

Channel Adjustments and Planform Changes – Part of the Upper Linggi River System

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ABSTRAK

Kajian ini meneliti perubahan kestrukturannya (bentuk pelan) sebahagian daripada hulu Sungai Batu Hampar, sebatang anak sungai utama Sungai Linggi di Negeri Sembilan. Kawasan ini mewakili persekitaran dataran sungai yang biasa dengan bahagian uncak yang curam bertukar kepada alur sungai berkelok. Dua kumpulan utama ambang berkaitan turun naik curah hujan dan perubahan guna tanah antara 1966 dan 1993 telah dapat dikenalpasti. Kajian ini mengaitkan ambang-ambang tersebut kepada interpretasi bentuk pelan alur dari foto udara tahun-tahun 1966, 1982 dan 1993. Perubahan bentuk pelan alur untuk tempoh tersebut diinterpretasikan berdasarkan bentuk alur keseluruhan dan pada likuan meander terpilih. Kedua-dua akibat turun naik curah hujan dan perubahan guna tanah ke hulu atau ke hilir likuan dijangka mempengaruhi perubahan pada keseluruhan alur dan ciri-ciri liku Sungai Batu Hampar. Bagaimanapun, mekanik proses alur tidak diukur di dalam kajian ini dan dengan itu menghadkan pemahaman tentang pencapaian perubahan keseluruhan bentuk pelan alur dari segi masa dan ruang.

ABSTRACT

The present study examines structural changes (planform) for part of the upper reaches of Batu Hampar river, a main tributary of Linggi river in the state of Negeri Sembilan. The area represents fluvial environments typical of steep headwaters grading into meandering river channels. Two main groups of thresholds associated with rainfall fluctuations and landuse changes for the period 1966 to 1993 were distinguished. The study relates these thresholds to a channel planform interpretation of aerial photographs for 1966, 1982 and 1993. Channel planform changes for the period mentioned were interpreted based on the overall channel form and at selected meander bends. Both the effects of rainfall fluctuations and landuse changes upstream on downstream loops are thought to influence changes in channel alignment and bend characteristics of the Batu Hampar river. The mechanics of channel processes, however, were not measured under the present study and this limits a good understanding of the full range of channel planform changes at a reach in space and time.

INTRODUCTION

The dynamic adjustments of alluvial channels could be explained by means of the stream power concept (Yang 1979). The change of velocity, slope, roughness, channel geometry and planform patterns are in turn self-adjustments a river makes to minimize its rate of energy dissipation to external stimulus (Harvey et al. 1982). Any dynamic equilibrium form therefore relates to events of a particular magnitude and frequency (Newson & Lewin 1991).

Previous work on event frequency and the adjustments of fluvial systems focuses on one of two aspects of these relationship; the frequency and magnitude of the external events in the context of sediment movements, and the relationship of these events to landform adjustments (Brizga & Finlayson 1990; Harvey 1991).

Changes imposed on a fluvial system be it natural or man-induced tend to be absorbed by the system through a series of channel adjustment (Mackin 1948; Schumm & Parker 1973). For example, changes in energy conditions could lead to a rejuvenation in stream erosion or stream deposition. Associated with these are process-response changes with the channel system.

The aims of the present study are to map and distinguish morphological changes of channel planform patterns for the period 1966 to 1993. No attempts are made however, to relate rainfall fluctuations and landuse changes to channel planform changes nor detailed discussion on the channel processes at work.

THE STUDY AREA

The study area is located in part of the middle reaches of the Linggi drainage basin (Figure 1). The main drainage tributary here is the Batu Hampar river – a gentle gradient and meandering river located within a constricted alluvial floodplain. The floodplains were traditionally cultivated with padi but had since been abandoned.

Three geomorphological regions could be distinguished for the study area. The Batu Hampar drainage systems and its adjoining floodplains, undulating hill lands towards the western part extending into more rolling country and undulating hill lands towards the eastern part of the area forming the foothills of the Main Range – the main mountain system of the Peninsular. The general relief of the area is relatively subdued. The hills bordering the flood plains generally terminate into steep bluffs, 0.2 to 0.5 metres high.

