THE NATIONAL RIVER MOUTHS STUDY

RIVER MOUTH PROBLEM IN MALAYSIA

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1. INTRODUCTION

1.1 There are more than 150 river mouths in the country. A large number of these river mouths and their immediate hinterland have been extensively developed for agriculture, industry, urban settlement, aquaculture, navigation, tourism and other economic activities. The economic utilisation of many of these river mouths is, however, affected by various problems such as siltation, water quality deterioration, poor navigability, flooding, etc. The problem of siltation is particularly disturbing since it has a direct impact on the performance and growth of the fisheries industry in this country.

1.2 The fishery industry has undergone rapid expansion in recent years to meet the increase demand for fish by the expanding and more health conscious population. In the past, fishermen operate largely in nearshore areas using small boats (less than 10 GRT). Fishing boats have since increased in size as the fishermen expand their operation into deeper waters further out into the sea. Boats engaged in deep sea fishing typically exceed 70 GRT. In terms of draft requirement, a 20 GRT boat requires about 1.0 meter while the 100 GRT boat requires 2.5 meters.

1.3 The fishing boats land their catches in private jetties and LKIM complexes, practically all of which are located inside river mouths. Currently, there are about 500 private jetties and 21 LKIM complexes catering for the landing needs of the local fisheries industry. In terms of fish landings in 1991, the larger LKIM complexes are Kuala Besut, Cendering and Kuantan. The bulk of fish landings (93 %), however, falls on private jetties. The most frequent complaint of local fishermen is inadequate draft for navigation (especially for the larger boats) resulting in considerable amount of time

being lost while waiting for tide to rise. In some cases, navigation safety is also a concern when the river mouth is used by passenger boats or ferries.

1.4 Marine fish landings in Malaysia reached a total of about 951,000 tons in 1990 with an annual growth of about 7.8 %. The retail value of marine fish landings for 1990 is estimated at about RM 2.5 billion (based on RM 2,700 per tonne), equivalent to about 2% of the gross domestic product of about RM 115 billion in 1990. There are 33,000 fishing boats in 1991 and the number of persons engaged in marine fisheries is estimated at 85,000, representing 1.2 % of the total labour force of 7 million. The distribution of fishermen and boat sizes by state is given in Table 1. It can be seen that about 50 % of the fishing boats fall within the class of less than 20 GRT.

1.5 The fisheries industry is forecasted to grow at an average rate of about 5.5 % in the period 1991 - 2010. This is expected to raise the industry's share of agricultural GDP from 10.0 % in 1990 to 15.9 % by the year 2010. The fishery expansion programme will be largely achieved through the development of deep sea fishing and aquaculture. To support deep sea fishing, major upgrading of landing infrastructure and support facilities is required to facilitate the use by larger boats (exceeding 70 GRT). Since the majority of the landing facilities are located inside river mouth, there is a need to develop a long term strategy and comprehensive masterplan to address the siltation problem in the affected river mouths of the country.

2. THE COASTAL AND RIVER MOUTH ENVIRONMENT

2.1 Waves and tides are the primary natural forces which shape the shoreline and river mouths in the country. The west coast of Peninsular Malaysia is largely sheltered by the island of Sumatra and hence the waves are relatively weak in magnitude, ranging from 0.5 to 1.0 m with a maximum height of 2 to 3 m. In the east coast of Peninsular Malaysia, the coast of Sarawak and the northwest coast of Sabah, the predominant waves are caused by the Northeast Monsoon. Over 65 % of the waves are from the northeasterly direction with a deepwater wave height of 4 to 5 m at the maximum.

2.2 There tidal range varies greatly from as low as 2 meters to about 6 meters. The largest tidal range of close to 6 meters is observed near Port Kelang and Kuching in

Sarawak. There are three types of tides, namely diurnal, semi-diurnal and mixed tides according to location and time of the year. The extent of tidal influence depends on river bed gradient and hence can range from couple of kilometers to as far as 150 kilometers inland.

2.3 The shoreline material in Malaysia comprises sandy to muddy materials. Sandy materials are found on the east coast of Peninsular Malaysia, the eastern half of Sarawak and the northeastern part of Sabah. The remaining shorelines of the country are mainly of muddy formations although localised pocket beaches do exist in some parts of the west coast of Peninsular Malaysia.

