Dam break analysis using HEC-RAS techniques. Case study: Cal Alb dam (NE Romania)

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Abstract

Along with the understanding of the importance of a water resource in the vicinity of a human settlement, human societies have begun to build weirs, dams or hydraulic structures to use more efficiently the natural resource. One of the most important works that can be done in the course of a river is the construction of dams for the formation of storage areas. The importance of storage areas is given by their extensive use, whether used for flood defense, pisciculture, water supply or recreation. The Cal Alb lake is located in the Bașeu river basin, which is further located on the territory of Botoșani county. Botoșani county is statistically mentioned as the second county in Romania with the largest surface of water. Cal Alb lake has an area of 180 ha and a retention volume of 16.3 million m^3. Immediately downstream of the Cal Alb lake are built 20 polders and 4 ponds, but with a much lower retention volume. The present study aims to model flood caused by the failure of the dam of Cal Alb lake and its impact both on the elements of retention of the downstream storage areas and on the localities in the surrounding area.

Keywords: flood, HEC-RAS, dam break, NE Romania

1. Introduction

Worldwide a huge number of dams had failed until now with a negative impact over the society (with loss of human life) and nature (with a high impact over the habitats). The dams that are more predictable to fail are the earth-fill with clay core and the often encountered mechanism that can produce the fail of an earth dam are overtopping and piping (Dam Safety Office, 1998). In Romania are built 84 earth dams with a volume greater than 1 million m^3 and the height greater that 10 m. The Cal Alb dam is an earth dam with a core of clay and is classified as B category (special importance), with a height of 14.5 m, a length of 296 m and a width of 5 m. Administratively the Cal Alb lake is located in North-East of Romania, Botoșani county, and hydrological is situated in the Bașeu river basin (Figure 1). The catchment area of the Cal Alb lake is 192 km^2 and the lake have a total volume of 16.3 million m^3 and a surface of 180 ha at the maximum level of the water. The lake has 3 important uses: flood defense; irrigation of 1100 ha of agricultural land; fish farming. This study aims to perform a flood simulation by creating a breach in the Cal Alb dam and analyze the flood extent (in terms of affected area and land use categories) and the retention capacity of the 20 polders and 4 ponds situated downstream of the dam. Besides the ponds and the polders, downstream of the dam are located 3 settlements with approximatively 5,000 habitants.

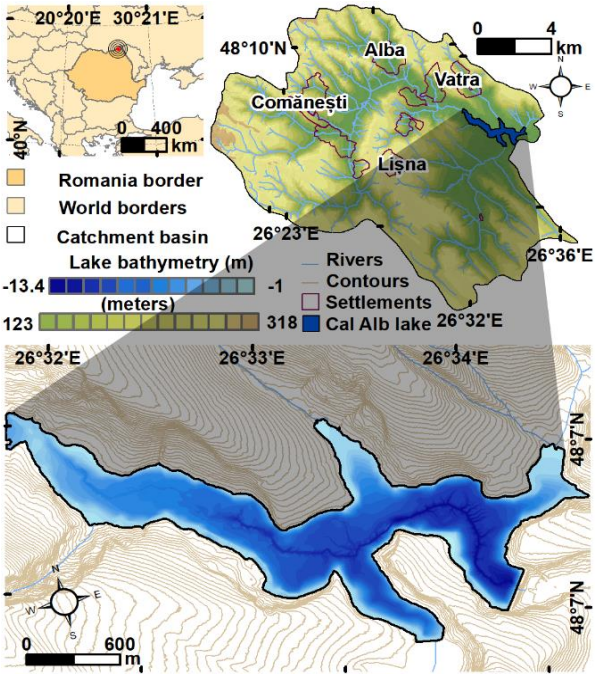

Figure 1. Geographical location of the study area

2. Methods

Regarding the flood and the failure simulation the HEC-RAS 5.0.6 software was used (Xiong, 2011; U.S. Army Corps of Engineers, 2014; Enea et al., 2018; Ghindăoanu, 2019). Based on a Digital Elevation Model (DEM) with a resolution of 1m/pixel (LiDAR) and the bathymetry of the Cal Alb lake all the layers needed for perform the simulation were generated in the RAS Mapper module, in the HEC-RAS software. For this study was used the overtopping failure mode and the most important parameters of the breach: average breach width (eq. 1) and failure time (eq. 2) were calculated using the equations developed by Froehlich (Froehlich, 2008).

$$B_{\text{ave}} = 0.27 K_o V_w^{0.32} h_b^{0.04} \qquad \text{(eq. 1)}$$

$$t_f = 63.2\sqrt{\frac{V_w}{g h_b^2}} \qquad \text{(eq. 2)}$$

where: B_{ave} is average breach width, K_o is constant 1.3 for overtopping failure, V_w is reservoir volume at time of failure, h_b is height of the final breach, g is gravitational acceleration (9.80665 m per second squared), t_f is breach formation time.

