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RUNOFF SIMULATION THROUGH THE NON-PERMANENT ACCUMULATION CIUREA USING HEC-RAS 2D

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ABSTRACT: *The paper presents the way of construction a model to simulate the runoff on the Nicolina river, through the non-permanent accumulation Ciurea, Iaşi County. HEC-RAS 2D software was used to create a hydraulic model with detailed two-dimensional unsteady flow river hydraulics calculations on the channel and floodplain. We used gridded data for terrain modeling and a Landcover data layer in the RAS Mapper module, to associate with a specific geometry input file, and a specific results output file. The Storage Area of the basin was defined by an elevation-volume curve. The Boundary conditions were set as outflows from Ciurbeşti and Ezăreni reservoirs, situated on the tributaries and a downstream flow measured at Ia i hydrometric station. The simulated event was the flood corresponding to a near 10% probability of exceedance, that produced on the River Nicolina in July 2013.*

HEC-RAS 2D software generates results in bidimensional hydrodinamic files that highlights the flow, speed, water level and space expansions of the flooded areas. The bidimensional model is calibrated with reference terms of the measured water level in the modeled area, the maximum limit of the hystorical flood recorded by physical landmarks.

Keywords: *runoff simulation; HEC-RAS 2D; water level; flooded area;*

1. Introduction

The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) is software that allows the user to perform one-dimensional steady flow hydraulics; one and two-dimensional unsteady flow river hydraulics calculations; quasi Unsteady and full unsteady flow sediment transport-mobile bed modeling; water temperature analysis; and generalized water quality modeling. The HEC-RAS software was developed at the Hydrologic Engineering Center (HEC), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers [9].

HEC-RAS can perform two-dimensional (2D) hydrodynamic routing within the unsteady flow analysis portion of the software. 2D flow modeling is accomplished by adding 2D flow area elements into the model in the same manner as adding a storage area. A 2D flow area is added by drawing a 2D flow area polygon; developing the 2D computational mesh; then linking the 2D flow areas to 1D model elements and/or directly connecting boundary conditions to the 2D areas. The following are the basic steps for performing 2D (or combined 1D/2D) modeling within HEC-RAS:

- Establish a Horizontal Coordinate Projection to use for the model, from within HEC-RAS Mapper.
- Develop a terrain model in HEC-RAS Mapper.
- Build a Manning's n layer data set within HEC-RAS Mapper, using land cover data layers and polygon layers.
- From within the HEC-RAS Mapper draw a boundary polygon for each of the 2D Flow Areas to be modeled.
- Layout any break lines within the 2D flow area to represent significant barriers to flow, such as: levees, roads, natural embankments, high ground between main

channel and overbank areas, hydraulic structures, etc.

- Using the 2D Flow Area editor, create the 2D computational mesh for each 2D Flow Area.
- Edit the 2D Flow Area mesh in order to improve it, such as: add additional break lines; use the refinement regions option to increase or decrease cell density as needed; Add, Move, or Delete cell centers where needed.
- Add any internal hydraulic structures or bridges inside of the 2D flow area(s) using the SA/2D Area Hydraulic Connection feature.
- Run the 2D geometric pre-processor from RAS Mapper in order to create the cell and face hydraulic property tables.
- Connect the 2D Flow Areas to 1D Hydraulic elements (river reaches, Lateral structures, storage area/2D flow area hydraulic connections) as needed.
- From the RAS Mapper or the Geometric Data editor, draw any external boundary condition lines along the perimeter of the 2D flow areas.
- Enter all of the necessary boundary and initial condition data for the 2D flow areas in the Unsteady Flow data editor.
- From the Unsteady Flow Simulation window, set any necessary computational options and settings needed for the 2D flow areas.
- Run the Unsteady flow simulation [9].

2. Materials and Methods

Within this paper, a case study was carried out for the non-permanent accumulation Ciurea, located on the Nicolina River, in Ia i County, at about 0.8 km upstream from the confluence with the Locii River, on the territory of Ciurea commune, Iaşi County, Romania [6]. The operation regime of this hydro-technical construction Ciurea established by the project, is of “non-permanent accumulation” with a global volume at the current dam canopy elevation of 1.118 mil. m3 and a global volume of 7.300 mil. m3 at the elevation of the high water spill. The dam is 18 m high and has a canopy length of 750 m. The maneuvering tower is equipped with flat metal gates to control the discharged flows on the bottom outlet. The high waters surface outlet, located on the right slope, has a 40.0 length spillway, that transit large flows freely, unobstructed. The bottom outlet is of the box type with two compartments measuring 2.0 x 2.0 m each [7].

