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Discussion

Propagation of surge waves in channels with large-scale bank roughness

By TOBIAS MEILE, JEAN-LOUIS BOILLAT and ANTON J. SCHLEISS, *J. Hydraulic Res.* 51(2), 2013, 195–202

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In open channels, a sudden rise in water elevation generates a positive surge. Positive surges are commonly observed in man-made channels (Bazin 1865, Treske 1994) and a natural occurrence is the tidal bore in macro-tidal estuaries (Tricker 1965, Chanson 2011a). The positive surge may propagate upstream or downstream (Fig. D1). It is a rapidly-varied flow and the flow properties immediately upstream and downstream of the front must satisfy the continuity and momentum principles (Rouse 1938, Liggett 1994). The authors investigated positive surge waves in a long channel with a range of sidewall configuration. Their configuration corresponded to a downstream surge configuration (Fig. D1, right). The contribution is a welcome addition to the literature on rapidly-varied unsteady open channel flows. In this discussion, it is shown that the effects of boundary friction were previously documented, and a recent investigation provided some insight into the energy dissipation induced by large-scale sidewall roughness.

The shape of a positive surge is closely linked with its Froude number $\mathsf{F_S}$, defined as: $\mathsf{F_S} = (V_w + U_1)/(gh_1)^{1/2}$ and $\mathsf{F_S} = (V_w - U_1)/(gh_1)^{1/2}$ for a surge propagating upstream and downstream, respectively, in a rectangular prismatic channel, where V_w is the surge celerity, U_1 the initial flow velocity, g the gravity acceleration and h_1 the initial flow depth (Henderson 1966, Liggett 1994). When the surge Froude number is between unity and 1.4–1.6, the surge front is smooth and followed by a train of secondary undulations: that is the undular surge (Treske 1994). For larger Froude numbers, a breaking bore is observed with a marked roller extending across the whole channel width (Koch and Chanson 2009). The effects of boundary roughness on positive surges were tested in laboratory channels (Chanson 2010, Docherty and Chanson 2012). The undular surge data exhibited some wave amplitude attenuation trend close to the theoretical development of Ippen and Kulin (1957), while the wave period and wave length data compared favourably with the wave dispersion theory for gravity waves in intermediate water depths (Dingemans 1997). Detailed velocity measurements showed the significant impact of bed roughness on the unsteady flow motion (Chanson 2010, Docherty and Chanson 2012). The bed roughness induced an attenuation of the undular free-surface effect on the velocity field in an undular surge. In a breaking surge, the bottom rugosity enhanced the transient recirculation motion next to the bed beneath and behind the roller during the front passage.

The effect of sidewall macro-roughness was tested on undular surges with a rapid constriction and expansion ($\Delta B/B = 0.235, L_c/B = 1.52$) (Chanson 2011b). The undular surge lost up to one-third of its potential energy per unit area as the result of form drag generated by the constriction/expansion, including the generation of large-scale surface scars after the sidewall expansion (Fig. D2). Figure D2 illustrates some surface scars associated with the propagation of a positive surge past an abrupt expansion. The regular sidewall macro-roughness investigated by the authors may be regarded as a succession of rapid constriction/expansion, and the above observations would predict a decay in wave height with increasing distance consistent with the authors' report. Detailed velocity measurements (Chanson 2011b) showed further the existence of energetic turbulent events behind the surge after it passed the constriction/expansion section. These events appeared to be some kind of macro-turbulence advected behind the surge front. Recent Computational Fluid Dynamics (CFD) modelling showed indeed the production of large-scale vortices beneath a positive surge front and their upstream advection (Furuyama and Chanson 2010, Lubin *et al.* 2010). Evidences of advected macro-

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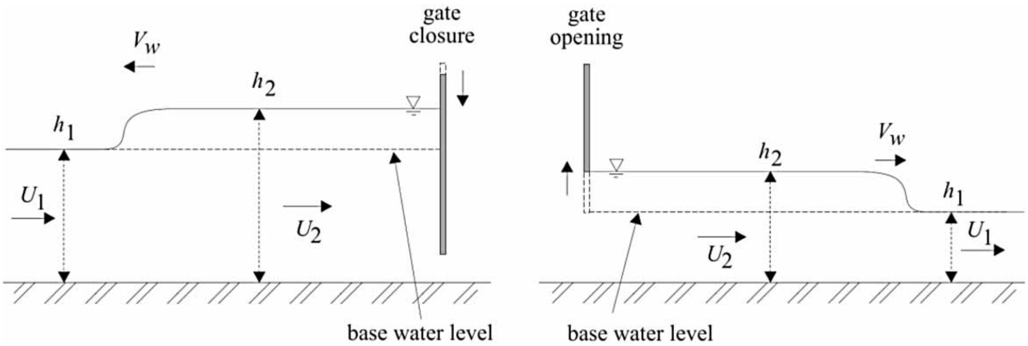