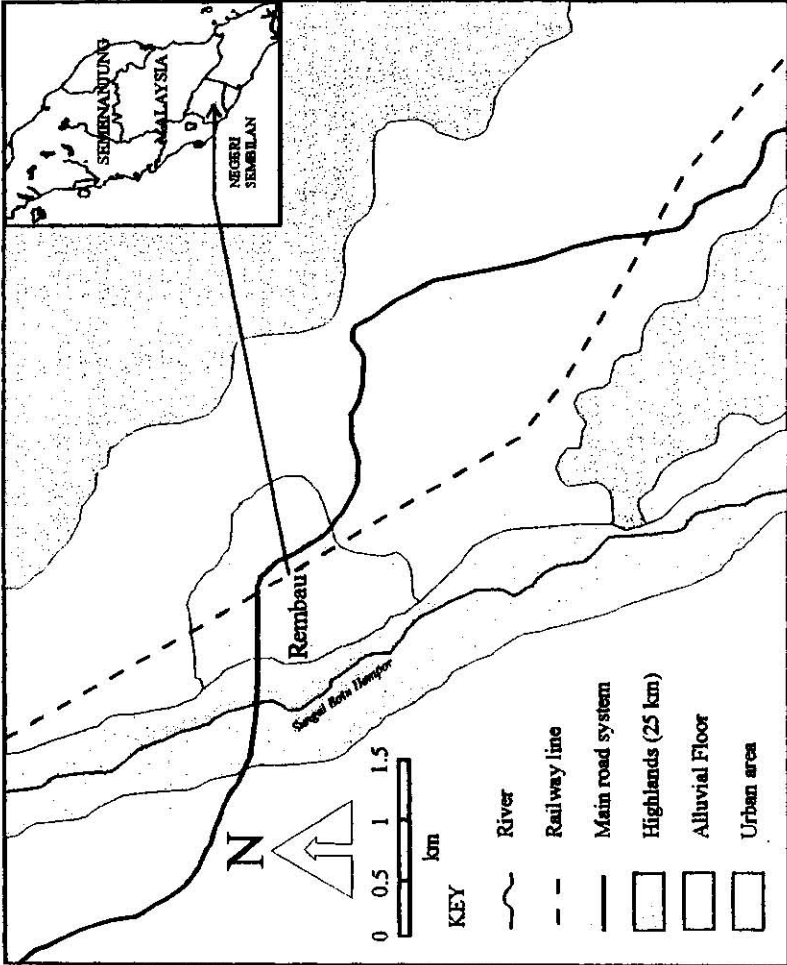


FIGURE 1. The general location of the study area.

The Batu Hampar river basin consists of a main floodplain – the Batu Hampar floodplain. The floodplain is about 3/4 km wide and 8 km in length at the study area. The gradient is gentle (less than 5%) here. The floodplain is joined by smaller floodplains upstream and downstream of the study area. In each case the latter floodplains are ephemeral valleys draining into the main floodplain and generally are much narrower (c.50 m) and steeper (c.20%).

The study area is part of the western fringe of the fold mountain system of Peninsular Malaysia. It lies within a region where regional metamorphism is widespread and most of the Palaeozoic and Mesozoic rocks show slight to moderate deformation (Geological Society of Malaysia 1985). Associated with this are fine grained metasediments to the east and southern parts of the study area.

The area also shows granitic and quartz vein intrusions, and at certain localities these have undergone severe chemical weathering forming tor like formations. The eastern and western hill lands are made up entirely of these granitic intrusions. Field observations revealed that localized rock strikes are N-S conforming with the general structural trend of the Peninsular, with dips locally up to 30° on the northern margins but gently inclined elsewhere.

Faulting on a regional scale is common. The area experiences a relatively recent faulting episode. These N-NW trending faults are believed to be small tensional faults related to a N-NE to S-SE stress field.

Quaternary deposits consisting mainly of unconsolidated to semi-consolidated, semi-rounded to angular gravel-sized and smaller occupy the floors of the drainage valleys with sediment of sand particle size and smaller occupying the floodplains.

