Abstract code: CP7

Development and implementation of a methodology of flood hazard mapping in Bulgaria, as required by Directive 2007/60 / EC

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Keywords:
Flood hazard map, hydrology, hydraulic modelling, GIS

INTRODUCTION

Floods are considered one of the most important natural disasters in Europe and have caused fatalities and billion euros economic losses. The magnitude and frequency of floods are likely to increase in the future as a result of climate change. The objective of the EU Flood Directive 2007/60/EC is to reduce flood risk in Europe. This Directive assigns the requirement for the Member States to develop a preliminary flood risk assessment and for the areas with significant flood risk to prepare flood hazard and flood risk maps.
Implementing Directive in our country National Institute of Meteorology and Hydrology Bulgarian Academy of Sciences (NIMH) developed a methodology that uses international experience and is consistent with the availability of the necessary data and is suitable for local circumstances.The development of the methodology is under contract between Ministry of Environment and Water (MOEW) and National institute of meteorology and hydrology (NIMH-BAS).
The flood hazard maps cover the geographical areas which could be flooded by the following scenarios according to the Water Law in our country: floods with a low probability (return period 1000 years), floods with a medium probability (return period 100 years), floods with a high probability (return period 20 years). The maps for each scenario present the flood extent, water depth and flow velocity, where appropriate. The flood hazard maps are prepared following hydrological analysis and hydraulic modeling. The process of creating flood hazard maps include the following steps: The first step is hydrological studies to to estimate discharges for specific return periods. The next step is determining the corresponding water levels using 1D or 2D hydraulic models. In the third step water levels from the hydraulic modeling are used to create grid of water surface. The water surface is compared with Digital Elevation Model (DEM) and the result is Flood hazard map. Examples of application of the methodology for assessment and mapping of flood hazard are presented for town Smolian along Cherna river

DATA AND ACTIVITIES NECESSARY FOR THE PREPARATION OF FLOOD HAZARD MAPS

Hydrological data and analysis*:* The source of hydrometric data and methodologies of its production, processing, storage and updating is NIMH.

1. Calculation of maximum water discharges with specified return period 20, 100 and 1000 years at gauging stations with the selected distribution function.
2. Determination of maximum discharges with the return period 20, 100 and 1000 for hydraulic modeling at points without direct measurements using regional relationships

3. Hydrological data necessary for initial and boundary conditions of the hydraulic model
4. Hydrological data necessary for calibration and validation of the hydraulic model

Hydraulic calculations

1. Selection of hydraulic model - 1D or 2D modeling, depending on the conditions
2. Selection of software - HEC-RAS, MIKE11, MIKE21, SOBEK etc.

Topographic data:

1. Surveyed cross sections, together with information for their location along the river
2. Information about the location of existing hydraulic structures along the river, and data for their geometry

Results of hydraulic simulations - water levels for simulated discharges Q20, Q100, Q1000

Flood hazard maps creation

Data necessary to create maps

1. Topographic data - creating a digital terrain model (DTM)
2. Water surface for required flood scenarios with return period 20, 100 and 1000 years

Water surface is subtracted from the DTM. The boundary of the flooded area is where DTM - water surface = 0

Flood maps for each scenario present the following elements:

Flood extent

Water depth or water level

Flow velocity where appropriate

Methodology will be applied for the river segments with potentially significant flood risk.

Figure 1 presents the areas that are defined in the phase of Preliminary Flood Risk Assessment.

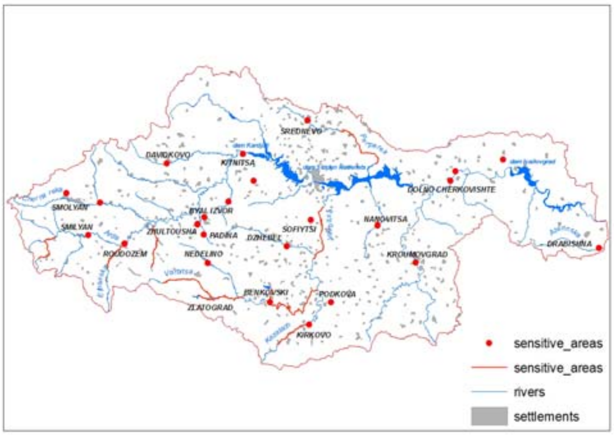


Figure 1. Areas with significant flood risk in Arda watershed

EXAMPLE OF APPLICATION OF THE METHODOLOGY - TOWN SMOLIAN

Figure 2 presents one of the historical flood events occurred in town Smolian - 2 flood events – 5-6.08.2005 and 20.12.2009.

