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Morphological modelling in reservoirs: the experience of Artelia

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***Abstract*— This paper displays an overview of the work done by ARTELIA in recent years on numerical modelling of sediment transport in reservoirs using the TELEMAC system. The goal of the paper is thus to show the present possibilities of the software as well as new developments that further improve it.**

I. Introduction

The studies presented cover different kinds of questions (from the impact of dam erasing to the impact of dam building), and different kinds of sediment and transport processes, from fine mud transported in suspension to coarse sand transported by bedload. They thus involve different software. When sand transport is the main mechanism, SISYPHE is used, coupled with TELEMAC 2D or 3D. In the case of mostly fine sediment transport, TELEMAC 3D is used. In some cases, both types of transport processes must be taken into account at the same time. Developments on TELEMAC 3D have been implemented in order to be able to compute mixed sediment transport with fine (clay, silt) and coarse sediment (here sand) at the same time. The results of these developments applied to compute sediment deposition over years in two reservoirs in Africa are presented.

Some of the studies presented have had access to detailed datasets that enable a proper calibration. In some other cases, calibration is not possible. This is the case when studying the erasing of an old dam, or when studying the impact of a dam that has yet to be built.

II. Example of studies

A. Study of the flushing of the inlet channel of Inga powerplant

Inga power plant, on the Congo River, cannot run to its full power, in part because of the sand deposits in the inlet channel.

A TELEMAC 2D - SISYPHE numerical model (with total transport formula) has first been calibrated using observed sediment deposition upstream of the dam (see Fig. 1 and 2 below). It has then been used to estimate the efficiency of the proposed works.