FLUVIAL PROCESSES

The Batu Hampar river is transitional to irregular in planform for the period of 1966 to 1993 and has undergone an active phase of meandering. Channel bends showed marked sinuosity at certain reaches along the river in the 1993 aerial photographs. These are often associated with the process of undercutting at the concave side of the bend. The upper strata of cut banks are formed on cohesive sandy silt with some clay.

Field observations showed that bank erosions are attributed mainly to a combination of failure mechanisms. These included movements by toppling and slumping. These processes are quite common for alluvial banks formed where a meandering river is flowing and cutting across its floodplains (Erskine et al. 1992; Moller 1992).

It is not clear whether the failure of the upper banks were internally driven or due to the effects of external fluvial forces. However, high magnitude – low frequency flood events associated with changing rainfall inputs could have provided the trigger mechanisms for bank failure (Newson & Lewin 1991). While periodic wetting and drying of the underlying stratum could have led to pore – water pressure differences that could account for internal failure (Knighton 1984; Montgomery 1989).

Cantilever failures associated with bank erosion are not easily identifiable in the area but could follow any of the three modes shown in Figure 2. The rapidity with which undercutting proceeds and cantilevers are generated depends on the removal and temporary deposition of failed bank materials which are dependent on the direction and type of flow components effecting a channel wall-bend (Rhoads & Welford 1991; Robert 1993). The net effect would be a change in the overall channel platform pattern (Brizga & Finlayson 1990).

CHANNEL PLANFORM DEVELOPMENT

Part of the Batu Hampar river located in the Mukim Batu Hampar (a Mukim is the smallest unit area of administration in the country) was mapped from large and medium scale vertical aerial photographs. The aerial photographs were available for the three time periods of 1966, 1982 dan 1993 (1:10 000 and 1: 20 000). The resolution of the aerial photographs were fairly good so as to provide detailed interpretation of changes in the overall channel planform and for interpretation at selected bends.

Overall channel planform changes was based on changes in channel alignment. Taking the 1966 aerial photographs as the alignment of reference channel deviation from 1966 alignment was measured on a magnified vernier scale every 50 mm along the river. A five average was used for smoothing purposes but even so the level of variation remains quite considerable indicating changes in channel planform (Figure 3).

Rates and patterns of changes at two meander bends (bends X and Y) were also interpreted from the aerial photographs. The rates of bank recession between the dates of air photography are given in Table 1. The development of bend Y tends to post-date bend X and it seems likely that the changes upstream are themselves in part responsible for downstream responses thus influencing the overall channel planform pattern. The rate of bank retreat depend on the pattern of basal scour, which itself responds to the distribution of boundary shear stress and to primary and secondary velocities (Thorne & Lewin 1982). This is significant and

