Interreg
Danube Transnational Programme
DAREFFORT

Pilot action on limited external model access
WP5 Output 5.2.

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National Institute of Hydrology and Water Management - NIHWM, Bucharest, Romania

Marius Mătreaţă, Nicu Ciobotaru, Simona Mătreaţă, Cătălina Petre, Andreea Ghinescu

Introduction

This technical report represents the Output 5.2 – Pilot action on limited external model access, as a result of the Activity 5.3. Sharing model calculation capacity for flood forecasting.

The Danube River Basin is the most international river basin in the world, including territories of 19 countries, with many important tributaries. Occurrence of severe floods in the Danube river basin in the last two decades (2002, 2005, 2006, 2009, 2010, 2013 and 2014), highlighted the need for a more effective and better harmonized regional and cross-border cooperation in the field of flood forecasting, especially during extreme flood events.

In general, the cooperation between hydrological services in transboundary river basins, uses one of the following two approaches:

- Exchange of real time observation data (water level, discharge, etc.) and hydrological forecasted data for representative river sections, based on bilateral data exchange agreement;
- Implement and operate a common Flood Forecasting and Warning System, covering the entire, or the most important part of the transboundary river basin.

The main objective of the implementation of the Activity 5.2 pilot action was to investigate and evaluate the possibility of using a new innovative cooperation approach, between forecasting services of two neighbouring countries, respectively by giving external access to a downstream neighbouring country (secondary National Forecast Center) for using and running independently a hydrological forecasting model, which is part of the forecasting system of the upstream country (main National Forecast Center).

This could be considered, in fact, a combined approach of the two standard cooperation solutions between different National Forecasts Centres, within a transboundary River Basin, with the advantage of avoiding the difficulties of implementation, maintenance and upgrade of a complete common Flood Forecasting System, while keeping the possibility for the secondary Forecast Center to use independently the shared operational hydrological forecasting modelling components.

1 General description of the pilot area

The geographic scope of the pilot action, is represented by the Danube sector between Bogojevo and Iron Gate Reservoir, an area of great importance for both Serbia and Romania, taking into consideration that on this sector the Danube River receives major inflow contribution from his tributaries, and that the Iron Gate Reservoir is jointly operated by the two countries.

This Danube sector (Figure 1) is very important also for the flood formation on the Lower Danube, due to the influence of the superposition of flood waves on the Danube, and the flood waves on his main tributaries on this sector (Tisza, Sava and Velika Morava).

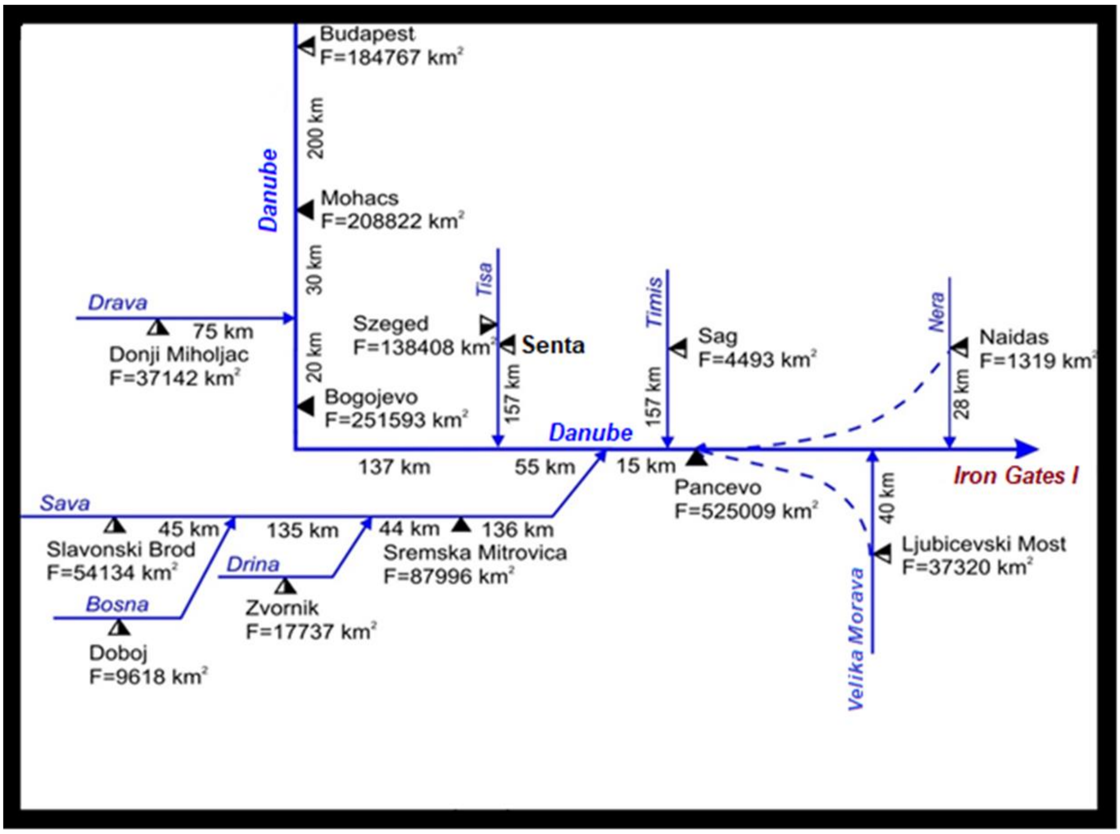

Figure 1: A schematic presentation of representative Danube River sector upstream Iron Gate I, including the selected sector for the Pilot Action (Bogojevo – Iron Gate I)

