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**CONSÉQUENCES DE LA MODIFICATION DU RÉGIME D'ÉCOULEMENT À L'AVAL DES RETENUES**

## IMPACTS OF SABO DAMS ON CHANNEL STABILITY

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ABSTRACT The purpose of this study is to simulate, numerically and experimentally, the impact of sabo dams upon channel degradation/aggradation behaviors of the Sou-Fong Creek, a creek located at the mountain area of east Taiwan. A series of model studies were conducted, and a 1-D sediment routing model, which is applicable to a supercritical flow condition, was developed. Three different layouts, existing condition, with No. 4 and No. 1 dams constructed separately and with No. 4 and No. 1 dams constructed simultaneously, were chosen in the study. In each case, three different frequency of floods, 2.33 year, 25 year and 50 year were simulated. The result was used to evaluate the effectiveness of the sabo dams in solving downstream channel aggradation problems and to determine the ultimate layout of the sabodams.

### INTRODUCTION

Due to geological reason or poor watershed management, large amount of sediments are brought to the river and hence aggradation happens. In the aggradation process, the river bed rises and usually causes severe innudation problem. The sabo dams, dams constructed to detain the sediments, are one of the most important mitigation measures in solving this problem. However, the constructions of the sabo dams are very expensive and usually induce degradation problems to the downstream reach and cause severe damage. A detail study has to be performed to choose the dam sites and the dimensions and to evaluate its impacts on the channel stability.

The Sou-Fong Creek is located at east Taiwan. The average slope of upstream reach is around 14% and that of the downstream reach is 2.5%. Due to the combinations of several factors, large amount of landslides happens in the watershed area and cause severe aggradation problems to the downstream reach. To solve this problem, a series of 5 sabo dams are proposed by the Bureau of Forestry of Taiwan Provincial Government. The purpose of this study is to determine the ultimate layout of the dams and to study their impacts on the channel stability.

### NUMERICAL SIMULATION

The model developed herein is a 1-D uncoupled model, in every time step the flow pattern is calculated first then the results are substituted into the sediment continuity equation to update the bed elevation. The assumptions are: (1) The whole reach is in a supercritical flow condition. (2) Only bed load is considered. (3) The effects of bank erosion are neglected. The flow pattern is calculated by the standard step method and the equation is:

$$Z_1 + d_1 \cos \beta_1 + \alpha_1 \frac{V_1^2}{2g} = Z_2 + d_2 \cos \beta_2 + \alpha_2 \frac{V_2^2}{2g} + H_e \qquad (1)$$

where, the subscripts $l$ and 2 represent the upstream and downstream crosssections respectively, $z$ is the river bed elevation, $d$ is the water depth, $\beta$ is the channel bed angle, $\alpha$ is the velocity correction coefficient, $g$ is acceleration due to gravity, $V$ is the crossectional average velocity and He is total energy loss. The sediment continuity equation is expressed as:

$$\frac{1}{B}\frac{\delta\,(q_b\,B)}{\delta X} + (1-\lambda)\frac{\delta\,Z}{\delta t} = 0 \qquad (2)$$

where $q_b$ is the bed load transport capacity per unit width of the channel, $B$ is the channel width and $\lambda$ is porosity.

Smart bed load transport equation (Smart, 1984) is used herein to calculate $q_b$. It is applicable to sediment mixtures with $D_{90}/D_{30}$ values up to 8.5. It is of the form:

$$\Phi = 4\,[(\frac{D_{90}}{D_{30}})^{0.2}\,S^{0.6}\,\frac{V}{V_*}\,\Theta^{0.5}\,(\Theta - \Theta_{cr})] \qquad (3)$$

where, $\Phi$ is the dimensionless sediment transport rate, $\Phi = q_b/[g(\gamma-1)\,D_m^3]^{0.5}$, $\gamma$ is specific gravity of sediment, $D_m$ is the medium grain size, $S$ is bed slope, $V_*$ is shear velocity, $\Theta$ is the dimensionless shear stress, and $\Theta_c$ is the critical dimensionless shear stress.

Limerinos formula (Limerinos, 1970) is used to calculate the roughness. This formula is found to be applicable to the rivers in Taiwan (Chien and Shen, 1987). It is of the form:

$$n = \frac{d^{1/6}}{9.66 + 19.5\,\log_{10}\,(d/D_{84})} \qquad (4)$$

where, $D_{84}$ is the sediment diameter for which 84weight of sediment is finer.