Construction of the numerical terrain model

The Digital Terrain Model (DTM) is one of the most important pieces of information in the model. For this paper we have chosen the 2D modeling option, because the bathymetry of the river was also available in the digital model of the land and the area lends itself perfectly to this type of modeling. Topographic data provides a physical description of the area. A digital terrain model (DTM) with a resolution of 0.5 m was used in this work.

Creating the database

The database developed in the GIS environment contains detailed information on:

- Numerical Land Model (fig. 1);
- Orthophotoplans (aerial photographs or satellite images of the earth's surface, geometrically corrected to obtain a highly accurate representation of the land and its use: forests, cultivated land, inhabited areas, rivers, communication networks, etc.) (fig. 2)
- Representation of the hydrographic network, the position of the hydrometric stations, and the location of the hydro-technical works in the GIS environment; (fig. 3)
- Significant flood, flow hydrograph, propagation time, flood volume;
- Features such as the capacity curve (fig. 4), high waters spillway, longitudinal section through the bottom outlet (fig. 5, 6), operating rules for the dam [4], tabular rating curves for the outlets;
- Cross-sections with reference system specification;

Hydraulic modeling

A complex model, developed using HEC-RAS software, was used for 2D hydraulic modeling of the river and floodplain.

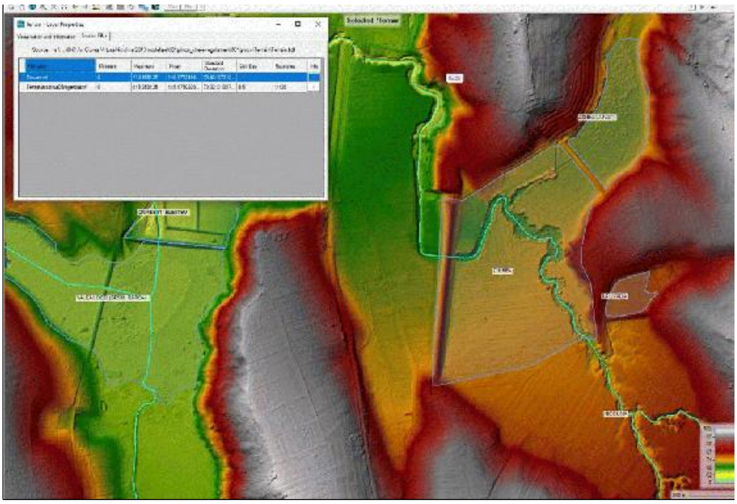

Fig 1. Digital Terrain Model (MDT with 0.5 m cell)

