Geophysical Research Abstracts
Vol. 12, EGU2010-2887-1, 2010
EGU General Assembly 2010

Influence of unsteady flows on pseudo-meandering river morphodynamics: An experimental study

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Natural channel patterns arise from the interaction between a turbulent open-channel flow and an erodible boundary. These interactions are usually studied by assuming a steady discharge. Nevertheless, the discharge unsteadiness is a fundamental feature of river flows. Water discharge, besides exhibiting its natural stochastic variability from daily to centenarian scale, is also influenced by river regulation and climatic changes. It is acknowledged that fluvial morphological features at short-scale are influenced by flow unsteadiness, notwithstanding a few experimental or field studies are available to clarify the modification of macroform (bends) and mesoform (bars) under unsteady discharge.

Our experimental research focuses on the effect of unsteady flow on the behavior of pseudo-meandering rivers. These single-thread gravel bed rivers are characterized by a low-sinuosity planimetric shape and by a sinuous thalweg which bends around large point bars. Pseudo-meandering rivers are widespread in the piedmont area and are very interesting because several aspects of both meandering channel - presence of point bar, evolving bends, and asymmetrical cross-section - and braiding (tendency to flow diversion and to create secondary channel) interact in the same reach.

We present the experimental results about the free initiation and development of the pseudo-meandering pattern, under unsteady flows. Runs with periodic step-like hydrograms characterized by a maximum, Q_{max}, and a minimum, Q_{min}, discharge, have been performed in an 18 m long and 4 m wide sand flume. Two set of parameters have been investigated, in order to simulate hydrograms with the ratio Q_{max}/Q_{min} ranging from 1.5 to 2 and the ratio of the durations of the discharges T_{Qmin}/T_{Qmax} ranging from 1 to 2. We compare these runs with the ones performed with a steady discharge equal to the mean value. All the runs have a Shields parameter two or three time greater than the critical threshold. We concentrated on the morphodynamic processes of the single morphological unit (such as bar growth, bed deformation, bank erosion, and bend initiation) and, through accurate measurements, we show how discharge unsteadiness plays a key role on them and on the mutual interaction between river features. Bed evolution has been surveyed by an innovative device, designed by the authors, which allows high-precision measurements of the channel bed with flowing water.

Even though a steady discharge is sufficient to obtain both pseudo-meandering and meandering patterns, we recognized cases in which unsteady flows can trigger the initiation of bends and other in which the discharge changes can inhibit the phenomenon and induce the channel to achieve a multi-thread configuration. Along a low sinuous channel, high discharges result to have a great formative effect on the bed configuration, so inducing a remarkable asymmetry in the cross-sections. However, low discharge,Q_{min}, which flows on the bed topography generated by the high discharge, Q_{max}, results to have a great impact angle on the bank and is able to trigger the bend initiation. Moreover, we discuss the way by which the discharge unsteadiness affects the morphology and mobility of the bars, leading to changes in the bank erosion and so in the bend shape.

The obtained results can be useful in identifying the role of rising and falling stages of the hydrograms on the stability and on the evolution of single-thread rivers, on the control by discharge on bar evolution, and on the resulting bar-induced bank erosion. Our experimental findings emphasize the complex interactions between the discharge at a given time and the bed configuration generated by the previous different discharge.