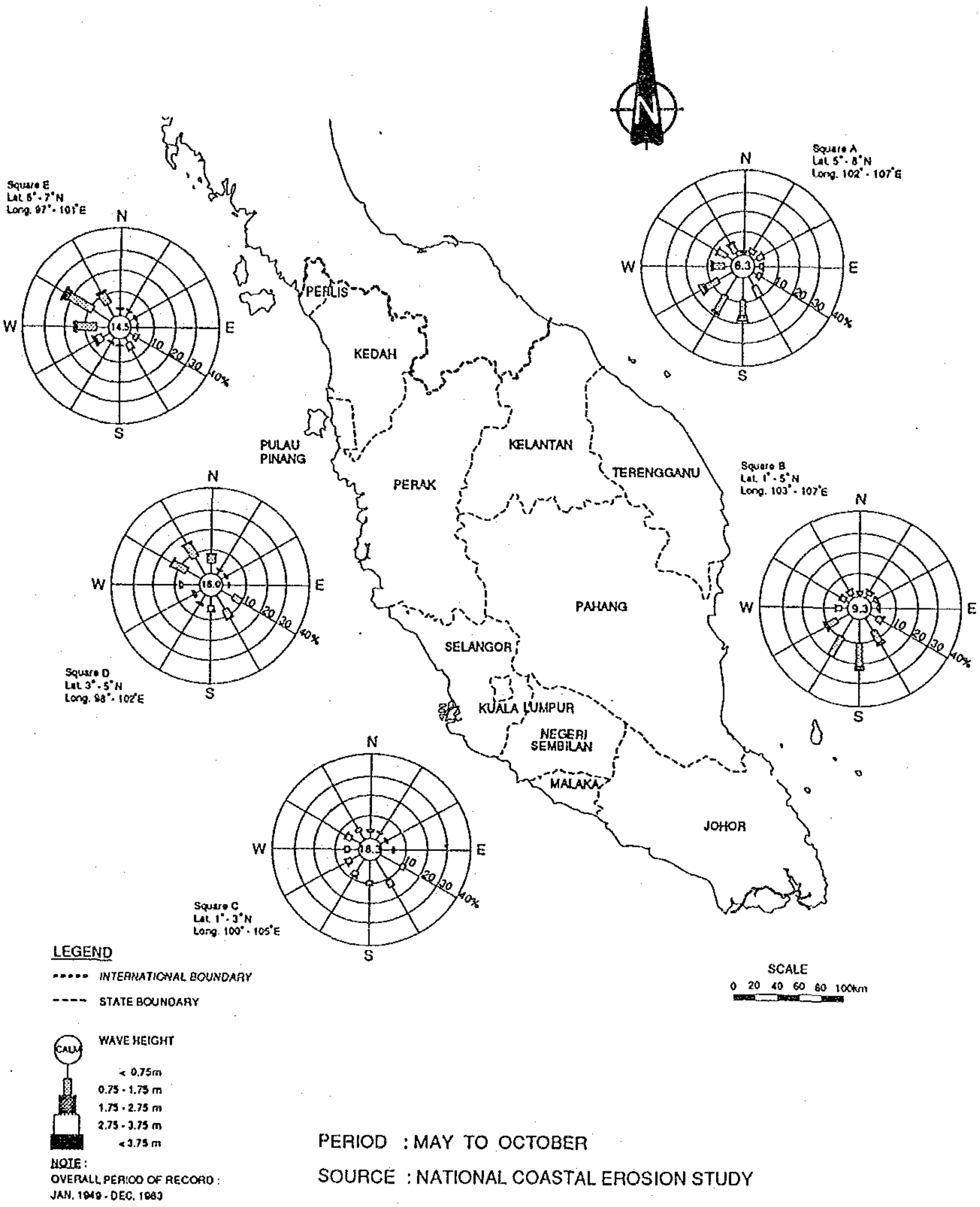
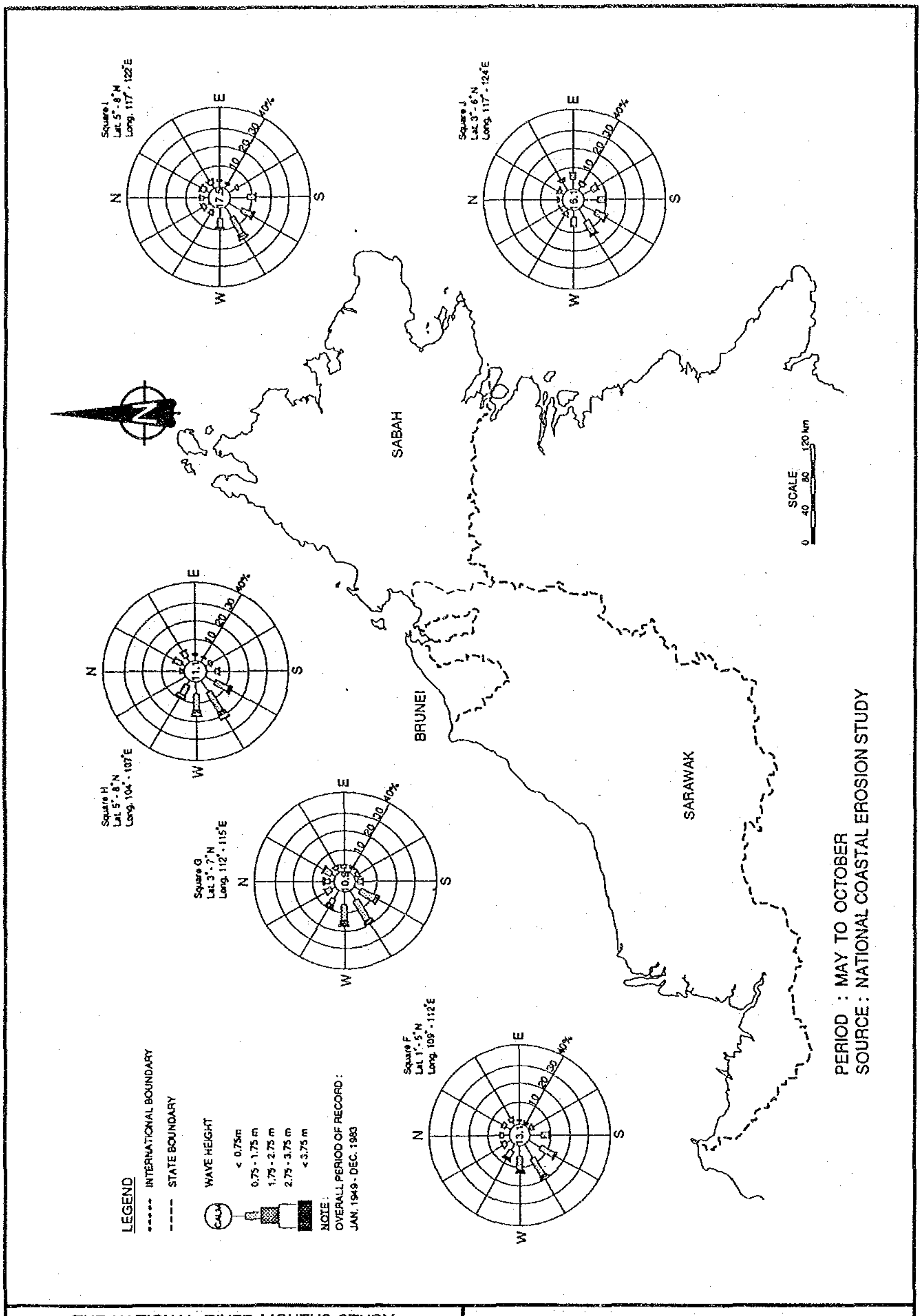


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE ROSES DURING SOUTHWEST MONSOON (PENINSULAR MALAYSIA) Fig. 1.2-6 (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE ROSES DURING SOUTHWEST MONSOON (SABAH AND SARAWAK) Fig. 1.2-6 (2/2)
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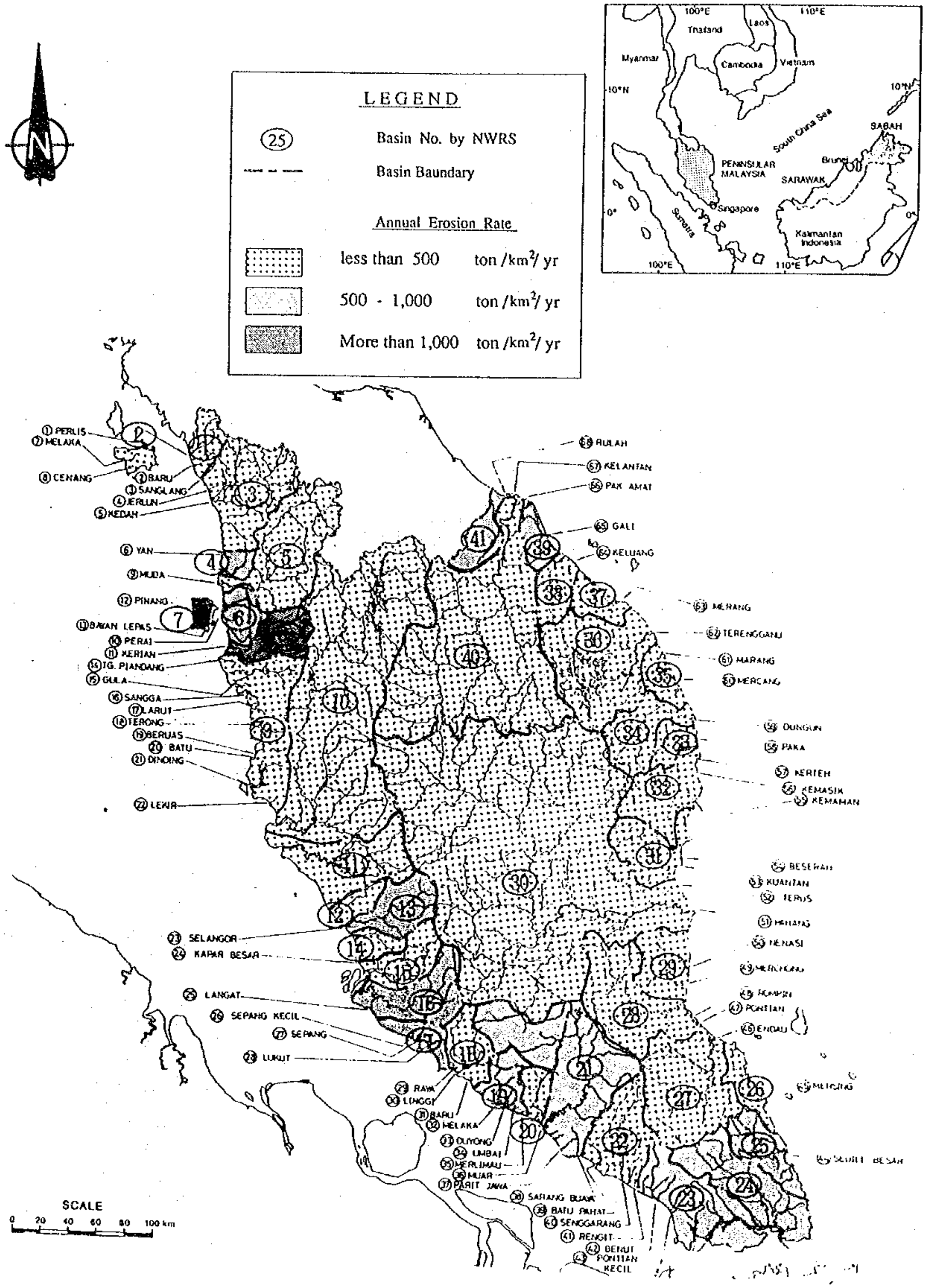
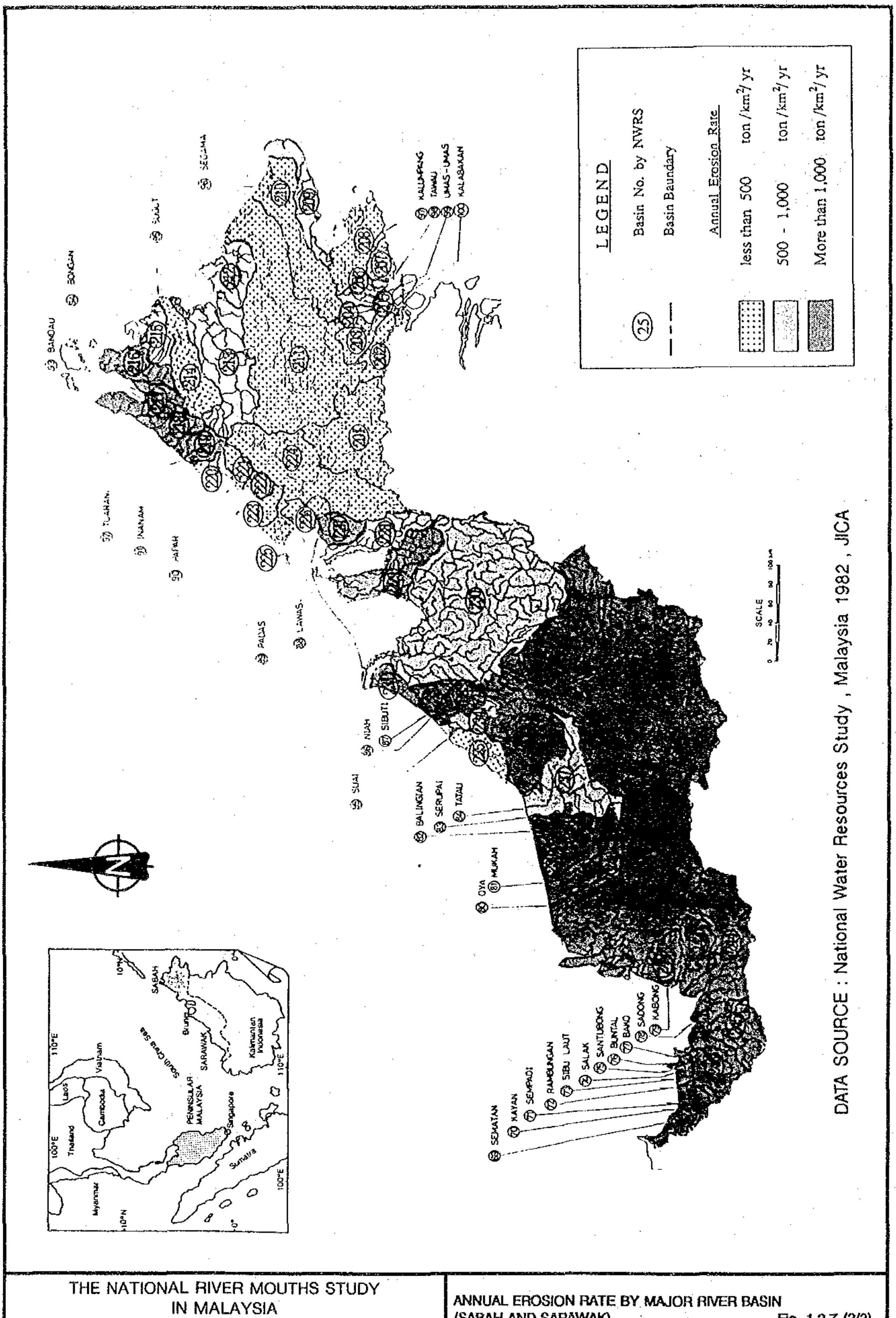
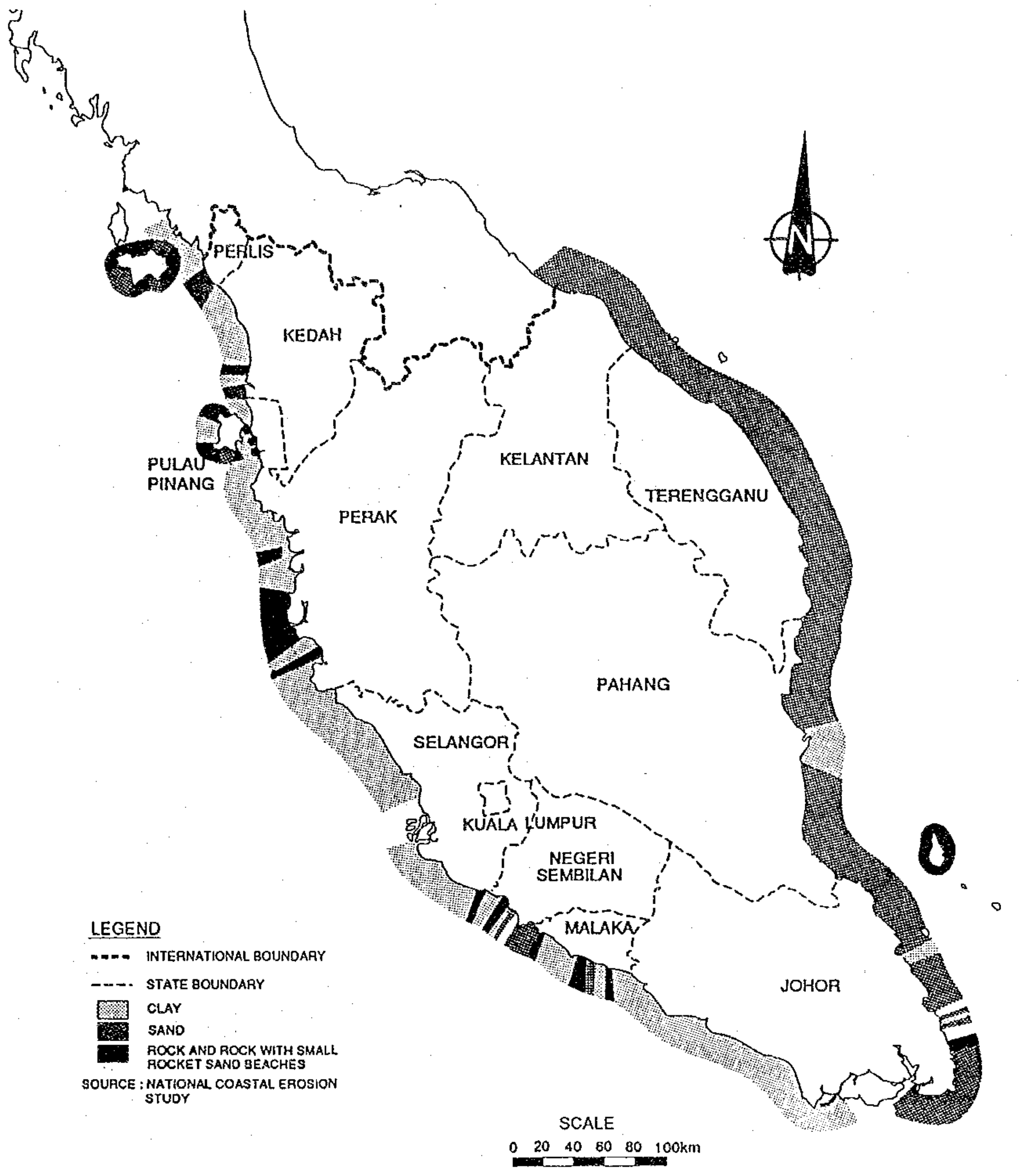


DATA SOURCE : National Water Resources Study , Malaysia 1982 , JICA

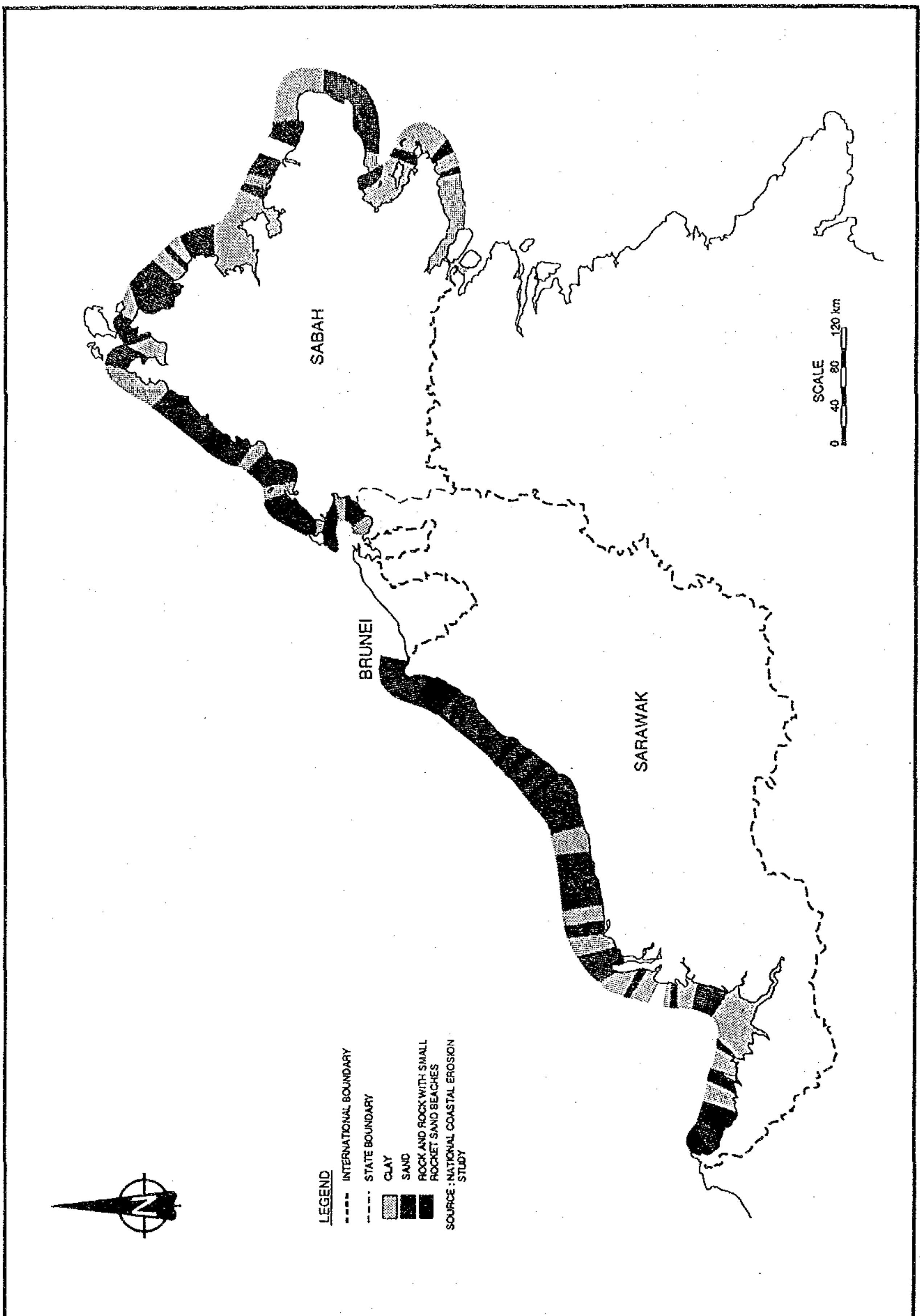
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ANNUAL EROSION RATE BY MAJOR RIVER BASIN (PENINSULAR MALAYSIA) Fig. 1.2-7 (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



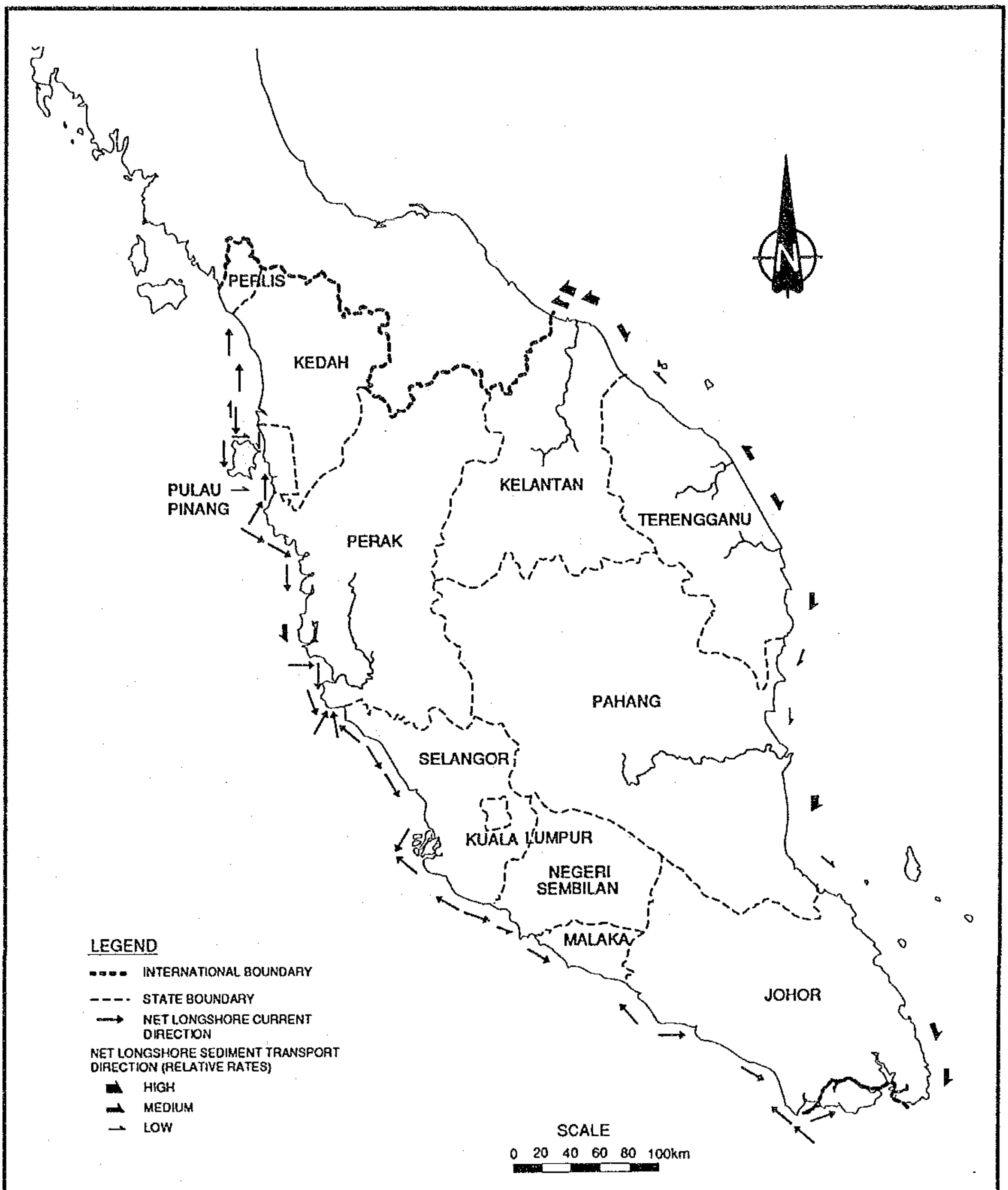
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ANNUAL EROSION RATE BY MAJOR RIVER BASIN (SABAH AND SARAWAK) Fig. 1.2-7 (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



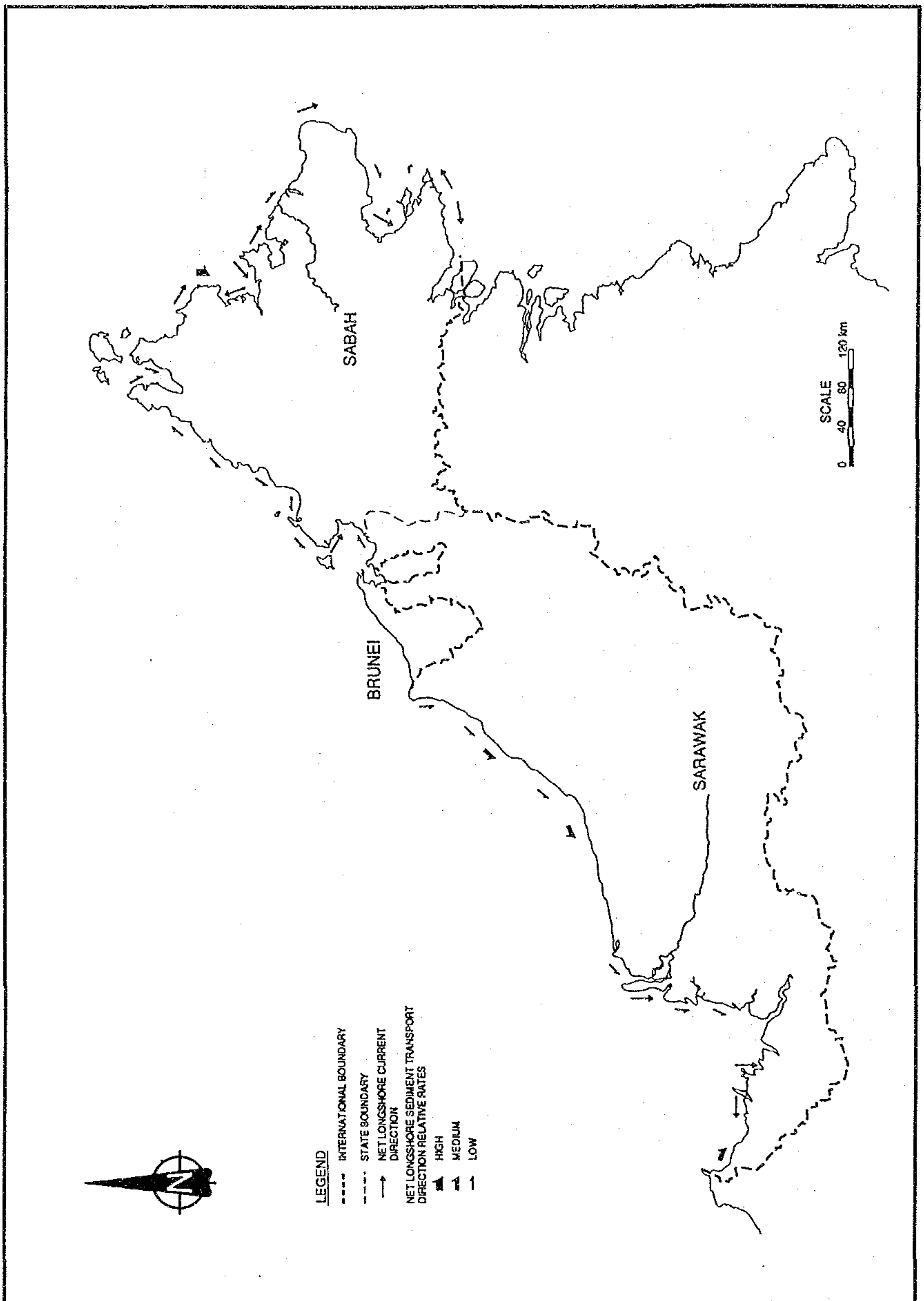
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF SHORELINE MATERIAL (PENINSULAR MALAYSIA)	Fig. 1.2-8 (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY		



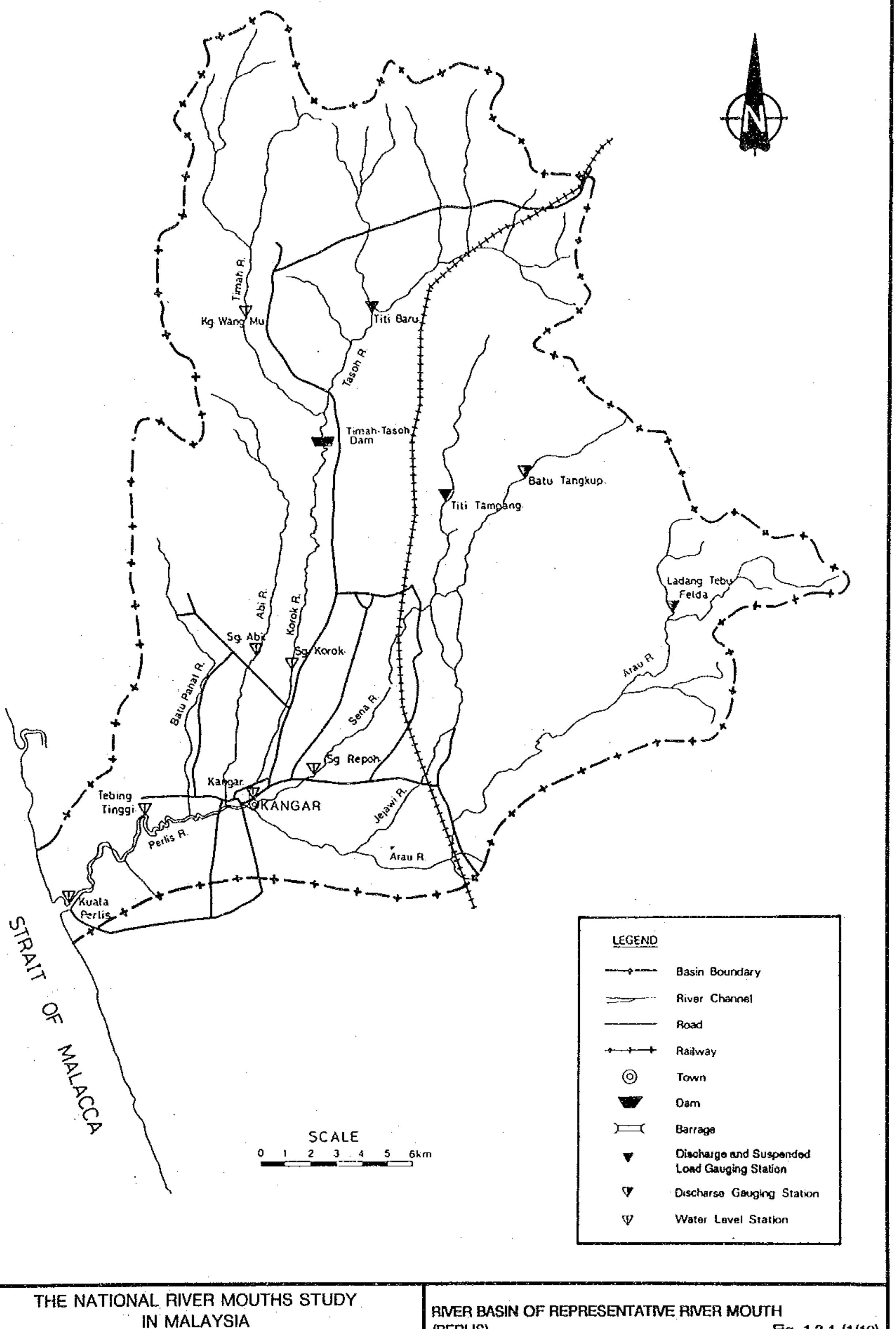
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF SHORELINE MATERIAL (SABAH AND SARAWAK)	Fig. 1.2-8 (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY		



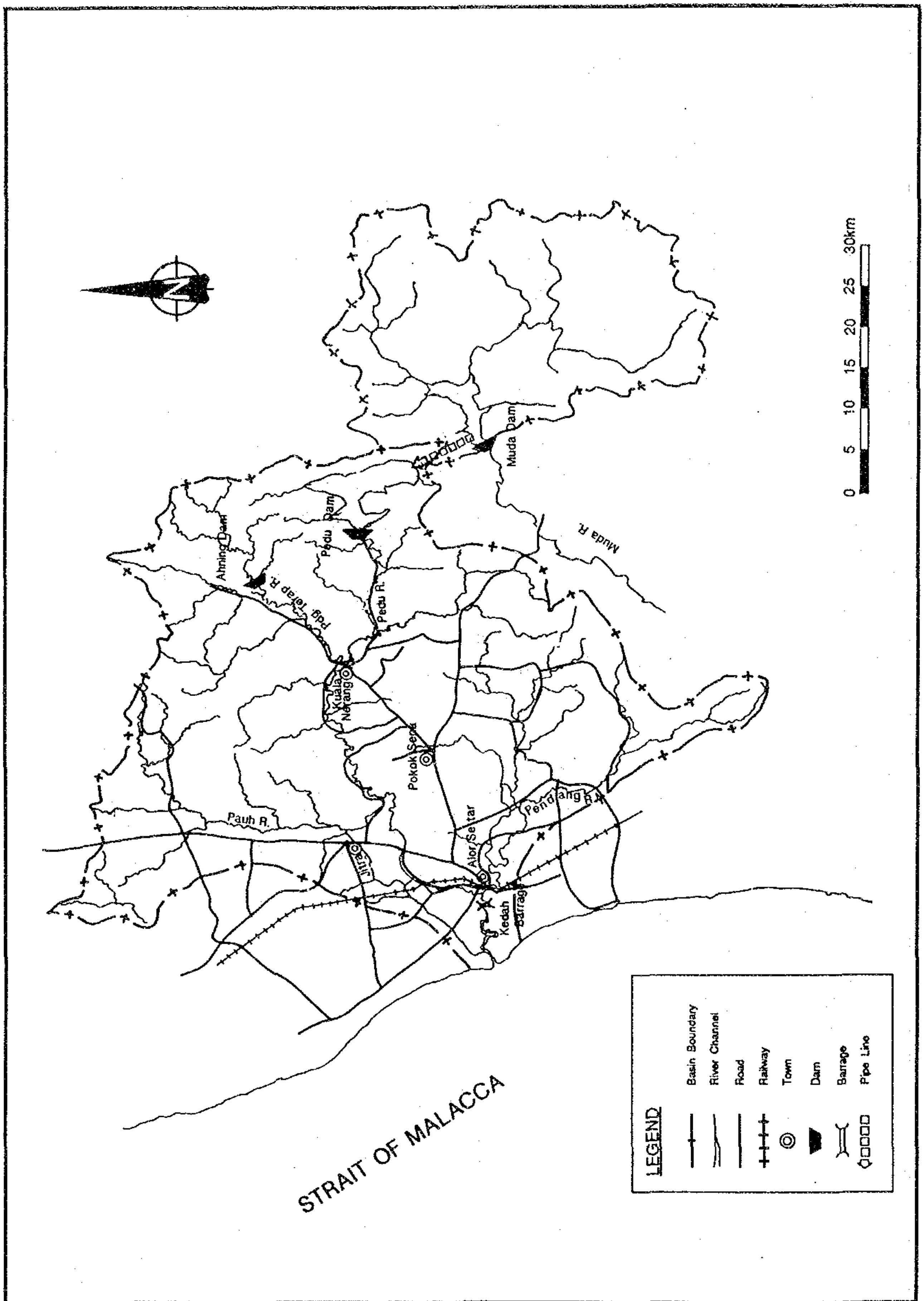
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	NET LONGSHORE SEDIMENT TRANSPORT AND RELATIVE RATES (PENINSULAR MALAYSIA) Fig. 1.2-9 (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



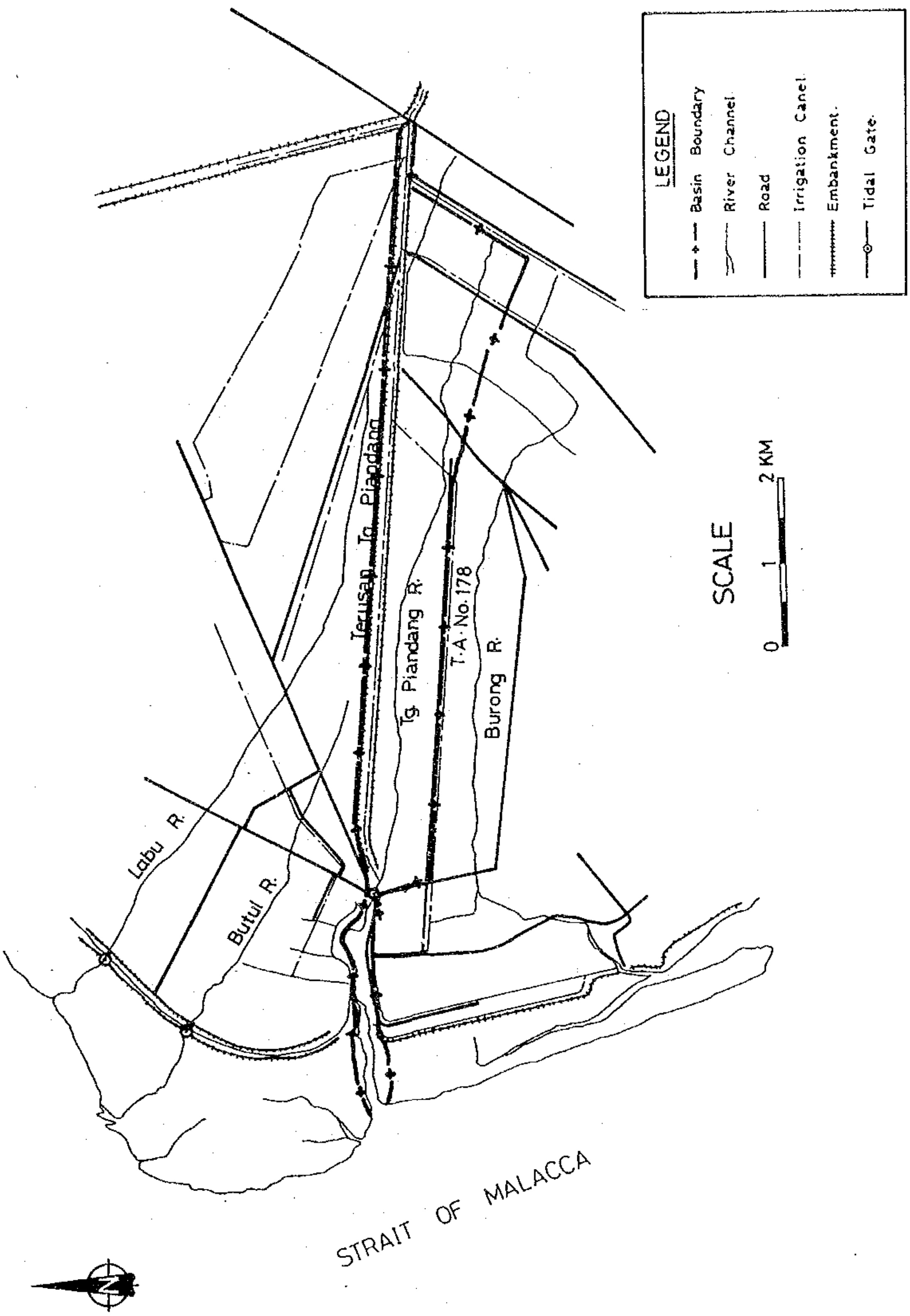
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	NET LONGSHORE SEDIMENT TRANSPORT AND RELATIVE RATES (SABAH AND SARAWAK)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.2-9 (2/2)