The analysis of the multiple-coincidence of flood waves on the Danube and its tributaries provides very interesting and useful results, demonstrating also the importance of an accurate simulation of the superposition and routing processes on this Danube sector for real time forecasting activities (Figure 2).

As example, a 100-year flood on Danube at Pančevo, may be generated by multiple-coincidences of different combinations of floods on the other upstream representative sections (Prohaska et al., 2012):

- 50-year Danube at Bogojevo, 10-year Tisa at Senta, and 2.2-year Sava at Sremska Mitrovica;
- 100-year Tisa at Senta, 33-year Sava at Sremska Mitrovica, and 5-year Danube at Bogojevo;
- 100-year Sava at Sremska Mitrovica, 10-year Tisa at Senta, and 3-year Danube at Bogojevo;
- And potentially many other coincidence combinations.

Also, an analysis of the Danube sectors with the main tributaries upstream Bazias section (entrance of the Danube in Romania), demonstrates the importance of the pilot area within the entire Danube River Basin (Table 1).

Table 1: Danube sectors with important tributaries, upstream Bazias section (Prohaska et al., 2019)

Node	Recipient	Hydrological station		Tributary	Hydrological station
		QIN	QOUT		qTR
1	Danube	Hofkirchen	Achleiten	Inn	P-Ingling
2		Vienna	Bratislava	Morava	Moravsky Jan
3		Bezdan	Bogojevo	Drava	Donji Miholjac
4		Bogojevo	Slankamen	Tisa	Senta
5		Slankamen	Smederevo	Sava	Sremska Mitrovica
6		Smederevo	Veliko Gradište	Velika Morava	Ljubičevski Most

