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Environmental Observations on the Kam Tin River, Hong Kong

Mervyn R. Peart, Lincoln Fok and Ji Chen
The University of Hong Kong
Hong Kong SAR
China

1. Introduction

Hong Kong, from being described as a barren rock with scarcely a house upon it in 1841, has undergone a remarkable transformation to a metropolis with, in 2008, a population of seven million. Whilst Hong Kong's economy has become increasingly service oriented since the 1980s, the industrial development of Hong Kong over the past few decades has been impressive (Poon and Tsang, 2010). Moreover, as Poon and Tsang (2010) note "despite the decline in manufacturing's share of GDP and employment, it would be a mistake to conclude that industries are of little relevance to the economy." They suggest that "In fact, the manufacturing and trading sectors have remained the most important sectors of the Hong Kong economy". However, the service sector has flourished in recent decades and has diversified to match the structural transformation of the Hong Kong economy (HKSAR Government, 2009).

Expansion of population, along with the growth and transformation of the economy, has been associated with considerable environmental change, both spatial and temporal, in Hong Kong. For example, urban areas have expanded and new towns have been developed. Moreover, as Wang (2010) observes "The process of urban development of Hong Kong in the past century has actually been a process of interaction between its urban transport system and its urban spatial expansion." This expansion of urban area has occurred into previously rural lowlands resulting in the loss of agricultural land and coastal wetlands (Corlett, 2010). Port and airport development has also accompanied the growth of Hong Kong. For example, Kai Tak Airport in Kowloon was built in 1925 but in the 1980s had reached saturation. A new airport was planned at Chek Lap Kok on Lantau Island and became operational in 1998. Moreover, expansion of port back-up facilities, such as container storage, has also contributed to land-use change. Electricity consumption has also increased in Hong Kong. Tso and Yau (2003) describe a substantial increase in domestic energy consumption in the 1990s. However, reflecting the structural changes in the economy Lam et al. (2010) report that the commercial sector was the largest electricity end user and that cooling-dominated office buildings accounted for most of the sector energy consumption.

The growth and development of Hong Kong has had consequences for the environment. This includes climate, ecology, land-use and upon streams and rivers for example. This paper will report some examples of the impact of this development upon the rivers and streams of Hong Kong by using the Kam Tin North River as a case study.
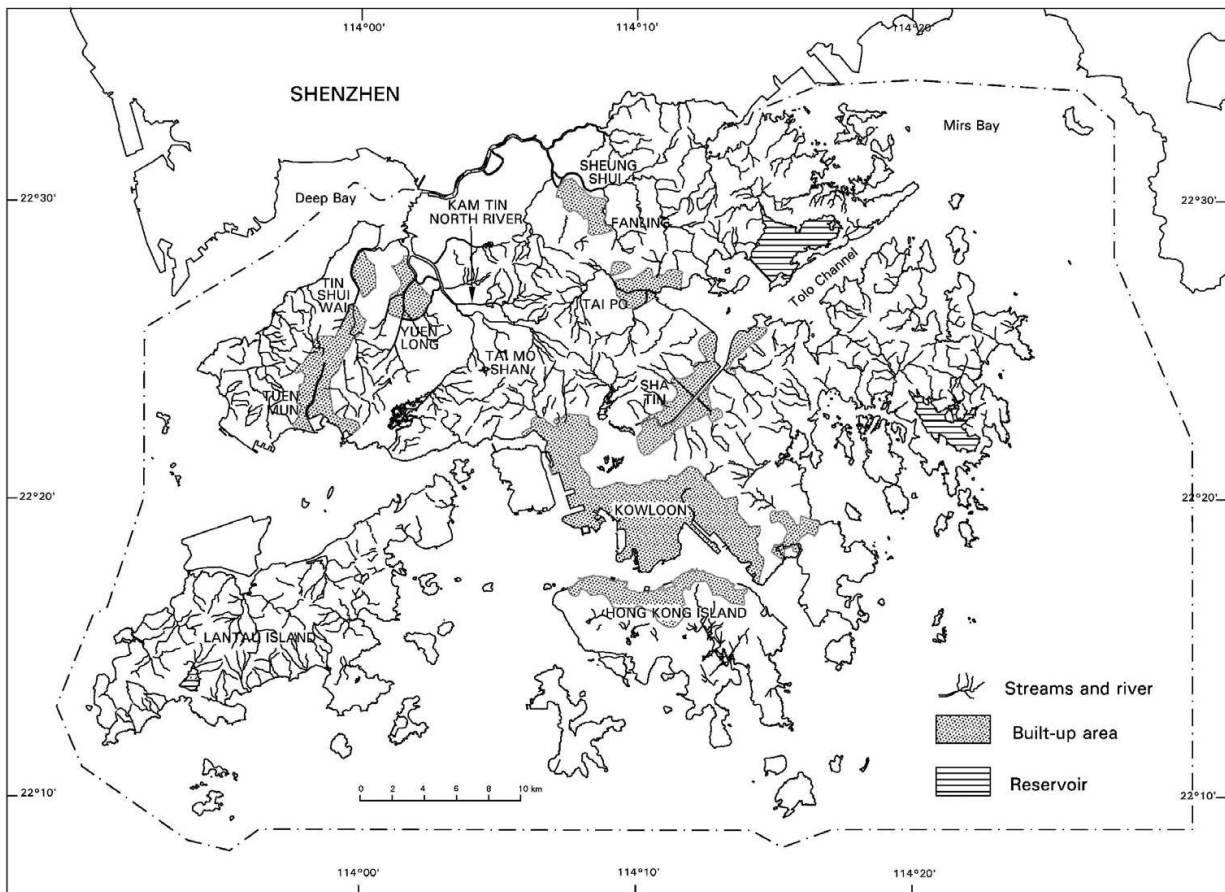
Fig. 1. Location of Hong Kong and the Kam Tin North River.

2. Study area

Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China. It has a coastal location and structurally it is part of the South China coastal massif. Two large marine embayments exist on either side of the SAR, namely Deep Bay to the west and Mirs Bay to the east (Fig. 1). The SAR has an area of around 1,100 km² of which 72% is part of the Kowloon Peninsula and New Territories and which is part of the mainland. Some 18% of the SAR consists of around 230 offshore islands of which the two largest are Lantau Island (13% of the SAR) and Hong Kong Island. Despite such a small area, Hong Kong has a variety of landscapes. Much of the land-area is mountainous with very little flat land: only 20% of the SAR has slope gradients of 0 to 5°, whilst 30% of terrain has slope angles of 15° or more (Styles & Hansen, 1989). The northwest New Territories has much of the lowland, but as Styles and Hansen (1989) note these often lie adjacent to steep slopes that form the uplands. Owen and Shaw (2007) reported that around 5% of Hong Kong is occupied by rivers and their floodplains, mostly in the northwest. It is in one of the drainage basins in the northwest of Hong Kong that this study is located: the Kam Tin River.

