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Vorgeschlagene Zitierweise/Suggested citation:

Valette, Eric; Sécher, Matthieu; Audouin, Yoann; Fontaine, Jacques; Goeury, Cédric (2019): Method to integrate a simplified erosion channel during flood in reservoir simulation with Telemac. In: XXVIth TELEMAC-MASCARET User Conference, 15th to 17th October 2019, Toulouse. <https://doi.org/10.5281/zenodo.3611611>.

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Method to integrate a simplified erosion channel during flood in reservoir simulation with Telemac

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A new tool which manage an automatic erosion channel generation in a TELEMAC 2D software is presented in this paper. This tool intended to solve the problem of overestimation of the water level that usually occurs when calculating a flood water line upstream a barrage without taking into account the erosion of the bottom.

The final result is a hypothetical equilibrium state corresponding to the lowest possible bottoms for the modeled flow, if the flood rise and the management of the reservoir level with barrage gates allowed enough time to reach this equilibrium state.

I. INTRODUCTION

Deposition of fine sediments could increase the bottom level of the reservoirs by several meters. If we don't take into account bottom evolution in numerical simulation of flood events, very high velocities (potentially supercritical flow) are obtained in front of the barrage. Consequently, simulated longitudinal water elevation could be higher than real water elevation. However, in reality, these high velocities cause the erosion of alluvial bottoms and the creation of a channel that will increase the flood capacity of the section in the reservoir. Generally, when the peak of the flood occurs on a barrage with all its gates opened, the longitudinal water elevation will be lower than that obtained with hard bottoms.

Hydro-sedimentary dynamics can be studied using Sisyphé. However, this kind of studies could be expensive in time and data.

A simplified approach is adopted here.

II. OVERVIEW OF THE METHOD

A PYTHON script apply an automatic erosion channel in the TELEMAC 2D bottom model according to inflow rate and water elevation at the barrage. Starting with a simple description of the supposed outline of the future channel (using a GIS software), this module allows to:

- Dig a trapezoidal channel in the bathymetry, based on geometric parameters imposed by the user or derived from simple morphodynamic laws based on Ramette hypothesis [1].

- Start TELEMAC 2D calculation of a hydraulic steady state of the flood peak with the Application Program Interface (API) mode (TELAPY) to realize a digging of the channel.
- Automatically perform several post-processing (2D map of the velocities and the bathymetry obtained after channel application, water elevation, volume of sediments removed) allowing to analyze and control the steady state.

The final result is a hypothetical equilibrium state corresponding to the lowest possible bottoms for the modeled flow, if the flood rise and the management of the reservoir level with barrage gates allowed enough time to reach this equilibrium state.

III. HOW TO DIG THE CHANNEL (THEORY)

A. Channel set up

First of all the channel set up is realised using an SIG software to define:

- The hydraulic axis of the channel (polyline - shape file).
- The area in which the algorithm is able to enlarge the channel (polygon - shape file). This area is useful to exclude zone like dike, unerodable bottom, etc.

B. Channel digging

Two options are implemented to dig the channel:

- The user define the depth of an initial channel upstream the dam, the slope and width of the channel.
- Depth, slope and width are calculated by the software based on morphodynamic laws based on Ramette hypothesis [1].

C. Morphodynamic laws

Some hypothesis are realise to describe the theoretical channel dimension:

- Manning Strickler equation is available :

$$Q = K_t S R_h^{2/3} \sqrt{J_t} \quad (1)$$

With:

K: Strickler coefficient ($m^{1/3}s^{-1}$),

S: Flow section (m^2),

R_h : Hydraulic radius (m),

J_t : Slope of the energy grade line (m/m)

- The evolution of the bed to an equilibrium state is carried out spending the minimum of energy. As a result of this hypothesis, the Froude number is maximised and we have :

$$L = 18h \quad (2)$$

With:

L: Width of the channel (m)

H: Water depth (m)

- The shear stress is equal to the critical shear stress

$$\rho g R_h J_p = \tau_c \quad (3)$$

Where

$$J_p = J_t \left(\frac{K_t}{K_p} \right)^{3/2} \quad (4)$$

With:

ρ : Water density (kg/m^3),

g: Gravity (m/s^2)

τ_c : Critical shear stress (Pa)

K_p = Skin Strickler coefficient ($m^{1/3}s^{-1}$)

J_p : Slope (due to skin Strickler coefficient) (m/m)

