Channel flood plain linkages on the Kam Tin River, Hong Kong

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Abstract A simple graphical comparison of superimposed courses of the Kam Tin (North) River for the period 1959/60 to 1983/85 reveals lateral migration of a number of meander bends. Field measurements also confirm erosion of the river bank. Observations on the properties of suspended matter transported by the Kam Tin River suggest that channel bank materials are not an important source under stable runoff conditions. However, during stormflow channel bank materials may provide sediment to the river. Engineering works associated with river training to alleviate flooding and improve drainage have resulted in a dramatic change to river plan form and decoupled the river from the flood plain. Main drainage channel construction also has an environmental impact that is briefly outlined.

Key words plan form change; maps; river training; sediment properties; Hong Kong

INTRODUCTION

The Kam Tin River basin is one of the largest in Hong Kong (around 46 km^2) and consists of two major tributaries (Fig. 1(a)). The upper parts of the basin are steep uplands with slopes covered in grassland, shrubland and woodland. Unusually for Hong Kong the Kam Tin basin contains extensive alluvial plains and flooding occurs quite frequently in the developed lowlands. River training works have recently been completed and others are in progress to help mitigate the flood hazard. The Kam Tin River exhibits a sinuous course and a number of well developed irregularly spaced meanders occur (Fig. 1(a)).

Consequently, the Kam Tin river affords the opportunity to study plan form changes and investigate channel flood plain linkages. While plan form changes have received much attention, in part due to the relative ease of data acquisition (Hooke, 1984), there has been no study on this aspect of fluvial geomorphology in Hong Kong. Lewin (1996) has suggested that for mobile river channels much of the river sediments may be derived from erosion of flood plain material: such linkage has not been evaluated in Hong Kong. Recent flood engineering works in the area have profound implications for channel plan form changes and it is of interest that Carling & Petts (1992) suggest that one of the recent trends in fluvial research is to examine the geomorphological consequences of major engineering works. Brookes (1996) identifies some of the major human impacts upon river channels, with channel management being a cause of direct change. This aspect has received little consideration in Hong Kong.

