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A modelling system for open-channel flows with mobile bed - Application as a decision-support tool for sediment management in a hydropower project

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Sediment related problems are of huge importance in most projects of river engineering and dam construction. In the later case, they may have long term impacts, by decreasing the reservoir capacity, as well short term ones, by damaging the turbines in the case of hydroelectric power plants. Therefore, the detailed analysis of sediment effects is increasingly present in the preliminary design of dam projects. The present communication covers, a detailed description of a complete modelling system suitable for simulating flows and morphological changes in rivers and in the vicinity of hydraulic structures. The modelling system is next applied in the case of an Alpine hydropower project, involving reservoir sedimentation issues and long-term management of the sediments by means of periodic flushing.

A challenging issue in sediment transport modelling is the need to handle accurately and efficiently a wide range of different time scales that are involved in the relevant phenomena. Indeed the time scales of interest extend from a few seconds or minutes (e.g. slope failures or scouring in the initial phase of a flushing operation ...) to periods as long as years or decades (e.g. reservoir sedimentation ...). Therefore, specific numerical modelling tools must be combined properly to handle reliably and at an acceptable CPU cost the processes characterized by time scales spanning over such a wide range.

The modelling system “WOLF”, developed at the University of Liege, includes a

series of complementary numerical tools designed to be combined for covering the whole range of relevant time scales encountered in sediment transport modelling. Therefore, the modelling system consists notably of the following components related to sediment transport:

- steady model computing bed equilibrium profile;
- unsteady model loosely coupling sediment transport and flow computation (quasi-steady);
- unsteady model tightly coupling sediment transport and flow computation (fully transient).

Besides, in cases where a direct coupling between sediment transport and flow computations appears not necessary, several post-processing tools (incl. a "Lagrangian"-type tracking of sediment particles) are available to analyze the results of the hydrodynamic depth-averaged simulations in terms of transport capacity, erosion risk ...

The application of several modules of the modelling system is subsequently described in the case of a hydropower project in the South-East of France.

First, the sediments likely to reach the water intake at the beginning of dam exploitation have been characterized. For this purpose, the flow field simulated in the reservoir with a k-ε turbulence closure is analyzed by means of the "Lagrangian"-type particle tracking method.

Secondly, the long-term equilibrium bathymetry of the reservoir has been computed with a quasi-steady approach (iterative steady-state hydrodynamic simulations). The sensitivity of the result has been verified to remain reasonably low with respect to variations in the main assumptions such as sediment yield and grain size.

Finally, the rapidly transient flow with high erosive capacity during different flushing operations has been simulated with the fully unsteady module, tightly coupling the computation of flow and sediment transport. As a result, this numerical study enables to evaluate the effect of a series of flushing scenarios in terms of changes in bathymetry in the downstream part of the reservoir as well as in terms of released discharge and deposition in the downstream reach. The overall efficiency of the flushing operation can then be evaluated with respect to the recovered storage capacity and its extension in space.

The integrated approach presented above takes benefit, at each stage, of the most appropriate and efficient modelling technique depending on the relevant time scales. It could obviously be applied to other similar projects.