Figure 2. Flood event in town Smolian occurred on 5-6.08.2005

Geodetic survey

The geodetic survey of cross sections and engineering structures along rivers Cherna and Biala in Smolyan region needed for hydraulic modeling and creation of digital terrain model are presented on Figure 3 and Figure 4.

Figure 3. Measured cross sections: Cherna river – 189 and Biala river - 14

Figure 4. Measured bridges: Cherna river – 31 and Biala river - 5

Hydraulic modeling platform and concepts

Hydraulic calculations:
Selection of the hydraulic model - 1D model
Selection of software - HEC-RAS (Hydrologic Engineering Center - River Analysis System, U.S. Army Corps of Engineers)
Data input
Topographic data:
Surveyed cross sections, together with information for their location along the river

Information about the location of existing hydraulic structures along the river, and data for their geometry. The model scheme is presented on Figure 5.

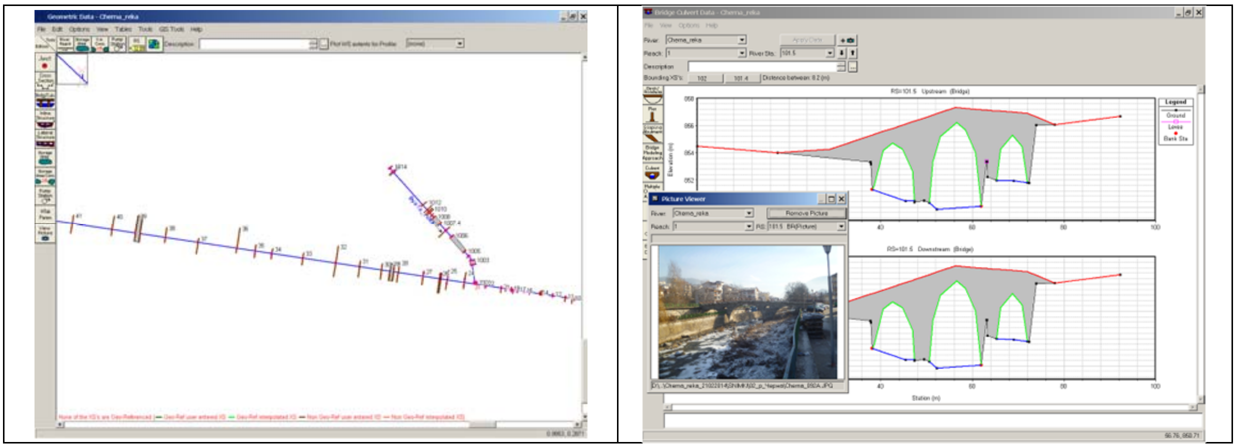


Figure 5. HEC-RAS model geometric data

Assigning roughness values along cross-sections

To determine the roughness values for river bed, river bank and floodplain is used software "Conveyance Estimation System" taking into account the components as vegetation, material (bank, bed or ground material) and irregularity. Some example of evaluation of the roughness is presented on Figure 6.