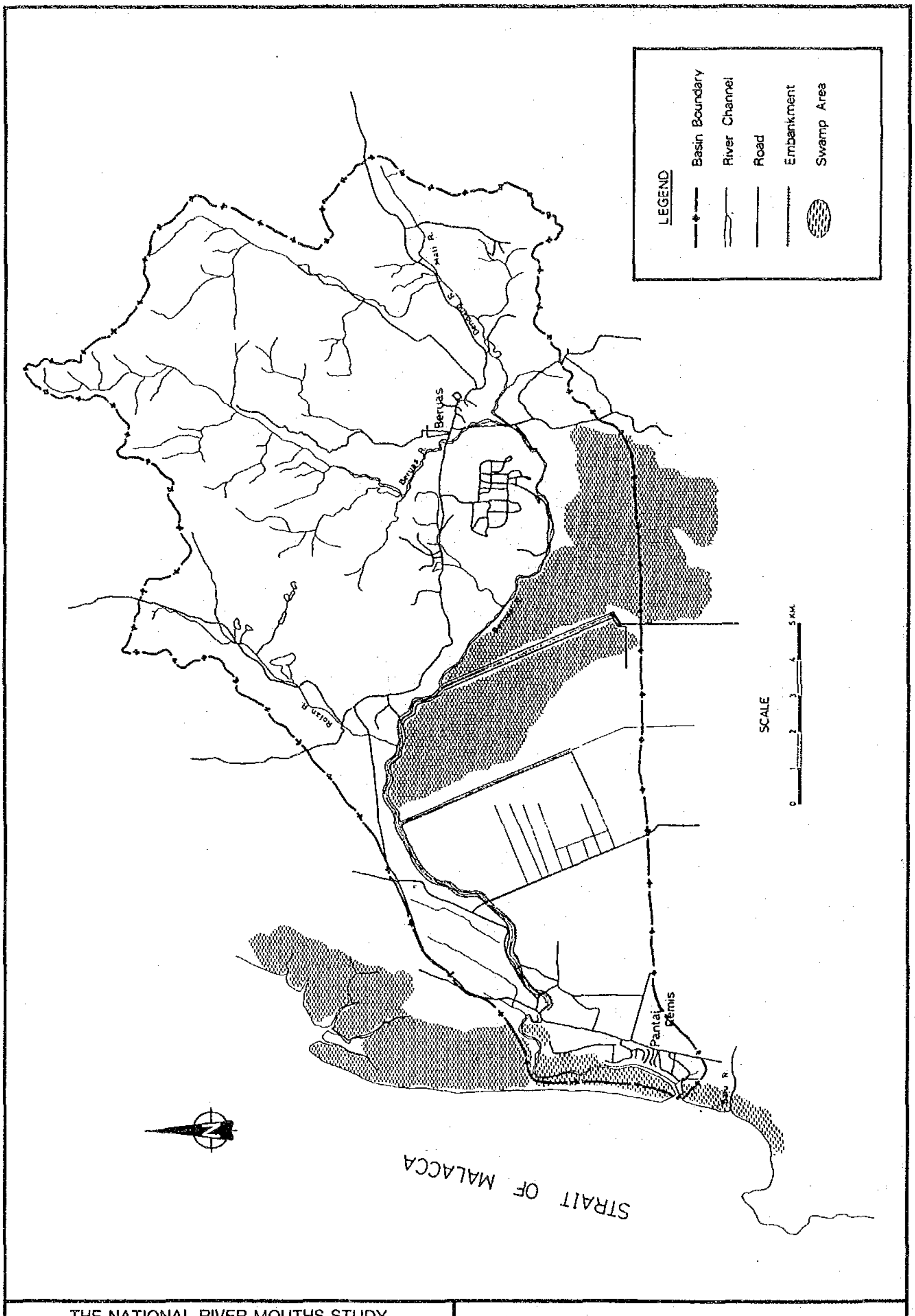
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (PERLIS) Fig. 1.3-1 (1/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	



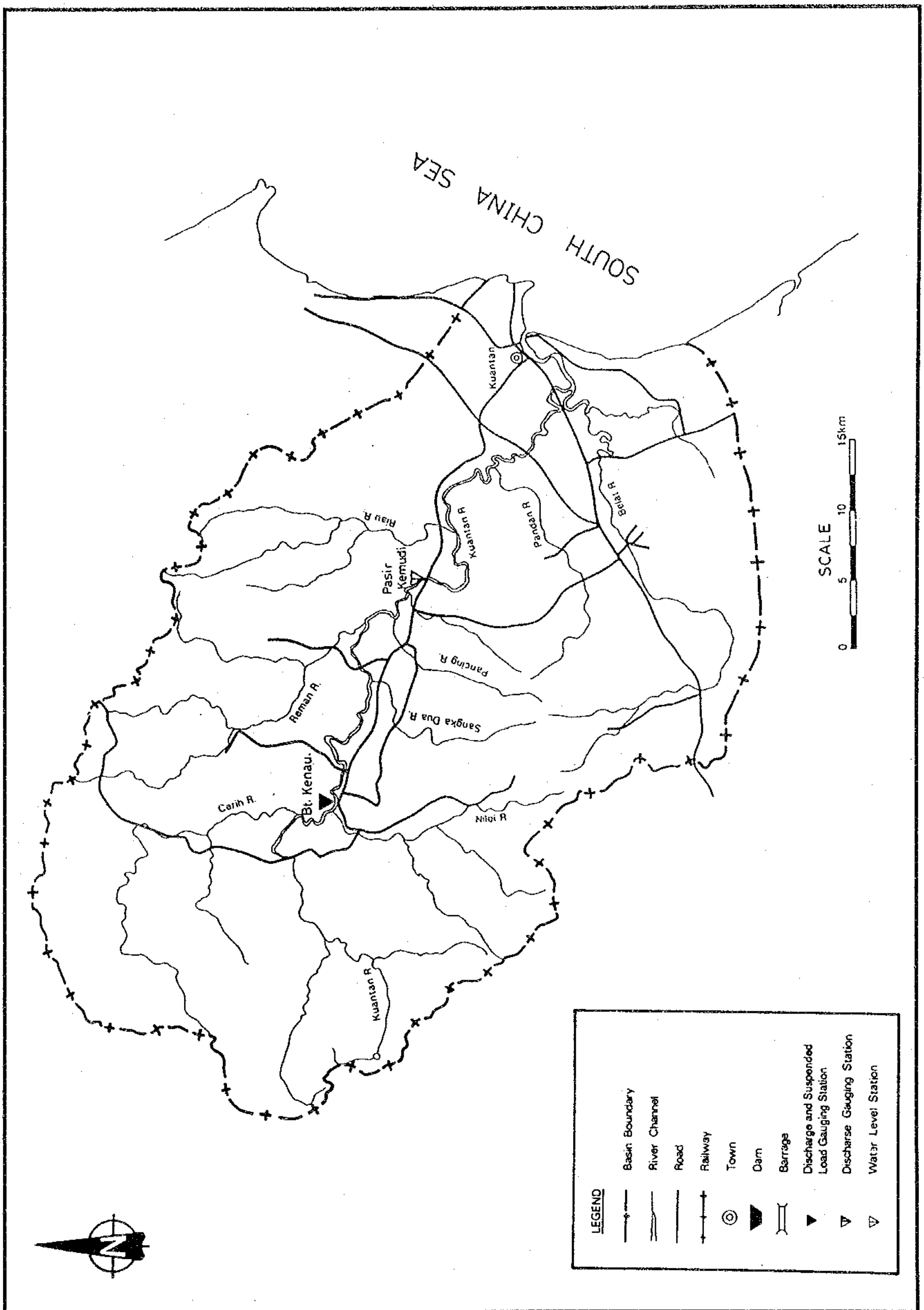
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (KEDAH)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-1 (2/10)



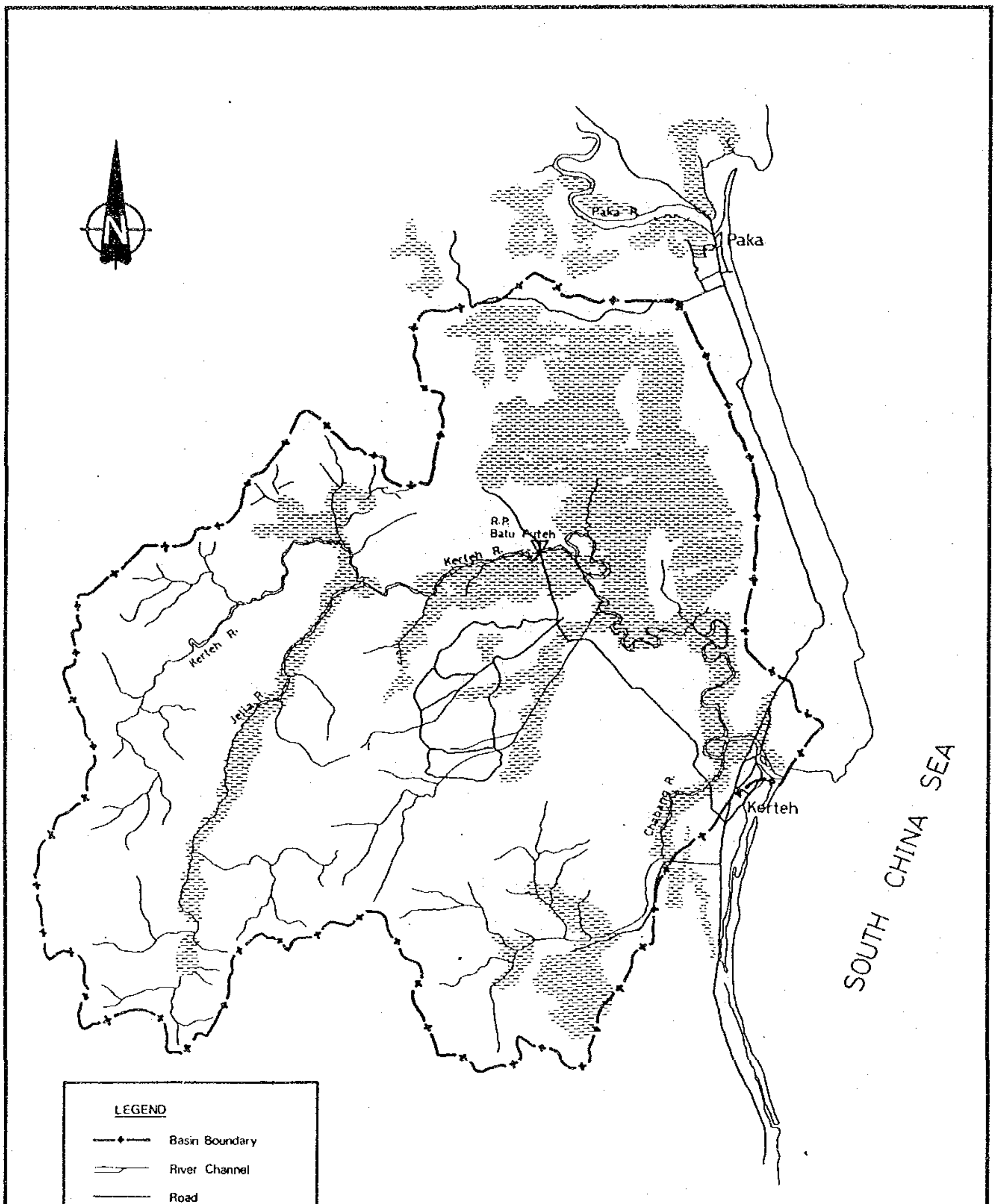
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (TG. PIANDANG)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-1 (3/10)



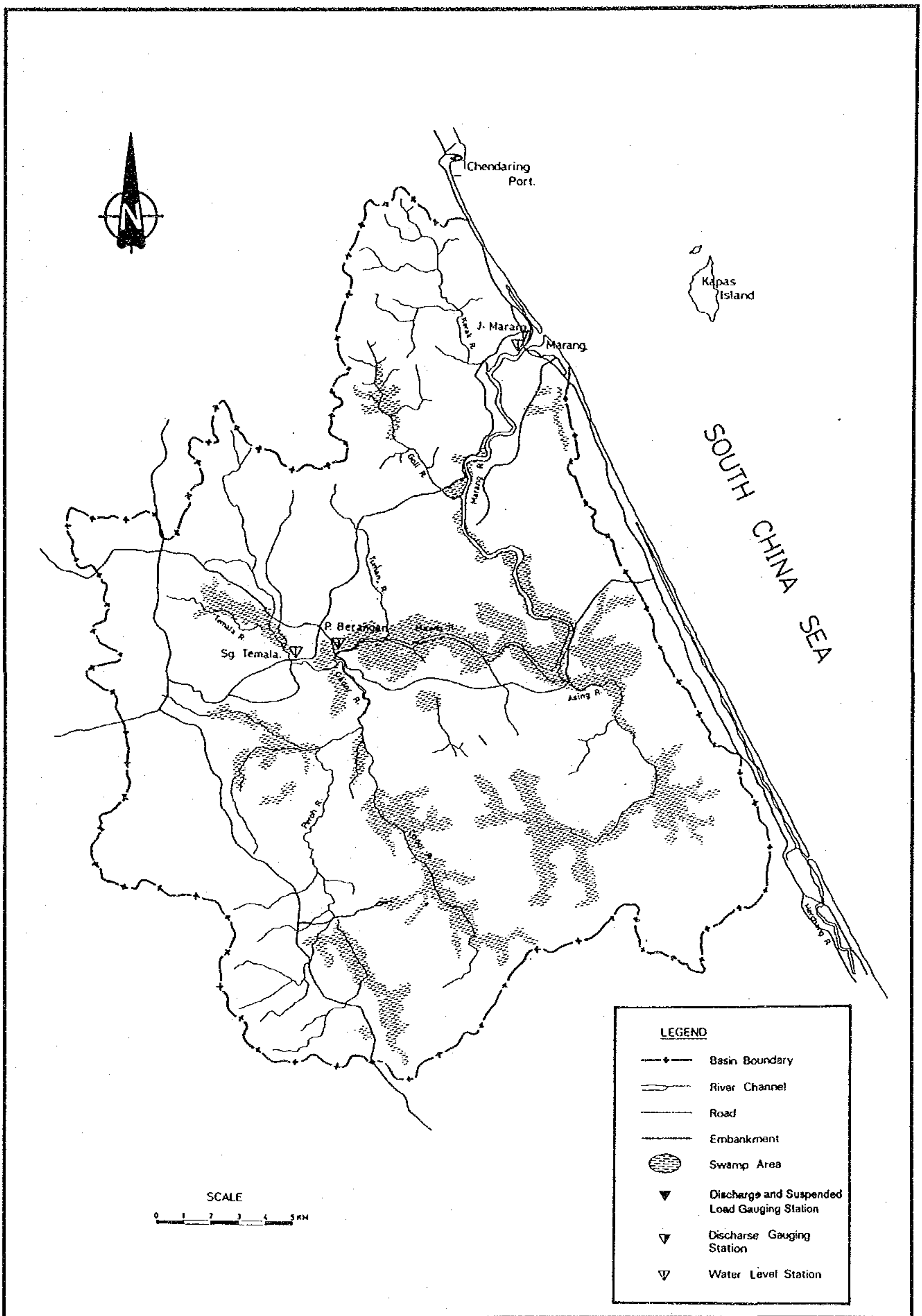
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (BERUAS) Fig. 1.3-1 (4/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	



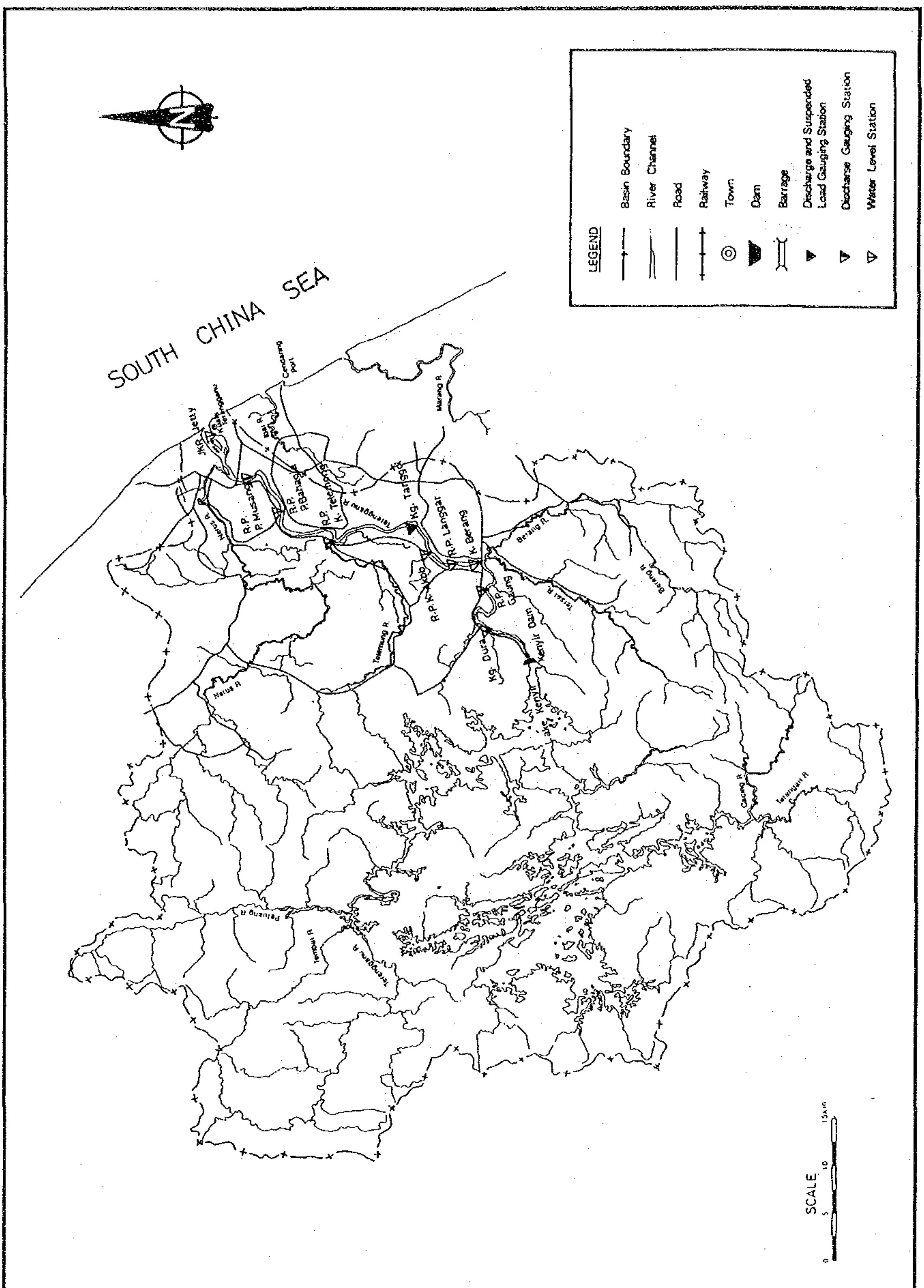
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (KUANTAN)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-1 (5/10)



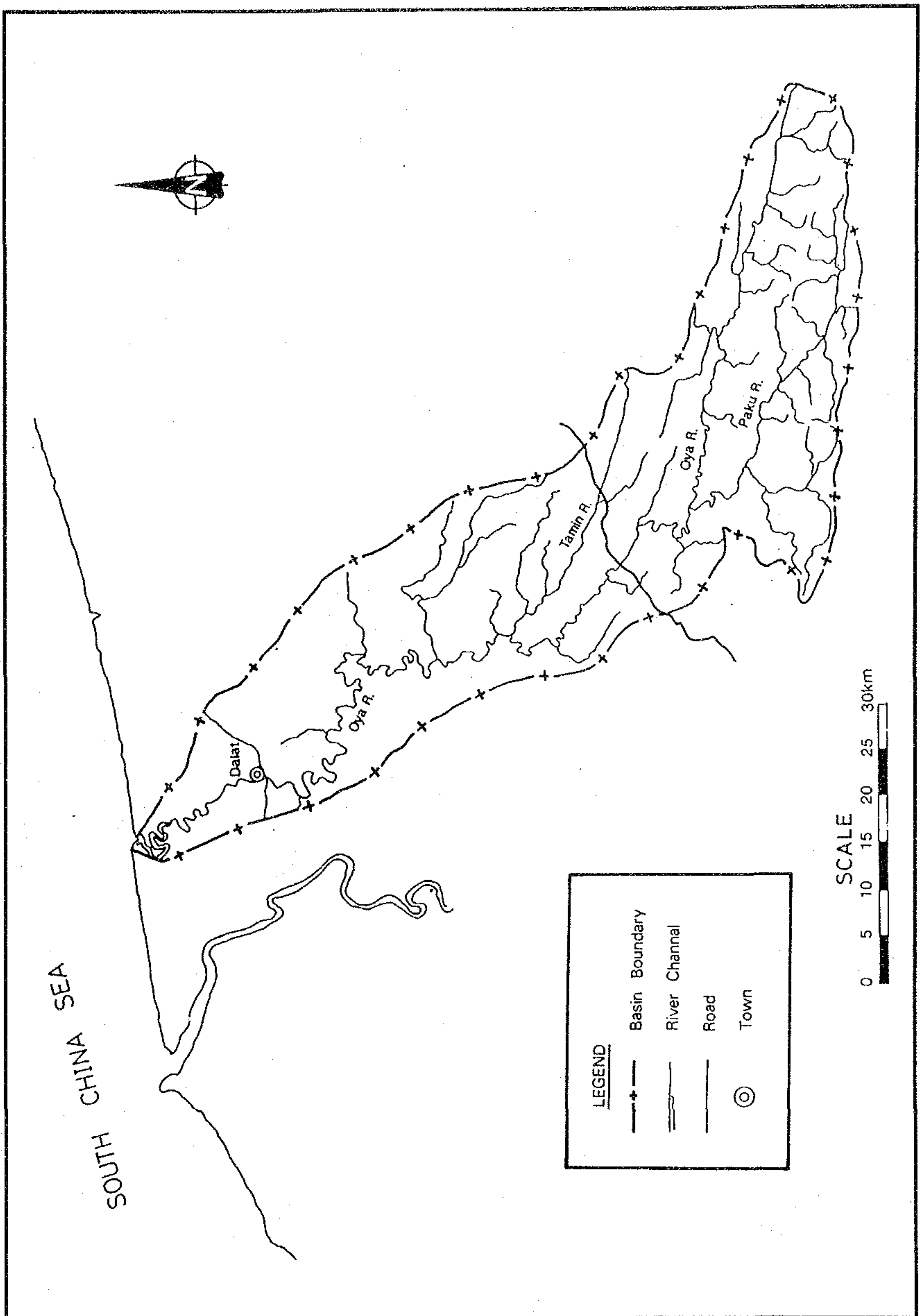
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (KERTEH) Fig. 1.3-1 (6/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	



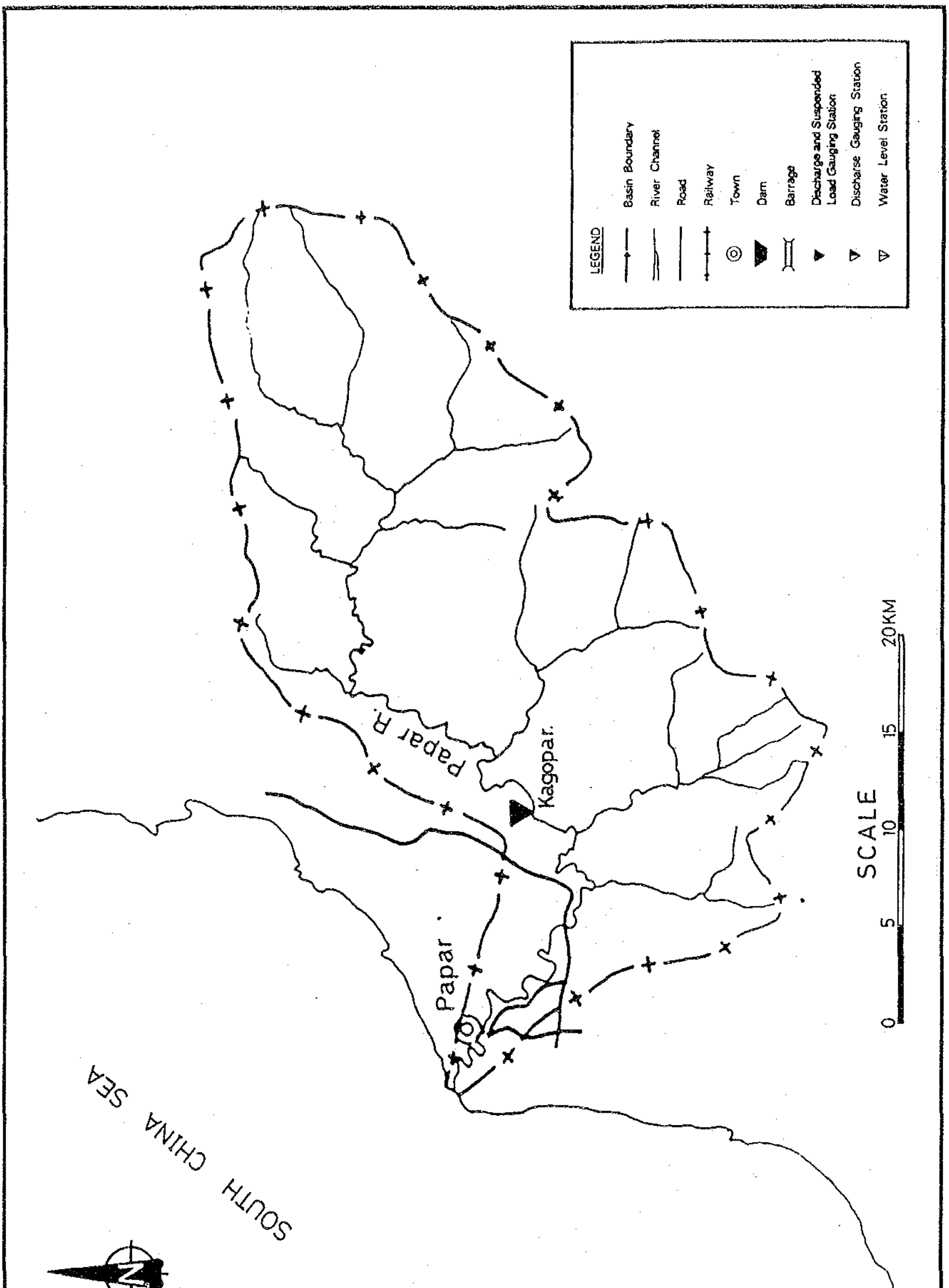
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (MARANG) Fig. 1.3-1 (7/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	



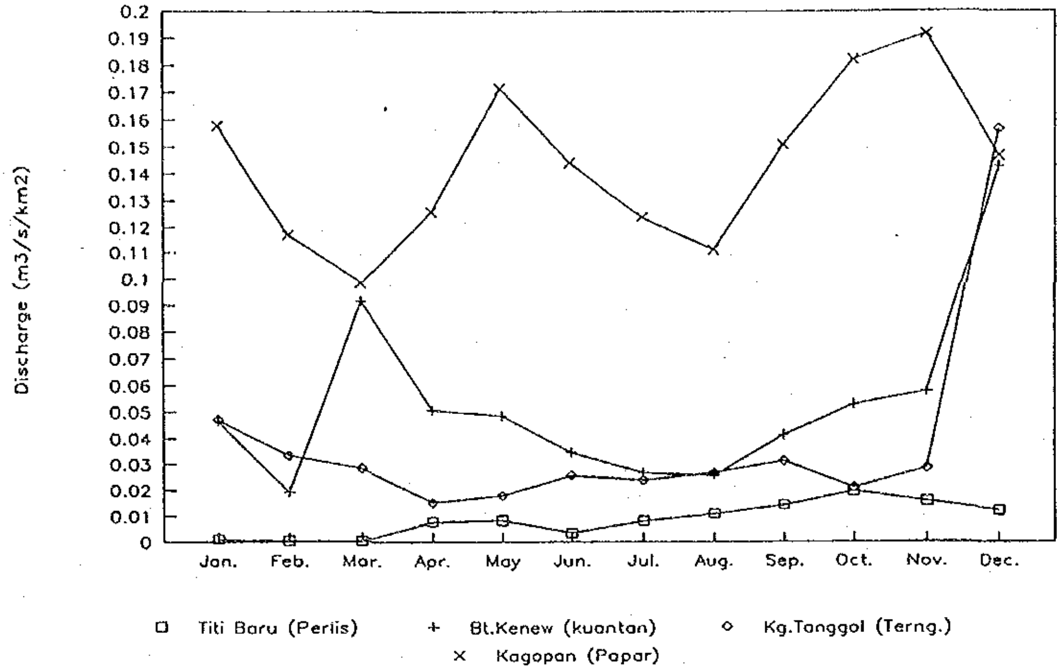
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (TERANGGANU) Fig. 1.3-1 (8/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	

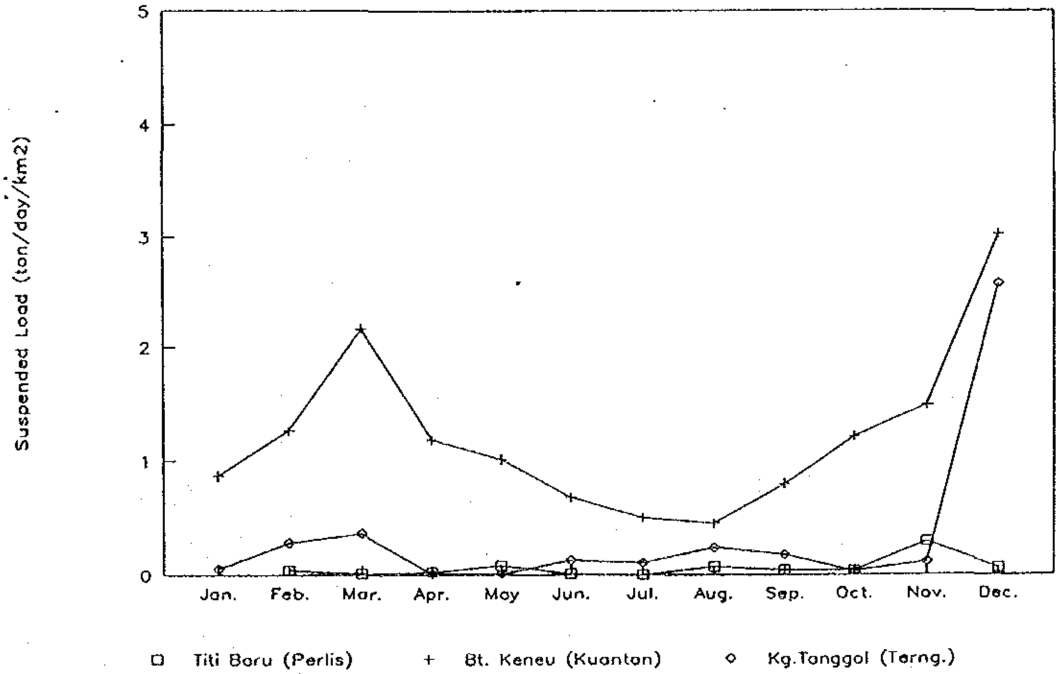


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (OYA) Fig. 1.3-1 (9/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	

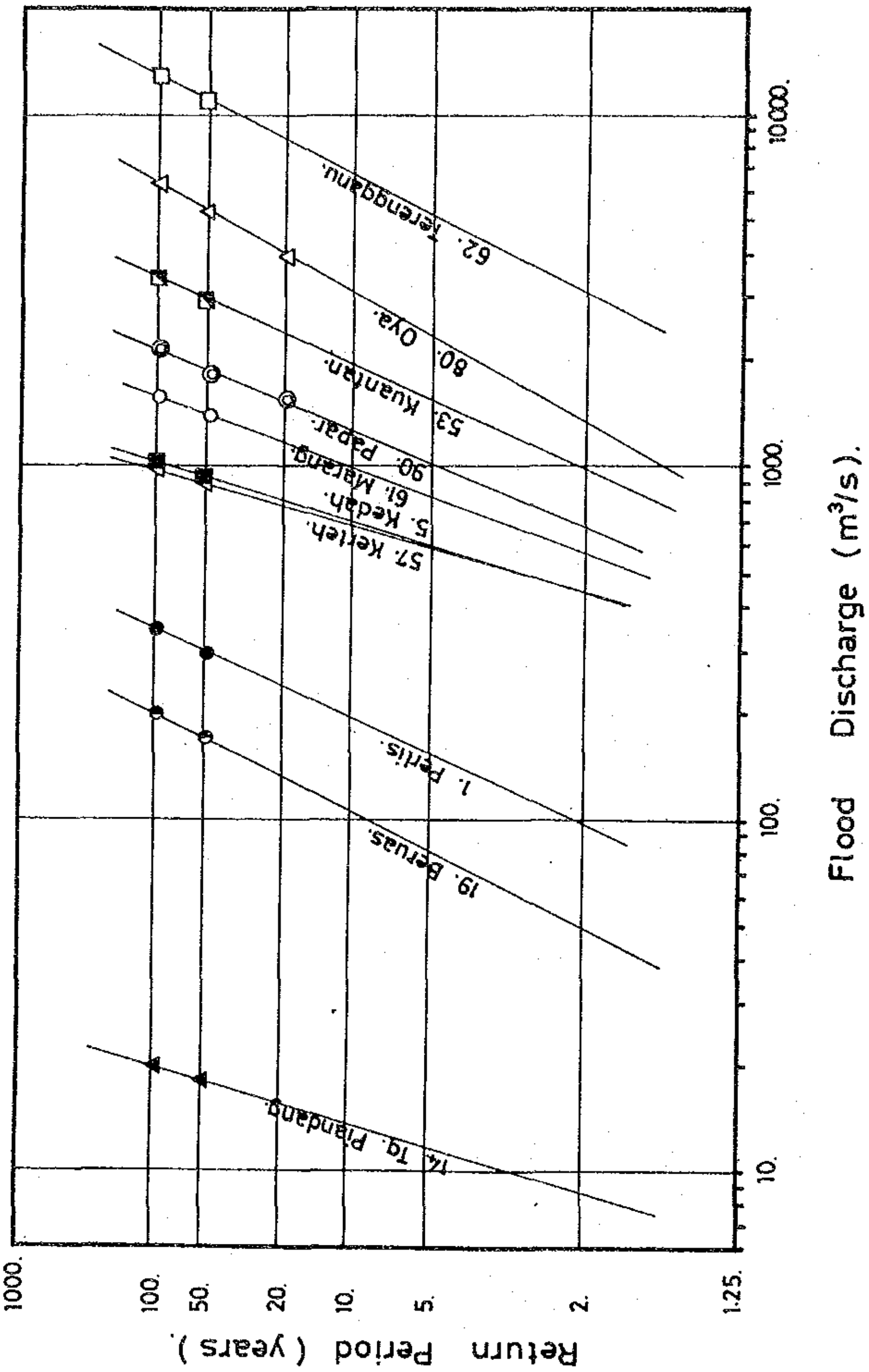


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RIVER BASIN OF REPRESENTATIVE RIVER MOUTH (PAPAR) Fig. 1.3-1 (10/10)
JAPAN INTERNATIONAL COOPERATION AGENCY	

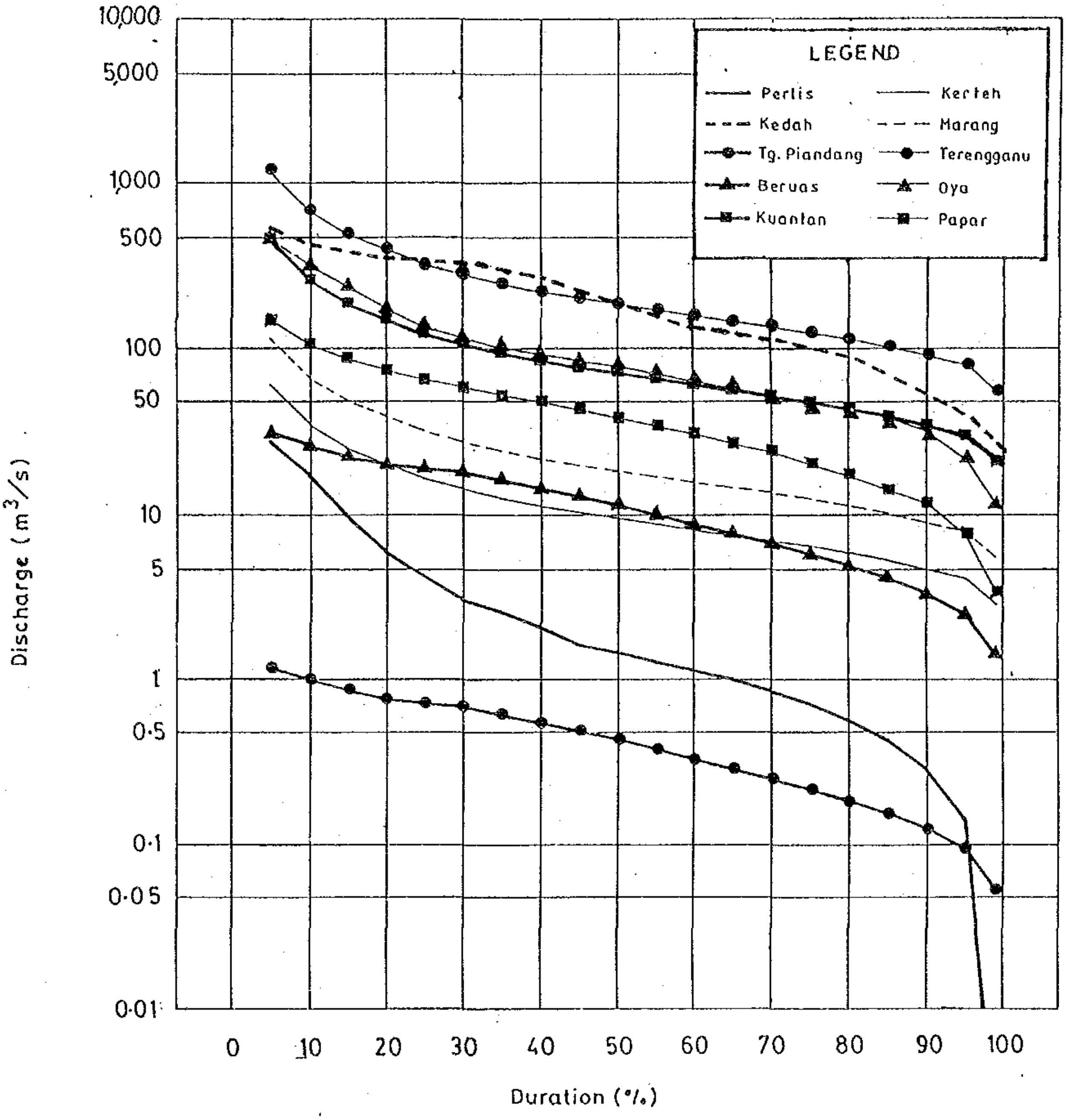




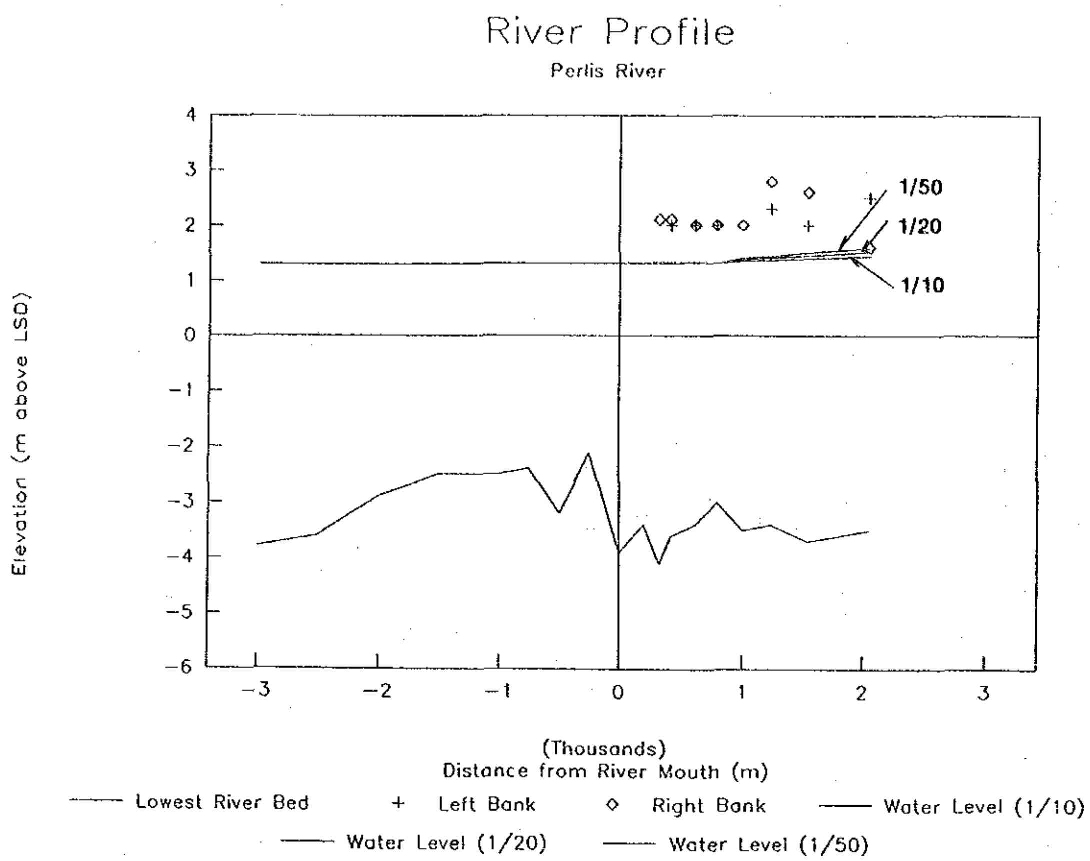
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	OBSERVED MONTHLY DISCHARGE AND SUSPENDED LOAD Fig. 1.3-2
JAPAN INTERNATIONAL COOPERATION AGENCY	

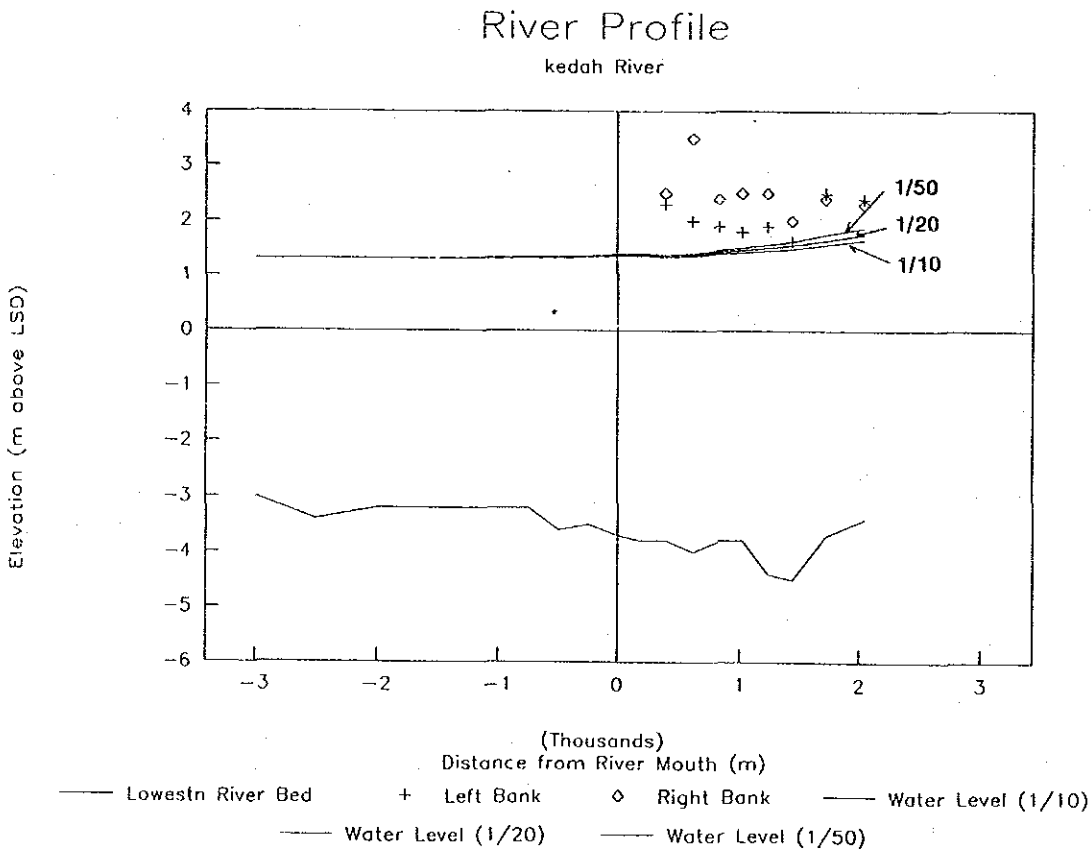


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATION OF FLOOD DISCHARGE FOR REPRESENTATIVE RIVER MOUTH	Fig. 1.3-3
JAPAN INTERNATIONAL COOPERATION AGENCY		