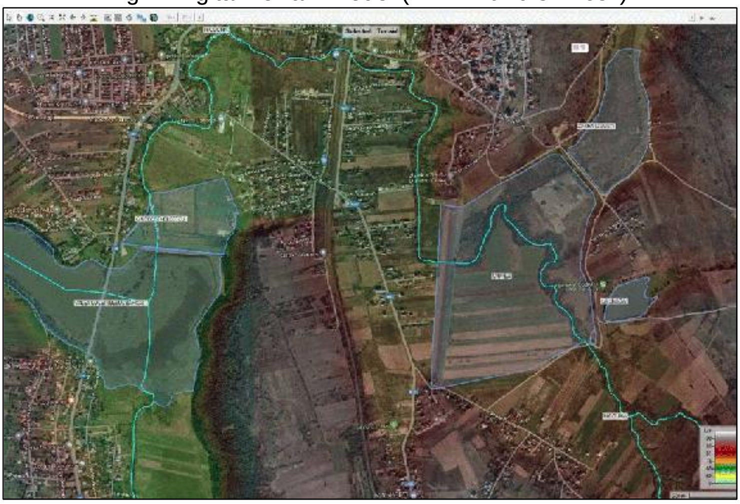

Fig. 2. Orthophotoplan of the study area

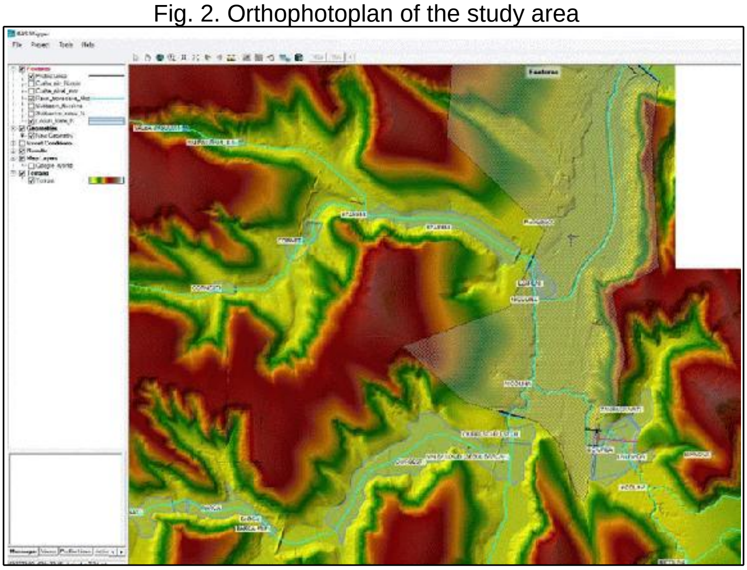

Fig. 3. Representation of the hydrographic network and simulation area

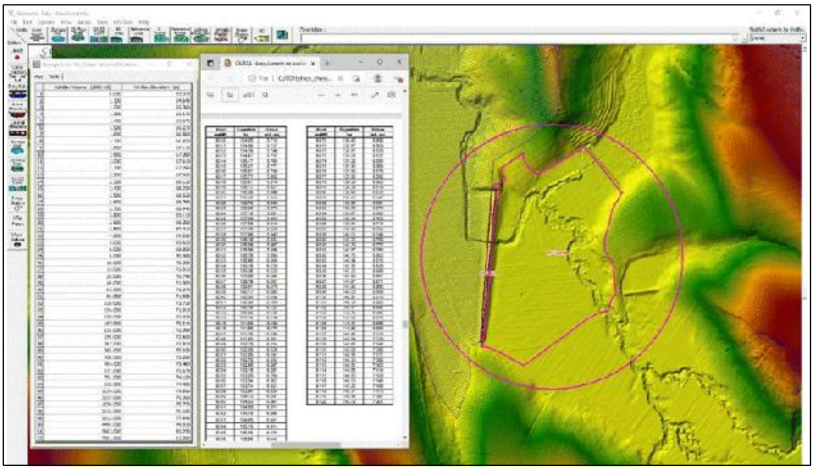

Fig. 4. The capacity curve of the accumulation presented in the Exploitation Regulation

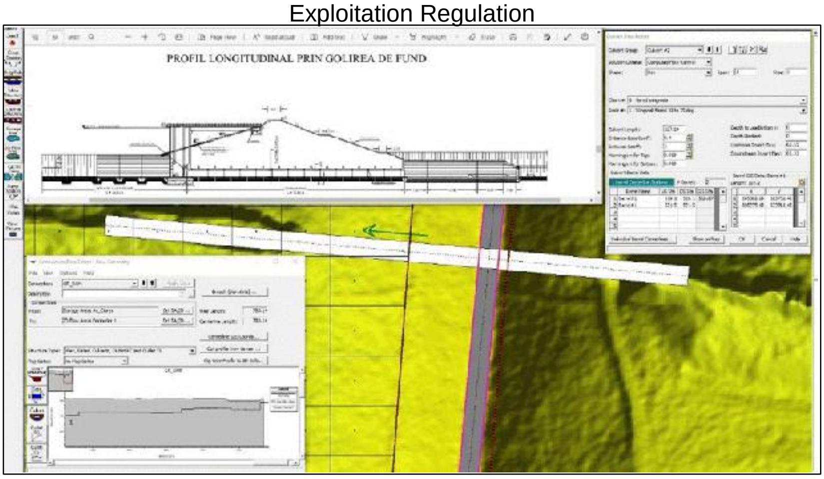

Fig. 5. Longitudinal section of the bottom outlet (top left) according to the design, alongside the scaled representation in the HEC-RAS model

