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Discussion

New criterion for the stability of a human body in floodwaters

By J. XIA, R.A. FALCONER, Y. WANG and X. XIAO, *J. Hydraulic Res.* 52(1), 2014, 93–104

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The authors must be congratulated for their original and important study. The flooding of urbanized areas constitutes a hazard to the population and infrastructure. Floods through inundated urban environments have been studied only recently and few considered the potential impact of flowing waters on pedestrians.

In January 2011, the Discussers conducted some detailed field observations in an inundated urban environment (Brown & Chanson, 2013, Fig. D1). During the field work, the Discussers went into the floodwaters to install, check, reposition and remove the equipment. They experienced first hand the force of the flood flow and used secured safety ropes and safety handrails to work safely in the flood waters. They would describe the flow conditions as unsafe for standing and evacuation. The conditions were treacherous because of the intense flow turbulence including water surges felt at irregular intervals. These were caused by hydrodynamic instabilities linked to some local topographic effects (Brown & Chanson, 2013). The depth and velocity data are summarised in Fig. D2 together with error bars indicating the instantaneous water depth and velocity range (Chanson & Brown, 2013). They are compared with stability threshold data based upon full-scale tests under

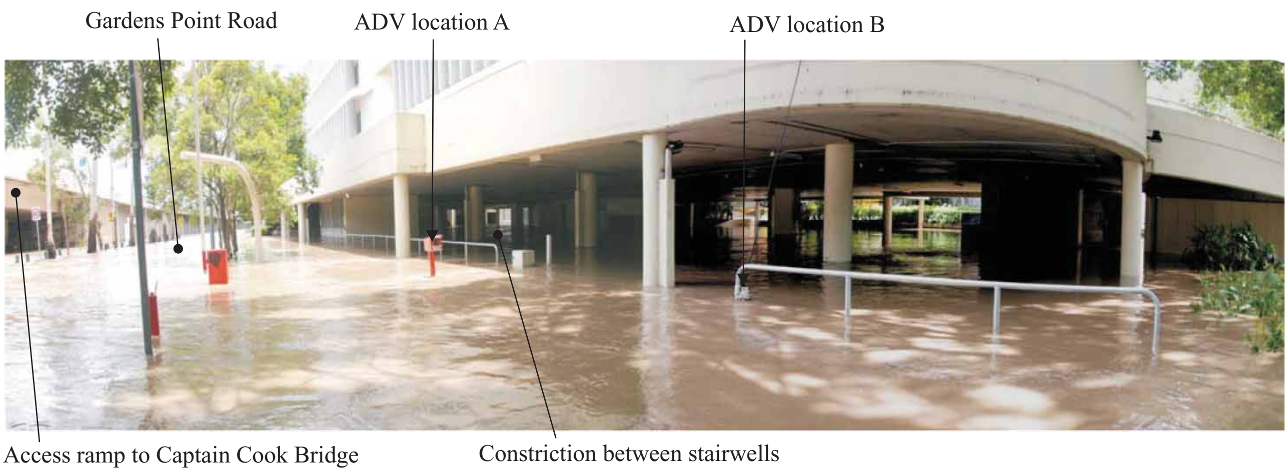

Figure D1 Inundated Gardens Point Road, Brisbane (Australia) on the morning of 13 January 2011; looking upstream

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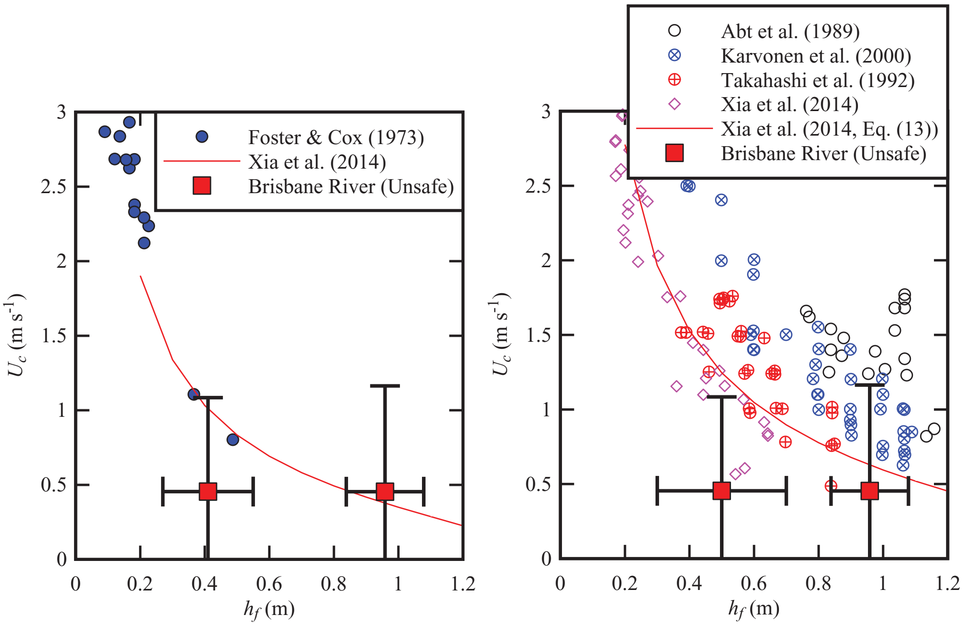