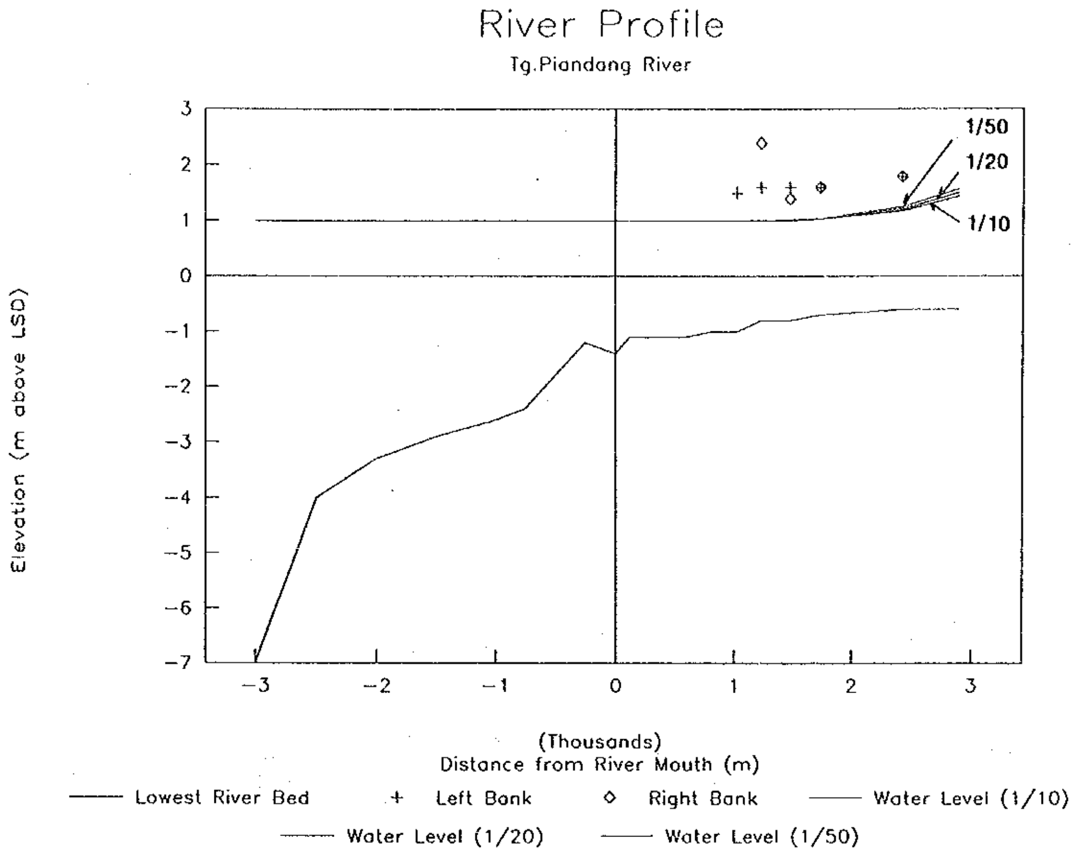


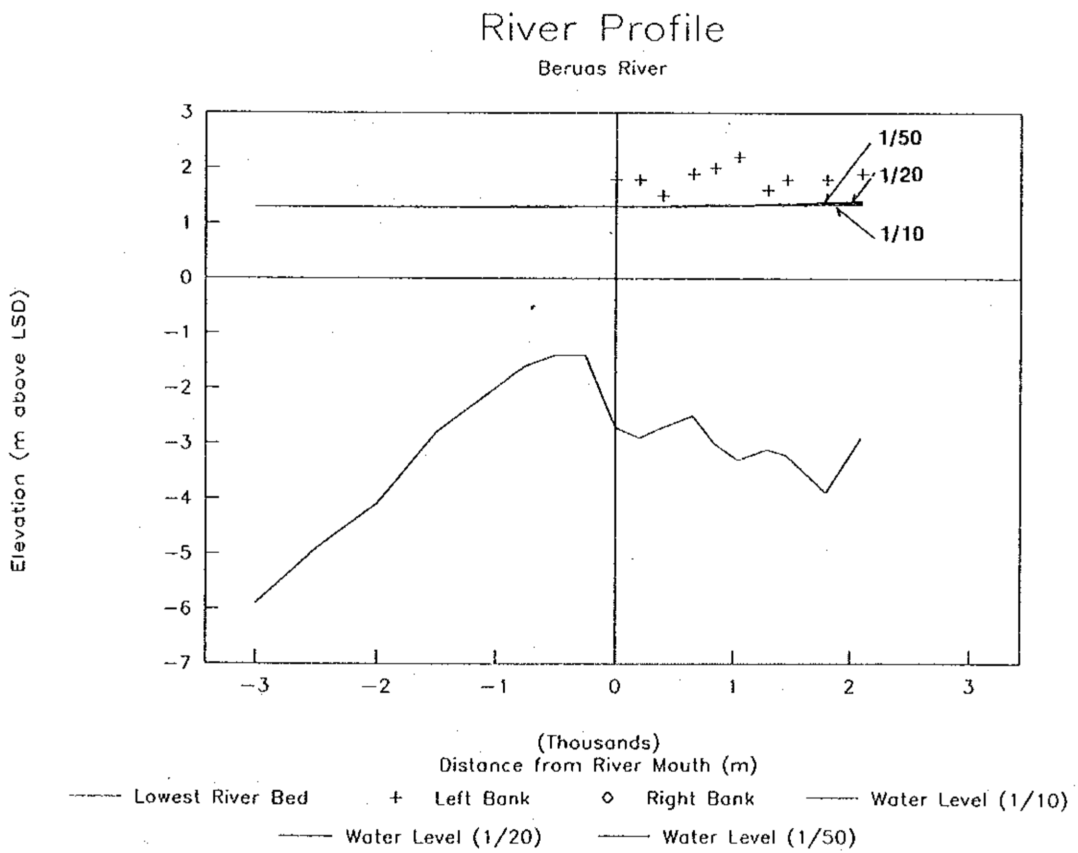
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED DURATION CURVE FOR REPRESENTATIVE RIVER MOUTH Fig. 1.3-4
JAPAN INTERNATIONAL COOPERATION AGENCY	



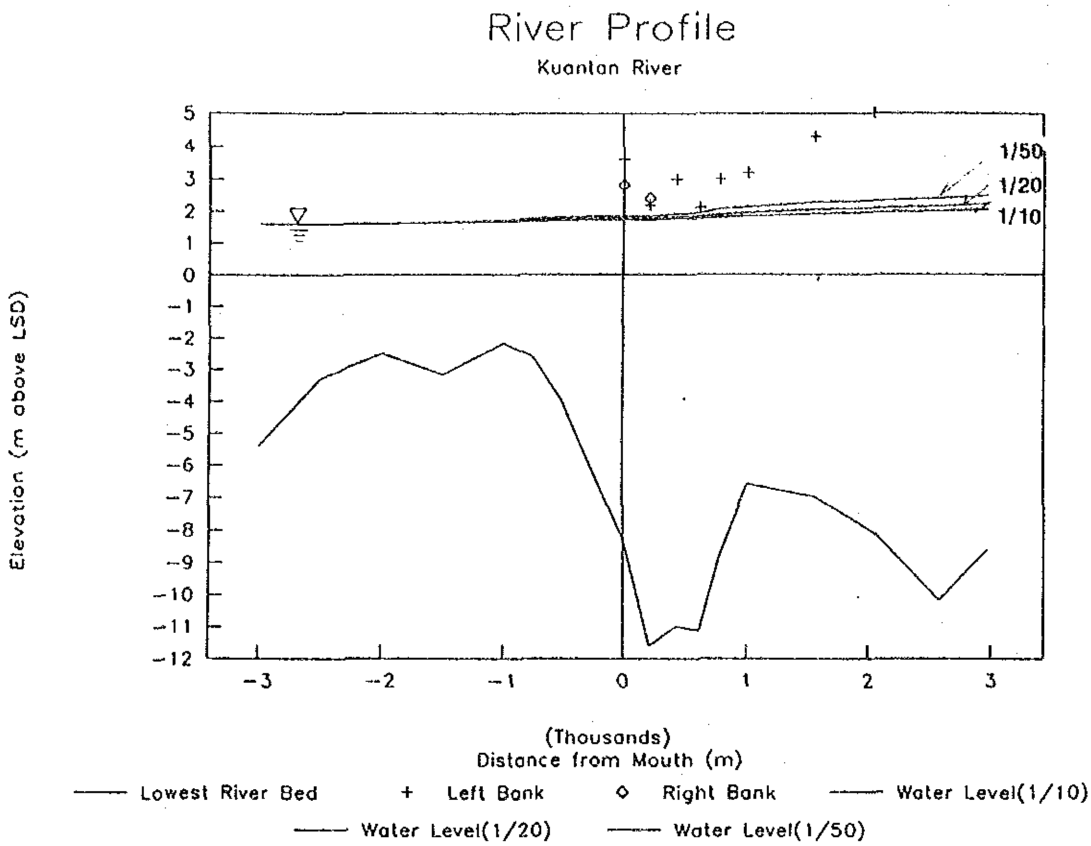


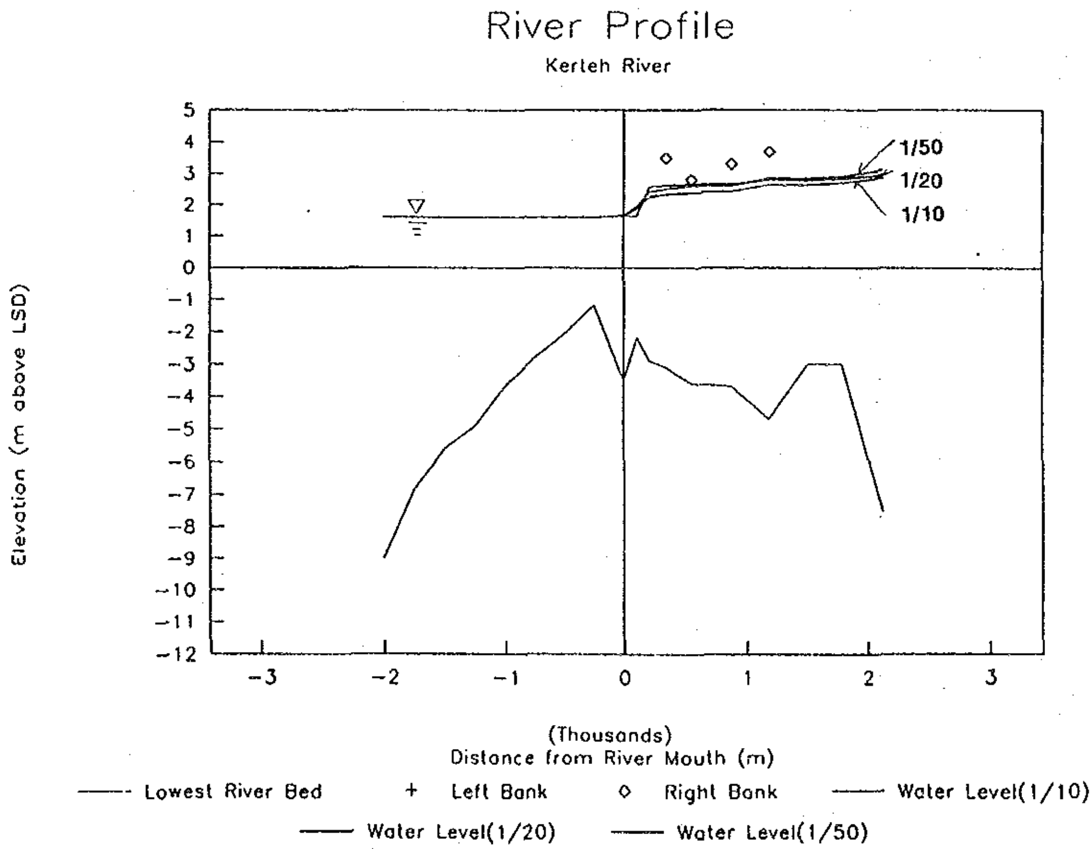
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED WATER LEVEL PROFILE (PERLIS AND KEDAH)	Fig. 1.3-5 (1/5)
JAPAN INTERNATIONAL COOPERATION AGENCY		



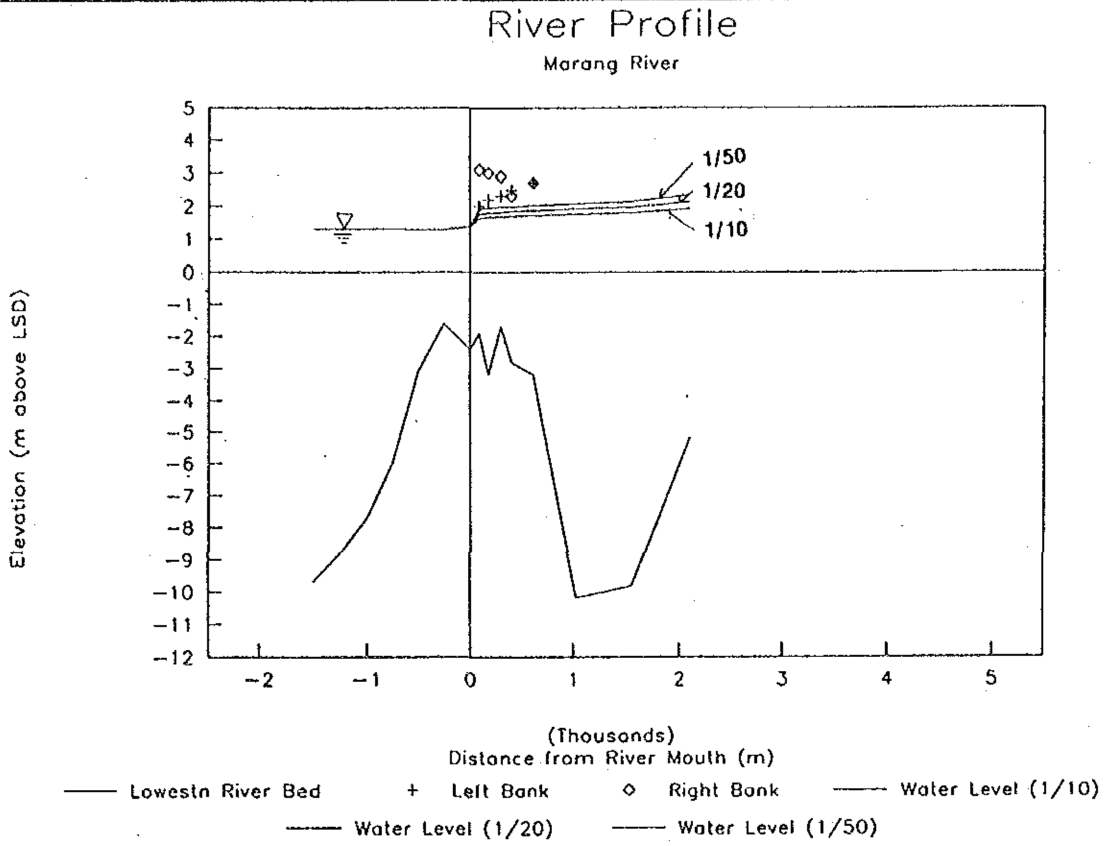


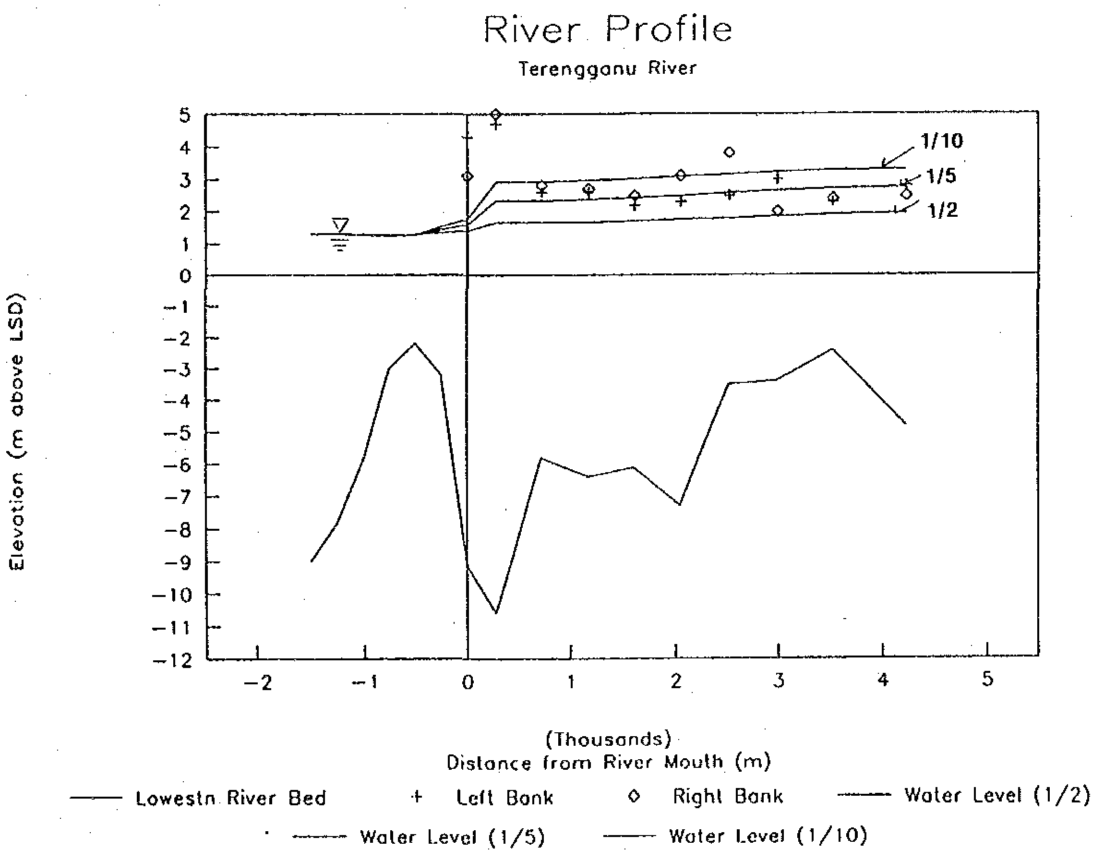
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED WATER LEVEL PROFILE (TG. PIANDANG AND BERUAS)	Fig. 1.3-5 (2/5)
JAPAN INTERNATIONAL COOPERATION AGENCY		



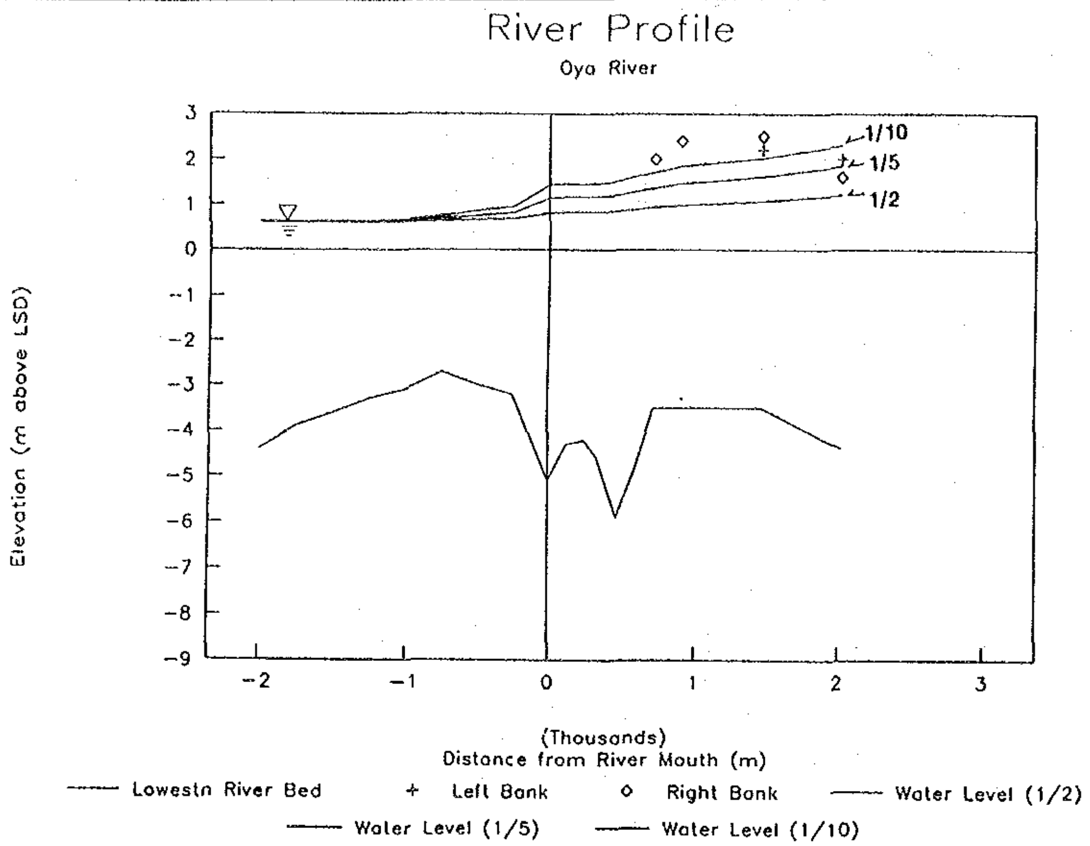


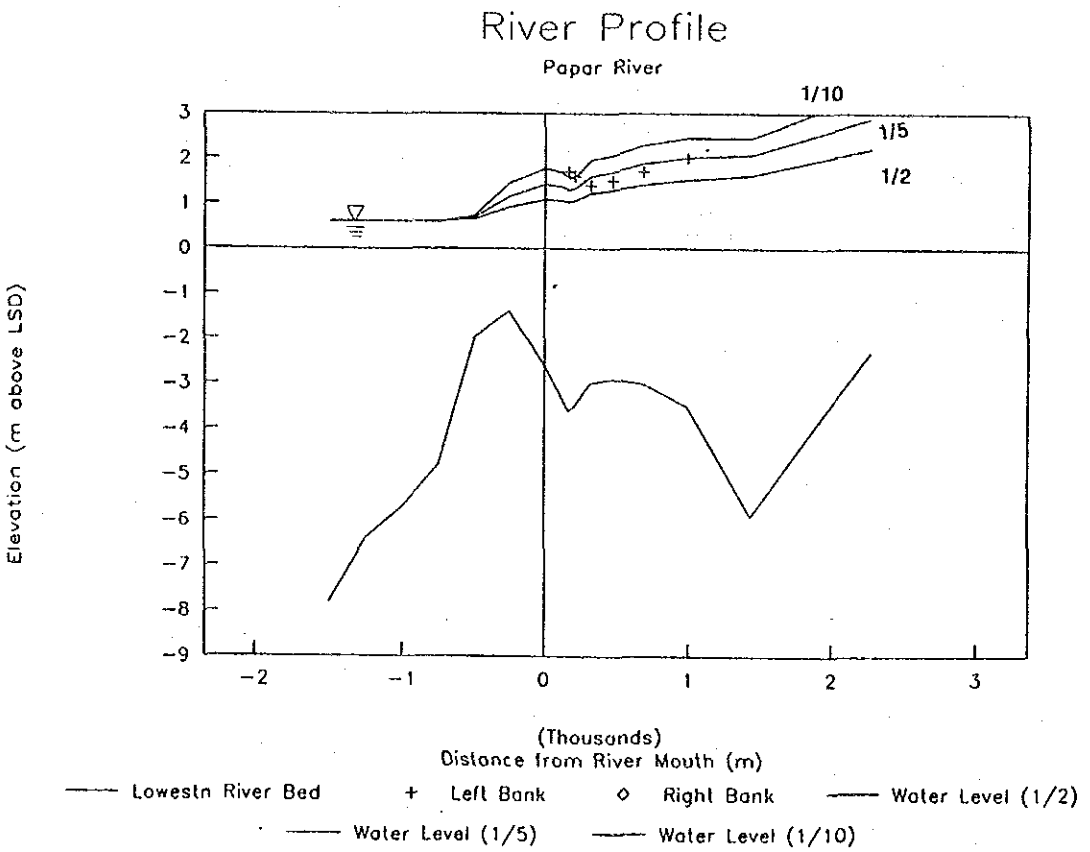
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED WATER LEVEL PROFILE (KUANTAN AND KERTEH)	Fig. 1.3-5 (3/5)
JAPAN INTERNATIONAL COOPERATION AGENCY		



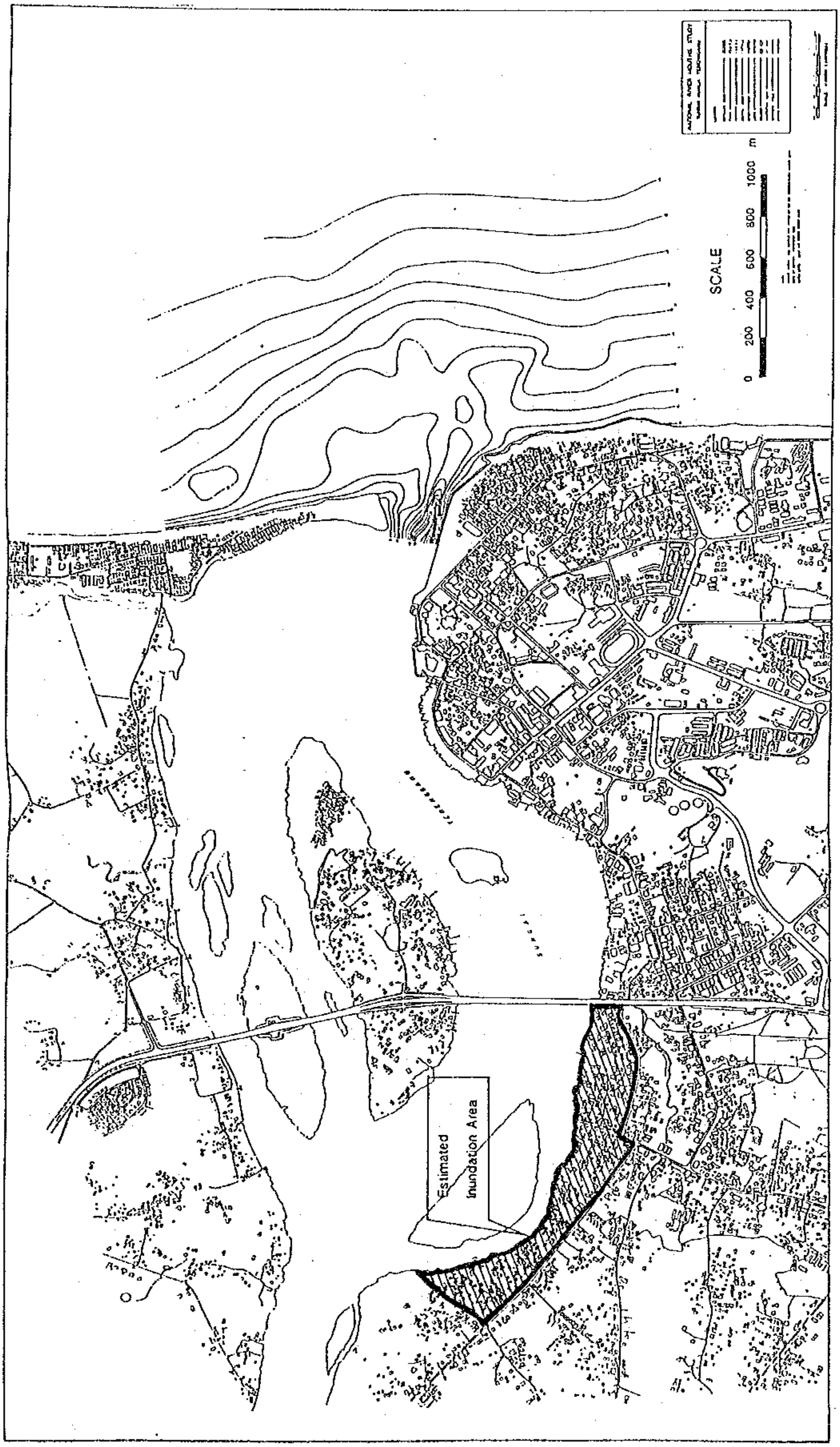


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA JAPAN INTERNATIONAL COOPERATION AGENCY	ESTIMATED WATER LEVEL PROFILE (MARANG AND TERENGGANU) Fig. 1.3-5 (4/5)





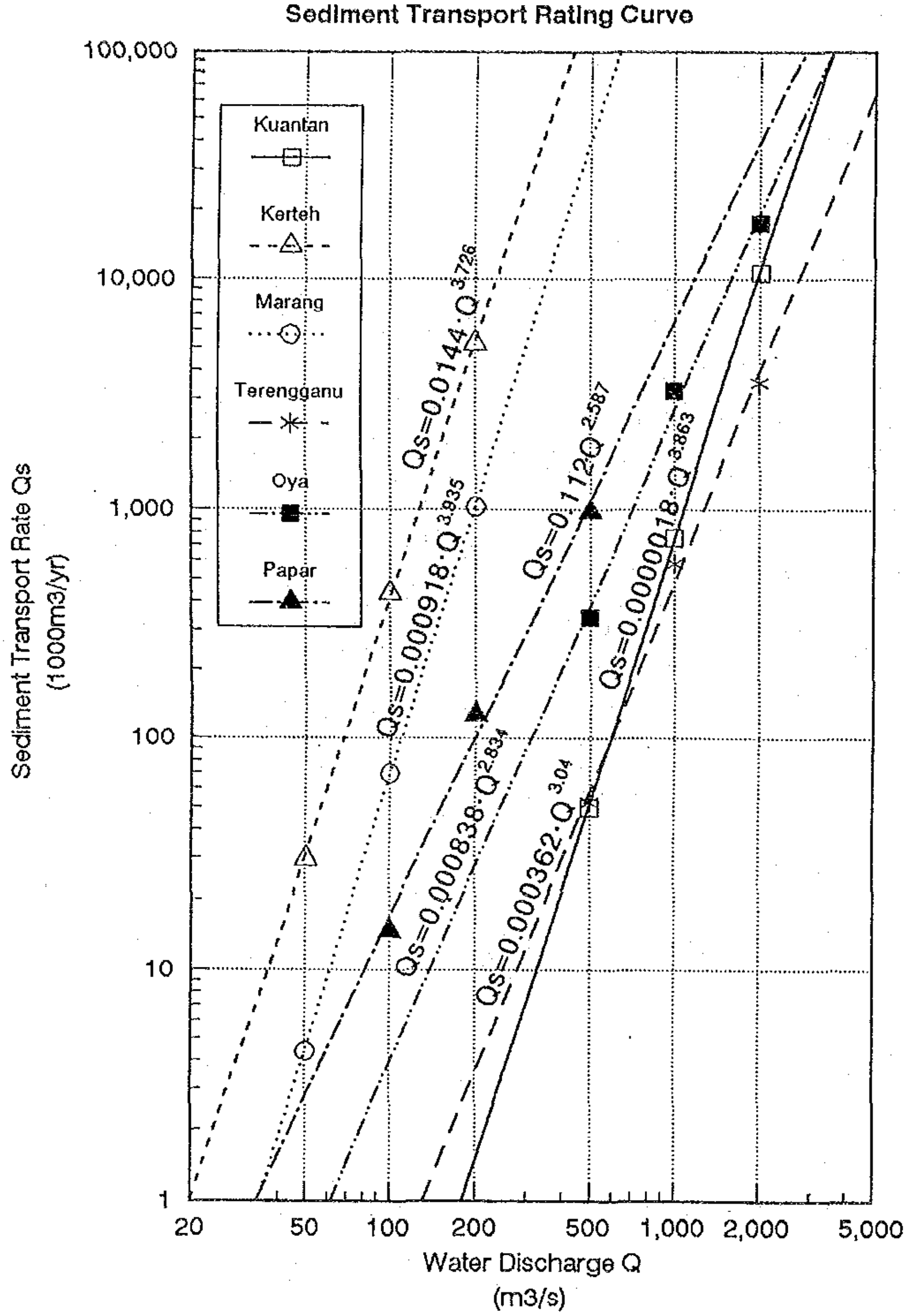
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED WATER LEVEL PROFILE (OYA AND PAPAR)	Fig. 1.3-5 (5/5)
JAPAN INTERNATIONAL COOPERATION AGENCY		



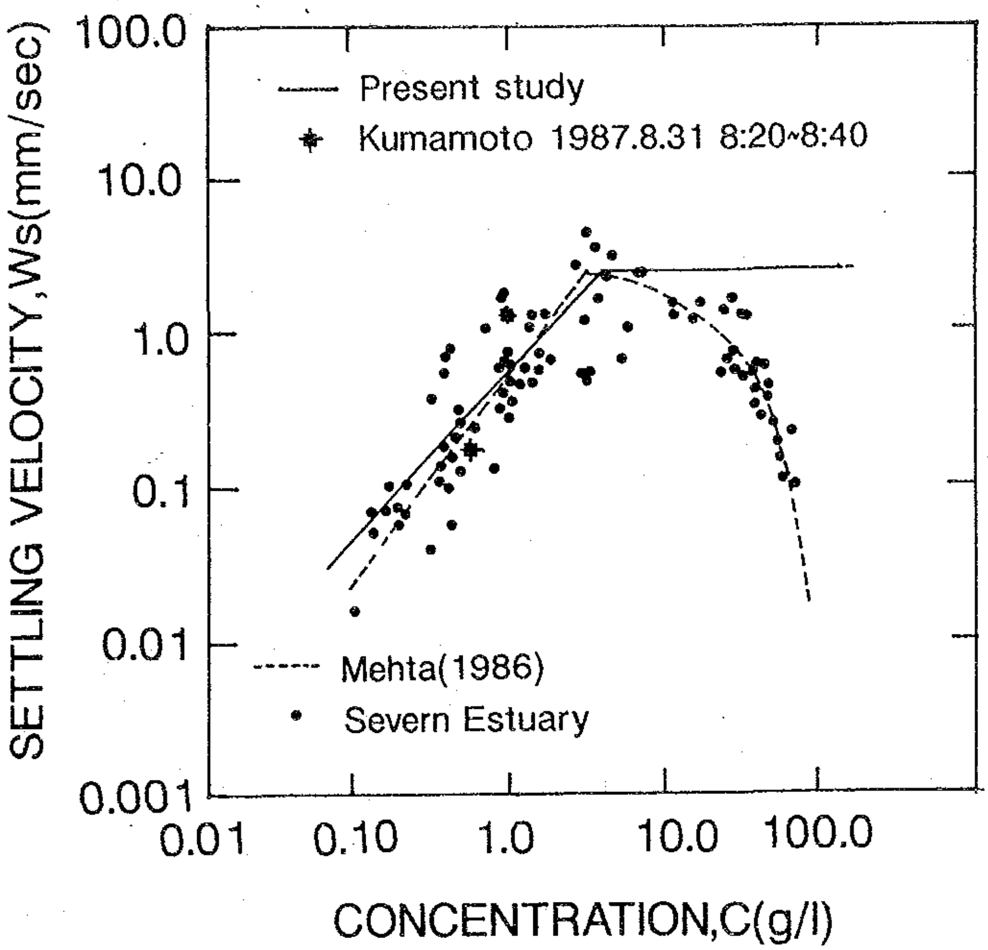
THE NATIONAL RIVER MOUTHS STUDY
IN MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

FLOOD INUNDATION AREA NEAR TERENGGANU RIVER MOUTH Fig. 1.3-6



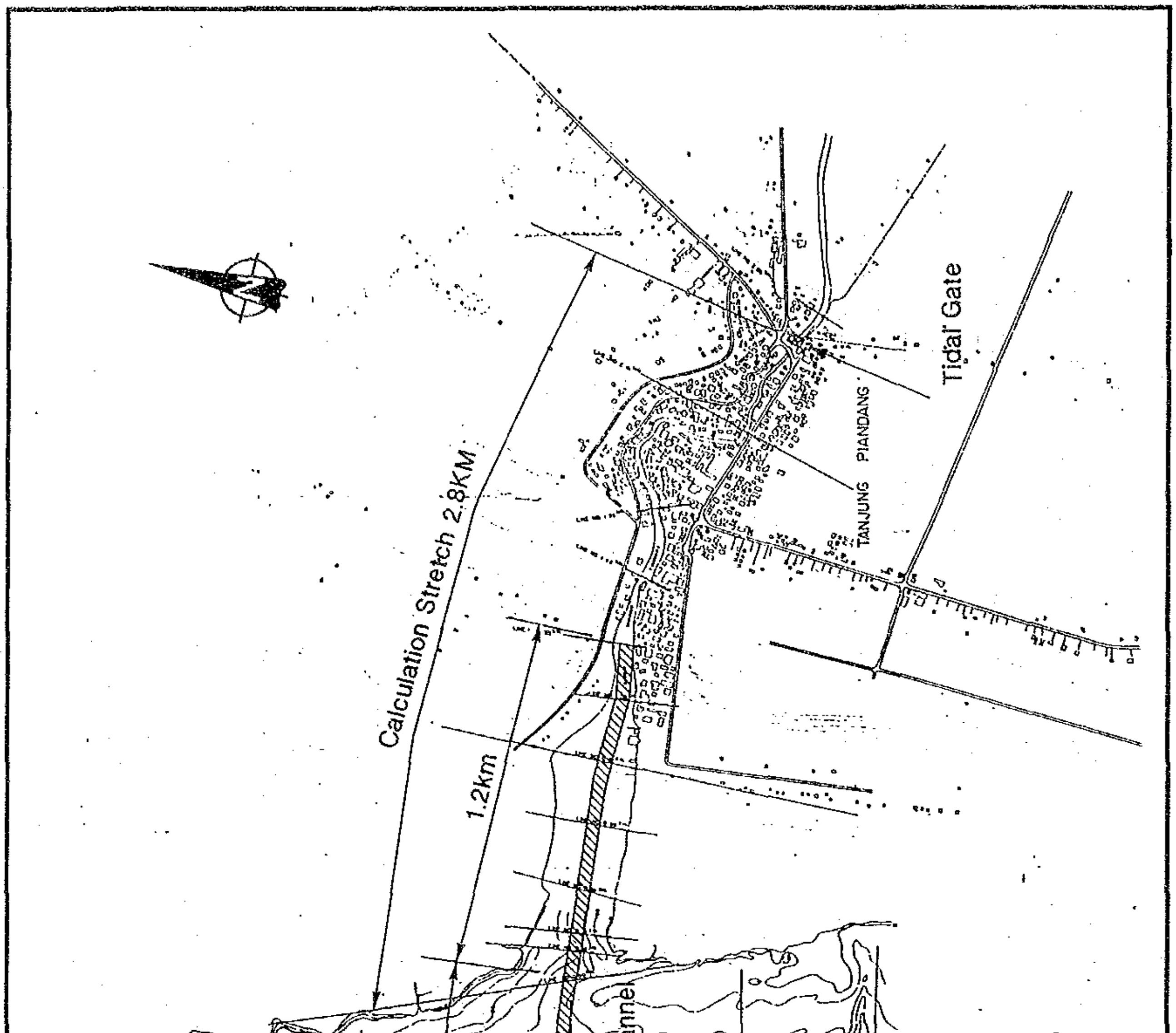
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	SEDIMENT RATING CURVES
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-7



Date Source :

H.Tsuruya and others:Mathematical Modeling of Mud Transport in Ports with a Multi-Layered Model -Application to Kumamoto Port- , Report of the Port and Harbour Research Institute,vol.29,Mar.1990

THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	SETTLING VELOCITY OF MUD MATERIAL	Fig. 1.3-8
JAPAN INTERNATIONAL COOPERATION AGENCY		