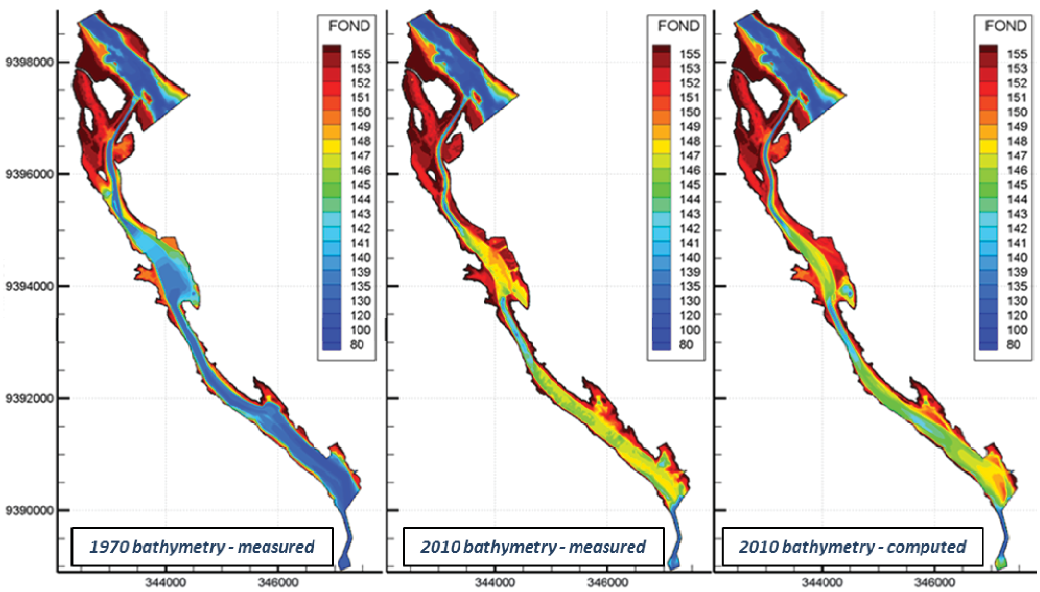

Figure 1. Inga – measured and computed bed evolution

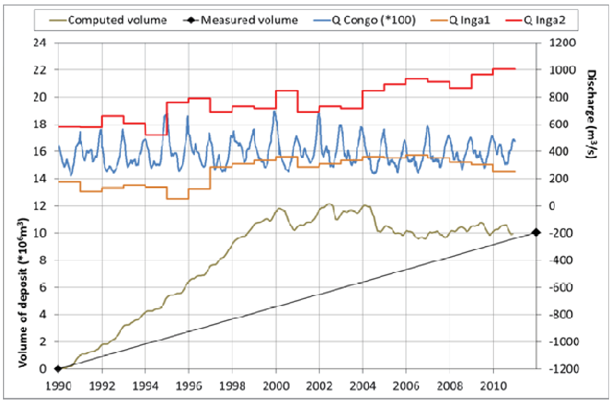

Figure 2. Inga – Evolution of the volume of deposit in the inlet channel

B. *Hydrosedimentary study of the Longefan basin*

A three-dimensional numerical model has been set-up to compute flow and sediment transport in the Longefan reservoir, a silt trap for the hydro-electric facilities diverting the Arc River (French Alps). The sediment in the basin was silt. Erodability parameters for the sediment are based on laboratory characterization in a flume. Flow measurements have shown that a complex circulation can develop in this reservoir. The model has been successful to simulate the measured flow circulation as well as the measured sediment transfer through the reservoir. Deposition patterns in the reservoir were also well reproduced (see Fig. 3 and 4). The model has then been used to help prepare flushings, and to study the impact of the deposits in the reservoir on the siltation capacity of the reservoir.

The work on this study is presented in more details in [1].

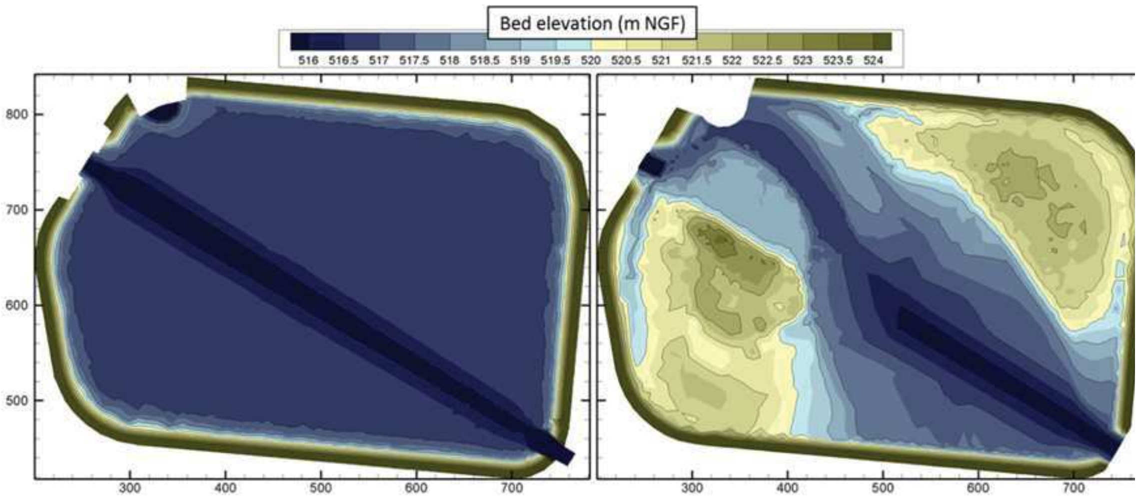

Figure 3. Longefan – Model bathymetry : initial state and with sediment deposits

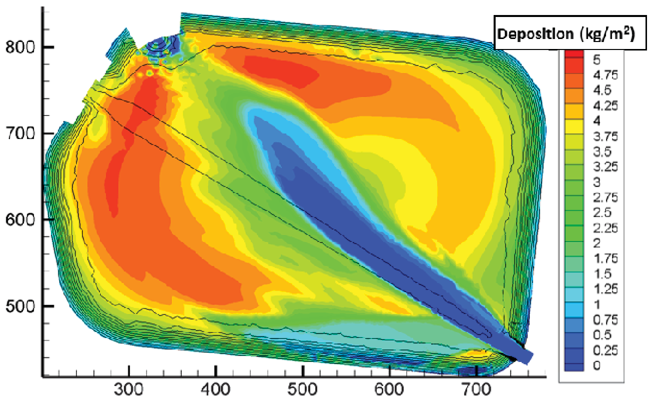

Figure 4. Longefan – Example of model results

C. Preliminary studies for the lowering of the Boutet dam

The town of Châtres-sur-Cher initiated a feasibility study to define a new layout for the Boutet dam on the Cher, both to restore the free circulation of migratory fish but also to ensure sedimentary continuity.

Numerical modelling (TELEMAC 2D coupled with SISYPHE) was carried out by ARTELIA in order to study the impact of two scenarios (partial and total removal of the dam) on the current patterns, on sediment transport and morphology. The new equilibrium profiles of the river following the work modifications have been calculated. Fig. 5 below presents the computed bathymetry at the site of the dam for different studied configurations.

The use of the multiclass formulation enables to have at the same time sand deposits in the middle of the reservoir and fine sediment deposits on the banks.

