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The effectiveness of check dams in controlling upstream channel stability in northeastern Taiwan

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Abstract Surveys of both sediment deposited in check dams and stream channel profiles were conducted to study the effectiveness of check dams in controlling stream channel stability in northeastern Taiwan. Results showed that the average annual sediment deposition in individual check dams ranged from 5.43 to 58.78 m^3 ha^{-1}. The gradient of the deposited surface was flatter than that of the original channel. The stream channel profile increased in width. The downstream reach might be unstable if the associated dissipator was not well designed. In the long term, most of the check dams in the study area can serve as stream power dissipators and stabilize the stream channel.

INTRODUCTION

Northeastern Taiwan is characterized by an alluvial plain deposited by the Lang-Yang River. The upstream areas of this river basin are associated with precipitous slopes, tectonic disturbance and heavy rainstorms, which promote mass movements and give rise to severe channel aggradation in the lower reaches.

The aggradation of stream channels has caused flooding and has also reduced the flow capacity of bridges constructed across the streams. In order to reduce these detrimental effects, intensive sediment control works have been implemented in these upstream areas since the 1970s (Taiwan Soil Conservation Service Bureau, 1979). Check dams have been the most widely used structures because it is expected that they can be used to trap sediment, to stabilize stream channels, to reduce channel slope and to prevent stream bank erosion (Yano, 1968; Lusby & Hadley, 1967).

The construction of check dams in the upstream channels may, however, alter stream channel profiles and destabilize the downstream channel. Some investigations have suggested that check dams might destabilize downstream banks and bridge foundations in the downstream reaches (Liu, 1983). In this study, we examine the long-term impact of check dams on stream channels and sediment transport characteristics. The results are used to evaluate the effectiveness of check dams.

METHODS

The study area includes three contiguous headwater drainage basins in northeastern Taiwan, i.e. the Song-Lou, Yuan-Sun and Su-To basins (Fig. 1). These basins drain 1400, 750 and 220 ha, respectively and they are characterized by narrow, steep-sided valleys with average slopes of 49, 57 and 58%. Mass movements have been frequent since the 1960s, because of forest operations in these areas (Taiwan Soil Conservation Service, 1973). Check dams were therefore constructed in these areas. A typical check dam structure is shown in Fig. 2. In general, the design is such as to provide a large size and a solid shape (Liu & Lin, 1984). Five check dams within these three basins were selected for study. The dimensions of these check dams are listed in Table 1.

A detailed survey was performed on the original stream channels. Bed load particle size composition was analysed. Selected channel cross sections in close proximity to the check dam sties were periodically surveyed. The cumulative volume of sediment deposits and their depositional pattern behind the check dam were obtained from periodic surveys.

RESULTS

From periodic surveys of channel profiles behind the check dam sites, we obtained estimates of the accumulated sediment storage and its depositional pattern. After installation, the storage capacity of the Yuan-Sun, Su-To 1, Su-To 2 and Su-To 3 check dams was completely filled by sediment within the first three years after completion. The average annual sediment volumes deposited behind the check dams were 58.8, 5.4, 14.6 and 13.6 m^3 ha^{-1} respectively. In 1991, the Song-Lou check dam still retained some storage capacity. During its life time, the average annual volume of sediment deposited behind the Song-Lou check dam was 26.5 m^3 ha^{-1}.

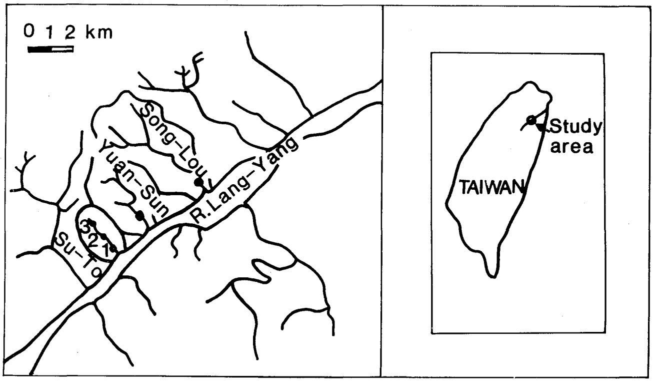

Fig. 1 The study area of the Song-Lou, Yuan-Sun and Su-To basins in northeastern Taiwan.

