Erosion and Sediment Yield: Global and Regional Perspectives (Proceedings of the Exeter Symposium, July 1996). IAHS Publ. no. 236, 1996.

Patterns of erosion and sediment production in Hong Kong

MERVYN R. PEART
Department of Geography and Geology, University of Hong Kong, Hong Kong

Abstract A series of maps is presented to illustrate the distribution of erosion in Hong Kong. Erosion has been widespread, but the latest map reveals that its spatial extent may be declining. This may reflect afforestation and the reduced utilization of vegetation as a source of fuel. Based upon accumulated quantities of sediment in submerged and lined sections of some river channels, estimates of annual sedimentation rates are given and are shown to be quite variable. Variability is reduced if consideration is given to basin size. Very high loadings of agricultural waste contribute to sedimentation in some rivers. Drainage Services Department data also confirm the spatial variability of sedimentation. Temporal variability of sediment production is illustrated with data from a small basin.

INTRODUCTION

Hong Kong has a small land area (1090 km^2) and supports a population of nearly six million. Inevitably pressure has been placed upon the environment and, while consideration has been given to pollution, little attention has been given to erosion and its consequences. This paper examines the consequences of erosion and the change in its nature and extent through time.

PROBLEMS ASSOCIATED WITH EROSION AND SEDIMENTATION

The impact of sediment deposition in river channels upon flooding has been documented by a number of studies in Hong Kong (e.g. Territory Development Office, 1989; Yip, 1992) and has been identified by the Drainage Services Department as a causal factor. In addition to raising the bed-level of the rivers and channels, where sediment includes animal waste from agriculture (or other pollutants) sedimentation may create adverse visual and smell impacts upon the environment.

Irrigation is important to agriculture in Hong Kong and is needed to ensure successful vegetable production. However, sediment and other materials can accumulate behind weirs used to direct water, thereby hindering their function. The Agriculture and Fisheries Department operate an extensive maintenance programme for sediment removal which includes some reservoirs used only for agriculture. In the past sedimentation in water supply reservoirs has resulted in significant loss of storage (e.g. Berry, 1955b; Davis, 1949). The Civil Engineering Services Department (1989) indicates that Water Supplies Department surveys of reservoir sedimentation indicate that rates of sedimentation give no cause for concern.

Hansen & Nash (1985) suggest that erosion may result in soil loss and terrain degradation and eroded areas have been regarded as unsightly. Berry (1955a) and Grant (1968) suggest erosion is of little consequence to agriculture, largely because terracing and good practice limited the severity of erosion. However, more recently, Yip (1992) indicates that soil erosion may be a problem on agricultural land. He suggests that this is due to the fact that up to 10 crops of vegetables are grown per year continuously exposing the soil to erosion. He also adds that the use of chemical fertilizers instead of farmyard manure has resulted in the deterioration of soil structure rendering it more susceptible to erosion.

SPATIAL EXTENT OF EROSION

Some of the earliest maps of the territory reveal the existence of an erosion problem. For example Berry (1955a) reports that the 1845 map of Hong Kong indicates that the Kowloon peninsula was "much cut up by ravines". Tregear (1955) describes the land use of Hong Kong and provides a map shown in modified form in Fig. 1. It shows the distribution of badlands (heavily eroded, often gullied areas devoid of vegetation) and they are most common on the granite outcrops around Castle Peak, Tai Lam Chung and to the north of Kowloon. In the 1950s some 4% of the territory might be regarded as badland. It should be noted that erosion might have existed on other slopes, especially those where the vegetation was cut for fuel, and therefore Fig. 1 only reveals the areas experiencing the most severe erosion. Berry (1955a) suggests that over 60% of the land is liable to intense accelerated erosion. The first map indicating the extent of erosion for most of the territory was presented by Grant (1960). His map reveals erosion to be widespread. Only the alluvial flatland areas in the North West New Territories exhibit no signs of erosion along with much of Hong Kong Island. The map of Grant (1960) identifies the badland areas of the 1950s land use survey as being gullied and suffering from serious loss of topsoil. In part response to coping with the landslide hazard, the Government of Hong Kong has undertaken a Geotechnical Area Studies Programme. The large scale or regional studies have now been completed. One of the products of this programme was a territory-wide mapping of erosion completed during the period December 1979 to December 1985. Styles & Hansen (1989), in the summary volume, report that only 54.9% of the territory exhibited no appreciable erosion. They also report that moderate to severe sheet, rill and gully erosion occurs on about 8.1% of the land area, while minor amounts of the same erosion processes occupy 15.4%. Well defined landslips were observed on 0.1% of the surface area with general instability in both recent and relict forms occupying a further 20.4%. Coastal instability is found on 1.1% of the territory. This suggest that erosion is widespread and is confirmed by Fig. 2 which plots, in simplified form, the distribution of erosion. Once again the map identifies the Castle Peak and Tai Lam Chung areas as exhibiting appreciable erosion. Furthermore, the lowland plains in the Northern and North West New Territories shown by Grant (1960) to have experienced little or no erosion are also identified as exhibiting no appreciable erosion in this later survey. In December 1989 the World Wide Fund for Nature undertook a further land use survey of Hong Kong. Their survey (Ashworth *et al.*, 1993) revealed that only 2% of the territory could be classified as bare rock or soil the distribution of which is shown in Fig. 3. It should be noted that this is a conservative

