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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF IRRIGATION AND DRAINAGE
MINISTRY OF AGRICULTURE
MALAYSIA

THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA

VOL. II

MAIN REPORT

MASTER PLAN STUDY

AUGUST 1994

CTI ENGINEERING CO., LTD.

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LIST OF REPORTS

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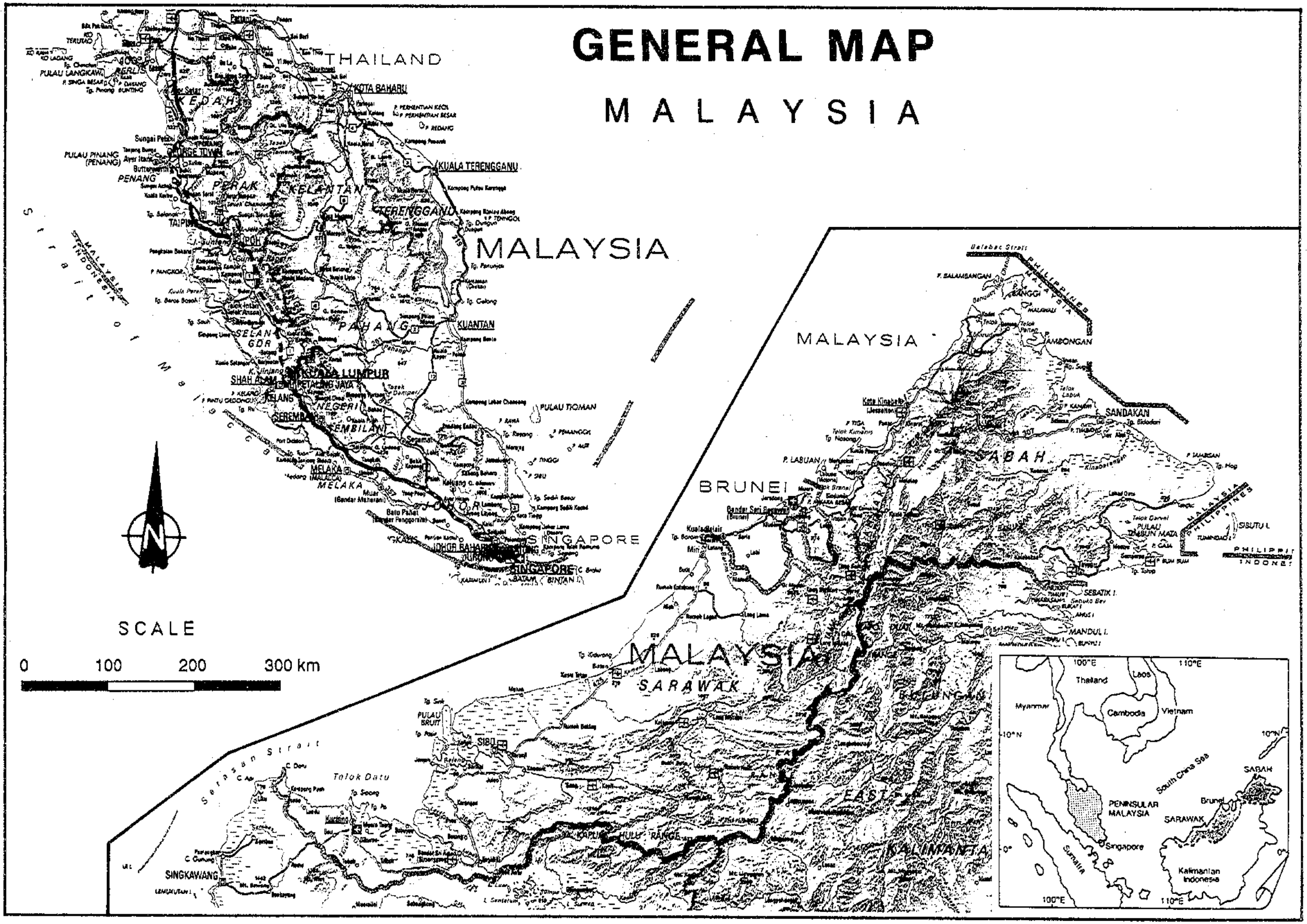
GENERAL MAP
MALAYSIA



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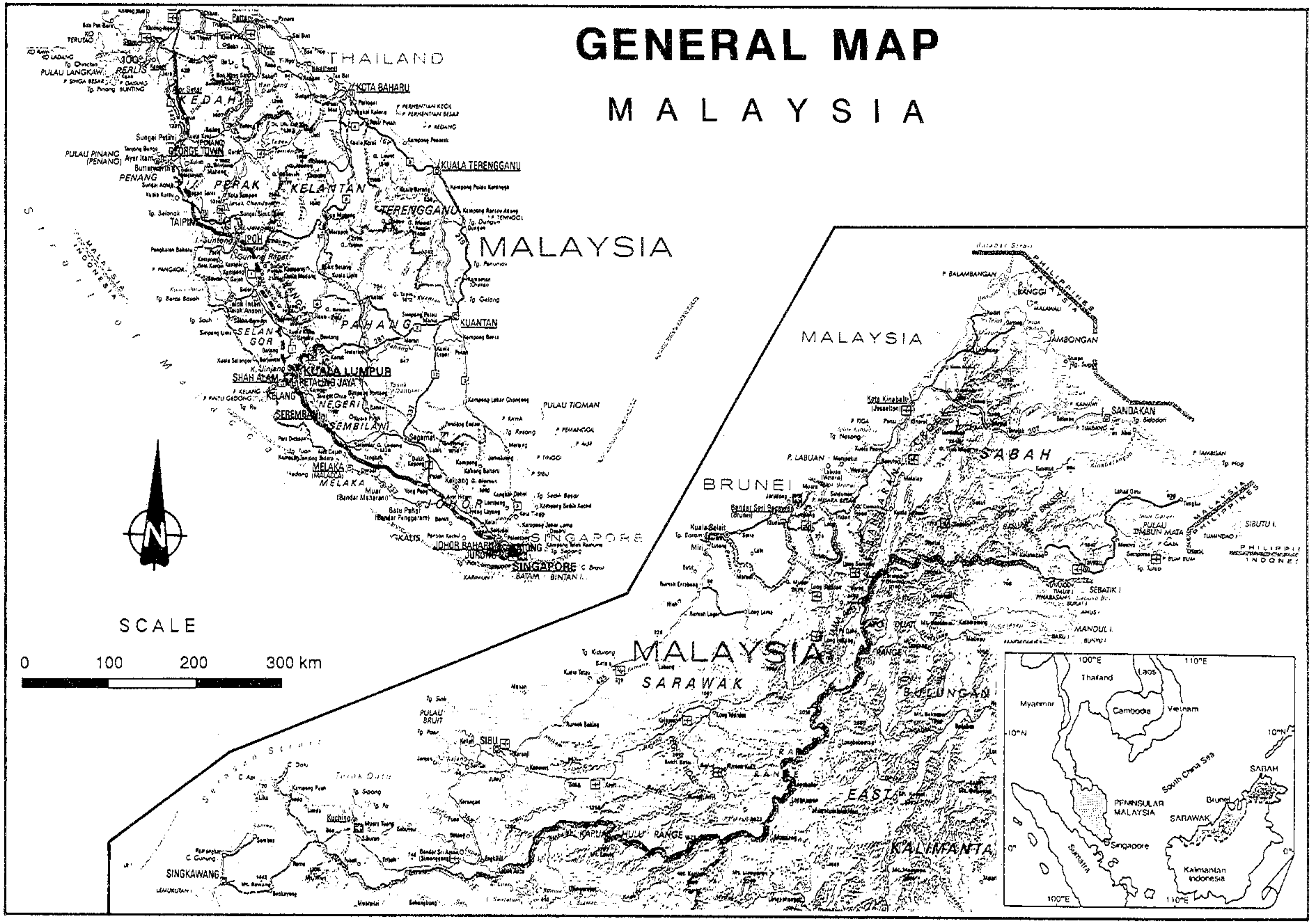
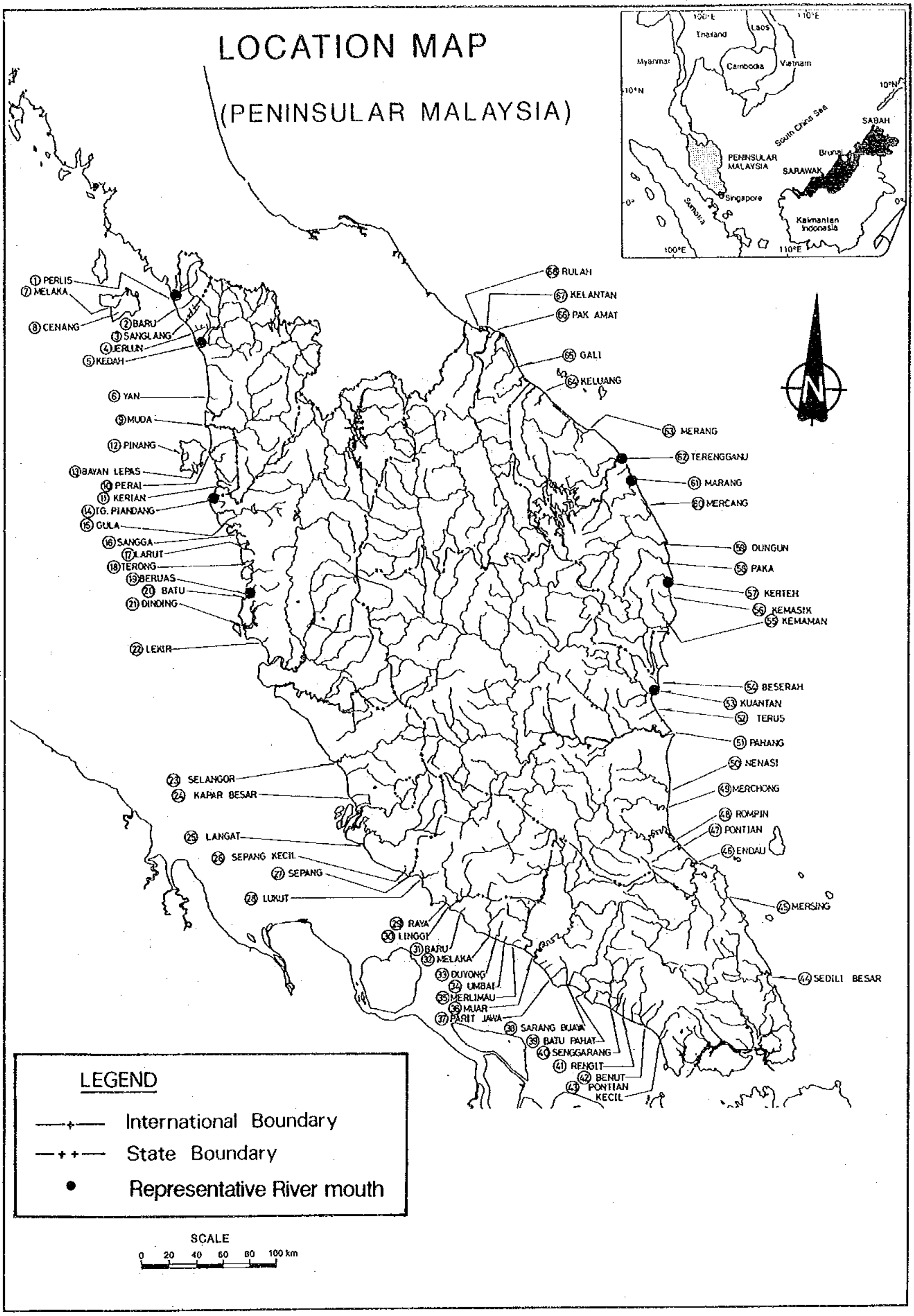
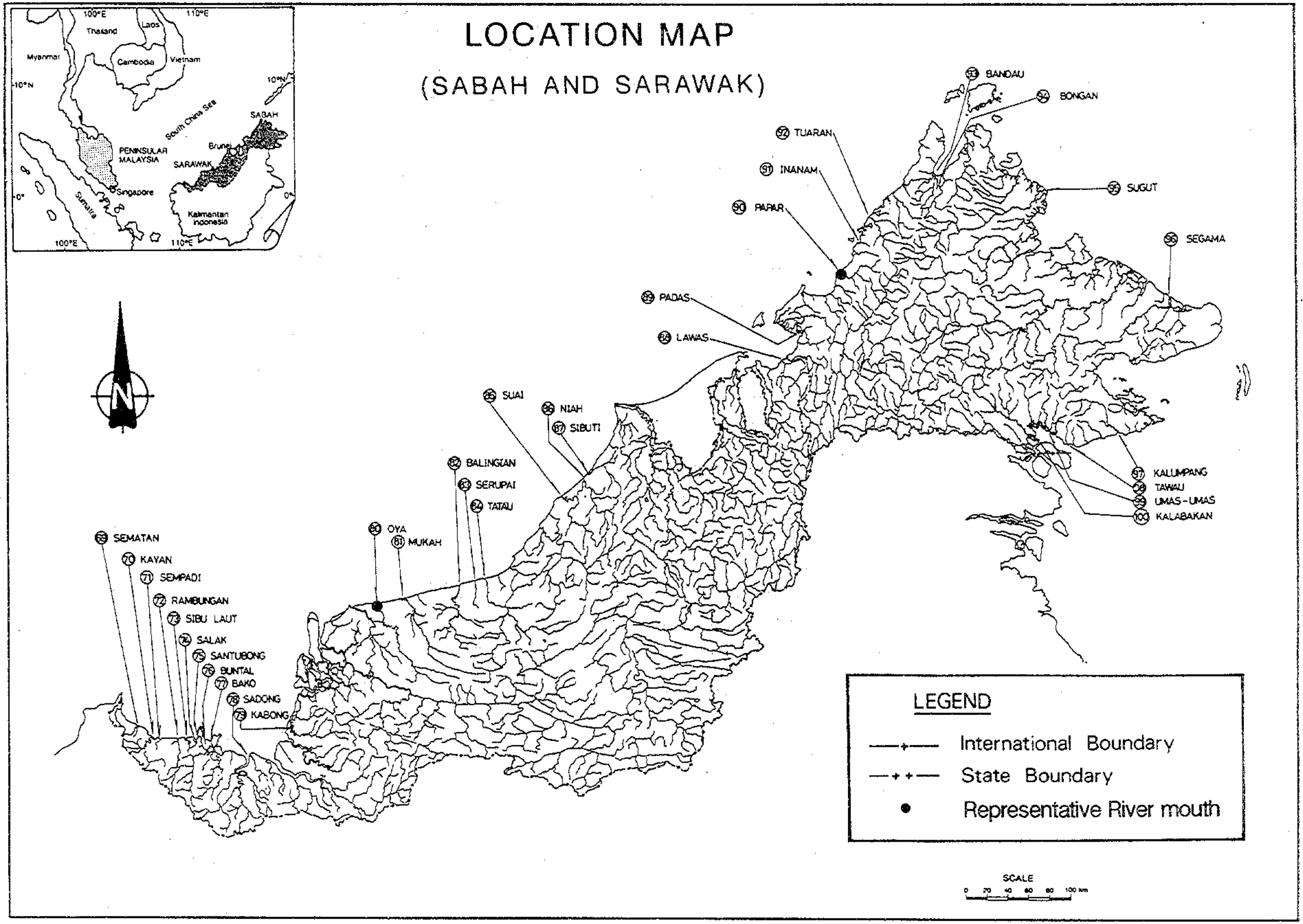
MALAYSIA