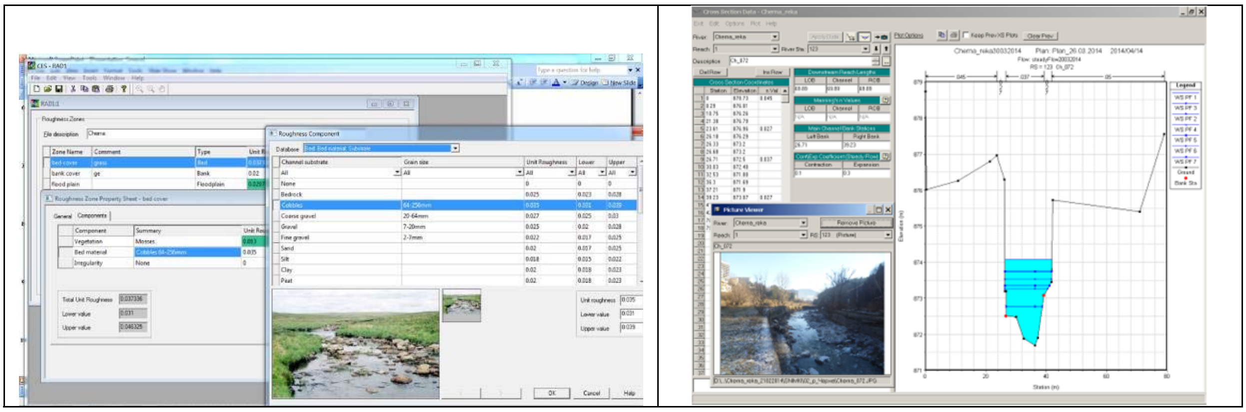
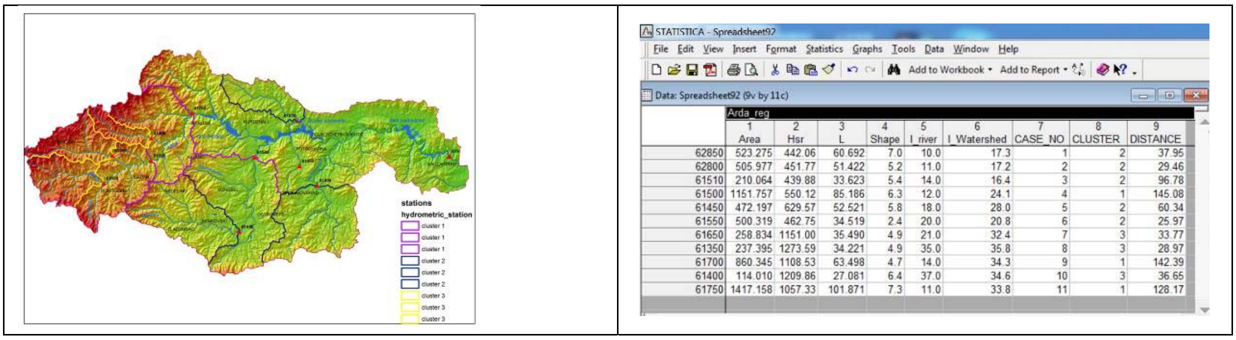


Figure 6. Evaluation of the roughness in cross section

Setting the boundary conditions and water discharges

Determination of the max. water discharges with return periods - 20, 100 and 1000 years Regional Hydrological analyses are applied. Cluster analysis is used to select the hydrometric stations that are included in the further hydrological analyses. The result from cluster analysis is presented on Figure 7*.*



	1 Area	2 Hsr	3 L	4 Shape	5 I_river	6 I_Watershed	7 CASE_NO	8 CLUSTER	9 DISTANCE
62850	523.275	442.06	60.692	7.0	10.0	17.3	1	2	37.95
62800	505.977	451.77	51.422	5.2	11.0	17.2	2	2	29.46
61510	210.064	439.88	33.623	5.4	14.0	16.4	3	2	96.78
61500	1151.757	550.12	85.186	6.3	12.0	24.1	4	1	145.08
61450	472.197	629.57	52.521	5.8	18.0	28.0	5	2	60.34
61550	500.319	462.75	34.519	2.4	20.0	20.8	6	2	25.97
61650	258.834	1151.00	35.490	4.9	21.0	32.4	7	3	33.77
61350	237.395	1273.59	34.221	4.9	35.0	35.8	8	3	28.97
61700	860.345	1108.53	63.498	4.7	14.0	34.3	9	1	142.39
61400	114.010	1209.86	27.081	6.4	37.0	34.6	10	3	36.65
61750	1417.158	1057.33	101.871	7.3	11.0	33.8	11	1	128.17

Figure 7. Distribution of the catchments to the corresponding clusters

The regional regression relationships between statistical peak discharges and physical-geographical characteristics of the watersheds are applied for ungauged cross sections.
period 81-2010 - GEV (generalized extreme value distribution)
$Q_T = f$ (A, I_river, I_watershed)
whrere:
Q_T annual max. discharge with T years return period
A watershed area
I_river - river slope
I_watershed - watershed slope

Calculation of hydrological scenarios

For the area of the town Smolyan are calculated two scenarios. The first is when the high wave is in the river Cherna and the second when the high wave is in the river Biala. Hydrological scenarios are presented in Figure 8.