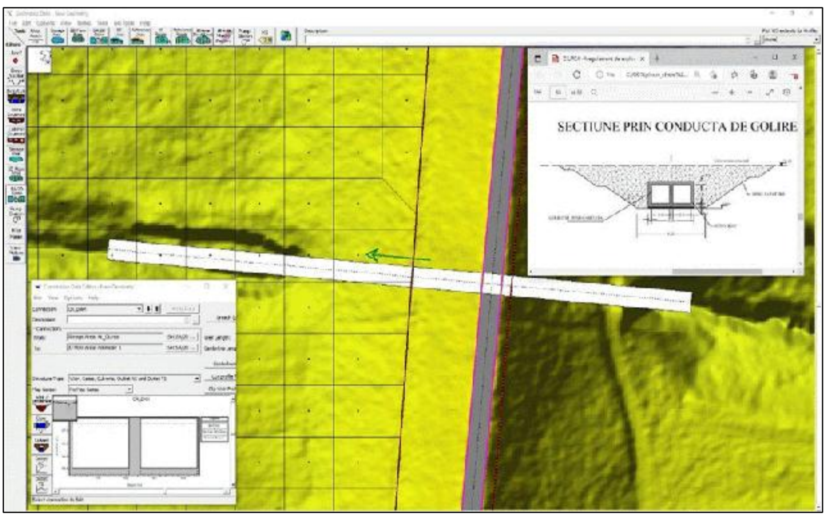

Fig. 6. Transversal section of the bottom outlet (top right) according to the design, alongside the scaled representation in the HEC-RAS model

The HEC-RAS program is based on the Saint-Venant hydraulic equations that can simulate the extent of the floodplain, determine the surface elevation and the water velocity distribution. It allows flow modeling with permanent and non-permanent free sources by evaluating water flows and depths on all sections of a river, so as to allow the integration of existing hydro-works. In modeling, it is essential to implement sections and structures, because they influence the dynamics of the water course and this program successfully allows these things.

In this stage, the hydraulic model of each calculation sector is created, including all the ramifications of the hydrographic network for which the determination of flood zones is required. Exceptions are those branches of the network related to the analyzed sector which, due to the size of the sub-basin's surface, are modeled distinctly.

The hydraulic model was calibrated based on recorded data (hydrographs, flows, levels) in certain sections of the same water course where these data are available. The flood propagation time, the time step, the variation of the roughness coefficient on different levels of the drainage section, including the length of the watercourse, depending on the field data, were used in the calibration, until the data resulting from the modeling could be compared with data recorded in the same section. When simulating a historical event, the water level in the accumulation at the initial moment will be taken into account, this fact being very important to know, as accurately as possible, the attenuation volume in the lake. It will also take into account the operability conditions of the hydraulic structures of the accumulation during the simulated event.

3. Results and discussions

The identification of the significant flood, for the period with data recorded at the hydrometric station, is an important step in order to calibrate and validate the hydrological and hydraulic parameters (roughness coefficients) of the minor and major river bed. For the calibration and validation stages, the hydro-technical arrangement at the time of the flood waves will be taken into account. For calibration and validation, it is recommended to choose a recent flood, corresponding to the current arrangement/runoff regime [5].

In July 2013 a significant flood was registered at the hydrometric station Iasi – Nicolina, that had a maximum flow of 31,8 m3/s [8] (Fig. 7).

