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LONG-TERM EFFECTS OF RIVER BED VARIATIONS DOWNSTREAM OF THE SHIHMEN RESERVOIR DUE TO CLIMATE CHANGE

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ABSTRACT

Most reservoirs in Taiwan are suffered from serious sedimentation problems due to extreme weather in recent years. In order to decrease sediment deposition in the Shihmen reservoir, the reservoir sediment was effluent into downstream river during flood period. At the downstream river reach, sediment deposition and erosion would affect bed variation significantly. The quasi-two dimensional model, NETSTARS, was applied to investigate hydraulic characteristics and corresponding river sedimentation behavior in the Dahan river basin. The model was calibrated and verified with field survey data, and then it was utilized to predict the spatial and temporal variations of downstream suspended solid concentration. Through investigating the change of suspended solid concentration at the Yuanshan weir which is one of the most important water supply facilities in the Taipei metropolitan area, the reduction of suspended solid concentration is a necessary effort. The water level and bed elevation variation in typhoon events are investigated by using the NETSTARS model at different river reaches. The joint operation of sluice gate in the Shihmen reservoir and the Yuanshan weir is also discussed for long-term effects due to climate change.

Keywords: suspended solid, river sedimentation, deposition and erosion, numerical model, Shihmen Reservoir.

INTRODUCTION

In recent years, reservoirs around the world suffer sedimentation problems due to great amount of yield sediment from their upstream watersheds [4, 5]. Carried by flood, eroded sediments flow into reservoir while heavy rain occurred and trapped by the reservoir [1].

Shihmen Reservoir is one of the most important reservoirs in northern Taiwan, in order to deal with reservoir sedimentation problem. The deposited sediment in reservoir was effluent into downstream river during flood period. The river sediment deposition and erosion would be thus more violent [4, 5]. The quasi-two dimensional model, NETSTARS [2, 3], was applied to investigate hydraulic characteristics and corresponding river sedimentation behavior in Da-Han river basin (Figure 1). The model was calibrated and verified with field survey data and then was utilized to predict the spatial and temporal variations of downstream suspended solid concentration.

GOVERNING EQUATIONS OF NUMERICAL MODEL

The governing equations include hydraulic and sediment continuity equations. The hydraulic equations include a continuity equation and an one-dimensional momentum equation.

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}(\beta\frac{Q^2}{A})+gA\frac{\partial y}{\partial x}+gAS_f-\frac{Q}{A}q=0 \tag{2}$$

where A = channel cross-sectional area; Q = flow discharge; t = time; x = coordinate in the flow direction; q = lateral inflow/outflow discharge per unit length; α =momentum correction coefficient; g = gravitational acceleration; y = water surface elevation; $S_f=Q|Q|/K^2$ = friction slope; $K=\frac{1}{n}AR^{2/3}$ = channel conveyance; n = roughness coefficient of Manning's formula, and R = hydraulic radius.

The sediment equations include a sediment continuity equation, a sediment concentration convection-dispersion equation. The sediment continuity equation is given as:

$$(1-p)\frac{\partial A_{dt}}{\partial t}+\frac{\partial}{\partial x}\sum_{k=1}^{Nsize}QC_k+\frac{\partial Q_b}{\partial x}=0 \tag{3}$$

Where Q_b = bed load transport rate and C_k = depth-averaged concentration of the suspended sediment of size fraction k . A_{dt} = amount of sediment scouring/deposition per unit length and p =channel bed porosity. The bed load transport rate Q_b equals to $\sum_{k=1}^{Nsize}Qb_k$. Where, Qb_k is defined as the bed load transport rate of size fraction k. The concentration C_k is calculated using the convection-dispersion equation shown as:

$$\frac{\partial(C_kA)}{\partial t}+\frac{\partial}{\partial x}(C_kQ)=\frac{\partial}{\partial x}(Ak_x\frac{\partial C_k}{\partial x})+S_k+(hk_z\frac{\partial C_k}{\partial z})\Big|_r^l \tag{4}$$

Where k_x and k_z = longitudinal and transverse dispersion coefficients, and S_k = source term of the suspended sediment of size fraction k.

RESULTS AND DISCUSSION

Through the investigating of suspended solid concentration changing at Yuanshan Dam, which is one of the most important water supplies facilities in Taipei metropolitan area, the success of decreasing the suspended solid concentration was certain. The water level and bed elevation movement in typhoon events were investigated via the numerical model at different river reaches. The joint operation of Shihmen sluice gate and YuanShan Dam was also discussed for Long-term effects due to climate change.

The results showed that the cumulative amount of sediment in the long-term case was more than the general typhoon flood event. Sediment deposition situation was also more serious, therefore, the water elevation was rise up at peak discharge; it was threaten to flood-prevention work. Figure 2 was the variation of bed elevation after 10, 20, 30 years, the bed movement will reach equilibrium 30 years ago (from Shihmen Reservoir to Yuanshan Dam). Table 1 showed that Yuanshan Dam and its backwater area were suffered from overbank floods. Through field survey and numerical analysis results, we can develop coping strategies in order to achieve sustainable river management purposes. The solution about the construction of sediment-prevent bypass tunnel could be offered in feature.

