattern of accretion up-coast, and erosion down-coast, of the introduced structures, which acted as a barrier to littoral drift. Erosion started in 1988 during the first Northeast Monsoon after completion of the breakwaters. Beach nourishment was carried out to protect the boat harbour, but this was unsuccessful and the harbour breached in March 1989. Subsequent work, including redesign of the northern breakwater and revetment down coast of it as well as beach nourishment was carried out to reduce erosion in the early 1990's.

A similar future is envisaged for the estuary at Kuala Kemasin; there continuing to occur erosion (and shoreline retreat) on the north side, but accretion (and shoreline advance) on the south side. Accretion on the south side will eventually lead to shallowing of the estuary, whilst erosion on the north side is already threatening several wooden houses as well as agricultural land.

CONCLUSION

It is concluded that the coast at Kuala Kemasin is under the influence of a predominantly northwest directed littoral drift as a result of the oblique approach of swell and storm waves from the South China Sea throughout the year, especially during the Northeast Monsoon. This littoral drift has led to several past coastal changes that mainly involved variations in the sizes of sand spits on both sides of the then estuary. Breakwaters, constructed on both sides of the estuary between 1989 and 1991, have accentuated the impact of the littoral drift; there occurring accretion of beach sediments (and shoreline advance) on the south side, but erosion of beach sediments (and shoreline recession) on the north side. Rates of shoreline advance and recession are relatively low, in the order of a meter or so per year, though erosion already now threatens several wooden houses and agricultural land on the north side of Kuala Kemasin. In view of the continued prevailing northwest directed littoral drift, it is concluded that there

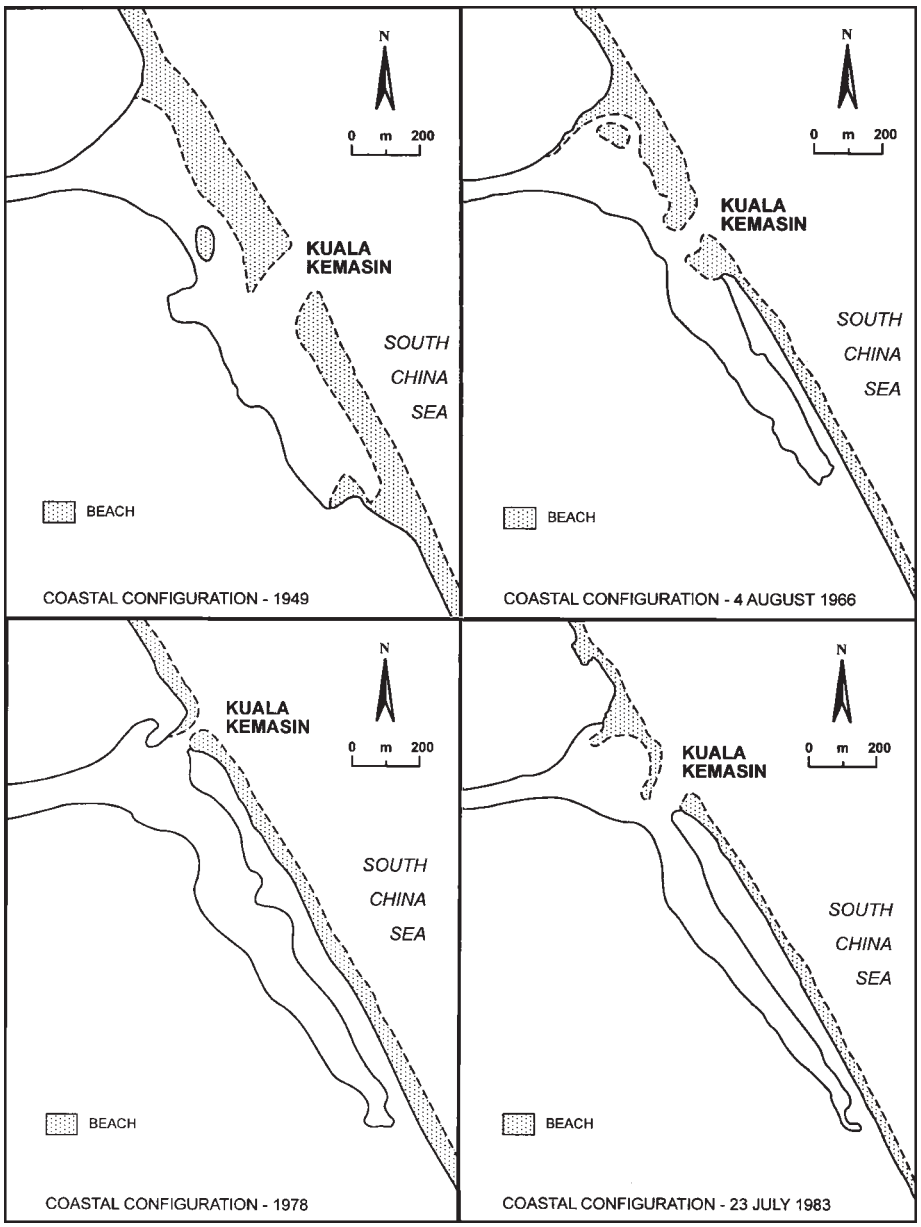

Figure 3: Pre-breakwater coastal configurations at Kuala Kemasin.

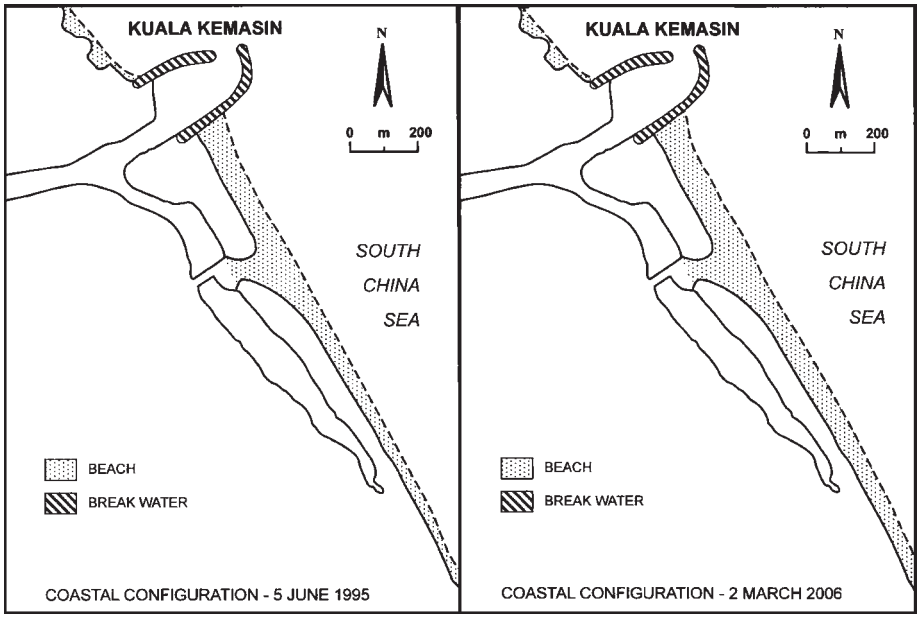

Figure 4: Post-breakwater coastal configurations at Kuala Kemasin.

will continue to be accretion of beach sediments on the south side of the Kemasin estuary, but erosion on its north side.

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