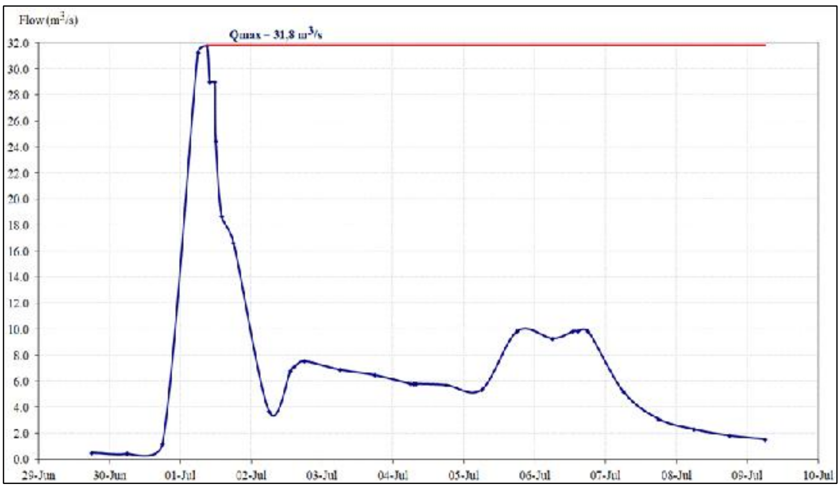

Fig. 7. Flood in July 2013 registered at Iasi - Nicolina hydrometric station

The simulated event was the flood corresponding to a near 10% probability of exceedance, that produced on the River Nicolina in July 2013. The measured flood at the most downstream point of the model, which is Ia i-Nicolina hydrometric station, represents the significant boundary condition that is to be considered in the model.

The River Nicolina collects 2 other tributaries downstream and is monitored hydrologically and hydrometrically with daily frequency at the hydrometric station Iasi situated several kilometers downstream. The River Valea Locii is a left tributary that transits the flow downstream of Ciurbeşti dam (fig. 8).

The River Ezăreni is a left tributary that transits the flow downstream of Ezăreni dam (fig. 9).

Considering the non-permanent exploitation regime, the non-permanent accumulation of Ciurea is not monitored hydrologically and hydrometrically with daily frequency. There is no centralized data with daily flows recorded on the Nicolina River in the Ciurea section. In special situations (floods), when there are discharges of uncontrolled flows from the accumulation (spillway), hourly readings of the water level are performed by the operation personnel, as well as at the downstream channel

