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Long term evolution of a reservoir dam subjected to regular flushing events case of Génissiat reservoir on the Upper Rhône river, France

Lucie Guertault[1], Kamelia Boussafeur[2], Benoît Camenen[1], Christophe Peteuil[2], André Paquier[1]
lucie.guertault@irstea.fr
[1]Irstea Lyon, Hydrology-Hydraulics research unit, 5 rue de la Doua CS 70077, 69626 Villeurbanne Cedex, FRANCE
[2]Compagnie Nationale du Rhone, 2 rue Andre Bonin, 69316 Lyon Cedex 04, FRANCE

Introduction

Geographical context

- Rhône river flows through Switzerland and France to the Mediterannean sea (catchment area: 95500 km²) (Figure1)
- 2 km downstream of Lake Geneva: confluence with Arve river (main sediment tributary: between 1-3 MT/year) (Figure 2)

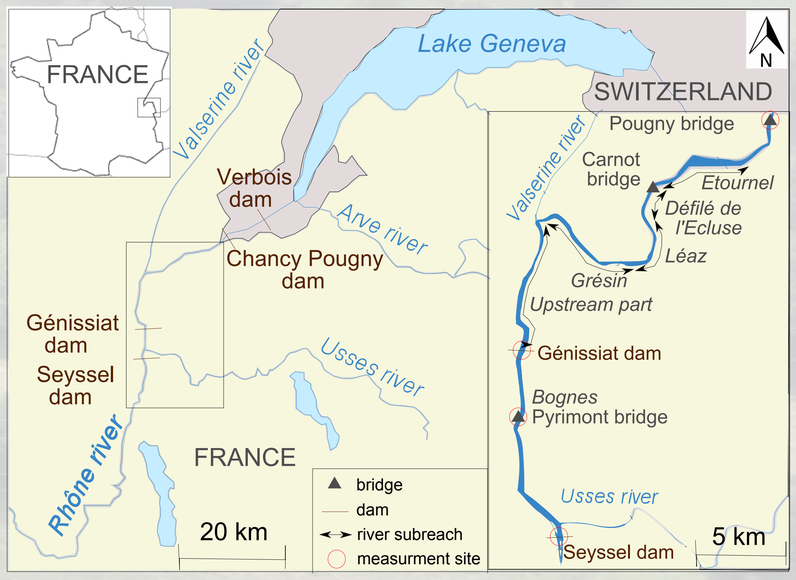

Figure 1 : Location of the study site

Figure 2 : Confluence between Rhône (left) and Arve (right) rivers (© SIG)

Hydropower development of the Upper Rhône

- Switzerland: Verbois and Chancy Pougny dams
- France: 70 m high Génissiat dam and 4 additionnal run-of-river developments operated by Compagnie Nationale du Rhône (CNR)

Génissiat reservoir

- Volume: 56 million m³ , length: 24 km

Significant geometrical variations: the upstream part is a large river (Figure 3a) with islands and the 15 km downstream are narrow gorges (Figure 3b)

- Longitudinal sorting in the reservoir: from gravel and coarse sand upstream to fine silt and clay close to the dam

(a) (b)

Figure 3 : Etournel site (a) and downstream part (b) (© CNR)

Reservoirs management

- Verbois reservoir: flushing operations must be regularly carried out to prevent over-flooding due to bed aggradation in some Geneva districts
- Downstream Genissiat reservoir: Environmental friendly flushing are carried out by CNR to release suspended sediment concentrations (SSC) bearable by the fluvial environment [Fruchart, 2008], [Peteuil, 2013]
- French-Swiss agreement to coordinate flushing operations (1967)

Bathymetric balance of the reservoir since 1984

- Volumetric budget estimated using bathymetric differences from 110 cross-sections collected before and after flushing events