LOCATION MAP
(PENINSULAR MALAYSIA)
Thailand
Laos
Myanmar
Cambodia
Vietnam
South China Sea
PENINSULAR MALAYSIA
SABAH
Brunei
SARAWAK
Sumatra
Singapore
Kalimantan Indonesia
100°E
110°E
10°N
0°
① PERLIS
⑦ MELAKA
⑧ CENANG
② BARU
③ SANGLANG
④ JERLUN
⑤ KEDAH
⑥ YAN
⑨ MUDA
⑫ PINANG
⑬ BAYAN LEPAS
⑩ PERAI
⑪ KERIAN
⑭ TG. PIANDANG
⑮ GULA
⑯ SANGGA
⑰ LARUT
⑱ TERONG
⑲ BERUAS
⑳ BATU
㉑ DINDING
㉒ LEKIR
㉓ SELANGOR
㉔ KAPAR BESAR
㉕ LANGAT
㉖ SEPANG KECIL
㉗ SEPANG
㉘ LUKUT
㉙ RAYA
㉚ LINGGI
㉛ BARU
㉜ MELAKA
㉝ DUYONG
㉞ UMBAI
㉟ MERLIMAU
㊱ MUAR
㊲ PARIT JAWA
㊳ SARANG BUAYA
㊴ BATU PAHAT
㊵ SENGGARANG
㊶ RENGIT
㊷ BENUT
㊸ PONTIAN KECIL
㊹ SEDILI BESAR
㊺ MERSING
㊻ ENDAU
㊼ PONTIAN
㊽ ROMPIN
㊾ MERCHONG
㊿ NENASI
51 PAHANG
52 TERUS
53 KUANTAN
54 BESERAH
55 KEMAMAN
56 KEMASIK
57 KERTEH
58 PAKA
59 DUNGUN
60 MERCANG
61 MARANG
62 TERENGGANU
63 MERANG
64 KELUANG
65 GALI
66 PAK AMAT
67 KELANTAN
68 RULAH
N
LEGEND
International Boundary
State Boundary
Representative River mouth
SCALE
0 20 40 60 80 100 km



LOCATION MAP
(SABAH AND SARAWAK)
69 SEMATAN
70 KAYAN
71 SEMPADI
72 RAMBUNGAN
73 SIBU LAUT
74 SALAK
75 SANTUBONG
76 BUNTAL
77 BAKO
78 SADONG
79 KABONG
80 OYA
81 MUKAH
82 BALINGIAN
83 SERUPAI
84 TATAU
85 SUAI
86 NIAH
87 SIBUTI
88 LAWAS
89 PADAS
90 PAPAR
91 INANAM
92 TUARAN
93 BANDAU
94 BONGAN
95 SUGUT
96 SEGAMA
97 KALUMPANG
98 TAWAU
99 UMAS-UMAS
100 KALABAKAN
LEGEND
International Boundary
State Boundary
Representative River mouth
SCALE
0 20 40 60 80 100 km

SUMMARY

SUMMARY

1. GENERAL

1.1 Background of the Study

Malaysia, which achieved a commendable economic growth of 6.7% per annum during the Fifth Malaysia Plan from 1986 to 1990, stepped into the Sixth Malaysia Plan for the period from 1991 to 1995 to see the Malaysian economy growing at an average rate of 7.5% per annum. Public investment in this plan is expected to increase at 3.0% per annum compared with the 0.2% in the previous plan due to the expansion of infrastructure facilities, so as to remove bottlenecks and to encourage larger private investment. To attain this objective, it is necessary to solve several problems.

Malaysia is geographically featured with a land of 329,750 km^2 in total area and a coastal line of 4,840 km in total length. Numerous rivers and creeks exist therein, and river mouths have the problem of siltation due to the heavy sediment deposition from the upper streams coupled with longshore drift. This results in the reduction of flow area for river discharge during flood time and obstruction to the smooth navigation of ships and fishing boats.

The Government of Malaysia has been making every effort to alleviate the problem by dredging and constructing breakwaters. The efforts, however, have not always succeeded and, recognizing the severity of the problem of river mouth siltation nationwide, the Government had decided to implement the National River Mouths Study (hereinafter referred to as the Study) to formulate a Master Plan of River Mouth Improvement and to conduct a Feasibility Study for the Urgent Project selected out of the Master Plan.

1.2 Objectives of the Study

The objectives of the Study are:

(1) to formulate a Master Plan for the improvement of selected river mouths for flood mitigation and navigation; and

(2) to conduct a feasibility study on the improvement of two river mouths selected for flood mitigation and navigation.

1.3 Study Area

The study area is the whole country of Malaysia. The 100 objective river mouths selected by the Government of Malaysia are shown in Table 1.2-1.

2. CATEGORIZATION OF RIVER MOUTH

To select the river mouths for the Master Plan Study, the 100 river mouths were categorized according to the seriousness of the existing problems into Category 1 (Critical), Category 2 (Significant), and Category 3 (Acceptable). The categorization was done based on three aspects: (1) the Physical Aspect as determined from the comparison between the minimum depth of the river mouth and draft of the registered boat at the river mouth; (2) the Economical Aspect as determined by the number of fishermen using the river mouth; and (3) the Social Aspect as determined by complaints brought by fishermen to the office concerned. As a result, 35 river mouths were categorized under Category 1, 40 river mouths under Category 2, and 25 river mouths under Category 3. Among them, the 75 river mouths belonging to Category 1 and Category 2 were selected as the objective river mouths for the Master Plan Study.

3. FORMULATION OF MASTER PLAN

3.1 Selection of Countermeasures for Representative River Mouth

(1) Grouping of Objective River Mouth and Selection of Representative River Mouth

Since it was difficult to carry out the same level of master plan study for the 75 objective river mouths, they were divided into 10 groups according to the similarity of physical characteristics such as wave, river mouth features and bed materials. A representative river mouth was then selected from each group considering the availability of data, seriousness of problems and others. The optimum countermeasures for each representative river mouth have been examined in detail.

(2) River Mouth Problem for Representative River Mouth

River mouth problems are mainly the inundation problems and navigation problems. According to the interview survey, problems on inundation are not found on many river mouths, while navigation problems of fishing boats prevail in all the river mouths. The navigation problems are caused by insufficient channel depth, shifting of river mouth location, shifting of river channel course and intrusion of rough waves. The river mouth problems for the representative river mouths are summarized in the following table.

Name of River Mouth	Inundation Problem	Navigation Problem			
		Insufficient Depth	Shifting River Mouth	Shifting River Course	Intrusion of Rough Wave
Perlis	-	Yes	-	-	-
Kedah	-	Yes	-	-	-
Tg. Piandang	-	Yes	-	-	-
Beruas	-	Yes	-	-	-
Kuantan	-	Yes	-	-	-
Kerteh	-	Yes	Yes	-	-
Marang	-	Yes	Yes	Yes	Yes
Terengganu	Yes	Yes	-	Yes	Yes
Oya	-	Yes	Yes	-	-
Papar	-	Yes	Yes	Yes	-

(3) Countermeasures for Representative River Mouth

The optimum countermeasures to cope with the river mouth problems were selected through the comparison study among the alternative cases, as follows:

Name of River Mouth	Dredging (Capital, Mainte-nance)	Jetty	Break-water	River Groin	Coastal Groin	Train-ing Dike	Reser-voir
Perlis	Yes	-	-	-	-	-	-
Kedah	Yes	-	-	-	-	-	-
Tg. Piandang	Yes	-	-	-	-	-	-
Beruas	Yes	-	-	-	-	-	-
Kuantan	Yes	-	-	-	-	-	-
Kerteh	Yes*	Yes	-	-	Yes	-	Yes
Marang	Yes*	Yes	Yes	Yes	Yes	-	Yes
Terengganu	Yes	-	Yes	Yes	-	-	-
Oya	Yes	-	-	-	-	Yes	Yes
Papar	Yes*	Yes	-	Yes	Yes	-	Yes

* Capital Dredging only

(4) Cost of Countermeasures for Representative River Mouth

The cost of countermeasures for the representative river mouth were calculated, multiplying the unit cost by the work volume required for river mouth improvement.

(5) Benefit

Benefits on river mouth improvement basically include the flood control benefit and the navigation condition improvement benefits for fishing and commercial boats. Among the navigational benefits, those for the fishing boats were estimated considering the following aspects: savings on boat running cost, savings on fishermens' opportunity cost, savings on fish refrigeration cost, and preservation of fish quality.

3.2 Countermeasures and Cost and Benefit for Other River Mouths

The countermeasures for the representative river mouth were applied to the other river mouths in the group. The cost and benefit for the other river mouths were modified from those of the representative river mouth considering the river mouth scale, number of fishing boats, etc.

3.3 Economic Evaluation of Master Plan

The economic viability of the Master Plan was evaluated in a manner of cost and benefit ratio (B/C). As identified in the B/C ratio of 0.72, the economic viability of the Master Plan is not so high. However, the economic viability for the critical group shows a high economic return. Hence, the Master Plan puts emphasis on the critical group, while project execution for the significant group considers the future development of the area surrounding the river mouth.

3.4 First Phase Project

To facilitate the realization of the Master Plan, a First Phase Project in the critical group with the target year 2005 was examined considering the implementation schedule in accordance with the prioritization. As a result, the First Phase Project gives the EIRR of 11.5% which shows viability for realization.

4. RECOMMENDATIONS

(1) The Master Plan for the river mouth improvement project is formulated to cover 75 river mouths. Although the economic viability of the Master Plan is not high, this kind of infrastructure project is essential to improve the living conditions of people in the vicinity of the river mouth. In this connection, it is recommended that the Master Plan be considered as a part of the Malaysian National Development Plan.

(2) To facilitate the realization of the Master Plan, a First Phase Project having 2005 as the target year is also formulated putting emphasis on the improvement of the 35 river mouths in critical condition identified in the Study. The First Phase Project should be considered for further study, since its economic viability of EIRR 11.5% with the total cost of about RM 300 million is high enough to promote it to the further study stage. In consideration of the future development of the fishing industry, however, the prioritization of components of the First Phase Project should be carefully made.

THE NATIONAL RIVER MOUTHS STUDY
IN MALAYSIA

VOLUME II

MASTER PLAN STUDY

TABLE OF CONTENTS

CHAPTER 4. CLASSIFICATION AND CATEGORIZATION OF RIVER MOUTH

CHAPTER 5. PRINCIPLES OF FORMULATION OF MASTER PLAN

CHAPTER 6. BASIC STUDY AND ANALYSIS ON THE IMPROVEMENT OF REPRESENTATIVE RIVER MOUTH

CHAPTER 7. IMPROVEMENT PLAN FOR REPRESENTATIVE RIVER MOUTH

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND GLOSSARY

Abbreviations

DID	:	Department of Irrigation and Drainage
DOA	:	Department of Agriculture
DOE	:	Department of Environment
DOF	:	Department of Fisheries
DOS	:	Department of Statistics
DSM	:	Department of Survey and Mapping
EPU	:	Economic Planning Unit
ESCAP	:	Economic and Social Commission for Asia and the Pacific (UNDP, United Nations Development Programme)
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRT	;	Gross Relative Tonnage
JICA	:	Japan International Cooperation Agency
JKR	:	Jabatan Kerja Raya (Public Works Department)
JPS	:	Jabatan Pengairan dan Saliran (= DID)
JPT	:	Jabatan Parit dan Taliair (= DID)
LEO	:	Littoral Environmental Observations
LKIM	:	Lembaga Kemajuan Ikan Malaysia (Malaysian Fisheries Development Authority)
MD	:	Marine Department
MMS	:	Malaysian Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance
NCES	:	National Coastal Erosion Study
NWRS	:	National Water Resources Study (by JICA)
NDP	:	National Development Policy
OPP2	:	Second Outline Perspective Plan
PA	:	Port Authority
PPC	:	Penang Port Commission
TNB	:	Tenaga Nasional Berhad (National Electricity Corporation)

Unit of Measurement

Area

ha	:	hectare
m^2	:	square meter
km^2	:	square kilometer

Weight

kg	:	kilogram
ton	:	1,000 kg

Volume

l	:	liter
ton	:	tonnage
m^3	:	cubic meter

Others

°C	:	degree centigrade
m^3/s	:	cubic meter per second

Currency

RM	:	Malaysian Ringgit
US$	:	U.S. Dollar
¥	:	Japanese Yen

Malayan Terms

Kg.	:	Kampong (village)
Kuala	:	river mouth
Pulau	:	island
Sg.	:	Sungai (river)
Telok	:	bay
Tg.	:	Tanjung (headland)

CHAPTER 1. INTRODUCTION

1.1 Background of the Study

Malaysia, which achieved a commendable economic growth of 6.7% per annum during the Fifth Malaysia Plan from 1986 to 1990, stepped into the Sixth Malaysia Plan for the period from 1991 to 1995 to see the Malaysian economy growing at an average rate of 7.5% per annum. Public investment in this plan is expected to increase at 3.0% per annum compared with the 0.2% in the previous plan due to the expansion of infrastructure facilities, so as to remove bottlenecks and to encourage larger private investment. To attain this objective, it is necessary to solve several problems.

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1.2 Outline of the Study

1.2.1 Objectives of the Study

The objectives of the Study are:

(1) to formulate a Master Plan on the improvement of selected river mouths, for flood mitigation and navigation; and

(2) to conduct a feasibility study on the improvement of two selected river mouths, for flood mitigation and navigation.

1.2.2 Study Area

The study area is the whole country of Malaysia. The objective river mouths selected by the Government of Malaysia are shown in Table 1.2-1.

1.2.3 Scope of Work

The scopes of work for the Study include:

(1) Phase I, Master Plan Study

(a) Study Collection and review of available data and information related to the

- Socioeconomic parameters
- Meteorology and hydrology
- Topography and geology including aerial photograph
- Land use
- River mouth condition
- Flood damage records
- Navigation information
- Existing projects and plans for river mouth improvement

- Existing projects and plans for coastal area development
- Previous study
- Others

(b) Field Survey

- River mouth survey
- Hydrological observation
- Flood damage survey
- Navigation survey
- Socio-Economic survey
- Others

(c) Study and Analysis

- Meteorological and hydrological analysis
- Identification of river mouth problems
- Examination of river mouth improvement alternatives
- Social and environmental study

(d) Formulation of Master Plan

- Formulation of a Master Plan on the improvement of river mouths for flood mitigation and navigation

(2) Phase II, Feasibility Study

(a) Supplemental Survey

- Data collection
- Socio-economic study
- Topographic survey
- Bed material and siltation analysis

- Model experiment
- Environmental impact study

(b) Project Formulation

- Preliminary design
- Construction schedule
- Cost estimate
- Project evaluation
- Implementation plan

1.2.4 Study and Staffing Schedule

The Study started in January 1992. It was carried out at the project site in Malaysia with further studies at the JICA Study Team's head office in Japan in accordance with the schedules shown in Fig. 1.2-1, Study Flow Chart, and Fig. 1.2-2, Staffing Schedule. The JICA Study Team was composed of 11 members, as listed in Table 1.2-2 together with the counterpart personnel. The members of the Advisory Committee which was organized to provide advise and technical support to the team and composed of four officials of the Japanese Government are listed in Table 1.2-3.

CHAPTER 2. NATIONWIDE NATURAL AND SOCIO-ECONOMIC SETTING

2.1 Topography

Malaysia consists of Peninsular Malaysia and East Malaysia. East Malaysia occupies the northern part of Borneo Island and is divided into two states, Sabah and Sarawak. The area of Peninsular Malaysia is 131,598 km^2, while those of Sabah and Sarawak are 73,711 km^2 and 124,449 km^2, respectively. 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 topography of Peninsular Malaysia is featured with a central mountain range, the Main Range. The mountain range splits the Peninsula into the east and west coasts surrounded by coastal flat plains. Flat plains are widely developed particularly in the southern part of the Peninsula.

