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Deformation of River-bed and Its Causes in the Recent Quarter Century in the Lam Phachi River Basin

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Abstract
Comparing the aerial photographs taken in the years 1974 and 1998 the changes occurring in channel morphology since the beginning of colonization and cultivation in Lam Phachi river basin were analyzed to consider the magnitude and site of deformation and its causes. Morphological features of channel changes during the last quarter of the century can be grouped mainly into the following types; bank erosion, bend cutoff in meander, lateral migration of flow with massive sedimentation and terrace deformation. The spatial distribution of reaches for each type of changes were mapped out with respect to channel slope and the amount of discharge. The largest magnitude of change among them was indicated in the site with lateral migration and massive sedimentation located around the middle reaches in the study area, and sediment load flooding there suggested that it was transported by flood from the upstream where terrace deformation had occurred. Compared with the channel's morphological feature in 1974, the major source area of sediment yield has shifted and expanded from upstream to about 13 km downstream so that it is necessary for channel adjustment and stabilization to prevent reactivation of sediment load existing in these reaches.
Keywords: bank erosion, bend cutoff, terrace deformation, lateral migration

1. INTRODUCTION

Fluvial morphology is dominated not only by increases or decreases in water discharge, but also by the process of sediment transport and deposition. Particularly, the channel's morphological features strongly depends on the amount of sediment yield in the source area and the frequency of flood events causing bedload movement. Transport process of sediment from the headwaters to the floodplain has been expressed as 'sediment delivery' (Walling, 1983).

The morphological changes in a river's course take place also because development of land significantly affects the type of sediment load to be transported from the source area across the alluvial plain. In the Lam Phachi river basin, located in western Thailand, the colonization had began in earnest about 30 years ago. At present, three quarters of the river basin is under cultivation and being used as settlement.

In this report, we attempted to clarify the morphological changes that have occurred in the channel and its causes since the beginning of colonization and cultivation by analyzing aerial photographs and field surveying. Based on our findings, we tried to explain the processes of sediment transport relative to time and space.

2. METHODS AND STUDY AREA

Lam Phachi river basin has a watershed area of 2,657 km^2. As the traffic road network along the river has not been well completed, the field surveying on each river site is difficult to carry out. Two kinds of aerial photographs taken in different years were therefore used for comparing and analyzing the changes in the channel morphology, because the differences in pattern and channel shape as identified can be of use in the interpretation of river behavior from aerial photography when no other data are available (Kellerhals et.al., 1976). The photographs used were taken in 1974 and in 1998 both by the Royal Thai Survey Department, Thailand. The scale used for the photographs was 1:15,000 in 1974 and 1:50,000 in 1998. In addition to the photograph analysis, the cross sections and gradient of channel slope were surveyed beside 14 bridges crossing over Lam Phachi to calculate the amount of water discharge.

The study plot covers an area from the river mouth to the junction with the main tributary located 74km upstream, belonging almost to flood plain at an elevation under 100 m, with scattered settlements and widespread over cultivated fields. Therefore, the area is characterized by a higher tendency of disaster occurrence caused by flood and sediment movement. The study area is 1,447 km^2 covering about 54% of the whole river basin. The aerial photographs indicate that the settlement developed scarcely along the river in 1974. However in 1998 the well-vegetated riverside were almost cleared to change for cultivated fields and settlement.

3. MORPHOLOGICAL FEATURES

New shapes of channel are formed as a result of sediment movement. The extrinsic thresholds of sediment load and stream power determine whether the river will be straight, meandering or braided (Schumm, 1977). Harvey (1992) classified the shape of channel change resulting from floods into several types with reference to sediment input and discharge in a river basin of northwest England. Comparing the aerial photographs in 1974 with those in 1998, channel changes that occurred during the 24-year period can be grouped mainly into the following types:

Type A: Channel widening by bank erosion

Where the channel made a curve, the floods run against the out-curved bank and intensively led to lateral degradation (Harvey, 1992). Almost bank erosion occurred in the study area at the bent site without forest cover. Fig. 1 shows the channel around the 3 km point upstream from the river mouth in 1974 and in 1998 respectively. Circles pointed in the photo indicate the places where bank erosion has occurred. The right bank had regressed approximately 30-50 m backward during the 24-year period and could be said to be responsible for the widening of the channel. The scale of eroded sheer cliffs reaches 80-350 m in length with 5-20 m relative height.