D. Analytic solution of Ramette criteria equations

The equations (1), (2), (3) and (4) have an analytic solution:

$$h = \left\{ \frac{\left(\frac{10}{9} \right)^{1/3} \cdot Q^2 \cdot \left(\frac{\rho g}{\tau_c} \right) \left(\frac{K_t}{K_p} \right)^{3/2}}{(18K_t)^2} \right\}^{3/13} \quad (5)$$

$$J_t = \left\{ \frac{18 \cdot \left(\frac{10}{9} \right)^2 \cdot K_t \cdot \left(\frac{\tau_c}{\rho g} \right)^{1/3} \cdot \left(\frac{K_p}{K_t} \right)^4}{Q} \right\}^{6/13} \quad (6)$$

$$L = 18h$$

If we consider a trapezoidal section, bottom width is given by:

$$B = L - 2 \cdot \frac{b}{2} = L - h/\alpha \quad (7)$$

With:

B: bottom width of the channel (m),

L: medium width of the channel (m),

α : stability angle of the sediment (elevation / base)



Figure 1: Trapezoidal geometrie.

This analytic system allow drawing curve of water depth as a simple function of critical shear stress and flow.

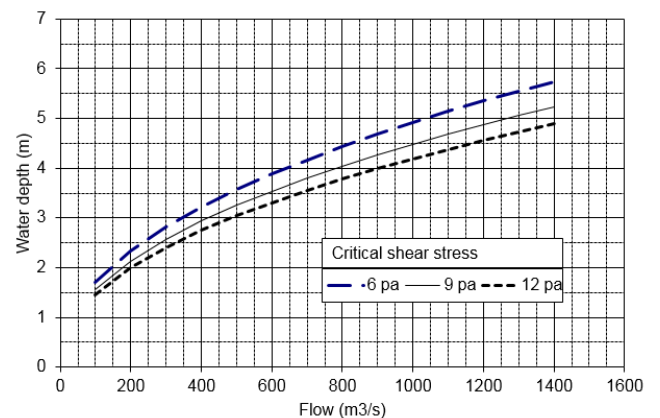


Figure 2: Water depth as a function of critical shear stress and flowrate.

IV. INTEGRATION AS A TELEMAC TOOL

Once the parameter of the channel choose by the user or compute with Ramette equation, the tool:

- Step 1: Apply the first erosion to shape the channel in the initial bathymetry with shapes file (polyline of the center of the canal, polygon limit of the channel) and geometrical parameters of the channel.
- Step 2: Create a StudyTelemac2D class used to prepare files and temporary folder of calculations and make a run with Telemac 2D API and the new bathymetry
- Step 3: If the depth is define by Ramette Law or Step 3 is converged the tool realized a final post-treatment to:
 - o Calculate erosion volumes.
 - o Create a text file with volume of erosion, the value of the criterion and the percentage of nodes where the target is not reached.
 - o Generate map of several variables (Froude number, velocities, bathymetry, etc.)