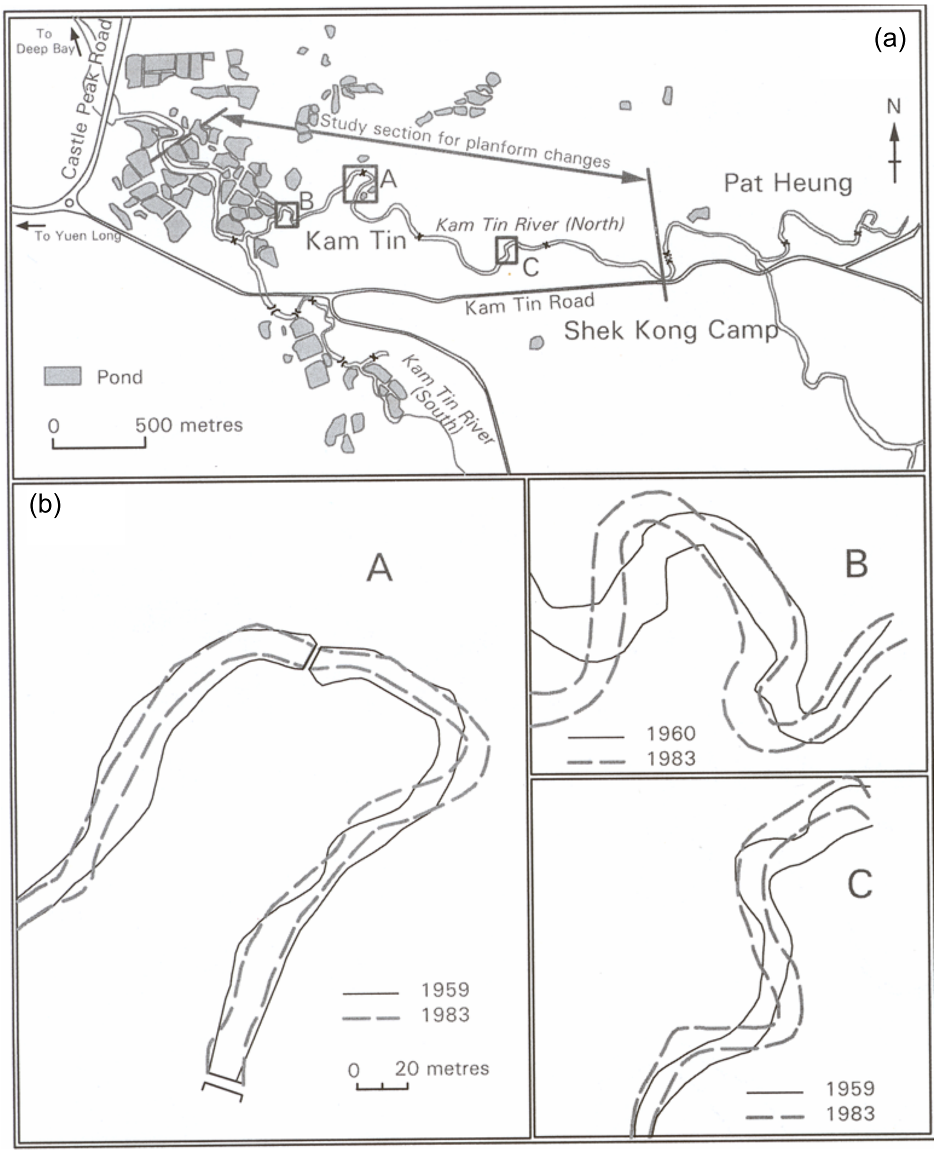

Fig. 1 Location of the Kam Tin River and study reach (a) and channel plan form changes (b).

STUDY BASIN AND METHODS

The Kam Tin basin is located in the North West New Territories and it drains the slopes of Kai Keung Leng, Tai To Yan and the western slopes of Tai Mo Shan. Two major tributaries of the Kam Tin River occur (Fig. 1(a)) and it discharges into Deep Bay. Topographically the basin consists of steep uplands and a contrasting lowland alluvial plain, areas of which are prone to flooding. The upland slopes are well vegetated and hillfires are relatively common. Agriculture has dominated the lowland plain and remains important and this includes areas of ponds (Fig. 1(a)). An increasing area is being occupied by housing, open storage and some light industrial uses. Shek Kong Camp is a military base (Fig. 1(a)). River training works have been undertaken to reduce the flood hazard and improve drainage (Fig. 2). Peakflow discharge in the new artificial main drainage channel, labelled 22 CD in Fig. 2, is 211 $m^3 s^{-1}$ while for the same area the old river channel had a peakflow of 188.2 $m^3 s^{-1}$ (ERM–Hong Kong, 1996). Mean annual rainfall ranges from about 3000 mm $year^{-1}$ at Tai Mo Shan, the highest point in Hong Kong at 958 m, to less than 2000 mm $year^{-1}$ over the western parts of the basin.

A graphical comparison of plan form changes has been undertaken for the Kam Tin River. Based upon 1:1200 and 1:1000 maps for the period 1959/60 to 1983/85 channel plan forms were superimposed using PC Arc/Info. Using PC Arcplot, maps, at a scale of 1:1000, showing plan form change were produced for a study reach identified in Fig. 1(a). Re-survey of channel banks has also been undertaken for two sections of meanders near Kam Tin. The first of these sections, 21 m long, was measured between 25 February 1997 and 3 June 1998. The same section was measured again from 25 November 1998 to 18 April 2000; the disruption of measurement being due to channel maintenance works. A second meander cliff was measured over the period 27 February 1997 to 22 November 1998. Both sections are located in the area identified as C in Fig. 1(a).

Near the settlement of Kam Tin, on the north branch of the river, water samples have been collected for total C and N analysis of suspended matter. Dip samples were collected during storm events generated by rainfall and under stable runoff conditions with no precipitation. Most of the samples were collected during 1998 to 2000. The suspended sediment was separated by filtration using GF/C filter papers. These were subsequently air dried and the sediment disaggregated before analysis. Bulked channel bank material samples were collected from two active meander bends located in the area identified as C in Fig. 1(a) and these were air dried prior to analysis. The suspended matter and channel bank material samples were not pre-treated to remove carbonates before total C and N analysis was carried out using a Perkin Elmer model 2400 elemental analyser.

CHANNEL PLAN FORM CHANGES

Evidence of river plan form change along the Kam Tin North River is presented in Fig. 1(b) for three active sections of channel. Superimposition of plan form maps for the