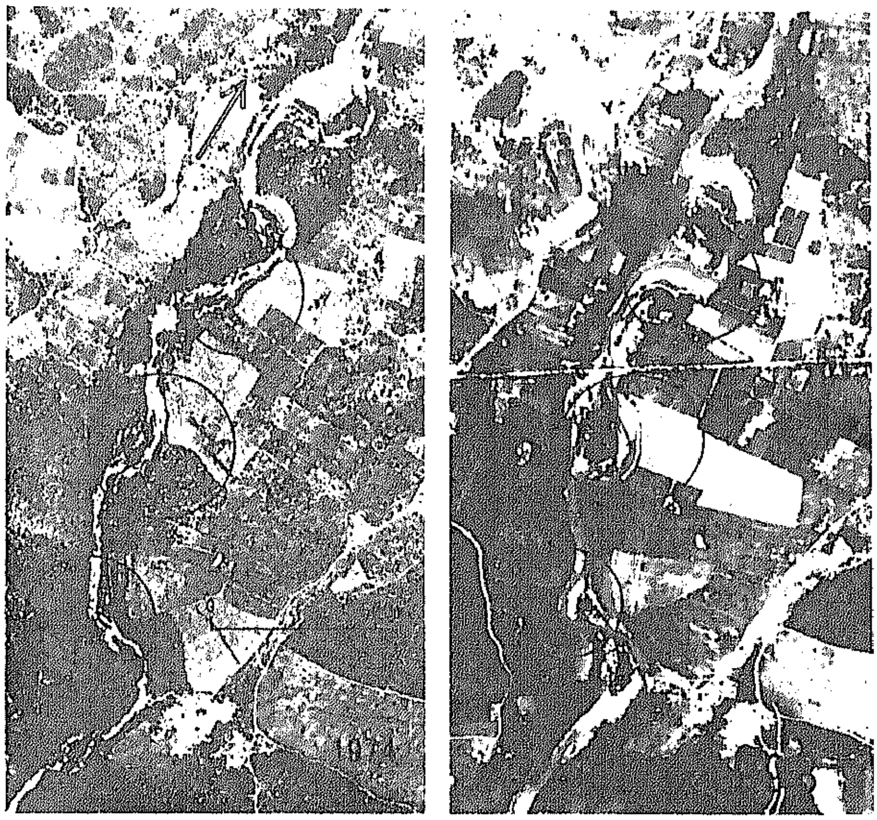

Fig. 1 Aerial photographs showing the bank erosion at the study site in 1974 and 1998

On the cliff the cultivated field of cassava, for example, extends until the edge of the cliff. As rainwater gathers between ridges and falls on the cliff, vertical erosion is accelerated resulting in a particular shape just like the teeth of a comb (Photo 1). Photo 2 shows the eroded steep cliff at the right bank located at a distance of about 1km upstream from the river mouth. The cliff reaches almost 12 m in terms of relative height. The site at which bank erosion occurred is observed where the stream bends, in addition to the cultivated fields extending up to the bank edge.

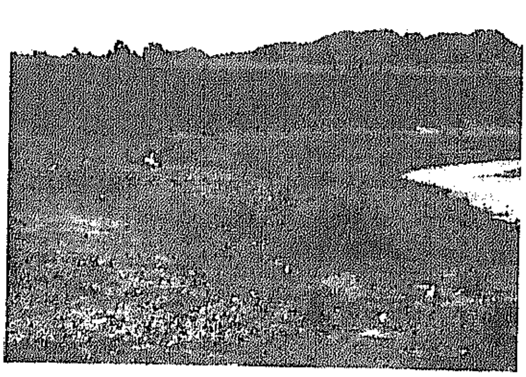

Photo 1 Bank erosion near the 3 km point

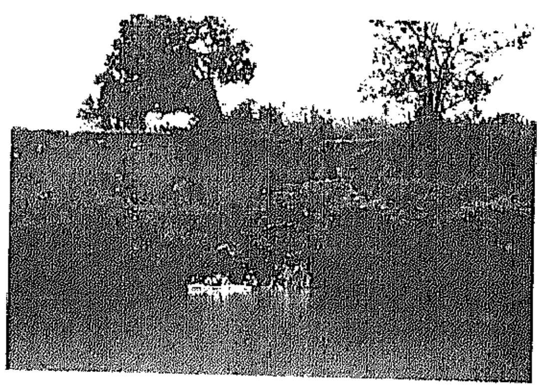

Photo 2 Bank erosion near the 1 km point

Type B: Bend cutoff in meander channel

This channel often shows meandering in plain reaches, where the gradient of the river-bed decreased and then the velocity of water flow reduced (Laronne & Duncan, 1992). Although water flows usually along bent course, the intensive floods flushed straightened across the floodplain foreshortening the course by bend cutoff, through which a new straight channel is formed.