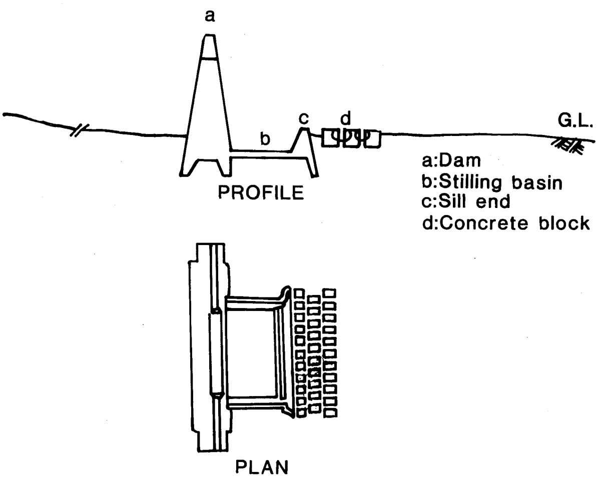

Fig. 2 A typical check dam structure.

The surface gradients of the deposits behind the individual check dams were almost half those of the original channel. In addition, the stream reaches behind each check dam increased in width. The length of the depositional surface behind each check dam was positively related to the height of the check dam and the gradient of the depositional surface, but negatively related to the original channel gradient (Table 2).

Analysis of the bed load particle-size composition showed that the particle-size distributions before and after check dam construction were very similar (Table 3). In addition, the deposited material closely resembled the coarse bed load existing in the original channel and possessed the typical particle-size distribution characteristics of recent alluvial material. The depositional surfaces behind each check dam can be divided into an upper and lower part, according to the maximum diameter of the bed load particles. The upper part mainly consists of gravel and boulders, while the lower part mainly consists of sand and gravel.

In the reach downstream of each check dam, the degree of stream channel deformation was measured by cross sectional and longitudinal profiles. Data from periodic surveys of these profiles showed that downstream channel

Table 1 The dimensions of check dams in the study area.

Check dam	Height	Width	Stilling basin:		Sill end	Date of completion
			Height	Length		
	(m)	(m)	(m)	(m)	(m)	
Song-Lou	9.5	169	16	133	1.8	July 1980
Yuan-Sun	9.5	100	10	90	1.8	June 1979
Su-To 1	3.5	32	12	20	1.2	June 1978
Su-To 2	5.8	21	10	15	1.0	July 1979
Su-To 3	7.5	47	12	20	1.2	July 1979

Table 2 Average annual sediment deposition rates (m^3 ha^{-1}).

Check dam	Mean rate of deposition	Original channel gradient	Depositional surface gradient	Depositional surface length (m)
Song-Lou	26.49	0.041	0.020	452
Yuan-Sun	58.78	0.070	0.036	268
Su-To 1	5.43	0.127	0.062	50
Su-To 2	14.60	0.147	0.067	80
Su-To-3	13.40	0.273	0.140	60

scouring occurred within the first three years after completion (see Figs 3-5). Due to channel scouring, additional concrete sill-end structures were installed downstream of the Yuan-Sun check dam in 1983. These structures provide increased energy dissipation (see Fig. 6). Subsequently, not only the channel downstream of the Yuan-Sun check dam but also the channels downstream of the Song-Lou. Su-To 1, Su-To 2, and Su-To 3 check dams became stable.

Table 3 Sediment particle-size distribution (% by weight) before and after construction of the check dams.

Check dam	Time of sampling	Boulders >76.2 mm	Gravel >4.76 mm	Coarse sand >0.149 mm	Fine sand <0.074 mm
Song-Lou	Before	33.6	054.6	11.7	0.1
	After	30.7	56.4	12.4	0.5
Yuan-Sun	Before	22.0	63.4	14.4	
	After	20.8	64.9	14.1	0.2
Su-To 2	Before	22.5	65.9	11.5	0.1
	After	46.6	42.7	10.5	0.2
Su-To 3	Before	23.6	64.2	12.1	0.1
	After	42.4	44.0	13.0	0.6

DISCUSSION

Results from this study suggested that the installation of check dams produced positive effects in controlling upstream channel stability. In the reaches upstream of each check dam, the stream channel became wider and flatter. In addition, the depositional surface behind the check dams was relatively stable when the storage capacity was filled.