The Crocker Range which runs parallel to the northwest coast divide the State of Sabah into two regions, the narrow northwest coastal low belt and the central and eastern plain areas. Swampy low areas adjacent to the northeastern coast are densely covered with mangrove. In Sarawak, alluvial coastal plains have developed northward and westward from the mountain ranges of the interior of Borneo Island.

2.2 Meteorology and Hydrology

Climate

Malaysian climate is equatorial with high uniform temperature, high humidity and copious rainfall influenced by the northeast and southwest monsoons. Northeast monsoons prevail from November to February and bring heavy rainfalls to the east coast of the Peninsula and to Sabah and Sarawak. Southwest monsoons usually start in April or May and end in September.

Wind

Wind over Malaysia is generally light and variable. There are, however, some uniform periodic changes in the wind flow patterns and four seasons can be identified; namely, the southwest monsoon, the northeast monsoon and two shorter inter-monsoon seasons.

During the northeast monsoon the prevailing wind flow is easterly or northeasterly with a velocity of 5 to 10 m/s. The more affected areas are the east coast of Peninsular Malaysia, where the winds may reach 15 m/s or more during periods of intense surges of cold air from the north.

In the later half of May, the southwest monsoon comes to the west coast of Peninsular Malaysia. The prevailing wind flow is generally light, below 5 m/s, due to the shelter effect of Sumatra Island. The winds during the two inter-monsoon seasons are light and variable. Thunderstorms are common during these seasons.

The seasonal wind flow patterns are presented in Fig. 2.2-1.

Rainfall

Malaysia receives comparatively abundant rainfall with an annual mean rainfall of 2,420 mm at Peninsular Malaysia, 2,630 mm at Sabah and 3,830 mm at Sarawak. Such heavy rainfall has contributed to the development of dense networks of rivers and streams.

The rainfall distribution pattern of Malaysia is dependent on the seasonal wind patterns and the local topographic features. According to the National Water Resources Study by JICA (hereinafter referred to as the NWRS), Peninsular Malaysia and East Malaysia are divided into 5 and 7 rainfall regions, respectively, as shown in Fig. 2.2-2.

2.3 Oceanography

Tide

Malaysian coasts are influenced by three types of tides, diurnal, semi-diurnal and mixed, according to location and time of occurrence.

Major features of tides are summarized in Table 2.3-1, and the astronomical maximum tidal ranges along the coasts are shown in Fig. 2.3-1.

The maximum tidal ranges are within 2 to 6 m. Maximum ranges greater than 5 m are observed along the coastlines near the Port Klang of the west coast of Peninsular Malaysia and near Kuching of Sarawak.

Wave

Statistical analyses of deepwater waves were carried out in the National Coastal Erosion Study (NCES) to construct wave roses for 10 square sea areas surrounding the territory of Malaysia, as shown in Fig. 2.3-2, 2.3-3 and 2.3-4.

Along the east coast of Peninsular Malaysia, the northeast waves are predominant during the northeast monsoon. Over 65% of the waves are northeasterly with a maximum height of 4 to 5 m.

The southern part of the west coast of Peninsular Malaysia receives comparatively calm waves because of the short fetch length across the Strait of Malacca.

Northwesterly waves from the Andaman Sea are predominant along the northern part of the west coast during the southwest monsoon. The wave heights are usually 0.5 to 1.0 m with a maximum height of 2 to 3 m.

The coast of Sarawak and the northwest coast of Sabah are affected by the northeast monsoon waves with a maximum height of more than 4 m. The northeast and southeast coasts of Sabah also receive the northeasterly wave during the monsoon, but the wave heights are comparatively lower because the shorter fetch lengths due to the presence of the Philippine Islands prevent the waves to develop very much. In addition, during the months of April to November, typhoons often pass off the northeast coast and develop the waves.

2.4 River Features

Although the number of rivers in Malaysia is not clear, the river features of the 100 objective river mouths proposed for the Study such as the size of river basin, the riverbed gradient, the flow capacity and sediment are described as follows.

Size of River Basin

The size of river basin relates to the supply of sediment and maintenance flow. The catchment area of the objective rivers in the study area vary in size from 3 km^2 to 28,492 km^2, as shown in Table 2.4-1.

Riverbed Gradient

Riverbed gradient relates to the tidal prism and the discharge velocity necessary to flush the river mouth of siltation. Most of the objective rivers are presumed to have gentle gradients of less than 1/5,000 from the condition that the river stretch showing a tidal influence is longer than 20 km, as shown in Table 2.4-2.

Flow Capacity

Data on flow capacity related to the flooding problem and the flush water against river mouth siltation are available only in Sg. Terengganu (3,500 m^3/s), Kelantan (3,000 m^3/s) and Pahang (1,000 m^3/s). The NWRS show that most of the rivers have the flow capacity corresponding to a 2 to 3-year return period flood discharge.

Sediment

The annual erosion rate by major river basins has been estimated in the NWRS based on land use conditions. The results are presented in Table 2.4-3 and in Fig. 2.4-1.

The average annual erosion rate is 359 ton/km^2/yr for Peninsular Malaysia, 510 ton/km^2/yr for Sabah, and 1,496 ton/km^2/yr for Sarawak. Sarawak has a very high erosion rate compared with the other two regions, and this is attributed mainly to the activities of shifting cultivation. The areas covered by shifting cultivation are already over half of the total area in several districts of Sarawak.

2.5 Coastal Condition and River Mouth Formation

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. 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. The coastal plains are formed from a deep marine clay strata. The presence of this clay material reflects the relatively calm sea in the Strait.

The Sarawak coastline is characterized by long and straight sandy beaches on the east half and mangrove fringed shoreline on the west half. 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 sediment brought down by the many rivers.

Sabah has the longest shoreline of all the coastal states in Malaysia. 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.

Bed Materials

The fact that a majority of the coastal land in Malaysia consist of alluvial low flat lands shows that beaches are composed mainly of sandy to muddy materials. The distribution of shoreline materials is illustrated in Fig. 2.5-1.

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 western 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 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, the 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.

2.6 Land Use

Malaysia consists of Peninsular Malaysia, the states of Sabah and Sarawak, and the Federal Territory of Labuan in the northwestern coastal area of Borneo Island. It covers a total area of 329,758 km^2, comprising the 131,598 km^2 of Peninsular Malaysia (40%), the 73,711 km^2 of Sabah (22%), and the 124,449 km^2 of Sarawak (38%) which include the 91 km^2 of Labuan.

Peninsular Malaysia has eleven states, which are subdivided into 80 administrative districts excluding the Federal Territory of Kuala Lumpur. Likewise, the states of Sabah and Sarawak comprise 23 and 28 administrative districts, which are grouped into five and nine non-administrative divisions, respectively. (See Fig. 2.6-1.)

Peninsular Malaysia

A large area of grassland and forest, more than 6,000 km^2, has been transformed into agricultural land between 1966 and 1974. The area of rubber and oil palm plantations has increased by about 1,640 km^2 and 3,860 km^2, respectively, although grassland and forest still account for 60% of the total area. As shown in Fig. 2.6-2, agricultural lands such as rubber, coconut and paddy concentrate in the west coastal area of the Peninsula, while forest, mangrove, nipa and the like cover the east coastal area except the northern part. (Refer to Table 2.6-1.)

Sarawak

Settlement and associated non-agricultural lands cover only 0.1% (1.5% in the Peninsula in 1974), and forest accounts for more than 70%. The bulk of agricultural land (about 90% in 1976) is used for shifting cultivation. Details of the land use are presented in Table 2.6-2.

Sabah

Agricultural lands in the State of Sabah cover less than 10% even in 1989, as presented in Table 2.6-3. This is occupied mainly by cacao and oil palm cultivation lands, which are about 30% and 40% of the total agricultural lands, respectively. The rest is covered mainly by dry and wet forests, as determined from the aero-investigation conducted by the JICA Study Team in March 1992, because statistical data on other land use categories are not available.

2.7 Navigation and Fisheries

Navigation

The nation's ports contribute significantly to the national economy by handling almost 80% of the foreign trade, and also to regional development in stimulating economic activities centering on the ports. The number of arrivals or departures in the whole Malaysia exceeded 16,000 in 1990, and the net registered tonnage totalled more than 81 million, as shown in Table 2.7-1.

The total cargo handled grew by 8.9% per annum during the Fifth Malaysia Plan. The number of Malaysian vessels increased by 4.7% per annum, from 714 in 1985 to 898 in 1990.

Fisheries

Registration of fishing boats in Malaysia started in 1978 under classifications "A", "B", "C" and "C2" as defined by the type of gear, size of boat and fishing zone, as follows:

Class	Type of Gear	Boat Size (GRT)	Fishing Zone (nautical mile)
A	Traditional	---	less than 5
B	Commercial	less than 40	5 or more
C	Commercial	40.0 to 69.9	12 or more
C2	Commercial	70.0 or more	30 or more (deepsea)

Since Class "A" boats are not defined with boat size, they can be more than 70 GRT in case of anchovy purse seiners. Commercial gears consist mainly of trawl and purse seine. Trawl gear is towed on the sea bottom to catch fish in the trawling path, while purse seine net is shot in an encircling form around the school of fish. Both "C" and "C2" boats conduct fishing offshore, but deepsea fishing boats are also classified as "C2".

Marine fish landings in Malaysia reached 951,307 tons in 1990 with an annual growth of 7.8% compared with 1989, to which the east coast of the Peninsula much contributed with a growth of 20.1%. In the states of Sabah and Sarawak including

Labuan, landings in 1990 resulted in negative growth (-3.1%) compared with 1989, especially those in Sarawak State which deteriorated by as much as 6.5% (see Table 2.7-2).

The landings show a seasonal change, especially in the east coast where the maximum and minimum monthly landings were recorded at 38,542 tons in October 1990 and 12,441 tons in December, respectively. The minimum corresponds to one-third of the maximum and this is mainly because monsoons from November to February seriously hamper the fishing activities in the east coast. (See Fig. 2.7-1.)

The wholesale and retail values of marine landings in Malaysia for 1989 and 1990 are summarized as follows, and the average wholesale and retail prices in 1990 are calculated at RM 2,061/ton and RM 2,734/ton, respectively.

	Wholesale (million RM)	Retail (million RM)
1989	1,665.8	2,123.5
1990	1,960.6	2,601.5
Increase Rate (%)	17.7	22.5

Licensed fishing boats totalled 39,541 units in 1990, consisting of 24,015 inboard-powered (61%), 13,869 outboard-powered (35%), and 1,657 non-powered (4%) boats. By area, they are 16,994 (43%) in the west coast of the Peninsula, 6,140 (16%) in its east coast, 9,200 (23%) in Sabah, 7,066 (18%) in Sarawak and 141 in Labuan. The total number had slightly decreased by 1.1% compared with 1989.

Table 2.7-3 gives the number of fishing boats and fishermen by state in 1990. The number of persons engaged in marine fisheries amounted to 88,494. The number of fishermen averaged at 2.2 persons/boat for Malaysia, and that for the east coast of the Peninsula was figured at 3.4 persons/boat, much exceeding the national average. On the contrary, that for Sabah decreased to 1.3 persons/boat on the average compared with the wholesale value of landings. The average product per capita was calculated at RM 22,155 per annum.

2.8 Population

Table 2.8-1 gives the population and annual growth rate by state. Population census has been conducted every ten years, and the recently available statistical data are based on the 1970 and 1980 census returns.

The total population of Malaysia reached 10,439 thousand in 1970 and 13,136 thousand in 1980. The latter consists of 10,945 thousand (83.3%) in Peninsular Malaysia, 956 thousand (7.3%) in Sabah and 1,235 thousand (9.4%) in Sarawak. In Peninsular Malaysia, about 8.8 million or 80% of its population concentrates in the west-side eight states (including Johor).

2.9 Related Development Plans

Fisheries Development Plan

Compared with the achievement of 1.3% per annum under the Fifth Plan, the economic subsector of fisheries, most related to the Study, is projected to grow at a higher rate of 7.6% per annum in terms of the fisheries value added in the Sixth Plan. Due to the depletion of inshore resources, stress will be given to the development of deep-sea fishing and aquaculture in fresh and brackish water. The development of artificial reefs and creation of marine parks will be programmed to conserve and enrich the inshore fish resources. Besides, landing centers for deep-sea fishing boats of 70 gross tonnage and above will be provided to facilitate the development of the industry.

An efficient marketing and distribution system for fish will be set up to increase the income of fishermen and entrepreneurs and meet the requirement of consumers. In this connection, a feasibility study on fish marketing and distribution system in East Johor has been conducted with technical assistance from JICA.

River Mouth Improvement Plan

River mouth improvement projects have been conducted in several river basins as a part of regional development projects, flood mitigation projects, etc., as mentioned hereafter.

(1) Kemasin-Semerak Integrated Rural Development Project

The main components of the project include agricultural development and improvement of social infrastructures including flood protection, drainage, irrigation, new settlement, aquaculture, agro-based industry, etc. In line with the feasibility study conducted in 1980, breakwaters were constructed at the mouths of Sg. Kemasin and Pengkalan Datu in 1989 and that of Semerak in 1993.

(2) Golok River Basin Development Project

The primary objective of the project is to improve the standard of living and socioeconomic well-being of the inhabitants in the Golok River Basin through the development of agriculture, fishery, forestry and social infrastructures. To achieve this objective, the project involved flood control works. Breakwaters were recommended in 1985 for the river mouth improvement and the project is now under the detailed design stage.

(3) Besut Flood Mitigation Project

The primary objective of the project is to mitigate flood damage and to assure the benefit of the Besut Integrated Agricultural Development Project on the lower Semerak river basin area. In the feasibility study conducted in 1988, breakwaters were recommended to mitigate flood damage and to solve the navigation problem caused by siltation at the river mouth. The project is also under the detailed design stage.

(4) Terengganu Coastal Region Study

This study was conducted in 1980, mainly to prepare an integrated socioeconomic and physical development plan for the Terengganu coastal area. A training levee and a breakwater were recommended to improve and maintain the river entrance by training the tidal flow. The training levee has been constructed at the right bank, but the breakwater is yet to be scheduled for construction.

(5) Northern Terengganu Rural Development Project Study

This study started in 1992 and was scheduled to be completed in the same year. The scope of work includes flood mitigation works in the Setiu River Basin and it is expected that a river mouth improvement plan will be proposed through a comparative study among the measures of breakwater, river training works, dredging of entrance channel, etc.

(6) Others

Other studies related to river mouth improvement have been carried out. These include, among others, the Pahang River Basin Study in 1970, the Kerian Laut Drainage Project in 1988, the Kelantan River Basin-wide Flood Mitigation in 1989, and the Western Johor Agriculture Development.

2.10 Economic and Financial Aspects

Gross Domestic Product (GDP)

The gross domestic product of Malaysia reached RM 114,683 million in 1990, growing at 12% per annum during the period 1986-1990. At the current market price, the per capita GDP is estimated at RM 6,460. The areal breakdown is tabulated as follows:

Area	GDP (million RM)	Per capita GDP (RM)
Whole Malaysia	114,683	6,460
Peninsular Malaysia	92,297	6,310
Sabah	10,072	6,850
Sarawak	12,314	7,380

The Peninsula contributed much to the GDP by about 80%, according to the areal distribution of population, although the per capita GDP is slightly less than the national average. Noticeable is the per capita GDP of Sarawak which marked an average of RM 7,380, much exceeding the national average of RM 6,310.