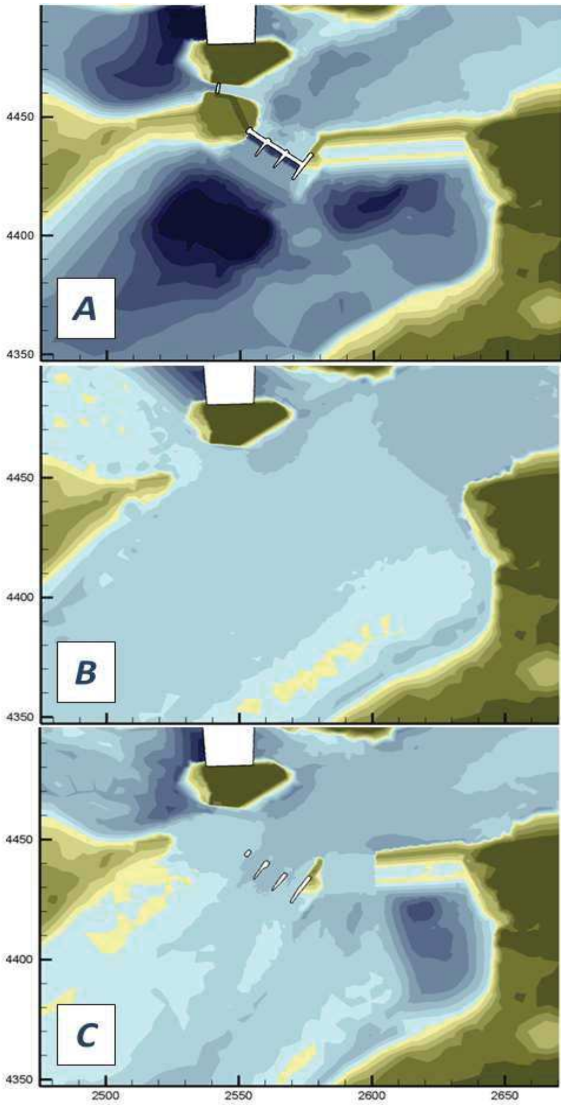

Figure 5. Boutet – A : initial bathymetry, B : computed equilibrium bathymetry for total erasing of the dam, C : computed equilibrium bathymetry for partial erasing of the dam.

III. New developments for multiclass computations

D. Description of the multiclass (sand – fine sediment) modelling.

New developments have been implemented in TELEMAC 3D v7p0 in order to compute transport of one class of sand (through total transport) and two classes of fine sediment (through suspension). For that purpose, the 'MIXED SEDIMENT' mode available in TELEMAC 3D has been adapted. In particular, a bed model has been developed, in order to properly manage the evolution of the mass of the different sediment classes in the bed, and to take into account the composition of the sediment bed to compute erosion fluxes.

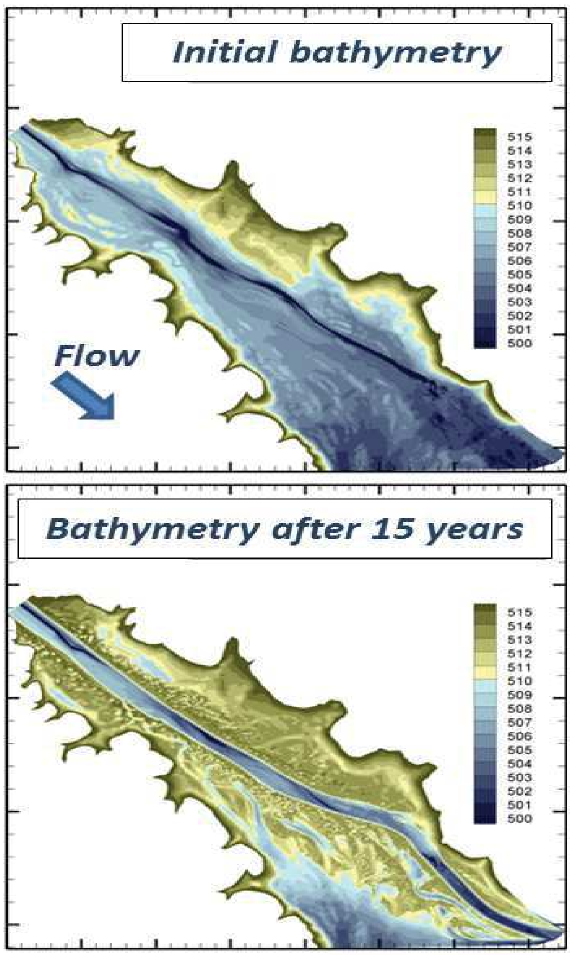

Figure 6. Computation of bathymetric evolution after the building of a dam on an African dam

For sand, Soulsby-Van Rijn formula (see [2]) is used to compute total load transport. For the two fine sediment classes, erosion fluxes are computed through Partheniades law (see [3]).