2.4 River mouths in sandy coast are characterized by sandspit and sandbar development caused by the littoral currents. The littoral sediment transport along any coast varies in magnitude and direction. Some studies on littoral transport rate have been carried out in conjunction with petroleum-based industrial development in the Dungun- Kertih region of Terengganu. The annual rate of sediment transport in this region is estimated at about 200,000 m^3 per year in a southerly direction. Such a rate of littoral transport has caused serious siltation problem in river mouths that have been artificially deepened to support commercial and fishing boat navigation. For the larger river systems, such as Sg. Kelantan, Sg. Terengganu and Sg. Pahang, the river flow through accreting deltaic formation as a result of deposition of large quantity of fluvial sediments brought down by the river.

2.5 Muddy shorelines are generally very flat (1 in 500 or less) extending for several hundred meters to a few kilometers from the coastline. River mouths in such areas are therefore characterized by the existence of long, flat- gradient channels cutting through the mud flat. The size of the channel is influenced by such factors as catchment area of the river, flood flows and tidal prism, etc.

3. THE MORPHO-DYNAMICS OR RIVER MOUTH

3.1 The depth of flow in a river mouth is governed by such factors as the river flow, tidal regime, riverine and coastal sediment transport and the storage capacity of the river mouth. Based on the relative strength of waves and tides and the direction of the

wave attack, it is possible to classify the following types of river mouth environment in Malaysia :-

(a) A sheltered condition exists when the mouth is sheltered by an island or a headland

(b) Moderate condition exists when the waves and tides are moderate in nature such as that experienced by the northwest coast of Peninsular Malaysia

(c) Tidal condition exists when the effect of tide is predominant such as the Strait of Melaka.

(d) Normal wave condition when high waves come normal to the river mouth

(e) Oblique wave condition when high waves approach the river mouth at an oblique angle.

3.2 There are many research studies carried out in the more advanced countries on the morpho-dynamics of river mouths. O'Brien (1969) found that there is a strong dependence between the cross section area of a river mouth and a parameter known as the tidal prism. Expanding on the work of O'Brien, Jarett (1976) has derived the following regression equation for river mouths in the Pacific coast of America as follows

$$A = 2.83 \times 10^{-4} P^{0.91}$$

Where

P = tidal prism (m^3)

A = cross section area of river mouth (m^2)

The tidal prism is defined as the volume of water from the sea to the river between low tide slack to the next high tide slack. In equation form, this is given by

$$P = 0.5 \times B \times L \times H$$

where

L = stretch of tidal influence (m)

B = mean width of river (m)

H = astronomical tidal range (m)

The above equation is a simplified version which assumes that the tidal influence decreases linearly upstream.

3.3 Based on a comprehensive assessment using the physical characteristics of some 100 river mouths, the JICA study team for the National River Mouth Study developed the following relationships relating cross section area, tidal prism, depth and width of river mouth :-

$$A = C_1 X P$$

$$D = K_1 \sqrt{W}$$

where

D = maximum depth at river mouth (m)

W = width of river mouth (m)

C_1 and K_1 are constants

Compared with the equation by Jarett above, it is found that the exponent on P is 1 as compared with 0.91 for American rivers in the Pacific coast. The constants C_1 and K_1 for Malaysian rivers are given below :-

Conditions	C_1	K_1
Sheltered	6.17×10^{-4}	0.17
Moderate	5.00×10^{-4}	0.17
Tidal	7.75×10^{-4}	0.28
Normal Wave	3.16×10^{-4}	0.22
Oblique Wave	1.78×10^{-4}	0.24
Mean	4.00×10^{-4}	0.21

3.4 The followings are some of the general observations on the morphological characteristics of river mouths in Malaysia :-

(a) A river mouth is relatively large when tidal currents are predominant. This is because bed materials consisting of silt and mud are moved easily by tidal

currents.

(b) River mouth is relatively small where there is an oblique wave because the river mouth tends to close itself because of the action of longshore drift.

(c) River mouth is relatively deep compared with the width in tide-dominated situations

(d) River mouth is relatively shallow when it is sheltered by an island or headland.

(e) The cross section area is directly proportional to the tidal prism. This means a 100 % increase in tidal prism leads to a 100 % increase in cross section area

(f) Tidal prism bears a cubic power relationship to depth. This means that a 100 % increase in tidal prism results in approximately 30 % increase in depth.