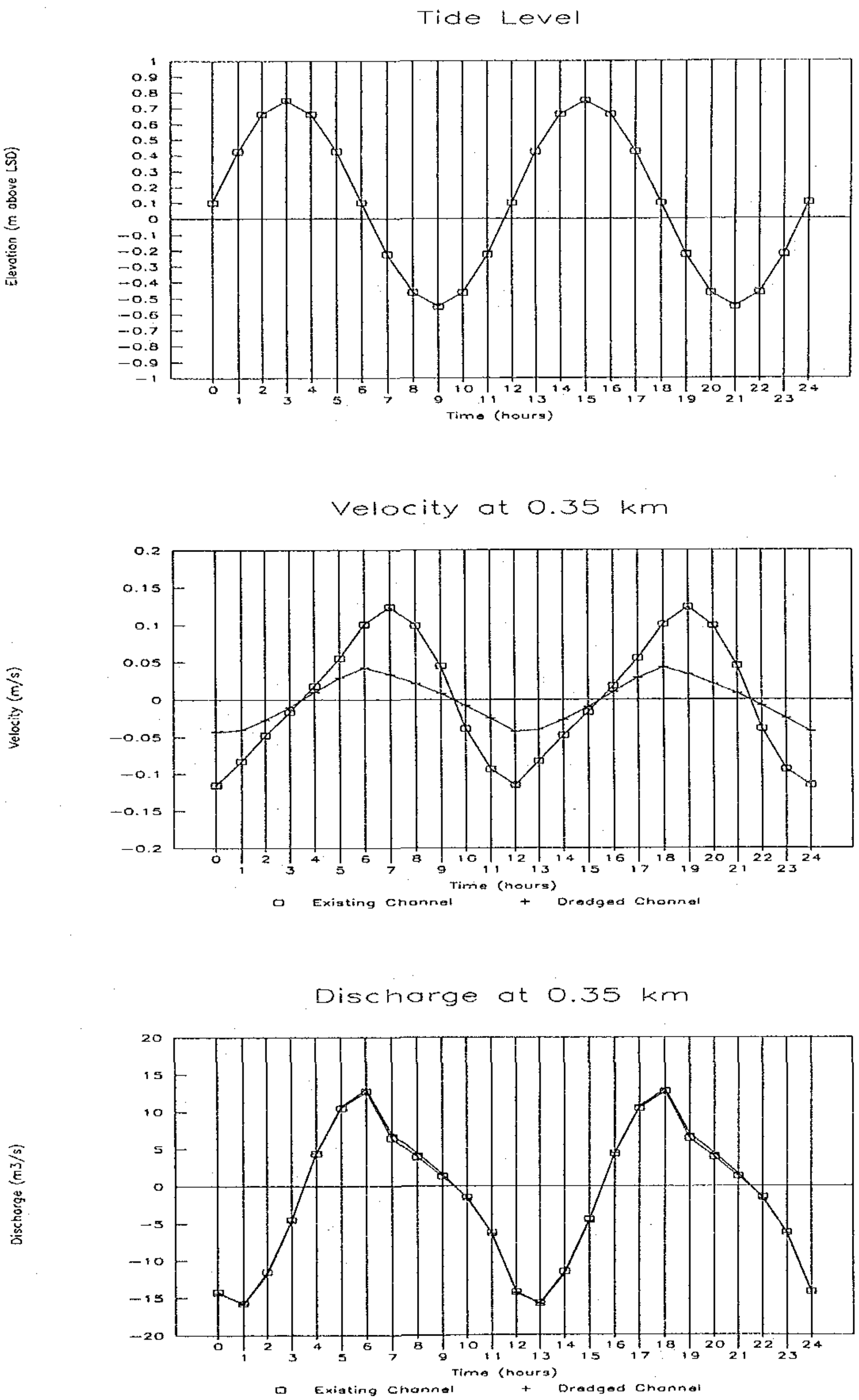


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA

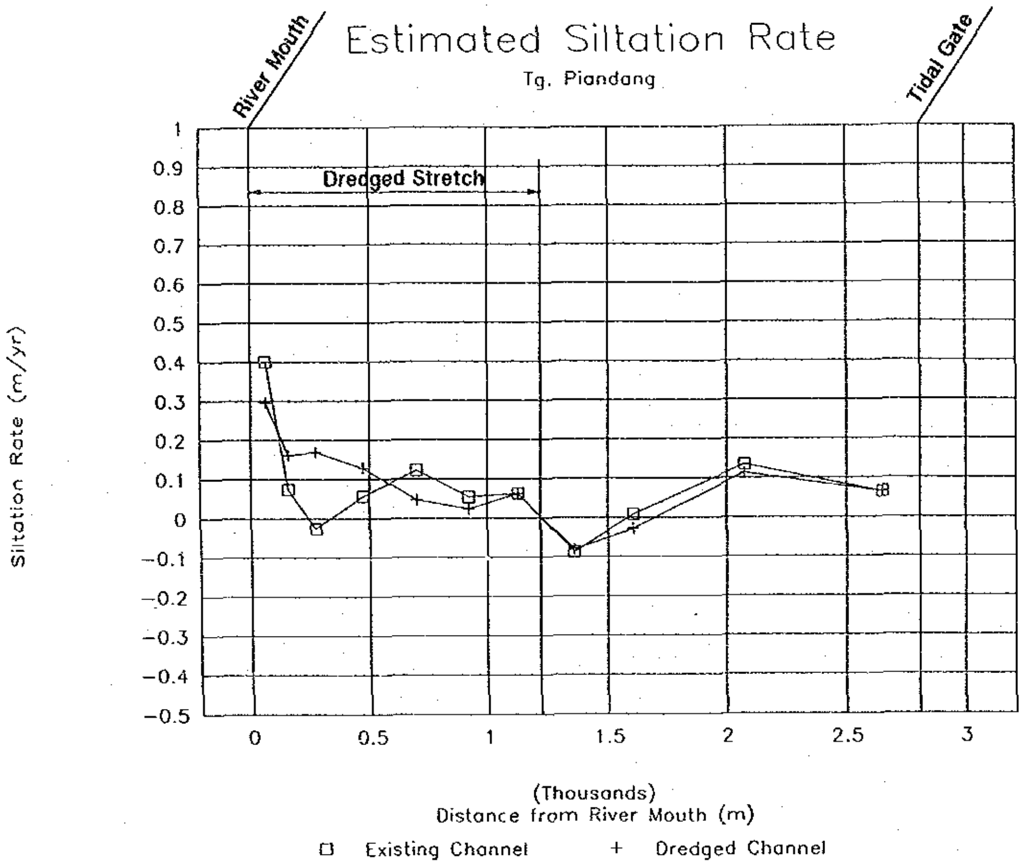
JAPAN INTERNATIONAL COOPERATION AGENCY

TARGET STRETCH FOR ONE-DIMENSIONAL DISPERSION ANALYSIS

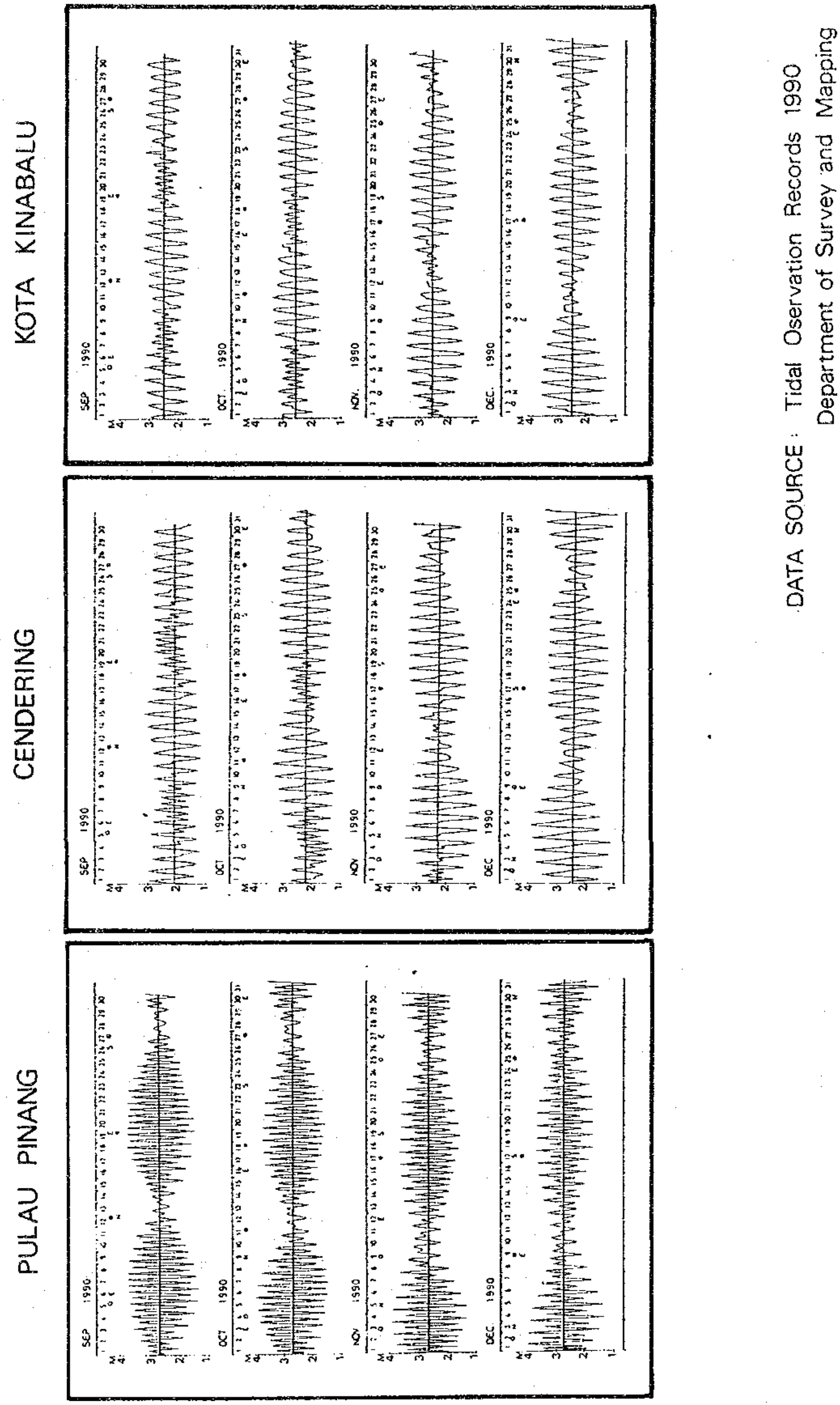
Fig. 1.3-9



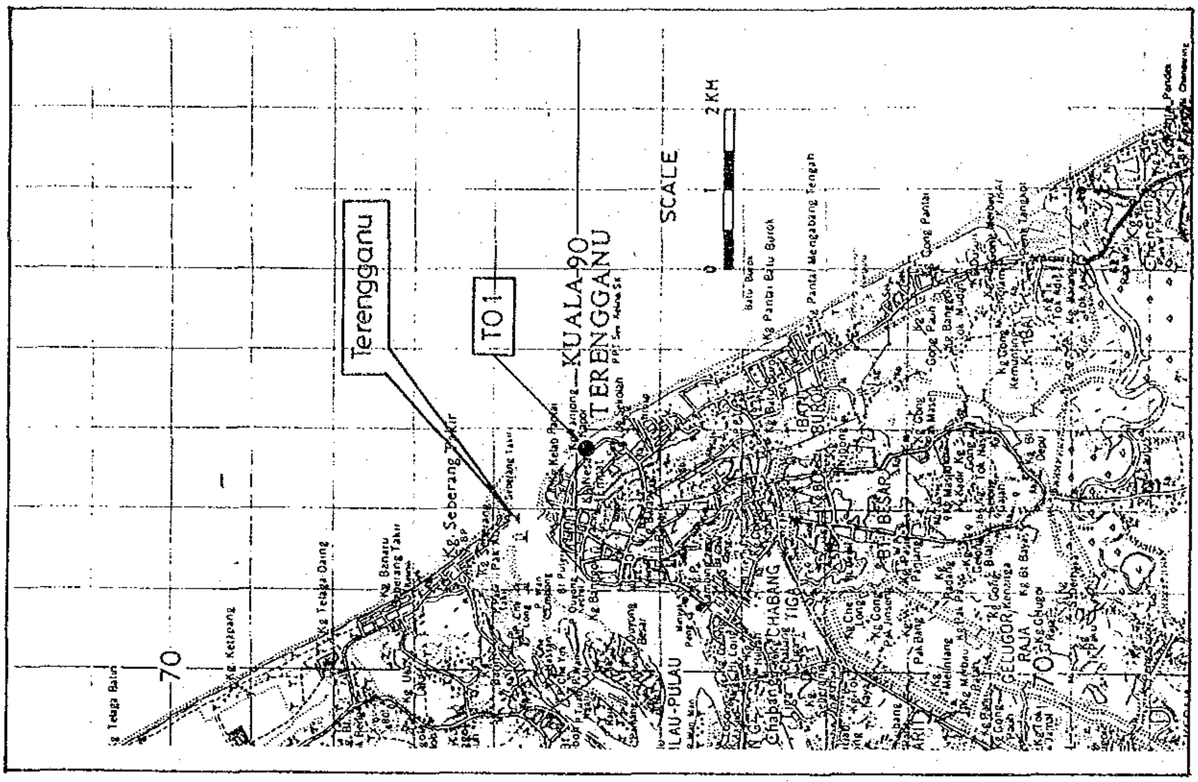
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RESULT OF UNSTEADY FLOW ANALYSIS
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-10



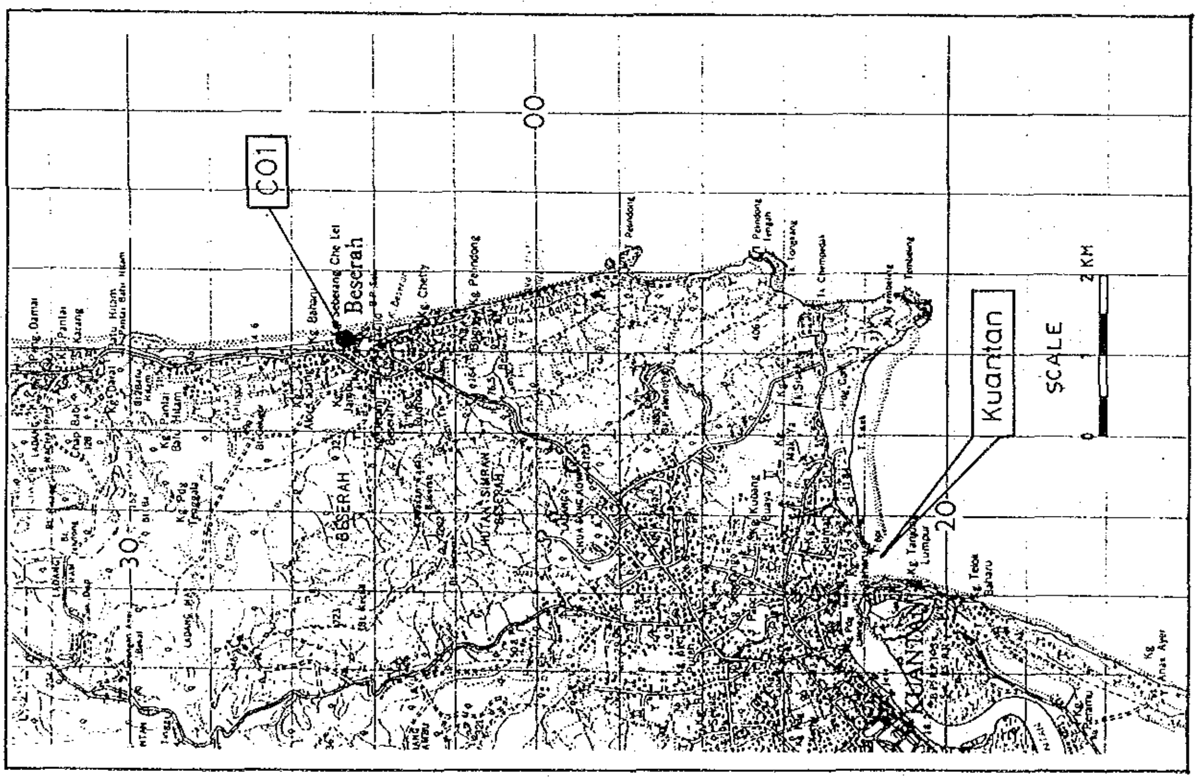
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED SILTATION RATE	Fig. 1.3-11
JAPAN INTERNATIONAL COOPERATION AGENCY		



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	OBSERVED TIDAL FLUCTUATION
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-12

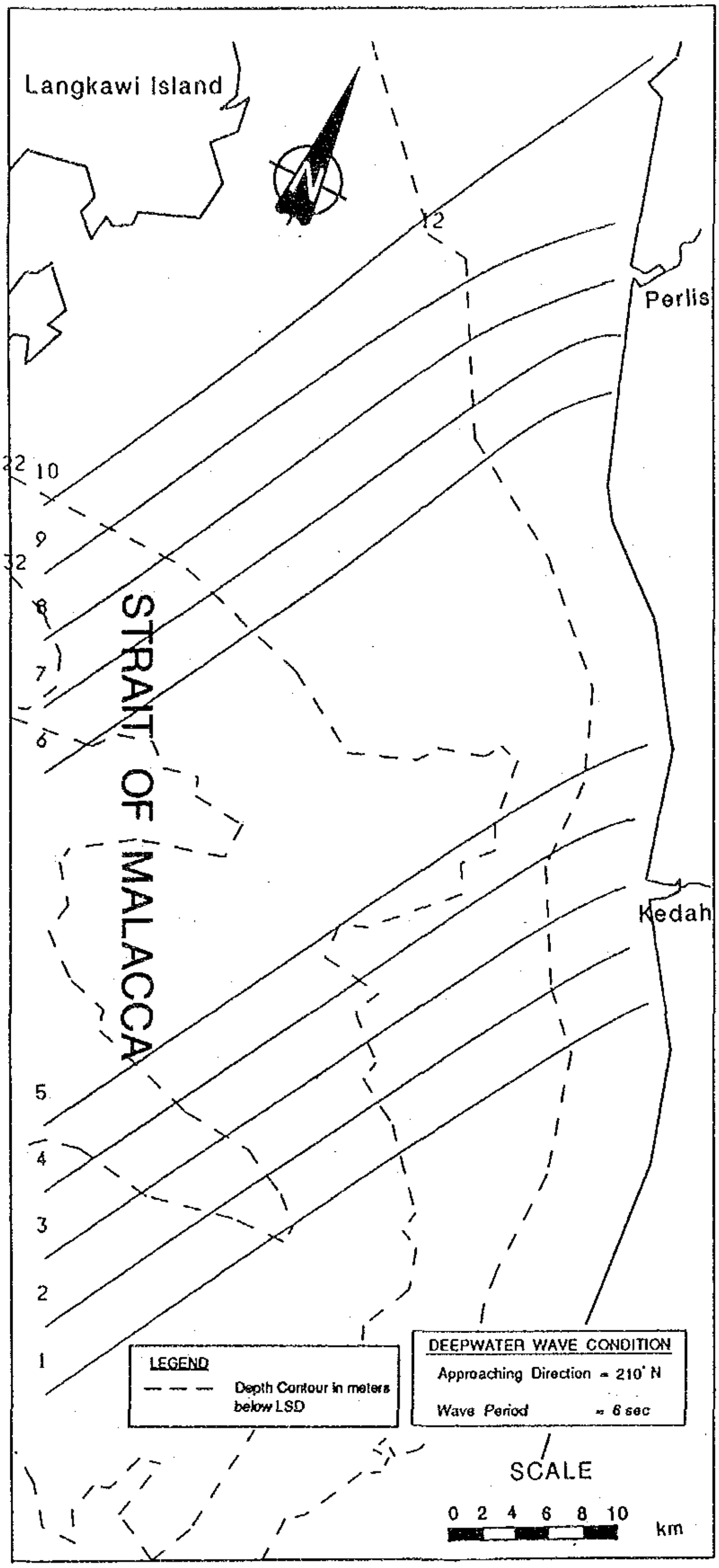


T01 Station

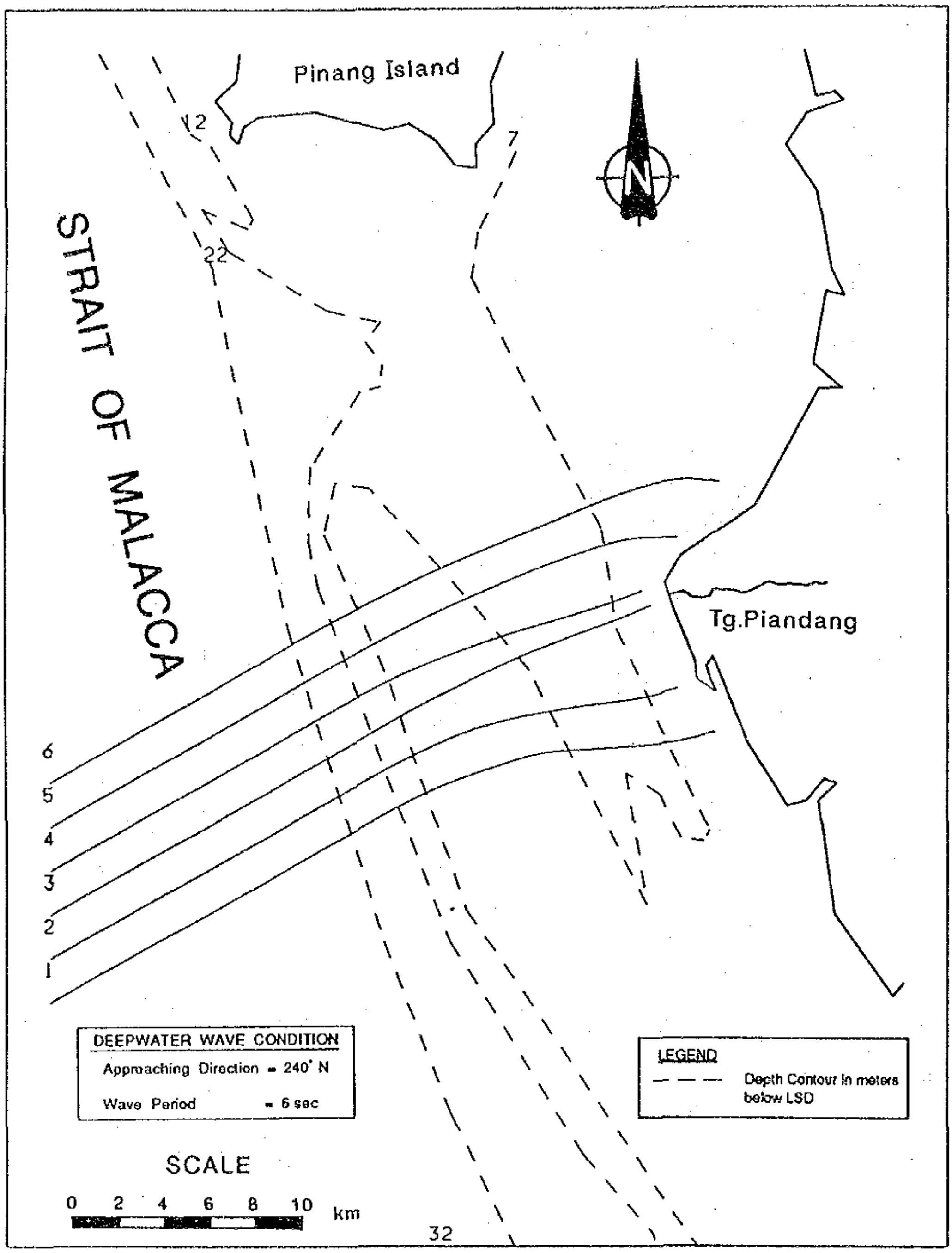


C01 Station

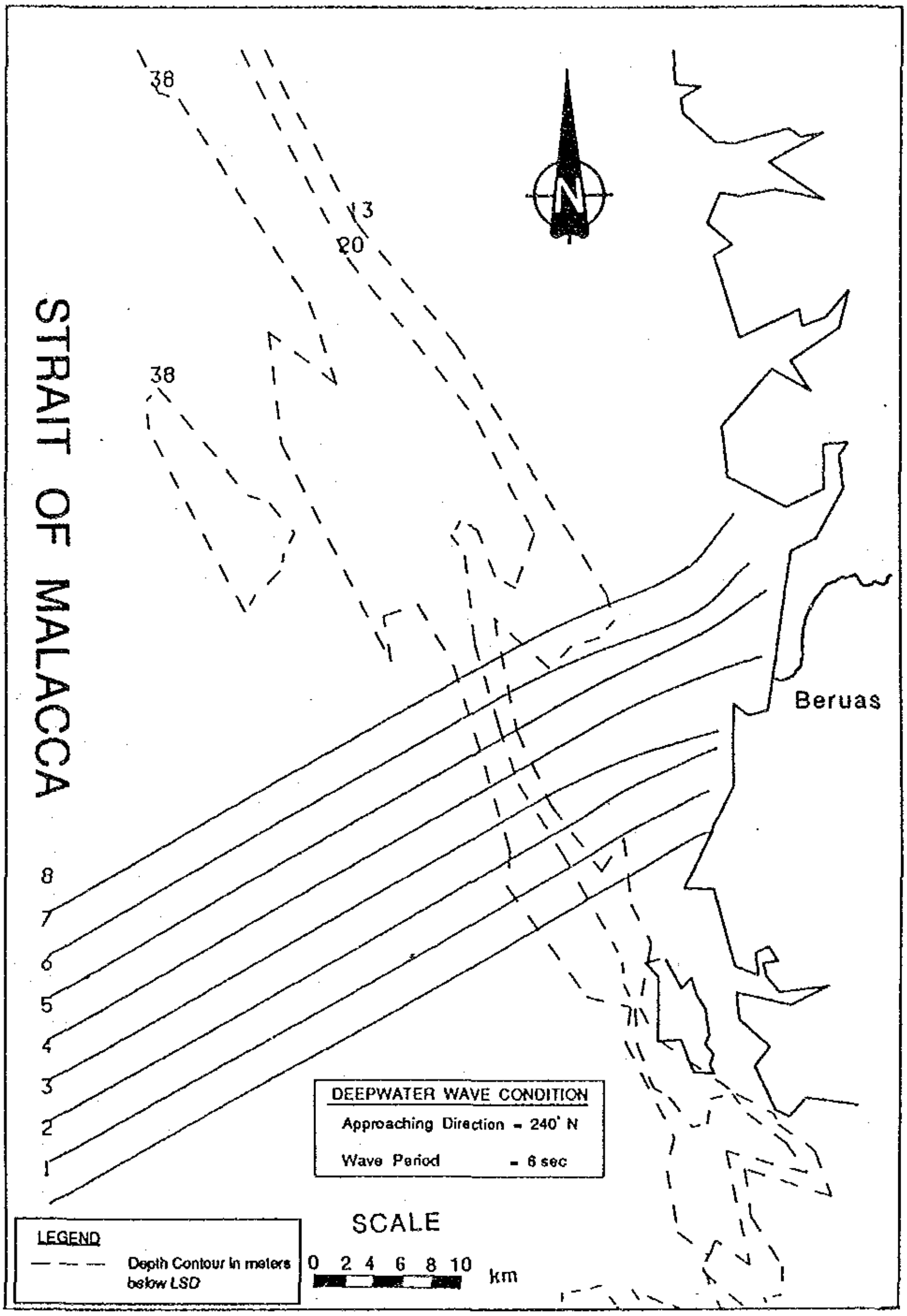
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF LEO PROGRAM STATIONS
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-13



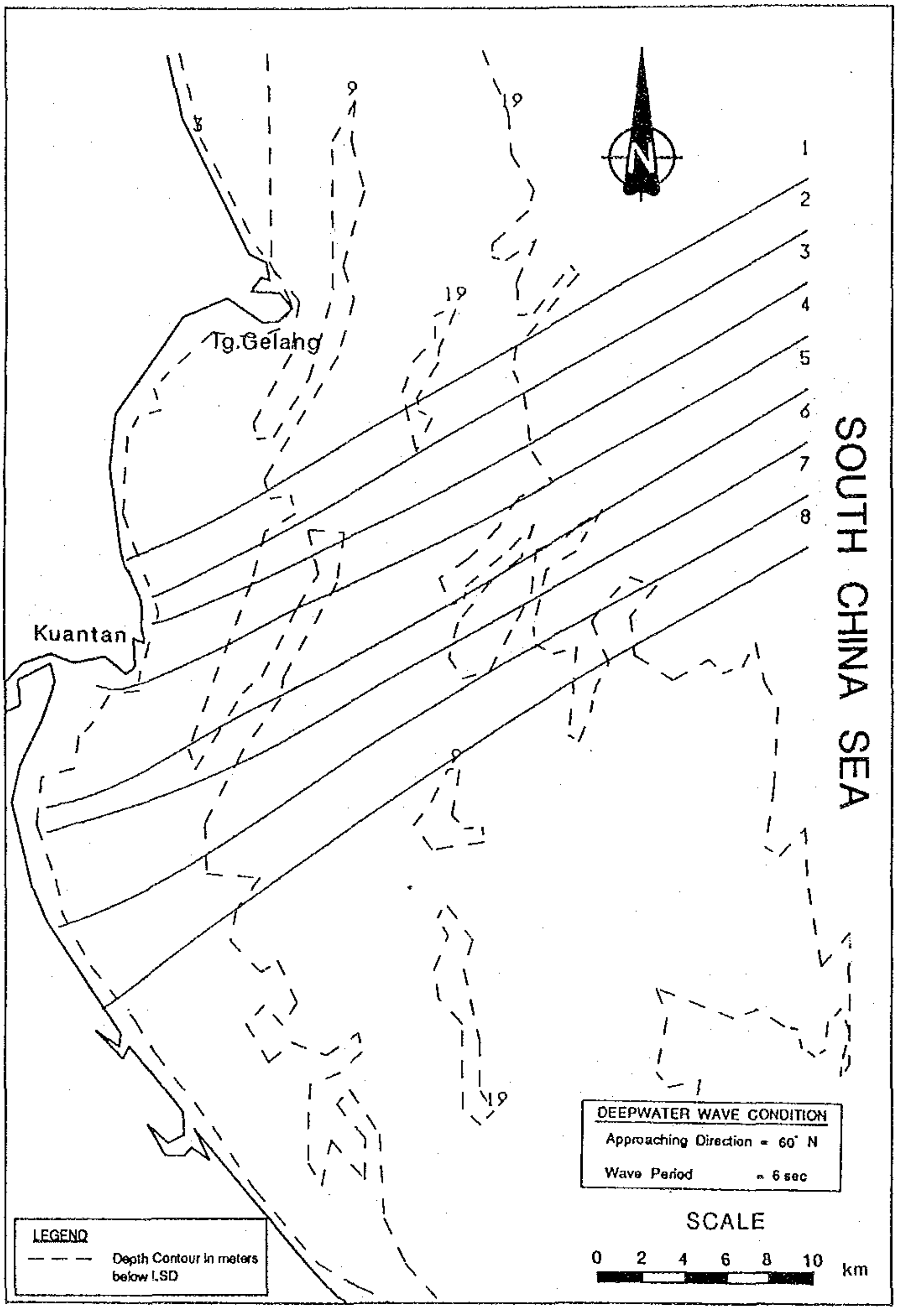
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (PERLIS AND KEDAH) Fig. 1.3-14 (1/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



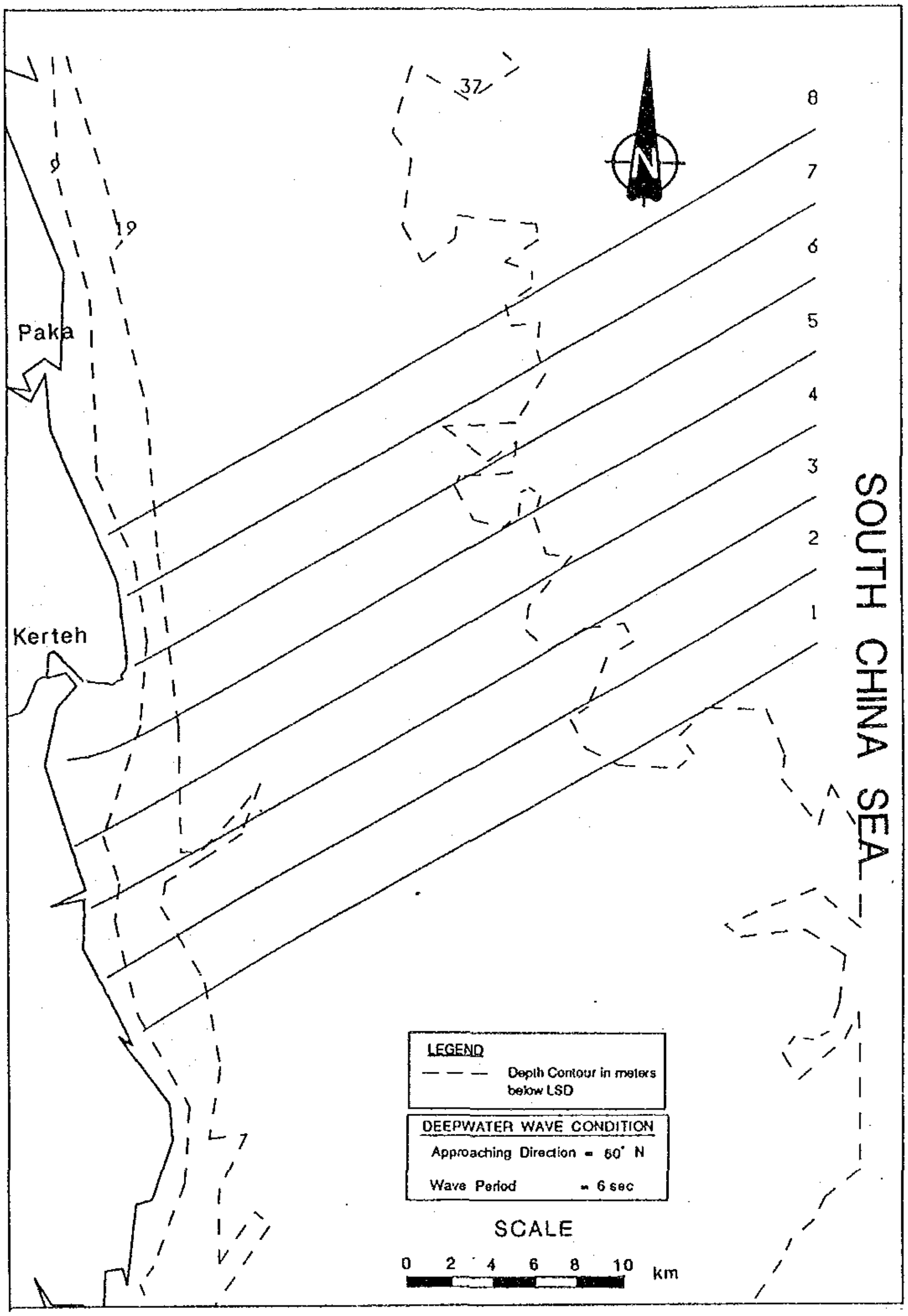
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (TG. PIANDANG) Fig. 1.3-14 (2/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



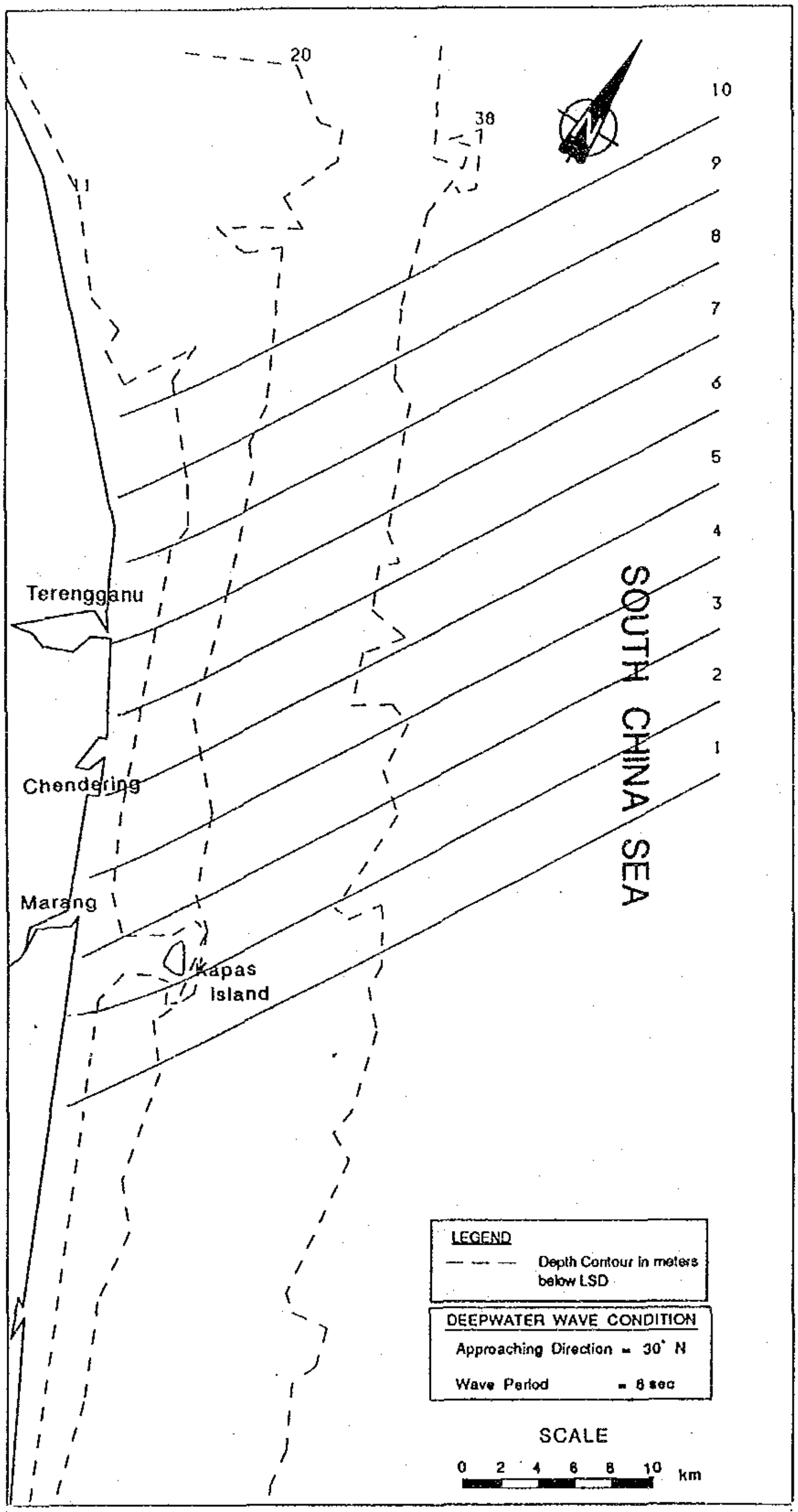
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (BERUAS) Fig. 1.3-14 (3/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



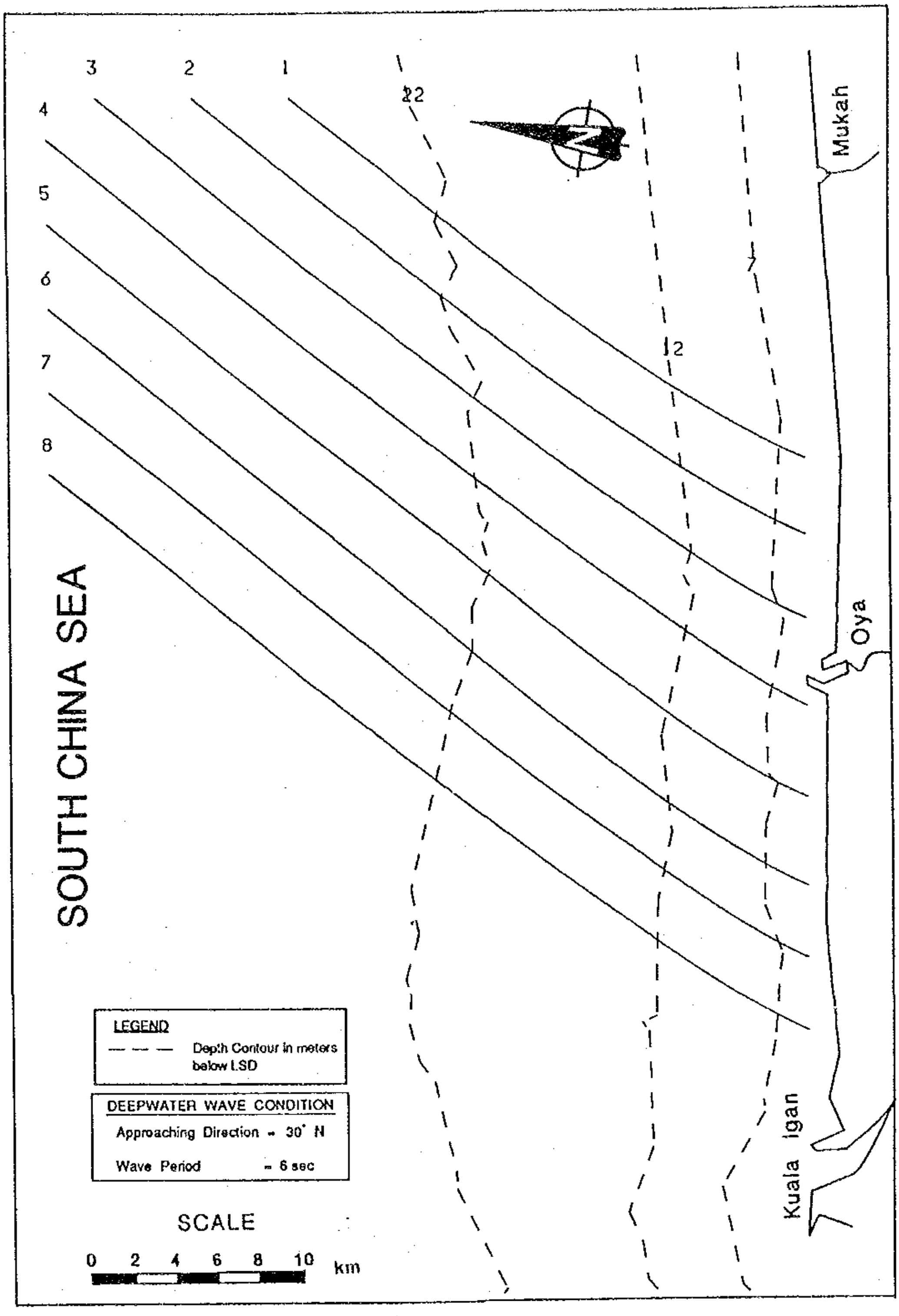
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (KUANTAN) Fig. 1.3-14 (4/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



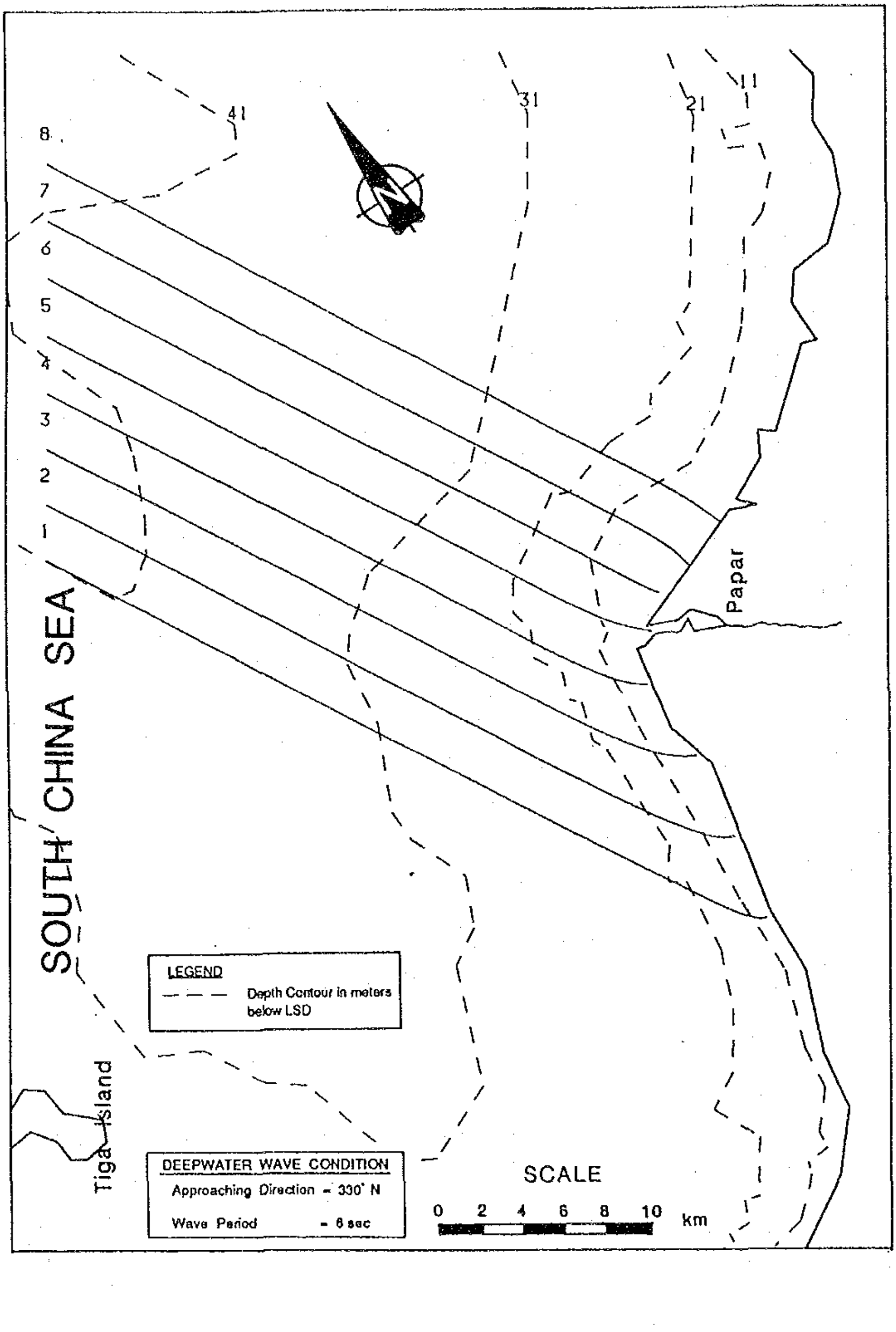
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (KERTEH) Fig. 1.3-14 (5/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