Fig. 2 shows the channel around the 22 km point upstream from the river mouth in 1974 compared with the channel in 1998. In spite of the bent shaped channel in the year of 1974, the straight channel is observed at the same position in 1998, and over floodplain between meander a sheet of sediment spread. The old meandering channel depicted on the aerial photograph in 1974 is still visible in the field, nevertheless the modification of meandering initiated the former channel partly abandoned. Compared with bank erosion newly formed straight channels caused by bend cutoff took place where the relative heights of bank are lower.

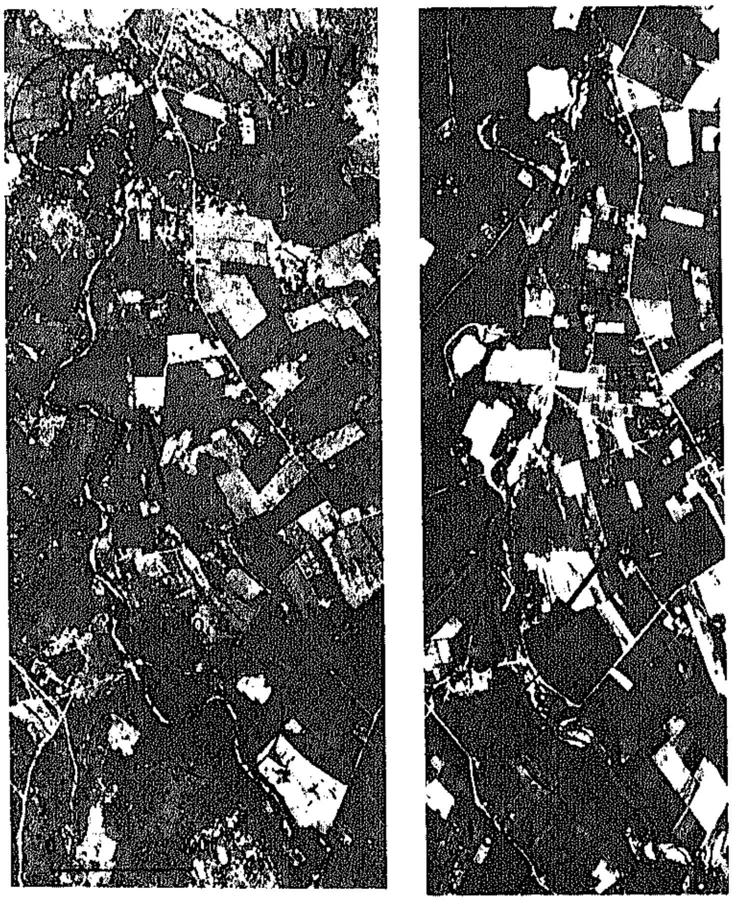

Fig. 2 Aerial photographs showing the bend cutoff at the study site in 1974 and 1998

Type C: Lateral migration and massive sedimentation

Massive sediment depositions by floods took place on reaches with widespread river-bed and caused lateral migration of channel forming a braid water course. Less water discharge and excess sediment input often led to a massive sedimentation, and through which a new widened river floor is initiated.

In 1998 a broad river-bed of 200-250 m width could be identified on the reaches between 38 and 40 km upstream from the river mouth, as shown in Fig. 3. Compared with the aerial photograph in 1974 the channel is entirely buried by new sediment, taken on a different

