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DESCRIBING LANDSCAPE STRUCTURE IMPROVEMENT ACCORDING TO EXPERIMENTAL RESULTS

Fu-Ming Chang[1] and Ning-Chien Tung[2]

Key words: physical model test, ecology investigation, structure improvement.

ABSTRACT

This study investigated silt movement and the influence of fine sand on downstream ecology during movement by using a small indoor physical model for simulating onsite conditions. The obtained data were analyzed to determine the impact of silt on ecological habitats and can serve as a reference for future onsite and ecology investigations.

Before a dam was removed to allow a downstream riverway to restore the initial environment, the riverway stabilized at approximately 960 s, and the dam was removed at approximately 1140 s. After the dam was removed, the silt in each channel section evidently increased, and after a certain time, it gradually stabilized. Before the dam was removed, some of the silt trapped by the dam was moved to the lower reach by flowing water and filled between coarse particles.

After the dam was removed, the silt was instantly moved to the lower reach. Consequently, the habitat was critically affected; however, the silt with a constant flow stabilized as time passed. Thus, the habitat was gradually restored. For this study, one half of the dam was removed at the beginning, and the other half was removed subsequently. However, the silt trapped by the remaining half of the dam was limited and, therefore, exerted little impact on the downstream riverway after the remaining half of the dam was removed. The phenomenon observed after the upstream dam was removed was repeated when a 6-cm dam was set downstream.

I. INTRODUCTION

Rivers in Taiwan are characterized by steep slopes, rapid currents, and weak geology. Typhoons bring abundant rainfall and a large amount of soil, which is also observed during heavy rainfall.

Summer and fall are the two seasons when Taiwan receives the most rainfall, and a considerable amount of rain water accumulates in reservoir areas. Therefore, the amount and time of flood discharging should be determined to minimize water shortage (Wei et al., 2007).

The main rivers and branches within the catchment area of the Shihmen Reservoir were affected by Typhoons Gloria, Aere, and Matsa in 1963, 2004, and 2005, respectively. To solve problems such as the presence of silt in reservoirs and to extend reservoir life, 122 silt-trap dams have been constructed on the upstream catchment area. These silt-trap dams have arrested a large quantity of silt over the years. However, Typhoon Wipha in September 2007 ruined the silt-trap dam of the upstream Baling Dam. The previously collected silt shifted considerably downstream.

Various experiments, theories, and numerical methods have been widely applied to study dam improvement. For example, Dai (1992) reported that the habitat of *Oncorhynchus masou formosanus* has changed considerably over time, particularly because of the negative influence of typhoons and floods. *O. masou formosanus* will significantly decrease in quantity or even become extinct because of natural disasters, such as landslides caused by typhoons and floods, and changes in riverbed sediment. Yeh et al. (1998) reported that the method for removing parts of the dams to restore the habitat of river fish strongly influences brook stability and silt movement, and can restore the initial environment of the riverway. Yeh (2004) reported that the riverbed is apparently scoured by small-diameter sand grains carried downstream, where they form a protective layer in the riverway, as observed from investigating the sediment of Chichiawan Brook. Therefore, river bed material #6 (large boulders, particle size >51.2 cm) constitutes the largest amount of river bed material (up to 40%), in Chichiawan Brook. In addition, river bed material #1 (smooth-surface, particle size <0.2 cm) is formed by sand grains of the smallest diameter in this area, similar to the riverway of a mountain stream. This indicates that sand grains with a small diameter are transported downward in this

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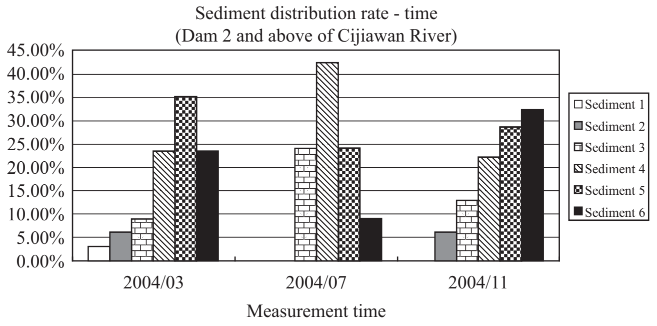


Fig. 1. Sediment distribution rate–time (Qijiawan Creek) (Dam 2, above of the Cijawan River).