The processes of channel erosion and sediment transport are dominated primarily by the stream power during flood events (Liu, 1982). In theory, the stream power is positively related to channel gradient and flood discharge, but negatively related to channel width. Therefore, after the installation of these check dams, the stream power should be significantly reduced. The capacity for sediment transport is also decreased and channel erosion is prevented.

As a result of the high flow energy of the storm discharges passing over the check dam structure, the downstream channel could suffer severe scouring unless the structure incorporated an associated dissipator (Peterka, 1978). In

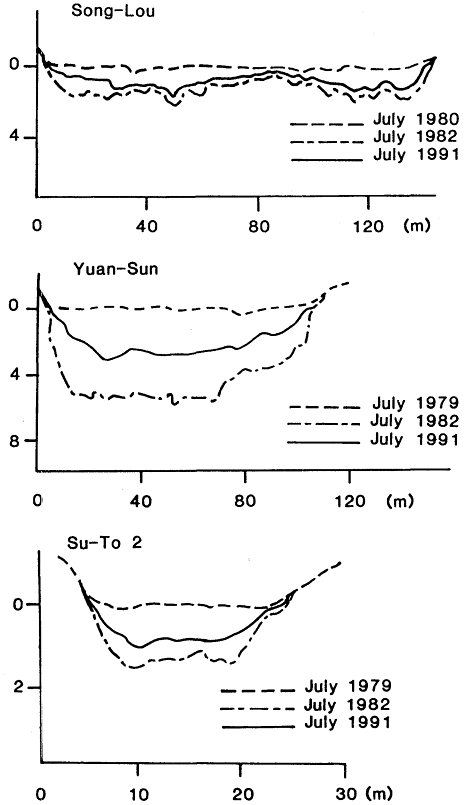

Fig. 3 Changes in the cross sectional profile 10 m downstream of the Song-Lou, Yuan-Sun and Su-To 2 check dams.

this study, the check dam structures all possess such energy dissipators. Although in the early period we found that channel erosion occurred downstream, the downstream channel became stable after several years as a result of the protection provided by the reinforced dissipators. This suggests that if the dissipators are well designed, the energy of the flood flows passing over these check dams can be greatly reduced.

Liu (1987) indicated that the sediment deposited behind the check dam

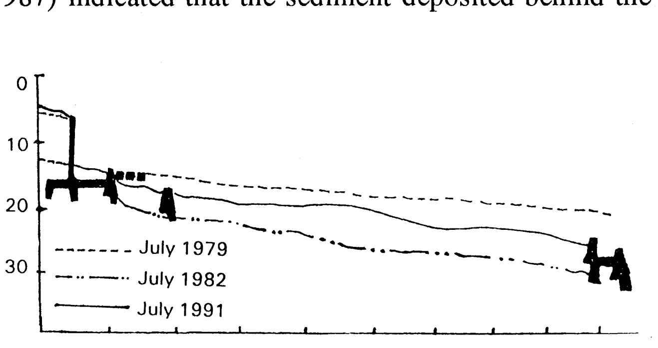

Fig. 4 Changes in the longitudinal profile downstream of the Yuan-Sun check dam.

might be derived from the upstream channel during flood events and that the coarse material did not move downstream continuously. The results of the sediment particle size analysis reinforced this conclusion. That is, the bed load material trapped by the check dams was largely derived from the upstream channel and is from mass wasting. This material moved down the stream intermittently and entered the check dam storage. The movement of coarse material, both in the stream channels and in mass movements, can therefore be temporarily slowed down by the check dams.

The sediment yields from these three watersheds were relatively high during the past decade. Such high sediment yields resulted in instability in these stream channels. Available evidence strongly suggests that such high sediment yields resulted from mass movements in the source areas caused by the forestry operations in these areas. The cause and effect of forestry operations in steep mountain areas are very obvious in this study area.

CONCLUSIONS

In order to stabilize a stream channel, check dam structures should be designed in the optimum way to maximise stream power dissipation. Not only the stream power from the source areas, but also the overflow energy passing through the check dam should be considered. If the check dams installations can serve as effective energy-absorbing dissipators, then channel erosion can be reduced and we can expect the stream channel to be stable in the long term. The use of check dams to dissipate stream power can only be effective within the limits of local stream reaches. In cases where very large mass wastage occurs, detailed sediment control programs should be carefully planned. Usually, more check dams are needed to stabilize the entire stream reach.

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