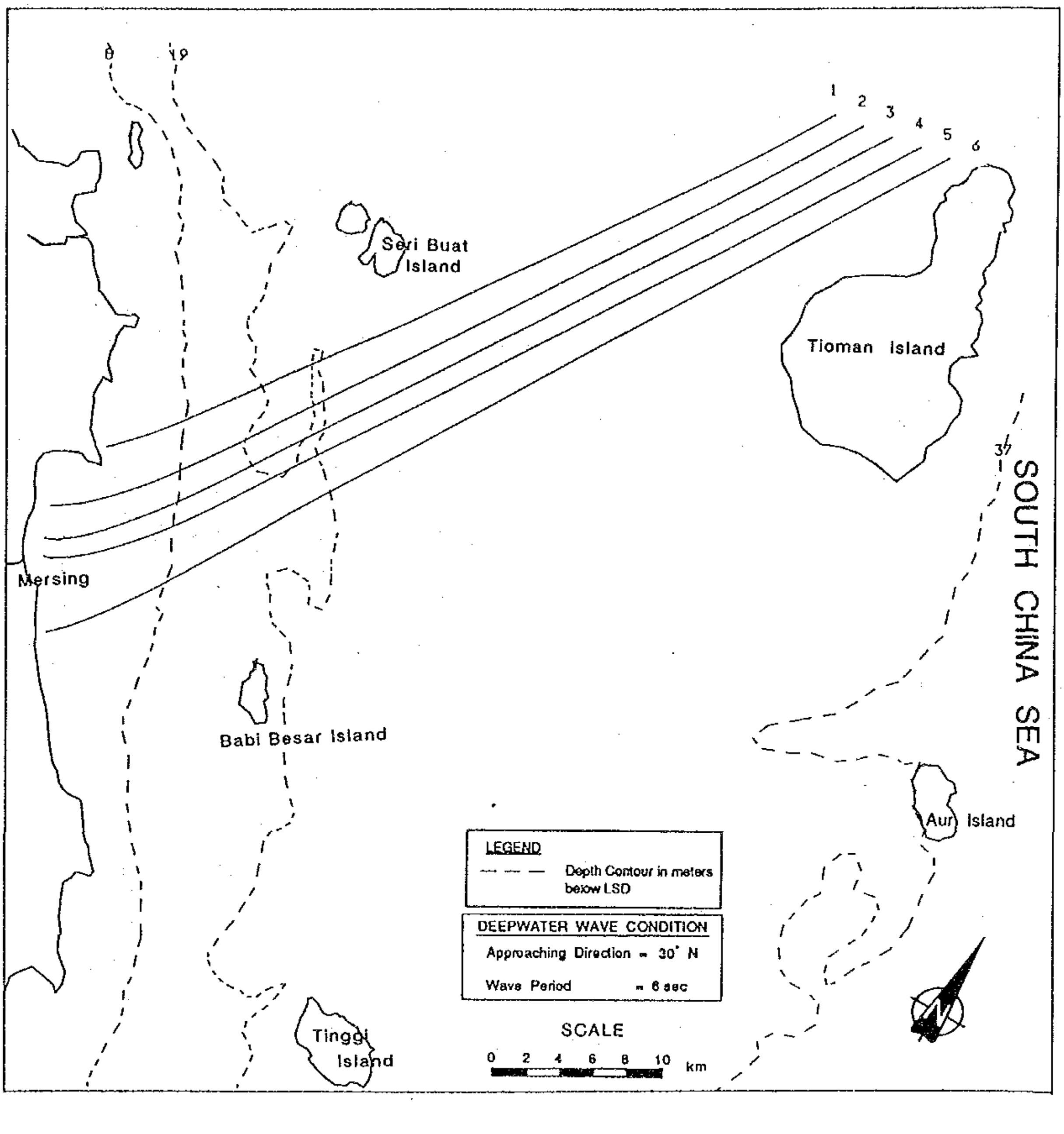
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (MARANG AND TERENGGANU) Fig. 1.3-14 (6/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	



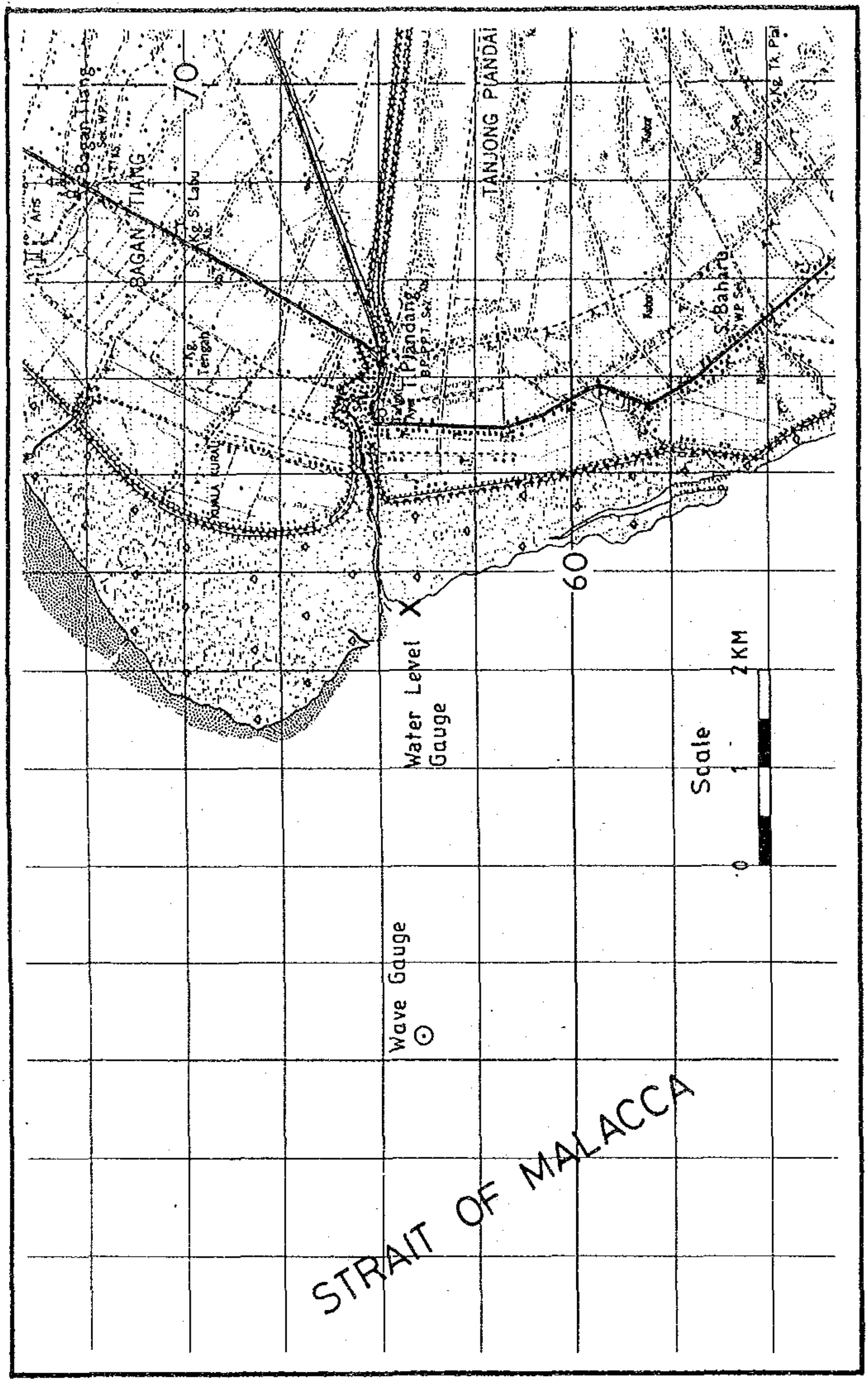
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (OYA)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.3-14 (7/8)



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR REPRESENTATIVE RIVER MOUTH (PAPAR) Fig. 1.3-14 (8/8)
JAPAN INTERNATIONAL COOPERATION AGENCY	

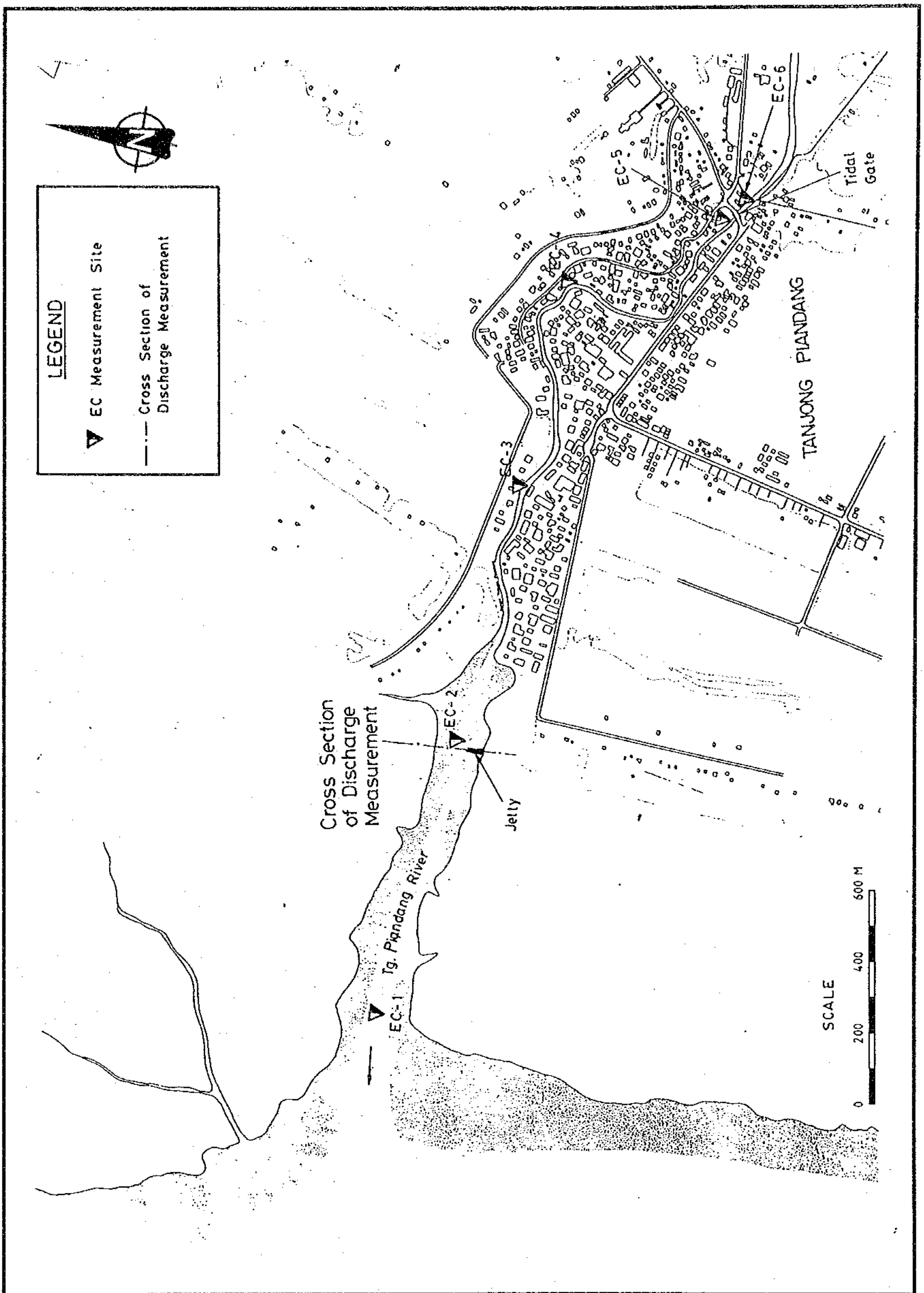


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM FOR MERSING RIVER MOUTH Fig. 1.3-15
JAPAN INTERNATIONAL COOPERATION AGENCY	

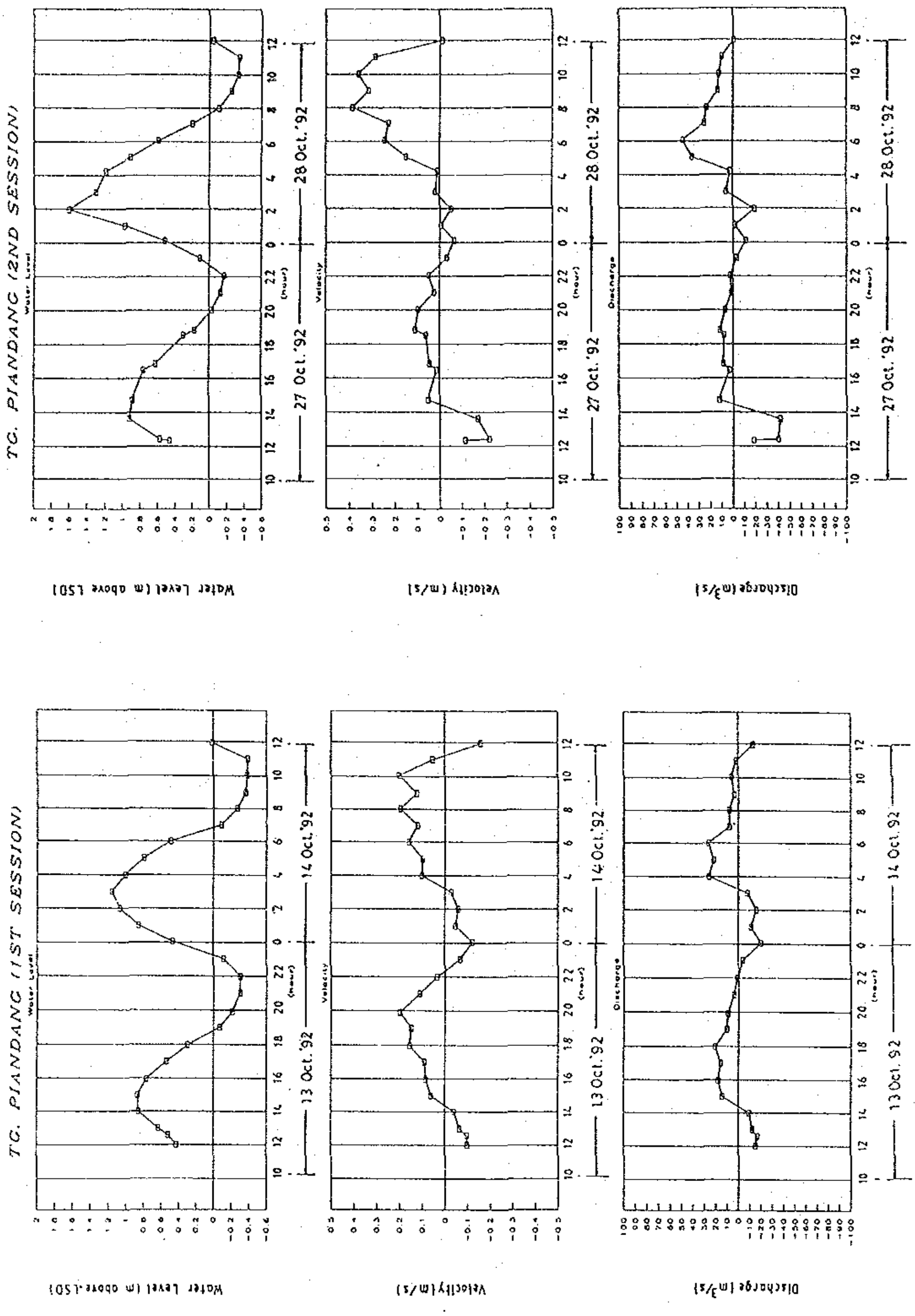


Tg. Piandang

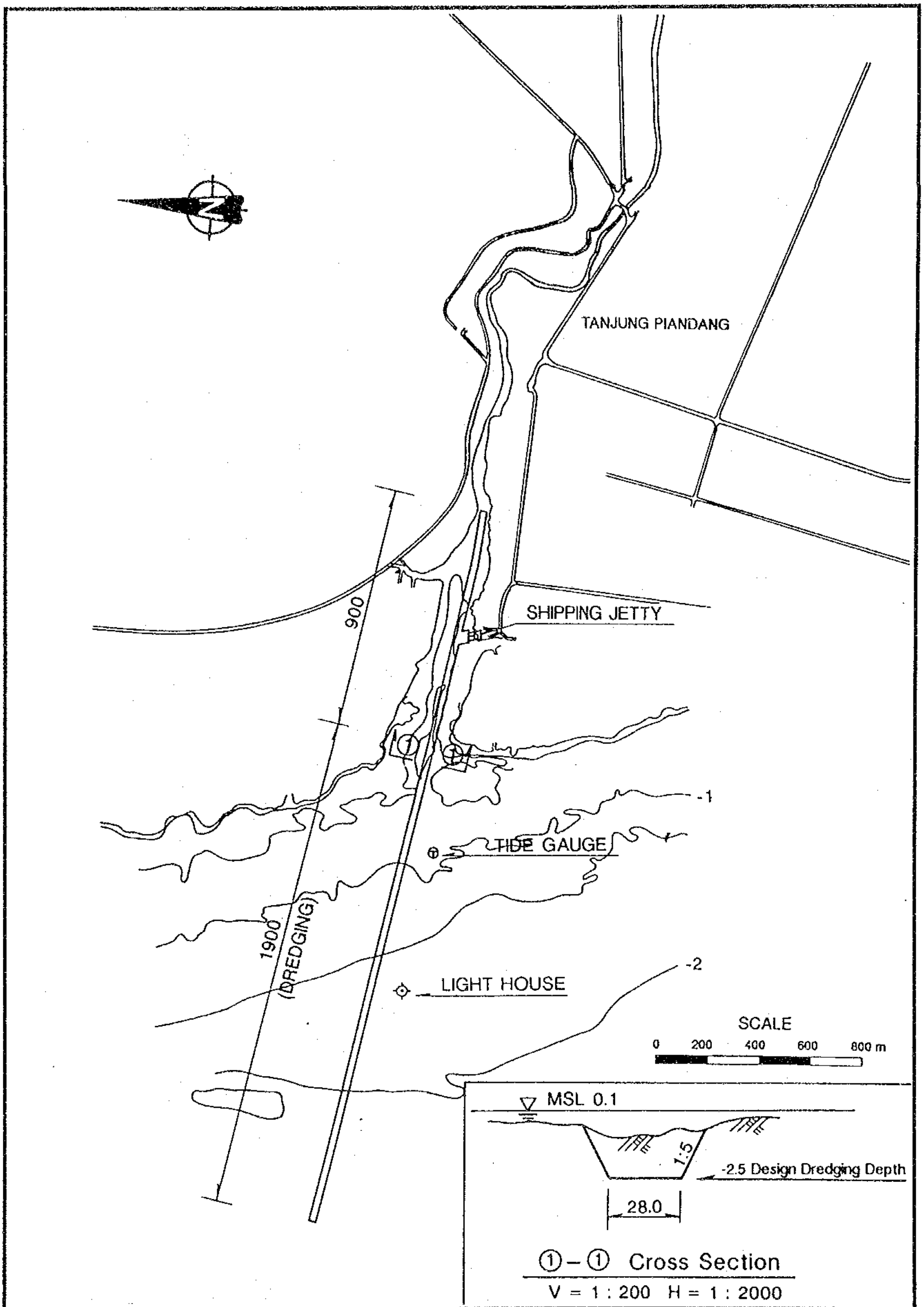
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF WATER LEVEL AND WAVE GAUGES IN TG. PIANDANG Fig. 1.4-1
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF HYDROLOGIC OBSERVATION IN TG. PIANDANG	Fig. 1.4-2
JAPAN INTERNATIONAL COOPERATION AGENCY		

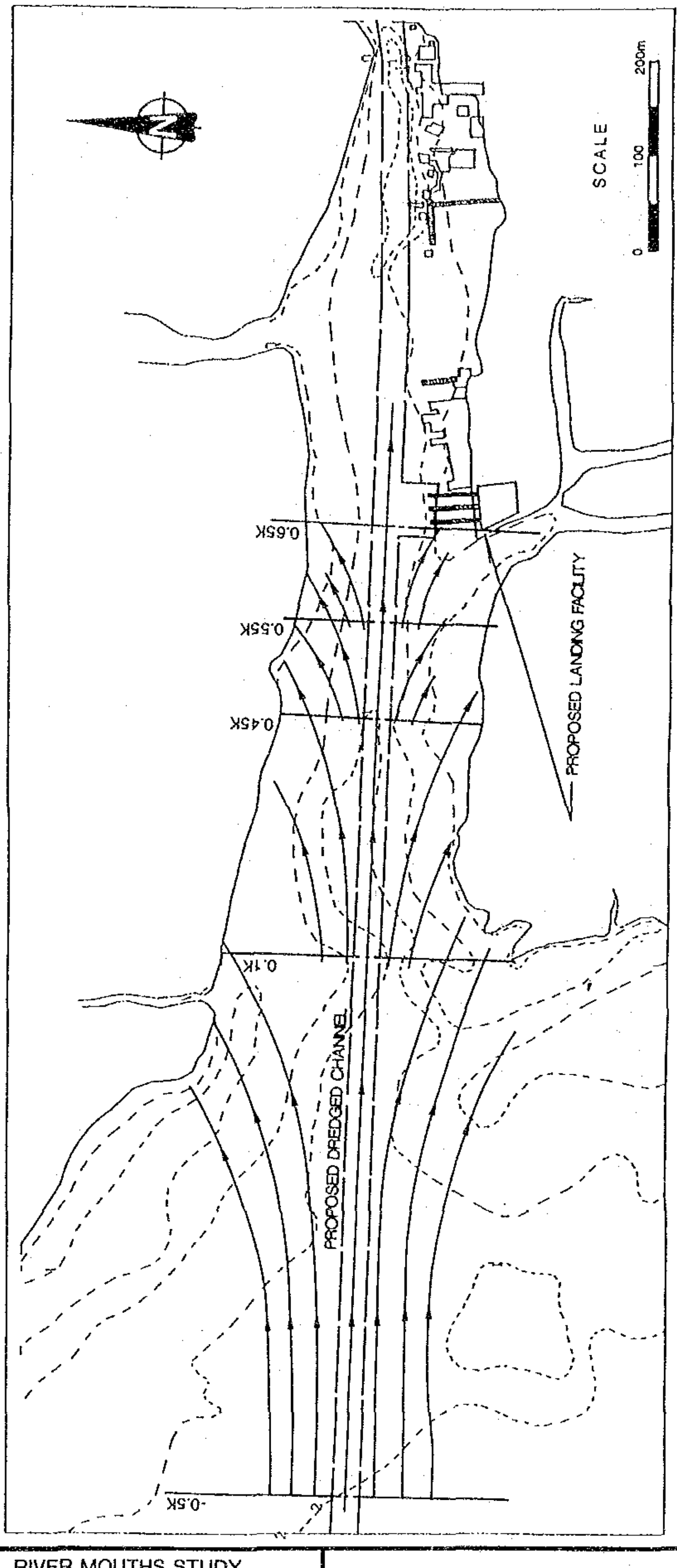


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	OBSERVED HYDROGRAPHS IN TG. PIANDANG
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-3

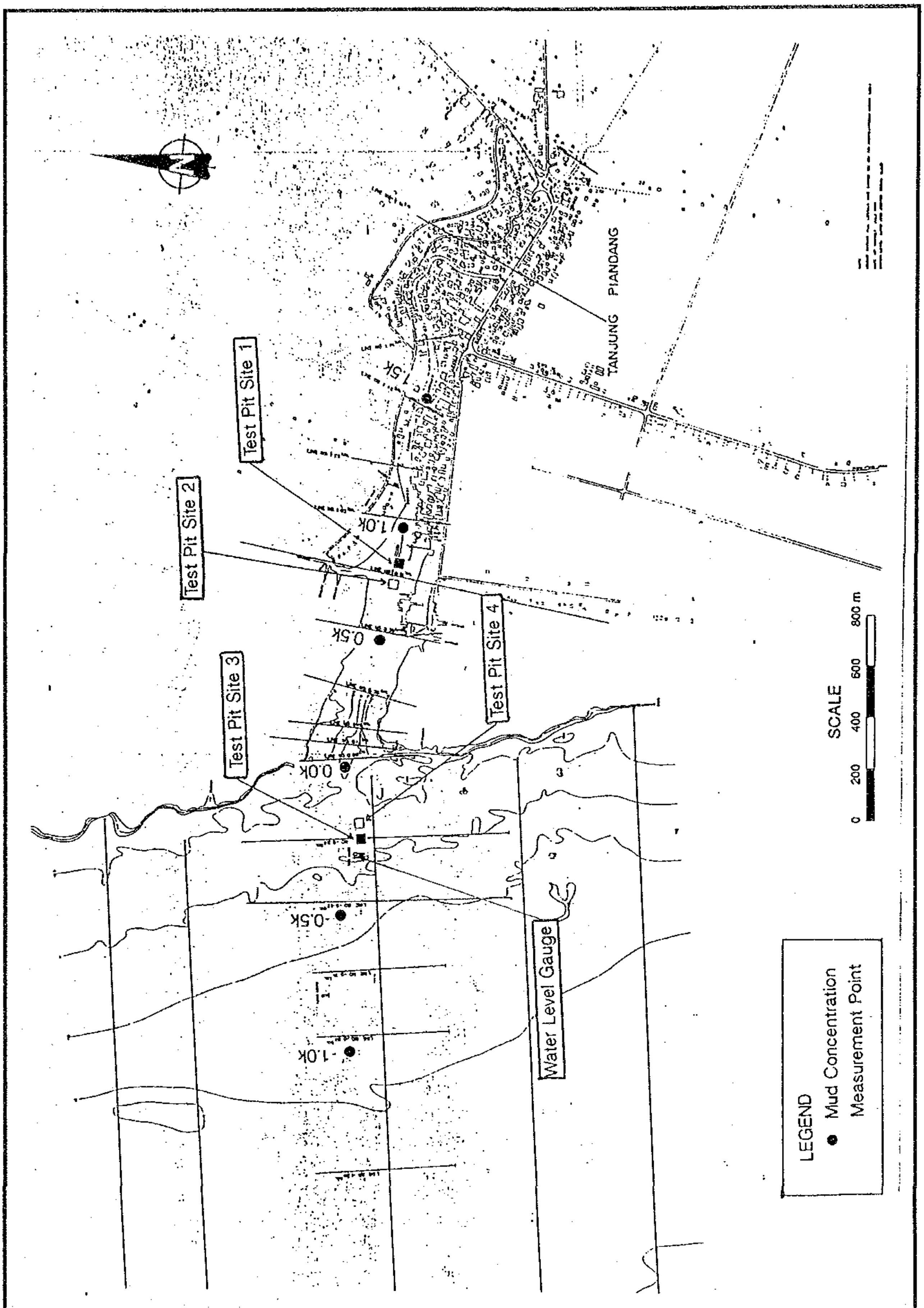


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	GENERAL LAYOUT OF OPTIMUM MEASURES AT TG. PIANDANG RIVER MOUTH Fig. 1.4-4
JAPAN INTERNATIONAL COOPERATION AGENCY	

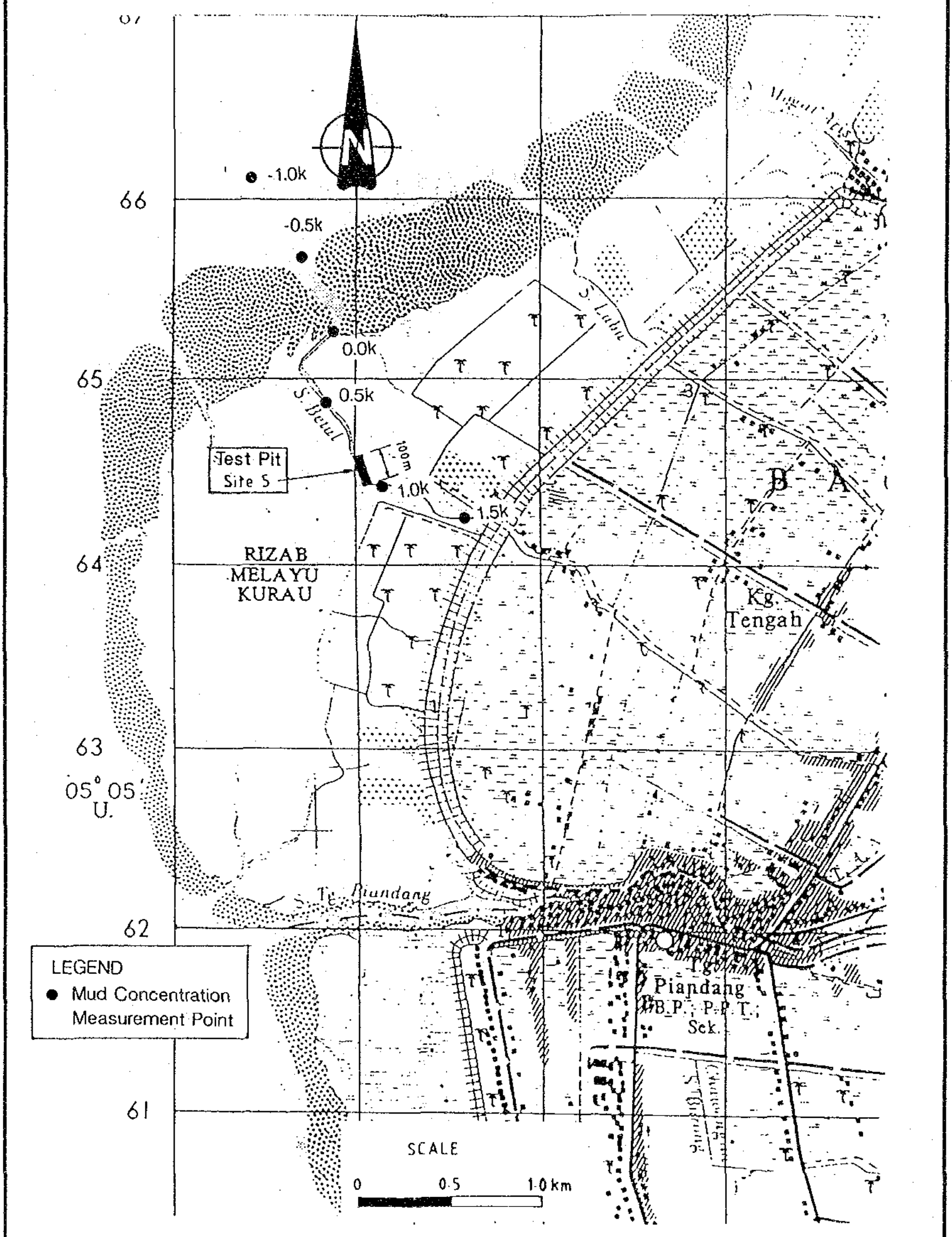
Wave Period = 6 sec.



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	WAVE REFRACTION DIAGRAM IN TG. PIANDANG
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-5

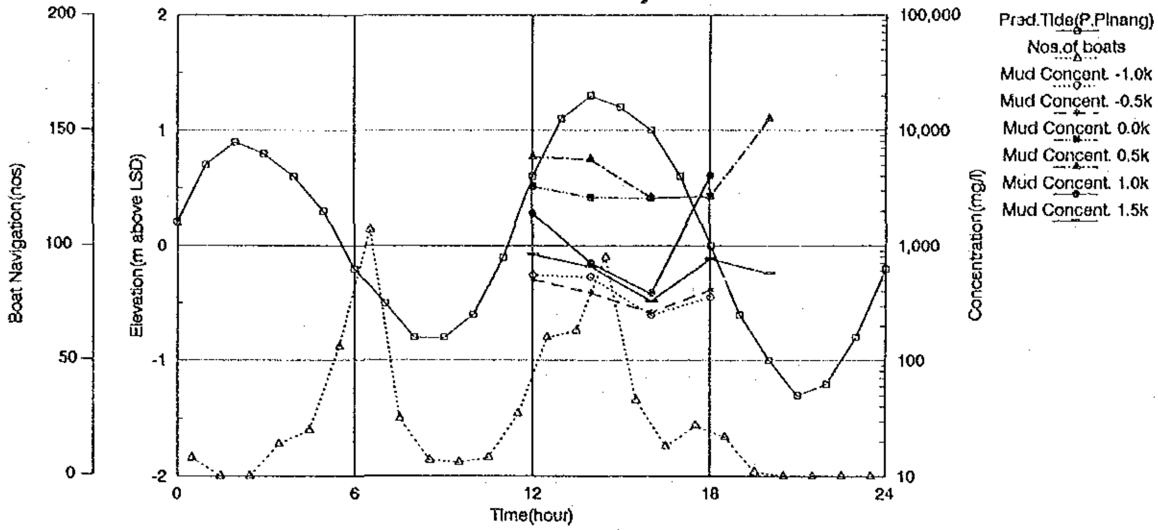


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF IN-SITU SURVEY SITE
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-6 (1/2)

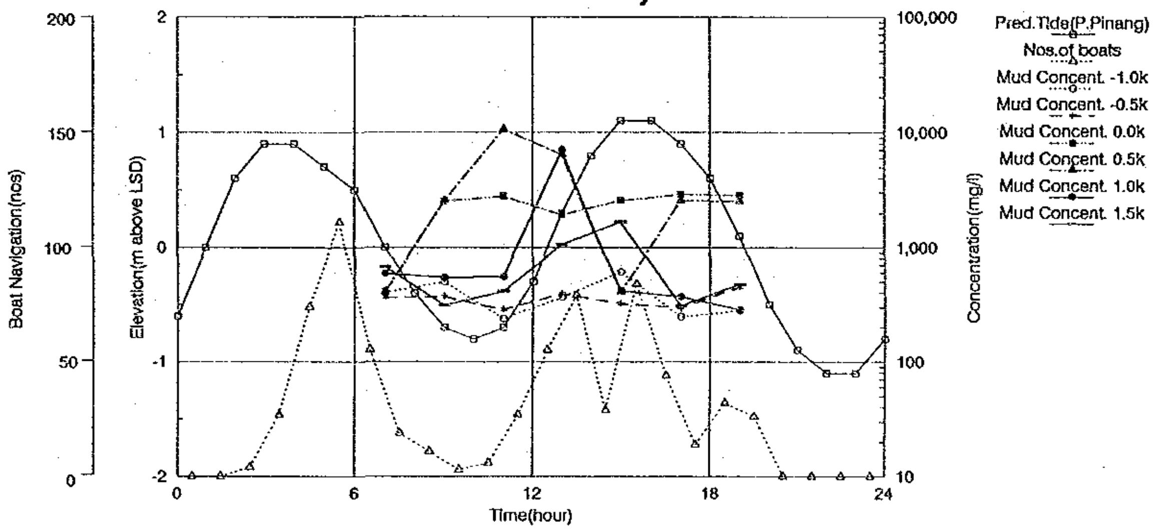


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF IN-SITU SURVEY SITE
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-6 (2/2)

21 July 1993



23 July 1993



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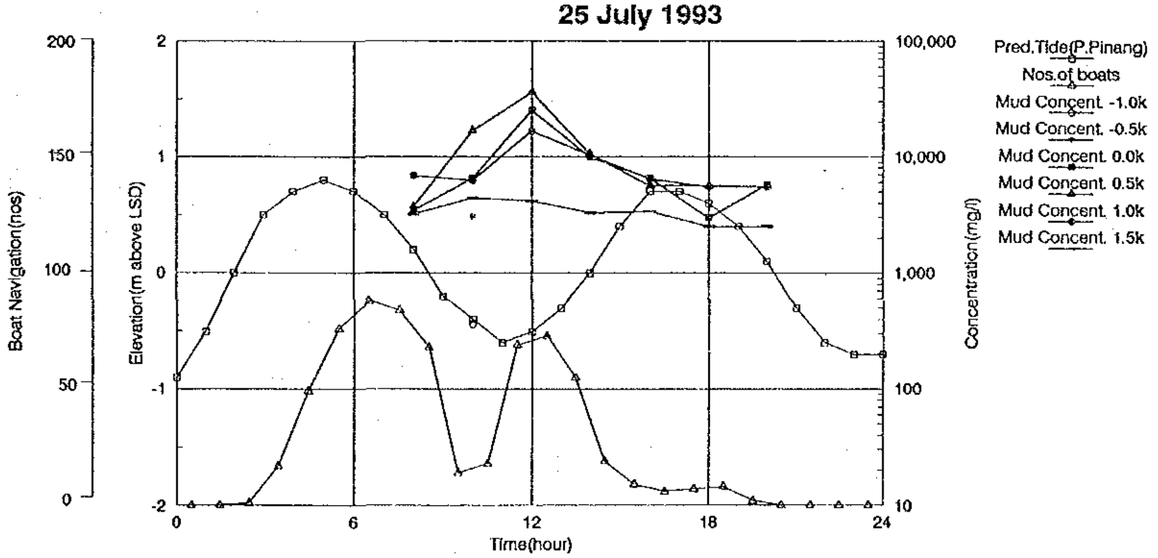
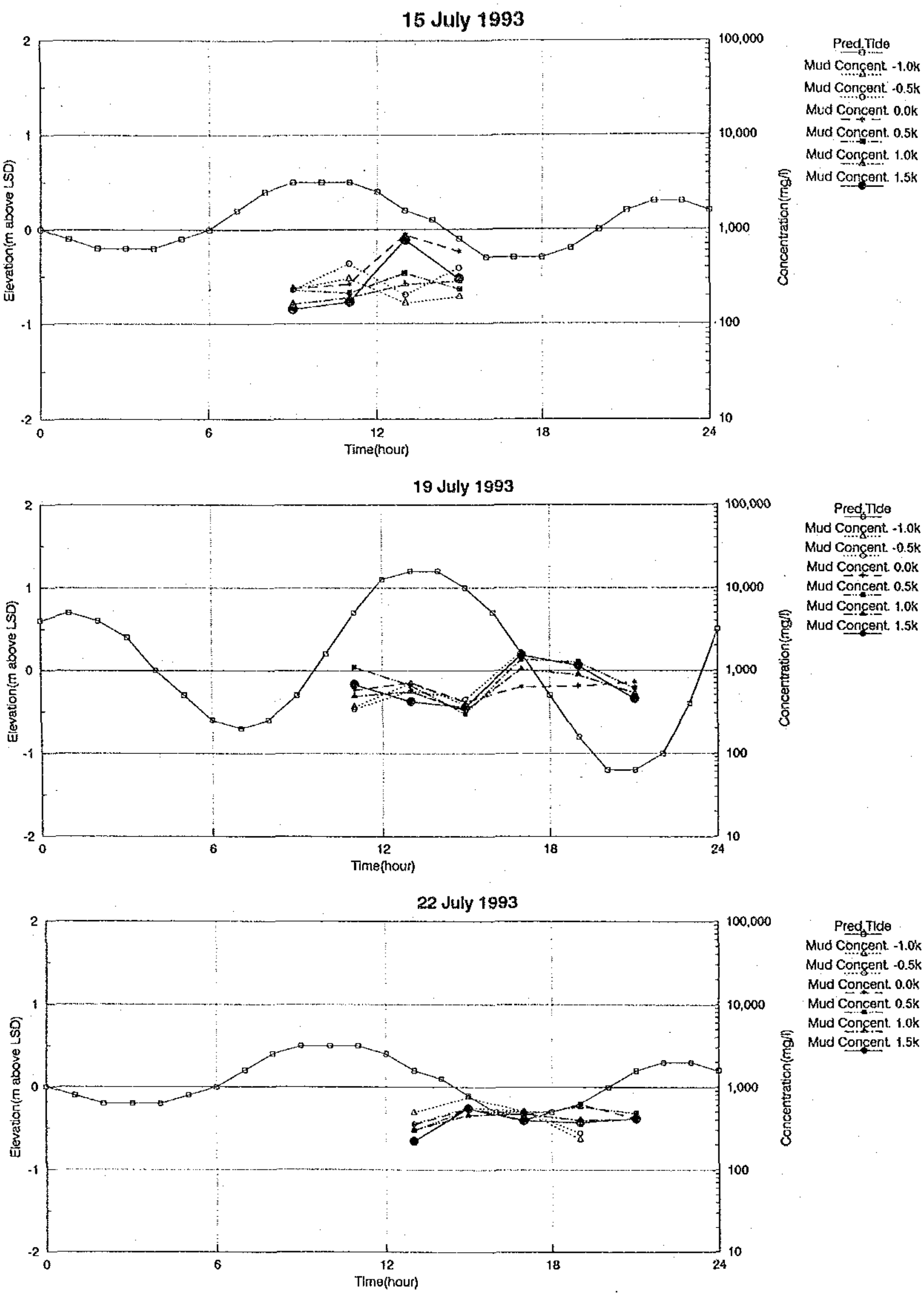
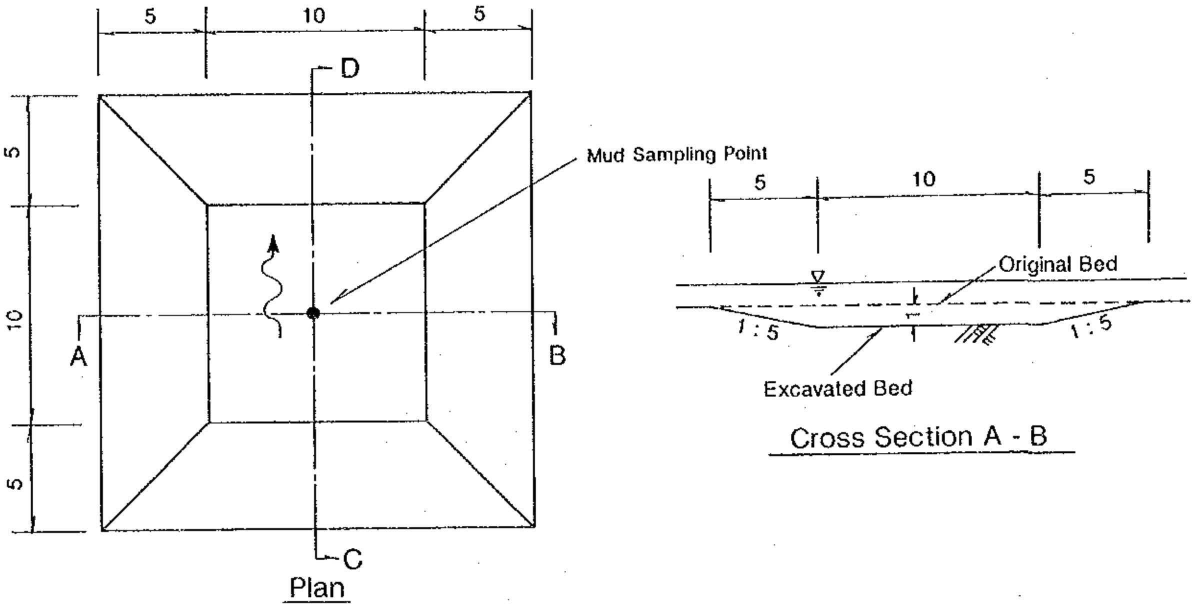