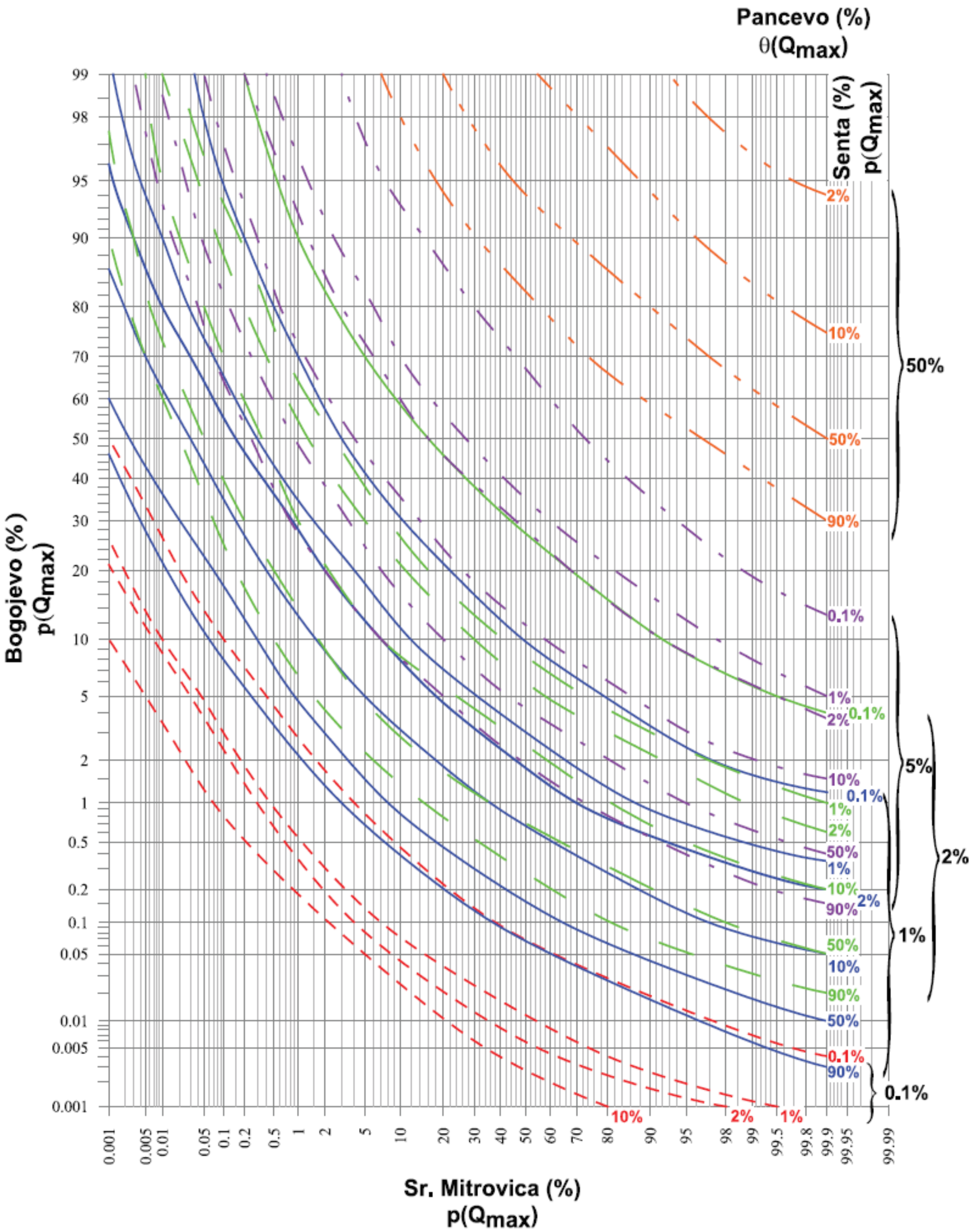

Figure 2: Multiple-coincidence of different return-period floods on the Danube River at Pančevo as a function of floods on the Danube at Bogojevo, the Tisa at Senta and the Sava at Sremska Mitrovica (Prohaska et al., 2012)

2 Design and concept of operation

The design and concept of operation are based on the following assumptions:

- The selected modelling component that will be shared is represented by a hydraulic routing model, for the Danube sector between Bogojevo and entrance in the Iron Gate I reservoir (Bazias section).
- For the implementation of this specific hydraulic routing model, the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) software will be used.
- The model is one of the components of the operational models used by the National Hydrologic Forecast Centre from Serbia (main Forecast Center), with complete access to the detailed model configuration and results in different sections.
- The National Hydrologic Forecast Centre from Romania (secondary Forecast Center), as a downstream country, will be able to access and run this model as a "black-box" model, for analysing different what-if scenarios evolution from upstream Danube, Sava, Tisa and Morava, in order to have the possibility to estimate with greater lead time the possible evolution of the inflow to Iron Gate Reservoir.
- The model can be used by the secondary Forecast Center also for other operational tasks / activities, like extending the lead time of the forecasts for the representative section for the downstream sector (in this case the Bazias section).
- The secondary Forecast Center does not have access to the detailed configuration and simulation results of the model on the territory of the upstream country, where the main Forecast Center have the responsibility for elaboration of hydrological forecasts and warnings.
- The access and use of the model by the secondary Forecast Centre do not have any impact on the operation, and use of the model by the main Forecast Centre.

For the implementations of the pilot action, an experimental environment was configured on the hardware infrastructure of NIHWM National Forecast Centre.

All the software used for the implementation of this experimental testing environment were based on open source or license free software packages:

- River Analysis System (HEC-RAS) software;
- HEC-RTS (Real Time Simulation), the public version of the Corps Water Management System (CWMS) Control;
- Oddjob Java Job Scheduling and Task Automation solution it is used as a workflow manager (https://sourceforge.net/projects/ojob/).
- Filezilla FTP Server and client.

Concept of operational cooperation and hydraulic model sharing:

- In order to run a hydrological forecasting model, we need the following:
  - Initial state values, for the model state parameters;
  - Properly formatted input data, for the entire period for which we need to run the model simulation;
  - Access to the model interface, or use of specific custom scripts for running the model.
- The National Hydrologic Forecast Centre from Serbia (main Forecast Centre), is accessing the dedicated virtual server 1, using a secured remote access and is analysing, checking the input data, and running the hydraulic routing model according to their needs, using the specific graphical user interface.
- The last updated model states, for the current day is updated on the dedicated local folder.
- National Hydrologic Forecast Centre from Romania (secondary Forecast Center), is preparing the command file and needed input data according with the scenario they want to analyse. This data is transferred by FTP protocol. The workflow manager (WM) from the second virtual server, is checking if any new command / run request was made by the secondary Forecast Center. If a new request is active, WM downloads and transfers the needed model run input data and parameters, launches the forecasting model run, postprocesses and exports the output from the model, restricted to the forecast location and information, according with the specific model results sharing configuration. If the model run was successfully, the WM sends a notification E-mail, and the output model data could be downloaded from the FTP server.

- The secondary Forecast Center does not have access for direct interaction with the hydraulic routing model.

3 Implementation of HEC-RAS hydraulic routing model for the pilot area

Within the pilot action, a specific implementation of a hydraulic routing model was done, in order to be used for testing the new concept for sharing a forecasting model between the two national forecasting services.

A new 1D hydraulic routing model was implemented for the Danube sector between Bogojevo and Iron Gate Reservoir, and includes the main Danube tributaries on this sector: Tisa, Sava and Velika Morava.

The model implementation was done using the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) software, which allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modelling.

The study area is represented in the routing model by the following river sectors:

- Danube River between Bogojevo and Bazias (320 km);
- Tisa River between Senta and its mouth on Danube River (123 km);
- Sava River between Sremska Mitrovica and its mouth on Danube River (165 km);
- Velika Morava River 30 km upstream to its mouth.