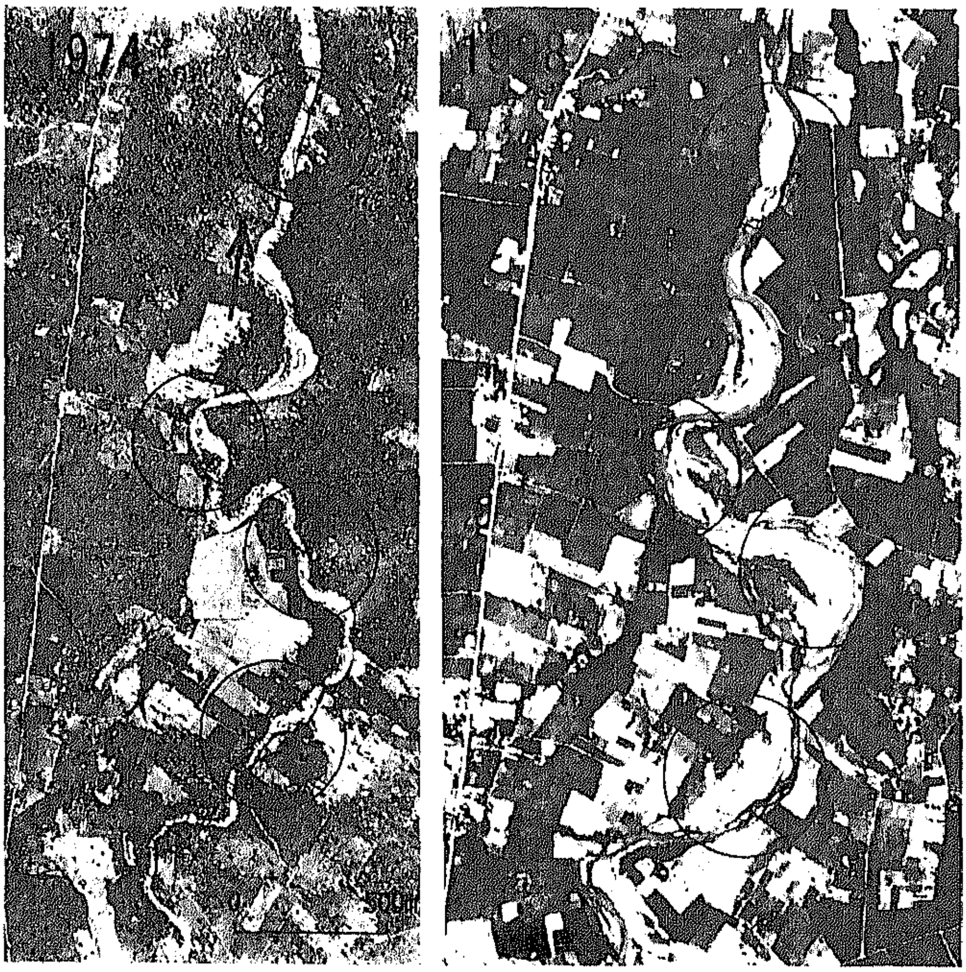

Fig. 3 Aerial photographs showing the lateral migration and massive sedimentation at the study site in 1974 and 1998

appearance and widened approximately 3 times as the previous figure. It is considered that the widening of the channel is caused by sediment floods rather than by scouring. The channel widening and braided flow has led to about a distance of 2.2 km, which indicates that among the study area the most massive deformation of channel has taken place in this site.

Type D: Terrace deformation

Different from water discharge, sediment is transported discontinuously and deposited from place to place under geomorphologic condition (Reid and Frostick, 1994). The widening of channel accelerated deposition and made the appearance of widespread sediment floods on river-bed. With scouring by flows thereafter, deposited sediment removed partly downstream which caused a depression of the river-bed and the formation of terraces beside the stream course.

Fig. 4 shows terraces with 20-100 m wide and vegetation covering the middle reaches of the study area on the aerial photograph in 1974. Even though the terraces were covered by vegetation, which suggested stabilization temporarily, the aerial photograph in 1998 indicated the disappearance of this vegetation cover over a long span. The terraces themselves have been deformed and altered to the widened bare channel. Deformation of terraces occurring in response to flood did not go beyond the river width, and scouring remained within the river. As scouring and deformation of terraces by floods extends over a wider area, reaches with this pattern could be a major source of sediment yield for downstream.