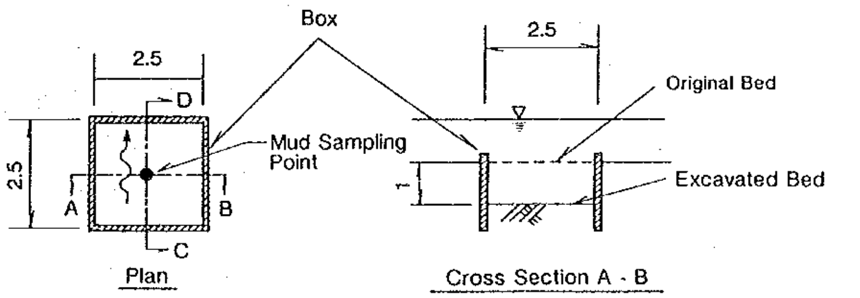
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MEAN MUD CONCENTRATION
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-7 (1/2)



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MEAN MUD CONCENTRATION
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-7 (2/2)



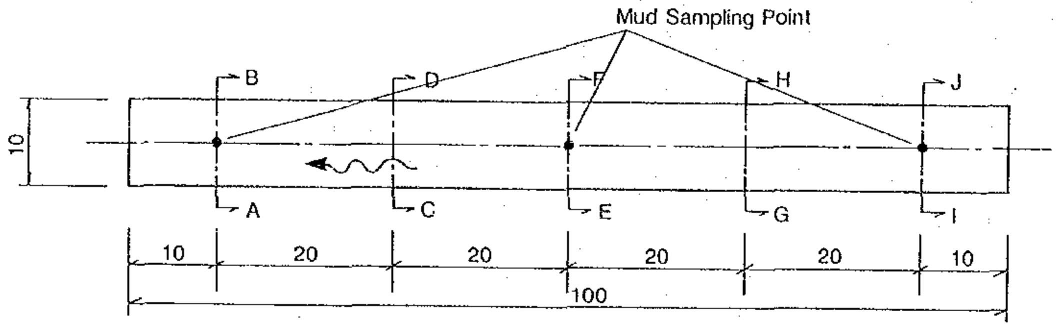
(1) SITES 1 AND 3



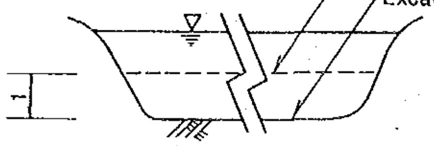
UNIT in meter

(2) SITES 2 AND 4

THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DIMENSIONS OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-8 (1/2)



Plan



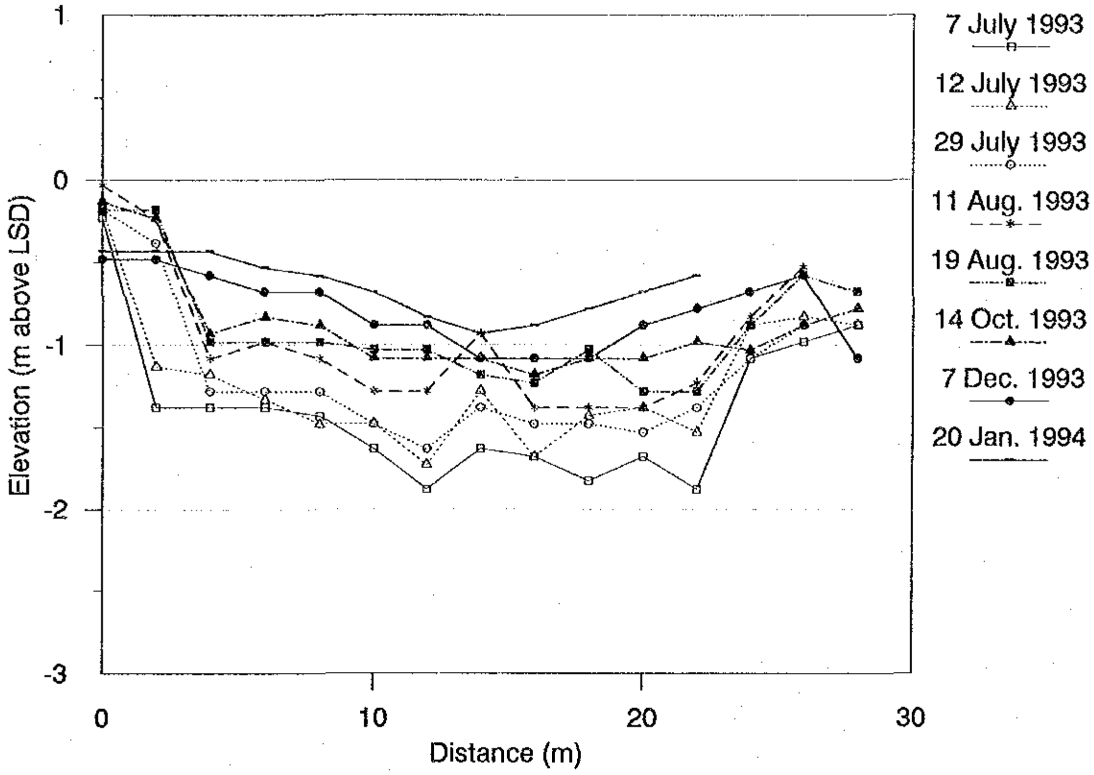
Cross Section E - F

UNIT in meter

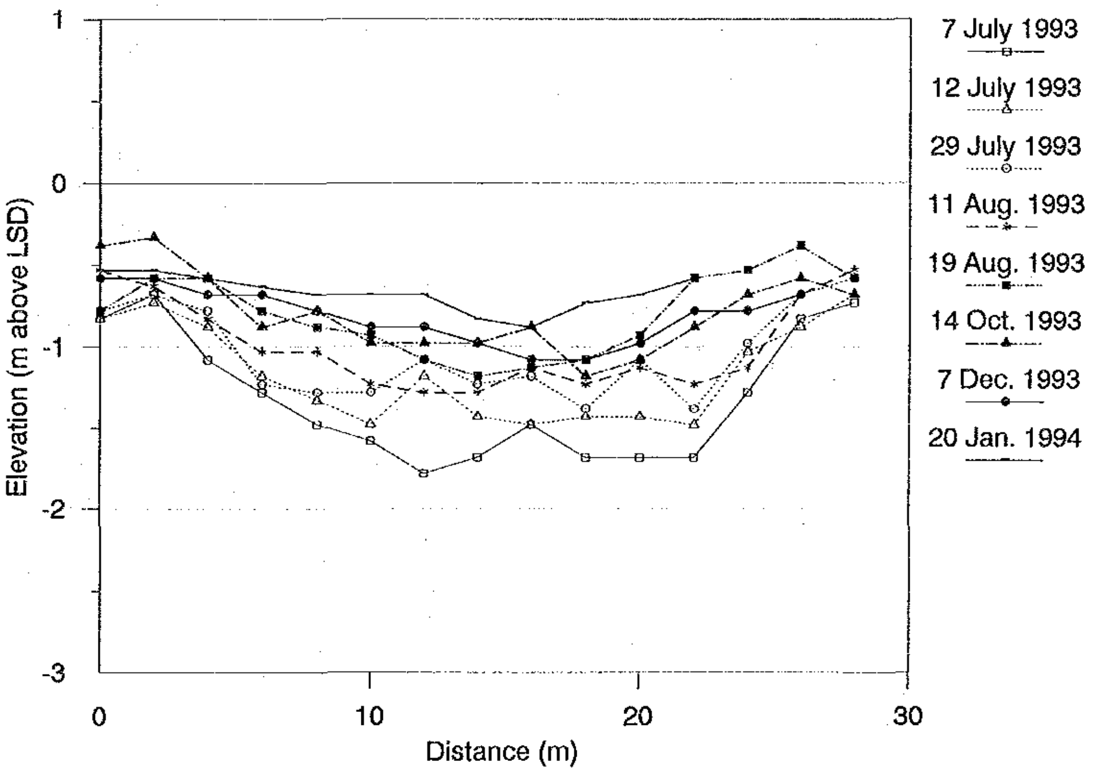
(3) SITE 5

THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DIMENSIONS OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-8 (2/2)

TEST PIT NO.1 (INNER CHANNEL OF TG.PIANDANG)
Cross Section 1-A-B

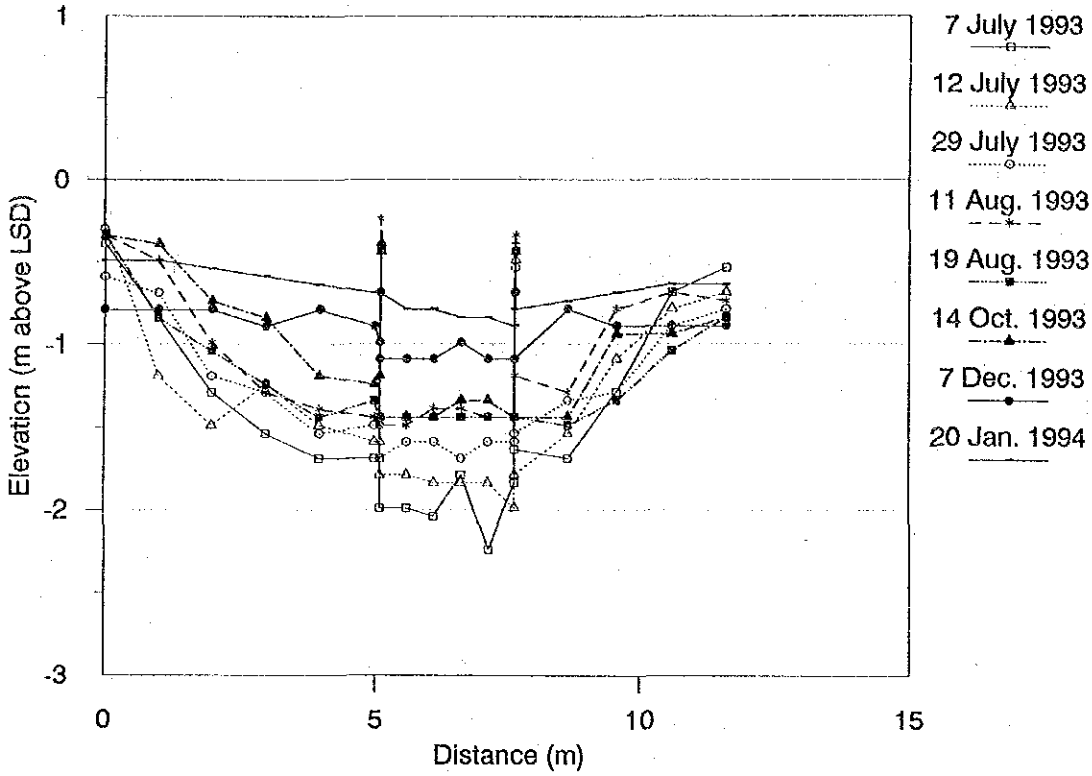


TEST PIT NO.1 (INNER CHANNEL OF TG.PIANDANG)
Cross Section 1-C-D

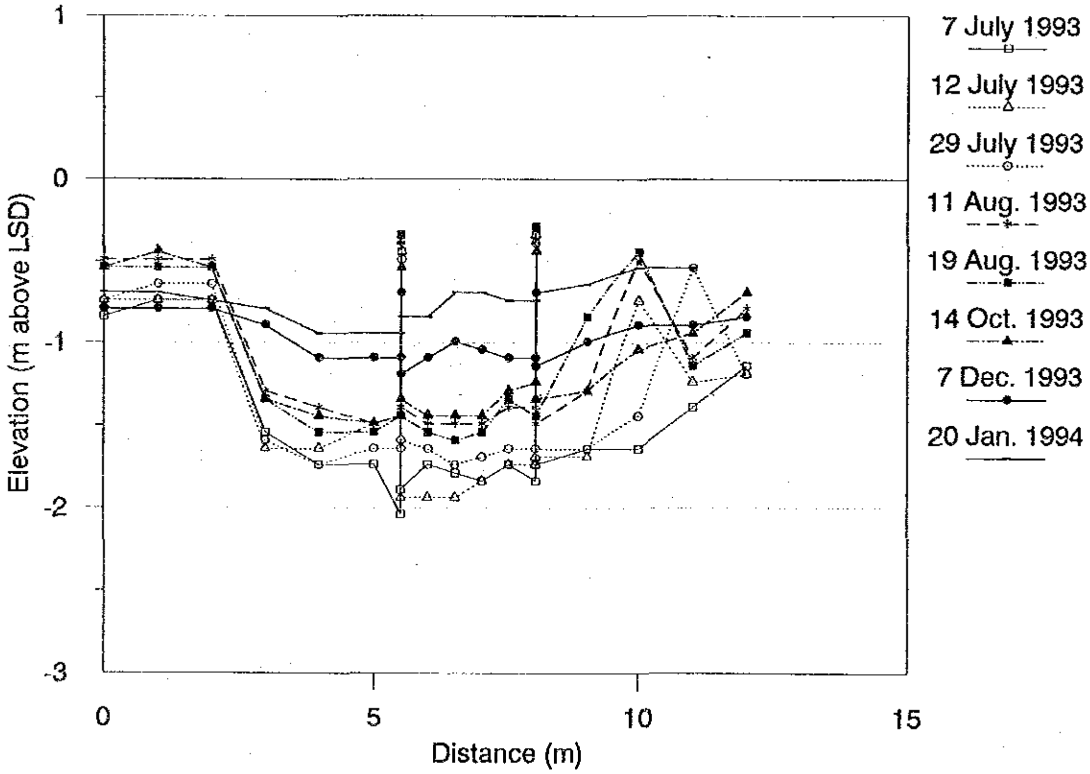


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (1/7)

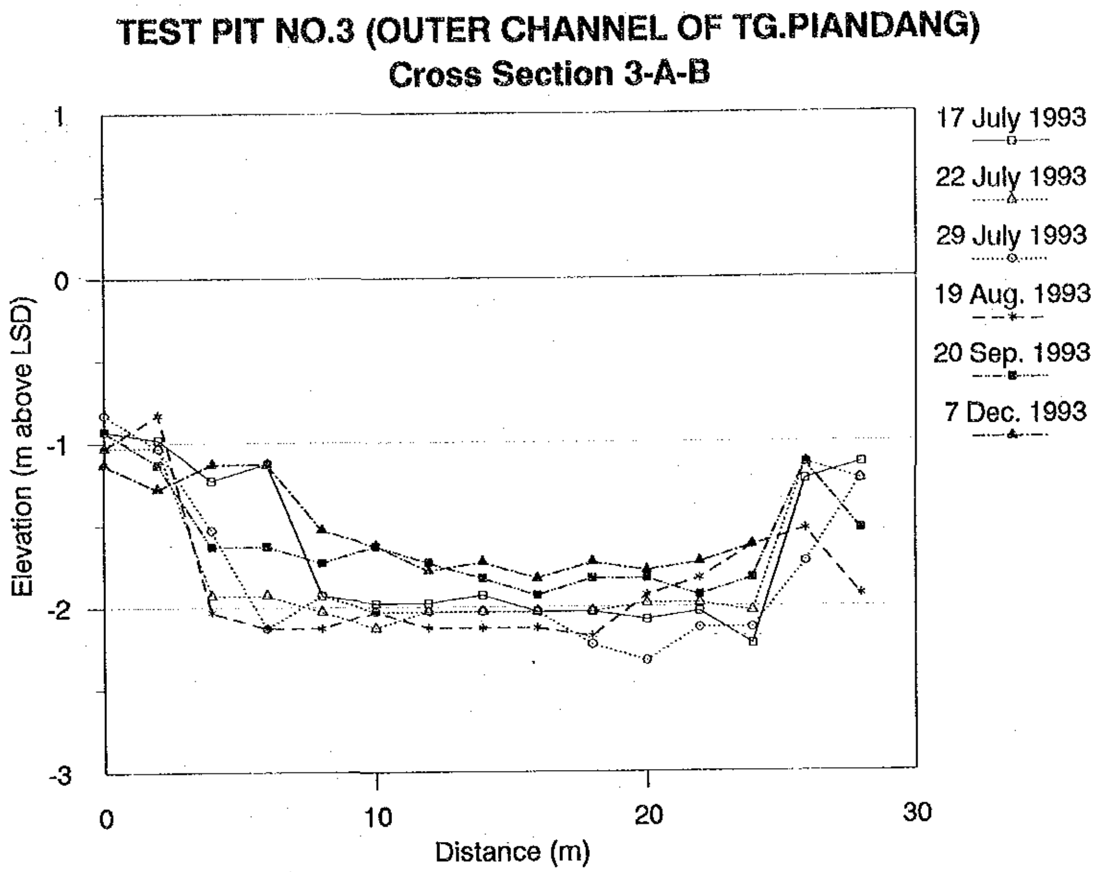
TEST PIT NO.2 (INNER CHANNEL OF TG.PIANDANG)
Cross Section 2-A-B

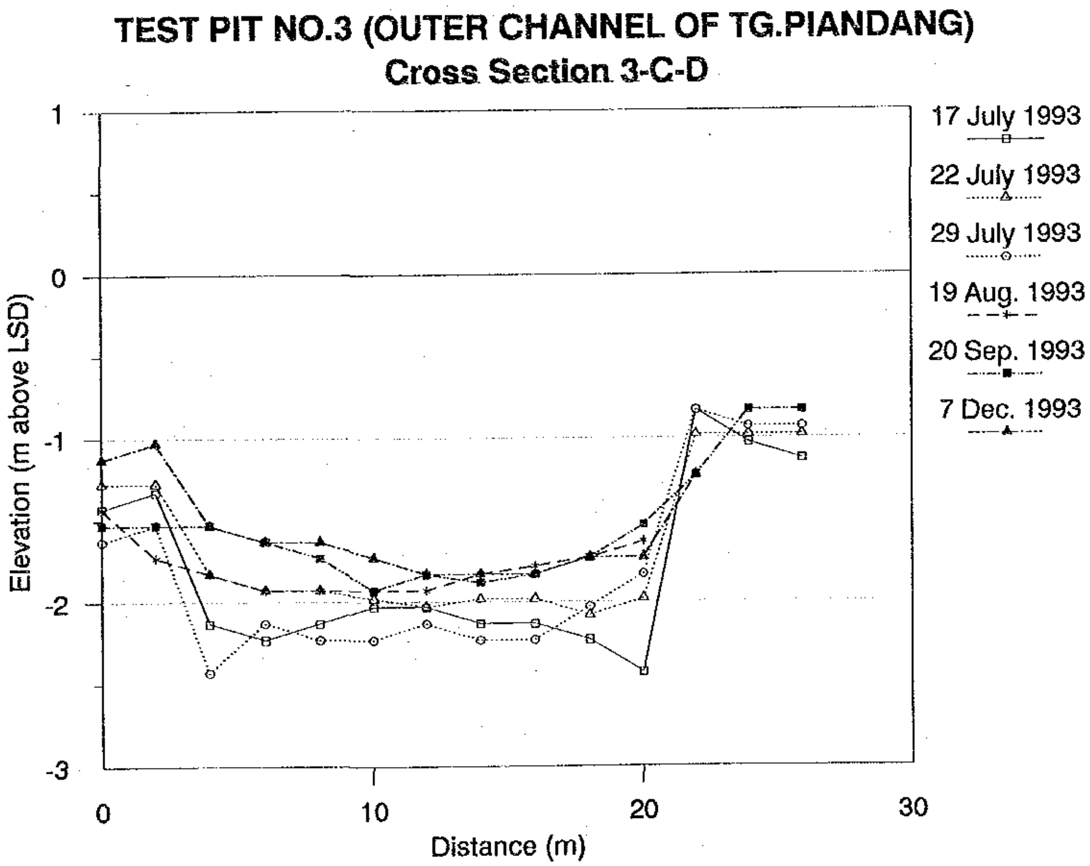


TEST PIT NO.2 (INNER CHANNEL OF TG.PIANDANG)
Cross Section 2-C-D



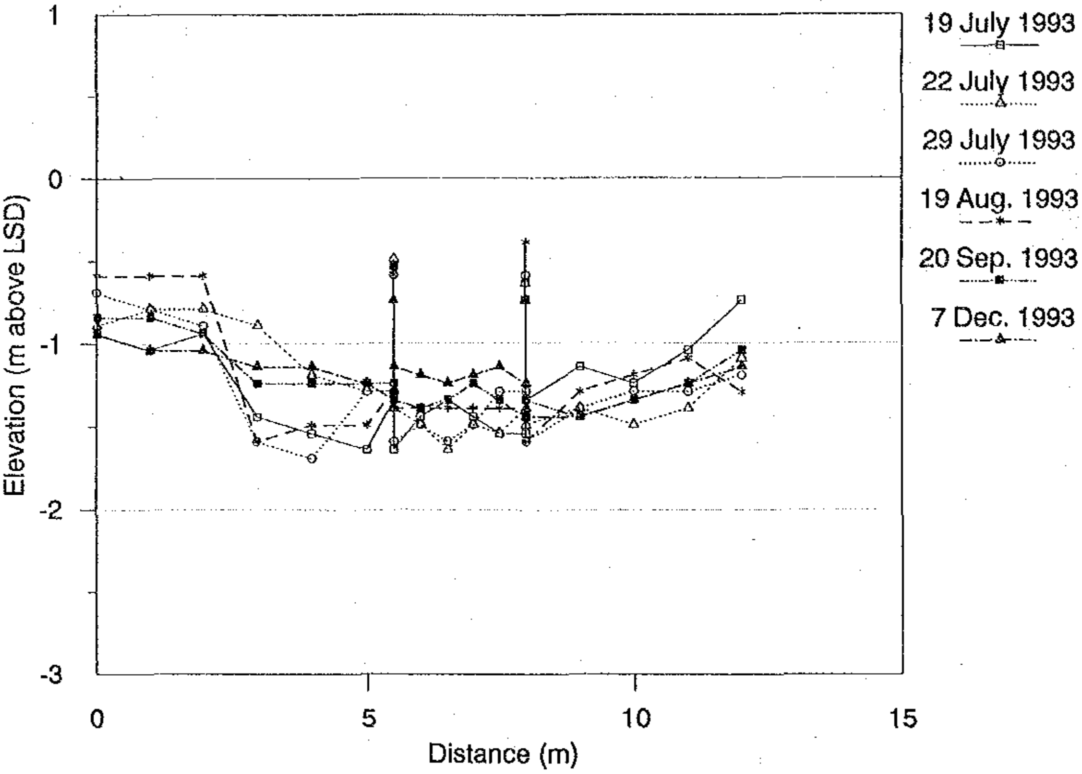
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (2/7)



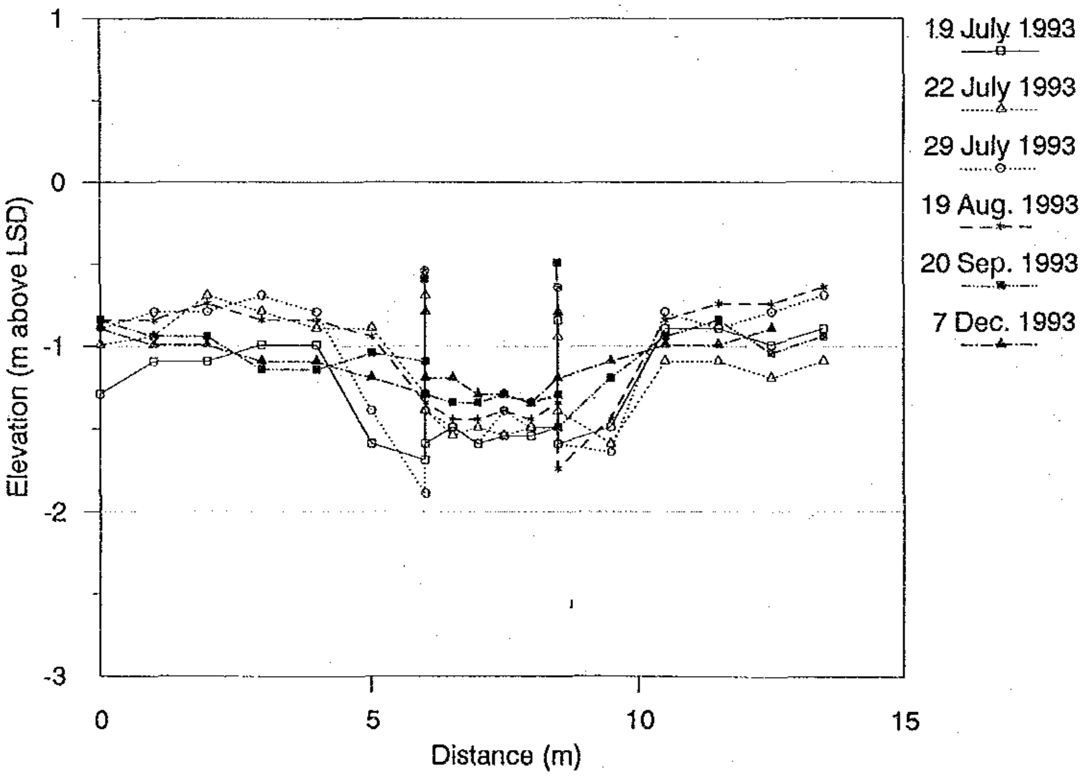


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (3/7)

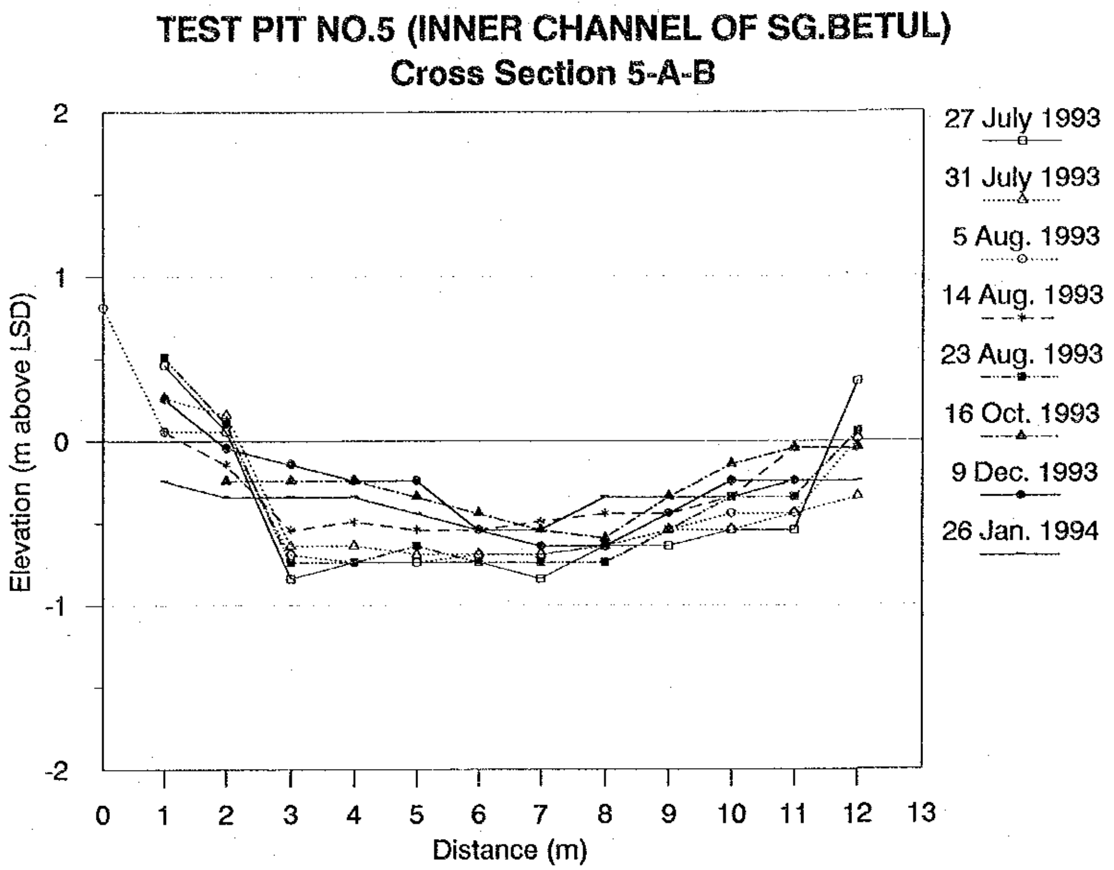
TEST PIT NO.4 (OUTER CHANNEL OF TG.PIANDANG)
Cross Section 4-A-B

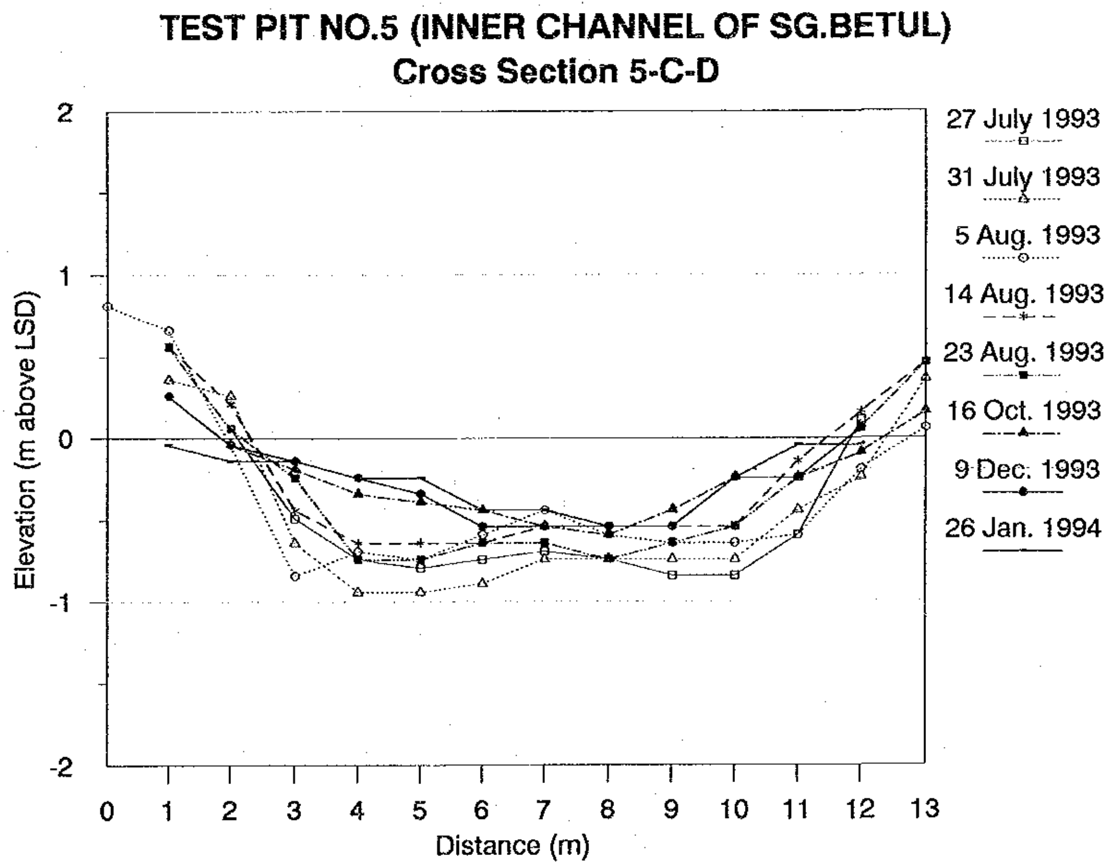


TEST PIT NO.4 (OUTER CHANNEL OF TG.PIANDANG)
Cross Section 4-C-D



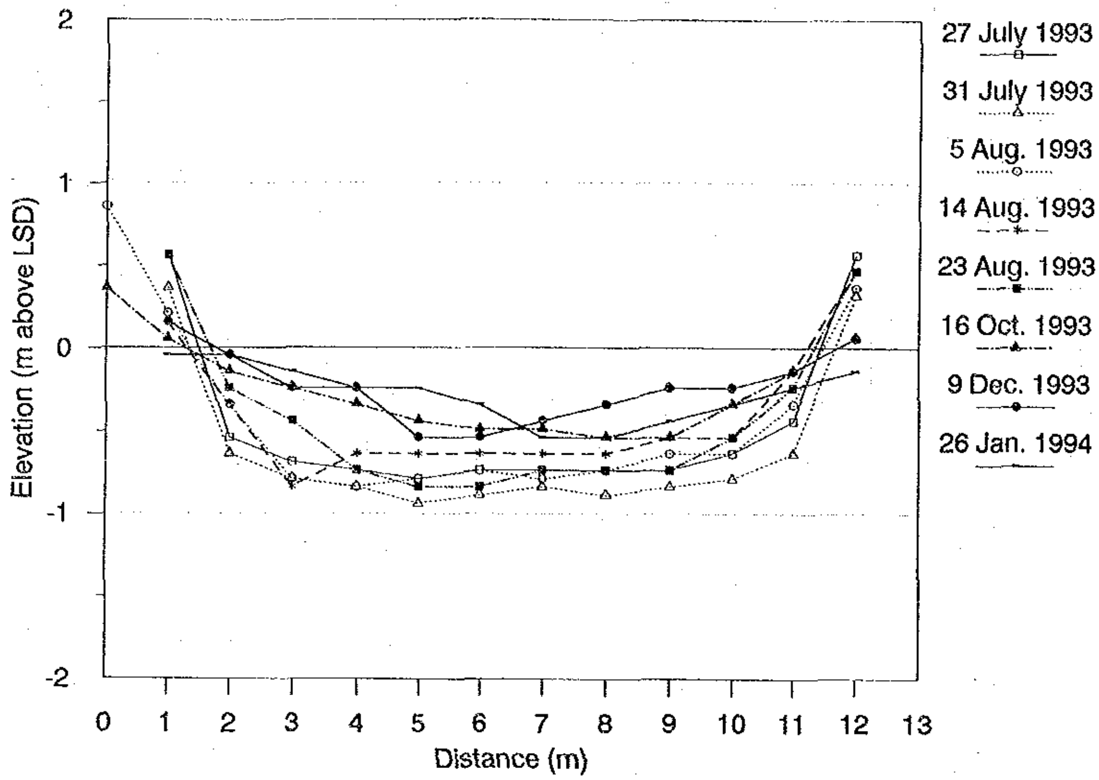
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (4/7)



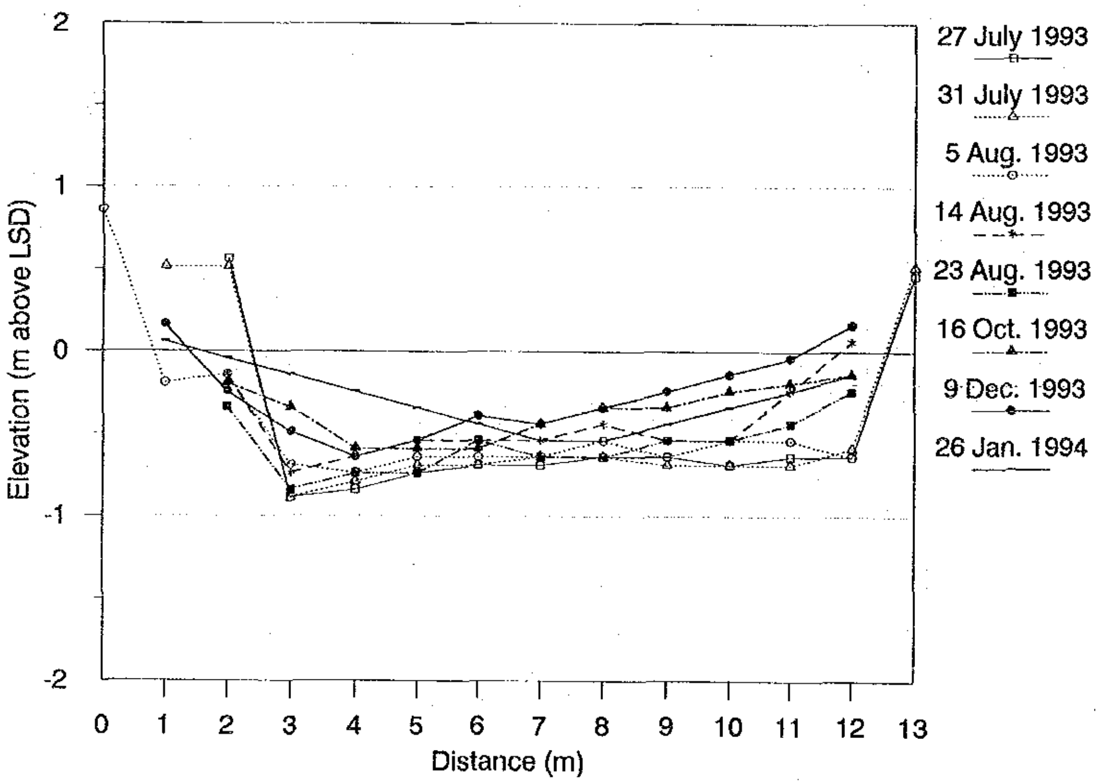


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (5/7)

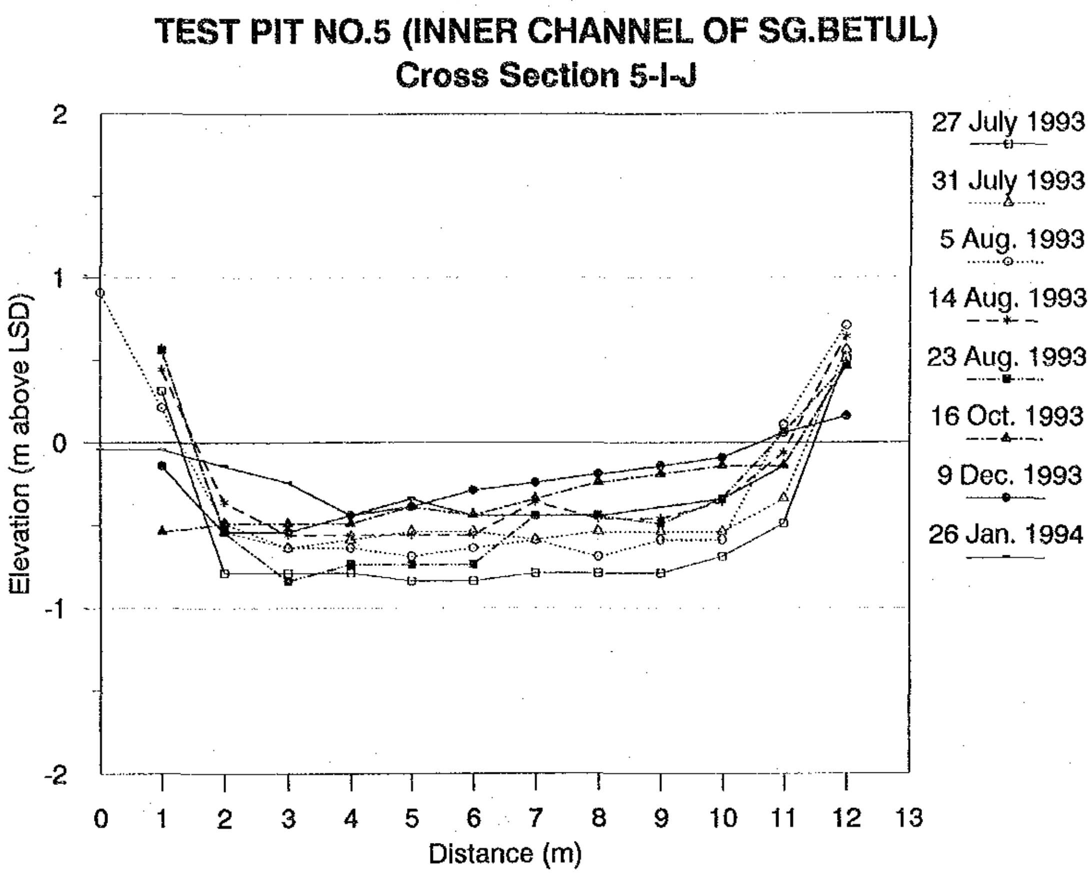
TEST PIT NO.5 (INNER CHANNEL OF SG.BETUL)
Cross Section 5-E-F



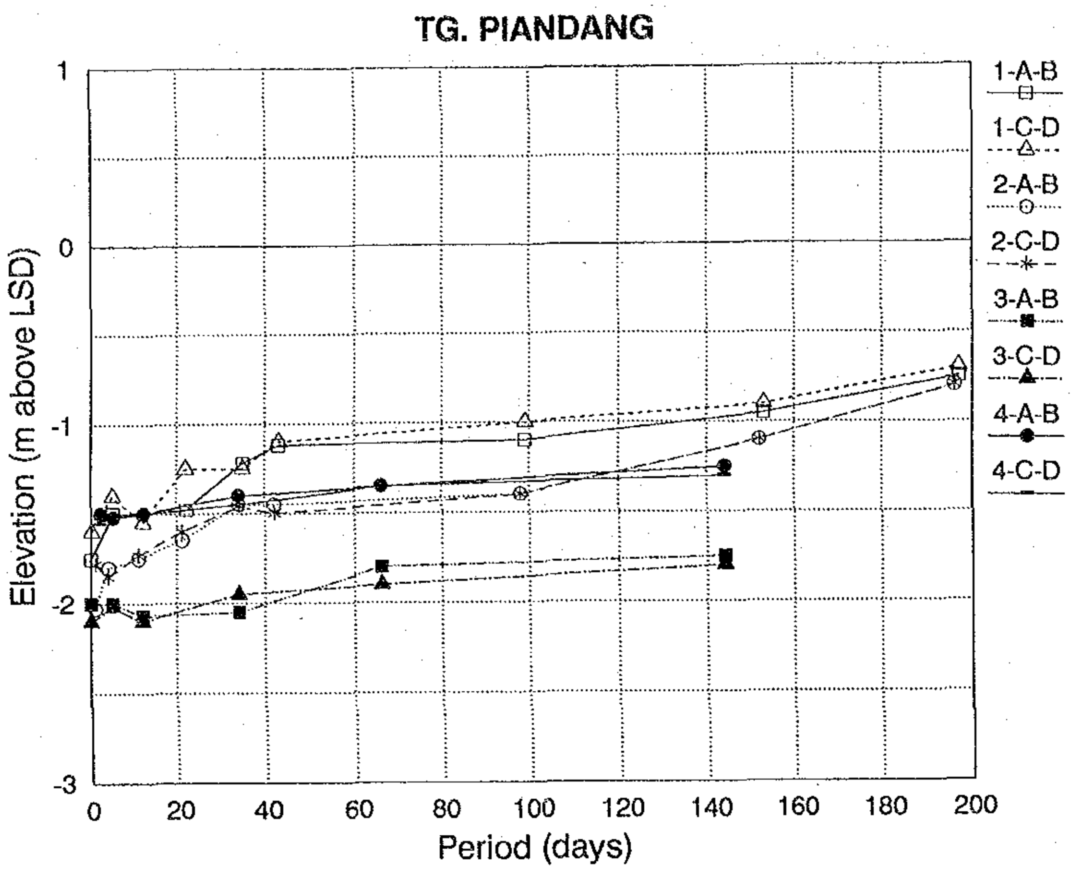
TEST PIT NO.5 (INNER CHANNEL OF SG.BETUL)
Cross Section 5-G-H