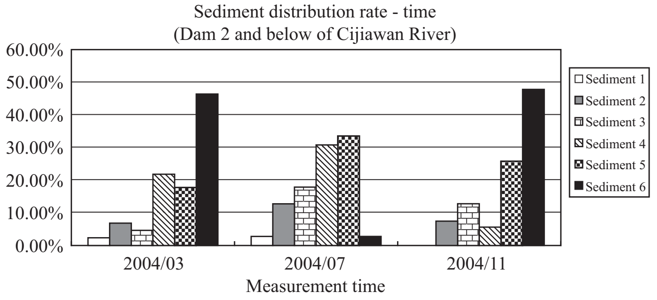


Fig. 2. Sediment distribution rate-time (Dam 2, above of the Cijiawan River).

scouring reach. The sediment change of each riverway is shown in Figs. 1 and 2 for each period.

Konrad (2009) reported that the U.S. Department of the Interior planned to remove two dams (30 and 60 m) from the Elwha River.

Dam removal can restore the river ecosystem of reservoirs through stream erosion and sediment deposition. A one-dimensional model can be used to simulate silt movement and stabilize the time of particle distribution in a riverbed and the recovery time of branches. After dam removal, the excessive quantity of silt may lower the diversity of an ecosystem, but the flow can rapidly carry silt away and restore the initial ecosystem of a river during this period. In 2007, the CALFED Ecosystem Restoration Program reported a water channel that was 28 m long, 0.86 m wide, and 0.9 m deep, according to silt supply, acoustic and laser scanners, and the measured details and terrains above and under water. Its allocation is shown in Fig. 3. The slope of the combined riverbed and the particle size in the riverbed (1), the relationship between the silt movement range and particle size distribution, and the permeation between sand grains with a small diameter and the distribution of particle size in a riverbed (2) were discussed. Sand grains with a small diameter should be transported forward as far as possible (3).

A mixture of particles of various sizes was obtained from nine riverbeds and divided into five categories according to particle size. The distribution of nine types of particle sizes is shown in Fig. 4. Gibson et al. (2009) presented a schematic

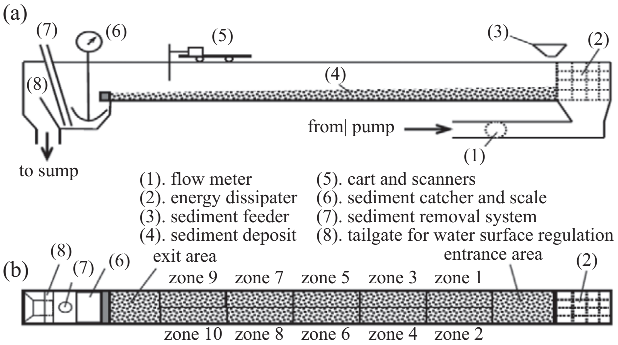


Fig. 3. Trough schematic. (a) Water channel and facility. (b) Permeation experiment of 10 sections in a trough.

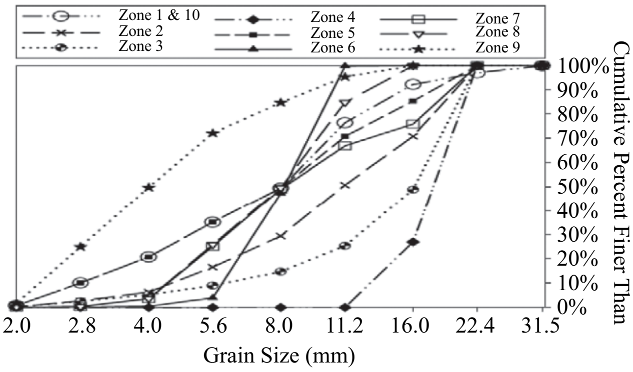
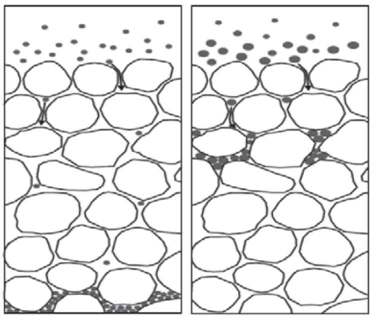


Fig. 4. Particle size of riverbed materials of 10 sections in the experimental segment.