Prices

Consumer price indices show that prices in Malaysia were stable with a low annual increase rate of 2.3% during 1986-1990. Noticeable are the prices in the State of Sabah which increased at the annual rate of only 0.97% during the same period, as shown in Table 2.10-1.

Labor and Employment

The total labor force in Malaysia amounted to 7,047 thousand persons in 1990, sharing about 40% of the total population, and it increased by 3.2% per annum during the period of 1986-1990. The labor force participation rate, or the percentage of the total number of economically active people to the total number of the working age population of 15 to 64 years old, showed about 66% throughout the period 1986-1990. The unemployment rate in 1990 was figured out at 6.0%, and it has a tendency to decrease compared with the 8.3% in 1987. (See Table 2.10-2.)

Federal Government Finance

As shown in Table 2.10-3, the total revenue reached RM 29,521 million in 1990, which accounts for about 26% of the GDP. It recorded double-digit gains in percentage for three consecutive years, from 1988 to 1990, compared with each previous year's figure, in spite of the downs in 1986 and 1987.

The total expenditure, consisting of operating and development expenditures, also increased considerably during the said three years (1988-1990), and amounted to RM 35,037 million in 1990; RM 27,105 million for operating expenditures and RM 7,932 million for development expenditures. The total expenditure accounts for about 31% of the GDP. The overall deficit has been largely financed from domestic sources of borrowing.

State Governments' Finance

The state governments' revenue comprises the states' own sources, federal grants and federal reimbursements. Petroleum and timber royalties are the major contributors to the state governments' own revenue, especially for the states of Sabah, Sarawak and Terengganu. The revenue has increased steadily during the period 1986-1990, and reached RM 6,264 million in 1990 with an increase rate of 11.6% from the previous year, accounting for about 21% of the federal government revenue.

The operating and development expenditures amounted to RM 4,297 million and RM 3,091 in 1990, respectively, totalling RM 7,388 million or 21% of the federal government's total expenditure in the same year.

Expenditure for Related Works

The Department of Irrigation and Drainage (DID), under the Ministry of Agriculture, is the main office in charge of river mouth treatment as discussed in detail in the following subsection. Thus, the federal government's expenditure for works related to river mouth clogging and siltation are made through the DID.

During the Fifth Plan (1986-1990), the development expenditure of the MOA totalled RM 2,804 million or about 10% of the federal government net development fund. That of the DID amounted to RM 386 million, which accounted for about 14% of the MOA's development expenditure and also 1.3% of the federal government's net development fund, as shown in Table 2.10-4.

Most of the related works in the DID's development expenditure are flood mitigation and coastal erosion protection works. The bulk of DID's development fund (more than 50%) has been allocated to flood mitigation works, while the actual expenditure for coastal erosion protection works which started to be implemented in 1988 was RM 13.5 million up to the end of the Fifth Malaysia Plan.

Dredging works were conducted by the DID for several river channels with a total expenditure of RM 9.2 million in the Fifth Plan period, as presented in Table 2.10-5.

CHAPTER 3. PROBLEMS AND MEASURES TAKEN

3.1 Problems on River Mouth Siltation

River mouths, which have a physically complex phenomena in the interference between river and sea, vary in form as a result of the interaction of several factors such as river flow, wind, wave, current, tide and sediment. River mouth siltation and the shifting of river mouth location are caused by different factors as well, and they present navigation and inundation problems in the study area (see Table 3.1-1).

Problems on Navigation

Most of the river mouths in the study area are heavily silted. As a result, fishing boats cannot navigate during low tide and fishermen have to wait until the next high tide to bring in their catch or go out into the sea. This problem is further aggravated if the river mouth has shifted to a new location, because fishermen find difficulty in locating the navigation channel. In the monsoon season, waves intruding into the river mouth cause problems to boats and facilities.

Commercial and passenger boats also have navigation problems during low tide. With the change in transportation system, however, some ports for transportation purposes have been relocated from the river mouth to the shore and the need for ports at river mouths has diminished. Some of such ports still existing have substantially no more activity for transportation purposes and, among the objective river mouths used for this purpose, only 16 have problems related to commercial navigation.

Problems on Inundation

Inundation by river floods is another serious problem concerning river mouth siltation, although inundation can be caused also by the poor flow capacity inherent to the river. Since land around river mouths is not always urbanized or used for agriculture, inundation does not always bring serious flood damage, and the number of river mouths identified to have inundation problems due to siltation is not so much.

3.2 Measures Taken

To solve the navigation and inundation problems at river mouths, the following measures have been implemented by offices concerned.

Dredging

Since the 1960's, dredging work in river mouths has been conducted by the MD and the DID. Some private enterprises have conducted dredging work also for their own purposes.

The MD, which carries out the work using its own four dredgers or the state-owned dredgers, maintains the river mouths for commercial navigation purposes such as Perlis, Kedah, Mersing, Terengganu and Kelantan (refer to Table 3.2-1).

The DID dredges river mouths mainly on contract basis in accordance with the requests from the committee chaired by the Ministry of Agriculture. When the river mouth is small, the DID sometimes use the dragline to excavate it.

The effect of dredging normally does not last so long. After the following monsoon season or sometimes within a few months after dredging, the river mouth is again heavily silted up. Maintenance dredging is, however, seldom done due to financial restrictions.

Since dredging is costly compared to the economic return as mentioned in the report "Mission to Malaysia, ESCAP, 1987," and because it also requires maintenance work, the DID had undertaken a study on the possibility of introducing low-cost dredging by agitation as recommended by the said Mission to remove silt at the muddy western coasts of Peninsular Malaysia.

Construction of Structures

Table 3.2-2 lists up the structures existing at river mouths. The first breakwater was constructed in the 1950's at the mouth of Sg. Melaka, and this was followed in 1989 by those at Sg. Pengkalan Datu, Kemasin and Gali for the purpose of flood mitigation under the Kemasin-Semerak Integrated Rural Development Project. A breakwater was also constructed in 1992 at the mouth of Sg. Cenang for the purpose of river mouth stabilization, and another breakwater is under construction at the mouth of Sg. Semerak for flood mitigation. The construction work is managed by the DID.

Several studies regarding breakwaters are going on. A breakwater was proposed in 1980 by the Terengganu Coastal Region Study to be constructed at the mouth of Sg. Terengganu, and those proposed at the river mouths of Sg. Golok and Besut are now in the detailed design stage.

As for the effect of breakwaters, those at the mouths of Sg. Kemasin and Pengkalan Datu are said to be self-maintained after construction, while that at the mouth of Sg. Gali is silted up in the dry season due to the insufficient low water discharge to flush out siltation. The construction of a breakwater is also said to bring about adverse influence to the surrounding area as in the case of the Pengkalan Datu River Mouth.

A training dike was constructed at the mouth of Sg. Terengganu to stabilize the river mouth and to prevent erosion of the river bank. A breakwater, together with a training wall, is being constructed by fishermen at the Kerteh River Mouth, and some jetties that function to maintain the river mouth have been constructed by the JKR.

CHAPTER 4. CLASSIFICATION AND CATEGORIZATION OF RIVER MOUTH

4.1 Classification of River Mouth

The subject river mouths, 100 in number as originally proposed, were first classified into groups according to natural and socioeconomic conditions. This classification was necessary to provide the basic data to screen the 75 objective river mouths for the Master Plan, to select the representative river mouths for the Master Plan Study, and to examine the measures for river mouth improvement.

4.1.1 Natural Conditions

It is essential to know the process at which the river mouth has undergone to form its current configuration in order to clarify the cause and behavior of river mouth siltation and to determine the countermeasure for the river mouth problem. Factors which characterize natural conditions are taken up, among others, for the classification of river mouths; namely, (1) coastal geomorphology, (2) oceanographic and hydrological conditions, (3) configuration of river course, (4) shoreline formation, (5) coastal materials, and (6) river mouth condition.

The first three factors are considered to belong to the external factors forming the river mouth configuration, while the latter three belong to the results coming from the external factors. As shown in Table 4.1-1, the river mouths are classified according to these factors which are explained briefly as follows:

(1) Coastal Geomorphology

Coastal geomorphology is one of the important factors to understand the characteristics and development of the river mouth. The objective river mouths are classified according to the type of coast where they are located, namely; (a) straight coast, (b) protruding coast, (c) embayed coast, (d) estuary, (e) headland, (f) sheltered by island, (g) delta formation, and (h) sand spit.

(2) Oceanographic and Hydrological Conditions

Oceanographic conditions, namely wave and tide, are the essential factors from the ocean side to form the river mouth configuration. Waves create littoral current and subsequent sandbar formation, and tidal prism contributes in maintaining the river mouth open by the current due to tidal fluctuation.

Hydrological condition represented by the river flow is also an essential factor for the river mouth condition. If the catchment area is large, the river flow is strong and it maintains the river mouth open, although it brings larger sediments from the river basin.

Wave is classified as either a high straight wave, a high oblique wave, or a low wave; while, tide is either a large tidal prism or a small tidal prism. On the other hand, river flow may be high or low from a large catchment area or a small catchment area.

(3) Configuration of River Course

The river course expressed in a manner of meandering or straight is also one of the factors to consider in order to know the river mouth condition.

(4) Shoreline Formation

Due to the unbalanced supply of sediment from river flow, tidal current and littoral drift, the shoreline at the river mouth could show a certain form such as convex, straight, concave or one-side bar. A convex shoreline at the mouth means sufficient supply of sediment discharge from the river, and a straight shoreline means low sediment discharge from the river. If longshore transport by waves is predominant, a sandbar develops at one side of the river mouth, and artificial dredging in the river mouth sometimes bring a concave shoreline.

(5) Coastal Materials

Coastal materials which are sensitive to the variation of external factors, are essential to know the predominant external one. They are classified broadly into four; namely, sandy, muddy, mixed (sand predominant), and mixed (mud predominant).

(6) River Mouth Condition

To understand river mouth problems and find proper solutions, knowing the river mouth condition is important. River mouth condition is classified according to configuration into four categories; namely, completely closed by sandbar, partially closed by sandbar, shallowed by submerged bar, and open to the sea.

4.1.2 Socio-Economic Conditions

Two main factors are taken up under the socio-economic condition; namely, land use condition and navigation condition (refer to Table 4.1-2). These are further classified into the following items, mainly to identify the significance of the inundation problem when it occurs and the navigation problem when the river mouth is silted up.

	Factors	Items
(1)	Land Use Condition	- Urban area - Village - Agriculture - Forest - Swampy area - Unused land
(2)	Navigation Condition	- Fishing boat only - Fishing and commercial boat

4.2 Categorization of River Mouth

To select the river mouths for the Master Plan Study, the proposed 100 river mouths are categorized according to the seriousness of the existing problems into three; namely, Category 1 (Critical), Category 2 (Significant), and Category 3 (Acceptable).

River mouths in Category 1 and Category 2, 75 in number, are the objective river mouths for the Master Plan Study.

4.2.1 River Mouth Problem

River mouth problems due to siltation are presented in Table 3.1-1. This table reflects the condition that problems on navigation of fishing boats prevail in all the river mouths, while problems on navigation of commercial and passenger boats occur on 16 river mouths including those once dredged.

On the other hand, problems on inundation are found on several river mouths. Since it is difficult to identify the seriousness of a river mouth problem in a numerical manner, several factors based on physical, economic and social conditions are considered.

4.2.2 Factors and Criteria for Categorization

As mentioned above, problems on inundation appear on several river mouths; hence, information regarding this matter is not useful for the categorization. More consideration is given to the seriousness of the navigation problem of fishing, commercial and passenger boats determined according to the physical, economic and social aspects, as follows:

(1) Physical Aspect

Seriousness of the navigation problem due to siltation can be identified by comparing the river mouth configuration; specifically, the assumed minimum water depth based on the observed one, together with the draft of boats plying the river mouth. Boats plying each river mouth are classified according to draft into large, medium or small (see Table 4.2-1) and, using the data on water depth, the physical condition at each river mouth is evaluated as either very serious, serious, or fair according to the following criteria (refer to Table 4.2-2 and 4.2-3):

(a) Very Serious

The assumed minimum depth is shallower than the draft of the largest boat.

(b) Serious

The assumed minimum depth is in the range between the draft of the largest boat and the clearance plus draft of the largest boat.

(c) Fair

The assumed minimum depth is deeper than the draft of the largest boat plus clearance.

(2) Economic Aspect

Among the available data, factors related to the economic aspect mainly include the number of fishermen and the number of fishing, commercial and passenger boats. On this regard, the number of fishermen is taken up, because the magnitude of economic influence caused by the navigation problem depends on the people involved in fishing activities which may be in proportion to the number of fishermen. As for the commercial activities, it is clear that such activities are confined in the ports which also have vivid fishing activities and thus, only fishing activities are considered in the economic aspect.

Since it is difficult to classify the magnitude of economic influence into three levels, very serious, serious and fair, river mouths are divided into three groups based on the number of fishermen, as follows:

Seriousness	Number of Fishermen	Number of River Mouths
Very Serious	More than 200	35
Serious	200 - 50	39
Fair	Less than 50	26

(3) Social Aspect

The existence of complaints from fishermen is taken up, since they reflect the situation as serious even if the number of fishermen at the river mouth is small. River mouths are then classified into three groups based on the existence of complaints, as follows:

Seriousness	Condition
Very Serious	Existence of very strong complaint
Serious	Existence of fairly strong complaint
Fair	No complaint

4.2.3 Categorization

Using the above-said levels of seriousness which amount to 27 combinations, the river mouths are categorized into three; namely, Category 1 (Critical), Category 2 (Significant), and Category 3 (Acceptable), in accordance with the following criteria:

(1) Among the three aspects, the physical and economic aspects are used as the primary factors for the categorization; and

(2) The social aspect is used as a supportive factor to upgrade the river mouths from a significant to a critical condition.

The combinations for the categorization are as follows:

(1) Category 1 (Critical)

River mouths that fulfill the following combinations are included in Category 1:

Combination 1: The river mouth condition is very serious in both the physical and economic aspects.

Combination 2: The river mouth condition is very serious in both the physical and social aspects, but it is serious in the economic aspect.

Combination 3: The river mouth condition is serious in the physical aspect, but it is very serious in the economic aspect and very serious or serious in the social aspect.

(2) Category 2 (Significant)

Except the river mouths in Category 1, those which fulfill the following combinations fall under Category 2:

Combination 1: The river mouth condition is more than serious in both the physical and economic aspect.

Combination 2: The river mouth condition is very serious in the physical aspect, but it is fair in the economic aspect and very serious or serious in the social aspect.

Combination 3: The river mouth condition is fair in the physical aspect, but it is very serious in the economic aspect and very serious or serious in the social aspect.

(3) Category 3 (Acceptable)

The remaining river mouths not categorized under either Category 1 or Category 2 belong to Category 3.

The combinations of seriousness in each aspect of categorization are shown in Table 4.2-4. The categorization results are shown in Table 4.2-5, and Table 4.2-6 shows the river mouths by category.

4.3 Selection of Objective River Mouth for the Master Plan

River mouths belonging to Category 1 and Category 2 in the categorization mentioned above are selected as the objective river mouths for the Master Plan Study. Since conditions in Category 3 are acceptable, river mouths under this category have not been considered. As summarized in the following table, there are 75 objective river mouths for the Master Plan Study.

Category	Number of River Mouths	Remarks
Category 1 (Critical)	35	Objective river mouths for Master Plan.
Category 2 (Significant)	40	Objective river mouths for Master Plan.
Sub-Total	75	
Category 3 (Acceptable)	25	Conditions acceptable; not considered for Master Plan.
Total	100	

CHAPTER 5. PRINCIPLES OF FORMULATION OF MASTER PLAN

5.1 Procedure for Formulation of Master Plan

As mentioned in Chapter 4, 75 of the 100 river mouths originally proposed for the National River Mouths Study are selected as the objective river mouths for the Master Plan Study. Herein discussed is the procedure for the formulation of the Master Plan.