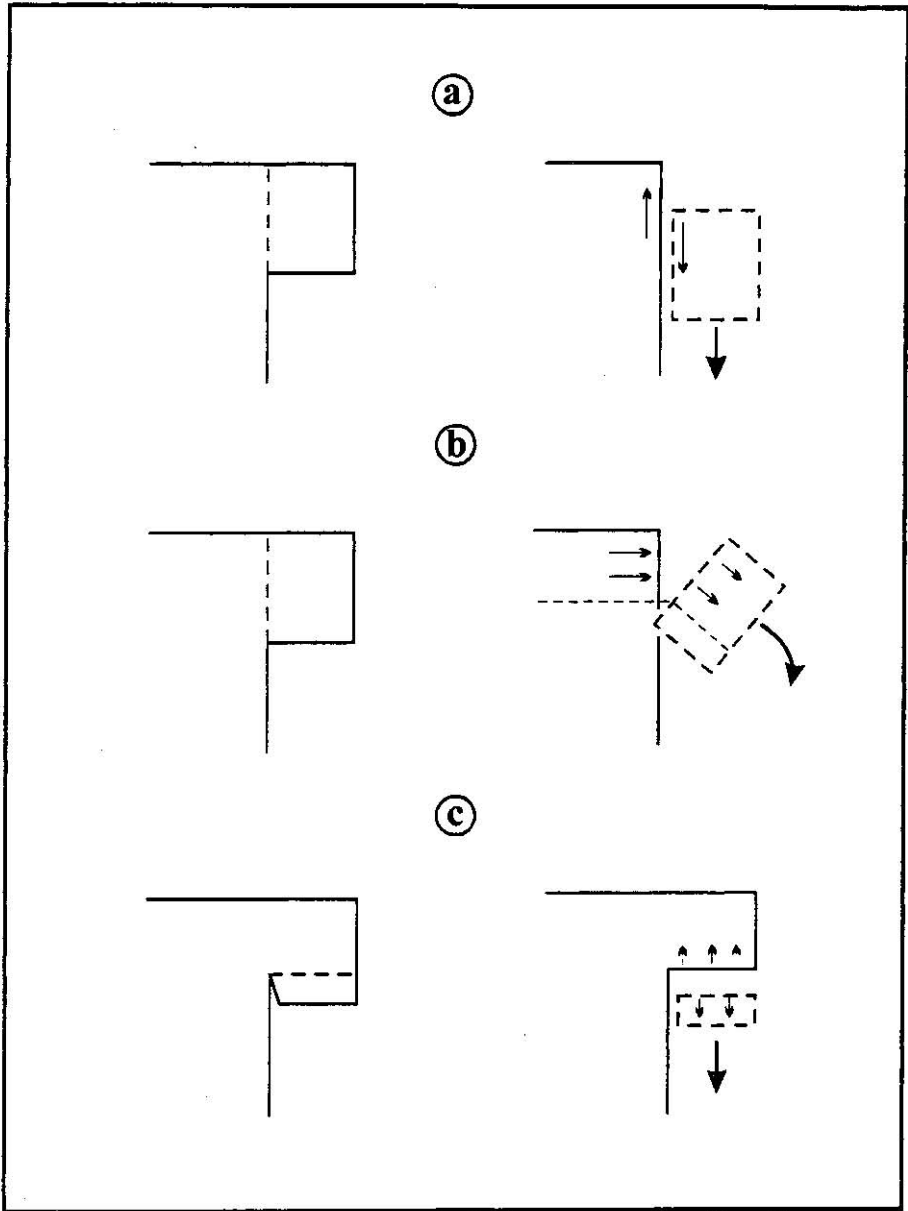


FIGURE 2. Different modes of failure of cantilever overhangs for composite bank (a) shear failure, (b) beam failure, (c) tensile failure
 (Source: Thorne & Lewin 1982)

