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Reply

Reply to AlQasimi, E.; Mahdi, T.-F. Comment on "Aureli et al. Review of Historical Dam-Break Events and Laboratory Tests on Real Topography for the Validation of Numerical Models. *Water* 2021, *13*, 1968"

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Abstract: This is the reply to the comments by Mahdi (2021) on the classification attributed to the Lake Ha! Ha! real-field test case by Aureli et al. (2021) in their review of historical dam-break events useful for the validation of dam-break numerical models. While admitting that this test case is affected by the data shortcomings reported by the Discusser, in the authors' opinion, it should remain included in the group of well-documented test cases due to the large and complete dataset available in digital format. This conclusion is also supported by the fact that the Lake Ha! Ha! case was chosen as a benchmark in the framework of the 2001–2004 IMPACT (Investigation of Extreme Flood Processes and Uncertainty) European project and was then widely used in the literature for the validation of one-dimensional and two-dimensional geomorphic flood models.

Keywords: dam-break modelling; field data; geomorphic floods; Lake Ha! Ha! breakout; test cases; validation

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We wish to thank the Discusser for his interest in our "Review of Historical Dam-Break Events and Laboratory Tests on Real Topography for the Validation of Numerical Models" [1] and for his valuable comments, which help to clarify the quality of the field data available for the test case of the Lake Ha! Ha! breakout flood. The comments of the Discusser will certainly contribute to improving modellers' awareness in relation to some limitations of the experimental database.

First of all, we stress that the aim of the review was to provide a list of historical dam-break events for which data useful for validation purposes are available in the literature in order to help modellers in selecting the most suitable test cases for their numerical models [1]. To this end, we have reviewed a large number of scientific papers and technical reports describing historical dam-break events, and we have examined the type and quality of available information. Obviously, it was not possible—and it was not our intention—to simulate all identified test cases and thoroughly analyse the reliability of all data, the direct awareness of which can only come from a deep knowledge and long experience of each individual case.

The Lake Ha! Ha! breakout flood, which occurred on 19–21 July 1996 in the Saguenay Region (Québec, Canada) due to the failure of a secondary earth dike, caused widespread flooding and drastic changes in the Ha! Ha! River morphology. This real-field case is "unusually well-documented" according to Capart et al. [2], and the dataset available in digital format, including the hydrology of the event, the pre- and post-flood topography, and the surficial geology, is "probably one of the best available for model validation in real-life situations" [3]. In addition, rich photographic documentation of the effects of the flood and water marks based on surveys and field assessments are provided by Capart et al. [2]. Table 1 of this reply, extracted from Table 1 of the original review [1], summarises the data available for this test case. Due to the large dataset available and its suitability for testing modelling approaches, the Lake Ha! Ha! case was used as a benchmark within the 2001–2004 IMPACT (Investigation of Extreme Flood Processes and Uncertainty) European project [3,4] and is still widely used in the literature for the validation of one- and two-dimensional geomorphic flood routing models (e.g., [5–12]), as well as for sensitivity analysis [6,7] and model calibration [13]. Moreover, the Lake Ha! Ha! test case is very challenging due to the irregular topography of the valley, the highly unsteady character of the flow caused by a dike-break, and the huge sediment transport accompanied by intensive morphological effects (including erosion, accumulation, river widening, and flow path changes).

As regards the topographic data, pre- (1994) and post-event (1996) bottom elevation data are available, thereby allowing the geomorphic effects of the flood to be assessed. In particular, the dataset provided by Capart et al. [2] includes pre- and post-flood 10-m digital elevation models (DEMs) covering the lake and the fluvial corridor of the Ha! Ha! River from the Lake Ha! Ha! up to the river mouth, and approximately 100 m-spaced cross-sections extracted from the DEMs. The locations of non-erodible bedrock outcrops are also specified, both in the DEMs and cross-sections. In [7], it is highlighted that the 1994 pre-flood topographic data are affected by an average error of 2 m. The Discusser observes that some of the cross-sections provided are incorrect, while others are useless because they do not cover the actual flow path followed by the flood in some stretches. This shortcoming could be addressed by re-extracting correct cross-sections from the DEMs, also on the basis of the available photographic documentation. This could solve the problem of the numerical models' difficulty in accurately reproducing the deep erosion surveyed at 20–23 km downstream of the cut-away dike, near Perron Falls (e.g., [8]), which according to the Discusser, is mainly due to the mentioned shortcoming.

Finally, the Discusser notices that a "debris flow occurred during the failure flood" and that the failure of the dike "created a new path for the water in an existing forest leading to huge erosion or removal of trees". The simulation of this complex situation requires suitable numerical models capable of describing all relevant hydrodynamic phenomena. However, this issue refers to the modelling capabilities of the numerical model and not to the quality of the field data available for validation purposes.

In conclusion, the Discusser is kindly acknowledged for his clarification on the shortcomings affecting some topographical data of the Lake Ha! Ha! test case, which could potentially limit the applicability of numerical models to a shorter stretch of the valley. However, the dataset available in digital format is undoubtedly unusually large and complete and includes a very wide variety of data (hydrological, topographical, geological). Therefore, in our opinion, the Lake Ha! Ha! test case should remain classified among the well-documented cases in the review by Aureli et al. [1].

Table 1. Dataset available for the Lake Ha! Ha! test case.

(1) N. §	(2) Dam Name	(3) Country	(4) Type [1]	(5) Cause [2]	(6) Year	(7) References #	Available Information [3]															(23) Sim. Flood [4]
							(8) Dam Charact.	(9) Reserv. Charact.	(10) Reserv. Level	(11) Phot. Docum.	(12) Breach Char.	(13) Dam Mater.	(14) Breach Devel.	(15) DTM	(16) Storm	(17) Peak Flow	(18) Breach Outfl.	(19) Water Marks	(20) Hydrogr.	(21) Flood Timing	(22) Flooded Areas	
5	Lake Ha! Ha!	Québec, Canada	EF (DK)	OT	1996	[2,8,11,14–19]	•	•	•	•	•	•		•	•	•	•	•			•*	1D-FD; 1D-FV; 2D-FV

[1] Type: EF = earthfill; DK = dike. [2] Cause: OT = overtopping. [3] • = complete; * = geomorphic changes. [4] Numerical model: approach-method; FD = finite difference; FV = finite volume. § With reference to the list of test cases reported in Table 1 of [1]. # Cited in Table 1 of [1].

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