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Discussion

Experimental investigation of reservoir geometry effect on dam-break flow

by A. FEIZI KHANKANDI, A. TAHERSHAMSI and S. SOARES-FRAZÃO, *J. Hydraulic Res.* 50(4), 2012, 376–387.

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The Authors deal with an important topic that deserves continuous experimental, theoretical and numerical efforts to improve the methodologies of hazard reduction. Often sophisticated technologies cannot be used due to the lack of information resulting in simplifications to evaluate the hydrograph following a dam break. The Authors' study on the effects of reservoir shape on a dam break wave is relevant.

The Authors claim that "existing studies consider only the rectangular reservoir shape" and that "practice often requires quick and rough estimates of the peak discharge and maximum water levels", underlining that the existing methodologies for evaluating this information are based on regression models derived from a limited database, so that the overall confidence on the quality of the results is moderate. However, the work of Pilotti *et al.* (2010) was overlooked, so that a formula for the peak discharge and a simple approximation to the entire hydrograph are presented. Only the hydrograph at the dam section is considered because its shape downstream of the breach is strongly conditioned by the local bathymetry (Pilotti *et al.* 2011). The observations are limited to the rectangular, wide reservoir; equations and tables of Pilotti *et al.* (2010) contain JHE (Journal of Hydraulic Engineering) added to the number.

As to the measurement of peak discharge at the gate section, the Authors extrapolated the discharge using the data at location G4–G6, comparing it with that provided by empirical formulae. It is not surprising that there is a wide scatter between the results (up to an order of magnitude) in Table 6. The Authors' results and these of Pilotti *et al.* (2010) may explain why empirical formulae may be so inaccurate.

Pilotti *et al.* (2010) computed the hydrograph at the breach section for a partial dam break in a rectilinear, constant slope reservoir of cross-sectional area $A = \delta h^{\lambda}$, in which h is the water depth and δ and λ depend on the cross-sectional shape, ranging from rectangular ($\lambda = 1$) to parabolic ($\lambda = 1.5$) and triangular ($\lambda = 2$). The explored breach ratio a/A_0, in which a is the breach area and A_0 the initial wetted area at the dam, ranges up to 1, so that the methodology applies also for the full dam break. The comparison is limited to the peak discharge because horizontal bathymetries were not considered.

It is interesting to compare Eqs. (12 JHE) and (25 JHE) with the results of Table 6. For the long and 90° bend reservoir, Eq. (25 JHE) reduces to Ritter's (subscript R) equation, providing for peak (subscript p) discharge Q_p the value $Q_R = 0.120\,\text{m}^3\,\text{s}^{-1}$ versus the experimental values of 0.123 and $0.125\,\text{m}^3\,\text{s}^{-1}$,

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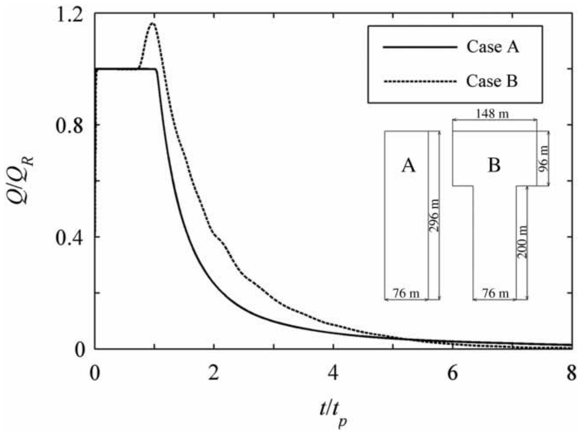

Figure D1 Comparison between dimensionless discharge hydrographs for rectangular reservoirs (B) with and (A) without widening. Breach is located in both cases along the lower short reservoir side (inset) and t_0 is computed from Eq. (D1) for case A

respectively for the two reservoirs. Whilst this good fit is not surprising, note the excellent result for the wide reservoir where a 25% higher discharge was measured by the Authors and the total dam break is hydraulically equivalent to a partial dam break with a breach ratio of $a/A_0 = 0.51/2 = 0.255$; this value provides a dimensionless peak discharge of $k = 0.138$ (Table 1 JHE), whereas Eq. (25 JHE) yields $Q_p = 0.161\,\mathrm{m^3\,s^{-1}}$, to be compared with the experimental value $0.168\,\mathrm{m^3\,s^{-1}}$. Accordingly, Eq. (25 JHE) is more accurate with respect to the formulas listed in Table 6.

Equation (25 JHE) reproduces the amplificative effect with respect to Ritter's solution providing the initial water depths and discharges immediately after dam removal for equal breach width. From the phenomenological point of view, this effect arises for breach ratio $a/A_0 < 1$ (Pilotti *et al.* 2010), as a consequence of the widening of the negative wave front upstream of the breach.

