Sediment suspension events and structures at the transition between flow acceleration and stabilization

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Introduction: Most sediment transport in rivers tends to occur during unsteady flows such as during flood events. The effects of flow unsteadiness on suspended sediment transport are not yet well known. We studied experimentally how suspended sediment transport events develop during flow acceleration and subsequent stabilization in order to understand and quantify the processes during floods.

Methods: We observed fine sediment dynamics during a simulated hydrograph composed of a sequence of steady (30 s) - accelerating (60 s) - steady (90 s) - decelerating (60 s) flow in a laboratory channel. A layer of fine sediment of mean particle size of about 120 µm was placed over a loose gravel bed (D50 = 5.5 mm). In this study, the PTV (Particle Tracking Velocimetry) technique was used to determine particle velocity and analyze the dynamics of suspended sediment. Measurements resolved turbulence scales and allowed us to identify individual suspended transport events.

Results: Examples of particle velocity vectors covering the range from 80 (near the end of the acceleration phase) to 101.24 s at the beginning of the flow stabilization phase are presented in Fig1, The vector field in each of these images is a one second average obtained from 80 frames. It is evident that sediment suspension occurs as individual events. The event structure can be linked to coherent flow structures. In the near bottom boundary layer, velocity vectors are often oriented upwards which indicates that fine sediments are put into suspension. During the final phase of the accelerating flow range a ripple pattern was rapidly created that remained nearly stationary from then onward. The ripples influenced sediment suspension dynamics. The height and the intensity of the upward suspension were related to the ripple dimensions: shorter and steeper ripples produced stronger and higher suspension. Once established, the ripple pattern migrated slowly in the direction of the flow, mainly by sediment particles that rolled up the ramp of the ripple and dropped over the crest. Sediment particles were ejected into the water column by vortex shedding from the ripple crest. Vortices are strongest near the ripple crest and then propagated into the flow in the form of burst-like events in the final phase of the acceleration range. Sequences of bursts can be identified in Fig. 1 a3), a4) and a5) and bursts rapidly grow in size and shape. During the final phase of the unsteady flow, suspension events are more frequent. In the time interval from 80 s to 85 s, images indicate that suspension is associated with ejection events (Fig. 1 a1) and a2) to a4) and a5)). These images show the passage of one coherent structure reaching up into the water column to about 0.4 water depth, which is then followed by a second one, as seen in Figs. 1 a4) and a5). In this flow, turbulence intensity and the strength of the burst events are not sufficient to suspend these particles over the full water depth. Particle transport is intense in the near bottom layer.

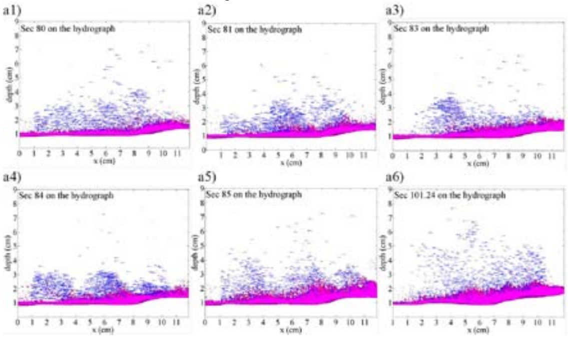

Fig. 1: PTV velocity vectors during 31.27 s covering the final phase of the accelerating and part of the peak steady range. Flow is from right to left and each image shows 9 cm of water depth.

Discussion: The event structure in fine sediment suspension during unsteady open-channel flow has been visualized by the PTV method. PTV velocity vectors varied in speed and orientation, but were organized in large coherent packets, mainly in the near bed layers, but also extending well above the bed. This pattern supports the concept that coherent structure events contribute to sediment suspension over ripples. Sediment particles were not suspended into the upper 40% of the water column. Intense sediment suspension continued during the decelerating flow even though flow velocity has decreased. This phenomenon is attributed to the presence of ripples which remained in place during this phase of the hydrograph. The results indicate that sediment suspension in the final phase of accelerating flow and the following steady flow is controlled by large scale turbulence processes comparable to those reported for steady flow in the literature.

References: [1] Bagherimiyab F. (2012) *PhD thesis N 5168 EPFL, Lausanne, Switzerland*.