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PHYSICAL MODEL STUDY ON THE SARAWAK RIVER ESTUARY, MALASIA

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Abstract: By means of a physical model the impacts of the Sarawak River regulation scheme and the dredged channel on tidal currents are studied. Sedimentation rate downstream of the project and proposed navigation channel is predicted by the model test.

Key words: Sluice, Navigation channel, Sarawak river, Model

1. INTRODUCTION

The Sarawak River is a major river in the Sarawak State in Malaysia with its upper reaches and middle reaches running through a hilly area. The river reach going through the plain area near Kuching city. Kuching Port is the largest port in Sarawak, Malaysia. Now, the approach channel of Kuching Port is the natural waterway of Sarawak River containing two shoals, namely the Inner Bar and the Outer Bar, with shallowest depth of 5.1m. Fig.1 is a schematic map of Sarawak Estuary. It is imperative to develop the navigation channel in order to meet the requirement of the newly-built Port and its increasing throughput. The Kuching Port Authority plans develop a navigation channel to enable ships of 20,000 tons to call at the new port complex at Senari.

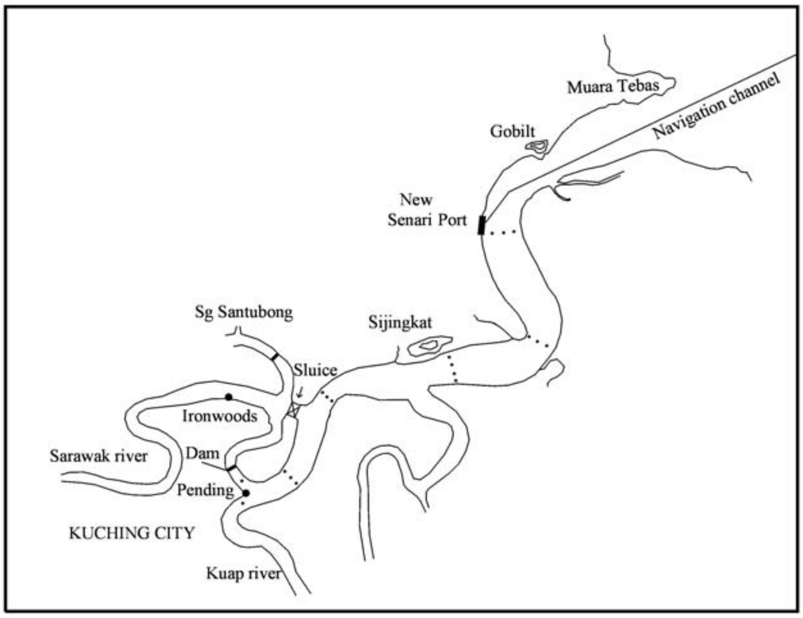

Fig. 1 Schematic map of Sarawak Estuary

The Sarawak River regulation project has just been built. The project includes a water retaining dam to the constructed upstream of oil terminal and a sluice to be built 1.8km downstream of Ironwoods. The main function of the project is to adjust the upstream water level of Sarawak River, especially to keep a high water level near Kuching City to beautify entironment. There were small automatic opening and closing gates on the big sluice gates, which were self-closed when the downstream flood tide level is higher than upstream level and self-opened when the upstream water level higher than bottom height of small gates and at the same time higher than the downstream water level. As the runoff of Sarawak River is rather small, the sluice gates are normally closed. The automatic opening and closing gates are only used to adjust the upstream water level. But when the floodwater comes, the sluice gates must be opened. The physical scale model of the estuary of Sarawak River was constructed at the NHRI to study the impact of river regulation project, siltation on downstream river of sluice and the new navigation channel. Location of the Sarawak River regulation scheme is shown in Fig.2.