For the initial main configuration of the HEC-RAS model for these rivers sectors, different available digital terrain models were tested, in order to have a proper river channel and banks shapes representation. Multiple digital elevation model (DEM) and a digital surface model (DSM) were tested for conformity with the channel and bank shape. The DEM's, such as SRTM 30 m, ASTER 30 m, and ALOS PLSAR 12.5 m, were too irregular in terms of channel and banks shape. The DSM at 10 m resolution, despite that it was regular in channel shape the banks were too irregular, due to vegetation influence. The best model among the tested models, was the EU-DEM at 25 m resolution, in both aspects.

In the next phase, the model geometry was checked and adjusted using available cross sections profiles data, and other local information.

The resulted hydraulic model was tested, adjusted and validated using selected historical flood events, from the years: 2006, 2010, 2013 and 2014.

Figures 4 – 8 present some examples of model configuration within the pilot area, for selected representative areas, and Figures 9 – 10 present some selected model simulation results from the 2014 historical flood event.

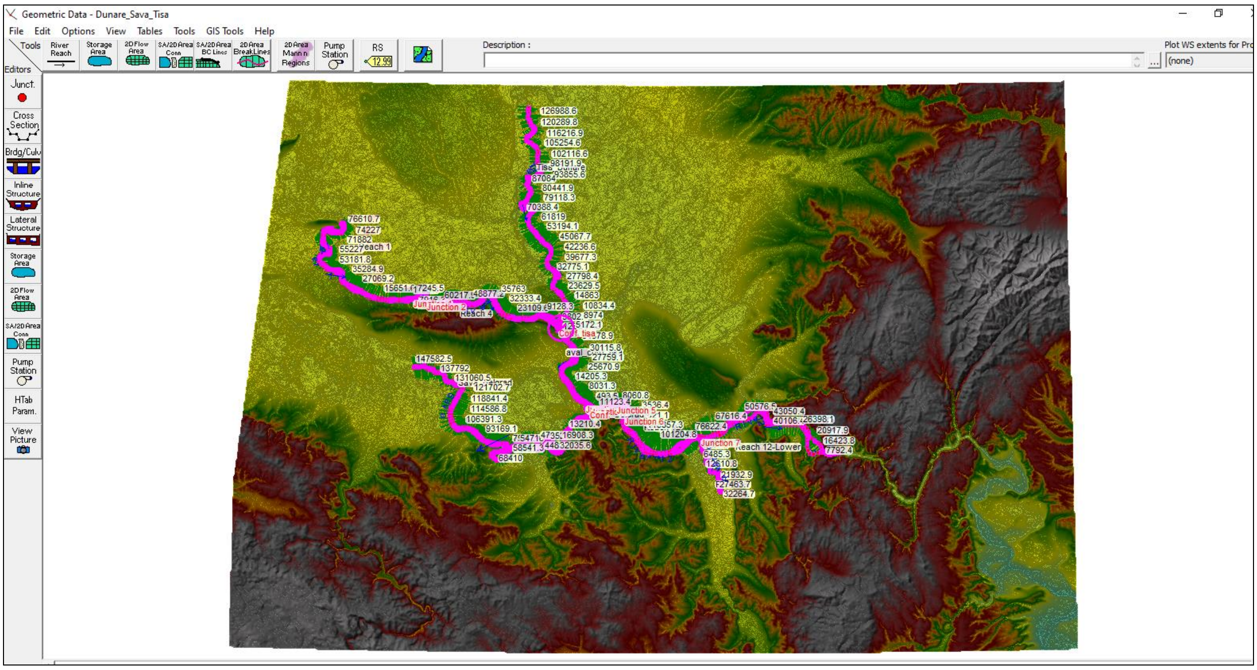

Figure 4: Pilot area general view within HEC-RAS geometric editor

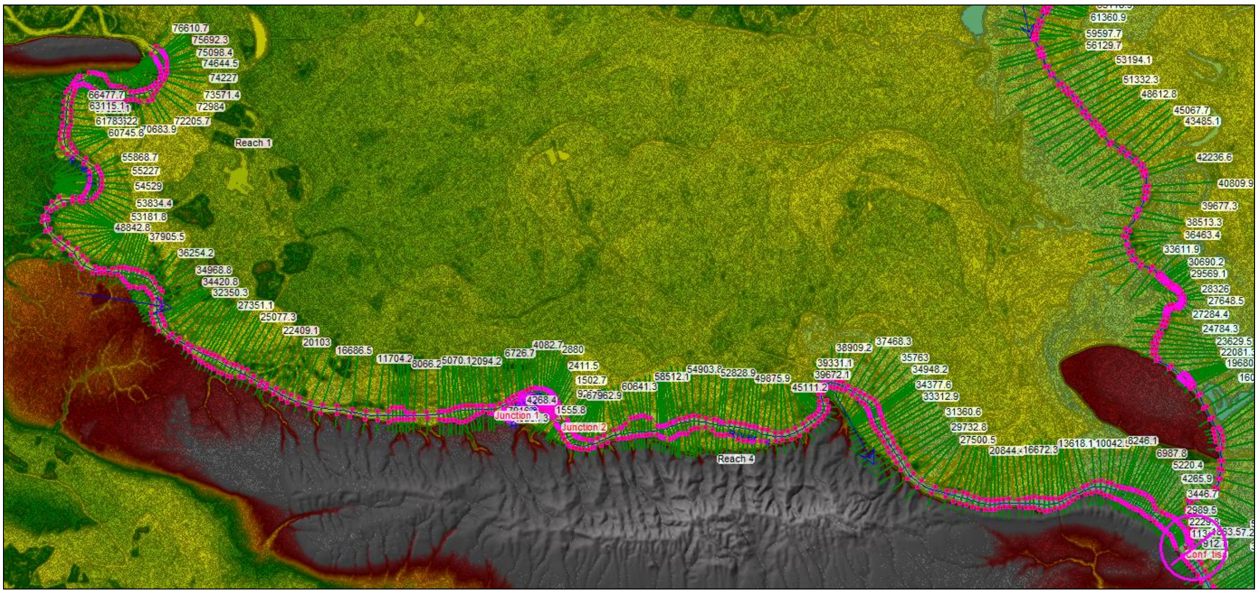

Figure 5: HEC-RAS geometric editor detail on Danube River sector between Bogojevo and confluence with Tisa River

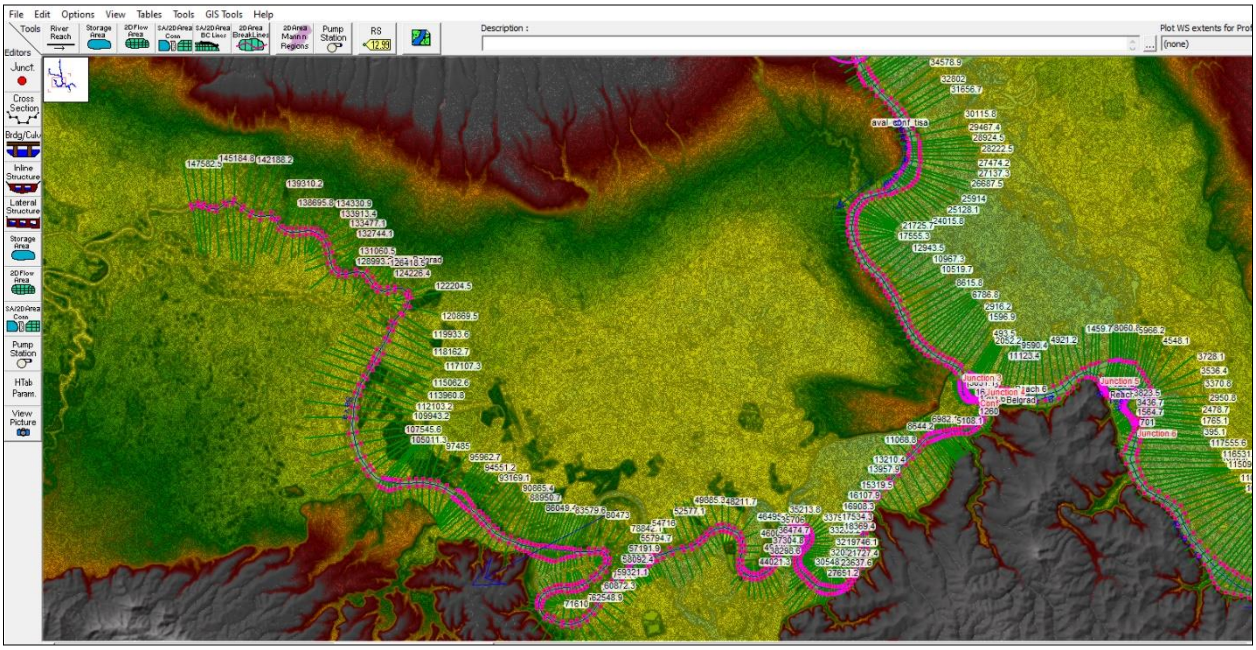

Figure 6: HEC-RAS geometric editor detail on Sava River sector between Sremska Mitrovica and confluence with Danube River