Eqs. 1 and 2 are expressed in a forward difference form and solved by finite difference method. The numerical model is calibrated and verified by the field data and then used to find the optimal combinations of the dams. The chosen layouts were then tested by the physical model study.

### MODEL STUDY

The Sou-Fong Creak is a bed load dominant Stream and hence the similarity of incipient motion is an important index. It is of the form:

$$\tau_* = \frac{\tau_0}{\gamma'_9\,D_9} \qquad (5)$$

where, $\tau_0$ is the average bed shear stress, $\tau_9$ is the submerged specific gravity of the sediment particle and $D$, is the size of the bed material. Another criterion to be satisfied is the Froude law. It requires the similarity of Froude number in both model and prototype. Based on the above two similarities, the scales of the hydraulic and sediment characteristics are calculated and listed in Table 1. To reflect the size of our experiment basin and pump capacity, the horizontal and vertical scales are chosen to be 1/300 and 1/75 respectively.

Table 1. — Scales of the important parameters.

| Item | Scale | Value |
|---|---|---|
| Horizontal length | $X$ | 300 |
| Vertical length | $Y$ | 75 |
| Discharge | $XY^{3/2}$ | 194856 |
| Particle size | $X^{-1}Y^2$ | 18.75 |
| Time | $X^{5/2}Y^{-2}$ | 277.13 |
| Sediment Discharge | $X^{-3/2}Y^3$ | 81.19 |

Sabo dam = check dam

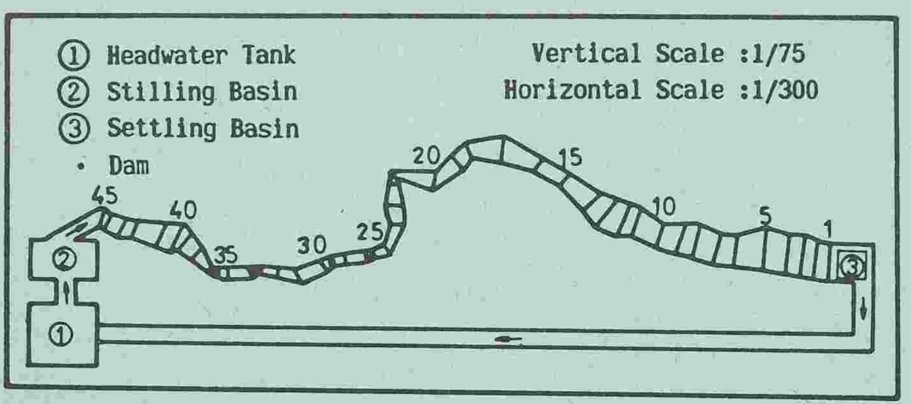


*Fig. 1 Layout of experiment facility*

The layout of the model is shown in Fig. 1. Three different cases are tested. The first case is the existing condition, the second case is with No. 1 and No. 4 dams constructed simultaneously and the third case is with No. 1 and No. 4 dams constructed separately.

## RESULT AND DISCUSSION

For the case without dams, the comparison between the numerical simulation and physical model study is shown in Fig. 2. The discharge used,in prototype, is 2,258 $m^3$/sec, sediment supply rate is 500 thousand $m^3$/day and the duration is 1 day. The result shows that the river is in an aggradation mode, and the agreements are quite satisfactory.

For the case with No. 1 and No. 4 dams constructed simultaneously, the simulation results are shown in Fig. 3. The flow condition used is same as case 1. It shows that the dams are filled during a single flood of this size. The toes of the dams are subjected to scouring but the reach 1 km downstream of the No. 1 dam is still in an aggradation mode.

Under same flow conditions, No. 1 dam is built first, and No. 4 dam is built after two days of flood, and let the same flood run for another day. The results are shown in Fig. 4. The results are similar to those of case 2. To study the effects of construction priority, we can plot the results of cases 2 and 3 in Fig. 5. It shows that the results are quite similar and more sediment are trapped in the dams if two dams are constructed separately.

## CONCLUSIONS

In this study, numerical simulation and physical model study are used to determine the sites and construction priorities of a series of 5 sabo dams. The results show that Constructions of No. 1 and No. 4 dams separately is the optimal layout. Only 1 km downstream of No. 1 dam is subjected to scouring, the reach further downstream is still in an aggradation mode.