Process 1:
Unimpeded static percolation

Process 2:
Fine bridging

Fig. 5. Permeation process of fine particles in two static gravels.

(Fig. 5) of the penetration process of the fine particles of two static types of gravel. Sand grains with a small diameter fall into the gravel bed and prevent its development when the connection space is sufficient (if the riverbed consists of rocks, deposits containing fine particles may enter the water channel at the bottom).

The semimovable riverbed experiment shows that riverway flow conditions mainly occur toward the right bank. Because of the topographic influence of mountain areas, a minor error was observed between the flood level at the frequency of 200

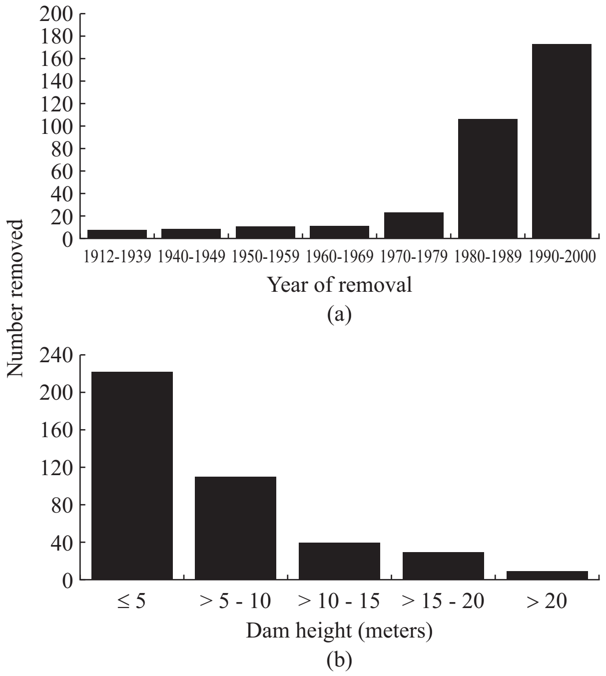


Fig. 6. Annual number of dams removed and height distribution in the United States (Poff and Hart, 2002).

years and the value calculated through mathematical modeling, but it was within a reasonable range. Kleinhans (2002) called this process unimpeded static percolation. Gravels remain static, allowing finer deposits to pass. Previous studies have reported on the behaviors of gravity and fluid dynamics (Savant et al., 1987; Joy et al., 1993; Packman et al., 1995, 2003). Einstein (1968) observed this mechanism when in conducting an initial water trough test. In addition, Lunt and Bridge (2007) reported this mechanism in their open-type gravel document; however, regarding natural systems, it is not a dominant document (Diplas and Parker, 1992). Poff and Hart (2002) observed that the number of dams removed in the United States had increased rapidly over the previous 20 years, as shown in Fig. 6; according to statistical data, 467 barrages were removed in the twentieth century. The total number of removed dams was approximately 200, but nearly half (approximately 220) of the removed barrages were small , lower than 5 m; barrages lower than 17 m accounted for 70% of the total number. The flow chart in Fig. 7 depicts the influence of barrages on the biophysical process produced by the geographic environment.

II. MATERIALS AND METHODS

A downstream fine particle filling experiment was conducted, mainly to understand the phenomenon of silt with fine particles filling a gravel-type riverbed when silt trapped by a dam flows to the downstream gravel-type riverbed. Such an experiment clarifies the impact of the upstream silt with fine particles on the downstream habitat environment after the upstream dam is removed or collapses. Thus, the time for which silt with fine particles remains in the gravel-type riverbed can be estimated to provide a reference for restoring the habitat in the future.