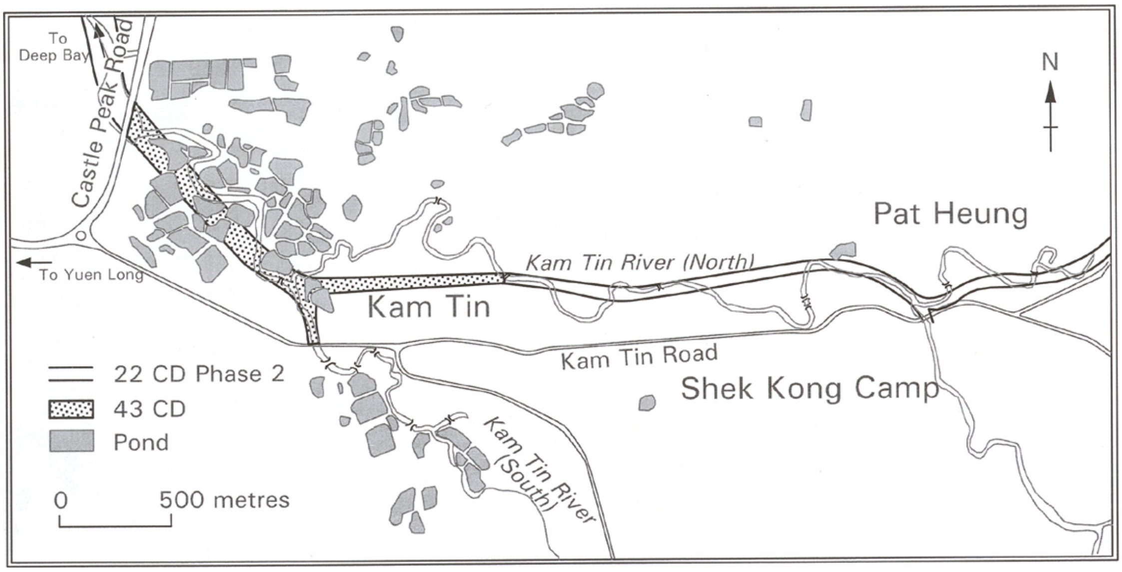

Fig. 2 New main drainage channels for the study reach of the Kam Tin River.

period 1959/60 to 1983 for three reaches of the river reveal lateral migration of the channel which may provide sediment for the river. Meander section A has a maximum lateral migration of 12.5 m while the two bends in section B both exhibited a maximum migration of 16 m. Section C contains three bends which exhibited maximum lateral migrations of 12, 11 and 10 m for the period 1959–1983. These maxima convert into average annual migration rates that range from 0.666 m $year^{-1}$ for both bends in B of Fig. 1(b); 0.5 m $year^{-1}$ for A and 0.48, 0.44 and 0.4 m $year^{-1}$ respectively for the three bends in C of Fig. 1(b).

Field measurement of river bank movement has also been undertaken for two sites associated with area C in Fig. 1(b). During the period 25 February 1997 to 3 June 1998 a 21-m section of bank gave an average lateral movement of 1.96 m. The same section measured from 25 November 1998 to 18 April 2000 exhibited an average migration of 1.59 m, with the interruption in measurement being due to channel maintenance work. Measurements on a second meander cliff for the period 27 February 1997 to 22 November 1998 reveal an average lateral movement of 2.09 m over a 33-m section. This covers two summer wet seasons, when most bank erosion occurs, and for a two-year period gives an average annual migration rate of 1.05 m $year^{-1}$. At this rate of movement it would take the river around 52 years to reach the higher confining ground to the south. These field observations support the activity noted in the plan form study, and further supports the possibility of sediment provision to the channel system. Other studies have documented the role of channel bank erosion as a supplier of sediment. For example, river bank erosion is recognized as a major source of sediment for many coastal rivers north and west of Sydney during flood dominated regimes by Erskine & Warner (1999). They conclude that for a 35-km study reach of the Hunter River around 18×10^6 t of sediment were eroded from the flood plain and channel between 1949 and 1979 and this could account for 29% of total sediment yield (suspended and bed load) during the 31-year study period. Working on the River Culm in Devon, England, Ashbridge (1995) has assessed the role of channel bank erosion in the provision of suspended sediment. Based on data for two years (1980–1981) he calculated that 19% of the suspended load may be derived from bank retreat processes.

IDENTIFYING CHANNEL FLOOD PLAIN LINKAGES

Whilst making observations on floating debris and rubbish in the Kam Tin River channel bank collapse has been observed and it resulted in increased turbidity of the water suggesting an input to sediment transport. Comparison of sediment properties, total C and N along with their ratio, for suspended sediment and channel bank material may provide evidence of the link between lateral channel migration, which has been documented for the channel system, and sediment transport in the river. It may also permit assessment of how important bank collapse, such as that reported above, may be in terms of suspended sediment transport. Channel bank materials were obtained from the meandering section labelled C in Fig. 1(b). Table 1 presents values of C, N and their ratio for the Kam Tin River. It can be seen that the channel bank materials fall into two groups, those that contain N and those that do not. Neither of the groups closely resembles those of the suspended sediment samples, especially samples obtained under stable runoff conditions. Winnowing of collapsed and slumped channel bank materials does not appear to provide the dominant source of suspended matter under these flow conditions. Storm period suspended matter most approaches the bank substrate material. The lowering of the percentage of C and N in the suspended sediment during storm events compared to the values observed under stable flow might reflect an input from channel bank materials. Table 1 provides evidence that channel bank sources, as characterized by these samples, do not dominate suspended sediment production. Other sources, such as surface soil erosion and landslides in the upland areas of the basin, may well have a more important role as providers of sediment.