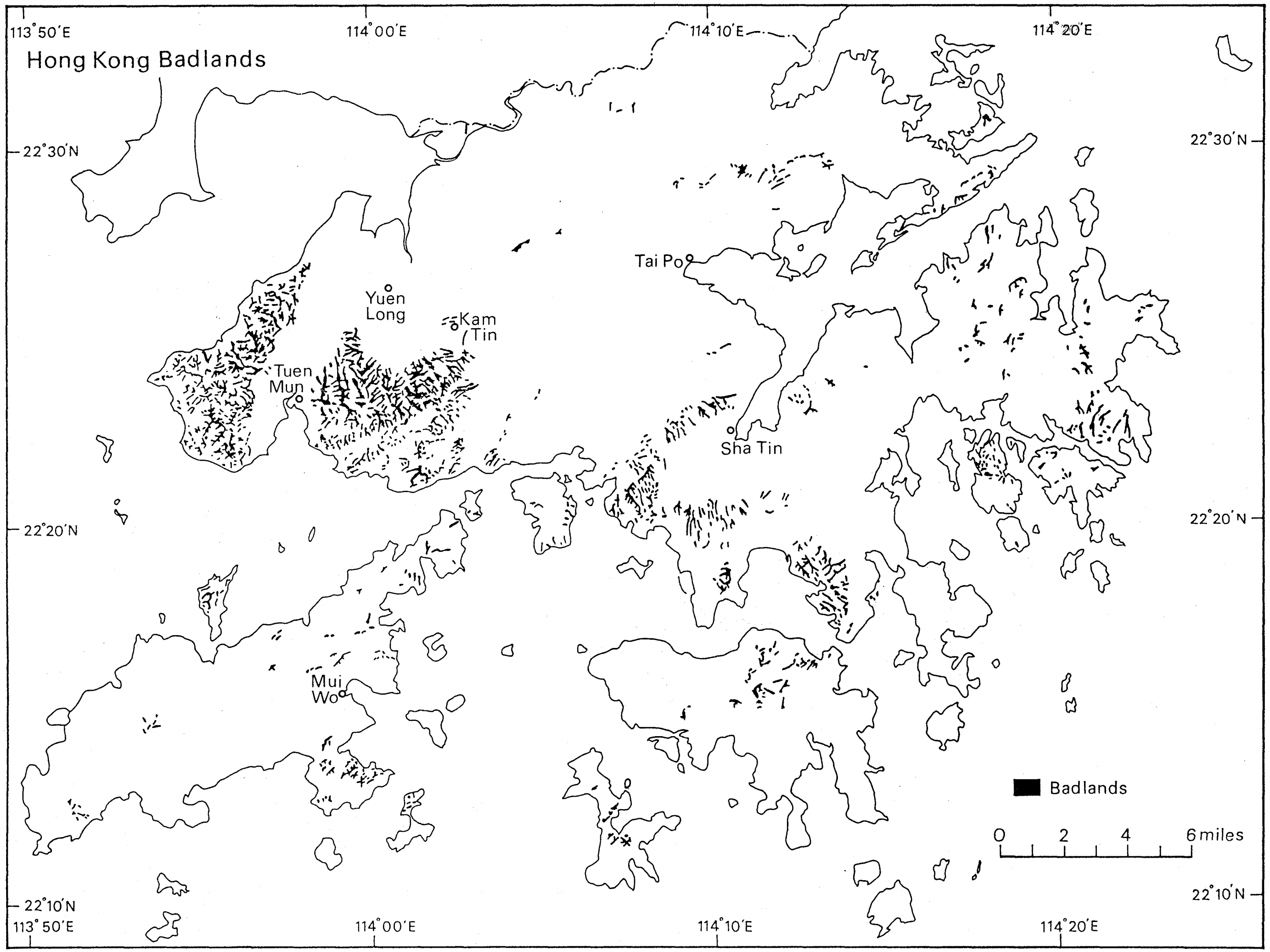

Fig. 1 The distribution of badlands (after Tregear, 1955).

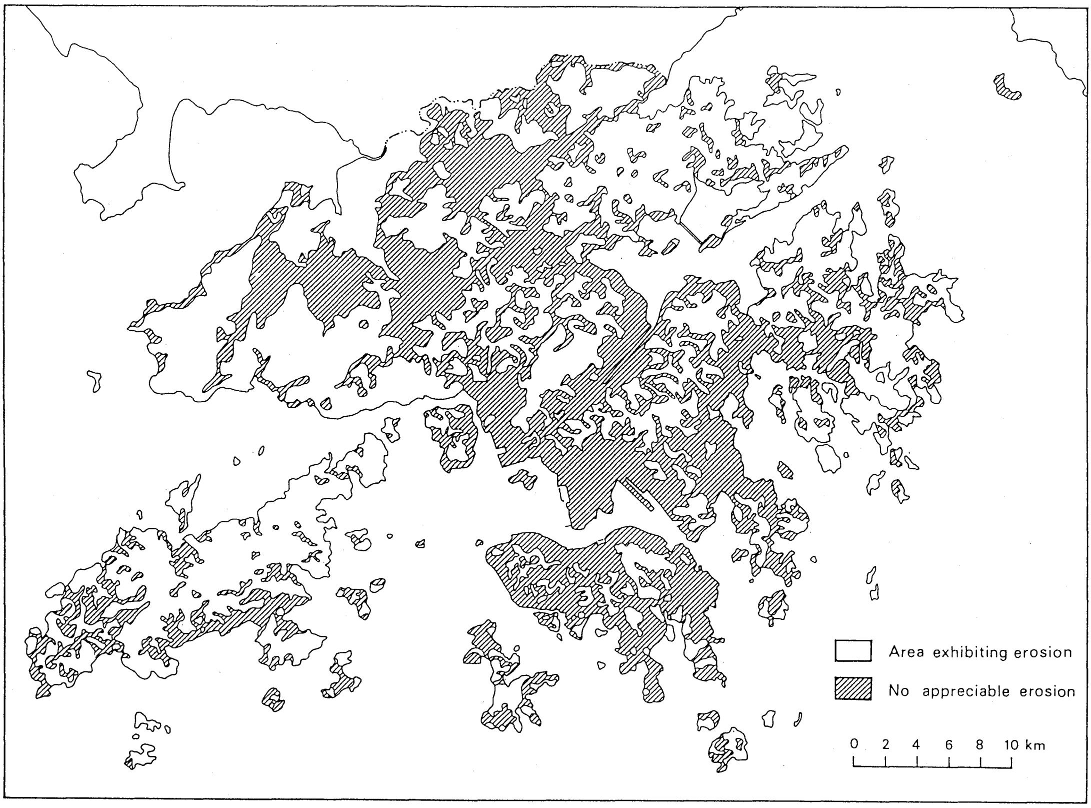

Fig. 2 Areas evidencing erosion (after Styles & Hansen, 1989).

estimate of the bare soil/rock area, because, in some cases it was not possible to differentiate it from vegetation cover on the air photographs, especially grass and low shrub. If all the vegetation cover that might be bare soil or rock is considered as devoid of cover, the maximum amount of exposed soil and rock is 9.9% of the territory. Whichever value is accepted it would seem that erosion has declined in extent since the GASP survey. Comparison of Figs 2 and 3 reveal this reduction to be most pronounced on Lantau Island.