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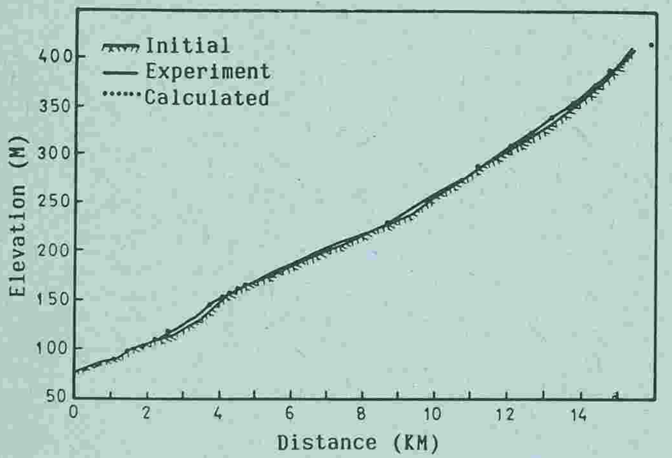


*Fig. 2 Comparisons of layout No. 1 (existing condition)*

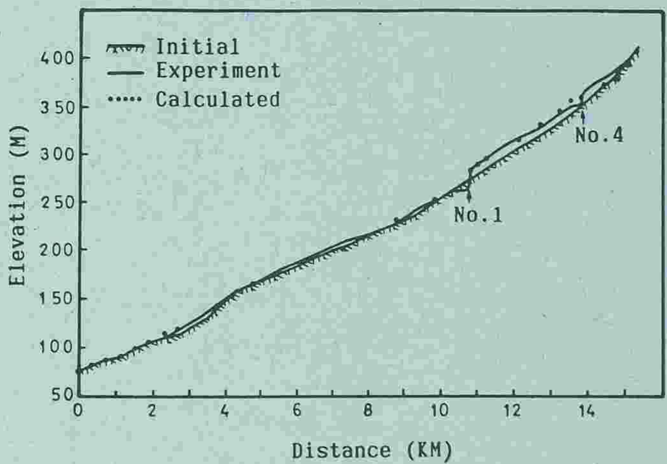


*Fig. 4 Comparisons of layout No. 3 (With No. 1 and No. 4 dams constructed seperately)*

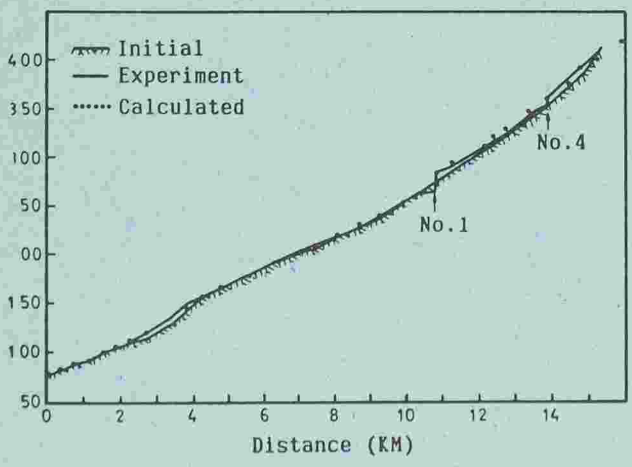


*Fig. 3 Comparisons of layout No. 2 (With No. 1 and No. 4 dams constructed simultaneously)*

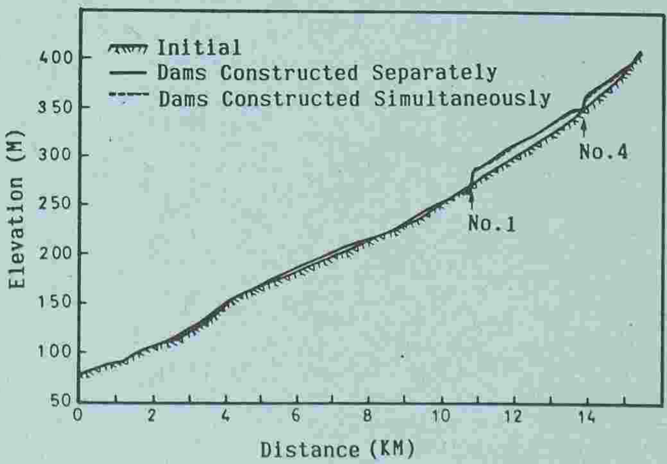


*Fig. 5 Comparisons of the Construction Priority of the dams*