The Kam Tin drainage basin is located in the Northwest New Territories (Fig. 1) with an area of 44 km² (ERM, 1995; HKEPD, 2004), one of the largest in Hong Kong, and it discharges into Deep Bay. The drainage system, partly developed on one of the largest floodplains in Hong Kong, is composed of two main tributaries - the Kam Tin North and

South Rivers. This study is based on the Kam Tin North River, and it reflects the tension between development and environment.
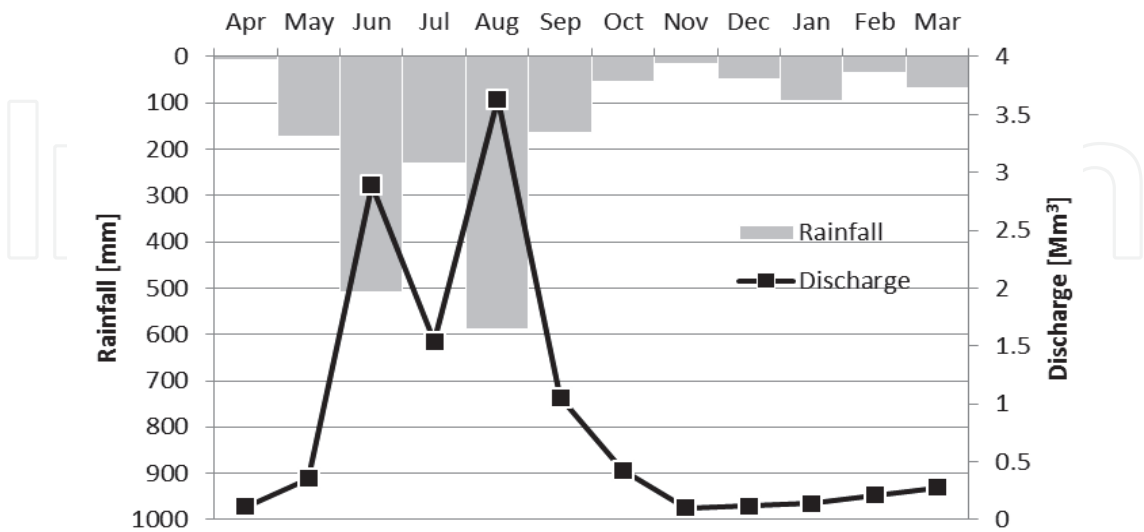

Fig. 2. Monthly rainfall and discharge of the Kam Tin North River, water year 1968.

In terms of climate, the location of Hong Kong puts it under the influence of the Asian monsoon system: accordingly a distinct seasonality exists. This is evidenced in Table 1 which presents climate data for two stations in the Kam Tin basin. These are located at 950 m near the summit of Tai Mo Shan (TMS), the highest peak in Hong Kong at 957 m, and the other sited on the lowland plain at Shek Kong (SK), at a height of around 5 m. In terms of runoff, and rainfall, the seasonality is illustrated in Fig. 2 which shows monthly rainfall and runoff at a Water Supplies Department gauging station for the 1968 water year. Based on data for the water years 1978 to 1988, on average, 68% of the annual runoff occurred during the summer wet season months of April to September. In the 1968 water year at Kam Tin the mean wet and dry season daily discharges were 52,254 m^3/d and 6,952 m^3/d respectively.

The major bedrock geology of the Kam Tin basin includes the volcanic rocks, largely tuffs, of the Shing Mun and Tao Mo Shan Formations and fine-grained Mesozoic granodiorites which form much of the uplands. The lowland areas of the basin are dominated by alluvial deposits, whilst extensive colluvial deposits occur along the foot-slopes of the uplands and extend up some of the stream systems into the hills.

In terms of land-use data for the lowland area of the Kam Tin River, information contained in the Outline Zoning Plans for the Kam Tin North, Shek Kong and Pat Heung districts (HKTPB, 2005a, b, c) show that residential development, village type development, industry, open storage, and major roads accounted for 6.3%, 18.6%, 4.5%, 5.6% and 1.9% respectively. Agriculture accounted for 26.8% of land-use with conservation areas occupying a further 25.9% of the area. There is also the Shek Kong Camp, a military base. However, as Jim (1997) indicates the lowland areas of Hong Kong (including the Kam Tin area) evidenced quite dramatic changes from the 1970s under the pressures of rapid urbanization, container-port expansion, village housing and increased cross-border linkages with China: rural areas, as Jim (1997) notes, had to accommodate multiple demands. The most significant physical consequence of these "demands" was the rapid decline of agriculture from the 1970s and the expansion of non-agricultural land-use, especially open

storage in addition to the expansion village type housing under the small house policy implemented since 1972 (c.f. Tang, et al. 2005). More recently drainage improvement schemes for the Kam Tin River have introduced dramatic changes in the form of channelisation/training of the river. Work began in downstream areas in the mid-1990s and on the Kam Tin North main channel works were scheduled from Kam Tin San Tsuen upstream to Wang Toi Shan from mid-1999 to early 2004. In contrast to the lowlands, little 'formal' use is made of the steep uplands and they are covered in grassland, woodland and secondary forest. Hillfires are common on the upland slopes in Hong Kong and influence vegetation, soil development and erosion (c.f. Peart et al., 2009; Dudgeon and Corlett, 2004; Marafa and Chau, 1999).

Month	Mean Air T° [°C]		Relative Humidity [%]		Total Rainfall [mm]	
	SK	TMS	SK	TMS	SK	TMS
January	15.4	10.6	74	82	27.2	34.3
February	17.0	12.0	78	89	40.6	42.5
March	19.6	14.2	79	91	47.7	72.1
April	23.3	17.3	81	93	130.1	145.2
May	26.0	19.8	82	94	252.6	301.5
June	27.6	21.5	85	95	471.4	579.6
July	28.6	22.1	83	95	320.3	397.0
August	27.9	22.0	85	93	407.0	403.5
September	27.0	20.9	81	90	303.0	329.1
October	25.0	18.4	75	88	35.4	56.4
November	20.9	15.0	72	82	27.7	28.4
December	16.9	11.7	71	78	26.2	24.1

Table 1. Climate of the Kam Tin basin, Hong Kong.