Table 1 Comparison of C, N and their ratio for suspended sediment and channel bank materials.

	C (%)	N (%)	C/N Ratio
Suspended sediment (mean)			
Stormflow*	13.95	1.94	7.35
Dry season stable-flow†	32.54	4.40	7.45
Summer wet season stable-flow‡	29.9	3.86	7.82
Bank material (range of values)			
Type A	0.26–0.80	0	Not available
Type B	1.45–1.54	0.06–0.08	18.63–25.6

* Sample size = 59.
† Sample size = 41.
‡ Sample size = 23.

NEW MAIN DRAINAGE CHANNELS

Increased recognition of the flood hazard, in both urban and rural areas, has had implications for the drainage systems of Hong Kong including those in the study area. This is because structural measures are regarded in Hong Kong as one of the fundamental components of the flood prevention strategy. In order to mitigate the flood hazard in the study section of the Kam Tin River basin, in which the drainage system has been described as "totally inadequate" (Binnie Maunsell, 1993), a major programme of structural works has been undertaken. For the section of the Kam Tin River from the Castle Peak Road up to the end of the study reach near Shek Kong Camp, and beyond, a completely new river channel has been created and its course is shown in Fig. 2. The downstream section (beginning at Castle Peak Road and identified as section 43 CD in Fig. 2) consists of a trapezoidal cross-section (21.1 m wide at the bed) with concrete lined bed and masonry on the channel side slopes with grasscrete on the upper slopes of the banks. A 4-m-wide dry weather flow channel is incorporated into the design (ERM–Hong Kong, 1996). Upstream from section 43 CD the new channel for the study reach will also be trapezoidal in cross-section, concrete lined and have a dry-weather flow channel. According to preliminary designs the bed will be stepped (ERM–Hong Kong, 1996). This section of main drainage channel is shown as 22 CD phase 2 in Fig. 2. Field measurements made near meander site C in Fig. 1(a) reveal a basal channel bed width of around 15 m and a dry weather flow channel width of 3 m. A major consequence of these river training works is that the new channels will remain fixed in position: lateral migration across the flood plain with associated re-working and re-mobilization of sediment will cease. Plan form changes of the Kam Tin River such as recorded in Fig. 1(b) will no longer be possible. Furthermore, flood waters will also normally be confined within the channel further reducing the linkage between the river and the flood plain. The process of overbank flow may be important in building a flood plain through deposition of sediment (Brookes, 1996). No longer will water and sediment be delivered to the adjacent flood plain on the Kam Tin River. Main drainage channels have recommended flood protection standards of 1 in 50 years, however embanked channels should be able to convey a 200-year flood within bank (Binnie Maunsell, 1993).

Comparison of the old "natural" Kam Tin river system and the new artificial engineered drainage system in Fig. 2 reveals a marked alteration to plan form, the channel becoming straightened with a number of meander bends becoming abandoned. Table 2 summarizes some of the channel changes associated with the engineering works. If channel lost and abandoned are summed and compared to the length of channel created a loss of 2.41 km of channel is revealed. The ecological value for residual habitat losses due to main drainage channel construction has been assessed by ERM–Hong Kong (1996). For sections 43 CD and 22 CD the river channel lost or abandoned was of medium ecological value whilst the riparian vegetation lost was qualitatively rated as medium, the latter value being assessed during baseline studies (ERM–Hong Kong, 1996). It should be noted that the observations of habitat loss refer to all three phases of the 22 CD drainage channel works and affects channels outside the study area: ERM–Hong Kong (1996) provides full details.

Table 2 Channel changes associated with new main drainage channel construction.

Contract	Channel lost*	Channel created	Channel abandoned†
43 CD	1.28 km	2.3 km	2.24 km
22 CD (Phase 2)	2.25 km	2.96 km	1.90 km

* Channel segments through which new main drainage channels will be built.
† Not to be filled with spoil.
Source: ERM–Hong Kong (1996)

The environmental considerations of the construction of main drainage channels for Ngau Tam Mei, Yuen Long and Kam Tin are outlined by ERM–Hong Kong (1996). According to them there are three key ecological issues that arise from main drainage channel construction when they become operational. These are firstly, the indirect loss of wetland habitats due to the control of flooding. Secondly, accelerated urbanization may occur due to the reduction in the flood hazard and finally, containment of storm period runoff within the new channel would lead to a direct loss of seasonal wetland habitats.

In terms of loss of wetlands ERM–Hong Kong (1996) report that the abandoned channel referred to in Table 2 have the potential to become compensatory wetlands. However, some of the abandoned stream beds adjacent to the new channels are to be filled with spoil and this precludes their use as compensatory wetlands. The use of grasscrete on the inside of main drainage channel embankment slopes may also help to mitigate against loss of wildlife habitat according to ERM–Hong Kong (1996).

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