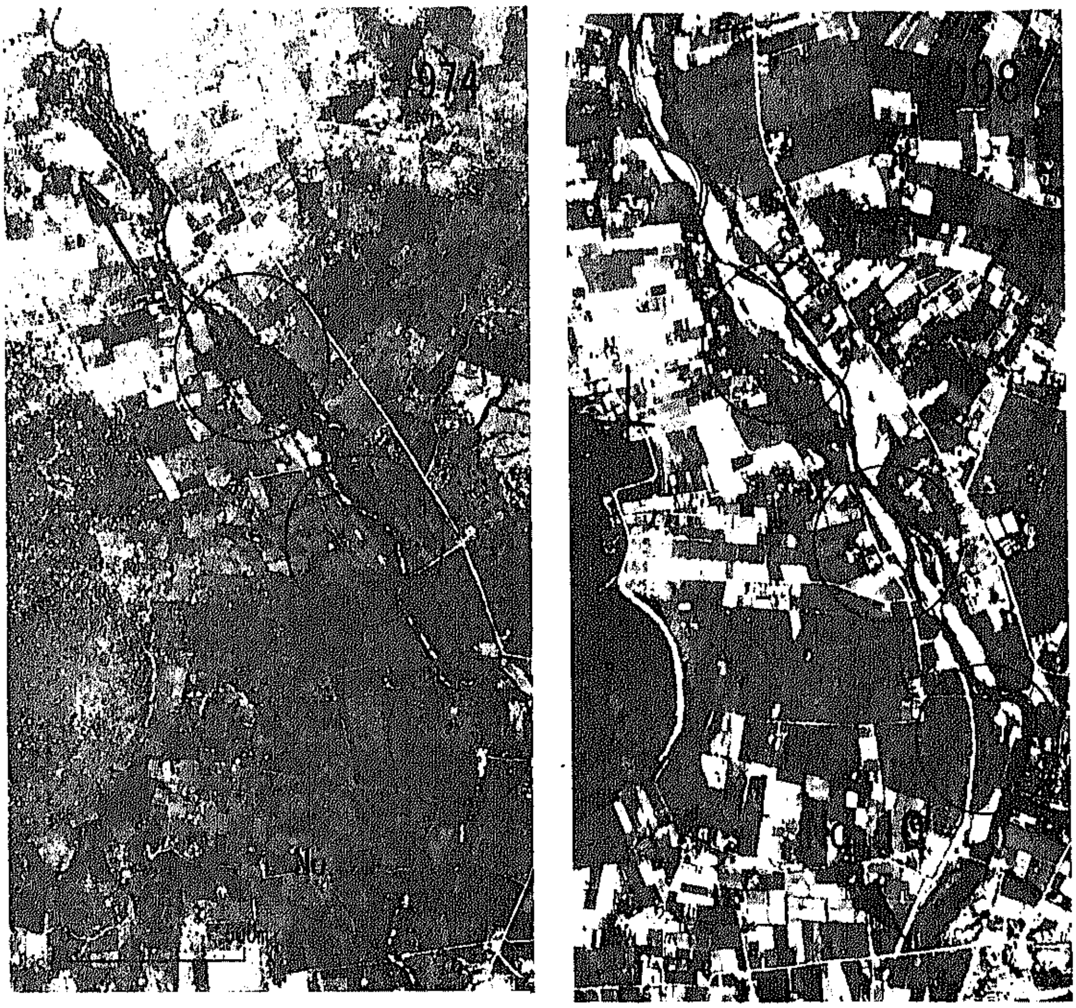

Fig. 4 Aerial photographs showing the terrace deformation at the study site in 1974 and 1998

4. CHARACTERISTICS OF DEFORMATION

4.1 Magnitude

Table 1 summarizes the site, types, magnitude and riverside of the whole channel deformations. Terrace deformation indicated the largest area among them, and its average value amounted to several tens of hectares per reach. The deformations with almost the same magnitude took place on the reaches with lateral migration and massive sedimentation. Therefore, the sections from 33 to 40 km and from 44 to 49 km could be pointed out as the sites on which massive deformation occurred in the channel during the last quarter of the century. Deformed areas due to bank erosion and bend cutoff in meander channel ranged from 0.2 to 3.2 ha, relatevely smaller in magnitude compared with other types.

Because it was difficult to estimate the depth of deformation from the comparison using aerial photographs, quantitative calculation of the morphological changes occurred in the channel could not be carried out. Considering the fact that floodplains with gentle slope constituted a greater part of the study area, the calculated values of the deformed area could reflect the amount of sediment that was contributed to the sediment load by floods.

Table 1 Types of deformed areas and their characteristics along the river

Distance from river mouth (km)	Type	Magnitude			Bank side
		Length (m)	Av. Width (m)	Area (ha)	
2.2	B	100	30	0.3	R
3.0	B	350	50	1.8	R
3.7	M,C	250	80	2.0	R
4.0	B	200	50	1.0	R
4.8	B	100	30	0.3	L
5.2	B	130	60	0.8	L
7.0	B	80	30	0.2	L
7.5	C	400	80	3.2	R
12.2	M,C	80	30	0.2	L
12.5	D	100	50	0.5	R
13.5	C	200	70	1.4	L
15.2	C	100	40	0.4	L
16.5	C	150	50	0.8	R
16.7	M,C	400	50	2.0	L
17.5	C	600	50	3.0	L,R
19.0	M	150	100	1.5	R
20.5	C	500	50	2.5	R
22.0	B	200	30	0.6	L
22.5	C	200	40	0.8	R
24.0	C	150	50	0.8	L
25.0	B	150	50	0.8	R
27.0	C	60	40	0.2	L
27.2	B	150	50	0.8	R
29.0	C	150	40	0.6	L
30.0	M	250	100	2.5	R
31.0	M	600	100	6.0	L,R
33.0	M	400	200	8.0	L
35.5	M	450	60	2.7	R
36.0	B,M	400	100	4.0	R
37.2	M	600	220	13.2	R
38.0	M	700	180	12.6	R
38.5	M	1,500	200	30.0	L,R
43.0	D,M	500	80	4.0	L
43.5	D	350	120	4.2	L,R
44.0	D	5,000	100	50.0	L,R
50.0	B,D	300	100	3.0	L,R
50.5	D	400	120	4.8	R
51.0	B	300	100	3.0	R
53.2	B	300	20	0.6	L
54.0	D	1,200	120	14.4	L,R
57.0	D	1,200	100	12.0	L,R
58.5	D	900	120	10.8	L,R
61.0	D	1,000	80	8.0	L,R
62.0	D	700	100	7.0	L
64.5	D	1,500	100	15.0	L,R
67.0	D	250	50	1.3	R
68.5	D	400	100	4.0	L,R
73.0	D	400	70	2.8	R
Total		24,550		250.2	

