EXPERIMENTAL AND NUMERICAL SIMULATION OF DEPOSITION AND SEDIMENT FLUSHING PROCESSES IN RESERVOIRS

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1. *Introduction*:

For the design and management of reservoirs for sustainable use, it is necessary to foresee the process of deposition and the feasibility of applying countermeasures against deposition in reservoirs. Thus, in this paper, the processes of front formation and sediment removal by hydraulic flushing were investigated by means of laboratory experiments and numerical computations assuming one-dimensional character.

2. *Experimental method*:

At the downstream end of a re-circulating straight flume, a dam facility with bottom gate was installed to perform deposition and flushing runs. The flume plan-shape is shown in Figure 1; it has three sections of different width to stimulate sediment transport in the upstream reaches and deposition near the dam.

Water surface elevations were measured continuously and the longitudinal bed profiles were measured at different times. The sediment consisted of silica sand with uniform size distribution, D_{50} equal to 0.0008 m and the specific gravity was equal to 2.65. Front formation runs were performed over an initial flat bed and under constant influent discharge. No sediment supply was provided, therefore degradation occurred in the upper reaches as the bed began to stabilize.

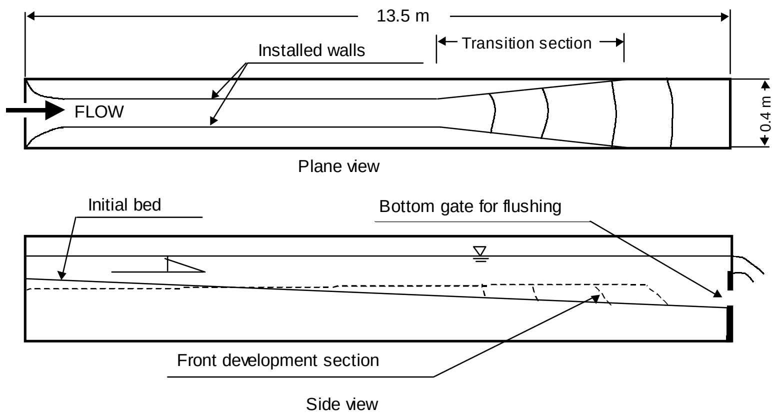

Figure 1. Schematic view of the straight flume

Normally, the sediment flushing runs were performed after the front formation was concluded. It began by opening the bottom gate to allow for water surface drawdown near the dam, thereby producing higher velocities and scour in the bed. Finally, the eroded material was expulsed through the bottom gate. For these runs, different initial bed conditions were employed, only for flushing run F0 an initial flat bed with low bottom gate elevation was used, in the others, instead, the bed configuration obtained in the previous front-formation run was used together with a particular bottom gate elevation. Thus, it was possible to observe the front erosion as the water drawdown progressed. Table 1 summarizes the conditions for each run.

Table 1: Conditions for the experiments

Run D=Deposition F=Flushing	Initial Bed Slope	Gate Elevation (m)	Influent Discharge (m3/s)
D1	0.0064	0.22*	0.0055
D2		0.22*	0.0082
F0	0.0031	0.11	0.0061
F1	-------	0.19	0.0055
F2		0.19	0.0065
F3		0.19	0.0048
F4		0.22	0.0064

* Bed elevation at the dam

3. *Numerical method*:

The developed model solves the Saint Venant`s equations including the longitudinal variation of width.

For momentum and water continuity :

$$\frac{\partial Q}{\partial t}+\frac{\partial(Qv+gA\bar{h})}{\partial x}+gA(S_f-S_0)-\frac{gh^2}{2}\frac{\partial B(x)}{\partial x}=0$$

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \qquad S_0=\frac{\partial Z_b}{\partial x} \qquad S_f=\frac{n^2v^2}{R_h^{4/3}}$$

For sediment continuity :

$$(1-\lambda)\frac{\partial(z_b)}{\partial t}+\frac{1}{B(x)}\frac{\partial Q_s}{\partial x}=0 \qquad Q_s=B(x)q_s$$

The sediment transport was estimated using Ashida-Michiue and Meyer-Peter&Muller equations. The method of finite differences using the explicit predictor-corrector **MacCormack scheme** was implemented in the discretization. The simultaneous change of bed with the water transients at every computational time step was included, so this model can be considered as coupled. The appropriate boundary conditions were provided for both types of runs. From the calibration of the hydrodynamic component, the Manning's resistance coefficient was fixed to 0.0135. Also, a correction of the sediment transport equations was necessary to account for the additional resistance produced by the wavy bed and the effect of the walls (values of width/depth<6).

Keywords: Sediment flushing, deposition, MacCormack scheme, reservoir, movable bed, numerical model
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*4.**Comparison of the experimental and numerical results**:*

- *Sediment deposition runs:* The front was observed to grow in size and moved toward the dam. The bed aggraded rapidly producing a sudden increase in bed elevation until a limiting or critical depth was reached, after that, the front developed almost horizontally. Figure 2 shows the front formation process at different times as observed and as computed by the numerical model. Figure 3 shows observed and computed results of the position and displacement velocity of the front in time. The front velocity decreased as the channel width increased, becoming nearly constant after 2000 seconds, corresponding to the time at which the front reached the widest section. In both figures, the agreement between the computed and observed results is good.

- *Sediment flushing runs:* Figure 4 shows the observed bed and water surface transients at different times for run F0 (initial flat bed and low gate elevation) as well as the corresponding computed bed profiles. Similarly, Figure 5 presents the observed and computed bed profiles for run F2 illustrating the retrogressive erosion on a previous formed front with high bottom gate elevation. Figure 6 shows the observed and computed effluent sediment discharge for run F0; also, the observed cumulative flushed sediment for all the flushing runs and the corresponding computed values for runs F0, F2 and F3. With reference to Table 1, the run F0 with the lowest gate elevation had the largest amount of flushed sediment at any time. Run F4 is the opposite condition of run F0, having the lowest flushed sediment quantities. Runs F1, F2 and F3 are between these extremes with intermediate gate elevations. Evidently, the gate elevation is a very important factor in the flushing process as it controls the resulting bed slope during the flushing.