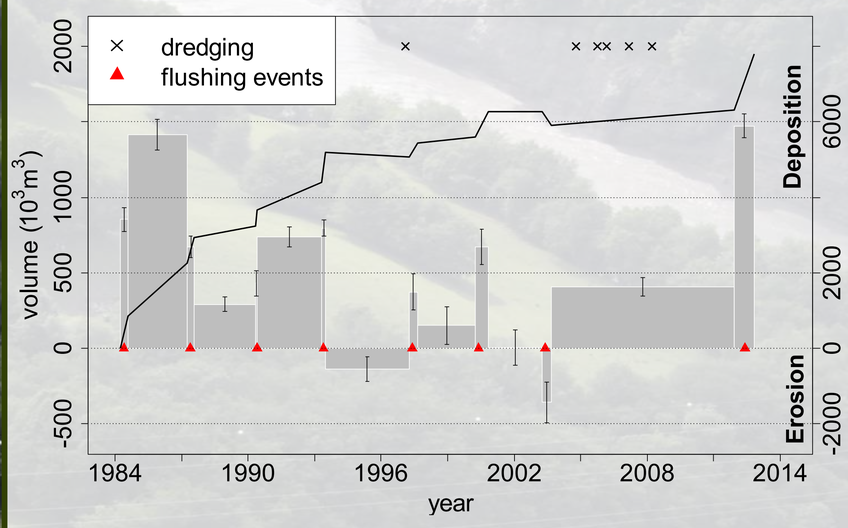

Figure 4 :Sediment volume budget of Génissiat reservoir since 1984

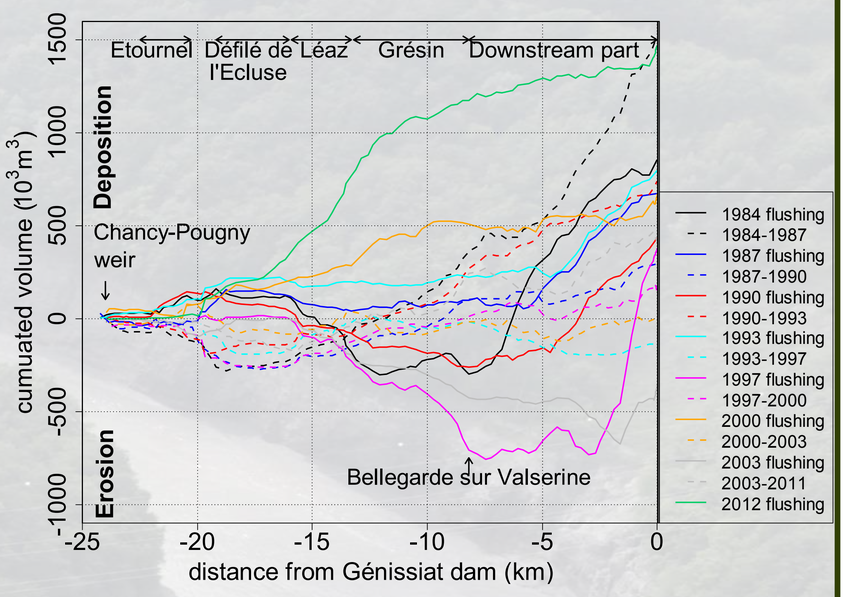

Figure 5 :Spatially cumulated sediment volume budget

- Flushing events: major contribution to the volume balance
- Interflush periods: mainly deposition with variability in volumes
- Deposition rate decreasing since 1997 (optimization of flushing operations)
- Huge deposition during 2012 flushing event: 9 year long period without flushing operations combined with unusual conditions in the reservoir management

- From Chancy-pougny weir to end of Etournel site: small deposition during flushing events and small erosion during interflush periods
- Défilé de l'Ecluse: equilibrium state
- Léaz and Grésin gorges: deposition during interflush periods and highly variable dynamics during flushing operations
- Last 9 km of the reservoir: deposition (more intense during flushing events, higher close to the dam)

Fluxes balance during flushing events since 1984

- SSC measurement and integration with discharge to get the mass of fine sediment transported throughout the even