3. Channel bank change

River channel bank erosion is a geomorphic process that occurs in many streams and rivers as an adjustment to accommodate the discharge and sediment supplied from the catchment area (Watson and Basher, 2005). It may occur during or shortly after stormflow events and, as Knighton (1998) observed, only limited erosion will occur in the absence of high discharges. Two main groups of processes may result in bank erosion, namely, hydraulic action at or below the water surface and mass failure (Knighton, 1998), although as noted by Watson and Basher (2005) these may be linked. Traditionally, river bank erosion has been regarded as having negative impacts such as loss of land along with the associated resources, damage to property and infrastructure (Piégay et. al. 1997). In addition river bank erosion delivers sediment from the channel banks to the river thereby contributing to the sediment load which may impact upon water quality and also contribute to the sedimentation problem. Kevin et al. (2008) have suggested that "the erosion of channel bank material is a major source of sediment for most rivers" and they also note that because eroded bank material is delivered directly to the river it may have an immediate impact. The importance of channel bank erosion as a source of sediment has been confirmed in a number studies evaluating sediment sources such as Juracek and Ziegler

(2009), Collins and Anthony (2008) and Mukundar et al. (2010). Bank erosion may now be regarded as a desirable attribute of rivers (Floursheim et at. 2008). This is because bank erosion may provide sediment that creates riparian habitat and active channel banks that may lead to the creation and maintenance of a variety of habitats of diverse structure (Florsheim et al. 2008). Pieguay et al. (2005) note that bank erosion provides ecosystem services and other benefits.

There is an array of factors that may influence bank erosion including flow properties, channel bank materials, climate, subsurface conditions, channel geometry, biotic factors including human impact (c.f. Knighton, 1998). Consequently, the amount, along with spatial and temporal distribution, of channel bank erosion are highly variable, as noted by Knighton (1998). The data from this study evidence both spatial and temporal variability of channel bank erosion on sections of the Kam Tin North River. These will be discussed in the following.

Information upon the change in channel bank position has been obtained from two sources, namely graphical comparison of plan-form changes and direct observation. A graphical comparison of plan-form changes was undertaken based upon 1:1200 and 1:1000 maps for the period 1959 to 1983 and for which channel plan-forms were superimposed using Arc/Info. Maps at a scale of 1:1000 showing plan-form change were developed for a study reach identified in Fig. 3 (Top panel). Direct observations by field measurement of channel banks has also been undertaken on two active meanders near Kam Tin which are located in the area identified as C in Fig. 3. The two active meander bends associated with section C in Fig. 3 have been monitored using a fixed baseline against which to measure channel bank retreat by means of repeat survey. Baseline lengths were over 30 m and the channel bank height for the sections were 1 to 3 m above low-flow water levels and channel width was around 14 m. Channel bank materials were sand, silt and clays with a sand content ranging from 38 to 96% and clay content from 0.5 to 6% by weight. A third meander scar (see erosion pin site in Fig. 3 top panel) had erosion pins emplaced around an 8 meter arc and at this location channel bank height was over 3 m. This meander arc was developed in a resistant cobble, sand and silt mix. Actively eroding sections around the three meanders were devoid of vegetation, and often vertical in profile, although at one site in particular gravitational failure frequently resulted in a slump deposit below an upper cliff-section. A further set of channel bank observations were carried out using over 70 erosion pins located in a relatively straight section of channel some 400 m upstream of the meander bends identified as C in Fig. 3. At this location the deepest channel bank height was around 3 m and channel bank materials were a mix of sand, silt and clay; with clay content typically being less than 5%, with sand content ranging from 38 to 80% by weight. Erosion pins were emplaced over a 200 m reach and arranged to take account of bank height.

Evidence of river bank erosion obtained from plan-form changes along the Kam Tin North River is presented in Fig. 3 for three active sections of the channel. Superimposition of plan-form maps for the period 1959 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 to 1983. These maxima convert into average annual migration rates that range from 0.66 m/year for both bends in B; 0.5 m/year for A and 0.48, 0.44 and 0.4 m/year respectively for the three bends in section C of Fig. 3. There is, therefore, spatial variability between active meanders and Peart and Wong (2002) provide further details.
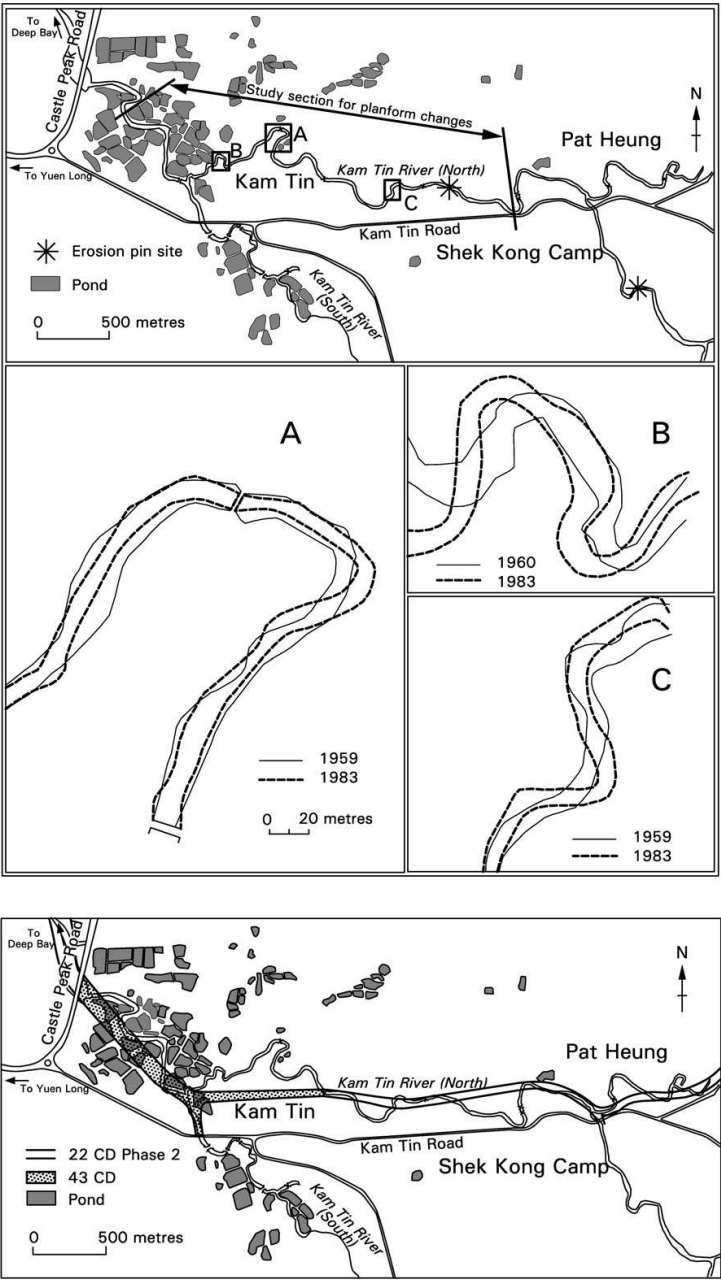
Fig. 3. Plan-form changes of the Kam Tin River. Top: Locations of the studied sections; Mid: Three active meander sections; Bottom: channalisation of the Kam Tin North River.