Flowcharts of the tool are given figure 3 and figure 4

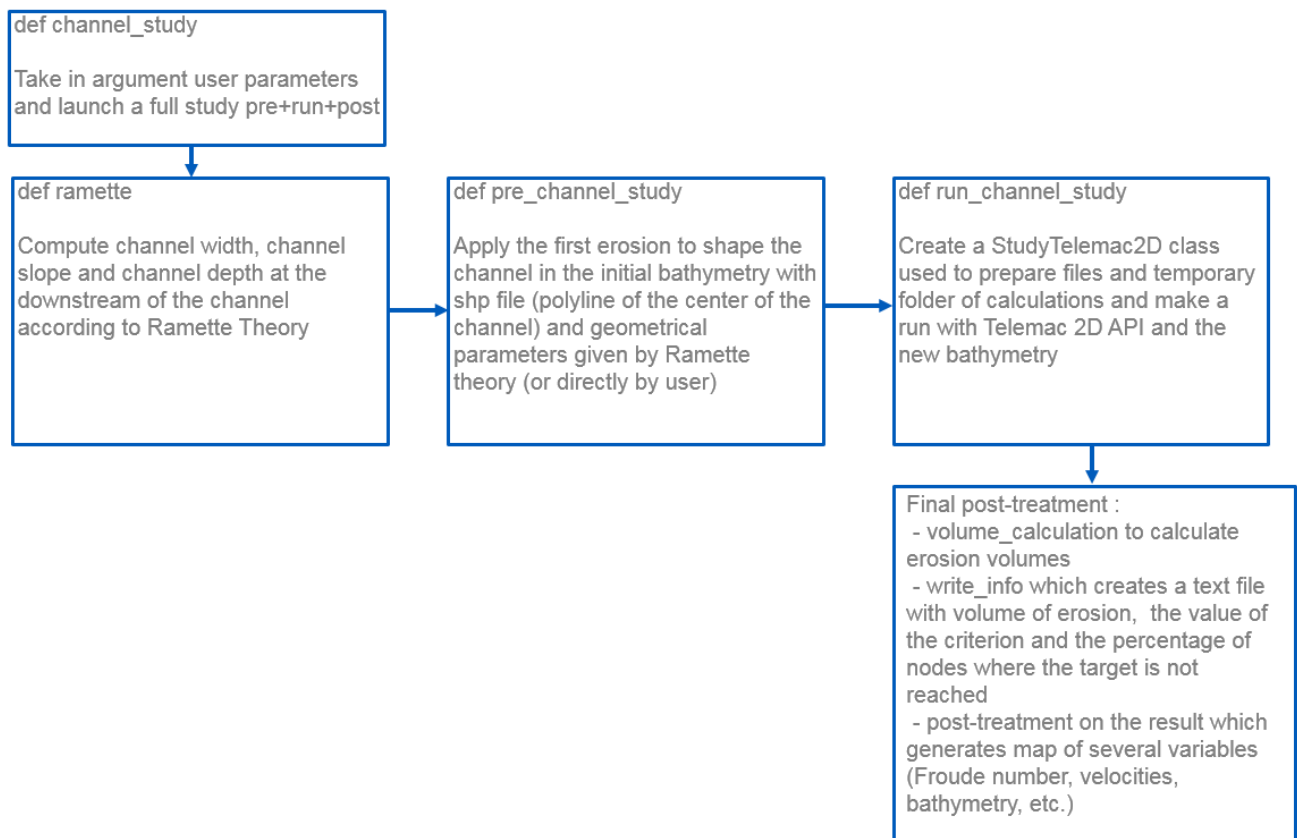


Figure 3: Flowchart with Ramette equations (figure 3)

V. EXAMPLE

Figures 4, 5 and 6 illustrate the erosion channel created by the tool in a reservoir. The Flowrate was equal to 3 800 m³/s. the eroded volume is equal to 1.14 Million m³ and the parameter calculated by Ramette equations with a critical shear stress of 12 Pa and a canal bank slope of 0.3 m/m are:

- Water depth : 7.90 m
- Slope : 5×10^{-4} m/m
- Width: 142 m.

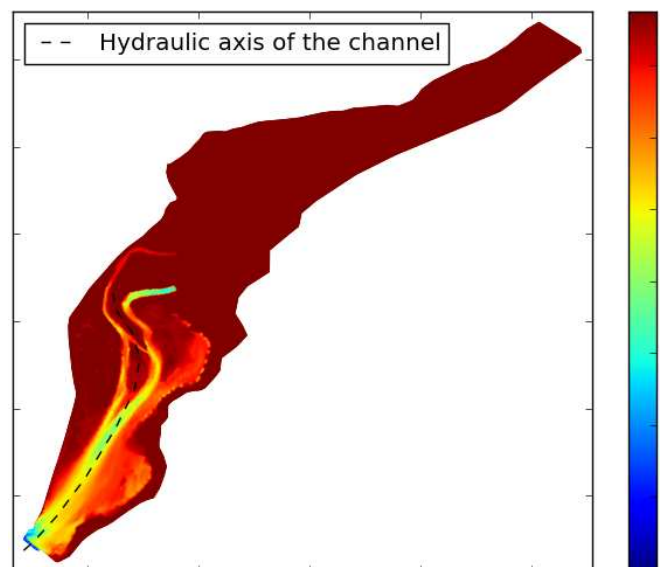


Figure 4: Initial bottom of the reservoir example with the line representing the hydraulic axis use to erode a channel