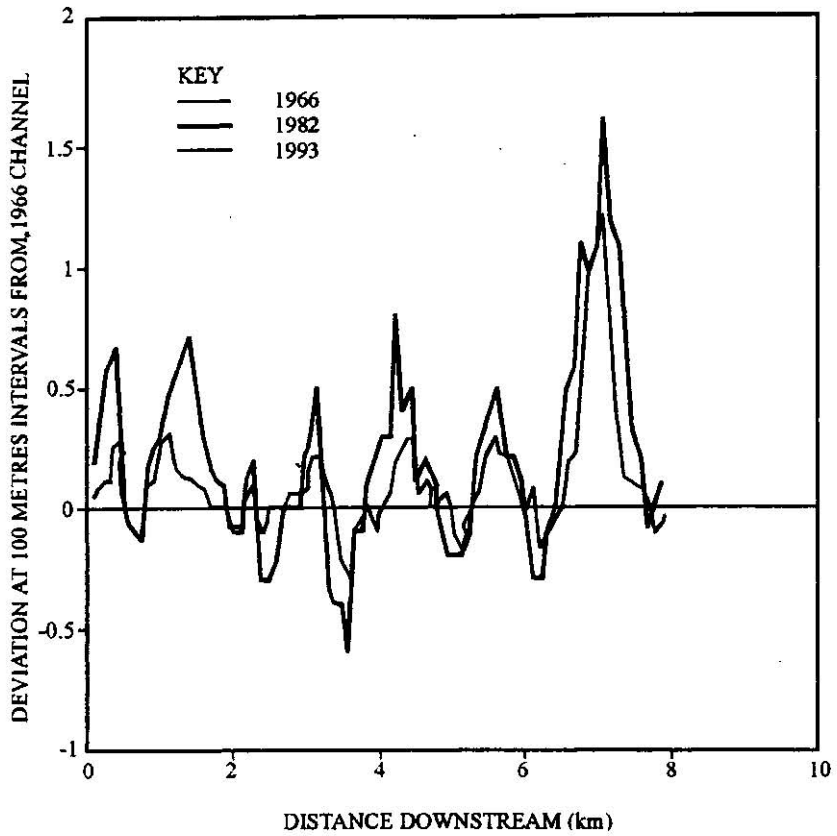


FIGURE 3. Channel planform deviation from the 1966 channel alignment.

TABLE 1. Rates of bank recession for two time periods 1966 to 1982 and 1982 to 1993.

Period	Years	Rates of bank recession (m/yr)	
		Bend X	Bend Y
1966 - 1982	17	15.7	6.3
1982 - 1993	5	7.6	4.0

illustrates the typical character of channel systems where changes on any one meander loop are dependent on upstream changes. Bank erosion and deposition may be altered and realigned following upstream channel changes with alterations in the rate of bank retreat or even the abandonment of sections of cut bank (Harvey et al. 1982).

The average rate of bank retreat for bend X was 0.5m/yr. Comparison between the aerial photographs show that the locus of maximum erosion shifts, in the short term, as bend planform geometry changes. Thus the value of 0.5 m/yr, is not constant with time. However, rates over shorter time spans cannot be obtained with sufficient proficent from the photograph available.

An attempt was also made to map sedimentation patterns at the selected meander bends. The depositional processes within the time periods studied may be complex and unknown but some interesting results could be observed. The sinuosity index increased from 1.53 in 1966 to 1.70 in 1982 and a maximum of 2.0 in 1993 at bend X while at bend Y it was 1.02, 1.3 and 1.5, respectively. Loop development cannot be inferred from the aerial photographs as point bar ridges and swales are not prominent on the floodplains. However, tonal variations and supported by textural analysis of the sediments suggest the possibility of different age zones (Figure 4).

In summary, the historical evidences (planform changes for channel and at the meander bends) showed that the processes involved have to be seen in the overall context of channel form changes. In particular, these may be triggered by high magnitude low frequency events. The whole channel is characterized by loop development which occur at a variety of spatial and temporal scales and which may be dependent on upstream changes. Many of these developments are difficult to anticipate and incorporate in the present study because they occur in response to rare events. The temporal evidence, however, confirm on a broader and general scale the significance of channel planform variations to external changes.

DISCUSSION

The importance of external stimulus and internal changes within the system in producing changes in the channel system have been well documented (Newson 1989; Lewin 1989). Rainfall fluctuations and changes in landuse utilization could trigger flooding and has always been the main element in floodplains adjustments (Newson & Macklin 1990; Jiongxin 1990).