Figure D1 Definition sketch of positive surges induced by gate operation: upstream surge propagation (left) and downstream surge propagation (right)

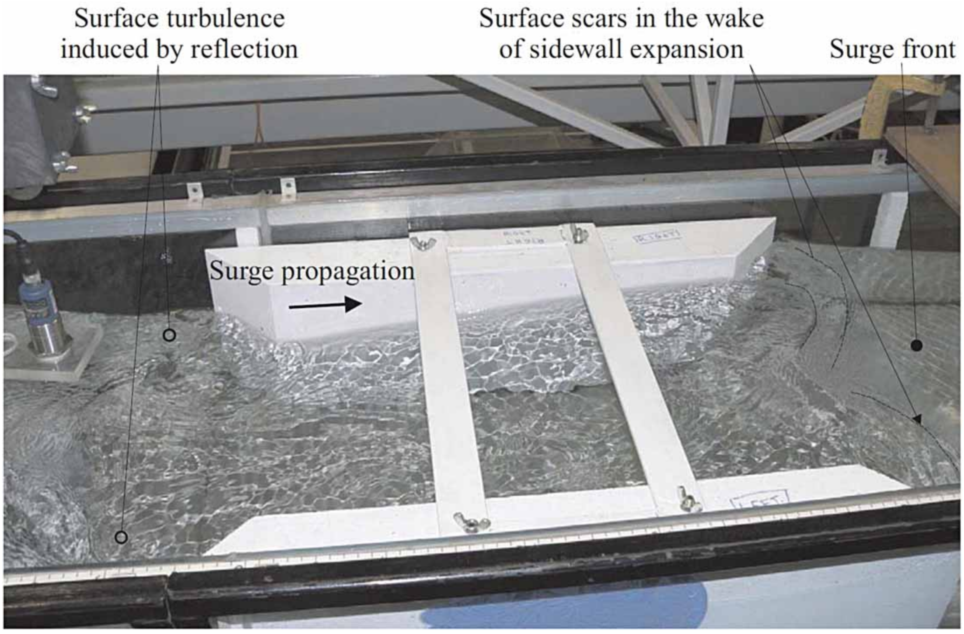

Figure D2 Undular positive surge propagating upstream through a constriction/expansion: the leading edge of the surge just passed the sudden expansion (surge propagation from left to right) – flow conditions: $Q_b = 0.0232\,\mathrm{m^3/s}$, $h_1 = 0.1552\,\mathrm{m}$, $V_w = 1.15\,\mathrm{m/s}$, undular surge ($\mathsf{F}_s = 1.15$) (Chanson 2011b). Note the surface scars induced by the surge propagation past the sidewall expansion

turbulence were also reported in natural channels (Chen 2003, Wolanski *et al.* 2004, Chanson *et al.* 2011).

In summary there is some existing literature on the effects of boundary friction and sidewall macro-roughness on positive surges, including in terms of the instantaneous velocity field. It is hoped that the present discussion will guide future researchers to the fairly broad range of relevant studies. Some more detailed comparative analyses between the literature and the authors' results would be some useful addition to the research literature on positive surge waves.

Notation

B = channel width (m) between constriction
h = water depth (m)
F_s = surge Froude number
g = gravity acceleration ($\mathrm{m/s^2}$)
L_c = constriction length (m)
Q = volume discharge ($\mathrm{m^3/s}$)
V_w = surge celerity (m/s)
U = flow velocity (m/s)
ΔB = channel width enlargement (m) on each side

Indices

b = base flow
1 = initial flow conditions
2 = flow conditions immediately after the surge front

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Closure to "Propagation of surge waves in channels with large-scale bank roughness" by TOBIAS MEILE, JEAN-LOUIS BOILLAT and ANTON J. SCHLEISS, *J. Hydraulic Res.* 51(2), 2013, 195–202.

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The authors thank the discusser for his interest in our work and the complementary information on the behaviour of undular surges in a channel with a local rapid constriction and expansion.

The purpose of the fundamental research by the authors was to study systematically the influence of longitudinal, uniformly distributed large-scale bank roughness, on the propagation speed and the height of the surge wave front. The study was motivated by the practical question if such morphological measures in the framework of river revitalization as lateral cavities at the banks can increase the flow resistance and the natural retention capacity of the rivers, in such a way that the ecological harmful effects of hydropeaking are attenuated. Thus, as mentioned, the study focused on the overall-effect of longitudinal, uniformly distributed large-scale bank roughness, and on surges as they occur during hydropeaking in rivers downstream of hydropower plant outfalls.

The discusser describes the effect of local transitions in the channel geometry (pertaining thus to local head losses rather than continuous along the channel), like a rapid constriction and expansion as they could occur at channel constrictions resulting from bridge abutments and piers, which was not the main focus of the author's research. Nevertheless, the authors have also observed similar flow features as the discusser, when the positive surge passes an abrupt expansion.

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