Fig. 4 presents the bank retreat data for the two meander scars derived from re-survey of channel bank position relative to the baseline. Meander scars one and two evidence spatial and temporal variation in the rate of retreat around the meander arcs. For meander scars one and two it is possible to compare erosion rates during the summer wet season of 1999 and median bank retreat values of 0.6 and 1.81 m, are obtained. Meander scar two permits observations of channel bank retreat for three summer wet seasons, namely 1997, 1998 and 1999, to be made. Respective median rates of bank retreat of 0.96, 1.23 and 1.81 m are obtained. Temporal variability is also evidenced by meander scar one in that for the year 1999, as noted above, a median bank retreat of 0.6 m was recorded; however by mid-April 2000 a median rate of bank retreat of 1.18 m had already occurred over the same length of

baseline. Earlier observations from a previous baseline on meander scar one, over a 21 m baseline, confirms the active nature of this meander: over the period from 25th February 1997 to 6th June 1998 a median bank retreat of 1.97 m was observed over the 15 months of observations. Spatial variation around the meander arcs are also evidenced in Fig. 4. For example, in meander one most change occurs from around 20 m whilst on meander two the most active section is from 10 – 20 m. A third meander scar, located in more resistant materials, has been monitored using erosion pins. During 1997 and 1998 median bank retreats of 0.02 m and 0.018 m respectively were recorded, far lower than recorded on the other two meander scars. This may reflect the more resistant nature of the channel bank materials at this site.
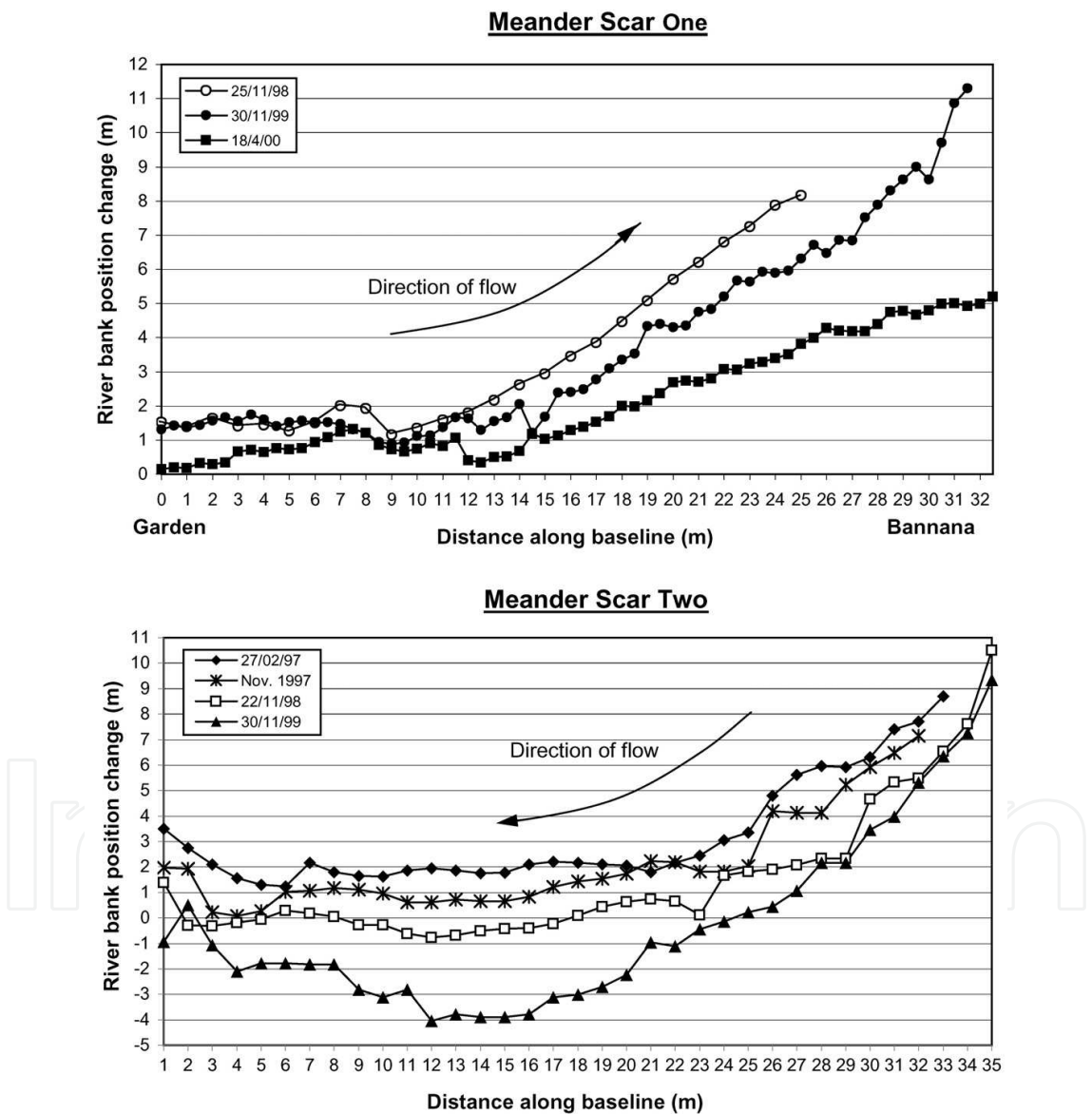

Fig. 4. River bank migration at two meander scars of the Kam Tin River.

Erosion pins have also been emplaced on a relatively straight section of the Kam Tin North River located around 400 m upstream of the two meander scars measured by baseline re-survey. During the year of 1996, for 70 pins on which measurements were obtained, a

median loss of 0.052 m was recorded: it should also be noted that of the 70 pins, 16 (23%) recorded a gain of material, evidencing deposition. Compared to the two "active" meanders downstream this evidences much less active river bank position change.