5.1.1 Selection of Representative River Mouth

Since it is difficult to carry out the same level of master plan study for all the 75 objective river mouths, they are classified into groups according to physical characteristics and a representative river mouth is selected from each group considering the availability of data, seriousness of problems and others. To select the countermeasures and calculate project benefit, a comparative study is made on alternative cases for each representative river mouth and the project benefit that will accrue from the optimum countermeasures considered is also estimated.

5.1.2 Application of Countermeasures to Other River Mouth

Countermeasures considered for the representative river mouth are also applied to the other river mouths in the group, but the design features are modified considering the river mouth scale such as river mouth width, depth, design boat size, etc. The costs of countermeasures for each river mouth are then estimated from the modified design features.

5.1.3 Estimation of Benefit for Other River Mouth

Project benefit for the other river mouths in each group is calculated applying the same parameters used for the representative river mouths, i.e., population, size of urban area and number of boats.

5.1.4 Formulation of Master Plan and Project Evaluation

The Master Plan is formulated based on the project cost and benefit mentioned above. Although it is necessary to provide an implementation schedule for the project evaluation in a manner of EIRR, it is not realistic to formulate the implementation schedule for such a great number of river mouth improvements covering 75 river mouths. In this connection, the project evaluation is made only in a manner of cost and benefit ratio assuming that project life is 30 years.

5.1.5 Formulation of the First Phase Project

The number of river mouths for the Master Plan is so large that one-time project execution may not be realistic. In this connection, a first phase project is examined to facilitate project realization and the project's viability is also examined in a manner of EIRR assuming the implementation schedule.

5.2 Criteria for the Formulation of Master Plan

5.2.1 Design Boat Size

The main problem on river mouth siltation prevailing in all the 75 objective river mouths is the navigation problem for fishing boats. Establishing the size of fishing boat that can navigate in each river mouth is essential to formulate the Master Plan.

In this regard, the Malaysian Government has a plan to develop the fishing industry through the introduction of larger sized fishing boats in the future, as given in the Table 5.2-1. The Master Plan is therefore formulated to assure navigation by the following design boat sizes.

GRT (Ton)	Length (m)	Beam (m)	Depth (m)	Draft (m)
40	14.02	4.20	2.40	1.70
70	18.35	6.02	2.50	2.18
100	23.90	6.09	2.52	2.37
150	23.50	7.50	3.00	2.93
200	29.43	7.30	3.45	3.21

Source: Department of Fisheries, Malaysia

Although the time to introduce the larger sized boats at each river mouth is not yet decided, it is assumed that the time will correspond to the project completion year so as to make a fair comparison of economic viability for each river mouth.

5.2.2 Design Flow Capacity for River Mouth Improvement

River mouth improvement is usually carried out to minimize flood damage. However, river mouth improvement is not effective unless river improvement upstream is also undertaken; especially, if flood damage is due to insufficient flow capacity in the upper stretches.

Therefore, river mouth improvement is to be designed to keep the existing flow capacity of the river channel in the upper stream. In case a river improvement plan has already been implemented or is to be realized in the near future as in the Perlis River Mouth, the design discharge of that plan is adopted for the river mouth improvement.

5.2.3 Project Completion Year

For the formulation of the First Phase Project, it is necessary to establish the project completion year. Since the river mouth improvement works are primarily for the fishing industry, the planning time scale must be related to the future fishery development in Malaysia. Under the above consideration, the Malaysian Government has figured out the year 2005 as the planning time scale.

CHAPTER 6. BASIC STUDY AND ANALYSIS FOR THE IMPROVEMENT OF REPRESENTATIVE RIVER MOUTH

6.1 Selection of Representative River Mouth

6.1.1 Grouping of River Mouth

Criteria for the Grouping of River Mouths

In accordance with the principle of formulation of the Master Plan, the objective river mouths are grouped according to physical characteristics, as mentioned in Chapter 5. The main physical characteristics of a river mouth are identified through quantification (for detailed explanation, see the Supporting Report on River Mouth Geomorphology). The quantification is further confirmed through empirical approach based on the results of the preliminary investigation.

For the grouping of river mouths, the following factors are considered:

(1) Coastal Geomorphology and Shoreline Formation

Coastal geomorphology and shoreline formation are divided into several categories, as shown in Table 4.1-1, and grouped into the following three main groups: (a) Straight, (b) Estuary, and (c) Protruding.

(2) External Force

External forces, namely wave and tide, are proven through quantification as the principal factors determining the condition of a river mouth. Wave is categorized into the following three types: (a) High Straight Wave, (b) High Oblique Wave, and (c) Low Wave.

Tidal prism is also a factor which characterizes river mouth condition. It is categorized into the following two types: (a) Large Tidal Prism; and, (b) Small Tidal Prism.

River flow with a parameter of catchment area is considered to be included in the scale of the tidal prism; namely, a larger tidal prism generally reflects a wider river and a larger catchment area. Accordingly, the river flow factor is not considered for the grouping.

(3) River Course Pattern, River Mouth Condition and Coastal Material

These factors are not taken for the grouping, since the river course pattern does not dominate the river mouth condition. On the other hand, river mouth condition and coastal materials are reflected in the coastal geomorphology and external force.

Results of Grouping

The objective river mouths are classified into groups, as shown in Table 6.1-1. Although the possible number of combinations is 18, the actual number of groups is 10 because there are no subject river mouths in eight of the combinations.

6.1.2 Selection of Representative River Mouth

A representative river mouth is selected for each of the 10 groups for the detailed study on optimum countermeasures and project benefit. Selection of the representative river mouth is made in consideration of the availability of data (Table 6.1-2), the seriousness of the problem (categorization results), the priority of the river mouth in the state where it is located, and the physical representation of the river mouth in the group. A representative river mouth for each group is selected, as shown in Table 6.1-3 and summarized in the following table.

Grp. No.	Coastal Geomor-phology	External Force		No. of River Mouths	Representative River Mouth	
		Wave	Tidal Prism		Serial	Name
1	Straight	High & Straight	Large	6	61	Marang (T'gganu)
2	"	High & Oblique	Large	10	53	Kuantan (Pahang)
3	"	"	Small	4	57	Kerteh (T'gganu)
4	"	Low	Large	4	1	Perlis (Perlis)
5	"	"	Small	26	14	Tg. Piandang (Perak)
6	Estuary	High & Oblique	Large	3	80	Oya (Sarawak)
7	"	Low	Large	16	19	Beruas (Perak)
8	Protruding	High & Straight	Large	4	62	Terengganu (T'gganu)
9	"	High & Oblique	Small	3	90	Papar (Sabah)
10	"	Low	Large	3	5	Kedah (Kedah)

6.2 Hydrological Analysis

6.2.1 River Discharge

River discharge is one of the major factors determining the river mouth configuration.

Flood Discharge

Probable flood discharges are estimated for the representative rivers mouth based on the results of the NWRS. The probable flood discharges are compared with the flow capacity of the river channel in Subsection 6.2.2 to examine the flood inundation problems caused by river mouth siltation. The probable flood discharges by return period are given as follows:

River Mouth Serial	Name	Catchment Area (km^2)	Flood Discharge (m^3/s) 2-yr	5-yr	10-yr	20-yr	50-yr	100-yr
1	Perlis	600	90	150	190	240	280	330
5	Kedah	4,040	510	690	790	920	1,070	1,200
14	Tg. Piandang	9	9	12	14	16	18	20
19	Beruas	240	50	80	110	140	170	200
53	Kuantan	1,710	1,000	1,600	2,000	2,400	3,000	3,500
57	Kerteh	240	450	600	690	780	900	1,000
61	Marang	460	580	820	1,000	1,100	1,300	1,500
62	Terengganu	4,650	2,300	4,100	5,300	6,600	8,600	10,100
80	Oya	1,820	1,400	2,400	3,200	4,000	5,300	6,400
90	Papar	770	700	1,000	1,300	1,600	1,900	2,200

Source: NWRS

Long term run-off characteristics are often expressed in a flow duration curve. Fig. 6.2-1 shows the flow duration curves of the representative river mouths, obtained by modifying the non-dimensional duration curves constructed for the main discharge stations in the NWRS.

6.2.2 Flooding Problem

Non-uniform flow calculation is carried out in the Study to estimate the flood water levels of the representative river mouths. The water level profiles obtained are shown in Fig. 6.2-2.

The calculated water levels are compared with the elevations of the river banks to estimate the flow capacities, and the results are shown in the following table. Also given in the table are the flow capacities estimated in the NWRS, which could be regarded as those of the upper reaches of the river mouths.

River Mouth		Existing Flow Capacity			
		Near River Mouth*		Upper Stretches**	
Serial	Name	(m^3/s)	Return Period	(m^3/s)	Return Period
1	Perlis	280	50 years	-	3 years
5	Kedah	1,070	50 years	-	3 years
14	Tg. Piandang	56	more than 100 years	No Data	
19	Beruas	730	-do-	No Data	
53	Kuantan	3,700	-do-	-	2 years
57	Kerteh	1,000	50 years	-	2 years
61	Marang	1,300	70 years	-	2 years
62	Terengganu	2,600	2.4 years	3,500	3.8 years
80	Oya	2,000	3.6 years	-	1 year
90	Papar	840	3.0 years	-	1 year

* Estimated in this Study
** Estimated in the NWRS

Except Terengganu, Oya and Papar, the other seven river mouths have a large capacity of not less than a 50-year return period flood, and flooding is considered to be negligible.

As for Oya and Papar, the flow capacity near the river mouth is as small as a 3-year flood, but greater than that of the upper reaches. This means that flood overflows in the upper reaches before reaching the river mouth and hence, flood damage is attributed to the lesser flow capacity in the upper reaches and not to siltation at the river mouth.

The situation of the Terengganu river mouth differs from the others. The flow capacity near the river mouth is 2,600 m^3/s, which is 900 m^3/s less than the 3,500 m^3/s capacity of the upper reaches. A maximum of 3,500 m^3/s flood could possibly reach the lower channel near the river mouth without overspill from the upper channels resulting in the inundation of low areas near the river mouth. The cause of the inundation could be the insufficient flow capacity due to the southeasterly expanding sand spit at the river mouth, and some countermeasures should be taken to mitigate the flooding problem. The inundation area of the 3,500 m^3/s maximum probable flood has been identified from the river cross section survey results, as shown in Fig. 6.2-3, and 45 ha of land and some 530 houses are estimated to be inundated.

6.2.3 Sediment

The river is one of the biggest source of sediment around the river mouth. Therefore, it is very important to estimate the quantity of sediment transported into the river mouth to clarify the river mouth configuration.

Observation

Suspended load is periodically measured by DID at the discharge gauging stations, as given in Table 6.2-1. The following table shows the annual suspended loads. Bed load is not systematically observed in Malaysia.

Station Name	River System	Catchment Area (km^2)	Annual Suspended Load* (ton/yr)	(ton/km^2/yr)
Titi Baru	Perlis	126	3,000	24
Bt. Keneu	Kuantan	582	260,000	447
Kg. Tanggol	Terengganu	3,340	1,492,000	447
Kagopan	Papar	536	42,000	78

* Wash load included.

Annual Sediment Discharge

(1) Sediment Rating Curve

Except those in the muddy west coast, sediment discharge is calculated to determine the sediment supply volume to sandy river mouths. This supply volume is used to estimate the siltation rate of the navigation channel proposed to be constructed by dredging.

The Brown's formula is employed to calculate the total sediment discharge of bed load and suspended load. The necessary hydraulic parameters such as friction velocity are obtained through the non-uniform calculation. The sediment rating curves for the river mouth are obtained by regression analysis of water and sediment discharge, as shown in Fig. 6.2-4.

(2) Annual Sediment Discharge

Annual sediment discharge is estimated by a combination of sediment rating curves and duration curves. The results are given as follows:

River Mouth		Catchment	Annual Sediment Discharge	
Serial	Name	Area (km^2)	(1000 m^3/yr)	(m^3/km^2/yr)
53	Kuantan	1,710	12	7
57	Kerteh	240	11	45
61	Marang	460	37	81
62	Terengganu	4,650	230	50
80	Oya	1,820	72	40
90	Papar	770	9	12
Average		1,608	62	39

6.2.4 One-Dimensional Dispersion Analysis

As discussed in Section 2.5, the west coast of Peninsular Malaysia is almost wholly covered with muddy materials. The movement of muddy materials is very complicated because of many factors such as flocculation, deposition, consolidation and erosion. The location of the river mouth, where wave, tidal flow and river flow exist and interfere with each other, makes the phenomenon more difficult to understand.

A numerical approach is tried to estimate the siltation rate in the river channel of Tg. Piandang by applying the results of recent studies. The one-dimensional dispersion model was applied to simulate such the phenomena. (Refer to Fig. 6.2-5.)

First, the unsteady flow analysis was carried out to establish the hydraulic parameters such as velocity, discharge area and shear stress. Using these parameters, the dispersion analysis is conducted to determine the movement of bottom materials.

A 24-hour calculation is conducted for both the existing and the channel proposed to be constructed by dredging which, as discussed in Section 7.3, is a 3.53 km long and 45 m wide navigation channel with a base elevation of LSD -3.7 m. Through this calculation, the siltation rate of the inner dredged channel is estimated.

The results of the unsteady flow and the dispersion analyses are presented in Fig. 6.2-6 and in Fig. 6.2-7, respectively. The annual siltation rate is obtained by multiplying the 24-hour estimated rate by 365 days, and the findings are summarized as follows:

(1) As shown in Fig. 6.2-6, velocity will decrease according to the dredging depth. A maximum velocity of 12 cm/s is expected in the existing channel, but only 4 cm/s in the proposed dredged channel. Discharge itself, however, will not change even after dredging because of the increase of cross sectional area.

(2) Siltation is remarkable near the river mouth. Siltation rates of 40 and 30 cm/yr at the lowest sections of the existing and the proposed dredged channels are estimated. At the upper stretches, siltation rate is in the order of 10 cm/yr for both channels although erosion is seen at 1.3 km.

(3) Considering that the existing channel has been practically stable, the obtained rates seem to be over-estimated. The inner channel is expected to be stable even after dredging.

(4) The dispersion analysis is governed by several coefficients of varying values due to local conditions. In this present study, the coefficient values assumed in preceding studies are adopted, but the available data is not enough to examine the assumptions. To upgrade accuracy, further data collection such as observation of mud concentration should be conducted.

6.3 Oceanographic Analysis

6.3.1 Tides

Malaysian coasts are influenced by three types of tides, i.e., diurnal, semi-diurnal and mixed tides according to the location and time of occurrence. The Strait of Malacca has a mixed, prevailing semi-diurnal tide, while a diurnal tide is predominant in the South China Sea.

Tide levels of the 10 representative river mouths are determined with reference to the Tide Tables by the Directorate of Hydrology, Royal Malaysian Navy and the yearly record book entitled "Tidal Observation Records" published by DSM, applying the closest stations to the representative river mouths (refer to Table 6.3-1). All the tide levels are reduced to the Land and Survey Datum (LSD) established at Pelabuhan Kelang in 1912 by the British Admiralty.

6.3.2 Waves

Waves are the principal causes of littoral process. The significant characteristics of waves affecting sediment transport near a beach are height, period and direction of breaking waves.

Available Data

(1) Shipboard Observation

The DID has a database of deepwater waves around the territory of Malaysia, which were observed on shipboard for a long period from 1949 to 1983. Wave statistics have been obtained for each square area called Marsden Square measuring 1 degree (latitude) by 1 degree (longitude).

