Master Thesis:

Longitudinal interactions of hydro- and thermopeaking waves in an Alpine river: a 1D numerical modelling approach

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Fig. 1: The Vorderrhein, downstream of Ilanz (Switzerland)

Motivation

Hydropeaking and thermopeaking are significant phenomena associated with hydropower production, particularly in Alpine regions. Hydropeaking refers to the artificial discharge peaks produced by hydropower plants (HPP) during peak demand periods. These discharge peaks, released into the river downstream, can cause severe cascading effects on the downstream ecosystem. Thermopeaking, on the other hand, involves sharp intermittent alterations of the stream's thermal regime associated with hydropeaking releases. These thermal alterations can occur at different scales and have significant implications for biological communities. The physical processes of hydro- and thermopeaking waves has been described by Toffolon et al 2010, which elucidate the characteristics of a single hydro- and thermal- wave dynamics by means of both a numerical and approximate models. After that, the measurements and implications of sub-daily thermal alterations due to hydropower received increasing interest in terms of both physical processes (e.g. Vanzo et al. 2016), and ecological effects (e.g. Carolli et al. 2012). Numerical modelling examples of hydro-thermodynamics in hydropeaking rivers are yet scares and challenging (Bakken et al 2016, Antonetti et al 2023).

Research objective

The main objective of this thesis is to investigate how hydro- and thermopeaking waves travel and interact in case of sub-daily repeated water releases from HPP. As reference, the river stretch of the Vorderrhein downstream of Ilanz (Switzerland) will be investigated. In particular, we intend the student to:

1. Analyze existing timeseries of river discharge and water temperature to characterize hydro-thermal characteristics at different stations of the study reach.
2. Setup, calibration and execution of a 1D numerical model for the simulation of hydro-thermodynamics for the reference reach
3. Based on the numerical results, analyze the longitudinal interactions and effects of repeated hydro-thermopeaking waves on the river thermal regime.
4. Discuss the findings also considering the seasonality of such alterations and the potential influence of global warming.

Methods

The thesis involves data analysis and the setup and execution of a 1D Hec-Ras model for unsteady hydro-thermodynamic simulations.

Remarks

Meetings and final report are in English. The thesis will develop in collaboration with Eawag - Swiss Federal Institute of Aquatic Science and Technology (Dr. Martin Schmid). The project requires an affinity for setup, execution and evaluation of numerical simulations and data analysis. General scripting skills are helpful.

References

Antonetti, M., Hoppler, L., Tonolla, D., Vanzo, D., Schmid, M., & Doering, M. (2023). Integrating two-dimensional water temperature simulations into a fish habitat model to improve hydro-and thermopeaking impact assessment. River Research and Applications, 39(3), 501-521.

Bakken, T. H., King, T., & Alfredsen, K. (2016). Simulation of river water temperatures during various hydro-peaking regimes. Journal of Applied Water Engineering and Research, 4(1), 31-43.

Carolli, M., Bruno, M. C., Siviglia, A., & Maiolini, B. (2012). Responses of benthic invertebrates to abrupt changes of temperature in flume simulations. River research and applications, 28(6), 678-691.

Toffolon, M., Siviglia, A., & Zolezzi, G. (2010). Thermal wave dynamics in rivers affected by hydropeaking. Water Resources Research, 46(8).

Vanzo, D., Siviglia, A., Carolli, M., & Zolezzi, G. (2016). Characterization of sub-daily thermal regime in alpine rivers: quantification of alterations induced by hydropeaking. Hydrological Processes, 30(7), 1052-1070.