Type: B(Bank erosion), C(Bend cutoff), M(Lateral migration), D(Terrace deformation)

4.2 Site

Fig. 5 illustrates the location of deformed sites classified into 4 types. There was scarcely any site without deformation in the study area, and the channel is morphologically changed in the section with a total length of 24.6 km being equal to one third length of the study area. Each type of site is not distributed uniformly, but concentrates obviously on the particular section which could be divided spatially.

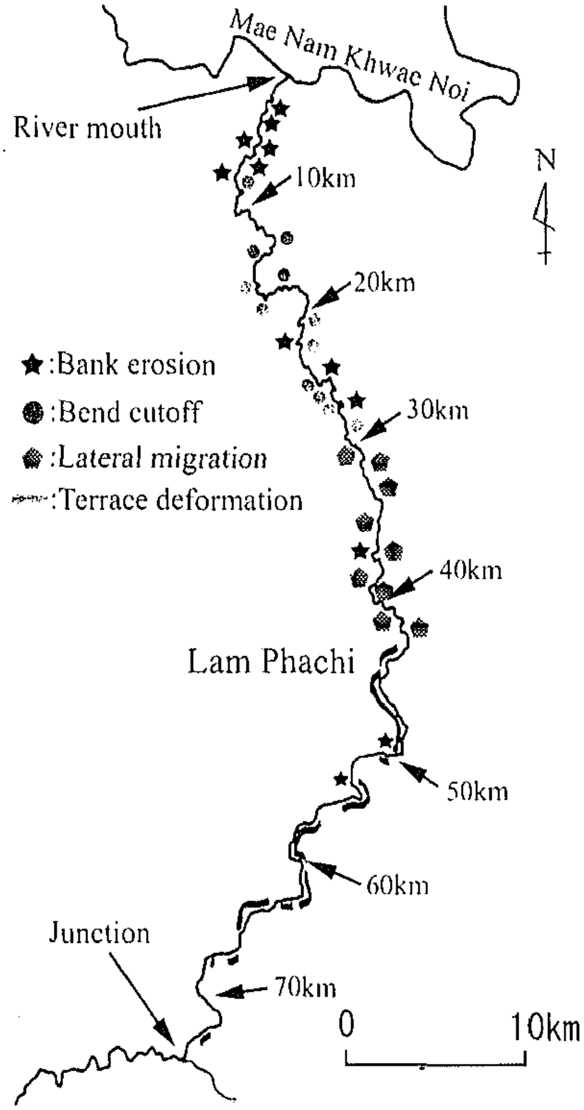

Fig. 5 Location of deformed areas

The bank erosion site was mainly found in the section from the river mouth up to 8 km upstream and from 35 to 38 km. The bend cutoff site was found to be concentrated around the meandering section between 12 and 37 km. The lateral migration site with massive sedimentation were located within reaches from 30 to 43km. Terrace deformation occurred from a point nearer to the 42 km mark up to the 68 km mark, extending several kilometers long per site. Consequently the morphological feature of the deformed channel could be defined spatially from the river mouth upstream as bank erosion, bend cutoff, lateral migration with massive sedimentation and terrace deformation in that order.

4.3 Causes

The distribution of channel deformation appears to be related to changes in river profile and the amount of water discharge. Fig. 6 indicates the graph of elevation against distance from the river mouth for the Lam Pachi river basin. It can be seen from this graph that the slope is gentle (1/1000) from the river mouth to a point roughly 5 km upstream. The gradient further reduces to 0.7/1000 up to the 33 km mark after which it changes to a value of 1.7/1000 up to the 56 km mark, before becoming gentle again (0.6/1000).