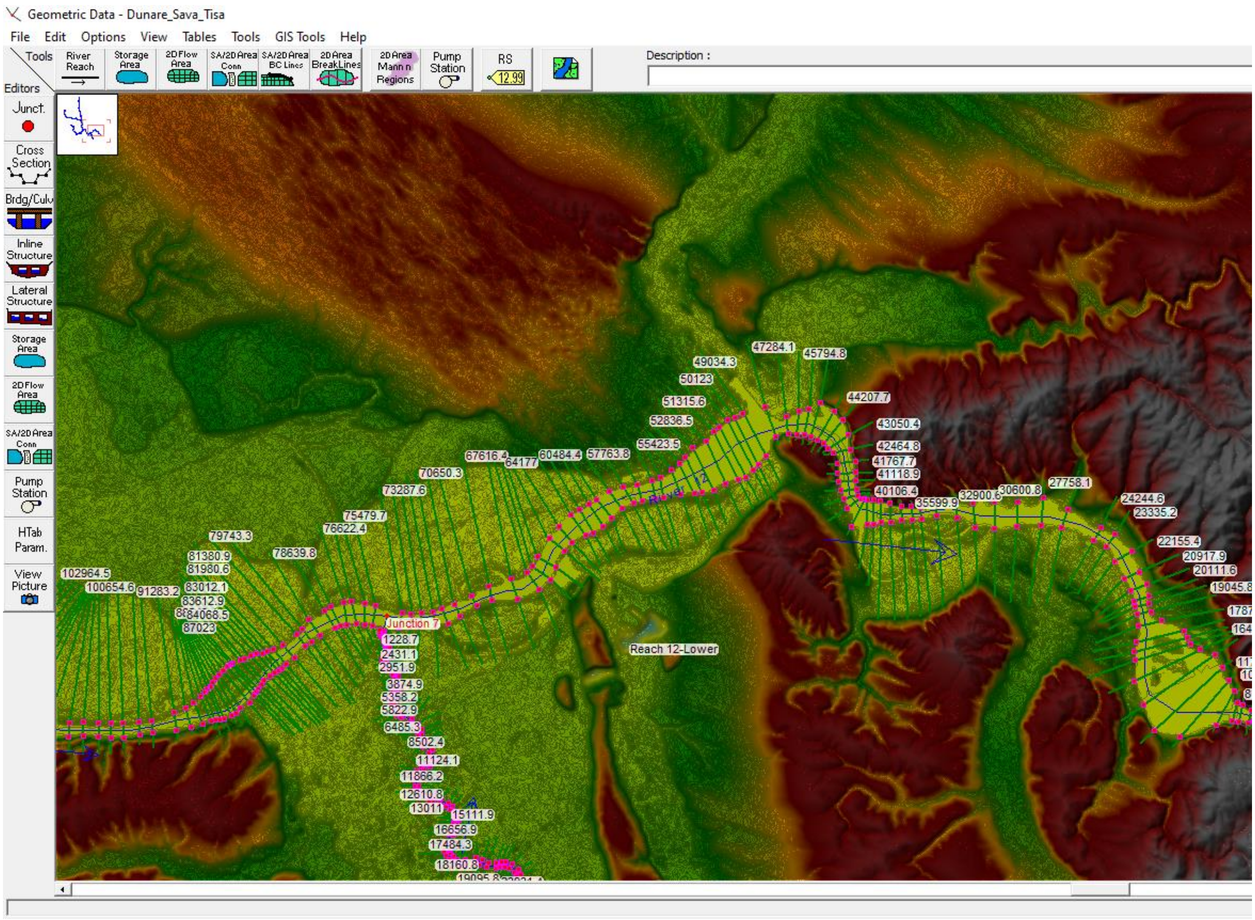

Figure 7: HEC-RAS geometric editor detail on Velika Morava River sector and confluence with Danube River

