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Wave propagation in linearized shallow flows of power-law fluids

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Flood waves may entrain high quantities of sediments and evolve into mud flows which may inflict damages and produce significant topographical changes. Among the different rheological descriptions of mud as a continuous non-Newtonian fluid, the power-law model adequately describes fluids that at low share rates do not posses any relevant yield stress, such as clay or kaolin suspensions, which are encountered in river flows with a finite fraction of coarse grains (Zhang et al., 2010). As for clear-water, unsteady shallow-layer of power-law flows may be described through full dynamic models or using simplified momentum equations, based on kinematic, diffusion, and quasi-steady approximations (Di Cristo et al., 2014).

In the present work the propagation of power-law flood waves determined by disturbances imposed to the upstream and downstream boundaries of a hypocritical uniform flow is studied. The analytical solution of the linearized flow model is found applying the Laplace transform method and obtaining first-order analytical spatio-temporal expressions of upstream and downstream channel response functions, thus generalizing the finding of Tsai and Yen (2001), as far as a clear water flood is concerned. The analysis, applied either to the full model or to its various simplifications, permits a critical comparison among the different models in terms of the physical characteristics and mathematical properties. Through the generalized upstream and downstream channel response functions, the effects of the downstream boundary condition on the different approximations are discussed and compared, for different values of the rheological index. The propagation mechanisms pertaining to the wave approximations are finally investigated in order to enlighten the the differences and similarities among the approximated models in comparison with the full one.

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