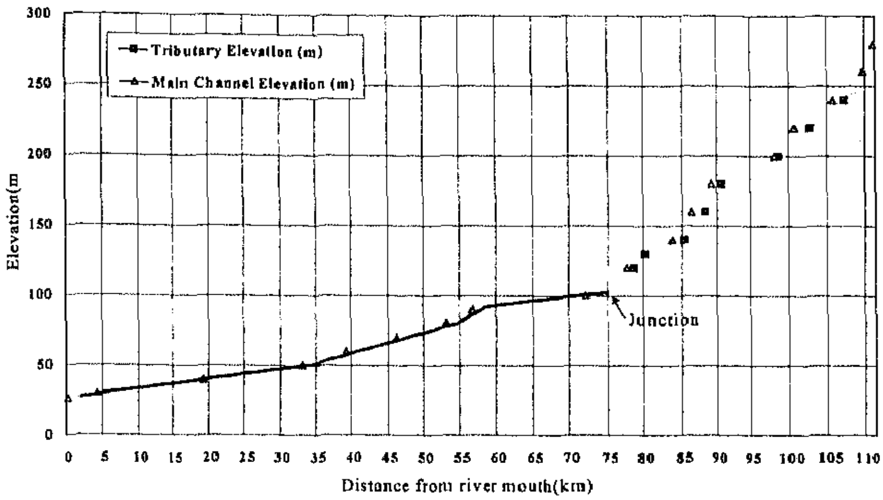

Fig. 6 Longitudinal profile for Lam Phachi River

Fig. 7 represents the water discharge during usual flows in the study area for the past two years calculated from the surveying of cross sections. Although there is a little difference in the tendency for the values to change according to the distance from the river mouth for both years, there was very little variation in the discharge from the junction to around the 30 km point and increased from there rapidly downstream.

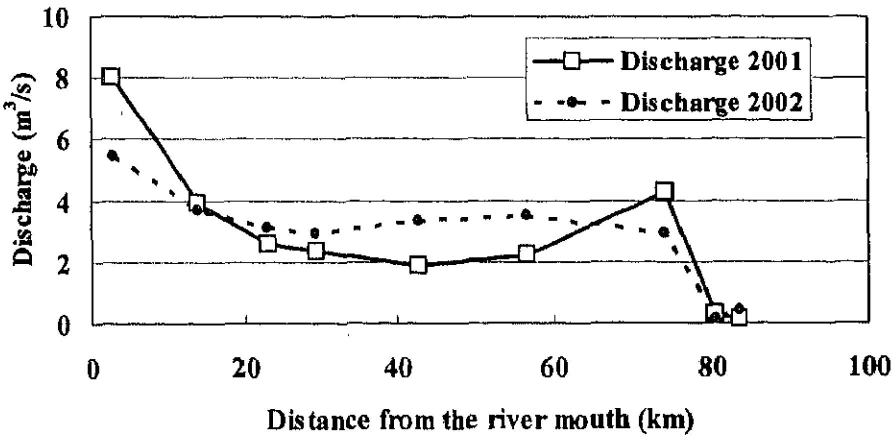

Fig. 7 Discharge during usual flow for two years

Considering both features, a massive sediment transport by floods from upstream might terminate around the point of 33 km due to mitigation of the channel gradient and little fluctuations in the water discharge. Especially, the tendency of the discharge to remain suggests an acceleration in the unloading of sediment. Terrace deformations corresponds remarkably with transitional reaches of channel slope from gentle to steep gradient.

After sediment deposition in large quantities, it is considered that flood flow might result in the straightening of the channel in the meandering section. According to the observation of water level by R.I.D., the highest water level resulting from a flood on 26th October 1999 is recorded approximately as 7 m. This is higher than the usual water level so the increase in the water discharge at the downstream reach could be related to escalation in the magnitude of bank erosion there.

5. DISCUSSION AND CONCLUSION

Alluvial channel morphology tends to adjust with the input of water and sediment to the fluvial system, with a high rate of coarse sediment input leading to unstable, often braided channels, and a lower rate to more stable, often meandering channels (Schumm, 1977). The patterns of channel deformation in the Lam Pachi river basin could be classified mainly into 4 types, and the site at which each pattern occurred has been divided spatially according to the channel slope and water discharge.

The largest magnitude of channel deformation occurred where the slope gradient changed from steep to gentle, and rare fluctuation of discharge according to distance is recognized. On this reach, sedimentation by flood is assumed to exceed scouring by lateral migration. Because of that the calculated values of water discharge indicated no remarkable changes with respect to distance, transported sediment should be deposited with a reduction in slope angle and widening of flow.

The reaches with terrace deformation upstream could therefore be pointed out as the main source of sediment yield, located from 44 to 60 km. In 1974 the distribution of existing wide terraces was limited to the upper reaches from 43km, but in 1998 it extended downstream until the 30 km point. After the floods which resulted in the deformation of terraces, vegetation has thriven quickly and recovered on the surface of the terrace within a short time (Photo 3, 4). With vegetation cover, the terraces appear to be stable, but in actual fact they are unstable and likely to move again.