In principle, these deepwater wave statistics are used in the master plan study. The wave statistics are summarized in Table 6.3-2, where the approaching wave frequency is tabulated by wave height, period and approaching direction.

(2) LEO Program

The DID established the Littoral Environmental Observation (LEO) Program in 1988 to provide data on coastal phenomena at low cost. At present, there are 17 LEO stations along the Malaysian coast. Breaker height, wave period, direction of wave approach, wind speed, wind direction, longshore current velocity and beach slope, as well as the presence of beach cusps and rip currents have been observed almost daily.

Two of the 17 stations, C01 and T01, are close to the representative river mouths of Kuantan and Terengganu, respectively, as shown in Fig. 6.3-1. The observation data of these two stations are expected to provide valuable information on wave, current and longshore sand transport.

Refraction Analysis

Deepwater waves are transformed into the shallow water condition by wave refraction analysis. Deepwater waves with several combinations of approaching direction and wave period of 6, 8 and 10 seconds are considered for each river mouth. The results are summarized in Table 6.3-2.

Breaker Index

The breaker height index is used to determine the location along any wave orthogonal at which a particular approaching deepwater wave breaks. The breaker index for each representative river mouth is estimated using the Weggel's formula, as shown in Table 6.3-3. Since the beach slope of representative river mouths are, in common, very gentle (less than 1/100), the estimated indices are all in the range of 0.77 to 0.79. The value of 0.78 is adopted as a common breaker index for all the river mouths.

6.3.3 Longshore Transport Rate

Longshore transport is a principal factor governing the river mouth configuration, and the transport rate is estimated at the sandy river mouths of Kuantan, Kerteh, Marang, Terengganu, Oya and Papar. These transport rates are used to estimate the siltation rate of the proposed dredged navigation channel.

Energy Flux Method

The energy flux method is an acceptable practice when sufficient data showing historical changes in the topography of the littoral zone (bathymetric survey charts, dredging records) are not available. This method is based on the assumption that the longshore transport rate depends on the longshore component of energy flux in the surf zone.

In this connection, the coefficient of longshore transport rate to longshore energy flux factor is usually determined by observation. In this Study, the coefficient is estimated based on the observed siltation rate of the dredged outer channel of the Mersing River Mouth. (Refer to Table 6.3-4.)

Longshore Transport Rate

Using the coefficient mentioned above, longshore transport rates are estimated for the six (6) sandy representative river mouths; Kuantan, Kerteh, Marang, Terengganu, Oya and Papar. The breakdown of the calculation is presented in Table 6.3-5, and the transport rates are summarized in the following table.

River Mouth		Longshore Transport Rate (1000 m^3/yr)		
Serial	Name	Q_r	Q_l	Q_r+Q_l
53	Kuantan	205	0	205
57	Kerteh	202	2	204
60	Marang	287	194	481
61	Terengganu	238	191	429
80	Oya	186	257	443
90	Papar	22	85	107

Q_r : Longshore transport rate from observer's left to right.
Q_l : Longshore transport rate from observer's right to left.

Use of LEO Data

An alternative method of calculating the energy flux factor P_{ls} is to use the LEO data. To evaluate the obtained transport rates at the representative river mouths, the available LEO data are used.

As discussed in Subsection 6.3.2, the two LEO Stations C01 and T01 are close to the representative river mouths of Kuantan and Terengganu, respectively (Fig. 6.3-1). The estimation is, however, conducted for only the C01 station because the T01 observation is found to be less accurate. The results are summarized below.

Station	Data Period	No. of Data	Energy Flux Factor (J/s/m)		Longshore Transport Rate (1000 m^3/yr)		
			P_{lsr}	P_{lsl}	Q_r	Q_l	Q_r+Q_l
C01	Jun. '88 to Dec. '90	375	395	346	70	61	131

P_{lsr} : longshore energy flux from observer's left to right.
P_{lsl} : longshore energy flux from observer's right to left.
Q_r : longshore transport rate from observer's left to right.
Q_l : longshore transport rate from observer's right to left.

The total rate of 131,000 m^3/yr is fairly smaller than the 205,000 m^3/yr for the Kuantan River Mouth, but still remains in the same order. The reason why Q_r and Q_l are almost balanced is that the shoreline at the station faces more perpendicularly to the approaching wave. The obtained transport rate of the representative river mouths is reasonable, taking the accuracy of such estimation into consideration.

6.4 Selection of Applicable Countermeasures

6.4.1 Possible Countermeasures

There are several countermeasures against the problem of river mouth siltation, and the following structural measures are considered (refer to Fig. 6.4-1).

(1) Breakwater

A breakwater is a structure for the protection of a shore area, harbor, anchorage, river mouth or basin from waves and, generally, protection against intrusion of drifting sand in the navigation channel is not included in the breakwater's function. Breakwaters for navigational purposes are constructed to create calm water in a river mouth and to provide protection for the safe mooring, operating and handling of ships, as well as protection for harbor facilities.

(2) Jetty

A jetty is a structure extending into the water to direct and confine river or tidal flow into a channel, and to prevent or reduce intrusion of littoral drifting sand into the navigation channel. Jetties located at the entrance to a bay or river also serve to protect the entrance channel from cross currents. When located at inlets through barrier beaches, they also serve to stabilize the inlet location. In case bed materials such as marine clay do not have enough bearing capacity for such a heavy structure, a submerged jetty is proposed because of its reduced load.

(3) Training Wall

A training wall is provided to stabilize the river mouth and the waterway by controlling the development of a sandbar and the shifting of the river channel.

(4) Groin

There are two types of groins; river groins and coastal groins. River groins are also known as spurdikes and are training structures that extend from the river bank to the river at an angle, or perpendicular, to the flow. Their functions are to train a river along a desired course, to protect the bank by keeping the flow away, and to contract a wide river channel and improve the depth for navigation.

Coastal groins are barrier-type structures that extend from the shore to the wave breaking zone. Their basic purposes are to interrupt longshore sand movement, to accumulate sand on the shore, or to retard sand losses.

(5) Dredging

There are basically three kinds of dredging methods applicable to navigation channel dredging, as follows:

(a) Cutter suction dredger with a booster station, discharging to the coastal area;

(b) Trailing suction hopper dredger, pumping ashore to the coastal area or continuing to the disposal ground offshore; and

(c) Dredging by grab or backhoe, discharging to barges; barges being unloaded and pumped onto the coastal area or offshore disposal ground.

Judging from the advantages and disadvantages of these methods, the cutter suction dredger is adopted for this master plan study.

(6) Reservoir for Extension of Tidal Prism

Generally, the water depth at a river mouth is maintained by the eroding current caused by tidal prism and that is maintained in proportion to the volume of tidal prism. To assure the water depth at the river mouth, provision of a reservoir to extend the tidal prism is sometimes considered. A reservoir however may not be effective to maintain the water depth of the outer channel unless a jetty is provided along the outer channel, because the current by tidal prism spreads out in the outer channel resulting in the reduction of sediment transport capacity.

6.4.2 Considerations for Setup of Alternative Study Cases

As mentioned above, there are six applicable countermeasures for river mouth improvement. However, these countermeasures are adopted according to the objectives to cope with the river mouth problem as shown in Table 6.4-1. These objectives are (a) to provide a navigation channel; (b) to provide maintenance or assurance of the navigation channel; (c) to provide protection against wave intrusion into the river mouth; (d) to provide stabilization of the river mouth; and (e) to provide stabilization of the river channel.

In this connection, the following considerations are made for setting the alternative study cases.

(1) Since objective (a), to provide a navigation channel, is indispensable to assure the navigation of the design boat at the first stage, dredging, which is the only applicable measure for this objective, is included in all the alternative cases.

(2) Since objective (b), to provide maintenance or assurance of the navigation channel, is to maintain the navigation channel at a certain depth, alternative cases are set up to compare the advantages of the three countermeasures applicable for this objective; the jetty, dredging and the reservoir.

(3) For comparison among the countermeasures in objective (b), it is assumed that a jetty is effective to completely provide protection against the intrusion of drifting materials into the navigation channel, so that maintenance dredging is not necessary for inclusion in the alternative cases. However, in the case of a submerged jetty, siltation in the navigation channel is partially prevented according to the height of the submerged jetty and, therefore, maintenance work is necessary. A reservoir may be effective for the maintenance of the navigation channel if a jetty is provided, so that a reservoir when possible using a natural reservoir like a lagoon and a swampy area is employed only in combination with a jetty.

(4) Since there is only one countermeasure having objective (c), to provide protection against wave intrusion into the river mouth, this countermeasure is applied to the alternative cases as necessary.

(5) As for objective (d), to provide stabilization of the river mouth, there are two countermeasures, jetty and training wall. The former has the additional function of maintaining/assuring the navigation channel, while the latter is provided only for the stabilization. Consequently, a training wall is adopted to the alternative

case requiring protection against shifting of the river mouth and does not include a jetty.

(6) Since there is only one countermeasure having objective (e), to provide stabilization of the river channel, this countermeasure is applied to the alternative cases as necessary.

The countermeasures are provided to solve the river mouth problems. However, the provision of countermeasures sometimes bring about adverse influences. In case of a jetty which traps drift materials, it sometimes causes coastal erosion in neighboring areas. To prevent such an adverse influence, countermeasures such as revetment, nourishment and coastal groin are considered, and the selection of the optimum countermeasure requires further detailed study using detailed basic data. In this study, the coastal groin, which is commonly used for the prevention of coastal erosion, is adopted when a jetty is considered as an alternative case.

6.5 Effect of Countermeasures

The effect of countermeasures can be evaluated in quantitative or qualitative terms. In this present study, the effect is examined for only the countermeasures that can be evaluated in quantitative terms.

6.5.1 Dredging

A study is made to examine the siltation rate of the dredged channel in order to know the maintenance dredging cost. The mechanism of siltation to the dredged channel is also examined to know the most effective dredging plan with less maintenance and to know the most effective measures to prevent siltation by investigating where and how the siltation takes place.

Mechanism of Siltation

Siltation has a very complicated process in relation to bed materials, wave and tide conditions, and so on. To study the mechanism of siltation of the dredged channel, it is necessary to classify bed materials into two; namely, sandy bed materials and muddy bed materials.

(1) Sandy Coast

In the case of sandy bed materials, siltation in the dredged navigation channel occurs when the drifting sand settles in the channel. In most cases, longshore drifting sand has an almost straight angle to the channel and drifting sand on both directions, i.e, left to right and right to left of the channel, will be trapped. For siltation of the dredged navigation channel, offshore drifting sand will not be dominant.

The volume of littoral drift sand can be calculated by empirical formulas, as discussed in Subsection 6.2.3.

(2) Muddy Coast

The study on siltation in muddy coasts is not yet well established worldwide and siltation in muddy coasts contains many unknown factors compared to that in sandy coasts. The actual siltation rates at various river mouths are checked and plotted to determine the general siltation rate for the purpose of the master plan study.

Study on Siltation

To obtain the siltation rate, a study is made for the Perlis, Kurung Tengar, Kedah, Beruas and Mersing river mouths based on the currently available data. The Mersing River Mouth is located in a sandy coast and the others are in muddy coasts.

(1) Outer Channel

The siltation volume in outer channels of river mouths in muddy coasts is summarized in the following table:

River Mouth		Siltation	
No.	Name	Height (m)	Period (month)
01	Perlis	1.5	12
01	Perlis	1.0	8
-	Krg. Tengar	2.5	36
09	Muda	1.4	76
19	Beruas	1.4	20
19	Beruas	2.0	29

These values are plotted in Fig. 6.5-1. The temporal rate of siltation is considered constant from the siltation mechanism, as discussed before. The rate of 1.0 m/year is shown in the illustration.

In the case of the sandy coast, the siltation rate on the dredged channel at 130,000 m^3 from July 1981 to April 1982 for the Mersing River Mouth is considered in the drifting sand calculation in Subsection 6.3.3. The siltation rates of the representative river mouths are obtained by summing up the longshore transport rates and the sediment supply rates from the rivers, as presented in Table 6.5-1.

(2) Inner Channel

Inner channels are maintained relatively deep compared to outer channels and there is less variation of sections. Siltation data after dredging are available only at the Beruas River Mouth and the siltation rate is comparatively smaller at 40 cm for 30 months than 1.4 m for 20 months and 2.0 m for 29 months.

In Subsection 6.2.3, a numerical approach is tried to simulate mud siltation in the inner channel of Tg. Piandang. The results show that the inner channel will remain stable even after dredging.

As discussed before, siltation in the inner channel is due to clogging of the outlet caused by siltation of the outer channel. If outer channels are maintained deeper, inner channels might be maintained deeper as in the case of other river mouths.

6.5.2 Increment of Tidal Prism

<u>Parameters Used for the Analysis</u>

An increase of the tidal prism leads to an increase of the river mouth cross-sectional area and thus, the depth of the river mouth is maintained. To know the effect of the increment of tidal prism, the characteristics of the 100 river mouths are analyzed using the following parameters:

(a) River mouth cross-sectional area

(b) River mouth width

(c) River mouth depth

(d) Tidal prism

(e) Wave and tidal condition

<u>Effect of Increase of Tidal Prism</u>

From the study results for the 100 river mouths, the following matters are pointed out as the effect of the increase of tidal prism:

(1) Increase of tidal prism brings about the increase of cross-sectional area of the river mouth, i.e., a 100% increase in tidal prism has an effect of about 100% increase in cross-sectional area. (Refer to Fig. 6.5-2.)

(2) Increase in cross-sectional area brings about the increase in depth. However, the relation between cross-sectional area and depth is in a cube root, so that a 100% increase in the cross-sectional area brings about only approximately 30% increase in the depth. (Refer to Fig. 6.5-3.)

The effect of the increase of tidal prism is clearly observed at the river mouth. However, the increase of tidal prism may not be effective to maintain the outer navigation channel, because current by the tidal prism spreads out in the outer channel. To maintain the effect of the increase of tidal prism, a combination of jetty is considered.

6.6 Design Criteria for Countermeasures

For the improvement of representative river mouths, the countermeasures studied in the alternative cases are dredging, breakwater, jetty, training wall, groin and reservoir. The design criteria for these countermeasures are discussed hereinafter. [Refer to Shore Protection Manual (1984); Guideline (Draft) of River Improvement (1975); Technical Standards for Port and Harbour Facilities in Japan (1991); and other related guidelines that include profiles of structures.]

<u>Navigation Channel Dredging</u>

For navigation channel dredging, the dimensions such as width, depth and stretch of dredging are decided under certain criteria, as follows:

(1) Width

A two-lane navigation channel is provided to assure safe navigation.

(2) Side Slope

The design side slope of 1:3 used in the Kuantan River Mouth is applied to sandy coasts and the design side slope of 1:5 used in the Perlis River Mouth is applied to muddy coasts.

(3) Depth

The design depth below MLWS or MLLW (refer to Table 6.3-1) is decided by the draft of ship plus allowance. The clearance of 1.0 m used for the dredging of the Kuantan River Mouth is applied.

(4) Stretch

The dredging stretch seaward is decided by the distance from the rivermouth to the point where the seabed height corresponds to the design water depth. That of the inner channel applies the shorter distance among the following two cases as long as the river has enough width for dredging by the design width: one is from the river mouth to the point where the riverbed height corresponds to the design water depth, and the other is from the river mouth to the center of the port where landing facilities are supposed to be provided. In case the river width is very narrow compared with the design navigation width, the stretch is decided at the point where the design dredging width corresponds to the river width.