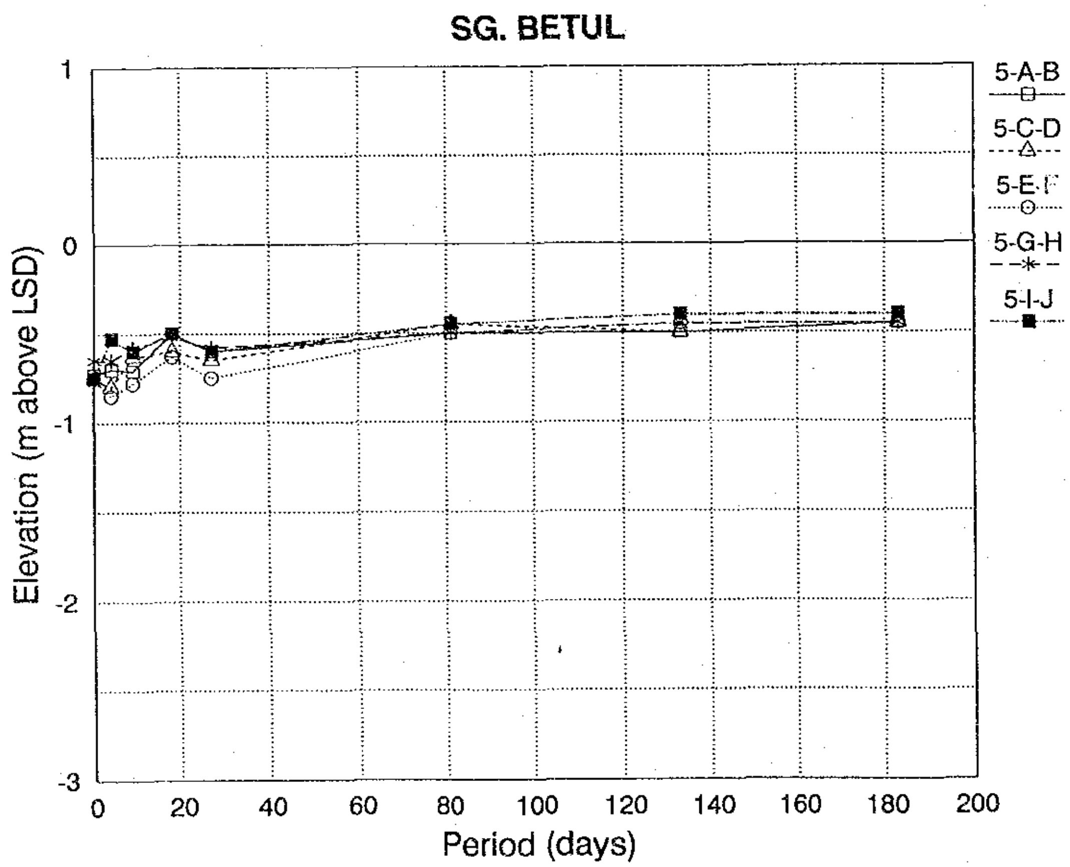


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (6/7)

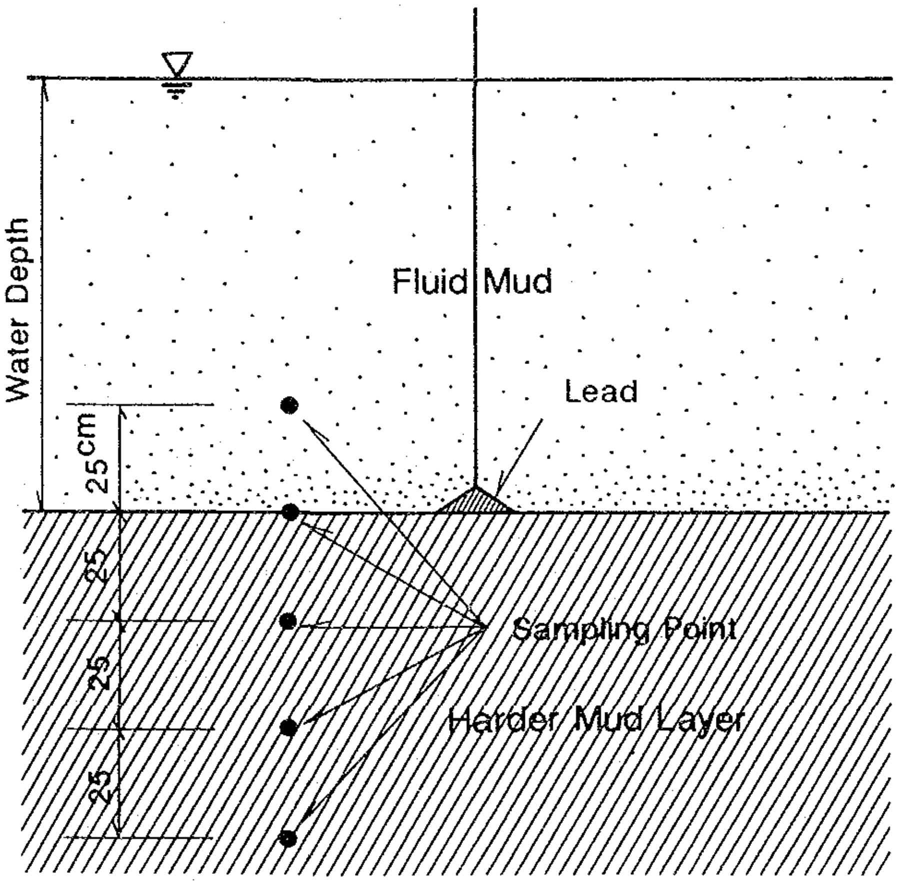


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CROSS SECTIONAL PROFILE OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-9 (7/7)

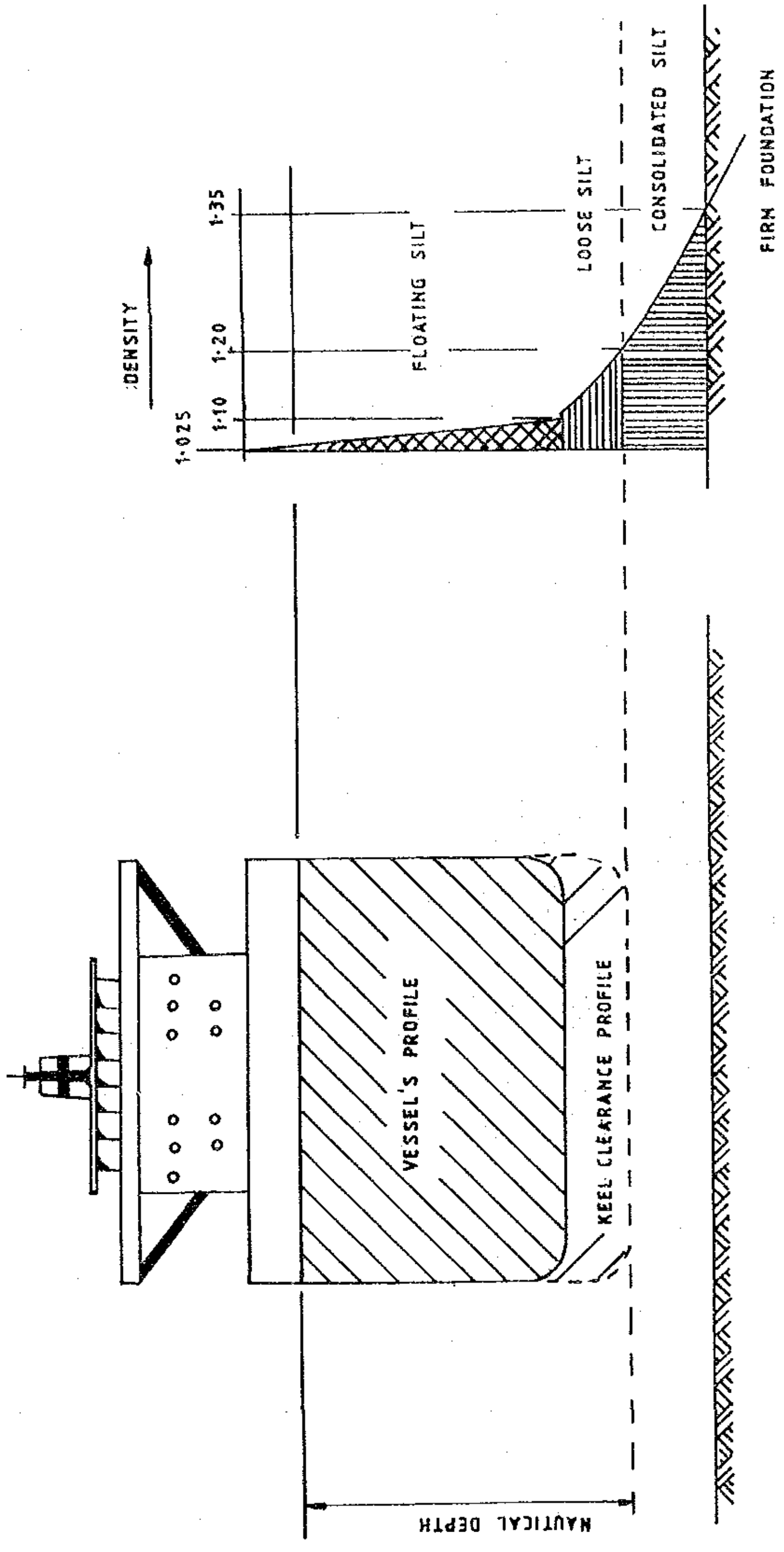




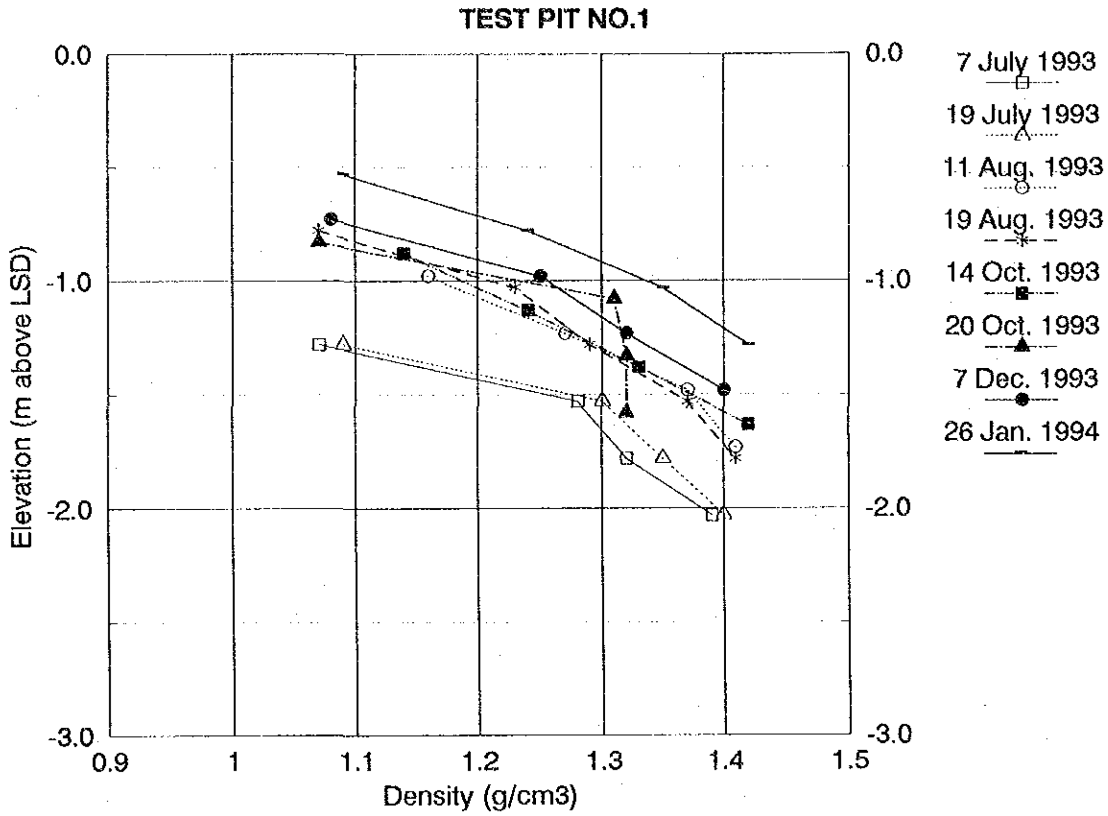
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CHANGE OF AVERAGE BED ELEVATION OF TEST PIT
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-10

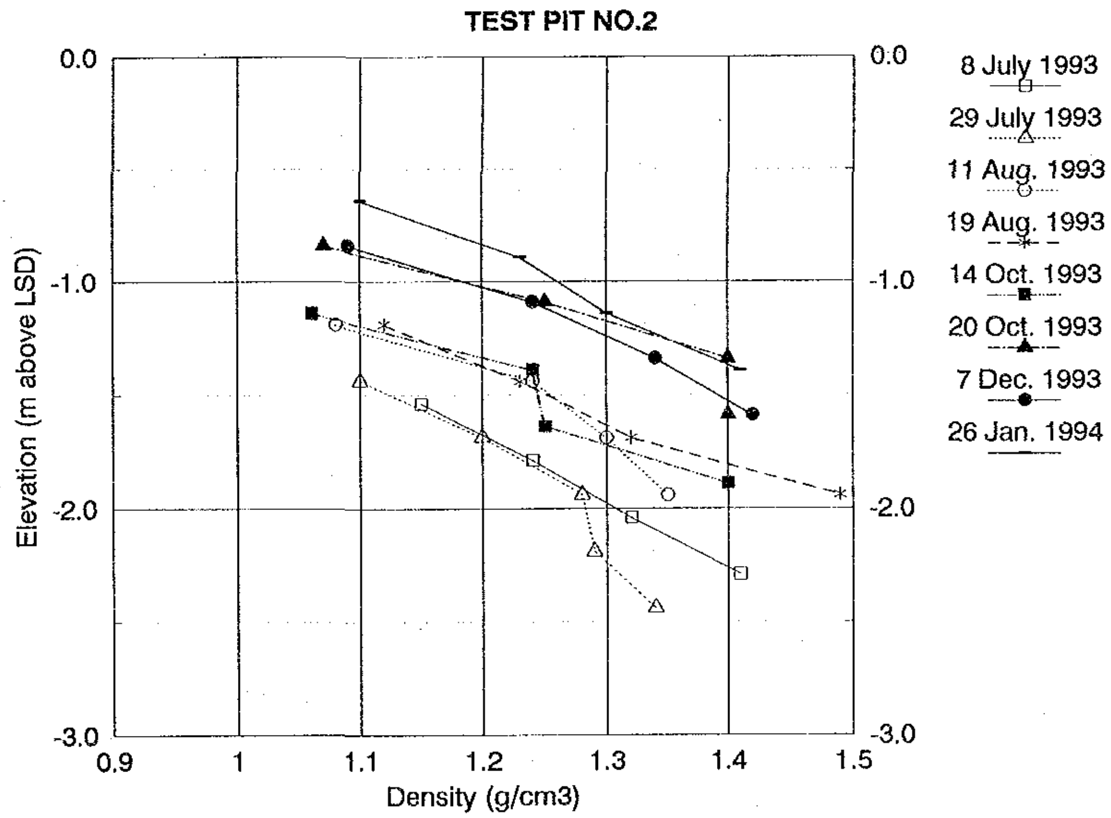


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	SAMPLING POINT FOR MUD DENSITY
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-11

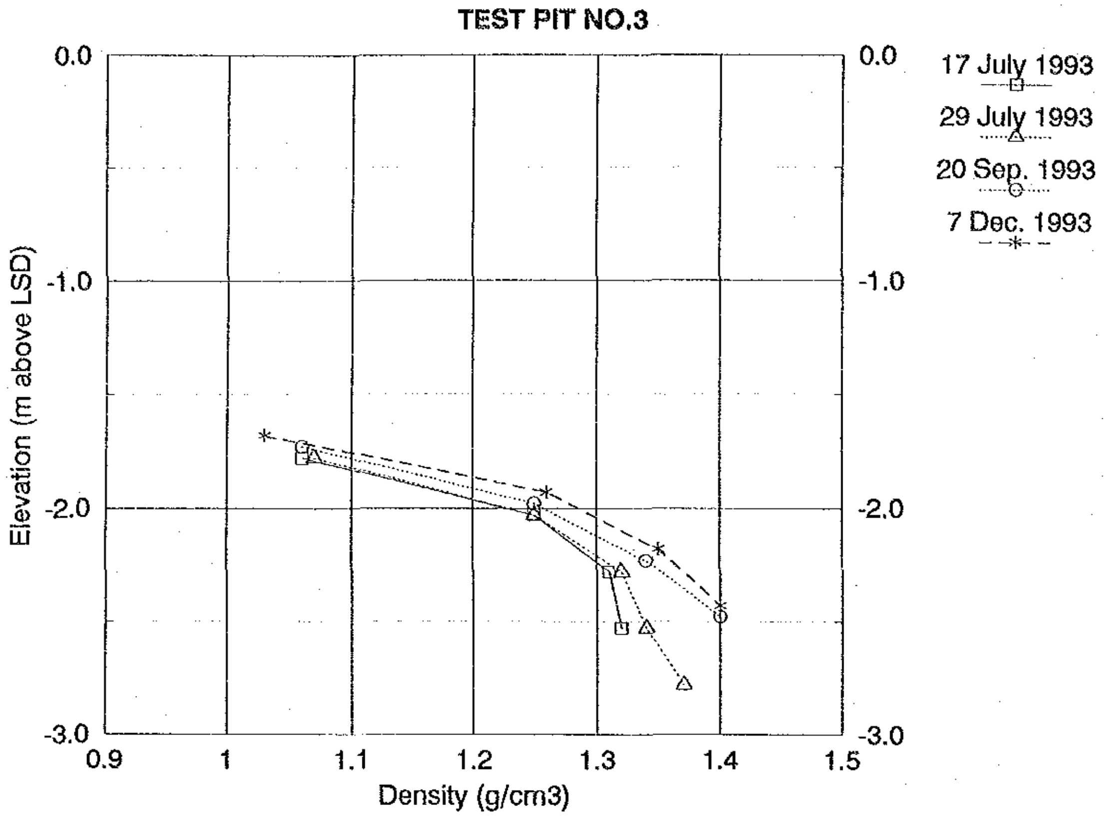


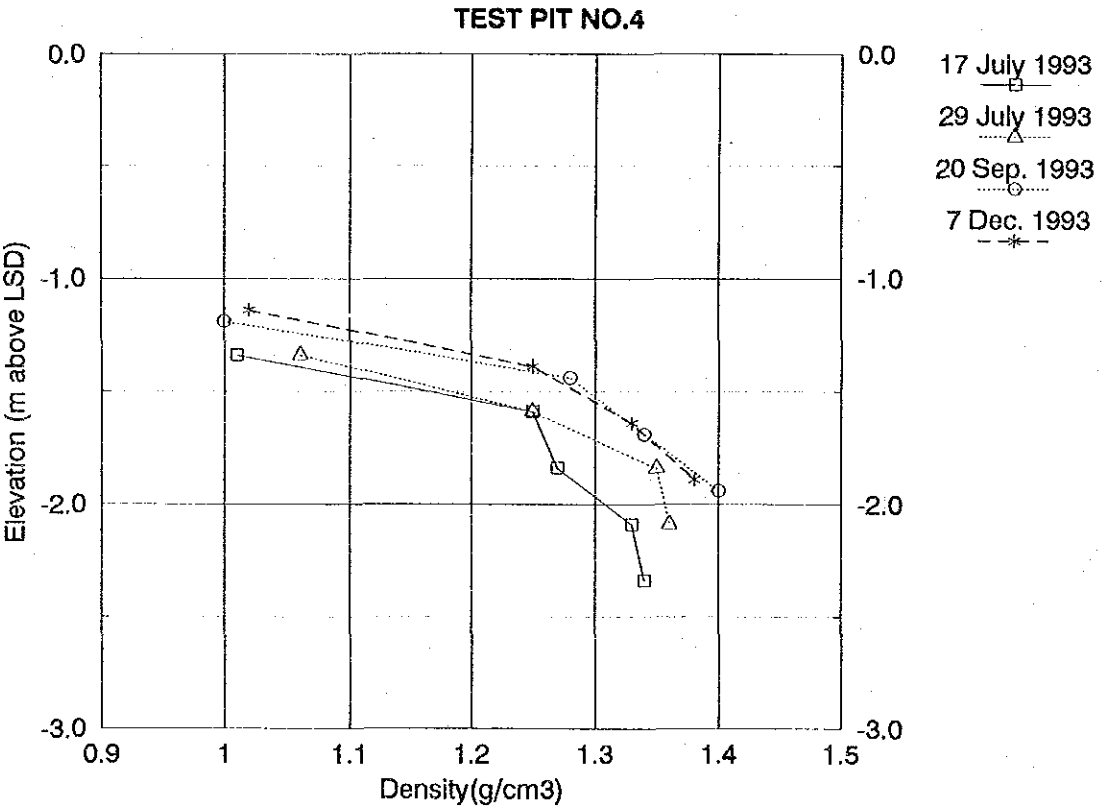
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	RELATIONSHIP BETWEEN NAUTICAL DEPTH AND MUD DENSITY Fig. 1.4-12
JAPAN INTERNATIONAL COOPERATION AGENCY	



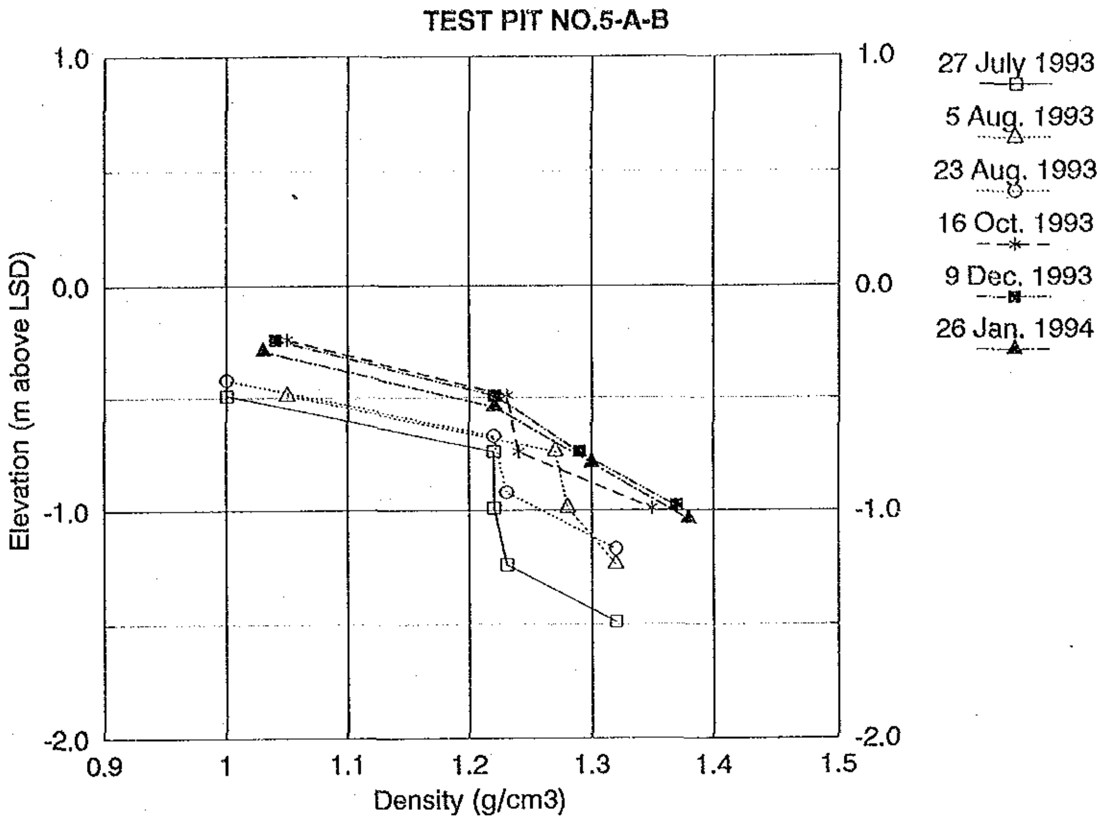


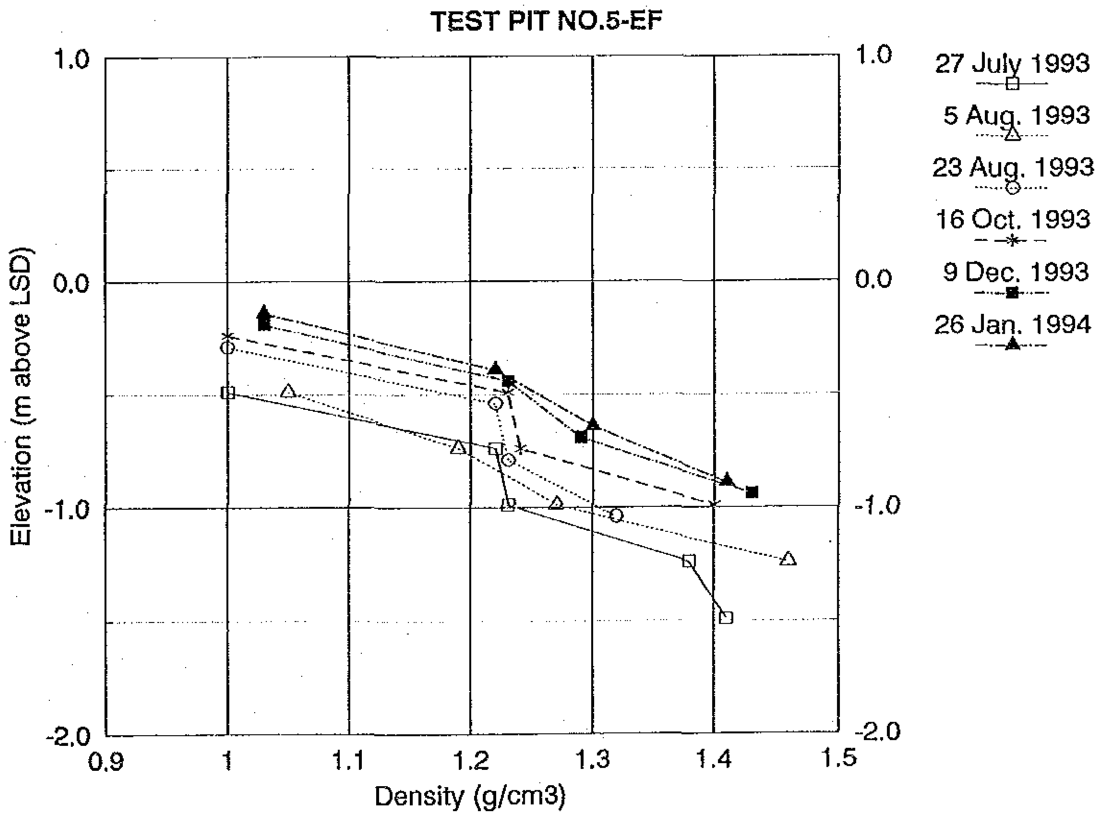
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MUD DENSITY
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-13 (1/4)



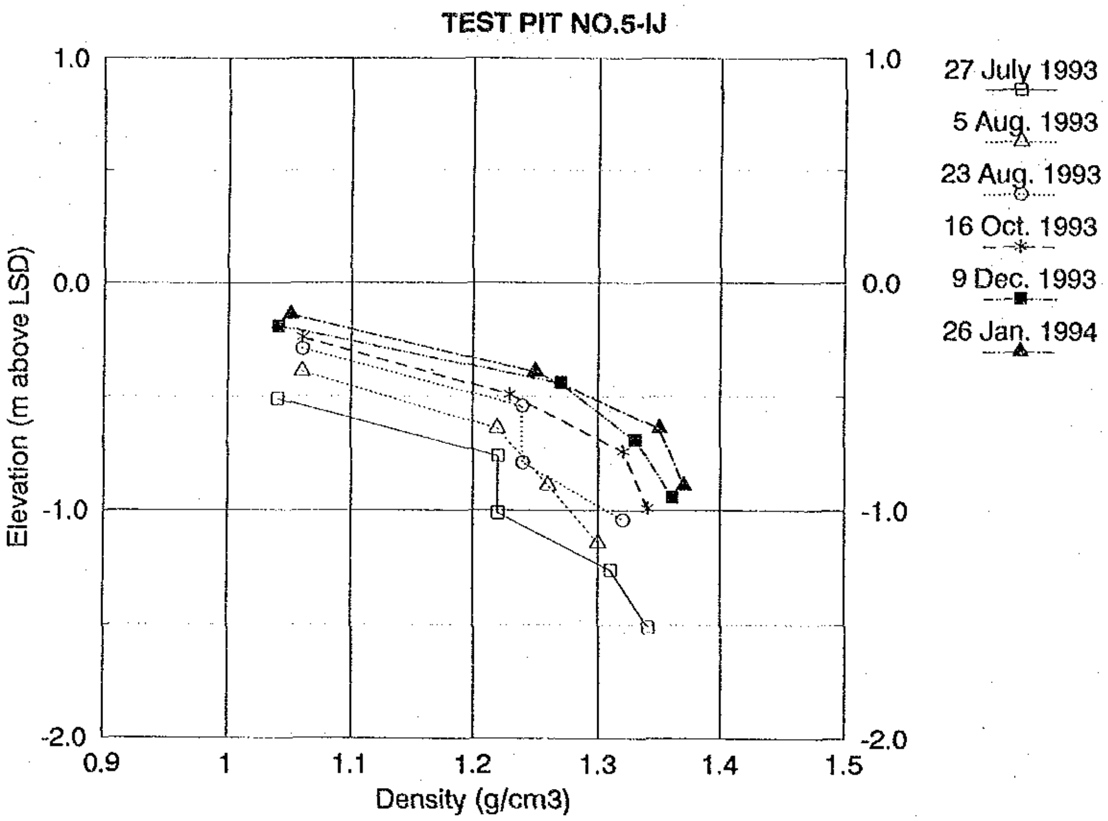


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MUD DENSITY
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-13 (2/4)

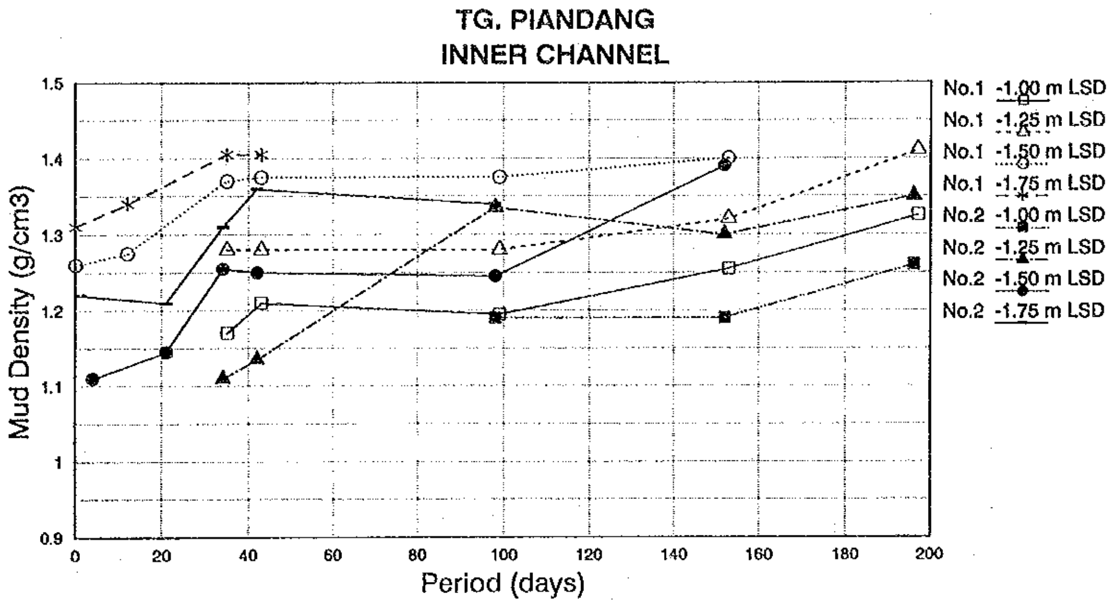


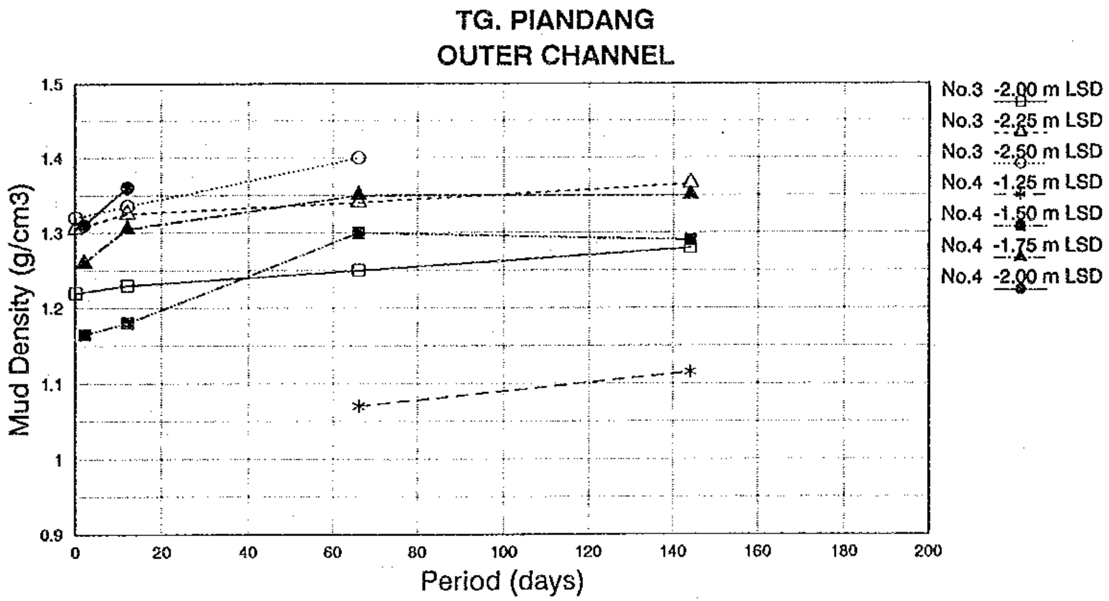


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MUD DENSITY	Fig. 1.4-13 (3/4)
JAPAN INTERNATIONAL COOPERATION AGENCY		



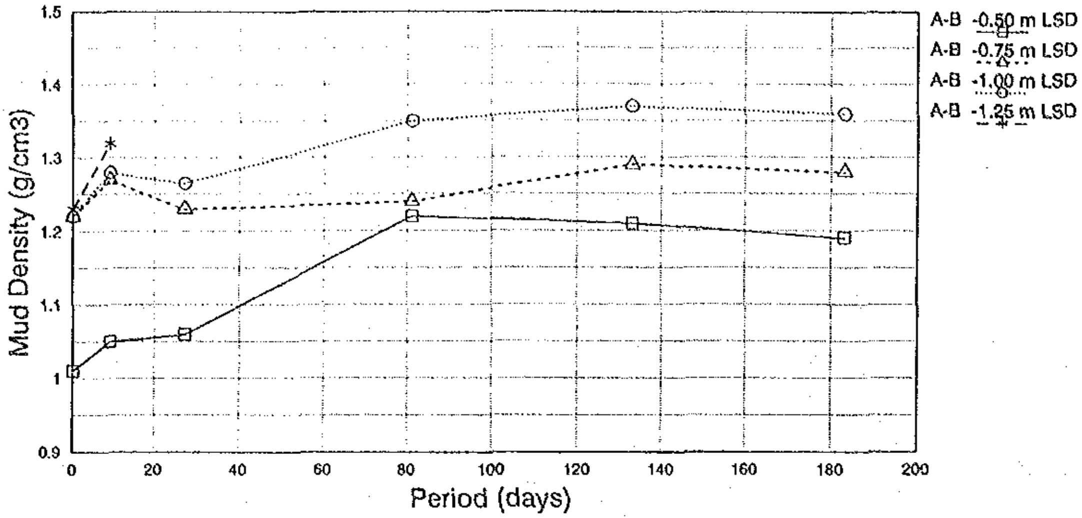
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	DISTRIBUTION OF MUD DENSITY	Fig. 1.4-13 (4/4)
JAPAN INTERNATIONAL COOPERATION AGENCY		



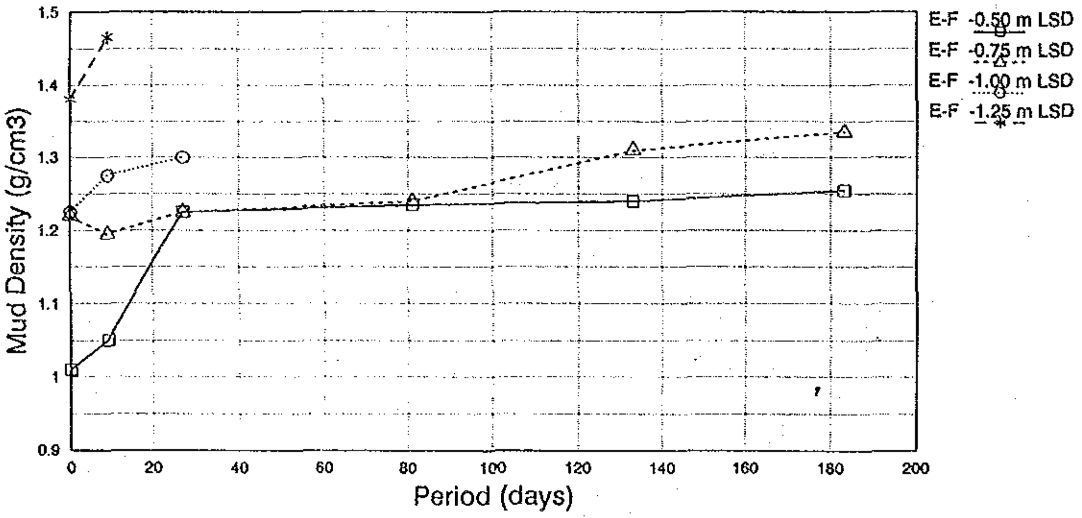


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CHANGE OF MUD DENSITY
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-14 (1/2)

SG. BETUL (TEST PIT NO.5)
CROSS SECTION A-B



SG. BETUL (TEST PIT NO.5)
CROSS SECTION E-F



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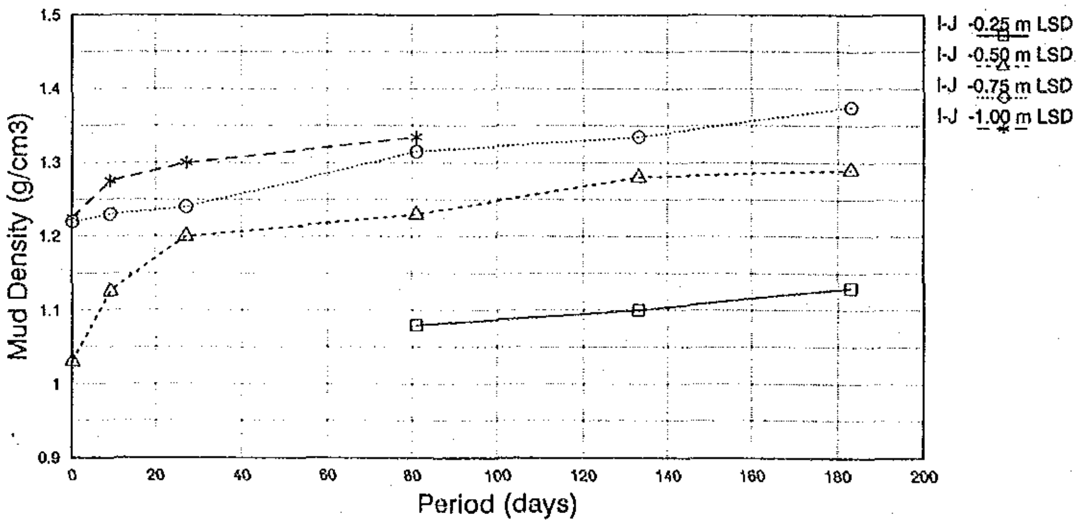
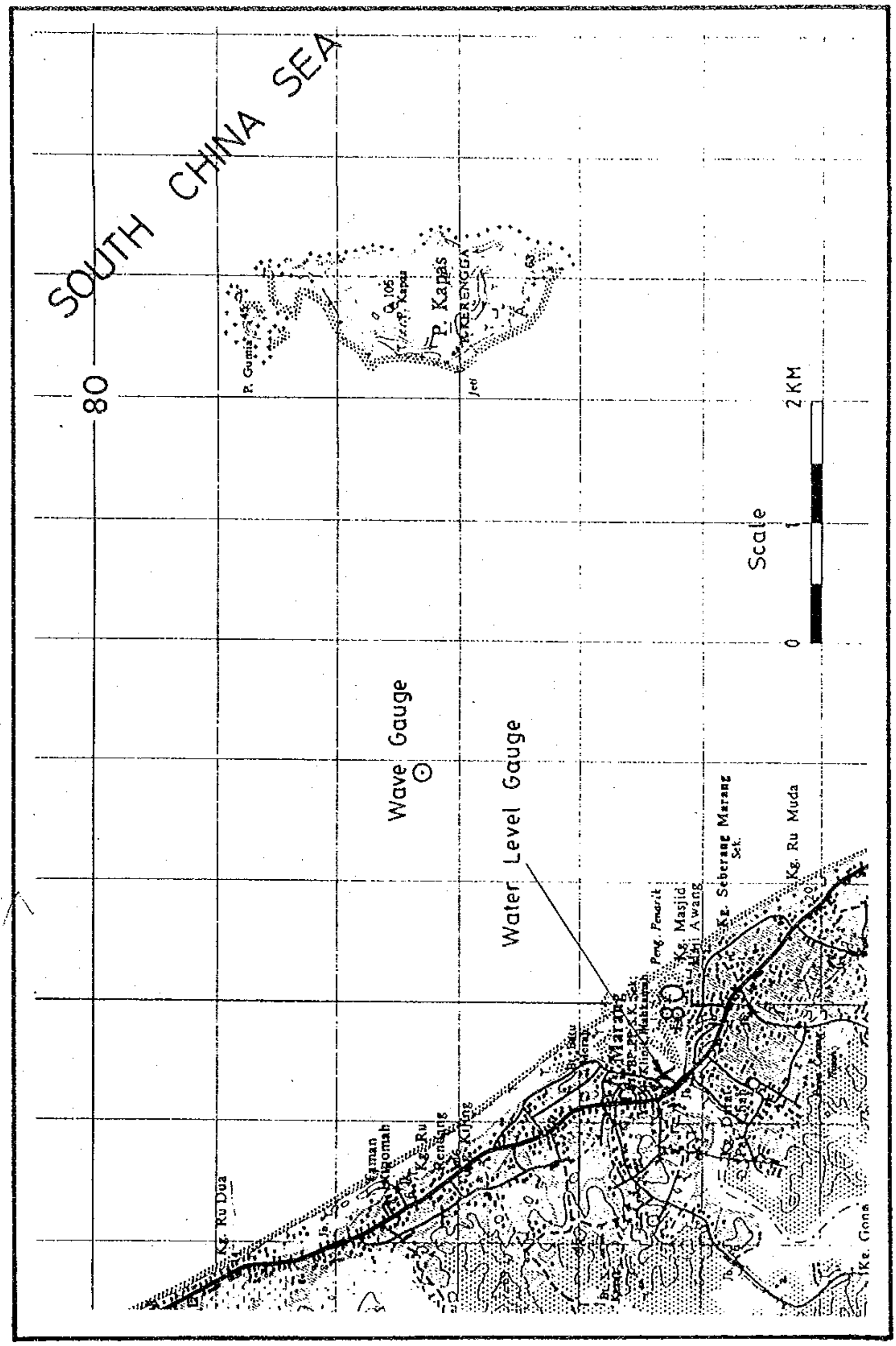
CROSS SECTION I-J