It is necessary to place the observations of channel bank erosion on the Kam Tin North River in perspective for Hong Kong. It should be noted that currently the Kam Tin North River has been channelised (following the bottom panel given in Fig. 3) which has drastically altered channel plan-form and effectively de-coupled the river from the floodplain in order to reduce the flood hazard: it is now for much of its lowland course an artificial channel. Channelisation is one of the human impacts pertinent to change in river channels identified by Gregory (2006). It should also be noted that the Kam Tin North River is not the only river to be channelised or trained in order to mitigate the flood hazard in Hong Kong and the Beas and Indus Rivers afford further examples (c.f. HKDSD, 2008).

The data obtained on channel bank change on the Kam Tin North River in Hong Kong can be placed in perspective with reference to the literature. Odgaard and Abdad (2008) cite Hooke (1980) who plotted bank erosion rate versus drainage area for 11 streams in Devon, UK, along with data for 43 other streams and rivers from the literature. Rates of change cited by Odgaard and Abdad (2008) from Hooke (1980) ranged from 0.05 m/yr for a 3 km^2 drainage basin to 800 m/yr for a 1 million km^2 basin. From the plot of erosion rate against drainage basin area Odgaard and Abdad (2008), based upon Hooke (1980), report an approximate relationship as mean erosion equals 0.05 times the square root of drainage basin area in square kilometers. Substituting a drainage basin area of 11.72 km^2 for the Kam Tin North River at the old Water Supplies Department gauging station (located adjacent to the erosion pin site and just 400 m upstream of the two meanders shown in Fig. 3 and 4, gives a mean erosion rate of 0.171 m/year. This value is within the range of observations reported in this study. Odgaard and Adbad (2008) also cite the work of Brice (1982) who found an approximate relationship of mean erosion rate in meters per year being 0.01 times channel width in meters based upon a study of 36 US rivers. Using a mapped width of 13.75 m for the meander bends at section C shown in Fig. 3 gives a mean rate of channel bank change of 0.1375 m/yr: rather lower than the baseline data but not too dissimilar to the maximum lateral migration of 0.66 m/yr derived for this location from map data for 1959/60 to 1983 (Peart and Wong, 2002). The straight reach above the meanders had a measured channel width of 8.7 m and using the formula from Brice (1982) a mean rate of bank erosion of 0.087 m/yr is obtained: similar to those recorded by the erosion pins for this site.

4. Sediment quality

A sampling programme has been undertaken to monitor the C and N content of suspended matter on the Kam Tin North River on the main channel near Kam Tin. At the sampling site under stable-flow conditions large volume samples of around 5 L were obtained whilst samples obtained under stormflow conditions varied in volume from 500 ml to around 5 L. The suspended sediment was separated by filtration using GF/C filter papers. These were subsequently air dried and the sediment removed and disaggregated before analysis. Suspended matter was not pre-treated to remove carbonates prior to analysis. Carbon and N were measured using a Perkin Elmer model 2400 elemental analyser. Particulate C and N in water can be expressed as either a percentage (by weight) of the suspended matter or as a mass per unit volume of water: both have been used to characterise C and N in the Kam Tin North River, and the results are presented in Table 2 for the year 2004.

Type of sample		C		N		C/N	SSC
		[%]	[mg/L]	[%]	[mg/L]		[mg/L]
Stable-flow*	Mean	28.20	24.82	3.88	3.18	7.44	90.8
	Median	29.93	18.45	4.06	2.39	7.62	61.97
Stormflow **	Mean	12.39	48.99	1.50	6.23	8.81	357.0
	Median	11.12	27.42	1.40	3.31	8.52	235.1

* n = 96 ; ** n = 33.

Table 2. C and N of suspended sediment of the Kam Tin River.

It can be seen from Table 2 that there is a contrast in C and N in the Kam Tin North River between samples collected under stable-flow and stormflow conditions: the median C and N percent by weight for samples collected under stable-flow being 2.69 and 2.90 times higher respectively. However, in terms of concentration under stormflow conditions, the median concentrations of C and N are 1.49 and 1.38 times higher than the stable-flow samples. These results can be placed in temporal perspective by comparison to Peart (2000) who reports percent by weight observations for samples collected on the Kam Tin North River in 1998 – 1999. He reports median percent by weight C and N for stormflow samples of 12.29 and 1.7 respectively which are similar to the values recorded in 2004 for this study. Moreover a median C/N ratio value of 8.52 is given in Table 2 which is broadly comparable with the value of 7.56 reported by Peart (2000) for stormflow samples. Regarding samples collected under stable-flow conditions, Peart (2000) reports median percent C and N and their ratio of 33.02, 4.27 and 7.77 respectively, which are very similar to those given in Table 2 for samples collected in 2004. It would appear that in the 5 year period from 1999 there has been no great change in C and N. This suggests stable sources exist in the Kam Tin North River.
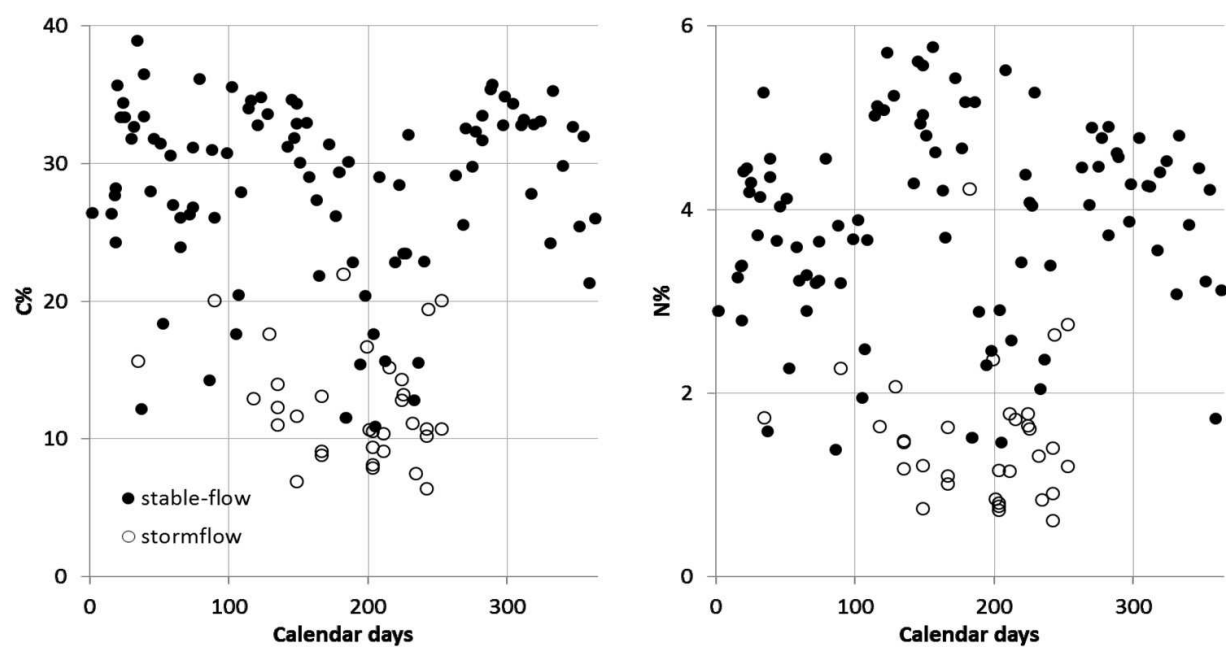

Fig. 5. C% and N% variation through the year 2004.