Structures

The design criteria for structural countermeasures such as breakwater, jetty, submerged jetty, training wall and groin are discussed with the height, length, crown width, interval and side slope as shown in the following table. The tidal records of each river are given in Table 6.3-1.

Item	Height	Length	Crown Width	Interval	Side Slope
Breakwater	HWL+Ho+Hr	Based on Land Condition	10.0 m	less than River Mouth Width	1:1.5
Jetty	MHHW	Dredging Length or CSMP	6.0 m	less than River Mouth Width	1:2 to 1:1.5
Submerged Jetty	MSL	Dredging Length or CSMP	3.0 m	less than River Mouth Width	1:2
Training Wall	MHWS+Hr or MHHW+Hr	Based on Land Condition	---	---	1:2.5
River Groin	MSL	1/10*B to 1/7*B	2.0 m	1.7*L or 3*L	1:3
Coastal Groin	MHWS or MHHW	Based on Land Condition	2.0 m	2*L to 3*L	1:1.5

Ho : Design Wave Height
Hr : Wave Run-up
B : River Width
L : Groin Length
CSMP : Critical Sediment Moving Point

Reservoir

Since a swampy area or lagoon is used for the reservoir in the alternative study cases, the design of the reservoir is made considering the present condition of such swampy area or lagoon. Therefore, the design criteria is not herein specified.

6.7 Cost of Countermeasures

Units cost of countermeasures are examined to facilitate the cost comparison among the alternative cases discussed in Chapter 7.

6.7.1 Estimation of Unit Cost

Unit Cost for Breakwater, Jetty, Submerged Jetty, Training Wall, Groin and Reservoir

The unit costs for breakwater, jetty, submerged jetty, training wall, groin and reservoir are estimated by cost comparison among the alternative types of structure (refer to Table 6.7-1 to 6.7-4). The results are summarized in the following table. The unit cost for dredging is discussed separately.

Countermeasures	Type of Structure	Unit Cost (RM)
Breakwater	Rubble Mound	14,880/m
Jetty	Rubble Mound	3,708/m
Submerged Jetty	Rubble Mound with Sand-filled Tube	5,165/m
Training Wall	Concrete Block	1,500/m
Groin	Rubble Mound	1,500/m
Reservoir	Riprap	10/m

Unit Cost of Dredging

The accurate cost of dredging for every objective river mouth is difficult to obtain, because of many unknown factors. To estimate the dredging costs for this master plan, cost investigation with several experienced Malaysian contractors are made and the costs quoted in similar projects undertaken by DID, MD and JKR are taken into account.

The following unit costs are applied. (Refer to Table 6.7-5.)

Dredged Material	Length of Sand Transportation	
	L < 1.5 km (Inner Channel)	1.5 km < L < 3.0 km (Offshore Channel)
Sandy Soil	RM 5.0/m^3	RM 6.0/m^3
Clayey Soil	RM 6.0/m^3	RM 7.0/m^3

6.7.2 Project Cost

Direct construction cost are estimated using the unit costs mentioned in the preceding subsection. Project costs for the objective river mouths discussed in Chapter 7 are estimated under the following conditions.

(1) Construction works are to be executed by bidding.

(2) Total construction costs are estimated in consideration of the following components:

(a) Main Works

(b) Minor and Preparatory Works [10% of (a)]

(c) Engineering and Administration Cost [10% of (a)+(b)]

(d) Physical Contingencies [15% of (a)+(b)+(c)]

(3) It is assumed that land acquisition is not required for the river mouth improvement works.

(4) Operation and maintenance cost (O&M) is calculated based on the following percentages of total construction costs:

(a) Rock Structures : 0.6%

(b) Concrete Structures : 1.0%

As for the flexible sand-filled tube, full replacement is to be made in every 15 years considering the durability of the material.

6.8 Project Benefit

6.8.1 General

River mouth treatment works are proposed to solve the existing problems such as the inconvenience to navigation of sea-going vessels and the flooding in the vicinity of river mouths that could cause economic losses. Here, project benefit is defined as the difference between "without-the-project" and "with-the-project" situations, and can be categorized broadly into two: "tangible" and "intangible" benefits.

In this study, tangible benefits may accrue in the areas of fishery, sea transport and flood mitigation. It is verified from the site investigation, interview-survey and basic analysis that the fishery benefit is dominant and common to all the objective river mouths of the master plan, while the other benefits are expected at only a limited number of river mouths.

Intangible benefits, though unquantifiable, include favorable effects in social and environmental aspects such as the enhancement of safety to navigation, the stabilization of living standards of fishermen and residents in the flood-prone areas and so on.

The without-the-project situation generally denotes the existing condition, but the following definitions are given to this master plan study on the 75 objective river mouths.

(1) For river mouths where no countermeasure for the problems has been undertaken, the present condition is considered as the without-the-project situation.

(2) In case that dredging works have been carried out at a river mouth, the previous condition without dredging is presumed to be the without-the-project situation, because the effects of dredging remain for only one or two years.

(3) The without-the-project situation at river mouths with other related projects under construction is the improved condition after those related projects are completed.

The above-said differences or benefits are quantified in monetary terms for the 10 representative river mouths. Based on the benefit for each representative river mouth, the benefit for the other river mouths in the same group is calculated by applying an appropriate parameter. The basic concepts and methodology of benefit calculation are discussed below. Since the sea transport benefit is expected at only a few river mouths, it is not reasonable to apply the benefit to the other river mouths in the same group where sea transport services are not available; hence, the sea transport benefit is calculated independently for the river mouth concerned.

6.8.2 Fishery Benefit

River mouth siltation causes enumerable economic losses to the fishing activities because the activities completely depend on tidal conditions, i.e., the time to leave and return to port is restricted by high tide.

<u>Tidal Fluctuation</u>

Tidal fluctuation is a key factor to calculate the unnavigable duration for boats, but this differs place by place. Hence, the tide records of each tide station in 1990 are studied to identify the features of the tidal fluctuation.

To calculate the unnavigable duration at the representative river mouths, the tide records of the following stations are made as reference: Pulau Langkawi Station for Perlis and Kedah; Kedah Pier Station for Tg. Piandang; Lumut Station for Beruas; Tg. Gelang Station for Kuantan and Kerteh; Chedering Station for Marang and Terengganu; and Kota Kinabalu Station for Oya and Papar. The differences of frequency distribution of hourly tide levels at these stations are presented in Fig. 6.8-1.

Boat Size and Required Water Depth

Fishing boats are grouped into four sizes: small (less than 10.0 GRT), medium (10.0 to 39.9 GRT), large (40.0 to 69.9 GRT), and deepsea (70.0 GRT and above). The number of small and medium sized boats are figured out from the available data, while those for large and deepsea boats are estimated from the data on boats of more than 40.0 GRT by applying the distribution ratio in the state where the river mouth is located. The minimum water depth required by boats with the draft of 10, 40, 70 and 150 GRT to pass through a river mouth are determined respectively as follows: 1.0 meter for small, 1.7 meters for medium, 2.2 meters for large, and 3.0 meters for deepsea boats.

Duration of Water Depth Affecting Navigation

Unnavigable hours are basically dependent on the accumulative percentage of the duration of water depth affecting navigation (Ap), which varies at each river mouth according to the following factors: the tidal fluctuation, the present riverbed or seabed height, the required water depth, or the boat size. The actual, average waiting time per day per boat is calculated by the formula [(Ap) x 24 hours x 50% x 50%], considering that the river mouth is used only in the daytime (50% of a day) and assuming that boats stay in the deep sea for normal fishing activities for about 50% of the duration affecting navigation at river mouths. (Refer to Table 6.8-1.)

Benefit Calculation

Each group size of boat has its own particular problem of river mouth siltation and annual benefit is calculated individually, as follows:

(1) Small Size Boats

The major problem of small size fishing boats may be the suspension of fishing operations with a catch lesser than the capacity so as to return to port during high tide, or, when going out to sea, to wait for the high tide. In either case, river mouth siltation causes the reduction of fishing duration with less fish catch which is calculated proportionately with the extension of fishing activity duration. In this context, the benefit for small boats is defined as the increase of catch, though incremental boat operation and refrigeration cost should be subtracted from the incremental catch amount. The details of calculation are given in Table 6.8-2.

(2) Medium and Large Size Boats

Medium and large fishing boats are supposed to keep on fishing until they gain a full catch, and the problem is to waste time waiting for the tide to rise. Benefit may accrue in the areas of:

(a) savings on fishermen's opportunity cost;
(b) savings on fish refrigeration cost; and
(c) preservation of fish quality.

Fishermen's opportunity cost (RM 1.7/hour/man) is calculated from the average wage (RM 2.0/hour) multiplied by the conversion factor to shadow wage (0.85). When fishermen miss the prime marketing time, they have to wait for the subsequent marketing time for a maximum of about 20 hours with value decrease of 10 to 20%. In this situation, the value decrease rate of 1% per hour is applied for the quantification of conservation of fish quality. The annual benefit is calculated as given in Table 6.8-2.

(3) Deepsea Fishing Boats

Deepsea fishing boats are also supposed to continue fishing operations until they attain a full catch regardless of tidal conditions, and are supposed to divert to other ports with additional time and costs when they come across low tide. The benefits of deepsea fishing boats thus include:

(a) savings on operation cost;
(b) savings on fishermen's opportunity cost;
(c) savings on fish refrigeration cost; and
(d) preservation of fish quality.

The beneficial items are similar to those of medium and large boats, but benefit calculation is based on the additional time, which should be less than the waiting time for high tide. (It is much better to wait for high tide if they spend more diverting time than the waiting time.) The additional time is assumed to be 80% of the waiting time. Annual benefit is calculated as given in Table 6.8-2.

6.8.3 Sea Transport Benefit

Commercial boats include passenger ferry, cargo ferry and cargo boats which are available at Perlis, Kedah, Marang, Mersing and Terengganu, and river mouth siltation causes restriction on service hours. The sea transport benefit is therefore calculated in the same manner as the small fishing boats, but only at the river mouths where these services are available; i.e., the benefit at the representative river mouth will not be applied to the other river mouths in the group. The details of calculation are given in Table 6.8-3.

6.8.4 Flood Control Benefit

Flood control benefit is defined as the reduction of potential flood losses attributed to the designed works. The reduction is obtained as the difference between the estimated flood losses under the "with-" and the "without-the-project" situations.

Flood losses are in general calculated in the concept of [(unit value of property) x (quantity) x (damage rate)], which are applied for flooding conditions under several cases of flood probability. Annual average benefit is also calculated by the following formula:

$$B = \sum_{i=1}^{n} 1/2 \times [D(Q_i-1) + D(Q_i)] \times [P(Q_i-1) - P(Q_i)]$$

where;

B : annual average benefit

$D(Q_r\text{-}1), D(Q_i)$	:	flood losses caused by flood with $Q_r\text{-}1$ and Q_i discharge, respectively.
$P(Q_r\text{-}1), P(Q_i)$	:	probabilities of occurrence of $Q_r\text{-}1$ and Q_i discharges, respectively.
n	:	number of floods applied.

As discussed in Section 6.2, only the Terengganu River Mouth may suffer from flooding due to river mouth siltation. The flood-prone area has been fully developed as a residential area, so that future increase of benefit is disregarded.

6.9 Environmental Study

The present environmental condition is investigated mainly at the representative river mouths, and an environmental impact matrix is prepared for the river mouth improvement project. The environmental impact assessment for each representative river mouth is presented in Chapter 7.

Description of the River Mouth Improvement Project

The proposed countermeasures for river mouth improvement are (a) breakwater, (b) jetty, (c) training wall, (d) groin, (e) dredging, and (f) reservoir. Under Section 34(a) of the Environmental Quality Act of 1974, the prescribed activities related to river mouth improvement are dredging involving an area of 50 ha or more and clearing of mangrove swamps covering an area of 50 ha or more. On this condition, the river mouth improvement project requires the implementation of an Environmental Impact Assessment Study.

Description of the Existing Environment

On the west coast of Peninsular Malaysia, mud flats are predominant and mangrove forests are the major vegetation at the banks of the river mouth. On the east coast, rivers flow into sandy beaches and mangrove trees are found only on muddy river banks. On the coasts of Sabah and Sarawak, mangrove, casuarina bushes, and nipa palm form the main natural vegetation of the coastal area.

Some of the representative river mouths are situated in wetlands which are important for nature conservation. These are the Beruas River Mouth at the southern edge of the Matang Mangrove Forest Reserve, the Papar River Mouth in the Benoni Coastal Wetlands, and the Oya River Mouth in the Third Division Swamp Forest.

Potential Impacts on Environment

The environmental impacts of the river mouth improvement project could be examined from two perspectives; namely, the short-term impacts resulting during the period of construction works and the long-term impacts occurring for longer periods at the operation of the project. The following are the possible activities during the construction and operation phases of the project.

(1) Preliminary Investigation

- (a) Engineering investigation (site and geophysical survey)
- (b) Hydrological survey
- (c) Oceanographic survey

(2) Construction

- (a) Breakwaters and jetties
- (b) Training walls
- (c) Groins
- (d) River works
- (e) Coastal works
- (f) Dredging
- (g) Excavation
- (h) Drainage alteration
- (i) Reclamation

(3) Operation and Maintenance

- (a) Dredging
- (b) Transportation

(4) Consequent Projects

(a) Fishery development

(b) Recreation

Environmental Impact Matrix

For a clear presentation of the impacts of activities on the environment, an environmental matrix is prepared, as shown in Table 6.9-1.

CHAPTER 7. IMPROVEMENT PLAN FOR REPRESENTATIVE RIVER MOUTH

7.1 Perlis River Mouth

7.1.1 River Mouth Geomorphology

Perlis River Mouth is selected as the representative river mouth in Group 4, where river mouth formation is emphasized with the straight coast formed by the external forces of low waves and large tidal prism (see Table 7.1-1).

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. 7.1-1. 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.

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.

Tidal prism, one of the major external forces forming 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. Under these circumstances the Perlis River Mouth is presumed to be formed by the external force of tidal action, and the effect of waves may be comparatively less.

Offshore Geomorphology

As illustrated in Fig. 7.1-2 to 7.1-5, off-channel seabed profiles of 1,000 m to the left and right of the river mouth are gentle at 1/1,200 and 1/1,450, respectively, for the stretch starting 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

As illustrated in Fig. 7.1-6, bed materials are silty with 14% clay (<0.002 mm), 78% silt (0.002 to 0.063 mm) and 8% sand (0.063 to 2.0 mm). The median diameter d50 is 0.013 mm and the mean grain diameter is 0.040 mm.

According to the Perlis Port Development Project study survey results on soil condition in 1984, 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, underlain at 12 to 24 m below ground level. This condition will likely create problems of subsidence, sliding and so forth, should facilities be constructed without taking any measure against high compressibility and the lack of stability of the marine clay.

Coastal Change in Neighboring Areas

As illustrated in Fig. 7.1-7, both right and left banks are retreating. Shoreline retreat is severe, especially at the left bank, at the rate of 30 m for the 8 years from 1966 to 1974 and another 30 m for the next 12 years from 1974 to 1986.

River Mouth Configuration

The river width gradually narrows toward the upstream section of the tidal prism stretch. The outer channel very easily silts up after dredging, but the inner channel is relatively well maintained by tidal flow and river discharge. 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 longitudinal shallowest part will be around LSD -1.0 m.

7.1.2 Identification of Problems and Measures Taken

Present Problem

The natural waterway formed by water flow of the Perlis River serves as the navigation channel at the Kuala Perlis Port. A shallow area is seen in the approach channel at about 2.0 km from the river mouth, with a water depth of about 2.8 m below Land and Survey Datum (LSD) according to the bathymetric survey in 1992 (refer to Fig. 7.1-5). On the other hand, the minimum depth of the inner channel is about 4.0 m below LSD.