PROBLEMS AND CONSTRAINTS

The primary problem of Malaysian river mouths is siltation which leads to navigation difficulties and flooding. The problem of siltation is a highly complex one depending on a large number of factors, many of which have not been fully understood. Based on the monitoring of a number of dredged navigation channels on the west coast, it was found that the rate of siltation in muddy river mouth can exceed one meter per year. In the case of river mouths in sandy coast, the siltation rate is largely dependent on the littoral drift. It is important to realize that a dredged channel will intercept the littoral drift in both directions and not just the net drift.

Field tests were carried out by the JICA study team on the rate of siltation in the river mouth of Tg. Piandang, representing a typical muddy river mouth condition. Test pits measuring 10 m square (bottom dimensions) and 1 meter in depth with side slope of 1 on 5 were excavated and the rate of siltation was monitored by periodic survey. The results showed that a rapid rate of siltation of about 0.2 meter per month during the first three months of observation.

4.3 Inadequate draft results in a problem of lack of access during the times of low tide. Valuable time is therefore lost by fishermen in waiting for the next high tide to bring in their catches or to go out to the sea. Such waiting time can be as high as 6 hours. This problem also affects commercial and passenger boats which operate between river mouths and offshore islands.

4.4 The JICA study team has conducted a navigation survey during June/ July 1993 to find out how the fishermen respond to tide. It was observed that where tides are favourable, most boats leave the river mouth during the period of 6.00 a.m to 8.00 a.m and return in the same afternoon at about 2.00 p.m. However, if low tide occurs at about 6.00 -8.00 a.m, the fishermen either leave early at about 4.00 a.m or wait until about 11.00 a.m. For those fishermen who leave late, they have a much reduced working hours in the sea since they have to get back before dark and before the next low tide.

4.5 Siltation in river mouth leads to a loss of hydraulic capacity resulting in a bottleneck for discharge of flood flows to the sea. This can result in inundation of the low lying lands adjacent to the river mouth due to spilling of flood flows from river banks and backwater effect. Fortunately, there are only a few river mouths with this type of problem and most of which have already been resolved under present and planned flood mitigation projects such as the Kemasin -Semarak project, Sg. Golok and Sg Besut. Flood routing computation for the Sg. Golok showed that the widening and deepening of Golok river mouth can reduce the 10 year flood level by about 0.8 meter benefitting large acreage of low-lying land up to some 13 km inland of the river mouth.

5. ENGINEERING SOLUTIONS FOR RIVER MOUTH PROBLEMS

5.1 Various engineering measures to cope with the river mouth problems have been developed and implemented with success both locally and overseas. These measures can be broadly classified under structural measures and dredging. The most frequently used structural measures are breakwaters and training groynes which function by constricting the width of a river outlet, thereby enhancing the scouring action of the river to form a deep channel. In addition, such structures also intercept

whatever littoral sediment transport across the river mouth, thereby cutting off a major source of sediment material contributing to river mouth siltation. This type of solution is usually workable in sandy river mouths but it is often necessary to provide mitigative measures against possible coastal erosion in the downdrift coast.

5.2 Where it is not cost -effective to implement structural measures, regular dredging is the next feasible solution for creating and maintaining a deep navigation channel. This approach has a low initial cost but requires regular maintenance cost especially in areas with high rate of fluvial and littoral sediment transport. For example, after the completion of dredging for the Sg. Kuantan river mouth in late 1993, it was found that about 500 meter of the dredged approach channel (just outside the river mouth) was rapidly silted up in less than 3 months as a result of interception of the littoral transport material. The survey shows that the quantity of siltation in the affected channel amounts to about 50,000 m^3 which tally well with the computed annual littoral sediment transport of about 200,000 m^3.

6. BENEFITS OF RIVER MOUTH IMPROVEMENT WORKS

6.1 The problem of siltation affects the use of the river mouth for commercial and fishing boats. The draft requirement of a boat is dependent on its weight and over the years, there is a tendency for larger boats to be used for a variety of reasons related to efficiency and economic scale of operation. The benefits of river mouth dredging will be discussed under three categories, i.e. small fishing boats, medium and large fishing boats and lastly deep sea fishing boats.

(i) Small size fishing boats (less than 10 GRT)

These boats normally operate in near-shore areas. They operate on a daily basis, leaving for the sea in the early morning and returning in the same afternoon. A shallow river mouth affects the effective duration of fishing activity. For example, when the tides are not favourable, the fishermen have to suspend their fishing operation before the full capacity to return to the port of call before the next low tide. Hence the economic benefit of river mouth improvement for small size fishing boats is the increase of fish catch after subtracting the incremental boat running cost.