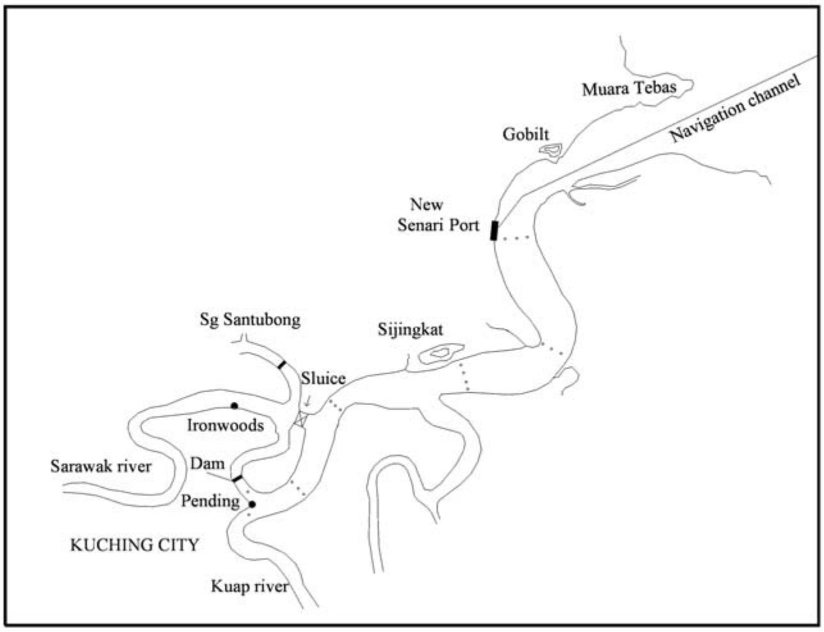

Fig. 2 Location of the Sarawak River regulation scheme

2. NATURE CONDITIONS OF ESTUARY OF SARAWAK RIVER

The Watershed area of Sarawak River is about 1,400km^2 with a good plant cover, thus producing a small quantity of sediment. The river bed is almost in the natural state of an alluvial plain river without any man-made embankment. The cross section of river is mainly in U-shape. The width, depth, and area of the estuary are relatively stable during 1978-1996. Near Pending, the main river meets its fairly large branch-Kuap River, with a small Watershed area, which is running through a plain swamp area with a small gradient and low sediment concentration, After meeting Kuap River and some other small branches, Sarawak River finds its way into the sea. The main river reach downstream of Muara Tebas flows into the South China Sea. At the mouth area leading to the sea there are some sand bars with the water becoming shallower, forming the main shallow water area affecting the navigation in the Kuching Channel.

According to the measured data of P.Lakei Station located outside the river mouth, the tidal range of spring tide is 3.9m, that of neap tide is 1.5m and the mean tidal range is about 2.9m. The tidal wave spreads toward the inside of the river mouth and the tidal range gets small under the joint action of river bed resistance and runoff from upstream. The maximum tidal current speed is about 1.4m/s occurred at Senari station. The tidal currents measured outside the river mouth show that the tidal flow is of come-and –go type and tidal velocity is smaller than 1.1m/s.

The average sediment concentrations are 0.15kg/m^3 during dry season and 0.33kg/m^3 during wet season in the river reach from Ironwoods to Senari. The sediment concentration located the outside the river mouth are obviously decreasing. The sediment concentration of Kuap River is smaller than that of Sarawak River. The sediment concentration is somewhat related to the dry season and rainy season, but the main factor is the value of the tidal flow velocity. When spring tide comes, the velocity becomes higher and the concentration increases; when neap tide comes, the velocity becomes smaller and the concentration decreases. The bed load upstream of Pending is mainly of coarse sand and medium sand, from Sijingkat to outer sea of muddy clay and fine silt. The mean of particle size of deposit is 0.01mm.

3. MODEL DESIGN AND VERIFICATION

The model was constructed to a horizontal scale of 600 and a vertical scale of 120. The upstream boundary of the Sarawak River model is located at Kuching, 10km away from the sluice and further upstream area is simulated by a zigzag waterway with the similar water capacity. Prototype velocity and tidal height at the river were measured. In a process called "verification," the model was adjusted by trial and error to reproduce those data. The hydraulic verification indicated that the vertical and horizontal water measurements were in agreement with the prototype and that the velocity distributions of the prototype were reproduced in the model.

The sedimentation in the river depends principally on the movement of the suspended load after project construction. In salt water,the sediment whose particle sizes is less than 0.03mm can be flocculated and settle down in form of flocculation. The settling velocity of fine particles in form of flocculation, in general, equal to 0.04cm/s. In the suspended sediment model, bakelite powder is selected as the model sediment with a density of 1.51g/cm^3. The medium diameter of model sediment is 0.032mm. The model obeys similarity criterion for river bed deformation. The scale of sediment concentration λ_s and the time scale of bed deformation $\lambda_{t'}$ were determined by verification.

In 1993, the Santubong River, one of the Sarawak River branches leading to the sea, was closed by a dam. According to the field data, the 900m closed reach upstream dam had been silted up everywhere. The mean of sedimentation rate is 1.5m/yr. The sedimentation concentration in model is kept at 0.5kg/m^3, at the beginning of test, one can see clearly the turbid water penetrate into the closed end reach. Table1 gives respectively the calculated and adopted scales.