For deposition and flushing runs under different conditions, the computed values are close to the observed ones. Thus, it is considered that this model is consistent and can be used for the prediction of bed changes in reservoirs with an elongated plan-shape, provided that bed-load predominates in the formation of the deposits.

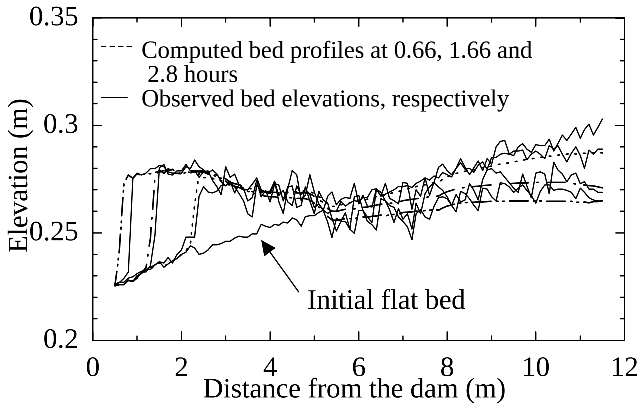

Figure 2: Experimental and calculated results for run D2

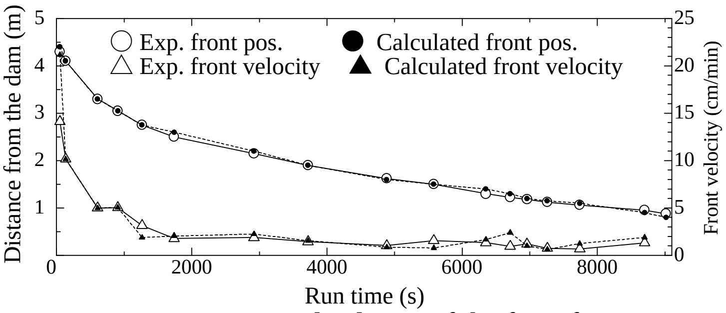

Figure 3: Position and velocity of the front for run D2

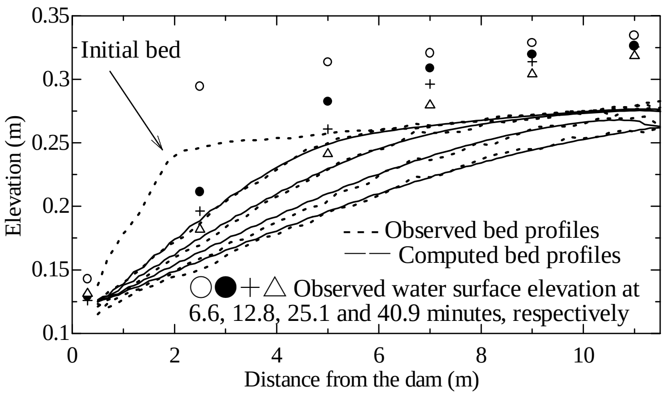

Figure 4: Experimental and calculated results for run F0

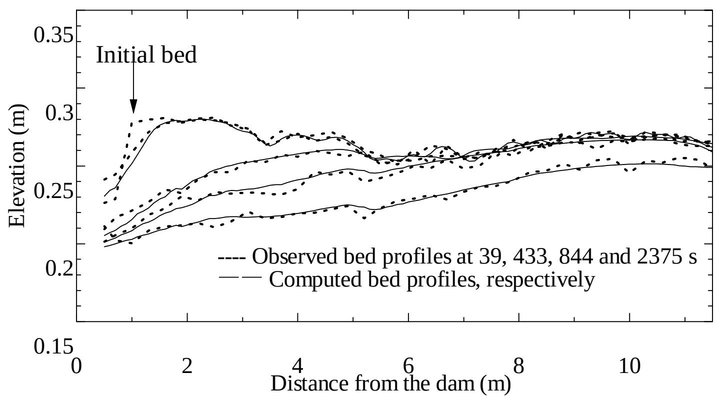

Figure 5: Experimental and calculated results for run F2

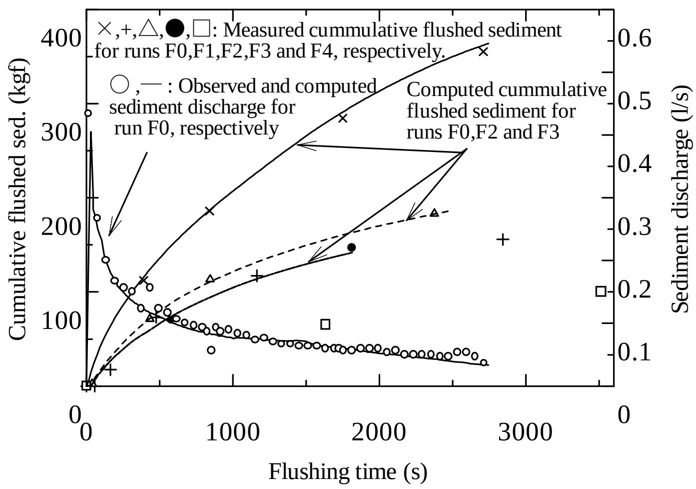

Figure 6: Experimental and calculated results for flushing

(1) Bhallamudy, M. and Chaudry, H. “Numerical modeling of aggradation and degradation in alluvial channels”. J.H.E.; ASCE 1989