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Integration of Multiple Outlets' operation and Sediment Management Options in the Reservoir for Increasing Efficiency of Turbidity Current Venting and Clear Water Storage

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INTRODUCTION

Turbidity current venting (TCV) has the ability to release a massive amount of the inflowing sediment load and deliver suspended sediment without drawdown the water level of the reservoir (Morris and Fan, 1998). The TVC is gaining more importance for mitigating reservoir sedimentation and prolonging reservoir life. Due to climate changes and increased extreme hydro-meteorological events, sustainable water resources from reservoirs are essential not only for human use and agriculture but also for manufacturing and the global economy. The TCV approach requires a reservoir with bottom venting facilities and sufficient velocity for turbidity current traveling to the dam. Moreover, turbidity current is prone to occur under strong typhoon events due to the intense rainfall causing extremely high inflow discharge and sediment. In Shihmen Reservoir, over ten turbidity current venting operations have been implemented in the past two decades. However, turbidity current venting operation under multiple reservoir outlets is a challenging decision-making process balancing the releases of turbidity currents with the maintenance of clear water circulation within the reservoir.

Numerous studies have proposed various methods to increase turbidity current venting efficiency. Still, some research gaps exist: (1) The systematical TCV operation is still limited. (2) No studies focus on the influence of sediment bypass tunnels operation on turbidity current arrival time at dam. (3) The balance between computational time and simulation accuracy simultaneously. (4) There are still no rules on systematical setup for three-dimensional numerical models. To fill these research gaps, the numerical models are the most appropriate tool, avoiding scale effects and providing numerous results, enhancing the understanding of the process. Thus, the open-source numerical model Telemac-3D coupled with Gaia, sediment transport, and bed evolution module is adopted in this study.

3-D NUMERICAL MODELLING SETUP

There are two liquid boundaries within the study domain. The prescribed time series inflow discharge and sediment concentration are used for an upstream boundary. The water level control and free outflow are adopted in the downstream boundary. The initial and boundary conditions for calibration and validation are shown in Fig. 1. The sensitivity analysis of the domain discretization, turbulence scheme, and morphodynamic are essential to calibrate the model by testing various equations and parameters. Through comprehensive sensitivity analysis, applicable scope of dimensionless numerical model setting was obtained (Table 1).

Table 1 Optimal numerical modelling setting

Numerical aspect	Options
Mesh size	$[b_0/6, b_0/3]$
Time step	$\Delta t/\Delta x = 5$
Layer style	LS2
Layer number	15
Horizontal turbulence model	Cst
Vertical turbulence model	κ-ω
Bed roughness fromula	Nikuradse
Settling velocity	Rubey