Table 1 calculated and Adopted Scales of model

Scales	Equations	Calculated	Adopted
Velocity	$\lambda_u = \lambda_v = \lambda_h^{1/2}$	10.95	10.95
Current time	$\lambda_t = \lambda_L / \lambda_u$	54.8	54.8
Settling velocity	$\lambda_w = \lambda_h \lambda_u / \lambda_L$	2.19	2.62
Sediment concentration	$\lambda_s = \lambda_{s*} = \lambda_{rs} / \lambda_{rs-r}$	0.54	0.4
Time scale for bed deformation	$\lambda_{t'} = \lambda_{ro} \lambda_t / \lambda_s$	244	350

3. MODEL TEST RESULTS

3.1 IMPACT OF THE REGULAION PROJECT ON TIDEAL LEVELS OF SARAWAK RIVER

The effect of the sluice upon the tidal level can be felt from pending down to the vicinity of Goebilt. The mean low tidal level at pending point decreases by 10cm, while high tide level hardly changes. The water level upstream of the sluice is related to the runoff and the operation of sluice gates. When the runoff from upstream is less than $500m^3/s$, the automatic opening and closing gates will be used. The stable high water level at Iron -woods point can reach 6.12m during spring tide. When the flood peak discharge becomes greater, the sluice gates should be opened to keep the water level at Ironwoods no higher than safety level of 6.0m.

3.2 IMPACT OF THE REGULAION PROJECT ON TIDEAL FLOWS OF SARAWAK RIVER

The construction of the sluice and dam on the Sarawak River leads to the decrease of tidal influx at the river mouth area. After the construction of the sluice, the flow velocity measured at Sijingkat decreases by 30% and that at Senari decreases by 10% at average. There is no much variation of velocity near the Inner Bar after the construction of the sluice lock and the dam. The velocities in the Kuap River hardly change. During the flood water, the sluice gates are to be opened. As a result, the downstream velocity of sluice will increase. Therefore, the downstream river bank should be protected properly.

3.3 SEDIMENTATION RATE ON SARAWAK RIVER

The siltation test results show that after the sluice construction, tidal influx decreases, leading to some siltation at both upstream and downstream sides with an average siltation thickness of about 0.3m in a year. The downstream sedimentation covered area almost reaches Sijingkat. In wet seasons, the sediment concentration in the river is comparatively high, the sluice opening time for water discharge is rather long, and the sediment transport in the downstream direction moves through a long river reach, almost getting to Muara Tebas. The sluice construction will not produce any direct effect upon the deep-water channel outside the river mouth.

A dam will be constructed at the location upstream of the oil dock of Kuching Port (Pending), thus forming two dead-end river reaches, each at the downstream and upstream sides of the dam. Serious siltation can be found at the two dead-end reaches, leading to the malfunction of the oil dock. The yearly siltation thickness of the upstream side is 0.5m, and that of the downstream side near the oil dock is 0.7–1.0m.

3.4 SEDIMENTATION IN THE PROPOSED CHANNEL

It is essential to estimate the siltation in the proposed deep channel before the dredging work to be carried out. However, sediment transport, erosion and siltation are very complex phenomena, which are still far from fully understood in quantitative terms and the study on siltation in dredged channel highly depends on the field data, model test results and trial dredging**.** Analyzed field data and test results, the amount of siltation estimated for proposal A and proposal B are $538,000m^3$ per year and $963,000\ m^3$ per year.

After the dredging in Senari Port channel, the velocity near the dredged channel varies within a rather small range. The crossing angle between the dredged channel axis line of proposal A and the tidal flow direction is smaller than 10^o, while that of proposal B is 20^o – 35^o at average. After comparing the two proposals, including axis of the channel, siltation intensity, engineering quantities, proposal A is preferred one as design for proposed navigation channel project, while proposal B is optional.

4. PROSPECT OF KUCHING PORT

Kuching Port plays a very important role in the economic development of Sarawak State, According to statistics, the throughout in 1996 increases 16% as compared with that in 1995. For the sake of economic development, it is necessary to further develop Kuching Port by increasing the berth standards, perfecting the cargo transport conditions and increasing container-shipment in a planned way.

Sarawak River is a fairly strong tidal river with abundant water and little sediment. The water depth of the waterway downsteam of Kuching city is quite deep, ideal for port construction. The deep water port can be located either at Senari or at Tg Po.

The Senari Port, just under construction, has such advantages as having a deep water basin, good protection conditions for water area, and flat and wide land area, etc., ideal for centralized management. But it also has some disadvantages, such as having a little bit long approach channel, going through two reaches of shallow water area. The Tg Po Port has such advantages as having ideal water depth and fairly short approach channel. But the protection conditions of its existing deep water area are rather poor, and its channel banks with a narrow land area are close to mountains, not ideal for constructing a container port along the bank. If a container port is to be built, it is better to construct an excavated port in the nearby shoal area. But the construction of an excavated port needs a big investment at the initial phase. Besides, infrastructures such as highways, water and electric power supplies and all port facilities need constructing. The port location can be properly selected through comprehensive technical and economic comparisons while considering the long-term planning and short-term and median-term construction conditions.

As for the approach channel, either dredging or training and dredging can be adopted after a thorough comparative study on the two options. According to the data measured in Aug. 1996 and in January 1997, training measures are more reliable to deepen the channel down to –9m or more inside the Inner Bar. After the training, many deep-water bank areas may be obtained near Senari. As the Sarawak River has rather few sediments coming from its Watershed area, the other channel may be deepened by means of dredging.

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