The widespread existence of badlands and gully erosion documented by Tregear (1958) and Grant (1960) along with the widespread moderate to severe loss of topsoil reported by Grant (1960) reflect the fact that the hillsides of Hong Kong were heavily utilized, which in turn exposed the soil to erosion. Reduction in the extent of moderate to serious erosion and gully erosion evidenced by the more recent surveys (e.g. Styles & Hansen, 1989) may be due in part to afforestation. However, the drastic reduction in the use of the hillsides as a resource is probably of greater importance. For example, vegetation no longer provides a source of fuel and the grass on the hillsides is no longer burnt to promote the growth of the hardier shrubs.

The effects upon sediment production and erosion of the lack of vegetation cover can be illustrated for Hong Kong. In a small basin with no badlands Lam (1978) reports a mechanical denudation rate of only 36 m^3 km^{-2} $year^{-1}$. In contrast in two basins with 24

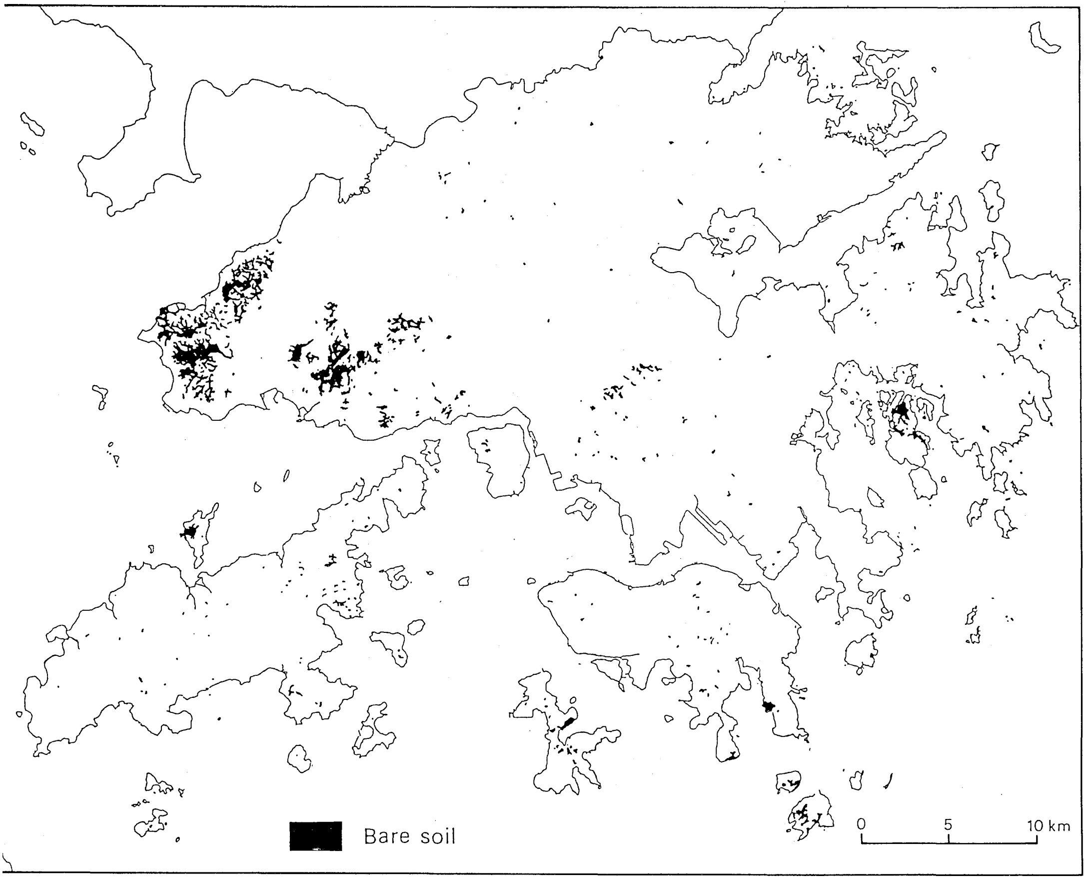

Fig. 3 Location of bare soil or ground (after Ashworth *et al.*, 1993).

and 40% respectively of badland areas, mechanical denudation rates were 485 and 865 m^3 km^{-2} $year^{-1}$. The estimated suspended sediment yield of 55 t for the vegetated basin, compared to 1682 t and 2422 t for the basins with 24 and 40% badland cover, for the 15 month study period also reveals the effect of bare ground upon sediment production.