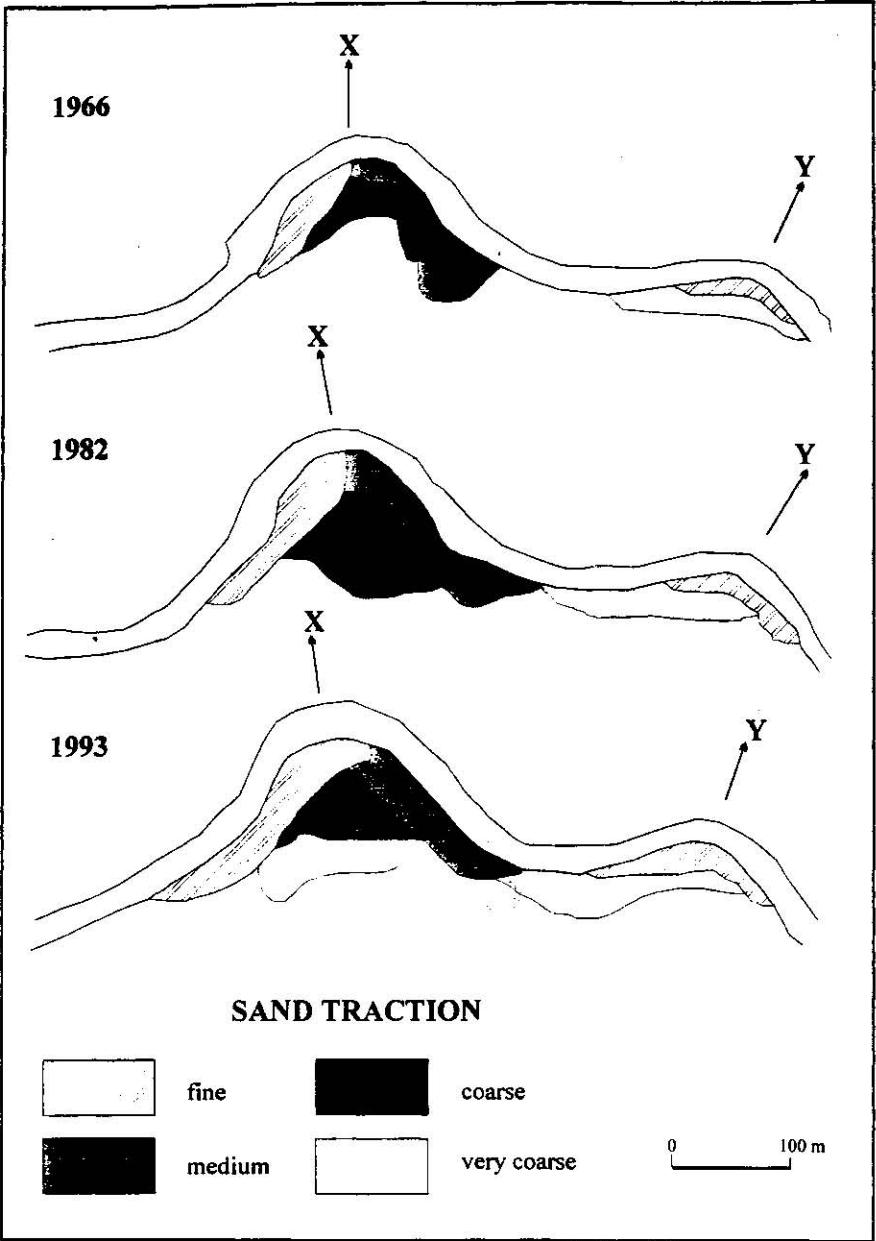


FIGURE 4. Sediment characteristics at meander bends X and Y.