Figure D2 Relationship between flow velocity and water depth for stability of (a) children and (b) adults. Comparison between full-scale tests, data of Xia et al. (2014), Equation (13) by Xia et al. (2014) and the field observations in the Brisbane River in January 2011 deemed unsafe for evacuation are shown. Error bars detail instantaneous data range (data sampled for 3 h 50 min and 4 h 30 min, respectively)

carefully-controlled conditions, the authors' data and Eq. (13) proposed by the authors (Xia et al., 2014). Note that the physical tests were performed mostly in the laboratory with constant water velocity. The comparison between the Discussers' observations, deemed dangerous, and past experimental results indicates that such approaches are not representative of some inundation situations. Any criterion solely based upon the flow velocity and water depth does not take into account the hazards caused by the water depth and velocity fluctuations, and the flow turbulence. For example, in the Brisbane River floodplain, large and rapid velocity fluctuations were observed, giving median acceleration amplitude and jerk amplitude of 0.46 m s^{-2} and 19 m s^{-3} respectively. The risks associated with large debris (e.g. logs, trees, bins, containers, entrained by the flood flow motion experienced in January 2011) should also be taken into account.

In summary, some flood flow situations in an inundated urban environment can be treacherous because of intense turbulence and water surges, as observed by the Discussers. Many recommendations based upon previous datasets could lead to hazardous and unsafe situations, when hydrodynamic instabilities develop as experienced in January 2011. It is hoped that the present dataset will complement studies such as Xia et al. (2014) to drive new safety guidelines.

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Notation

h_f = water depth (m)
U_c = critical velocity for stability threshold (m s^{-1})

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The Authors appreciate the Discussers' constructive remarks on their work by further plotting the calculations using the derived formulae and the field measurements in an inundated urban environment. We wish to make the following comments in response to the discussion:

(1) The stability degree of a human body in floodwaters is primarily associated with the incoming flow conditions, such as velocity and depth, as well as the body attributes such as physical and psychological factors (e.g. Milanesi, Pilotti, & Ranzi, 2015). For an urban flood, the floodwater is usually characterized by the intense flow turbulence caused by hydrodynamic instabilities related to local topographic effects and a few other factors, as described by Brown & Chanson (2013). We agree that these turbulent velocity fluctuations in real urban floods can lead to lower critical conditions for human instability. Previous criteria for people stability in floodwaters were mostly derived from laboratory-based experimental studies. However, these experiments were usually conducted in laboratory flumes with steady flows and weak turbulence (e.g. Abt, Wittler, Taylor, & Love, 1989). Therefore, these criteria cannot account for the influence of intense flow turbulence on the body stability.

(2) The field observations in the Brisbane River conducted by Chanson & Brown (2013) indicated that the water depth fluctuated between 0.3 and 0.7 m with a mean depth of 0.5 m at an observation point, with such a large fluctuation range in depth causing a marked variation in the critical velocity for human instability. Figure R1 shows the relationships between $dU_c/d(h_f/h_p)$ and h_f/h_p calculated using Eq. (13) in Xia, Falconer, Wang, & Xiao (2014), where U_c is the incipient velocity for a human body at toppling instability (m s^{-1}), h_f is the water depth (m), and h_p is the height of a human body (m). It can be seen from R3 that the effective incipient velocity U_c is sensitive to the value of the relative depth h_f/h_p, particularly for values less than 0.5. This means that a small change in the incoming water depth can cause a relatively large change in the value of incipient velocity.

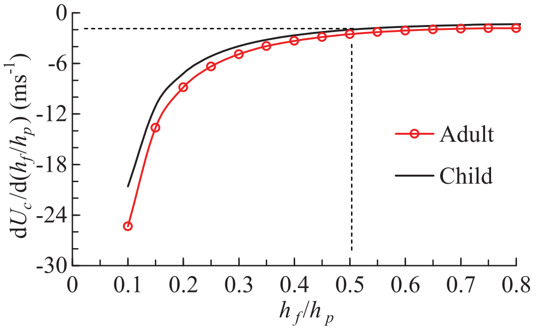

Figure R3 Relationships between $dU_c/d(h_f/h_p)$ and h_f/h_p for adult and child

(3) We agree with the Discussers that it is necessary to account for the effect of hydrodynamic instabilities in inundated urban areas and debris effects when further developing the stability criterion for a human body in floodwaters.

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