SEDIMENTATION OF RIVERS

The sedimentation rates of various river channels in the territory have been investigated by the Ports Works Division of the Hong Kong Government (1988) and Table 1 presents the results of their study. Table 1 reveals that sedimentation rates for natural or normal erosion processes vary widely around the territory and this reflects contrasts in basin area. In addition sedimentation rates per unit area have also been calculated and these are also presented in Table 1. When basin area is considered, with the exception of the Tai Shui Hang and Kam Tin basins, sedimentation rates are less variable being between 3000 and 4500 t km^{-2} $year^{-1}$ for natural sediment. In Tai Shui Hang, the high yield per

Table 1 Annual sedimentation of river channels in Hong Kong (modified from Port Works Division, 1989).

Location	Sedimentation rates:				
	Annual natural sediment:		Annual agricultural sediment	Total loading:	
	(t $year^{-1}$)	(t km^{-2} $year^{-1}$)	(t $year^{-1}$)	(t $year^{-1}$)	(t $year^{-1}$ km^{-2})
Sha Tin + Fo Tan + Siu Lek Yuen	124 500	4 535	10 700	135 200	4 925
Tai Shui Hang	55 000	11 000	-	55 000	11 000
Tai Po + Lam Tsuen River	74 000	2 905	1 800	75 800	2 976
Tuen Mun	51 500	3 466	28 000	79 500	5 350
Yuen Long	36 000	3 297	50 000	86 000	7 875
Kam Tin	14 000*	316	96 000	110 000	2 483
Mui Wo	25 000	3 602	900	25 900	3 732

*Rough estimate.

unit area may reflect very efficient sediment delivery in the small basin along with a highly erodible source. Table 1 also reveals that in the Tuen Mun, Yuen Long and Kam Tin basins agriculture (in the form of animal waste) provides over 50% of the sediment accumulating in the channels. If agricultural waste materials are considered sedimentation, rates per unit area vary from around 2500 to 11 000 t km^{-2} $year^{-1}$. However, with recent legislation pollution from agriculture should be decreased. For example, the Deep Bay water control zone was established in 1990. Enforcement of the Water Pollution Control Ordinance and the Waste Disposal Ordinance has not proved easy.

Further evidence of the sedimentation problem in Hong Kong and its spatial variability is provided by the maintenance work of the Drainage Services Department. The Department is charged with removing silt such that the drains and watercourses remain free flowing and pollution levels are low. Table 2 presents data for three districts. It can be seen that little sediment is removed from the watercourses of Hong Kong and other islands. In comparison to the Mainland South, much more material is removed from the rivers and drains of the Mainland North Division, especially from 1992 onwards. The greater amounts of material removed by the Drainage Services Departments Northern District reflect, in part, waste from agriculture which has accumulated in the channels. It may also reflect the attempts to alleviate the flood hazard in the lowland areas by improved maintenance of the drainage system. With improvements in legislation, the importance of agriculture as a source of sediments should decline. The very low rates of sediment accumulating in the Islands Districts may reflect low rates of sediment production in the urban basins; efficient drainage channels for removal of sediment through the system; low sediment production in the vegetated rural basins, or some other factors.

Table 2 Sediment removal by the Drainage Services Department.

A. Hong Kong Island and Islands District

	1990	1991	1992	1993	1994
Length of river channels cleaned (km)	0.25	0.39	0.64	5.73	4.18
Length of drains cleaned (km)	69.31	88.76	30.75	46.66	76.24
Total silt removed (m^3)	1526	1378	7432	11247	5108

B. Mainland North District

	1990	1991	1992	1993	1994
Length of river channels cleaned (km)	14.49	13.74	29.72	50.17	61.84
Length of drains cleaned (km)	1.40	14.11	20.75	15.87	11.85
Total silt removed (m^3)	60 871	55 128	263 727	246 818	293 391

C. Mainland South District

	1990	1991	1992	1993	1994
Length of river channels cleaned (km)	5.35	5.47	7.98	11.42	9.53
Length of drains cleaned (km)	161.00	144.09	232.33	255.43	183.45
Total silt removed (m^3)	43 344	18 237	39 311	25 474	8 243

SEDIMENT PRODUCTION IN A SMALL BASIN

Observations of bed load yield have been made in a small drainage basin (< 1 km^2) since 1989. The data reveal considerable variability with the lowest yield (0.4 t) recorded in 1990 being only 10% that of the highest yield (3.9 t) measured in 1989. The investigation also revealed that much of the material associated with the higher yield years was produced rapidly over, at most, a few days in association with high rainfall events. This variability needs to be considered in assessing average sediment yield.