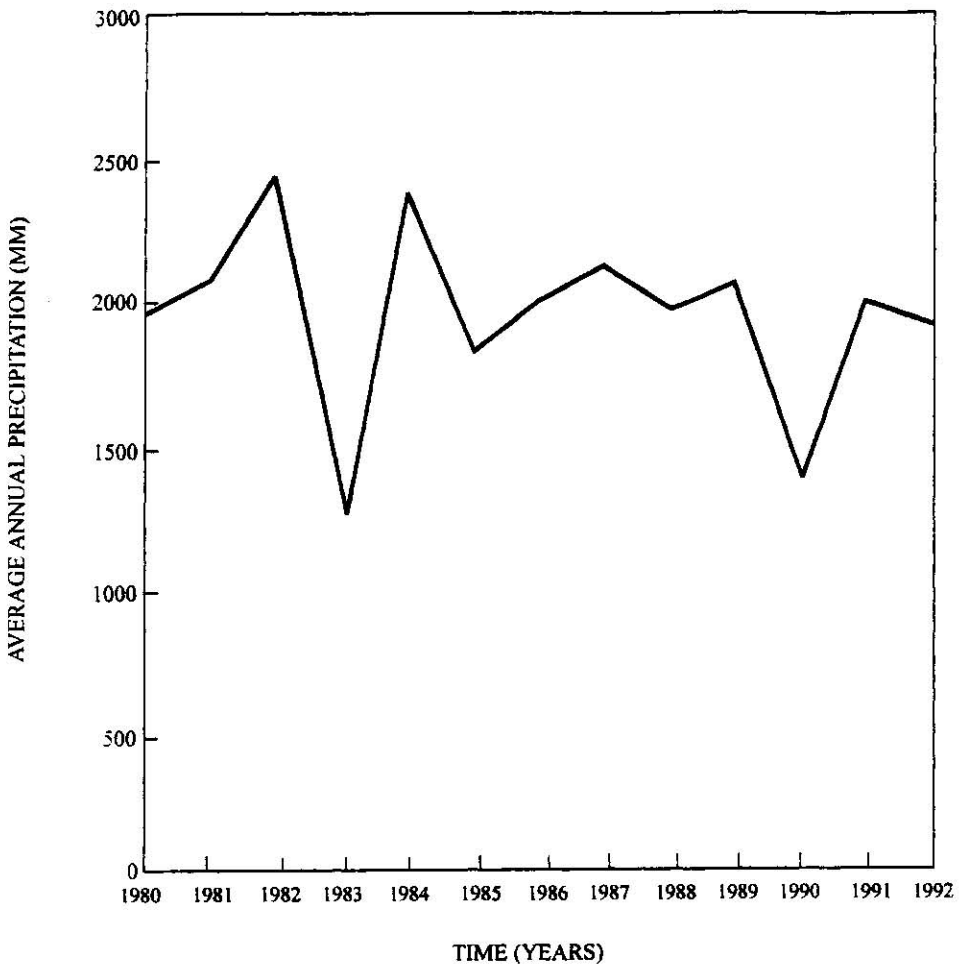


FIGURE 5. Average annual precipitation of Mukim Batu Hampar, Negeri Sembilan from 1980 to 1992.

The period 1966 to 1993 witnesses two breaks in the rainfall pattern in the study area in 1983 and 1990 (Figure 5). Whether these breaks are cyclical (i.e. a return period of about 10 years) have been determined, as rainfall records are unavailable prior to 1982. However, these breaks do show the possible existence of external thresholds in operation that could have influenced channel response. Studies by Love (1982) and Kesel et al. (1992) have shown that periodic changes in rainfall inputs would increase or decrease channel flow response thus influencing the operation of

channel processes. Furthermore, the marked decrease in average yearly precipitation experience in 1983 and 1990 could have also led to the problem of irrigation and changing patterns in padi cultivation culminating with the total abandonment in 1990. Whether this is typical prior to 1996 has not been ascertained but local padi cultivators have generally mentioned the problems associated with irrigation in the past (Dobby et. al. 1957).

Rivers are sensitive components of the physical landscape, with an ability to respond rapidly to external and internal disturbances. These disturbances vary considerably in character but they generally alter the flow regime and sediment load of the river, creating a disequilibrium in the channel (Knighton 1989). Channel response at an individual reach for example occur by overheightening and oversteepening of the bank, by degradation and by undercutting and the effects of seepage forces at the foot of the bank (Simon 1989). Piping and tension cracks in the bank materials enhance bank failures by internally destabilizing the bank. Typical of such mechanisms are the various forms of mass movements mentioned earlier. Apart from this, depositional processes are also at work where bar – swale formations could realign stream flow and process and channel morphologies. Any of these mechanisms and processes could have been responsible for changes in channel planform alignment and meander bends evolution since 1966.

CONCLUSION

Aerial photographs interpretation showed that part of the Batu Hampar river had undergone an active phase of channel adjustments. These were evident in the overall change in channel pattern and at selected meander bends for the time period 1996 to 1993. One reason to account for this could be associated with the fluctuating nature of mean annual rainfall evident in the study area. This must have influenced channel flow and channel processes and associated land utilization and channel planform adjustments in the area. However, the interactions between river channel change, sediment transport, climatic and hydrological fluctuations, and human activities are so complex that a simplistic response model relating morphological response to changing rainfall and landuse pattern is just not practicable.