Further insights are obtained by the analysis of the data at sections G2 and G3. The overall hydrograph shape depends on the relation between the breach geometry and the reservoir bathymetry. In the rectangular reservoir of width b, axial length L and initial water depth h_0, the water level at the breach suddenly falls and then stays constant until the arrival time t_p of the first negative wave reflected by the upstream boundary (Fig. D1, Case A), where the Shallow Water Equations were numerically solved for the rectangular reservoir shown in inset A with $L = 296$ m, $b = 76$ m and $h_0 = 30$ m. A physically-based approximation of time t_p, that represents also the onset of the falling hydrograph limb, is

$$t_p = \frac{L}{\sqrt{gh_0}} + \frac{L}{\dfrac{Q_p}{bh_0} + \sqrt{gh_0}} \tag{D1}$$

where $Q_p/(bh_0)$ is used to estimate the bulk velocity of the water mass within the reservoir after the passage of the first negative wave. In case B, the plateau corresponding to Ritter's discharge

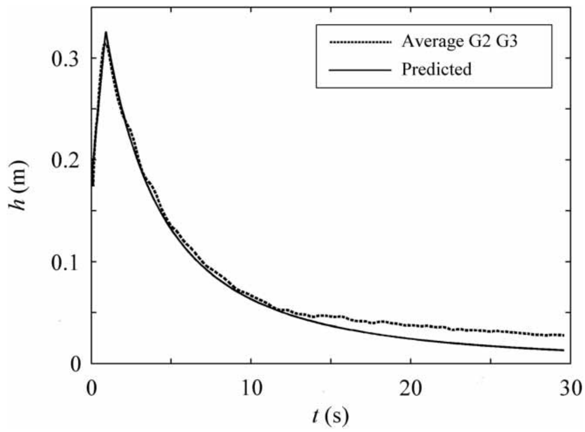

Figure D2 Comparison between measured and reconstructed stage hydrographs for the wide reservoir

Q_R is interrupted by the increase due to the widening of the negative front in the upper reservoir portion. This simple example demonstrates when a peak amplification occurs.

Considering the more interesting wide reservoir case, an approximation of the hydrograph was obtained in this way. The rising limb is approximated by a straight line between the initial discharge Q_R and the peak value Q_p computed from Eq. (25 JHE). The falling limb at the breach was obtained by coupling a weir flow with a mass conservation law as

$$Q(t) = \frac{Q_p}{\left[1 + \dfrac{Q_p}{2V_p}(t - t_p)\right]^3}, \quad t > t_p \tag{D2}$$

with V_p as the volume remaining in the reservoir at time t_p. No direct comparison is possible with the Authors' data but considering that Q_p, t_p and the reservoir volume are matched, the discharge hydrograph must be close to reality. To make a direct comparison with the measured stage hydrograph, Eq. (D2) is written in terms of the water depth h as

$$h(t) = \frac{h_p}{\left[1 + \dfrac{Q_p}{2V_p}(t - t_p)\right]^2}, \quad t > t_p \tag{D3}$$

in which $h(t = t_p) = h_p$ results directly from V_p using the reservoir stage–volume relationship. Figure D2 compares the experimental hydrograph (average of data at G2 and G3) with that predicted. Time $t_p = 0.87$ s obtained from Eq. (D1) with $L = 0.89$ m, $b = 0.51$ m and $h_0 = 0.405$ m is in excellent agreement with the timing of the observed peak, and Eq. (D3) describes the most relevant portion of the falling hydrograph limb, whilst the frictional effect is responsible for the slight gap in the final portion. The rising hydrograph limb is approximated by the linear connection between $h_R = 0.18$ m and the peak value $h_p = 0.326$ m.

In conclusion, the Authors provided interesting results when compared with ours, giving experimental evidence of the amplification effect of peak discharge in partial dam break scenarios with respect to Ritter's solution at the breach section; from the comparison with the experimental data referring to the wide reservoir, this aspect is accurately predicted by our theoretical approach. Another result concerns the widening of the word 'prismatic'. The rectangular and 90° bend cases with identical axial reservoir lengths exhibit similar hydrographs, so that prismaticity relates mainly to the cross-section but not to the thalweg, which can be non-rectilinear. This result extends the applicability of the simplified estimation of the outflow hydrograph at the breach section, which we originally explicitly restricted to the prismatic reservoir geometry. Note that the 1D scheme leading to Eq. (D1) provides $t_p = 3.13$ s both for the straight and the 90° bend reservoirs, in excellent agreement with the observed timing. Once the peak value is determined, the entire hydrograph is described by Eqs. (D1)–(D3), also explaining the shape effect of dam break waves in other situations.

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Closure to "Experimental investigation of reservoir geometry effect on dam-break flow" by A. FEIZI KHANKANDI, A. TAHERSHAMSI and S. SOARES-FRAZÃO, *J. Hydraulic Res.* 50(4), 2012, 376–387.

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It is interesting to note that the approach for the prediction of the peak discharge proposed by the Discussers provides excellent results when compared with the laboratory work conducted for the well-defined Authors' geometries. In the opinion of the Authors, this good agreement shows that the discharge–prediction should be based on the flow physics rather than on an empirical extrapolation. It is thus encouraging to perform more laboratory work on different geometries, which are closer to the prototype breach shapes.

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