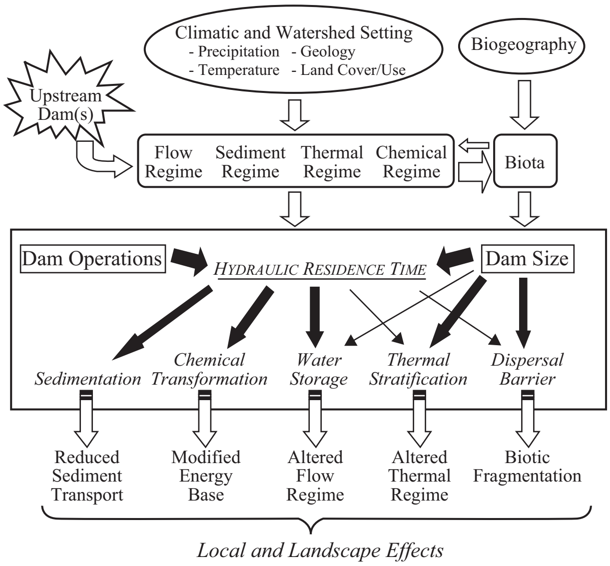


Fig. 7. Flow chart of influence of dam on biophysical process (Poff and Hart, 2002).

Lin et al. (2005) used a physical modeling experiment to compare a hydraulic phenomenon before and after dam construction. The similarity rate of the movable riverbed of the prototype and model was deduced using a method similar to the hydraulic model of the movable riverbed developed and used by the Delft Hydraulic Research Institute combined with the E-H (Engelund-Hansen) formula to obtain the sediment transport equation:

$$\frac{q_s}{D_s^{3/2}\sqrt{g}} = 0.084\left(\frac{\mu h s}{D_s}\right)^{5/2} \tag{1}$$

1. Physical Model Test

1) Experiment Configuration

As shown in Fig. 8, the experiment had a trough 80 cm long, 4 cm wide, and 30 cm high. A water tank was above the trough, which was mainly used for supplying clean water for the test. Two dam structures were set at the 0- and 40-cm positions from the lower reach to the upper reach and were 6 and 15 cm high, respectively. The particle size and discharge height of the downstream gravel-type riverbed were 15 mm and 6 cm, respectively. The particle size of fine sand grains trapped by the upstream dam was 0.1 mm; its layout is shown in Fig. 9. The downstream riverway was divided into five sections to demonstrate the phenomenon of the fine sand grains moving downstream after dam removal. The sections were disturbed, as shown in Fig. 10. The length of Sections 1-4 was 8 cm, and the length of Section 5 was 4 cm. The silt transport was observed from the profile of each section.

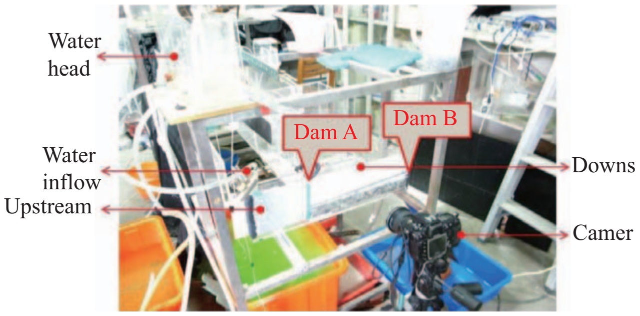


Fig. 8. Experimental configuration.

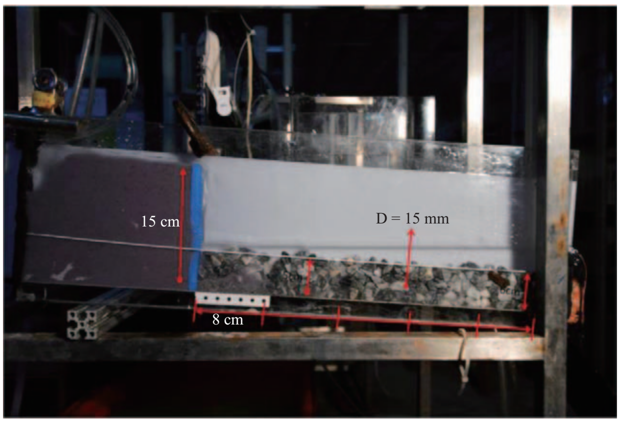


Fig. 9. Onsite arrangement.