(ii) Medium (10 to 40 GRT) and large fishing boats (more than 40 GRT)

The medium and large fishing boats normally continue their fishing operation until they reach the full storage capacity of the boat. Hence they may return to the landing jetty at a time when the tides are low and thus have to wait for hours for the tide to rise before they can enter or sail pass the river mouth. The benefit of river mouth improvement in such cases are:-

- Saving of fishermen's opportunity cost (during waiting)
- Saving of fish cooling cost
- Improvement of fish freshness

(iii) Deep sea fishing boats (more than 70 GRT)

This type of fishing boats operate in the deep sea with each fishing operation lasting up to one month. When a deep sea fishing boat is unable to navigate to the desired landing jetty, they are assumed to be diverted to other ports, thus incurring additional time and cost. The benefit of river mouth improvement in such cases are :-

- Saving of boat running cost
- Saving of fishermen's opportunity cost
- Saving of fish cooling cost
- Improvement of fish freshness

6.2 The above discussions covered the quantifiable economic benefits only. It is relevant to mention that there are also a number of non-quantifiable benefits. The most notable one is that of navigation safety. The occurrence of a bad storm when the boats are waiting outside the river mouth can lead to mishaps such as boat capsizing. Lately, there has been a number of such mishaps occurring in river mouths on the east coast of Peninsular Malaysia.

7. INSTITUTIONS FOR RIVER MOUTH WORKS

The are a number of government agencies which play specific roles in the management of river mouths. They include the Department of Irrigation and Drainage, the Marine Department, the Department of Fisheries, the Malaysian Fisheries Development Authority, Public Works Department and the Department of

Environment.

(a) Department of Irrigation and Drainage (DID)

DID is the engineering wing of the Ministry of Agriculture and hence is responsible for implementing works to improve river mouths for purposes of drainage, flood control and fishing boat navigation. These works comprise structural and non-structural types. Since a large number of river mouths are involved while the development funds are extremely limited, there is a special committee established in the Ministry of Agriculture to decide on the priority of implementation of dredging works for problem river mouths. Under the Sixth Malaysia Plan, the original allocation for dredging works was RM 7.774 million which was subsequently revised to RM 10.774 million in January 1994. The river mouths which have been dredged in recent years are Kuala Sg. Besut (in 1992/1993), Sg. Kuantan (1993) and Kuala Sg. Sedili Besar (1993/1994). Dredging works for Sg. Pahang, Sg. Tg. Piandang (Perak) and Sg. Bharu (Perlis) are likely to commence in 1994/1995.

(b) Marine Department

The Marine Department is responsible for the maintenance dredging of minor ports under the Merchant Shipping Ordinance of 1952. There are 50 gazetted minor ports under the above Ordinance. The minor ports are to be differentiated from the major ports of Port Kelang, Penang, Johor, Kuantan and Bintulu which fall under the jurisdiction of the Port Authorities under the Port Authorities Act of 1963. While the minor ports are largely for commercial shipping, many of them are also being used by fishing boats. The Marine Department has a rather limited budget for river mouth improvement works and their operations are largely centered in the minor ports of Kuala Perlis, Sg. Kedah, Sg. Terengganu, Sg. Kelantan and Sg. Mersing. Currently, the Marine Department operates a total of 4 dredgers.

(c) Department of Fisheries and Malaysian Fisheries Development Authority (LKIM)

The Department of Fisheries is responsible for the planning, development and control of the fishing activities in the country. The Malaysian Fisheries

Development Authority was established in November 1971 under the jurisdiction of the Ministry of Agriculture to improve the social and economic status and welfare of fishermen. While these two department/ agency are highly concerned regarding the navigability of river mouths, the engineering works for improvement are largely entrusted to the Public Works Department and the Department of Irrigation and Drainage.

(d) Public Works Department

The Public Works Department is involved in the design and construction of fishing ports and landing facilities with funds provided by the Department of Fisheries and the Malaysian Fisheries Development Authority.

(e) Department of Environment

Land and natural resources development activities in the waters of the river mouth and its adjoining land are subject to control by the respective local authorities. If the type and scale of development falls within the list of prescribed activities under the Environmental Quality Act, it is necessary to seek the approval of the Department of Environment with the submission of an EIA report. This is to ensure that economic development activities do not lead to undesirable impact on the estuarine and coastal environment.