Fig. 5 plots the percent by weight C and N values for both stormflow and stable-flow samples collected during 2004. The plots reveal the contrast between the two types of

sample (stormflow vs stable-flow). However, there is some evidence of seasonality in Fig. 5, especially for C which is comparatively lower in the summer wet season: this is reflected both in the stormflow samples, but can also be discerned in the stable-flow data. Peart (2000) also detected seasonality in percent by weight C and N in suspended matter of the Kam Tin North River.

It is also of interest to examine the sediment concentration data in Table 2 in terms of the water quality objectives utilised by the Hong Kong Government. These state that the median suspended sediment concentrations on an annual basis should not exceed 20 mg/L: Table 2 reveals that median suspended sediment concentrations in the Kam Tin North River are much higher. Indeed, some 99.6 and 90.4 percent respectively of stormflow and stable-flow samples exceed 20 mg/L in the Kam Tin North River in Hong Kong. Collins and Anthony (2008) adopted an annual average SSC of 25 mg/L to indicate achievement of 'good ecological status' for rivers in England and Wales. Utilising this value for the data on suspended sediment concentrations presented in Table 2 for the Kam Tin North River reveals that only 1 of the 33 stormflow samples is below this value while only 6 (6.3%) of the stable-flow samples were below 25 mg/L. In terms of stable-flow samples Peart (1999) reports mean and median suspended sediment concentrations of 88.9 and 54.4 mg/L for 77 samples collected in 1997-1998. Based upon the use of 25 mg/L, the Kam Tin North River would not meet 'good ecological status' as defined by Collins and Anthony (2008) for England and Wales.

A comparison can be made between the C and N data from the sampling site located in the lowlands near Kam Tin to those in an upland headwater stream in the same basin. Based upon samples collected in the period 1998 – 2001, Peart (2003) reports median percent by weight values of 12.8 and 1.0 respectively under stable-flow conditions and 12.6 and 1.0 respectively under stormflow for C and N in an upland headwater stream. Kong (2005), for the same upland stream and based upon samples collected in 2003, provides further information on C and N in the upland stream. Under stormflow conditions he reported median C and N content by weight of 15.2% and 1.15%. The equivalent values for samples collected under stable-flow conditions are 14.37% and 1.07%. Kong (2005) also gives median C/N ratio values of 13.26 and 13.46 for stormflow and stable-flow samples respectively. A number of contrasts are immediately apparent to samples collected at the Kam Tin North River. Firstly, C and N content in suspended sediment in the upland basin are much lower than observed in the main channel. Secondly, there is no great contrast between stormflow and stable-flow samples in the upland basin, in contrast to the Kam Tin North River and, finally, the C/N ratio of the upland stream at 12.5 to 13.5 is much higher than observed in the Kam Tin North River.

It is interesting to compare the C and N data of the Kam Tin North River to that of the channel bank material and other potential sources. Peart and Wong (2002) report low C and N by weight values for channel bank materials. This observation is supported by data on C and N obtained from two vertical sections in the meander scars at location C in Fig. 3. Some 23 and 25 samples were analysed in vertical bank profiles 2.2 and 2.5 m deep respectively. The 2.2 m vertical profile had median C, N and C/N ratio values of 0.44%, 0.04% and 16.60 respectively whilst the second 2.5 m vertical profile had equivalent values of 0.41%, 0.05% and 9.47 respectively. A number of algae samples have been collected from the Kam Tin North River basin and their analysis gives C, N and C/N ratios ranging from 28.2 to 48.7; 5.22 to 9.78 and 4.46 to 6.17 respectively. The algal C and N characteristics are similar to those of the suspended matter in the Kam Tin North River especially samples collected

under stable-flow conditions. Li et al. (2009) present N and C/N ratio data for 7 common plant species in Hong Kong and the mean N% and C/N ratios for these 7 species ranged from 1.0 to. 2.2% N and 17.4 to 42.3 for the C/N ratio, with these end members being defined by *Ficus fistulosa* and *Pandanus furcatus*: these C/N ratio values are much higher than observed in the Kam Tin North suspended matter, suggesting that fresh leaf litter is not a major source.

In addition data on C and N in the suspended matter of the Kam Tin North River information has also been collected, under stormflow conditions, of major elements along with trace metals and rare earth elements in the particulate matter. These data are presented in Table 3. The dominance of SiO_2 is clear, it being 3 times higher than the next most dominant element, Al_2O_3. Both Langford et al. (1989) and Davis (1952) report the dominance of SiO_2 and Al_2O_3 in the bedrock geology of the Kam Tin North basin: SiO_2 content ranged from 56.7 to 68.8% and Al_2O_3 from 13.4 to 23.8%, which are similar to the values observed in the suspended sediment. Langford et al. (1989) also reports that MgO is higher than MnO for both granodiorite and rocks of the Tai Mo Shan Formation which is also their rank order in the suspended matter of the Kam Tin North River. Concentrations of the major elements are broadly comparable to those obtained from the East River (Fok and Peart, 2010); Hong Kong background mean (Sewell, 1999) and the average river particulate matter (McLennan and Murray, 1999), with CaO being the exception. CaO is lower in the Kam Tin North River compared to average river particulate matter, probably reflecting the lack of calcareous bedrock in the basin. Compared with average crustal values for China (Li, 1994) enrichment occurs in the suspended sediment of the Kam Tin North River for aluminum (Al), manganese (Mn), potassium (K) and phosphorus (P) oxides whilst those of magnesium (Mg) and calcium (Ca) are depleted by comparison.