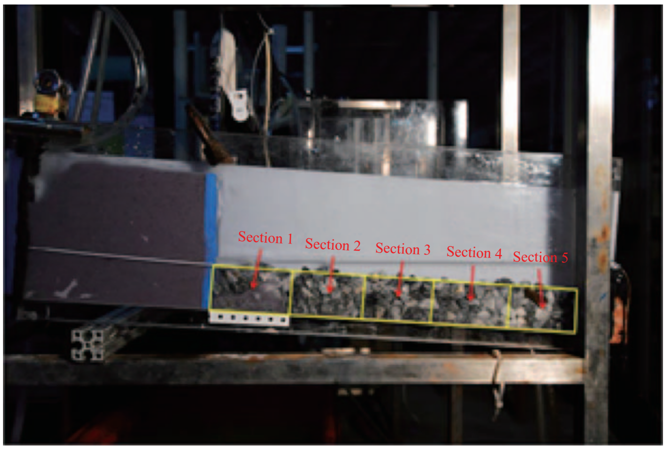


Fig. 10. Experimental section.

Fig. 11. Flow valve opening.

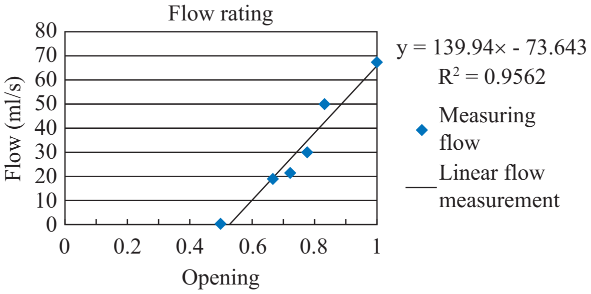


Fig. 12. Flow rating.

2) *Observation and Experimental Steps*

Instruments were used for comparing and observing the percentage of the upstream silt that fills the downstream gravel-type riverbed. The comparison equipment was an acryl container 4.5 cm long, 2 cm wide, and 5 cm high. This container was proportionally filled with gravel, water, and sand grains (Fig. 7). The experimental gravel accounted for 18% of the total volume, and the water and sand grain proportions were changed to analyze the percentage of sand content in each section. A comparison diagram is shown in Fig. 8, and the experimental comparison is shown in Fig. 9. The flow of the water tank was calibrated, and the water tank was controlled by a valve (Fig. 11). The calibration curve for each flow was formed, as shown in Fig. 12.

2. Experimental Steps:

1. The trough was filled with an appropriate amount of water (6 cm), and the downstream gravel-type riverbed was allowed to reach saturation.
2. A low flow (approximately 5 mL/s) was initiated, and the dam was filled because of the downstream filling phenomenon, allowing a natural riverway to form downstream.
3. High-flow (approximately 68 mL/s) downstream silt movement was simulated (the flow simulated that resulting from an approaching typhoon).
4. One half of the dam was removed.
5. After prolonged observation, the downstream silt distribution was analyzed (the downstream silt transport was observed after one half of the dam was removed).
6. The downstream silt movement was observed after the remaining dams were removed.
7. The silt in the riverway was observed after the downstream dam was removed.

III. RESULTS

The experimental results are described as follows. Fig. 13 shows the percentage of the sand content when the dam was

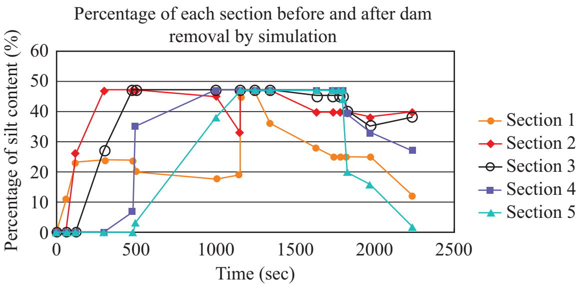


Fig. 13. Percentage of silt content of each section when dam was removed.

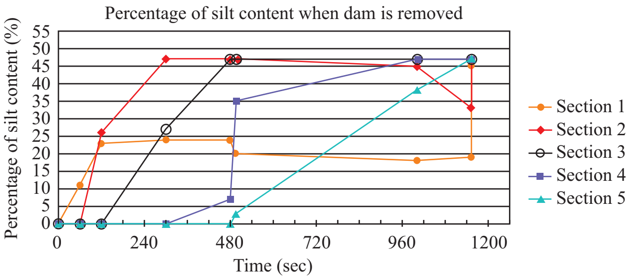


Fig. 14. Percentage of silt content after dam removal.