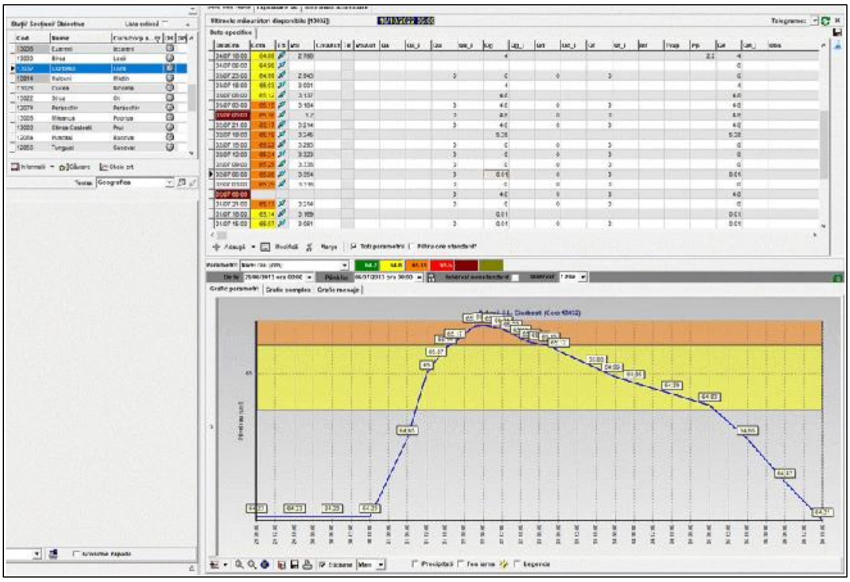

Fig. 8. The stages hydrograph of the flood for the Ciurbeşti Reservoir

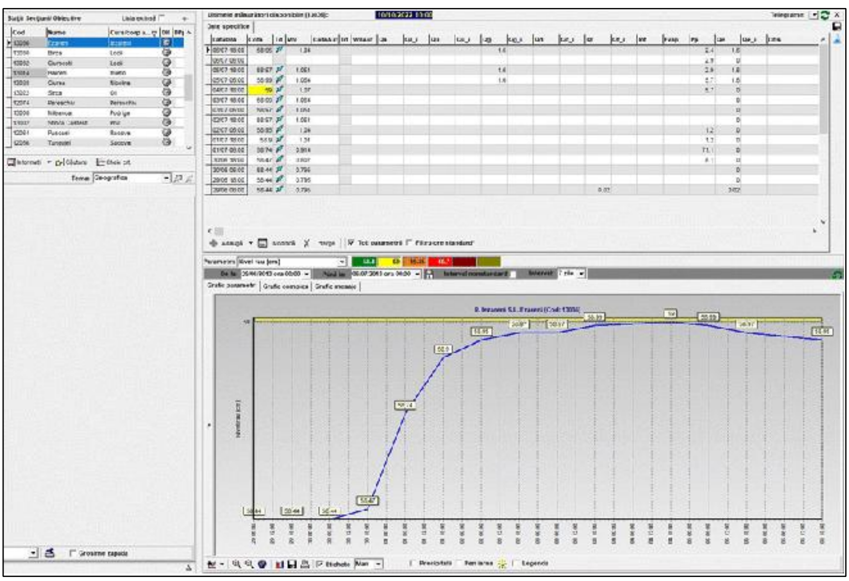

Fig. 9. The stages hydrograph of the flood for the Ezăreni Reservoir

(Nicolina River) with transmission to the Dispatch of Water Management System Iasi [2, 3].

The flow hydrographs recorded on the tributaries were compiled to determine the tributary flows on the Nicolina River, upstream of the non-permanent Ciurea accumulation, and then all of them were used in the Unsteady Flow Data Module of the software (fig. 10), as boundary conditions.

downstream point of the model, which is Ia i-Nicolina hydrometric station.

We noticed that Hec Ras accurately reproduced the inundation area [1], comparing with the actual water extent seen in July 2013. The maximum water height of 68,55 maSL corresponds to a water depth of 3,47 m in front of the manoeuvring tower (fig. 11).

The simulated flood showed a maximum flow of 32.66 m3/s and it was by 2,7% higher