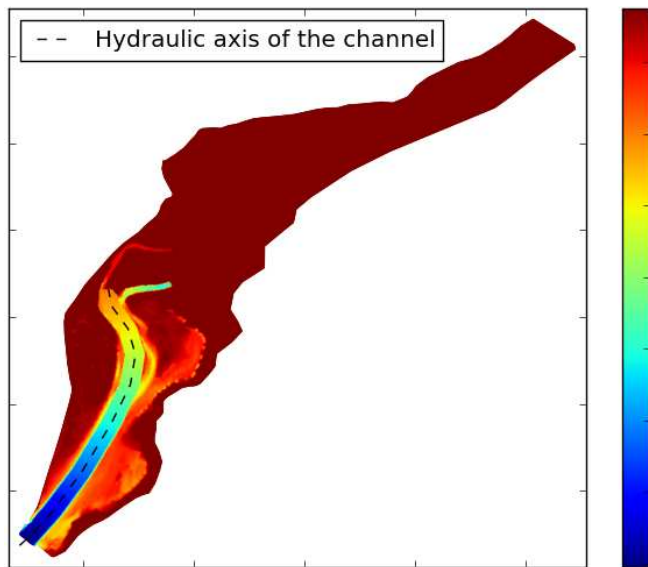


Figure 5: Final bottom of the reservoir example with the line representing the hydraulic axis used to erode a channel

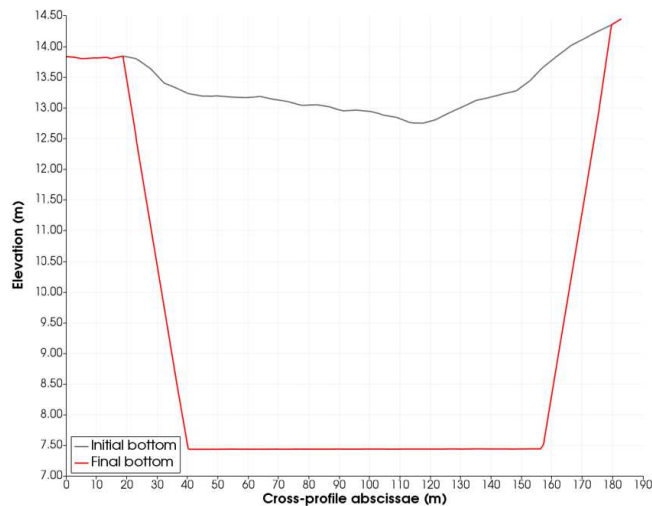


Figure 6: Cross profile of bottom before and after applying the erosion of the channel extracted at the middle of the channel

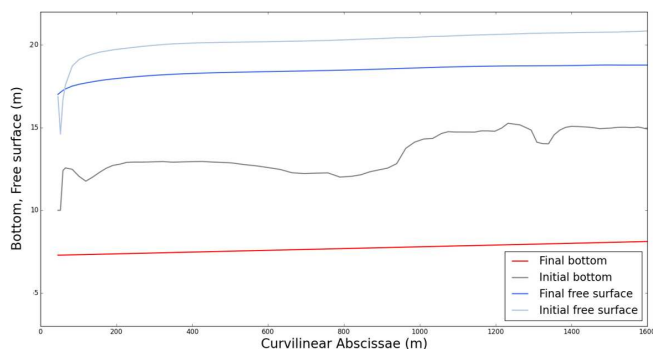


Figure 7: Longitudinal profile of bottom and free surface ($3\,800\text{ m}^3/\text{s}$) before and after applying the erosion of the channel extracted along the hydraulic axis (see Fig. 4 and 5)

The figure 7 give the comparison of the initial and the final water level in the reservoir

VI. TO CONCLUDE

This method should be considered as a tool decision support using to evaluate the potential margins between water elevations evaluated with fixed-bottom model and erodible bottom model. If margins are highlighted, a complete hydro-sedimentary calculation may be initiated; if not, civil work (increase levees elevation, increase of dam spillways capacity, etc.) can be directly considered.

Other applications can be considered with this method:

- first-order estimate of volumes eroded during flushing, or sluicing,
- first-order estimate of volumes eroded during reservoir drawdown.

This method was developed in PYTHON during a hackathon that was held over 3 days at the CIH with 3 members of EDF R&D and 2 members of EDF CIH.

REFERENCES

- [1] M. Ramette, "Modélisation mathématique du processus morphologique des fleuves" AIRH, XIX congrès, New Delhi, India, 1981, pp 392-400
- [2] J-M. Hervouet, "Hydrodynamics of Free Surface Flows", Wiley, 2007, pp. 83–130.
- [3] Hunter, J. D. Matplotlib: A 2D graphics environment, IEEE COMPUTER SOC Volume 9 Number 3 Pages 90-95 (2007)
- [4] G. van Rossum, Python tutorial, Technical Report CS-R9526, Centrum voor Wiskunde en Informatica (CWI), Amsterdam, May 1995.