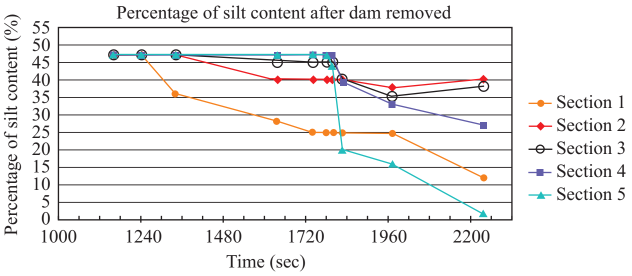


Fig. 15. Percentage of silt in each section before and after simulation of dam removal.

removed. Before the dam was removed to allow the downstream riverway to restore the initial environment, the riverway stabilized at approximately 960 s, and the dam was removed at approximately 1140 s. Fig. 14 shows the percentage of the sand content of each section after the dam was removed. The silt in each section increased after the dam was removed; however, after 1830 s, it gradually stabilized. Fig. 15 shows the situations before and after dam removal. Before the dam was removed, some of the silt trapped by the dam was moved to the lower reach by flowing water and filled between coarse particles. Section 1 was below the dam and formed a scour pit; therefore, its sand content changed irregularly. For other sections, the riverway stabilized after a period and moved the silt to the lower section over time.

After the dam was removed, the silt was instantly moved to the lower reach. Consequently, the habitat was critically affected; however, the silt with a constant flow stabilized over time. Thus, the habitat was gradually restored. For this study, half of the dam was removed at the beginning, and the other half was removed subsequently. However, the silt trapped by the remaining half of the dam was limited; therefore, it exerted little impact on the downstream riverway after the remaining half of the dam was removed. The phenomenon caused by removing the upstream dam was repeated when the 6-cm dam was set downstream.

IV. DISCUSSION

1. The silt-trap dam affected the transport channel of the silt, separated the silt source of the upstream, enhanced the scouring of the downstream, and rearranged the riverway silt. According to this study, the influence of the silt-trap dam on the riverway consists of three blocks: downstream dam washout, changes between two dams, and accumulation at the dam upstream. However, most studies have focused on upstream deposit scouring and have rarely discussed changes between two dams. The silt carried from upstream to downstream of the dam accumulated at an appropriate place, thus forming a braided riverway. Compared with the upstream, the braided riverway had higher resistance; therefore, the low stress caused a considerable amount of silt to accumulate there. As time passed, it naturally formed a dam and eroded the downstream riverway. The aforementioned procedure was repeated and affected the development of the riverway between the two dams. In general, the number of times the procedure is repeated depends on the number of dams naturally formed.
2. Because there was a height of water between the upstream and downstream riverbeds, it formed a free jet when the water flowed through the top of the dam, and resulted in a pool after long-term scouring. The durations required for constructing and designing dams are not identical, and a dam may be damaged; therefore, determining the relationship between the dam height and the dam pool is difficult.
3. When the dam broke, the filling phenomenon occurred rapidly. Therefore, the required time depends on the number and intensity of floods, if the riverbed sediment must be restored before the dam breaks.

V. CONCLUSIONS

1. Particles in a silt-trap dam are distributed such that the upstream area contains fine particles, whereas the downstream area contains coarse particles. This may be due to the following factors:
   (a) The silt is blocked upstream of the dam; the water drained is powerful and has high sediment carrying capacity. Therefore, the silt in the lower reach is carried away and only coarse particles remain. Because the soil at the bottom of the dam cannot be washed away, it deposits at the bottom.
   (b) The waterfall effect generated by a dam increases the scouring force between gravels and carries silt away.

2. The influence of downstream dam removal on the improvement of the upstream filling situation is limited.
3. Because of the removal of half of the upstream dam, a flood event causes heavy floods to carry silt downstream. If the silt trapped by the other half of the dam is insufficient, the impact of silt downstream decreases after the remaining half of the dam is removed.
4. Taiwan is an island where many disasters, such as landslides and mudslides, occur frequently. In the future, the influence of hydrological geography on the stability of landslides can be considered (Ku et al., 2008). In addition, the side gravel requirements of the main river, such as gravel colluvia, can be considered for investigating the influence of slope and water level on mudslides (Hsiao et al., 2007).
5. We can assumed the lower sand layer to be the lower transmissibility coefficient, and the permeable dam constructed on this sand layer was used to obtain the theoretical solution when the dam bottom $K \approx 0$ (K = permeability coefficient); the water level was equal to the dam height. It is mainly used to solve the equation $\vec{\nabla} \bullet \vec{q} = 0$ for the dam hypothetically, where q (q = discharge) can be obtained from $\vec{q} = -k\vec{\nabla}h$ (h = water level). The obtained theoretical solution is applicable to the permeable rate of a project.