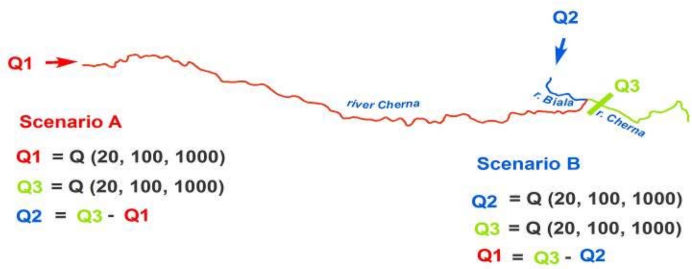


Figure 8. Calculation of hydrological scenarios

Results for water levels of the hydraulic simulations are presented on Figure 9.

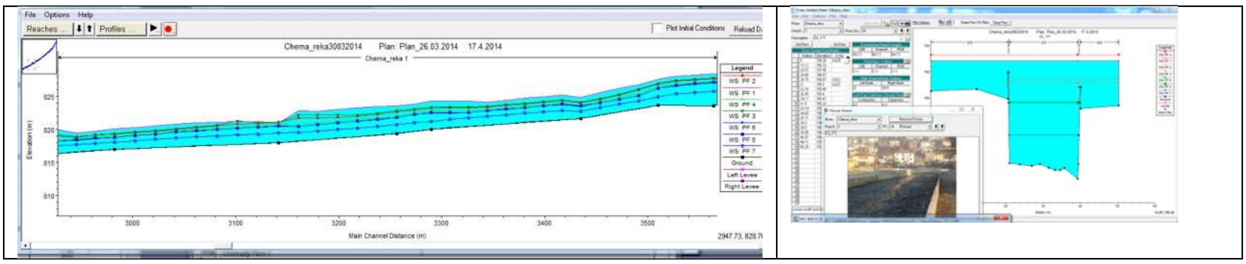


Figure 9. Calculated water levels at cross sections

Flood hazard maps

Probability classifications:
Flood events with a return period of 20 years: high probability
Flood events with a return period of 100 years: medium probability
Flood events with a return period of 1000 years: low probability

Data required for Mapping
Elevation data for creating a digital terrain model. Created DTM with pixel size 10m is presented on Figure 10.

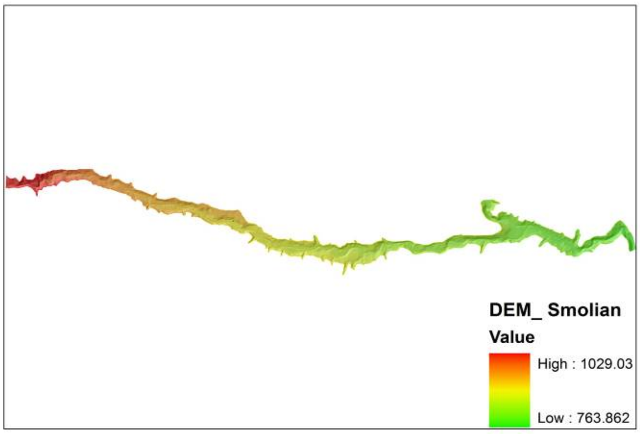


Figure 10. Digital terrain model

The water levels resulting from hydraulic modeling under simulated discharges Q20, Q100, Q1000 are used to create a water surface.
Flood boundary defined as DTM - Water surface = 0

RESULTS

The created flood hazard maps are implemented in early warning system for Arda river basin.

Flood warning system establishment in Arda river basin
The flood warning system is devoted under ARDAFORECAST project between Bulgaria and Greece. Arda River is a cross border river, that springs in Bulgaria and continues into Greece. The river is generating the most hazardous floods in the southeast Balkans, which are propagating downstream to Maritza/Evros causing serious losses at the BG-GR CBC region. The system is presented on Figure 11.