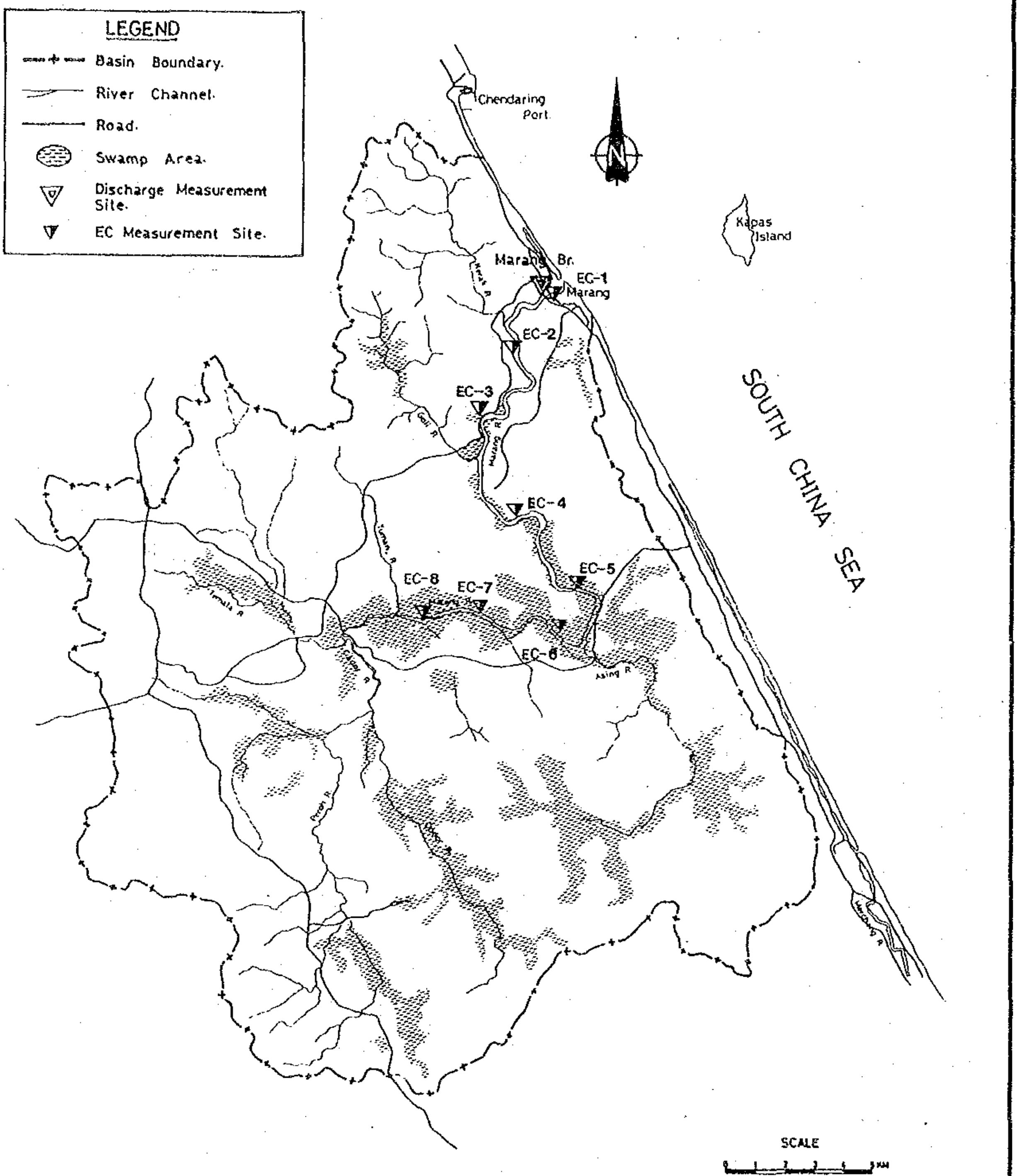


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CHANGE OF MUD DENSITY
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-14 (2/2)

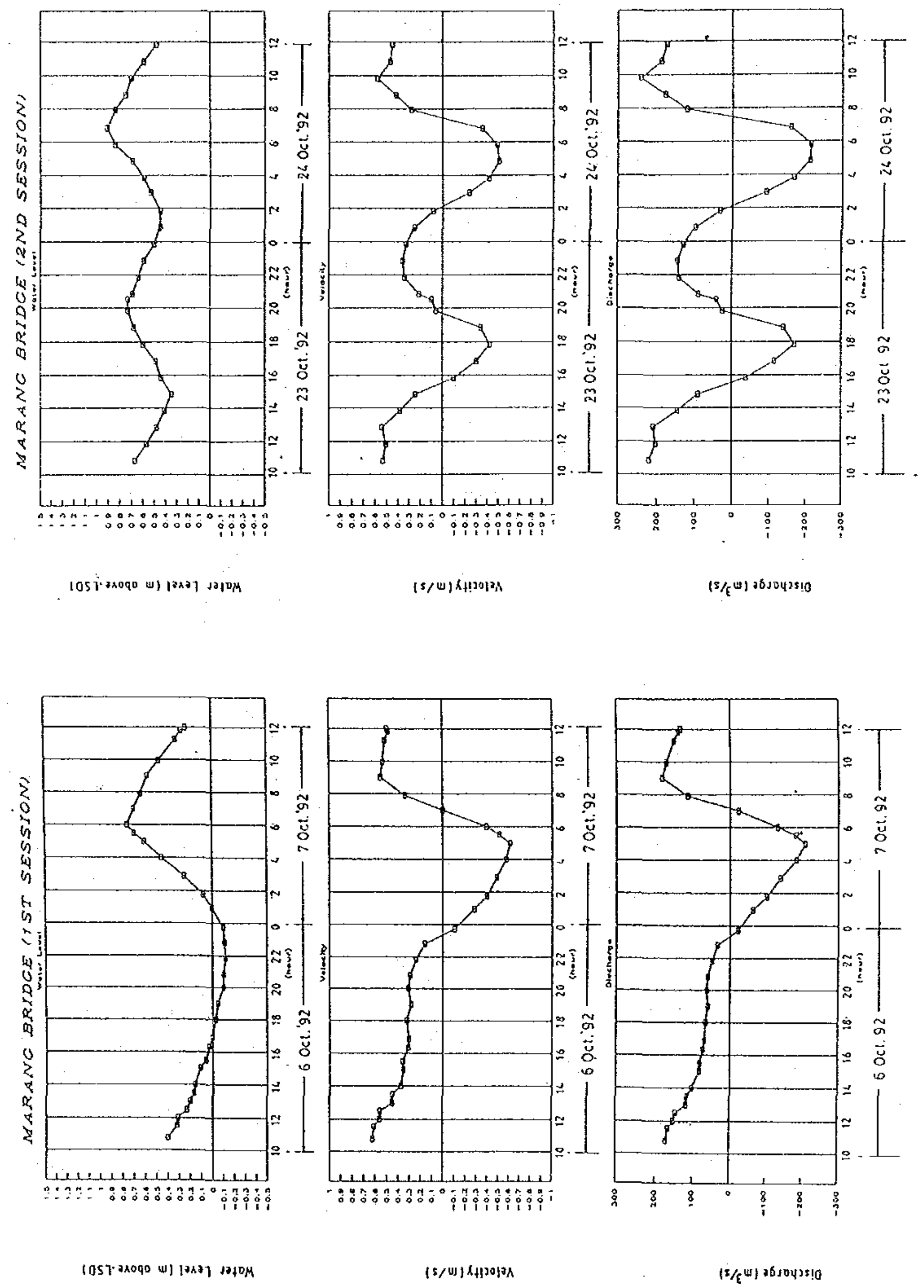


Marang

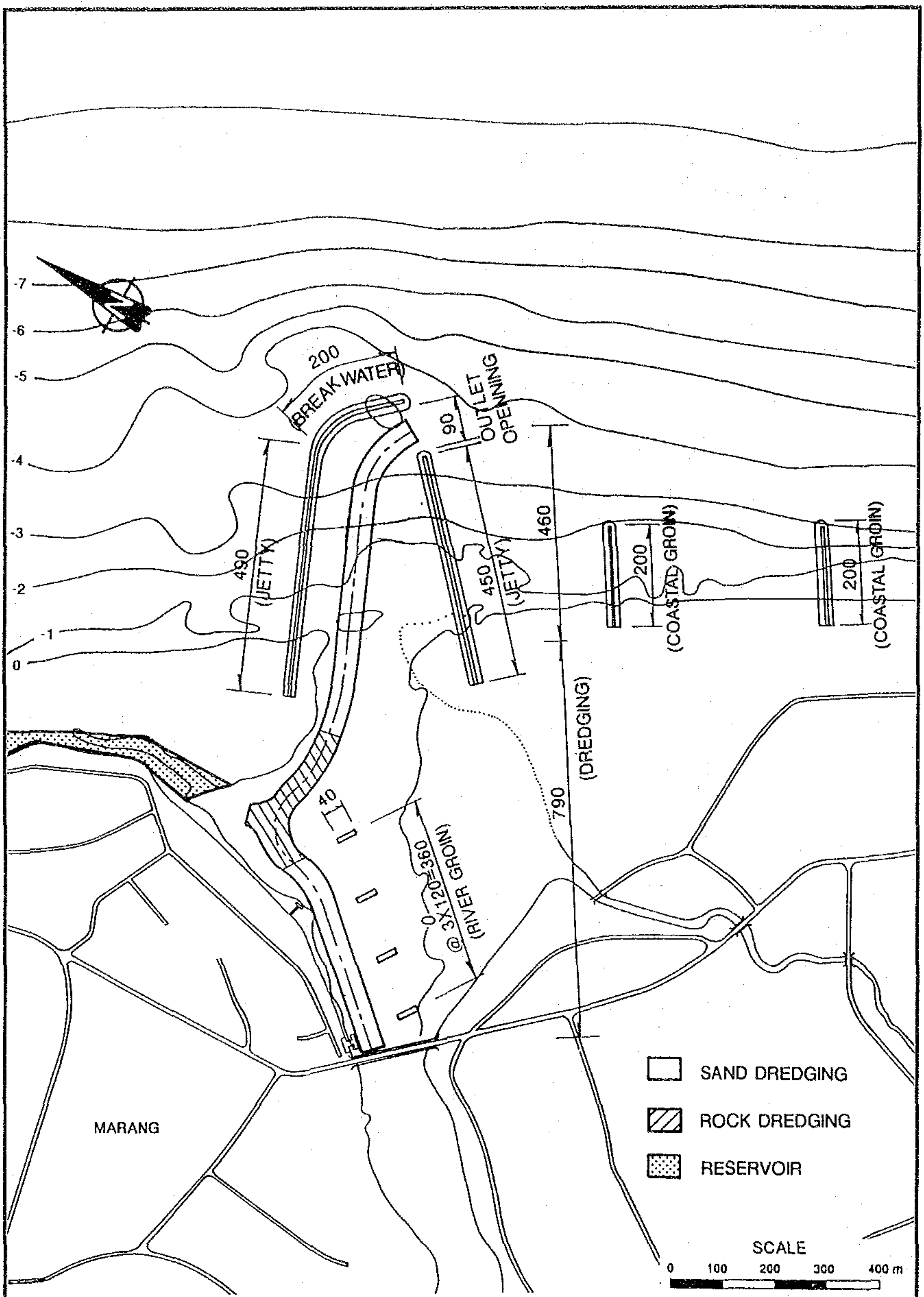
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF WATER LEVEL AND WAVE GAUGES IN MARANG Fig. 1.4-15
JAPAN INTERNATIONAL COOPERATION AGENCY	



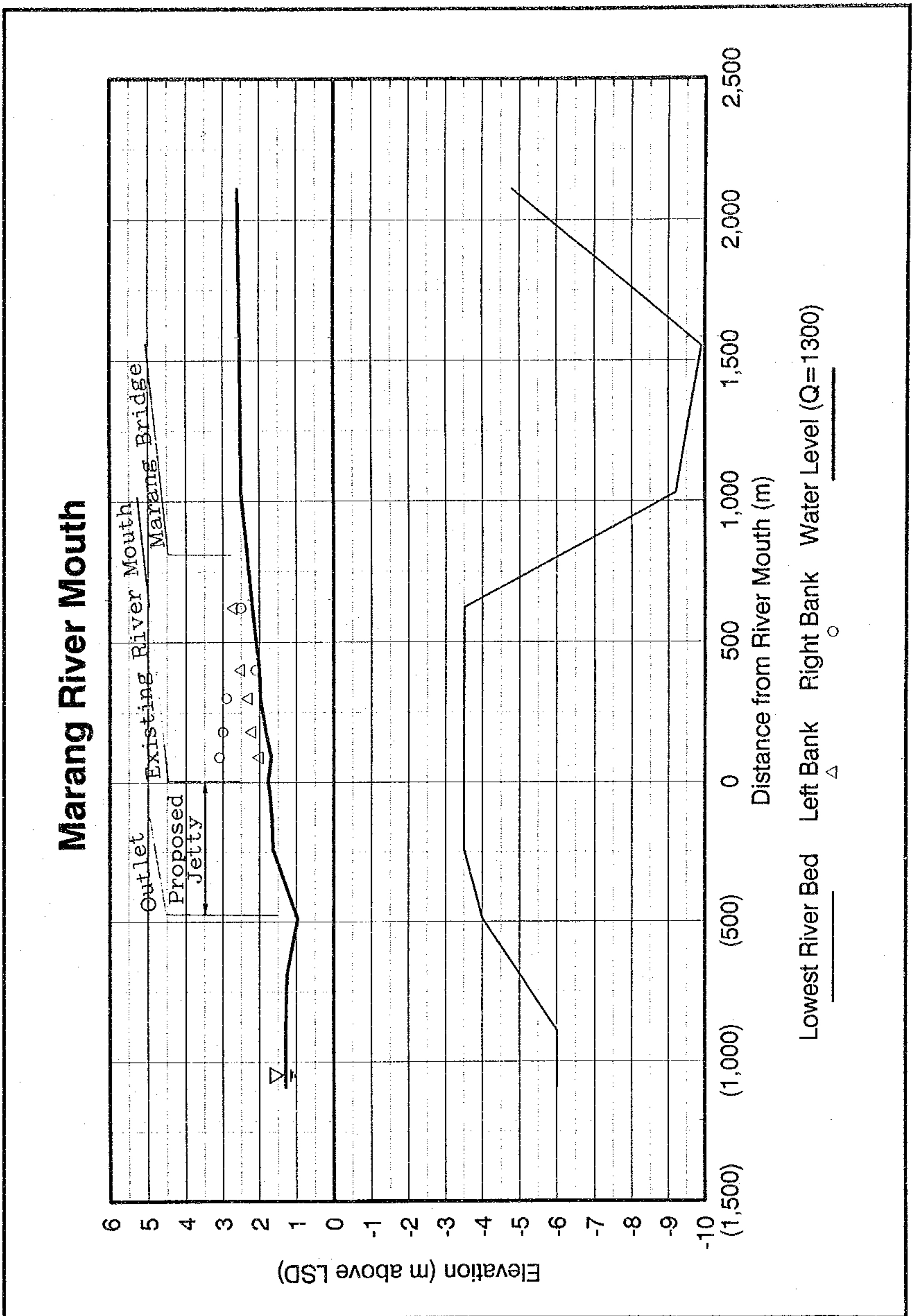
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	LOCATION OF HYDROLOGIC OBSERVATION IN MARANG Fig. 1.4-16
JAPAN INTERNATIONAL COOPERATION AGENCY	



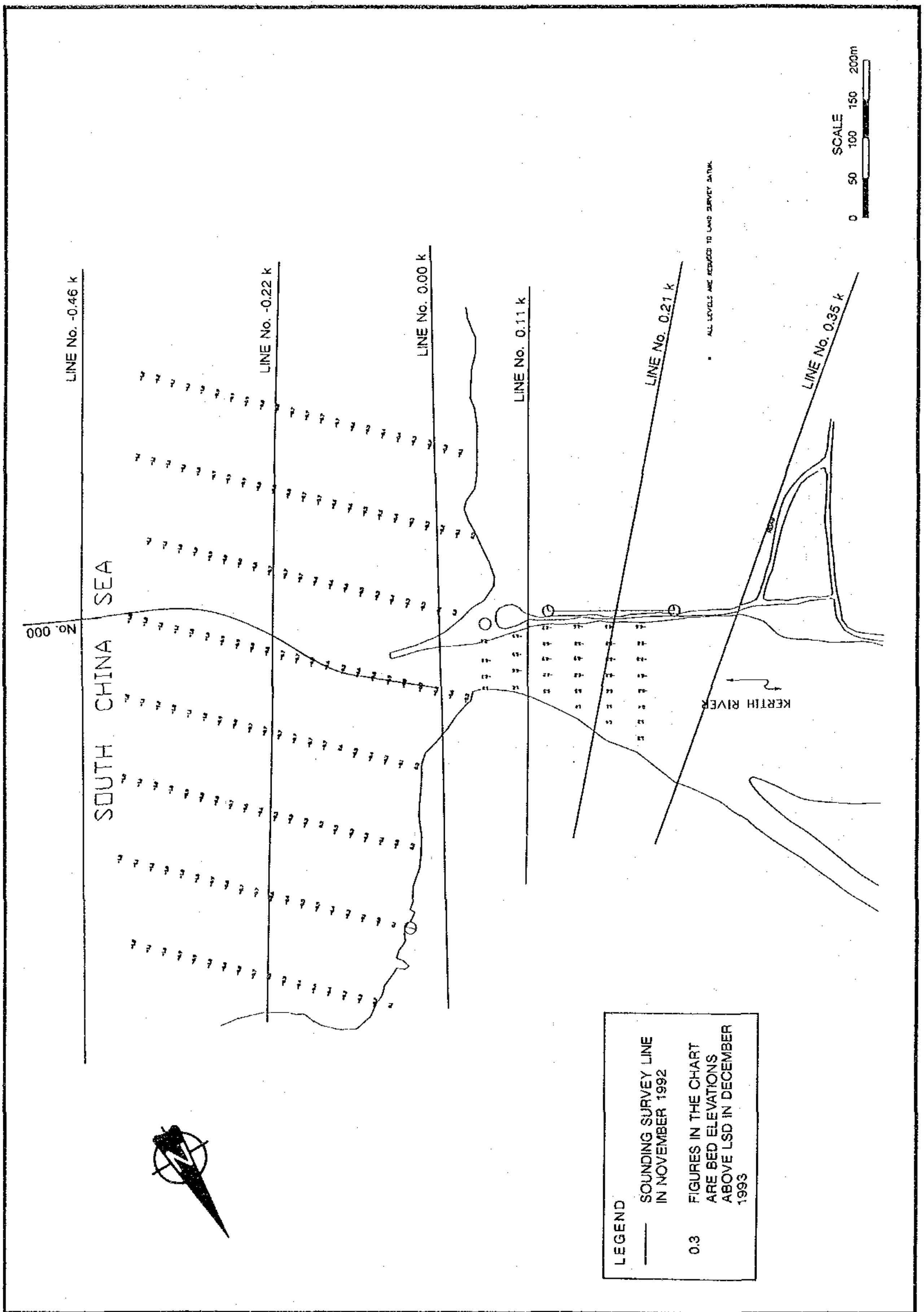
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	OBSERVED HYDROGRAPHS IN MARANG
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-17



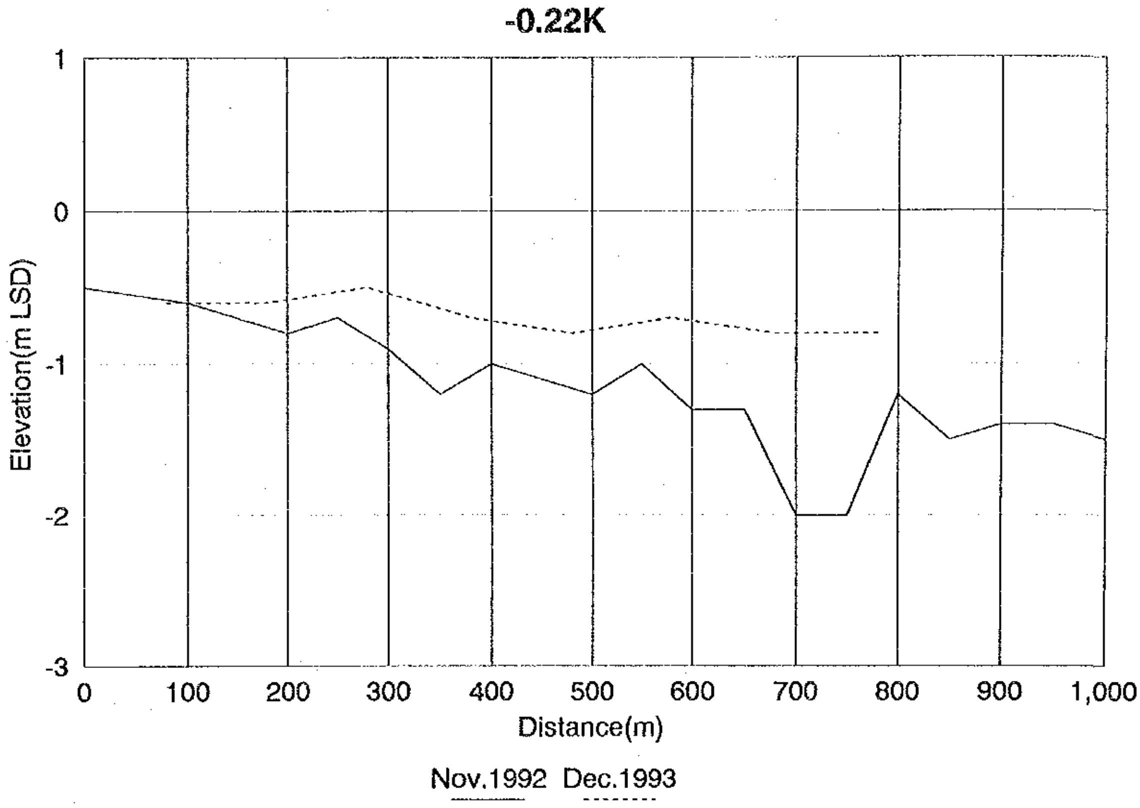
THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	GENERAL LAYOUT OF OPTIMUM MEASURES AT MARANG RIVER MOUTH Fig. 1.4-18
JAPAN INTERNATIONAL COOPERATION AGENCY	

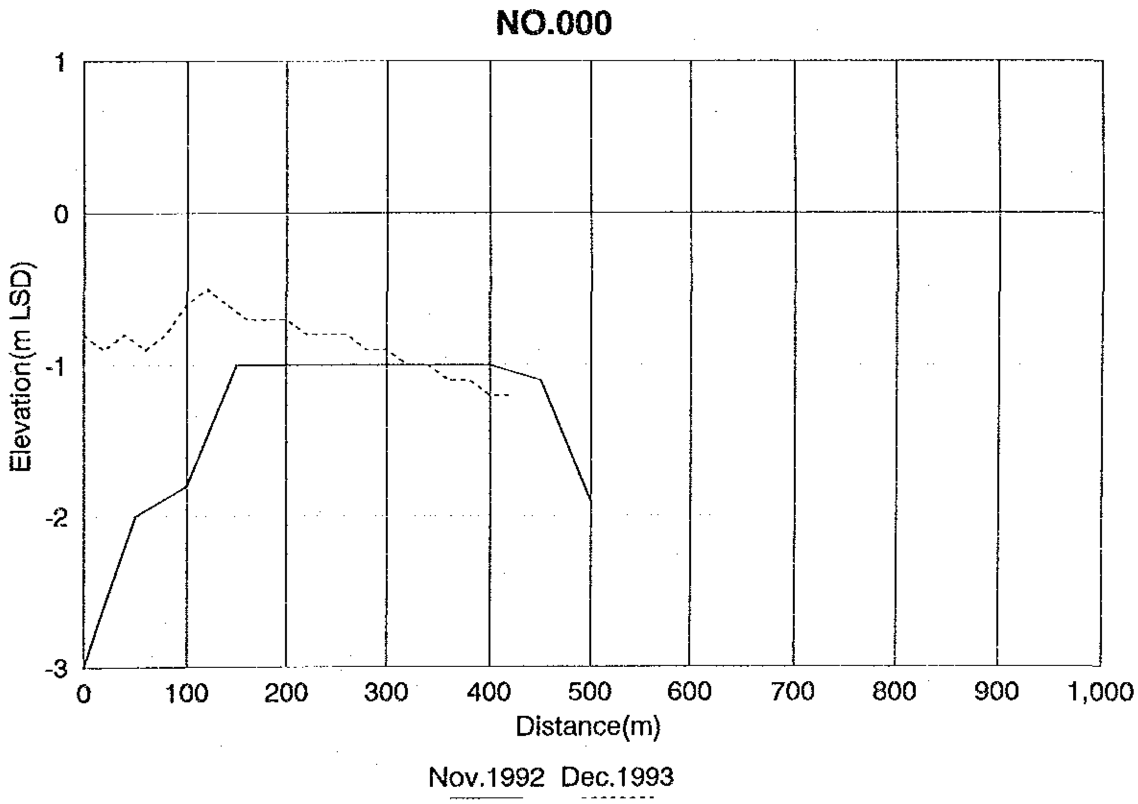


THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	ESTIMATED WATER LEVEL PROFILE IN MARANG RIVER MOUTH Fig. 1.4-19
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	SOUNDING SURVEY AREA IN KERTEH RIVER MOUTH
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 1.4-20





THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA	CHANGE OF CROSS SECTION IN KERTEH RIVER MOUTH Fig. 1.4-21
JAPAN INTERNATIONAL COOPERATION AGENCY	

2. RIVER MOUTH GEOMORPHOLOGY

THE NATIONAL RIVER MOUTHS STUDY
IN MALAYSIA

SUPPORTING REPORT NO. 2

RIVER MOUTH GEOMORPHOLOGY

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SUPPORTING REPORT NO. 2

RIVER MOUTH GEOMORPHOLOGY

1. NATIONWIDE COASTAL CONDITION AND RIVER MOUTH FORMATION

Location

The coastline of Malaysia is about 4,800 km in total length. This is composed of 860 km in the east coast of the Peninsula, 1,110 km in the west coast, 1,040 km in Sarawak and 1,800 km in Sabah.

The Peninsula is bounded by the South China Sea on the East and the Strait of Malacca on the West. Sabah and Sarawak face the South China Sea on the West. The northern and eastern boundaries of Sabah are the Sulu and Celebes seas. The South China Sea is the largest body of water incident to the Malaysian coasts. The effective minimum and maximum fetches for Sabah-Sarawak and the east coast of the Peninsula are 360 and 1,240 km, respectively.

The body of water lying to the west coast of Peninsular Malaysia is the Strait of Malacca, a narrow, shallow channel lying between the Peninsula and Sumatra Island. Fetches in the Strait are 500 km to the north and 40 km in the south, averaging about 130 km.

Coastal Geomorphology

The east coast of Peninsular Malaysia is less irregular than the west coast. Much of the coast is a series of large and small hook-shaped bays. Almost all of the entire length of coastline is fully exposed to direct wave attack from the South China Sea. The coastal landscape is dominated by low elevation coastal plains, interrupted by numerous upland spurs and river outlets. The major rivers are the Kelantan, Besut, Terengganu, Kuantan and Pahang. The coastline has a very gentle slope ranging from 1/400 to 1/600 with 5 m depth contour at 2 km to 3 km from the coastline. The depth contours generally run parallel to the coastline.

The west coast of Peninsular Malaysia is relatively long and irregular. A majority of the coast is open to the waters of the Strait of Malacca. Exceptions to this condition are the island sheltering effects of the islands of Langkawi and Pinang. A majority of the coast comprise low elevation coastal plains. The plains are formed from a deep marine clay strata. The presence of this clay material reflects the relatively calm seas in the Strait. In the Perak area, the plain is dissected by numerous rivers and estuaries.

The Sarawak coastline is characterized by long and straight sandy beaches on the east half and mangrove fringed shoreline on the west half. The entire coastline is open to wave attack from the South China Sea during the Northeast Monsoon. The mangrove shore is punctured by wide estuaries at fairly regular intervals and by pocket beaches bounded between rock outcrops and headlands. Most of the deltaic and estuarine areas are fringed by mangrove forests. Sand buildup is evident at most of the estuarine areas due to the sediments brought down by the many rivers.

Sabah has the longest shoreline of all the coastal states in Malaysia. The coastline is rugged and faces the South China Sea to the Northwest, the Sulu Sea to the Northeast and the Celebes Sea to the Southeast. Numerous offshore islands shelter the coastline from the open sea at its western tip, the northern coast and the southeastern coasts. Coral reefs abound in the waters off the southeastern coast attending protection against wave attack. The coastline is also characterized by bays of various shapes and sizes; the notable ones being Kimanis Bay, Marudu Bay, Labuk Bay, Lahad Datu Bay and Tawau Bay.

Bed Material

As the fact that a majority of the coast in Malaysia consists of alluvial low flat lands shows, beaches are composed mainly of sandy to muddy materials. The distribution of shoreline material is illustrated in Fig. 2.1-1.

Along the entire stretch of the coastline in the east coast of Peninsular Malaysia, sandy beaches dominate. The notable exception is the stretch of coast north of Kuala Pahang where mangrove and nipa palms grow profusely.

On the contrary, very few sand beach areas can be found on the west coast. The areas that do exist include Pulau Langkawi, the north and south coast of Pulau Pinang, south from the mouth of Sg. Muda to Butterworth, north and south of Lumut, in Port Dickson to Tanjung Tuan area and in the Tanjung Keling area north of Melaka, and at the mouths of some other rivers. In general, sand beaches are formed as pocket beaches between prominent rocky headlands.

The Sarawak coastline generally consists of sandy beaches on the east half and mangrove-fringed muddy shores on the west half. In Sabah, sandy beaches dominate the northeastern coastline; whereas, clay material is more commonly encountered on the northeastern and southeastern coasts.

Longshore Sediment Transport

Net longshore sediment transport direction and relative rates presented in the National Coastal Erosion Study (NCES) are shown in Fig. 2.5-2. As shown in the illustration, there is no distinct tendency of longshore sediment transport direction in the west coast of Peninsular Malaysia where no high waves attack. On the contrary, the east coast of Peninsular Malaysia is attacked by high waves during the northeast monsoon season and a clear tendency is found; namely, in the northern east coast, longshore sediment transport directions are to the north and south from the mouths of Sg. Kelantan and Terengganu, respectively; whereas, in the southern half, southward sediment transport is more distinct.

In the west coast of Sabah and Sarawak, westward longshore sediment transport is dominant. This corresponds to the wave direction during the northeast monsoons.

Coastal Change

In Malaysia, a larger part of coastal erosion/accretion is a natural phenomenon and some by human action. Coastal erosion is persistent and serious, as well as extensive, occurring in every state and along at least 1,300 km of the 4,800 km coast of the country. The major cause of erosion and accretion in Malaysia is longshore transport by storm waves.

The rate of erosion varies widely from year to year at any given location and from location to location at any given time. Over long terms of 25 years or more, the average rate is usually less than 10 m/year. In the short term, the erosion rate is often as much as 20 m/year. Along 140 km of shore, coastal erosion seriously threatens important facilities. Along another 240 km, it may seriously threaten other important facilities in the foreseeable future.

River Mouth Formation

The formation of river mouths in Malaysia corresponds well to the coastal material distribution. The east coast of Peninsular Malaysia is composed mainly of sandy material and the river mouths there are distinguished by sand bar development caused by littoral current and subsequent siltation. This tendency is found also in river mouths in the northeastern shore of the Sarawak coast and the western shore of the Sabah coast.

The west coast of the Peninsula, on the other hand, consists mainly of muddy shallow beach extending several hundred meters to a few kilometers from the coastline, and long and narrow channels develop in the muddy beach from the river mouth to the sea. This formation is also found in the western coast of Sarawak and the eastern and southern coasts of Sabah. Rivers with a relatively larger catchment area and a larger tidal prism in this area generally maintain wider and deeper river mouths.

The location of the river mouth is directly affected by the coastal change mentioned above. Where the coast is eroded, the river mouth is retreating and vice versa. Artificial influence to the river mouth is by the construction of structures. A lot of barrages for irrigation and drainage, as well as for the prevention of tidal inflow, have been constructed in the west coast of Peninsular Malaysia, especially in the northern and southern districts where river mouths are generally shallow due to the regulation of high discharges. In the east coast of the Peninsula, breakwaters have been constructed in several river mouths for the purpose of maintaining them in good condition for navigation and passage of flood flow.

2. GEOMORPHOLOGY OF REPRESENTATIVE RIVER MOUTH

2.1 Perlis River Mouth

The Perlis River Mouth is selected as the representative river mouth in Group 4, where river mouth formation is emphasized with the straight coast and the external forces of low waves and large tidal prisms (see Table 2.2-1).

Topography

The Perlis River Mouth is located in the northernmost part of the west coast of Peninsular Malaysia just south of the Thailand border, as shown in Fig. 2.2-1. The location is also in the northern end of the low, flat land which extends from this place to 70 km south. The area is a granary region in Malaysia under the Muda Agricultural Development Project.

The area is located in the southeastern end of the Andaman Sea and at the same time at the northern end of the Malacca Strait, as shown in Fig. 2.2-2. The islands of Langkawi and Terutao are located west of the river mouth.

The catchment area and total channel length of the Perlis River are 600 km^2 and 45 km, respectively. The mountains in the headwaters are not very high at around 500 m, and the river flows in the low, flat land from north of Kangar, the capital of Perlis State.

The low, flat land in the river mouth area is used for agriculture. A tidal bund was constructed to prevent saltwater intrusion to the agricultural land.

External Force

Langkawi and Terutao islands shelter the river mouth from swells intruding from the Andaman Sea and wind waves generated in the Strait of Malacca. These waves are also attenuated by breaking, with bottom friction, as they move into the shallow water area near the shore.

The tidal difference between high and low spring tide is about 2.6 m, while observed ocean current velocity is about 0.5 m/s in maximum and less than 0.3 m/s in ordinary condition.

Tidal prism, one of the major external forces to form the river mouth configuration of the Perlis River Mouth, is relatively very large with a tidal intrusion stretch of about 20 km from the river mouth and an average river width of about 60 m. The Perlis River Mouth under these circumstances is presumed, as it is formed with the external force of tidal action, and the effect of waves might be comparatively less.

Offshore Geomorphology

Fig. 2.2-3 is the navigation chart of this area and Fig. 2.2-4 shows isobaths developed through the sounding survey conducted during the second field survey in 1992. As shown in the illustrations, isobaths in the area present gentle lines with not many transformations, except in the channel portion dredged for navigation.

Seabed gradients are in general gentler in the northern part and comparatively steeper in the south. The seabed profile from the river mouth offshore developed from the navigation chart is shown in Fig. 2.2-5 with those of the other representative river mouths, and the same prepared through sounding survey during the second field work is presented in Fig. 2.2-6.

As shown in the illustrations, off-channel seabed profiles of 1000 m to the left and to the right from the river mouth are gentle at 1/1,200 and 1/1,450, respectively, for the stretch from the shoreline to about 3.0 km offshore. Seabed gradient from this point to 8 km offshore is much gentler at 1/2,000.

Bed Material

A gradation curve of seabed materials sampled in the outer channel at the mouth is presented in Fig. 2.2-7. Curves for the other representative river mouths in the muddy coast, namely in the west coast of the Peninsula, are also illustrated in the figure.

As shown in the illustration, the material is silt with the ratio of clay (<0.002 mm), silt (0.002 to 0.063 mm) and sand (0.063 to 2.0 mm) at 14%, 78% and 8%, respectively. The median diameter d50 is 0.013 mm and the mean grain diameter is 0.040 mm.

According to the survey results on soil condition in 1984 through the study on the Perlis Port Development Project, the first layer in this area is very soft marine clay, the second is stiff to very stiff clay, and the third is limestone or highly weathered shale, which are underlain at the depth of 12 to 24 m below ground level. It is concluded that this will likely create problems of subsidence, sliding, and so forth, should facilities be constructed without taking any measures against the high compressibility and lack of stability of the marine clay.

Coastal Change in Neighboring Areas

The NCES says that the Perlis coastline tends to retreat due to the demise of mangrove. Coastlines interpreted from aerial photographs for this area for the year 1966, 1974 and 1986 are presented in Fig. 2.2-8.

As shown in the illustration, both right and left banks are retreating. Shoreline retreat is severe, especially in the left bank, with a rate of 30 m for the 8 years from 1966-74 and another 30 m for the next 12 years from 1974-86.

The retreating land is mostly of mangrove forest. Tidal bunds were constructed in the area as of 1966, and the hinterland is used mainly for agricultural land. A lot of discussions have been made regarding the cause of demise of mangrove, and it is most probably due to the change of ecosystem through the obstruction of fresh water supply by bund construction.

River Mouth Configuration

The width of the river is gradually narrowed toward the upstream sections in the tidal prism stretch. This is a characteristic of rivers in this group, and the most important point for the configuration of the Perlis River Mouth is the stability of both inner and outer channels. Although the detailed discussion on the stability of channels will be made in Subsection 6.5.1, a summary of the discussion is given as follows.

The outer channel is very easily silted up after dredging, but the inner channel is relatively well maintained by tidal flow and river discharge. It is pointed out that sediment volume carried by the Perlis River is supposed to be small because the catchment area is relatively small, and the agricultural area and forest vegetation sufficiently reduces land erosion. The shoaling of the navigation channel is caused by sediment transport due to waves and tidal currents rather than sediment discharge from the river basin.

If dredging is not conducted, the section at just the mouth will remain at the present condition with an elevation of about LSD -4 m (see Fig. 2.2-6), although the channel bottom elevations at around 400-600 m off the mouth will be silted to almost the same elevations as bank elevations. Accordingly, the longitudinal shallowest part in the case of no dredging will be around LSD -1 m.

2.2 Kedah River Mouth

The Kedah River Mouth is selected as a representative river mouth in Group 10, where river mouth formation is emphasized with the external force by low waves and a large tidal prism on a protruding coastline (refer to Table 2.2-1).

Topography

The Kedah River Mouth is situated in the center of the coastline of the vast alluvial plain in Kedah State, as shown in Fig. 2.2-1. This alluvial plain, the same plain where the Perlis River Mouth is located, covers an area of about 120,000 ha with a coastline of approximately 70 km from the Thailand border to the north up to the Yan River Mouth (No. 6 river mouth for the Study) to the south. The areas are developed under MADA.

This alluvial plain is formed by a series of rivers which flow westward from the mountains in the northernmost part of the central mountain ridges of the Peninsula. The Kedah River is one of these rivers, with a total catchment area of 4,040 km^2, including the 980 km^2 catchment area of the Muda Dam, and an entire river length of 110 km. The river mouth is situated at the tip of the gently protruding coastline which the Kedah River has formed. Langkawi Island is located 50 km to the northwest of the river mouth.

External Force

Wind waves generated in the Strait of Malacca and the Andaman Sea by the wind predominantly from the direction between West and North-West are partly sheltered by Langkawi Island. These waves are attenuated by breaking, with bottom friction as they move into the shallow water area near the shore.

The tidal difference between high and low spring tides is about 2.6 m, while the surface ocean current velocity is about 0.3 m/s from northwest to southeast in June and from southeast to northwest in December.

The tidal prism of the Kedah River Mouth is quite large, with a long tidal intrusion stretch up to the tidal barrage 10 km upstream of the river mouth and a wide river width of about 200 m. Under these circumstances, the Kedah River Mouth is mainly formed by the external force of tidal action than wave.

Offshore Geomorphology

Fig. 2.2-9 is the navigation chart of this area and Fig. 2.2-10 shows the isobaths developed through the sounding survey conducted during the second field survey in 1992. As shown in the illustrations, isobaths in the area present gentle convex lines almost parallel to the shoreline near the coast but become gradually straight offshore. A straight channel extends from the river mouth, which was formed artificially by dredging the stretch of approximately 1 km from the river mouth.

The seabed profile from the river mouth offshore developed from the navigation chart is shown in Fig. 2.2-5, and the same prepared through sounding survey during the second field work is presented in Fig. 2.2-11. As shown in the illustrations, the off-channel seabed profile at 1000 m to the right is almost flat from the shore to about 1.7 km offshore and the same at 1000 m to the right is gentle at 1/1,600. At the center, the average seabed gradient for the stretch from this point to 8.5 km offshore is much steeper at about 1/330 and the entire profile is generally convex.

Bed Material

A gradation curve of seabed materials sampled in the outer channel at the mouth is presented in Fig. 2.2-7 with the curves for the other representative river mouths in the muddy coast, namely the west coast of the Peninsula. As shown in the illustration, the material is silt with the ratio of clay (<0.002 mm), silt (0.002 to 0.063 mm) and sand (0.063 to 2.0 mm) at 22%, 76% and 2%, respectively. The median diameter d50 is 0.014 mm and the mean grain diameter is 0.027 mm.

Although there is no report describing the other soil conditions in the river mouth, it is presumed that marine clay covers the seabed with a depth of more than 3.0 m which was found through the dredging then being conducted.

Coastal Change in Neighboring Areas

Coastlines interpreted from aerial photographs of this area for the year 1966, 1974, 1980 and 1986 are presented in Fig. 2.2-12. As shown in the illustration, both right and left banks are retreating. The average shoreline retreat for 20 years from 1966-86 is 70 m in the northern shore and 120 m in the southern shore. The retreat of shoreline ceased in the northern shore after it reached the bund. The annual retreat rate in the southern shore is about 6.0 m.

The retreating land is mostly of mangrove forest and the cause of shoreline retreat is most probably due to the demise of mangrove, as in the case of the Perlis River Mouth, and not due to direct erosion by waves. The demise of mangrove is most probably due to the change of ecosystem through obstruction of fresh water supply by bund construction. The shoreline retreat will stop when it reaches the tidal bund, although there is a possibility of bund erosion because the bund may not have been designed for shore structures.

River Mouth Configuration

The river width gradually narrows from the mouth toward upstream in the tidal prism stretch, and this is a characteristic of rivers in this group. Siltation emerges in the approach channel at the river mouth.