REFERENCES

CALFED Ecosystem Restoration Program (2007). Physical modeling experiments to guide river restoration projects dam removal experiments: Final technical memorandum. Stillwater Sciences, Berkeley, CA.

Dai, Y. T. (1992). The research of the tribe ecology of *Salmo Formosanus*. Ph.D. Thesis, National Taiwan University, Taipei, Taiwan.

Diplas, P. and G. Parker (1992). Deposition and removal of fines in gravel-bed streams. In: Dynamics of Gravel-Bed Rivers, edited by Billi, P., Hey, R.D., Thorne, C.R. and Tacconi, P. Wiley, London, UK, 313-329.

Einstein, H. A. (1968). Deposition of suspended particles in a gravel bed. Journal of Hydraulic Engineering 94, 1197-1205.

Gibson, S., D. Abraham, R. Heath and D. Schoellhamer (2009). Vertical gradational variability of fines deposited in a gravel framework. Sedimentology 56, 661-676.

Hsiao, P. J., C. Y. Ku and P. C. Hsieh (2007). Modeling of granular debris flow using discontinuous deformation analysis. Journal of Soil and Water Conservation 39, 29-47.

Joy, D. M., W. C. Lennox and N. Kouwen (1993). Stochastic model of particulate transport in porous medium. Journal of Hydraulic Engineering 119, 846-861.

Kleinhans, M. G. (2002). Sorting out sand and gravel: sediment transport and deposition in sand-gravel bed rivers. Netherlands Geographical Studies 293, 317.

Ku, C. Y., S. M. Hsu, M. C. Chung, L. Y. Fei, J. F. Lee and T. W. Su (2008). Investigation of hydrogeological properties for landslides. 97th Annual Conference and Academic Seminar of Geological Society of Taiwan and Chinese Taipei Geophysical Society, 65.

Konrad, C. P. (2009). Simulating the recovery of suspended sediment transport and river-bed stability in response to dam removal on the Elwha River, Washington. Ecological Engineering 35, 1104-1115.

Lin, G. F., J. S. Lai, K. L. Tu and L. H. Chen (2005). Simulation study on hydraulics of riverway of mountain areas before and after dam construction. Agricultural Engineering Conference Proceedings, 100-1-100-6.

Lunt, I. A. and J. S. Bridge (2007). Formation and preservation of open-framework gravel strata in unidirectional flows. Sedimentology 54, 71-87.

Packman, A. I. and N. H. Brooks (1995). Colloidal particle exchange between stream and stream bed in a laboratory flume. Marine and Freshwater Research 46, 233-236.

Packman, A. I. and J. S. MacKay (2003). Interplay of stream-subsurface exchange, clay particle deposition, and streambed evolution. Water Resources Research 39, 1097.

Poff, N. L. and D. D. Hart (2002). How dams vary and why it matters for the emerging science of dam removal an ecological classification of dams is needed to characterize how the tremendous variation in the size, operational mode, age, and number of dams in a river basin influences the potential for restoring regulated rivers via dam removal. BioScience 52, 659-668.

Savant, S. A., D. D. Reible and L. J. Thibodeaux (1987). Convective transport within stable river sediments. Water Resources Research 23, 1763-1768.

Wei, C. C., C. C. Cheng and N. S. Hsu (2007). Decision-tree analysis for the optimal reservoir release in advance upon a typhoon warning. Taiwan Water Conservancy 55, 63-72.

Yeh, Z. X. (2004). The research of high mountain creek changes and physical habitat. Shei-Ba National Park Administration, Construction and Planning Agency, Ministry of the Interior, Chinese Soil and Water Conservation Society.

Yeh, Z. X., J. H. Duan and H. B. Lian (1998). Pilot study on the improvement of river bank habitat of Chi Chia Wan Creek. Shei-Ba National Park Administration, Construction and Planning Agency, Ministry of the Interior, Chinese Soil and Water Conservation Society.