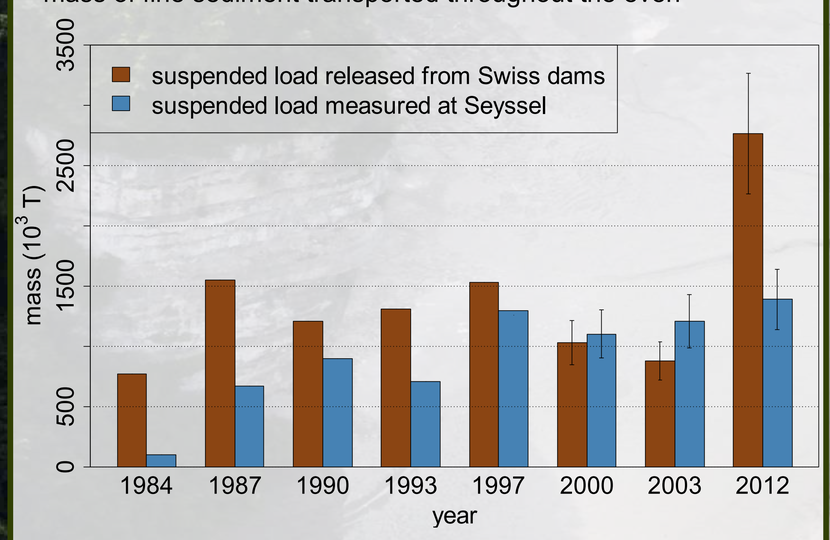

Figure 6 : Suspended load upstream and downstream of Génissiat reservoir [updated from Thareau, 2006]

- Input mass generally higher than output mass (Figure 6)
- Since 1997 input and output masses are more or less in balance (improvement of the flushing scenario)
- Significant input during the 2012 flushing event (9 year break without flushing plus unexpected excess regarding volume of sediment released from Swiss dams)
- Bedload sampling and estimation in 2012: ratio bedload over suspended load in 2012: 0.6 % at the upstream part of the reservoir and 3,6 % downstream Genissiat dam (estimated using measurements)

Discussion

- Conversion of volumic bathymetric budget into massic budget with a longitudinally variable bed sediment density estimated using granulometry and nature of sediments

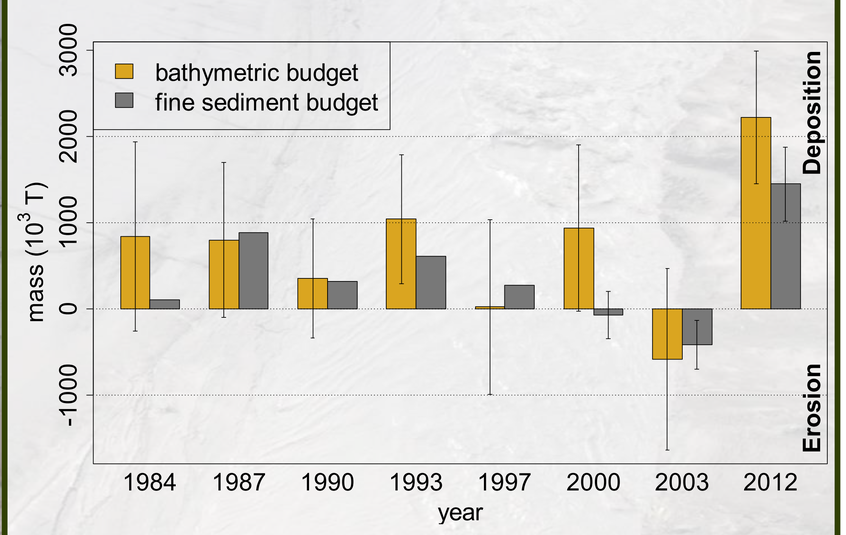

Figure 7 : Comparison between budgets for flushing events

- Significant cumulated uncertainties on bathymetric budget due to propagation of volume and density uncertainties (Figure 7)
- A part of the difference between budgets could be imputed to sand

- Deposition/erosion system typical of bedload transport at the upstream part
- Very small mass of coarse sediments transported compared to the mass of fine sediments
- Significant role of sand in the dynamics of upstream subreaches of the reservoir

Conclusion

- Study of the long term evolution of Génissiat reservoir considering both flushing and interflush periods with a comparison between bathymetric and fluxes budgets
- Further investigations on coarser sediments contribution and reservoir dynamics variability

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