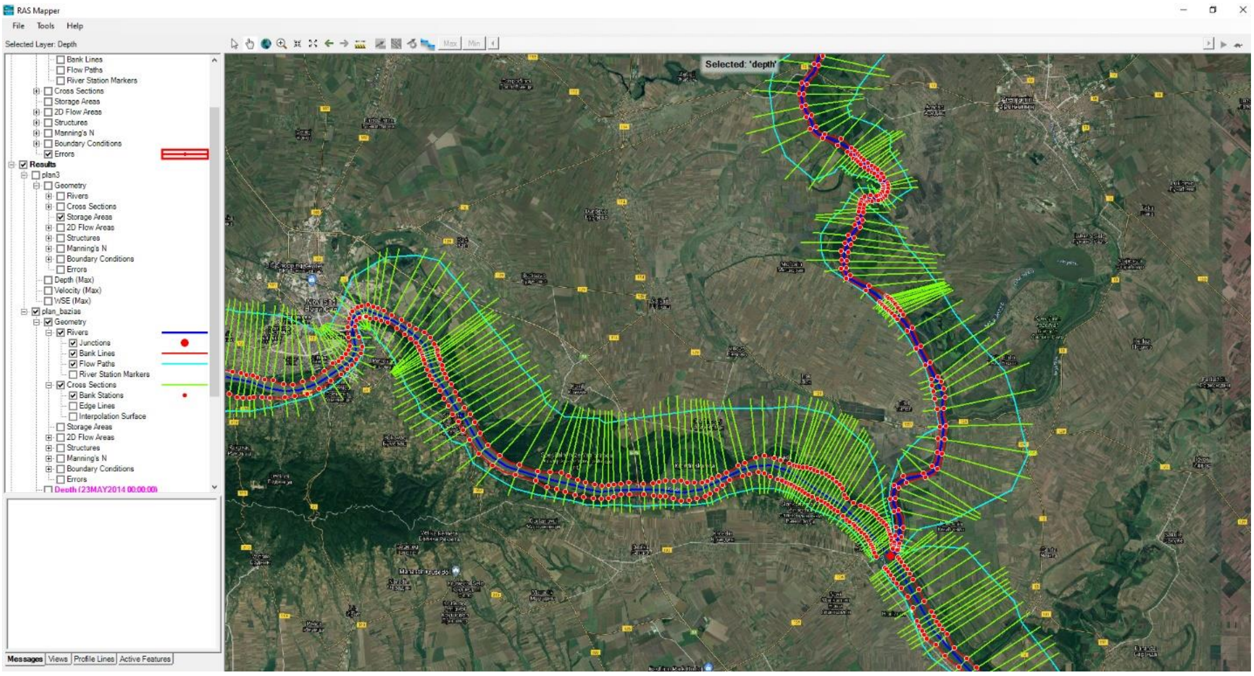

Figure 8: RasMapper analysis of the Hec-RAS model

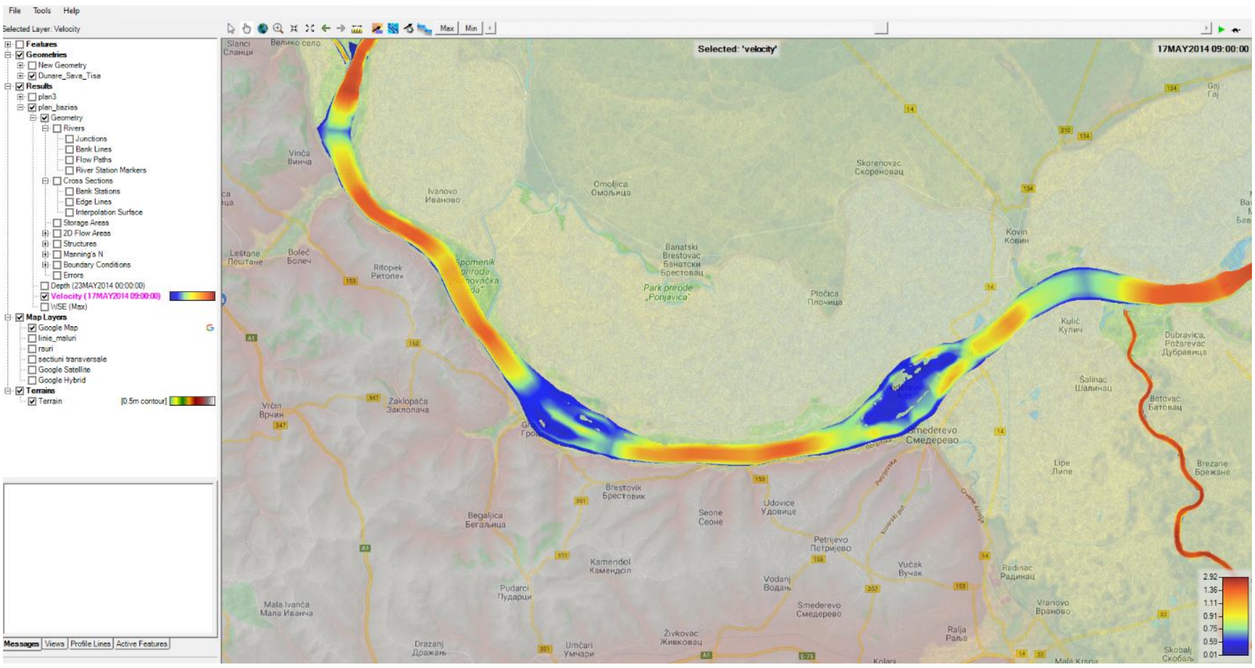

Figure 9: Simulated flow velocities on the Danube sector near Smederevo

- 17 th of May 2014

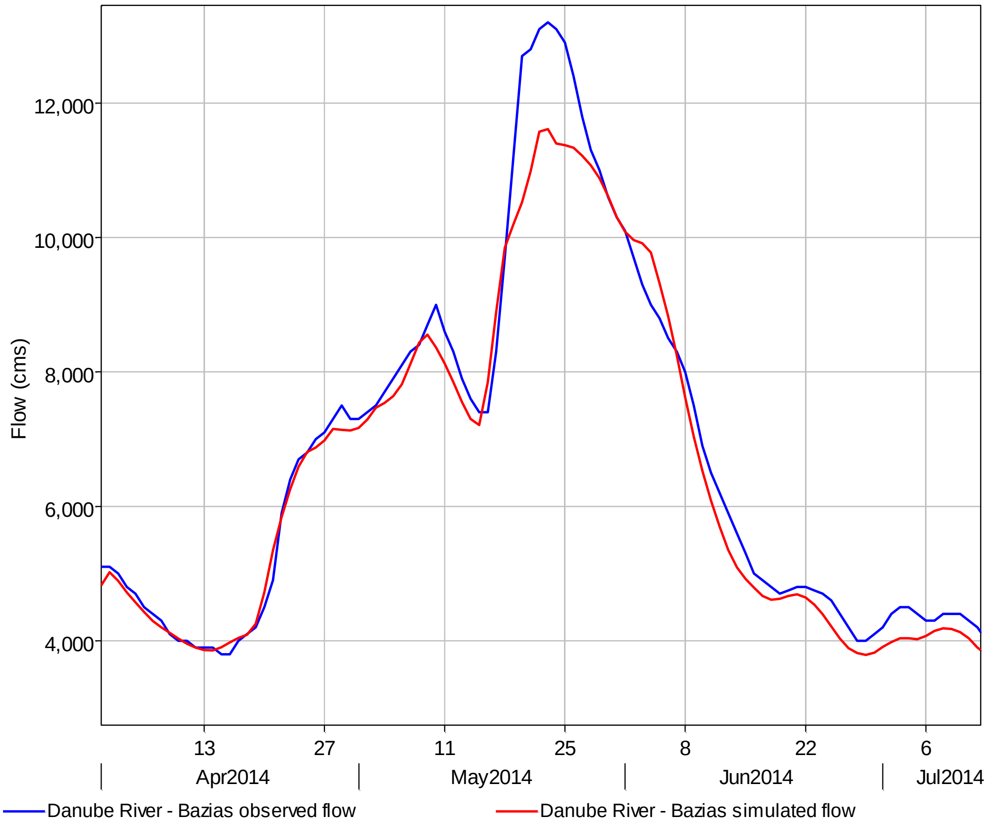

Figure 10: Simulated and observed discharge hydrographs, on the Danube River – Bazias section, April – July 2014

It should be mentioned, that the observed discharge hydrographs values, for the Bazias section on the Danube, are in fact estimated values, by hydrological computation. Standard observed discharge derivation using a rating curve is not used for this section due to the influence of the Iron Gate reservoir on the water flow regime. Also, when comparing the simulated discharge hydrographs with the observed one, we need to take into consideration that the contribution of small Danube river tributaries is not included in the specific hydraulic routing model configuration currently implemented for the pilot area.

4 Recommendations for possible extension within the Danube River Basin

The pilot action was successfully and the experiences show good potential for using the results and, in general, this approach in the future, after the project ends, for improving the flood forecasting capabilities in both cooperating countries.

Also, based on the pilot action experience, we consider that this approach could be extended on other sectors within the Danube River Basin, with the following recommendations:

- This specific way of sharing a hydraulic routing model (or a hydrologic routing model) between a main and a secondary Forecast Center could be used in principle for any Danube River sector.
- The technical solution used for the implementation could be different, in most probably will be different than the solution used for the testing during the pilot action, in relation with the particularities of the existing forecasting platform, hardware and software infrastructure from the cooperating partners.
- We recommend this approach with priority for the important river sectors on the Danube or on the tributaries of the Danube, where we have a great influence during flood events from the existing important reservoirs.
- For these specific cases, with great influence on the flow regime from reservoir operations, the sharing component model could be reduced just to the level of the hydrologic model corresponding to a specific reservoir. The great advantage in such cases, will be that the secondary Forecast Center have the possibility to take into account the influence of the reservoir, but without the need to have access to all the detailed reservoirs characteristics, data, parameters, operating rules and other information which are used for the configuration of the reservoir model.