Table 1. Variation of bed elevation from Shihmen Reservoir to Yuanshan Dam

Section NO.	Distance (m)	Initial Bed Elevation (m)	Variation of Bed Elevation (m)	Water Elevation (m)	Height of Left Hand Embankment (m)	Height of Right Hand Embankment (m)
Yuanshan Dam	41716.00	43.22	0.29	57.56	**57.00**	66.00
T066	42164.00	43.22	0.07	61.52	**59.31**	70.48
T067	42664.00	45.91	0.22	61.55	61.31	**59.89**
T068	43128.00	45.30	0.30	61.58	71.19	63.87
T069	43857.00	46.75	0.22	61.58	**59.84**	64.69
T070	44585.00	46.74	0.67	61.57	67.29	90.82
T071	45006.00	47.68	0.16	61.63	62.67	133.53
T072	45574.00	50.58	0.32	61.78	67.23	103.67
T073	46328.00	51.98	0.00	62.44	71.48	85.40
T074	46957.00	55.02	0.01	65.27	73.83	98.62
T075	47576.00	59.08	-0.02	66.90	81.10	96.54
T076	48253.00	61.27	0.39	70.29	101.67	104.32
T077	48805.00	61.34	-0.19	75.38	105.53	78.42
T078	49487.00	65.03	0.44	75.92	91.76	87.63
T78A	49765.00	74.68	0.20	80.72	103.99	92.60
T78B	50286.00	73.29	0.31	84.52	95.17	95.17
T079	50391.00	72.29	0.18	85.63	93.12	114.73
T080	51025.00	78.73	0.01	86.04	95.61	92.35
T80A	51514.00	81.51	0.03	90.03	93.88	95.79
T081	51688.00	82.54	0.06	90.73	95.79	124.83
T082	52370.00	85.47	0.00	92.48	99.64	106.99
T083	53308.00	88.70	-0.10	97.89	103.52	116.02
T084	53766.00	90.68	0.04	99.64	105.92	107.87
T085	54422.00	94.10	0.67	101.69	116.50	146.29
T086	54934.00	95.63	0.79	105.98	114.10	152.86
T087	55652.00	101.81	0.17	109.36	124.41	116.17
T088	56171.00	106.23	0.11	115.06	164.93	119.97

T089	56988.00	109.12	0.10	120.16	123.24	134.43
T090	57558.00	111.98	0.23	120.54	126.44	134.62
Shihmen Reservoir	58335.00	121.17	0.15	126.63	140.76	140.88

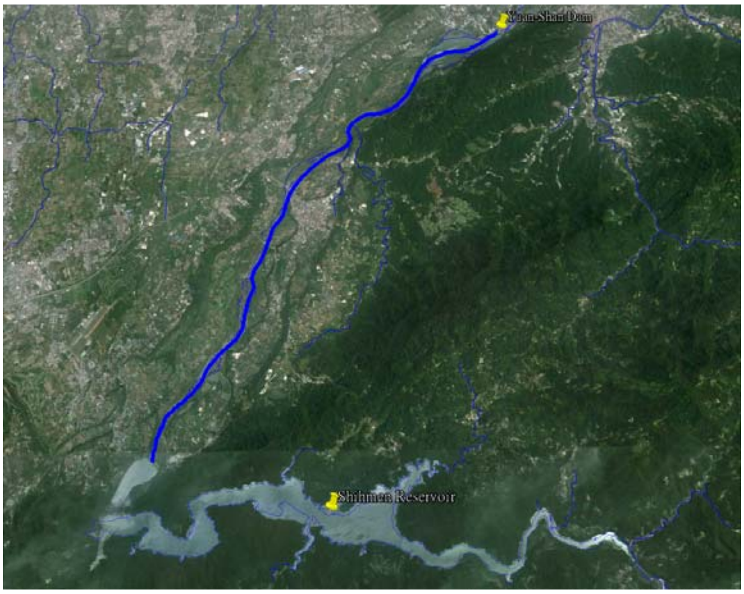

Figure 1. Research area from Shihmen Reservoir to Yuanshan Dam

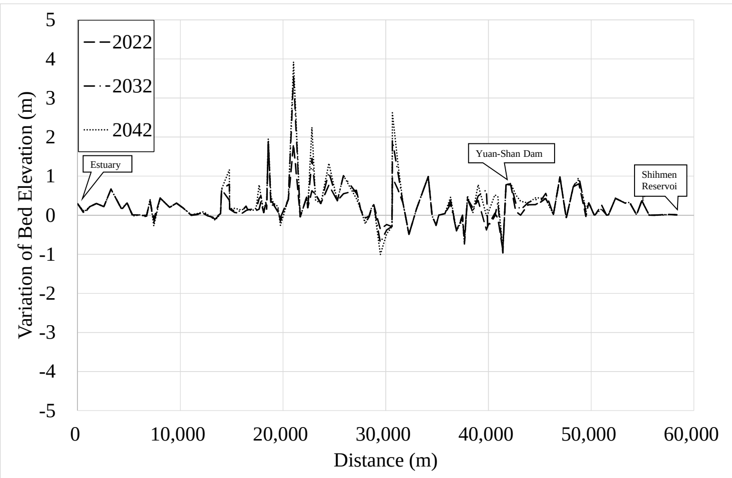

Figure 2. Variation of bed elevation from Shihmen Reservoir to estuary

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