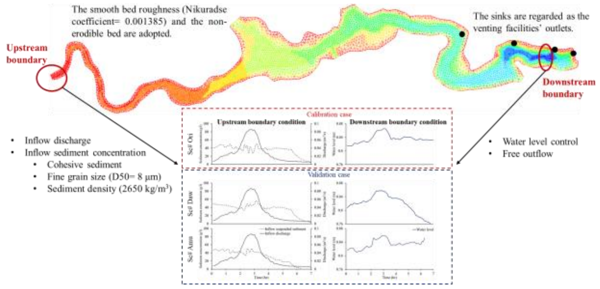

Fig. 1 Initial and boundary conditions

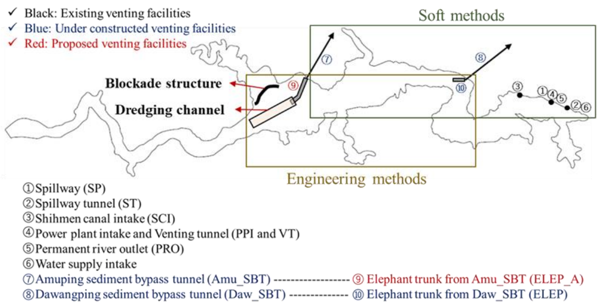

Fig. 2 The proposed soft and engineering methods

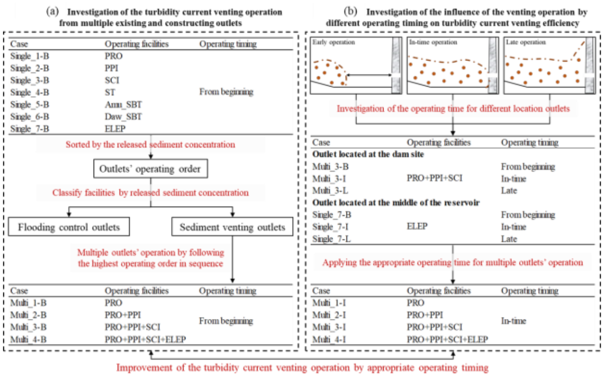

Fig. 3 The proposed scenarios of soft methods.

CONCLUSION OF IMPROVING PROPOSAL

This section aims to evaluate the feasibilities of the proposed improvement scenarios for increasing turbidity current venting efficiency and prolonging the water supply during flooding events. To achieve this goal, the soft and engineering methods are considered in this study (Figure 2).

As illustrated in Figure 3, the soft methods was discussed with existing outlets: (1) multiple outlets' operation. (2) operating timing. According to the understanding of turbidity current process, the additional structures for guiding and concentrating turbidity current was investigated (Figure 4): (1) blockade structures. (2) additional extended pipe from Amu_SBT. (3) dredging channel.

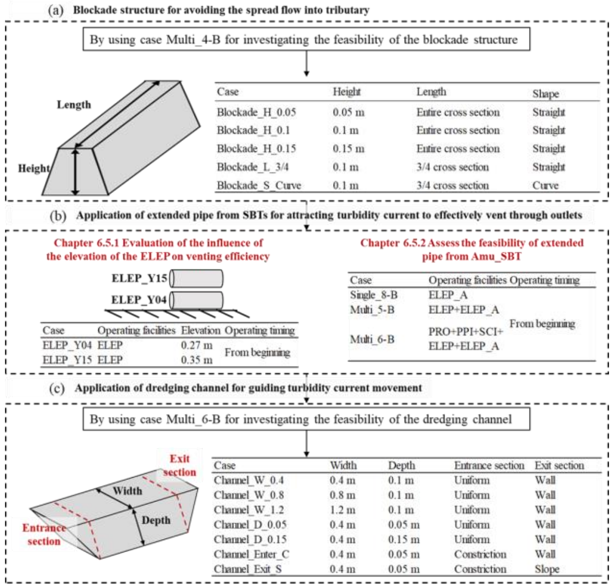

Fig. 4 The proposed scenarios of engineering methods

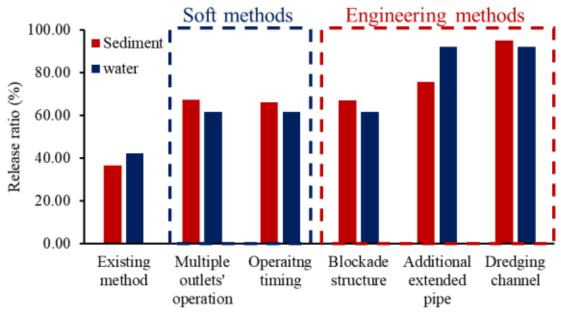

Fig. 5 The performance of existing and improving methods.

Based on the scenario testing, Figure 5 provides a references for multiple outlets' operation and sediment management options. Reservoir managers can evaluate the feasibility of applying the proposed improving soft and engineering methods.

In conclusion, through considering computational time and accuracy simultaneously, the applicable scope of the dimensionless numerical model setting gives a reference for 3-D modeling. Meanwhile, the turbidity current process and shortcomings of the existing venting methods were found by fully 3-D numerical model. Thus, the proposed improving methods provide reliable suggestions for multiple outlets' operation and sediment management options.

REFERENCES

Morris, G. L., & Fan, J. H. (1998) *Reservoir Sedimentation Handbook: design and management of dams, reservoirs, and watersheds for sustainable use*. McGraw-Hill Book Co., New York, USA.