E. Application for a project of a dam on an African river (confidential)

For a dam project in Africa, ARTELIA was requested to carry a numerical study aimed at determining the medium-term sediment deposits in the reservoir and in particular upstream of the inlet channel, and checking the effectiveness of bottom outlet works to flush out deposited sediments. An example of model results is presented in Fig. 6.

F. Application on Kapichira reservoir

Kapichira reservoir, on the Shire river in Malawi, has experienced significant deposition since its building in 2001. Field data have been collected from the site, including bathymetry survey data, suspended sediment samples and bed sediment samples (granulometric analysis of these shows that the deposits consist in both sand and fine sediment). This has enabled the set up and calibration of a numerical model which is able to reproduce the sediment deposits in the reservoir since the building of the dam. An example of results of this calibration is presented in Fig. 7.

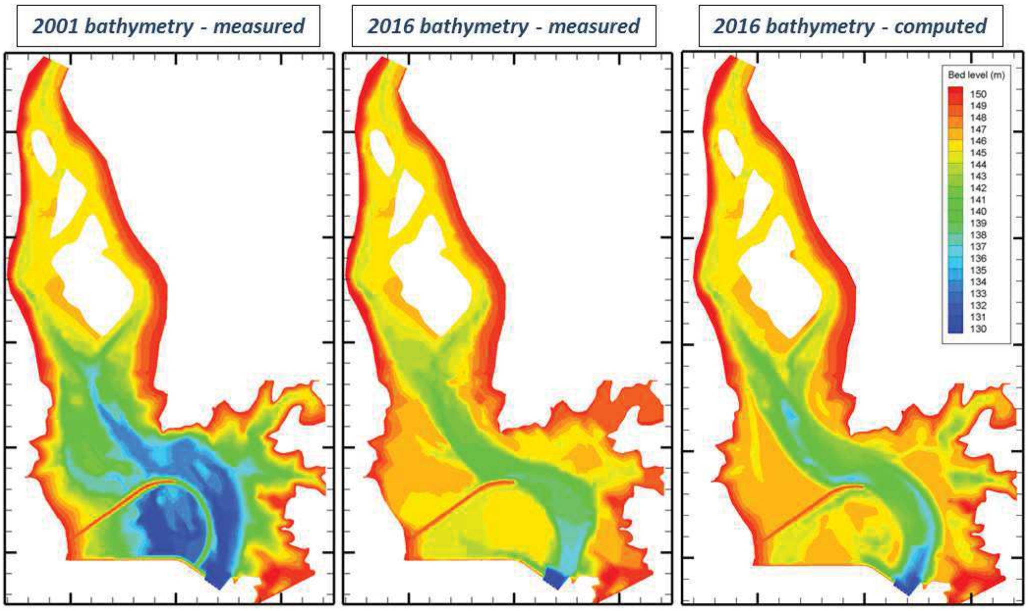

Figure 7. Kapichira _ comparison of computed and measured bed evolution

G. Possible improvements

The formulation for multiclass transport used here is very simple, as the different classes do not interact. A more complex formulation for sand-mud transport like the one presented in [4] and already adapted in TELEMAC 3D for an estuarine model (see [5]) could be used. Furthermore, a more general model should allow for any number of fine sediment classes and sand classes.

Another possible improvement would be to implement a more refined bed model, able to store the information on successive layers of deposit. Fine sediment consolidation should also be taken into account within this bed model.

IV. CONCLUSION

The examples presented here show that TELEMAC is a powerful tool for studied sediment transport and morphological evolution in reservoirs, for a wide range of processes and configurations.

Proper calibration of the model is not always possible. More experience is needed on well-documented cases to improve confidence in the model on such cases where calibration is not possible.

A proper data set for calibration should include bathymetric evolution, suspended sediment, and bed granulometry. Ideally, laboratory measurements on the sediment found on site should also be performed to help define fall velocity, the parameters of the erosion law and the parameters of the bed model (most notably consolidation).

Multiclass computations are needed in some cases. At the present time the Telemac system is still limited in this regard. Some improvements have been presented here.

The formulation for the transport of multiclass sediment needs lots of inputs and parameters, it is thus necessary, in order to use them adequately, to dispose of a detailed data set.

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