Soil pipes are quite common on the slopes of Hong Kong (e.g. Gray, 1986; Nash & Dale, 1984). However, few observations have been made in terms of sediment production. Preliminary observations on a pipe system in the small basin reveal suspended matter concentrations to be low. For example, during the summer of 1991 about 85% of samples had concentrations of less than 50 mg l^{-1}. Only 12 out of 164 samples exceeded 100 mg l^{-1} (Chan, 1992). A similar tendency to low concentrations has been observed in 1994. Further work is needed to evaluate the role of pipe systems in sediment delivery to streams and rivers.

CONCLUSION

Some problems associated with erosion and associated sedimentation have been identified. The spatial variability of erosion and sedimentation rates in some Hong Kong rivers has also been documented. Temporal variability of sediment production has also been described. More information is needed on sediment delivery from slopes, especially an assessment of the role of landslides in river sedimentation. Also of interest would be monitoring of the impact of new water pollution legislation on pollutant inputs from animal husbandry and the impact of construction upon erosion and sedimentation.

REFERENCES

Ashworth, J. M., Corlett, R. T., Dudgeon, D., Melville, D. S. Y. & Tang, W. S. M. (1993) *Hong Kong Flora and Fauna: Computing Conservation*. World Wide Fund for Nature, Hong Kong.

Berry, L. (1955a) Problems of soil erosion in Hong Kong. *Far Eastern Economic Rev.* **19**, 65-68.

Berry, L. (1955b) Effects of erosion in Hong Kong. *Far Eastern Economic Rev.* **19**, 98-100.

Chan, W. M. (1992) Water quality of a soil pipe in a small catchment near Shek Kong. Unpubl. BA Dissertation, Geography and Geology Dept, University of Hong Kong.

Civil Engineering Services Department (1989) *Territorial Land Drainage and Flood Control Strategy Study*. Phase 1, Task 2 Technical considerations in the main report. Civil Engineering Services Department, Hong Kong Government, Hong Kong.

Davis, S. G. (1949) *Hong Kong in its Geographical Setting*. Collins, London.

Grant, C. J. (1960) *Soils and Agriculture in Hong Kong*. Hong Kong Government Printer, Hong Kong.

Grant, C. J. (1968) Gullying and erosion characteristics of Hong Kong soils. In: *Recent Advances in Tropical Ecology* (Proc. Varanaisi, India. Symp.), 94-107.

Gray, I. (1986) Case studies of natural soil pipes in Hong Kong slopes. *Geotechnical Control Office Discussion Note DN 3/86.*

Hansen, A. & Nash, J. M. (1985) A brief review of soil erosion causes, effects and remedial measures. In: *Geological Aspects of Site Investigations* (Proc. Hong Kong Conference, 1984), 139-150. Geol. Society of Hong Kong.

Lam, K. C. (1978) Soil erosion, suspended sediment and solute production in three Hong Kong catchments. *J. Trop. Geogr.* **47**, 51-62.

Nash, J. M. Y. & Dale, M. J. (1984) Geology and hydrogeology of natural tunnel erosion in superficial deposits in Hong Kong. In: *Geology of Surficial Deposits in Hong Kong* (Proc. Hong Kong Conference, 1983), 61-74. Geol. Society of Hong Kong.

Port Works Division (1988) *The Sedimentation of Various Man-made River Channels in the Territory*, 2 vols. Civil Engineering Services Dept, Hong Kong.

Styles, K. A. Y. & Hansen, A. (1989) *Territory of Hong Kong*. GASP Report XII. Geotechnical Control Office, Civil Engineering Department, Hong Kong Government, Hong Kong.

Territory Development Office (1989) *River Indus Study*, 5 vols. Territory Development Office, New Territories, North East.

Tregear, T. T. (1955) *Land Utilization in Hong Kong*. Hong Kong University Press.

Tregear, T. T. (1958) *A Survey of Land Use in Hong Kong and the New Territories*. Hong Kong University Press, Hong Kong.

Yip, S. M. (1992) Hong Kong. In: *Environmental Impact Assessment in Agricultural Projects in Asia and the Pacific* (Proc. APO Seminar, Tokyo, Japan, 1990), 201-217. Asia Productivity Organization, Tokyo.