Enrichment of Zn (9.6 times), W (8.7 x), Pb (7.1 x), Cu (5.7 x), Sb (3.6 x), S (2.1 x), As (1.8 x), Ta (1.7 x), Be (1.2 x) and Rb (1.2 x) against the crustal averages are also observed for Kam Tin samples whilst, U (4 x), Th (2.1 x) along with rare earth elements (Y and Lanthanum series), which were known to be associated with granites, are also found enriched. The study of Cheung et al. (2003) allows further contextualization of the data. They sampled riverbed sediments in the Pearl River Delta region including Hong Kong. For the six sites in Hong Kong they report that Cd, Cr, Cu, Ni, Pb and Zn had ranges of 1.2 - 2.7, 1.9 - 46.1, 8.7 – 140.0, 6.3 – 31.9, 48.1 – 139.3 and 46.4 – 533.3 mg/kg respectively. One of their sites is also comparable to that utilised in this study on the Kam Tin North River and mean concentrations of around 1.6, 15, 72, 14, 128 and 330 mg/kg respectively for Cd, Cr, Cu, Ni, Pb and Zn were reported. For the range of concentrations observed at six Hong Kong sites by Cheung et al. (2003) the values detected in suspended sediment of the Kam Tin North River for Cr, Ni, Pb and Zn fall within the limits. However, Cd and Cu are respectively lower and higher than the range of values reported by Cheung et al. (2003) for Hong Kong. In direct comparison of the data, the suspended sediment of the Kam Tin North River, Cd and Pb were 2.3 and 1.4 times higher respectively than in the bottom sediments analysed by Cheung et al. (2003). In contrast Cr (2.5 x), Cu (2.6 x), Ni (1.4 x) and Zn (1.5 x) were enriched in the suspended sediment samples analysed in this study. These contrasts may, at least, in part reflect the differing total C amounts in the samples: Cheung et al. (2003) report that C is around 2% whilst the average C content of the 19 suspended sediment samples is 4.4%, around 2 times higher. With reference to sediment quality guidelines developed for Hong Kong (Chapman et al. 1999), As, Cu and Pb concentrations for the suspended sediment of the Kam Tin North River exceeded the threshold level (ISQV-1) guideline. Zn in particular, slightly exceeds the effect level (ISQV-h) guideline. These elements are known to be related to anthropogenic activities.

Analyte	Unit	This study		ER	Sewell	Csl	Susp.	ISQV-l	ISQV-h
		Median	MAD						
SiO2	%	54	6	55		58	62		
Al2O3	%	17	3	20		9.6	18		
Fe2O3	%	5	0.65	6.9	4.1	4.7	6.9		
MnO	%	0.082	0.016	0.18	0.13	0.03	0.14		
MgO	%	0.81	0.13	0.76		2.3	2.0		
CaO	%	0.8	0.58	0.36	0.67	10	3.1		
Na2O	%	0.36	0.1	0.23		0.30	0.96		
K2O	%	3	0.19	2.8		2	2.4		
TiO2	%	0.6	0.055	0.88	0.6	0.44	0.93		
P2O5	%	0.42	0.28	0.19	0.11	0.16	0.26		
As	ppm	14	3	29	27	5		8	70
Ba	ppm	480	34	471	317	260	600		
Be	ppm	4	0	4		1.8			
Br	ppm	3.9	0.3	5.7		3.6			
Co	ppm	10	0.74	20	6	33	20		
Cr	ppm	38	7.7	94	49	52	100	80	370
Cs	ppm	12	2.2	14	12	6.9	6		
Cu	ppm	188	142	36	102	28	100	65	270
Hf	ppm	6.8	1.3	13		3.9	6		
Ni	ppm	20	1.5	35	11	25	90	40	
Pb	ppm	89	13	76	104	11	150	75	218
Rb	ppm	210	30	180	216	95	100		
Sb	ppm	1.8	0.15	2	2.8	0.39			
S	%	0.13	0.11	0.029		0.042			
Sc	ppm	10	1.6	16	9.4	10	18		
Sr	ppm	48	8.9	45	35	330	150		
Ta	ppm	2.4	0.3	2.7		0.9	1.2		
Th	ppm	27	3.9	27	44	8.7	14		
U	ppm	10	0.89	8.3	8.7	2	3		
V	ppm	68	12	110	43	54	170		
W	ppm	11	1.5	13	11	1.2			
Y	ppm	47	7.4	65	51	20	28		
Zn	ppm	477	305	136	141	45	350	200	410
Zr	ppm	187	73	438	802	130			
La	ppm	52	8.7	90	52	34	46		
Ce	ppm	98	13	150	127	64	88		
Nd	ppm	51	4.4	70		28	33		
Sm	ppm	9	1.3	12		5.5	7		
Eu	ppm	1.8	0.24	2.2		1.1	1.5		
Tb	ppm	1.5	0.3	1.6		0.76	0.89		
Yb	ppm	5	0.61	5.8		2	3.2		
Lu	ppm	0.7	0.089	0.86		0.3	0.52		

MAD: median absolute deviation; ER: East River bed sediments (<63 µm) median value (Fok and Peart, 2010); Sewell (1999): Geochemical Atlas of Hong Kong, fluvial bed sediments (<150 µm); Csl: China's sedimentary layer abundance (Li, 1994); Susp.: Average river particulate (McLennan and Murray, 1999); ISQV: Interim sediment quality threshold (-l) and effect (-h) level value of Hong Kong (Chapman et al., 1999).

Table 3. Median and median absolute deviation for geochemistry of Kam Tin River sediment samples, along with reference values and quality guidelines.

The information presented on suspended sediment geochemistry for the Kam Tin North River should be viewed in the context of the observation of Walling (2009) that whilst measurements of sediment dynamics in rivers have traditionally revolved around magnitude, timing and concentrations there is increasing recognition of the importance of the quality dimension of sediment fluxes. This is because, Walling (2009) suggests, that sediment associated nutrients and contaminants may generate environmental problems. Other commentators who identify the importance of knowledge on sediment geochemistry in rivers include Miller and Orbock-Miller (2007) whilst Owens et al. (2005) also outline the importance of quality in sediment fluxes and they observe that many rivers are showing evidence of increasing concentrations of contaminants and nutrients which are often approaching or above available sediment quality guidelines. The National Sediment Quality Survey of the USA (USEPA, 1997) further attests to the importance of sediment geochemistry as does the work reported by Chapman et al. (1999) in Hong Kong.