The average breach width resulted was 78.6 m and the formation time 2 hours. Other parameters used were: center station (148 m); final bottom width (67.6 m); final bottom elevation (123 m) left/right slope (10%) and the breach weir coefficient (1.44). For downstream of the dam was used a 2D Flow Area with a number 177,301 cells, with an average surface of 906 m^2. The Manning value was set at 0.03. The hydraulic model was run as an unsteady flow analysis with a computational interval of 10 seconds and a mapping output interval of 10 seconds. The hydrograph output interval was set at 1 hour.

3. Results

The discharge of the lake affected a surface of 993 ha (632 ha was polders, ponds and wetlands). The polders and ponds situated downstream of the dam has a total surface of 632 ha and retained 2 million m^3 of the flood wave, protecting a high number of households (Figure 2).

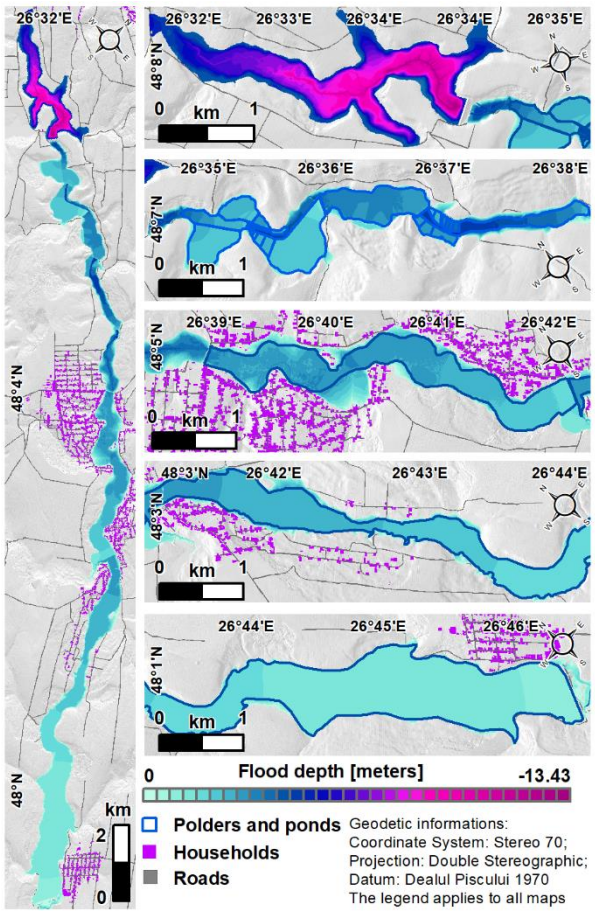

Figure 2. Flood extent and depth downstream of the Cal Alb dam and the geographical position of the settlements near Başeu River

To obtain the land use data orthoimages were used (ed. 2015). Downstream of the dam, near the Başeu River are located 5014 buildings (houses and attachment buildings) that means approximatively 1,670 of households (an average of 3 buildings per household). The surface of the households that was affected is 6.4 ha. The flood wave affected a number of 181 of buildings (60 households). In terms of land use, the flood wave affected 5 important categories: arable land, forest vegetation, roads, grassland, degraded land and 4 other categories with a small affected surface: orchard, unproductive land, shrubbery, vineyard. Arable land was affected on an area of 154 ha; forest vegetation was affected on an area of 13 ha; roads (county roads, local roads and exploitation roads) was affected on an area of 8.5 ha; grassland was affected on an area of 173 ha; degraded land was affected on an area of 4.1 ha. The other 4 categories were affected on an area of 2 ha.

4. Conclusions

The HEC-RAS software offer the necessary resource to make a complex scenario regarding a flood simulation or break dam analysis with the possibility to implement a number of structures that are very important in the manifestation of a flood event (weir, storage area, break lines etc.). This study aimed to perform a break dam analysis using a free software (HEC-RAS) and analyze the effect of the discharge of a huge volume of water (16.3 million m^3), caused by a breach in the Cal Alb dam. To accomplish the analysis an overtopping mode was run in a 2D module. The affected area was 993 ha of which 632 ha belong to the aquatic areas (polders, ponds, wetlands). A number of 60 households were affected, but without the 20 polders and 4 ponds located downstream of the dam which retained 10 million m^3 of water, the number of households would have been higher.

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