River mouth shifting and wave intrusion are not serious problems at the Perlis River Mouth. Ferries and fishing boats at the Perlis River Mouth must wait for the high tide, because they have the draft of more than 2.0 m and the water depth at low tide is not enough for navigation. Besides, the boats tend to leave or return to the port at the same time in high tide but the present limited capacity of port facilities makes landing and loading operations inefficient. The facilities remain free in low tide.

Inundation due to river mouth siltation seems not to be the main problem. Flood damage has been reported in Kangar, the capital of Perlis State located at about 10 km upstream. However, the stretch between the river mouth and 2.0 km upstream has a large capacity, enough for the design discharge corresponding to a 50-year return period flood.

Measures Taken

The Marine Department has been conducting dredging works since 1986, mainly to maintain the navigation channel for ferries to Langkawi Island. The stretch dredged was about 3.0 km offshore from the river mouth, 60 m wide and 3 m deep below chart datum (CD).

Related Projects

The projects related to the Perlis River Mouth are the following:

(1) Perlis Port Development Plan

The study for the Perlis Port Development Plan was conducted by JICA in 1984 to minimize the expenditure for dredging, to promote the effective use of facilities through the appropriate allotment of functions between the existing port area and the new port area, to establish a new port administrative organization suited to the situation at the Kuala Perlis Port, and to promote the port and urban development taking advantage of the Langkawi Island development. Land reclamation along the coastal area south of the Perlis River Mouth is presently being carried out by the State Economic Development Corporation.

(2) Flood Control Plan for Kangar

In the Perlis river basin, a flood control project is being executed mainly to mitigate flood damage at Kangar, the capital of Perlis State, through river channel improvement and floodway construction together with dam construction.

(3) Timah-Tasoh Dam Project

Timah-Tasoh Dam is planned to provide a dependable and adequate water supply for domestic and industrial use and to augment irrigation water supply for the main season while providing additional supply for off-season paddy cultivation. Flood control is included in the main purposes. Except some minor works, construction of the dam was almost complete in October 1992 and impounding in the reservoir had started.

7.1.3 Selection of Countermeasures

<u>Applicability of Countermeasures and Alternative Cases</u>

Some countermeasures are conceptually excluded for the Perlis River Mouth, as presented follows.

(1) The Perlis River Mouth is not seriously affected by wave action; hence, a breakwater is not necessary.

(2) A jetty is effective for protection against the intrusion of drifting materials; however, a heavy structure is not applicable at the Perlis River Mouth, because the bed soil of marine clay will likely create problems of subsidence, sliding and so forth unless a measure against high compressibility and the lack of stability of the marine clay is undertaken. The only applicable facility may be the submerged jetty using flexible sand-filled tubes that can reduce the weight because of the light materials inside the tube.

(3) Training wall for stabilization of the river mouth is not necessary, because the Perlis River Mouth is relatively stable.

(4) River groin for stabilization of the river channel is not necessary, because the Perlis river channel is relatively stable.

(5) A large space is required to provide a reservoir to increase the tidal prism using a lagoon or a swampy area. Since there is no suitable space for a reservoir around the Perlis River Mouth, this countermeasure is not applicable.

To summarize the above, the applicable countermeasures for the Perlis River Mouth include a submerged jetty and dredging with conventional equipment. Since a submerged jetty cannot completely prevent the intrusion of drifting sand into the navigation channel, it is necessary to provide additional countermeasures such as maintenance dredging to maintain the navigation channel. In this connection, the following two alternative cases are studied:

Case 1: Capital and Maintenance Dredging of Navigation Channel

Case 2: Capital Dredging and Combination of Submerged Jetty and Maintenance Dredging

The combination of countermeasures for each study case is given in Table 7.1-2, for comparison with those of other representative river mouths.

Design Feature of Countermeasures

The design feature of countermeasures is described below.

(1) Capital Dredging

In the Perlis River Mouth, boats are proposed to have the design size of 150 GRT, the draft of 2.93 m and the beam of 7.5 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the said design size of boats and design alignment, the design features for dredging works are figured out, as given in Table 7.1-3. The required dredging volume based on the design features is given in Table 7.1-4.

(2) Maintenance Dredging

The volume of required maintenance dredging depends on the annual siltation rate, as discussed in Chapter 6. The necessary maintenance dredging volume is calculated for the Perlis River Mouth, as given in Table 7.1-4, based on the annual siltation height of 1.0 m for muddy coasts.

(3) Submerged Jetty

Since the mean sea level of the Perlis River Mouth is 0.0 m above LSD (1.9 m above CD), the top elevation of the jetty at the river mouth is LSD 0.0 m. The design features and work volume of the submerged jetty are as given in Table 7.1-5.

In the case of a submerged jetty which cannot completely prevent the intrusion of drifting materials, the volume for maintenance dredging is expected to decrease because siltation after capital dredging is reduced. The reduction of siltation is due to two factors; namely, (a) that the submerge jetty can partly prevent dispersion and transportation of bed materials stirred up by waves and tidal current from entering the navigation channel depending on the height of the jetty and water depth; and, (b) that the tidal prism is confined in the navigation channel bringing about an increase of sediment transport capacity depending on the depth of the navigation channel with a submerged jetty. In this study, it is assumed that the reduction rate by the former factor is 50% and that by the latter factor is 10%, or a total of 55%. The annual maintenance dredging volume will then be 162,400 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost is estimated in a manner of net present value (NPV) which is obtained by the following formula:

$$NPV = \sum_{n=1}^{N} \frac{C_n}{(1+i)^n}$$

where,

N	:	project life
C_n	:	cost in *n-th* year (capital cost, annual maintenance cost)
i	:	discount rate
n	:	*n-th* year

The results are summarized in the following table, assuming that project life is 30 years and discount rate is 8%. (Refer to Table 7.1-6.)

Case	Capital Direct Cost (1000 RM)	Annual Maintenance Cost (1000 RM)	NPV of Project Cost (1000 RM)
Case 1	10,134	2,526	49,395
Case 2	29,704	1,092	58,342

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same between the two alternative study cases. Thus, the combination of capital and maintenance dredging, which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Perlis River Mouth. (Refer to Fig. 7.1-8.)

7.1.4 Project Benefit

The Kuala Perlis Port located at the Perlis River Mouth is the largest fishing port in Perlis State with a total of 432 fishing boats registered. It is also used briskly for sea transport including passenger and cargo ferries, and the number of ferry passengers to Langkawi Island has reached as much as 1,382,000 in 1991. Flooding problems in the vicinity of the river mouth have not been reported as discussed in Section 6.2. Benefits are, therefore, expected in the areas of fishery and sea transport.

Calculation of annual benefit is based on the concepts and methodology mentioned in Section 6.8 and thus, the without-the-project situation is assumed to be the previous, inherent condition without the dredging works being carried out in almost every year to assure stable navigation.

The annual fishery benefit at the Perlis River Mouth is RM 6.61 million, including RM 1.02 million for small, RM 3.19 million for medium, RM 1.56 million for large and RM 0.84 million for deepsea fishing boats, as given in Table 7.1-7.

Ferry service to Langkawi Island is available through 11 passenger boats with an average 150 GRT, and the number of trips in 1991 was recorded at about 5,500. As for cargo ferries, about 580 trips were reported in the same year. The annual benefit in the area of sea transport, calculated in the same manner as the fishery, amounts to RM 1.28 million, as given in Table 6.8-3.

The annual average benefit therefore amounts to RM 7.88 million under the present conditions, as given in Table 7.1-8.

7.1.5 Environmental Impact Assessment

The proposed countermeasures for the improvement of the Perlis River Mouth are capital and maintenance dredging. The possible environmental impacts of these countermeasures are given in Table 7.1-9.

Dredging of the navigation channel at the river mouth will modify the river flow, drainage pattern, and water quality due to the change of tidal flow and wave conditions. The change will also affect aquatic and marine life and may destroy their estuary habitats and communities. The environmental impacts are summarized as follows:

(1) Beach erosion in the adjacent coastline due to modification of the littoral sediment transport and sediment supply from the river, as well as destruction of the buffer zone along the river mouth.

(2) Destruction of nursery and breeding areas by siltation during the dredging period.

(3) Impact to aquatic and marine life and their estuarine and marine habitats and communities.

To alleviate such impacts, it is necessary to consider the following:

(1) Provision of dumping yard for dredged materials at areas where erosion and destruction of the buffer zone are expected.

(2) Appropriate planning of the dredging schedule and selection of the dredging method to minimize the impact.

(3) Selection of site for the dumping yard to minimize the impact to aquatic and marine life and their estuarine and marine habitats and communities.

Reclamation of the shore for a port development project is ongoing at the left bank of the Perlis River Mouth and dredging has been conducted. Compared with the project scale of the reclamation, the scale of the proposed capital and maintenance dredging is not so large to cause any significant impact to aquatic and marine life, and no severe environmental impact by dredging has been reported. However, the right bank where a remarkable retreat of the coastline has been observed seems to be susceptible to any change of physical conditions, so that careful consideration is required for project execution.

The proposed river mouth improvement project will provide a safer and deeper navigation channel and improved access to the landing jetty. Hence, substantial economic benefits and improvements are expected for the fishing community.

7.2 Kedah River Mouth

7.2.1 River Mouth Geomorphology

The Kedah River Mouth is selected as the representative river mouth in Group 10, where river mouth formation is emphasized with the protruding coastline formed by the external forces of low waves and a large tidal prism (refer to Table 7.1-1).

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. 7.1-1. 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 by the Muda Agricultural Development Authority (MADA).

External Force

Wind waves generated in the Strait of Malacca and the Andaman Sea by the wind predominantly from the direction between West and Northwest 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 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 formed mainly by the external force of tidal action than wave.

Offshore Geomorphology

As illustrated in Fig. 7.2-1 to 7.2-3, the off-channel seabed profile at 1,000 m to the right is almost flat from the shore to about 1.7 km offshore and the same at 1,000 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

As illustrated in Fig. 7.1-6, bed materials are silty with 22% clay (<0.002 mm), 76% silt (0.002 to 0.063 mm) and 2% sand (0.063 to 2.0 mm). The median diameter d50 is 0.014 mm and the mean grain diameter is 0.027 mm. It is presumed that marine clay covers the seabed at a depth of more than 3.0 m found through the dredging currently being conducted.

Coastal Change in Neighboring Areas

Both right and left banks are retreating, as shown in Fig. 7.2-4. The average shoreline retreat for 20 years from 1966 to 1986 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.

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.

7.2.2 Identification of Problems and Measures Taken

Present Problem

The natural waterway formed by the water flow of the Kedah River serves as the navigation channel at the port. The water depth at both the inner channel and the approach channel is around 3 m below LSD, but the depth at the stretch between the river mouth and 2 km offshore was previously between 1.5 m to 2 m below LSD according to the bathymetric survey in 1990, and it is presumed that the water depth was only some 10 cm at spring low tide at that time. Under the condition, ferries and fishing boats must wait for the high tide to go in and out of the port.

River mouth shifting and wave intrusion are not serious problems at the Kedah River Mouth. So far, no inundation due to river mouth siltation has been reported, but inundation could be caused by the insufficient flow capacity of the river channel.

Measures Taken

In the Kedah River Mouth, countermeasures to cope with the siltation problem started only in 1992, when dredging work was planned by MD in the stretch of 4.0 km offshore from the river mouth with the width of 60 m and a depth of 3.0 m below chart datum. The work started in May 1992.

Related Projects

There is one project related to the Kedah River Mouth, the MUDA Irrigation Project, which was implemented to provide irrigation, drainage and other facilities for the double cropping of rice in the coastal plain of Kedah and Perlis. The gross area covers approximately 126,000 ha, out of which the net paddy area is about 96,000 ha. The project is divided into three main parts; namely, reservoir, barrage and primary canals, and internal reticulation system.

Construction works started in 1966 and substantially completed in 1970. The Malaysian Government established a regional authority named Muda Agricultural Development Authority (MADA) in 1970 to promote, stimulate and undertake the social and economic development in the Muda Region.

7.2.3 Selection of Countermeasures

Applicability of Countermeasures and Alternative Cases

Some countermeasures are conceptually excluded, as in the case of the Perlis River Mouth. In this connection, the following two alternative cases consisting of the remaining countermeasures of dredging and submerged jetty are studied:

Case 1: Capital and Maintenance Dredging

Case 2: Capital Dredging and Combination of Submerged Jetty and Maintenance Dredging

The combination of countermeasures for each study case is given in Table 7.1-2, for comparison with those of the other representative river mouths.

Design Feature of Countermeasures

The design feature of countermeasures is described below.

(1) Capital Dredging

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works are figured out, as given in Table 7.1-3 (refer to Fig. 7.2-5). The required dredging volume based on the design features is shown in Table 7.1-4.

(2) Maintenance Dredging

The necessary maintenance dredging volume is calculated for the Kedah River Mouth based on the annual siltation height of 1.0 m for muddy coasts, as given in Table 7.1-4.

(3) Submerged Jetty

Since the mean sea level of the Kedah River Mouth is 0.0 m above LSD (1.9 m above CD), the crown elevation of the jetty is LSD 0.0 m at the river mouth. The design features and work volume of the submerged jetty are as given in Table 7.1-5.

In the case of a submerged jetty, it is expected that the volume for maintenance dredging is reduced because siltation after capital dredging is reduced. The annual volume of maintenance dredging will then be 149,600 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value (NPV) is summarized below, assuming that project life is 30 years and discount rate is 8%. (Refer to Table 7.1-6.)

Case	Capital Direct Cost (1000 RM)	Annual Maintenance Cost (1000 RM)	NPV of Project Cost (1000 RM)
Case 1	8,347	2,327	44,223
Case 2	28,187	1,017	55,279

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same between the two alternative study cases. Thus, the combination of capital and maintenance dredging, which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Kedah River Mouth. (Refer to Fig. 7.2-6.)

7.2.4 Project Benefit

The Kedah River Mouth is used for fishery with a total of 536 fishing boats registered, and also for sea transport including passenger and cargo ferries. As in the Perlis River Mouth, ferry service is available between Langkawi Island and the Kedah River Mouth with about 190,000 passengers a year, and about 1,500 cargo vessels anchor at the Kedah Port. Flooding problems in the vicinity of the river mouth have not been reported, as discussed in Section 6.2. Benefits are therefore expected in the areas of fishery and sea transport.

Calculation of annual benefit is based on the concepts and methodology mentioned in Section 6.8 and thus, the without-the-project situation is assumed to be the previous, inherent conditions without the dredging works. The design boat size, one of the essential conditions for the benefit calculation. is determined at 150 GRT for the Kedah River Mouth.

The annual fishery benefit at the Kedah River Mouth is RM 6.86 million, including RM 0.53 million for small, RM 3.04 million for medium, RM 2.13 million for large and RM 1.17 million for deepsea fishing boats, as given in Table 7.1-7.

Ferry service to Langkawi Island is available through 10 passenger boats of 150 GRT on an average, and the number of trips in 1991 was recorded at about 1,870. As for cargo ferries, medium and large sized vessels use the port with annual trips numbering about 670 and 840, respectively. The annual benefit in the area of sea transport amounts to RM 1.52 million, as given in Table 6.8-3.

The annual average benefit therefore totals RM 8.38 million under the present conditions, as given in Table 7.1-8.

7.2.5 Environmental Impact Assessment

The proposed countermeasures for the improvement of Kedah River Mouth are capital and maintenance dredging. The possible environmental impacts of these countermeasures, which are quite similar to the case of the Perlis River Mouth, are