- On a longer time scale, if such sharing solutions will be accepted and adopted, we could have a network of integrated National and/or Regional Hydrological Forecasting Centers, sharing and using in common selected modelling components, finally using a distributed hardware and software infrastructure.
- The sharing of modelling component could be extended in principle also for rainfall-runoff models, but in this case the implementation will be more complex and difficult. The associated complexity could be reduced, and the benefits of such cooperation could be greater if a common rainfall-runoff model is adopted by the cooperating Forecast Centers. For the implementation, the recommended solution will be to use also, in all the cooperating Forecasting Centres, the same platform for

model integration, with advanced functionalities, for instance using the Delft-FEWS platform, or other similar specific software system is a very good option.

- As final recommendation, in order to facilitate the implementation of this approach on large scale, we consider that the sharing of hydraulic routing components, potentially between all the Forecast Centers within the Danube River Basin, could provide great benefits if they will be coupled and used in combination with the rainfall-runoff ensemble simulations outputs from a regional system (e.g. EFAS). This approach could also significantly reduce the needed resources and time of implementation for further developments of the National Flood Forecasting Systems.

For the long-term sustainability of this project activity results, NIHWM and RHMSS partners are preparing a technical cooperation agreement, in order to continue the common activities for improving the configuration of the hydraulic routing model implemented within this Pilot action, and also for preparing for the next step, respectively to implement and use these results in the real time flood forecasting activities, in both countries. This agreement will be finalized and signed in the next period, after reaching a common agreement on the future cooperation activities.

References

Prohaska S., Ilić A., Tripković V. (2012), *Methodology for Assessing Multiple-Coincidence of Flood Wave Peaks in Complex River Systems*, Water Research and Management, Vol. 2, No. 1 45-60.

Prohaska S., Ilić A. (2019*), Coincidence of the flood flow of the Danube River and its main tributaries*. In: Pekárová, P., Miklánek, P. (eds.), Flood regime of rivers in the Danube River basin. Follow-up volume IX of the Regional Co-operation of the Danube Countries in IHP UNESCO. IH SAS, Bratislava, 215 p. + 527 p. app., DOI: 10.31577/2019.9788089139460.