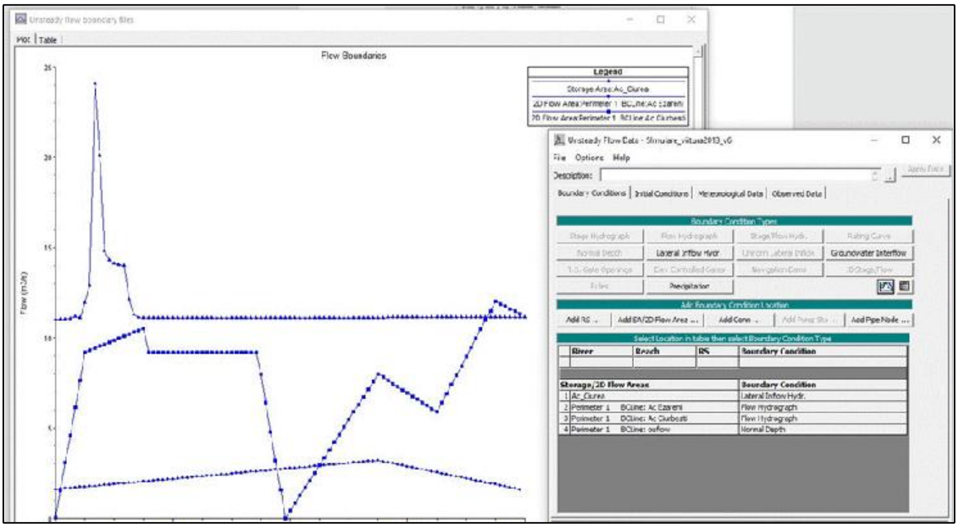

Fig. 10. The flow hydrographs used in the model

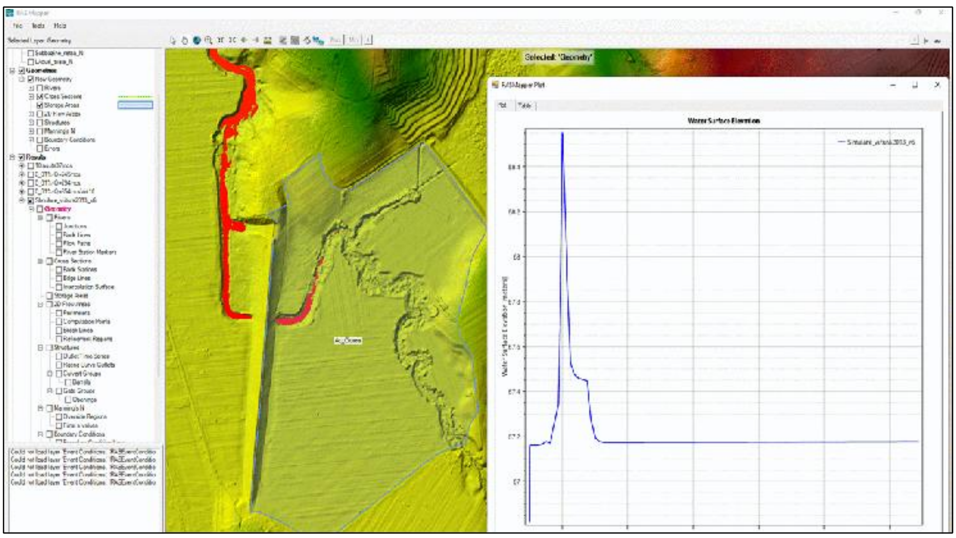

Fig. 11. The stage hydrograph for the Ciurea accumulation, resulted in the simulation

Once we have computed the simulation, the results were annalyzed and the modeled flood was compared to the measured flood at the most

than the maximum flow of 31,8 m3/s for the measured flow. The error falls within acceptable range of less the 5% difference (fig. 12).

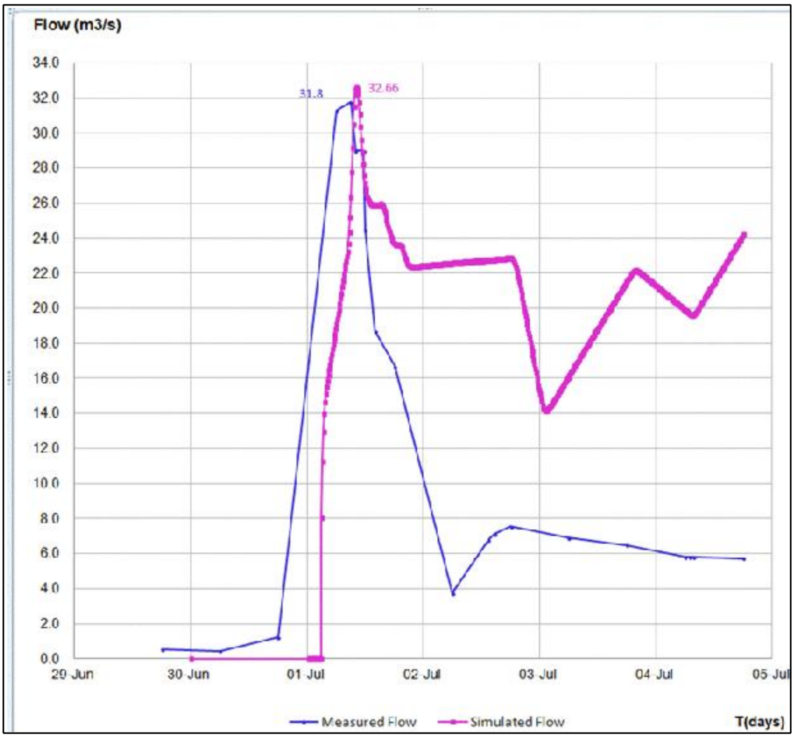

Fig. 12. The final hydrograph at Iaşi - Nicolina hydrometric station

4. Conclusions

Although the construction of the hydraulic protection works plays an important role in flood control, they are not sufficient to reduce the damage caused by the floods. The results obtained from the simulation are used to estimate and assess flood damage as well as flood control planning. The paper aims to map the floods in the study area with the help of the HEC-RAS hydraulic model, that performs the flood simulation and allows the characterization of the hazard in space and time, the water level, flows, velocities and other necessary parameters in each cross-section.

Direct measurements are difficult, expensive, dangerous (in the case of floods) and not all hydraulic parameters can be measured at any moment of time and at all points of the flow domain, for any event. However, well-calibrated models can calculate them with an acceptable error. Models also have a predictive role: to show what can happen in the event of a hypothetical event.

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