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Thermal wave dynamics in rivers impacted by hydropeaking

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Release of hypolimnetic water from reservoir for hydropower generation production generates hydro- and thermo-peaking waves which propagate downstream. The resulting thermal regime alteration causes detrimental impacts on habitats and ecosystems due to both direct (e.g. spatial-temporal patterns of maximum and minimum temperature) and indirect (e.g. affecting timing of lifecycle stages, growth rates restriction or alterations) effects. In order to reduce such effects, mitigation procedure must be studied and implemented.

The phenomenon is studied using the one-dimensional model governed by the Saint Venant equations coupled with an equation imposing thermal energy conservation. The difference between the propagation celerity of the hydrodynamic wave and that of the thermal wave identifies two different phases: (I) where the hydrodynamic wave strongly interacts with the thermal wave; and (II) where the hydrodynamic wave separates from the thermal wave.

The diffusive approximation for the hydrodynamic model is assumed to hold while the hydropeaking initial condition is schematized as a square wave characterized by a peak value over a base flow. The resulting problem is solved assuming constant coefficients, i.e. the celerity is taken as a constant function of the two uniform states computed with the peak and base discharges. The resulting flow field is used to evaluate the propagation of an initial square thermal wave, assuming that the tail and the head travel downstream with different celerities in phase I and with the same celerity, equal to the velocity of the base flow, in phase II.

Comparison between the proposed analytical solution and numerical solutions of the fully hydro-thermal problem are in good agreement, showing its applicability in predicting the thermal field occurring under hydropeaking conditions. The proposed model can be employed to study the spatial-temporal patterns of maximum and minimum temperature maximum that arise downstream of hydropower plants. Such simplified model is shown to be an effective tool for understanding the main processes and for assessing mitigation procedures.