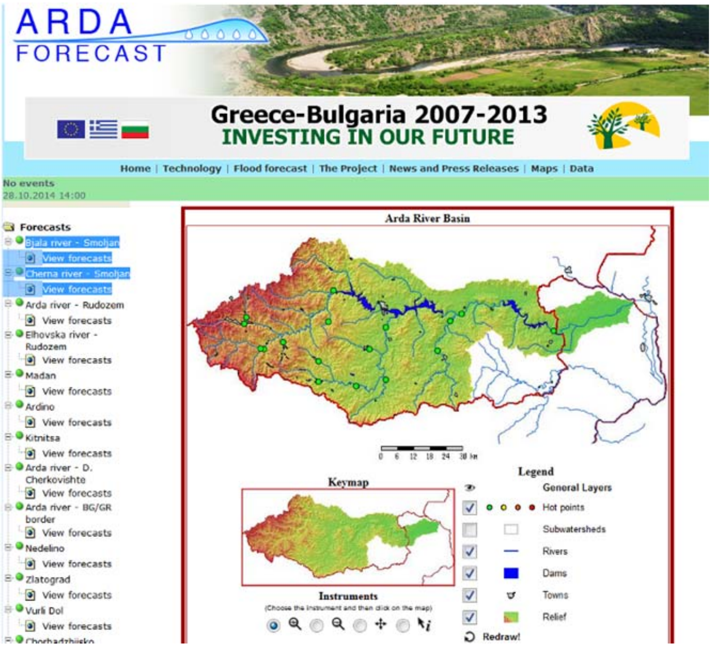


Figure 11. Early warning system Arda Forecast

The relationship between early warning system, flood hazard maps, decision makers and stakeholders affected by flooding is presented on Figure 12.

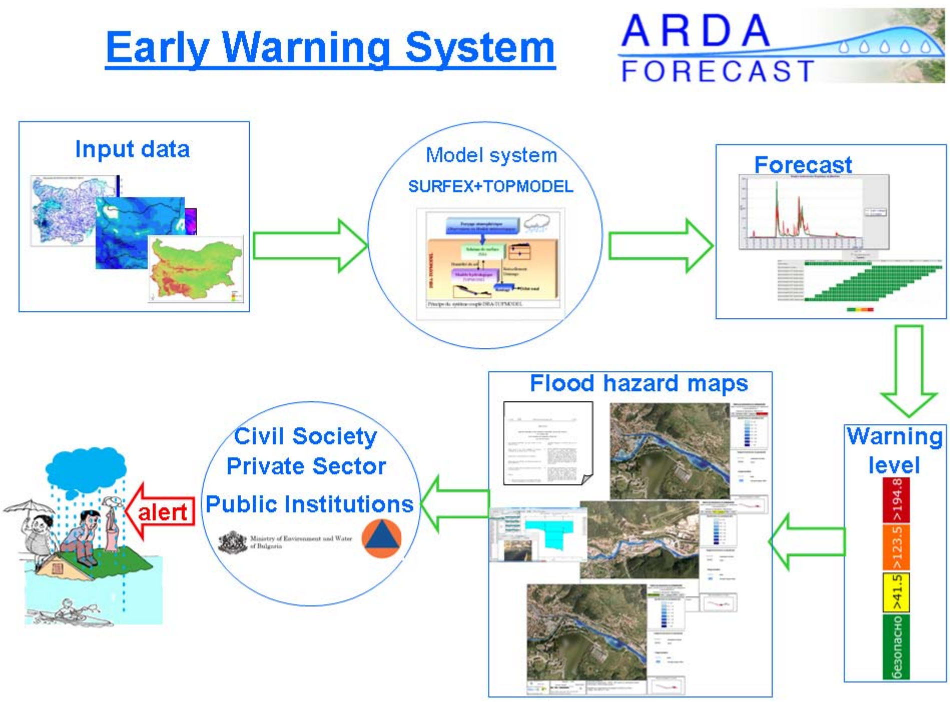


Figure 12. Early warning system Arda Forecast

CONCLUSIONS

The flood hazard maps will be useful in emergency planning and flood mitigation. They can use to improve land use planning with respect to flood hazards. Flood mapping is a wellknown non-structural measure in flood management to reduce flood hazard and improve preparedness and awareness of all actors in flood prone situations.

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