5. Floatable debris

In 2009, 6,014 tonnes per day of domestic waste were collected in Hong Kong; 10 years earlier in 1999 this value was 7,426 tonnes per day. Regarding municipal solid waste (consisting of domestic, commercial and industrial waste) in 2009 and 1999 some 8,963 and 9,269 tonnes per day were produced. For Yuen Long District, which is adjacent to the Kam Tin basin, some 496 and 472 tonnes per day of domestic waste were produced in 2009 and 1999 respectively. In terms of municipal waste in Yuen Long district in 2009 and 1999 respectively 721 and 646 tonnes per day were generated. These are significant volumes of materials and Hong Kong is facing a challenge in terms of waste disposal (HKEPD, 2005). In terms of Hong Kong's environment waste can pose a problem. As Yung (2001) notes, with respect to marine waters and beaches, floating refuse has been a problem for many years. In fact Morton (1976) identifies rubbish as being a problem in Hong Kong coastal waters and beaches. In terms of origins of this floating rubbish Yung (2001) states that some of the debris may be derived from open waters, bought in by wave and tides, whilst some materials are derived from land sources consequent upon illegal dumping in storm water drains and open nullahs. It is this latter source that is of interest herein. Whilst floating rubbish and debris in beach and coastal waters has received considerable attention in Hong Kong it has been largely ignored in local streams and rivers, with only Peart (1999) offering any data.

Regarding the composition of domestic waste disposed of at waste facilities in 1999, the HKEPD report that glass bottles accounted for 2.7%, paper, including cardboard 25%, and plastics 18.9% of which 1.7% was beverage bottles, 11.6% plastic bags, and 10% polyfoams (HKEPD, 1999). In 2009 the composition of domestic waste delivered to waste facilities was similar to that of 1999 (HKEPD, 2009).

Observations have been made of floating debris and rubbish on the Kam Tin North River prior to channelisation/training. During May 1998, in excess of 8 m³ of floating rubbish and debris accumulated under and against the bridge at Kam Hing Wai, part of the settlement of Kam Tin. This material was washed down during storms of the previous week. Some 897 pieces of debris/rubbish were counted and classified with plastic distilled water bottles of less than 2 liters in volume forming the largest category (163 pieces or 18.2%). If other categories of drinks and miscellaneous contents are included, this volume of plastic bottles accounted for 284 pieces. The next most common type of debris were polystyrene food

containers (107 pieces or 11.9%) followed by drink boxes (84 pieces or 9.4%). Detergent, shampoo and other such containers accounted for 68 pieces or 7.6% of the sample. A wide range of other rubbish was recorded including tin cans, motor oil containers, glass bottles and jars, plastic pots and jars, plastic bags, flip-flops, light bulbs, wood, aerosol cans and basket-balls. Large debris not included in the count were car tyres and wheels, a 100 gallon oil drum, several 20 litre drums, wood pallets, 14 cupboard draws, and a small polystyrene surf board. Surveys of counts of debris moving down the river during subsequent storm events revealed the above findings to be not unusual. For example, in the storm of 9 June 1998 during a 15 minute counting period, 42 pieces of rubbish/debris were counted. Polystyrene accounted for 21.4%, plastic bottles of less than 2 L, 16.7% of the sample. Plastic materials accounted for a further 14.3% while tin cans were 4.8% of the sample whilst Peart (1999) provides further details.

Additional monitoring in 1999 and 2000 of floating debris and rubbish involved counting a further 460 pieces of debris and a major survey was undertaken after the storm of 21/6/99 when a further 601 pieces were counted. For the 460 pieces of debris (year 2000), plastic bags accounted for 20%, drink PETs 7.8% and polystyrene food trays/lunch boxes 10.6%. Wood and glass were 5% and 4.8% of the debris respectively. For year June 1999 storm, the debris mainly comprised of plastic bags (20%), drink PETs (9.2%), polystyrene food trays (16%), wood (1%) and glass (4%).

The observations on rubbish and floatable debris can be placed in perspective with reference to the composition of domestic waste in 1999 reported previously (HKEPD, 1999). To recap briefly, they report that glass bottles, paper and plastics (including bags, EPS food/drink, PET bottles, polyfoams etc.) accounted for 2.7%, 25% and 18.9% of domestic refuse by weight. Moreover, Yung (2001) cites the Hong Kong Marine Conservation Society territory wide Marine Debris Survey in 1996 – 1997 as finding that 46.8% of debris was plastic with polystyrene foam accounting for 16.1%, glass 13%, paper 8.2% and wood 6.2%. Both the data on domestic waste composition and the data from the Marine Debris Survey demonstrate a degree of similarity to the observations on domestic rubbish in the Kam Tin North River. This finding does suggest that some marine floatable debris were derived from rivers, as previously indicated by Yung (2001).

6. Conclusion

Channel plan-form change and bank erosion have been documented on the Kam Tin North River whilst observations on floating debris and rubbish have been presented. Information on sediment quantity and quality in the Kam Tin North River has also been made. These observations on channel bank erosion are important for they illustrate an "active" river which has implications for ecosystem function contributing to habitat and biodiversity maintenance. However, channelisation/training has halted this process and affords an example of the human impact upon the river. The observations on floating debris also confirm the human impact upon the river. It may also be a damming verdict of society values --- it would appear that the river was being used as a waste disposal system. The data on sediment quality confirms the need to consider this aspect of sediment fluxes in rivers: there is evidence that some elements in the suspended matter of the Kam Tin North River may exceed sediment quality guidelines and these elements are associated with human activities.

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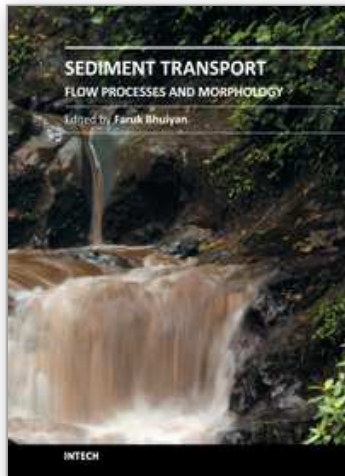
Sediment Transport - Flow and Morphological Processes

Edited by Prof. Faruk Bhuiyan

ISBN 978-953-307-374-3

Hard cover, 250 pages

Publisher InTech

Published online 26, October, 2011

Published in print edition October, 2011

The purpose of this book is to put together recent developments on sediment transport and morphological processes. There are twelve chapters in this book contributed by different authors who are currently involved in relevant research. First three chapters provide information on basic and advanced flow mechanisms including turbulence and movement of particles in water. Examples of computational procedures for sediment transport and morphological changes are given in the next five chapters. These include empirical predictions and numerical computations. Chapters nine and ten present some insights on environmental concerns with sediment transport. Last two contributions deal with two large-scale case studies related to changes in the transport and provenance of glacial marine sediments, and processes involving land slides.

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