REFERENCES

- Brizga, S.O. and B.L. Finlayson. 1990. Channel avulsion and river metamorphosis: The case of the Thompson river, Victoria, Australia. *Earth Surface Processes and Landforms* 15: 392-404.
- Dobby, E. H. G. et. al. 1957. Part III: Mukim Batu Hampar, Negeri Sembilan. In: Padi Landscapes of Malaya. *Malaysian Journal of Tropical Geography* 10: 81-102.
- Erskine, W., C. Mcfadden, dan P. Bishop. 1992. Alluvial cut offs as indicators of former channel conditions. *Earth Surface Processes and Landforms* 17: 23-27.
- Geological Society of Malaysia. 1985. *Annual Report*. Ministry of Primary Industries, Malaysia.
- Harvey, A. M., D. H. Hitchcock, dan D.J. Hughes. 1982. Event frequency and morphological adjustment of fluvial systems in upland Britain. In Rhodes, D.D. and G.P. Williams, (eds.). *Adjustments of the Fluvial System*. Boston: George Allen & Unwin.
- Jiongxin. X. 1990. An experimental study of complex response in river channel adjustment downstream from a reservoir. *Earth Surface Processes and Landform* 15: 43-53.
- Kesel, R. H., E. G. Yodis, and D. J. McCraw. 1992. An approximation of the sediment budget of the lower Mississippi river prior to major human modification. *Earth Surface Processes and Landforms* 17: 711-722.
- Knighton, A. D. 1984. *Fluvial Forms and Processes*. London: Edward Arnold
- Knighton, A. D. 1989. River adjustment to changes in sediment load: The effects of tin mining on the Ringarooma river, Tasmania, 1875-1984. *Earth Surface Processes and Landforms* 14: 333-359.
- Lewin, J. 1989. Floods in fluvial geomorphology. In Beven, K. and P. Carling, (eds.), *Floods: hydrological, sedimentological and geomorphological implication*. Chichester: John Wiley & Sons. Ltd., 265-284.
- Love, D. W. 1982. Quaternary fluvial geomorphic adjustment in Chaco Canyon, New Mexico. In Rhodes, D. D. and G. P. Williams, (eds.), *Adjustment of the Fluvial System*. Boston: John Wiley & Sons.
- Mackin, J. H. 1948. Concept of the graded river. *Geological Society of America, Bulletin* 59: 463-512.
- Moller, J. K. 1992. Lateral sediment transport by bedforms in a meander bend. *Earth Surface Processes and Landforms* 17: 501-513.
- Montgomery, J. 1989. Concepts of equilibrium and evolution in geomorphology: the model of branch systems. *Progress in Physical Geography* 13(1): 47-66.
- Newson, M. 1989. Flood effectiveness in river basins: progress in Britain in a decade of drought. In Beven, K. dan P. Carling, (eds.), *Floods: hydrological, sedimentological and geomorphological implications*. Chichester: John Wiley & Son Ltd., 151-169.
- Newson, M. and J. Lewin. 1991. Climatic change, river flow extremes and fluvial erosion – scenarios for England and Wales. *Progress in Physical Geography* 15(1): 1-17.
- Newson, M. D. and M. G. Macklin. 1990. The geomorphological-effective flood and vertical instability in river channels – feedback mechanism in the flood

- series for gravel bed rivers. In White, M. R., (ed), *River Flood Hydraulics*, Chichester: John Wiley and Sons, 123-140.
- Rhoads, B. L. dan M. R. Welford. 1991. Initiation of river meandering. *Progress in Physical Geography* 15(2): 127-156.
- Robert, A. 1993. Bed configuration and microscale processes in alluvial channels. *Progress in Physical Geography* 17(2): 123-136.
- Schumm, S. A. and R. S. Parker. 1973. Implications of complex response of drainage basins for Quaternary alluvial stratigraphy. *Nature* 243: 99-100.
- Simon, A. 1989. A model of channel response in disturbed alluvial channels. *Earth Surface Processes and Landforms* 14: 11-26.
- Thorne, C. R. and J. Lewin. 1982. Bank processes, bed material movement, and planform development. In Rhodes, D. D. and G. P. Williams, (eds.), *Adjustments of the Fluvial Systems*. Boston: George Allen & Unwin.
- Yang, C. T. 1979. Unit stream power equation for total load. *Journal of Hydrology* 40: 123-138.

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