8. THE NATIONAL RIVER MOUTHS STUDY

8.1 In response to the above issues and concern, the Government have sought the technical assistance of the Japanese Government to carry out the National River Mouth Study. The study commenced in January 1992 and is expected to be completed in May 1994. The study covers a total of 100 river mouths located in various parts of the country. The primary objective of the study is to develop a masterplan for river mouth improvement and to carry out feasibility study on two representative river mouths. This study is expected to formulate the strategy and action plan for the comprehensive solution of the river mouth problems in the country.

8.2 The detailed methodology, approach and the specific findings of this study form the subject of a separate paper to be presented by the JICA study team and hence will not

be duplicated here. It is, however, relevant to highlight that the comprehensive solution of the river mouth problem requires a significant financial commitment on the part of the Government. The preliminary findings revealed that major improvement works are required in 35 river mouths at a initial cost of about RM 300 million (to be spent over 10 years), followed by an annual maintenance cost of about RM 20 million per year. The latter alone is more than 10 times the amount currently allocated to DID for maintenance dredging works. Inadequate funding support is widely acknowledged as the primary reason for the poor state of upkeep of many river mouths in this country.

9. CONCLUSIONS

9.1 The river mouths of Malaysia serve the primary functions of navigation and discharge of flood waters. The first function is far more important as most of the river mouths are too shallow to meet the navigation draft of the boats using them. This problem is expected to further aggravate in the years to come as larger boats are being utilised by fishermen to tap the fisheries resources in the deeper waters beyond their traditional operation ground.

9.2 Coastal engineering concepts can be used to arrive at a better understanding of the causes of siltation in river mouths. There are a variety of engineering solutions but basically, they can be categorized into structural measures and maintenance dredging. The development of a feasible solution for any river mouth improvement should take into account the site characteristics such as existing navigable depth, the wave and tidal conditions, sediment inflow, sediment type and the draft requirements.

9.3 The undertaking of a National River Mouth Study represents the first step towards the development of a long term strategy and action plan to address the aggravating river mouth problem in the country. This is necessary in order to ensure the success and future growth of the fisheries industry. The study is near completion and the preliminary findings demonstrate a need for a much higher financial commitment on the part of the Government to cope with this problem effectively.

REFERENCES :-

Government of Malaysia, " The National River Mouths Study - Interim Reports and Progress Reports" submitted by Japan International Cooperation Agency, 1992-1994

Ministry of Agriculture, " Review of the National Agricultural Policy"; December 1992.

Coastal Engineering Research Center, Department of the Army, " Shore Protection Manual, Vol 1 ", 1984

TABLE 1

DISTRIBUTION OF FISHERMEN AND BOAT SIZES (1991)

STATE	NO. OF FISHERMEN	SMALL * BOATS	BOAT WITH INBOARD ENGINES (GRT)						GRAND TOTAL
			<20	20–25	25–39	40–69	>70	TOTAL	
PERLIS	4157	137	351	40	106	50	32	579	716
KEDAH	7025	871	822	65	206	128	71	1292	2163
PENANG	4320	1578	701	4	104	37	3	849	2427
PERAK	10468	1027	3205	132	128	276	72	3813	4840
SELANGOR	5976	659	1977	49	179	104	8	2317	2976
N. SEMBILAN	436	161	51	0	0	0	0	51	212
MELAKA	1450	609	223	0	0	0	0	223	832
WEST JOHORE	4381	1825	1013	42	10	0	0	1065	2890
WEST COAST	38213	6867	8343	332	733	595	186	10189	17056
EAST JOHORE	3845	538	577	13	130	172	67	959	1497
PAHANG	5091	149	661	20	79	84	120	964	1113
TERENGGANU	10069	89	1977	95	9	62	64	2207	2296
KELANTAN	4091	238	796	24	47	25	29	921	1159
EAST COAST	23096	1014	4011	152	265	343	280	5051	6065
SARAWAK	6966	631	1646	114	104	45	214	2123	2754
SABAH	16133	4818	1967	172	214	26	7	2386	7204
LABUAN	454	123	2	1	1	4	3	11	134
EAST MALAYSIA	23553	5572	3615	287	319	75	224	4520	10092
MALAYSIA	**84862**	**13453**	**15969**	**771**	**1317**	**1013**	**690**	**19760**	**33213**

* Small boats include those without engines and those using outboard motors.