It is considered that the extension of reaches with terrace formation is due not only to

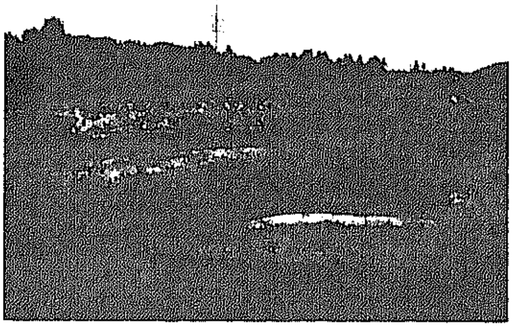

Photo 3 Vegetation cover on terraces

Photo 4 Vegetation cover on river-bed

sediment input from the upper reaches, but it is also related to the changes in land use in the river basin. However, the data to discuss the relationship between channel deformation and human impact is insufficient.

The channel in meandering reaches is assumed to be relatively narrow, and no large-scale sediment deposition has been found. As a massive deposition of sediment took place on the upper reaches, only small size materials such as silt, loam and sand are transported as suspended load by usual flow, but in our opinion, the cross section of the river was not able to handle the discharge by the flood. Furthermore, increment of discharge downstream tends to lead to enlargement of bank erosion.

For stabilization of the river in study area, it is necessary to prevent reactivation of scouring as well as to reduce removability of sediment deposits on the river-floor in middle reaches, to adjust channel width artificially at meander sections and to protect both banks against lateral erosion downstream (Fig. 8).

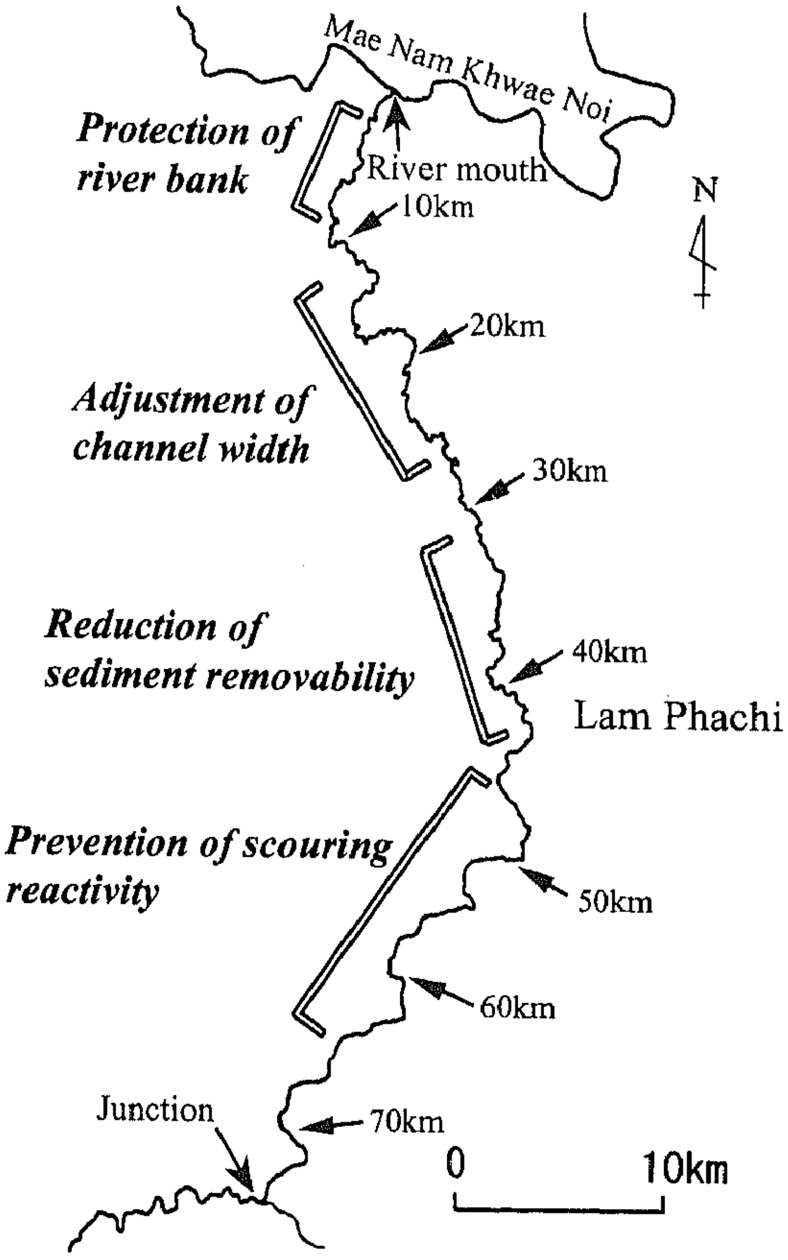

Fig. 8 Proposals to prevent sediment disasters and flooding

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