Proceedings

Danube Conference 2014

Bridging the sciences - crossing borders

XXVI CONFERENCE OF THE DANUBIAN COUNTRIES
ON HYDROLOGICAL FORECASTING AND
HYDROLOGICAL BASES OF WATER MANAGEMENT

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What are the Major Current Challenges for the Hydrological Service?

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Abstract/Introduction

In general the role of National Hydrological Service usually includes the operation of gauging network, process the data (data quality control, stage – discharge conversion), store the data in database, perform evaluation of water balance and trends, provide near real time (NRT) data (via web) and provide forecasting service. Although the exact terms of reference differ among states and services the main activities are similar as well as problems and challenges. The aim of this contribution is to identify problematic areas of current methodologies, tools and product of hydrological services and propose the way out.

1. Observation as a threat

A process of design of hydrological monitoring network has a very long history and it gained a lot of experience. Therefore we are able to select the proper gauging site according its representativeness and hydraulic suitability and to design the measuring device. However hydrologist, but even more the users of data are overconfident about its quality.

With modern development of measuring technique (especially NRT data transfer) human observers have disappeared. While NRT data transfer enables sooner identification of problems, some information might be not available to assess the quality of measured data, e.g. icing phenomena or the water stage on datum. Thus we are vulnerable to errors due to velocity pressure on sensor in the stream, icing of sensors, changes in cross section because of ice development etc.

However the main source of uncertainty is a rating curve in my opinion. The fresh experience from the 2013 flood in Czech Republic proved that although the previous catastrophic flood in 2002 provided the solid estimation of the peak stage and discharge, the shape of the rating curve might be uncertain (>10 % difference for Berounka River in Beroun) or might be changed due to changes of flood plain in the vicinity of the gauge (about 8 % for Vltava River in Prague) (CHMI, 2014). These problems might be eliminated by as frequent measurement as possible in combination with legal protection of the stability of the gauging profile.

The modern measurement of discharge uses ADCPs. But no calibration method exists for this equipment. CHMI has implemented its own procedure to calibrate (evaluate the functionality of) ADCP. The procedure is based on inter-comparison of several ADCP at same time together with a current meter (propeller) as an etalon. Still this method does not provide justifiable information on the precision of ADCP measurements especially in case of floods. The lack of the method is comparison of different measuring techniques with different uncertainties. We have to keep in mind that classical current meter is calibrated to measure properly the velocity of flow. However point velocities measured by a current meter could not be compared to velocities indicated by the ADCP for a relevant cell simply because ADCP does not measure velocity in this cell right beneath the device but in a cone around this cell. We can only end up with comparison of output discharge from two methods not know which one is right if providing differing results. Hopefully the WMO project on Assessment of the Performance of Flow Measurement Instruments and Techniques (WMO, 2014) will provide hydrological services with guidance and proposed calibration procedures for ADCP as soon as possible.

2. Natural regime as a myth

Most of the streams and rivers are regulated or affected by human activities. We have to keep in mind that such human - basin and human – river (flood plain) interactions have developed for many centuries trough the land use changes and water management construction. An illustrative example of such interaction might be the development of Prague settlements. As Prague started to grow water mills were constructed together with weirs from the 11th century. Weirs caused gravel sedimentation on the Vltava river bottom up to 3.2 to 3.8 m thick (Kovanda et al. 2001). That resulted in increase of flood water level that has started to affect previously save settlement on the right bank river terrace. Most probably two floods in 1272 and 1273 initiated fast (finished not later than few decades later) anthropogenic increase of the street surface to current level with the aim to escape from flood. That by the way left many old buildings with floors buried few meter bellow the ground what we might enjoy as ambient restaurants and pubs today.

Examples of human – basin interaction are land use changes in general and some large pond systems constructed from 12th to 17th century in particular (not speaking about modern reservoirs, levees, diversions etc.). These interactions have been understood for a long time, e.g. large pond systems were blamed for the wet years 1770-1772 that lead to crop failure and famine (Vašků, 1997). In result many ponds were canceled and removed at the end of 18th century in Bohemia and Moravia. It is funny that when the drought affected Southern Moravia in 2012, many have blamed that pond cancelation for the drought.

The result of all about mentioned human interactions is that we do not observe nature flows, e.g. in case of floods we always experience some small dam or a levee breaks on one hand and reservoir retention on the other.

The question is should we attempt to separate those effects to obtain nature flow if the risk of e.g. dam breaks persist in the basin? But what should we do if the reservoir does not exist anymore? Elleder et al. (2012) researched all available information about disastrous large scale flash flood of Berounka River in May 1872. They have found that for the most heavily affected stream of Střela (923 km^2) water level has been reported to rise more than 11 m above the banks, however that has been caused by the dam break of Mladotický pond (area 91 ha, dam height 14 m). The pond has not been restored thus should we account for the flood in designing flood probabilities?

The complexity of the issue of natural and anthropogenic effects is well illustrated by the experience from Mělník inundation behavior during 2013 flood. The water level there exceeded the level recorded in 1890 flood although the discharge was significantly smaller in 2013 (app. 4 000 m^3 in 1890, 3 040 m^3 in 2013). This issue still needs more detailed investigation however several factors have been identified as potentially contributing:

- natural aggradation of the terrain
- natural interaction of the confluence of Elbe and Vltava rivers (although in both cases Vltava dominated)
- new levees and hydraulic construction (including lest bank navigation channel from 1930s and flood levee in Mělník at the outflow from the inundation)
- different levee breaks during both floods
- land-use changes in the flood plain (several crops, scrubs and alleys may change the hydraulic roughness of the area; the question is how much these factors might be considered natural or anthropogenic).

This results in impact on calibration of hydraulic models (usually use historical flood for calibration) for delimitation of flood zones on one hand and on the misunderstanding of the flood magnitude and behavior by flood authorities (as flood does not match with flood plan) on the other hand.
All that leads me to conclusion that we should reflect current state of the basin in our hydrological expertise; however we lack proper methodologies as our statistics are based on historical data reflecting different basin conditions.

3. What is a 100 years flood?

We apply more or less complicated statistics to compute design flood values but we still do not reflect the hydrological meaning behind as Klemeš noted more than 20 years ago (see Klemeš, 2000). How is a probability of disastrous summer Vb track floods like 2002 or 2013 connected to a probability of a common spring melting flood? How can we properly asses the change in hazard of extreme summer floods without considering the probability of occurrence of the causing meteorological event?
The same comes with flash floods at small river basin (often ungauged). The flash flood occurrence in a particular basin is a matter of accident - although some orographic features might contribute to induce the convection and thus affect repeatedly same basin; in the scale of few km of basin and storm size one basin might suffer flash flood while neighboring basin remains unaffected. Meteorologist use regional pooling procedures (putting more rain gauges time series together) when estimating a point value of 100year precipitation. But in hydrology as many other factors comes in play (e.g. slope, land use, soil, initial saturation) pooling technique application remains scientific challenge. Nevertheless I believe that when estimating Q_{100} for small basins flash floods has to be considered independently based on regional information and/or assessment of physical geography conditions of the basin as a “stable” factor defining the potential of the basin to produce flash flood if hit by heavy downpours.
Similar should apply for large scale regional floods taking in to account the synoptic cause of the flood and basin exposure.

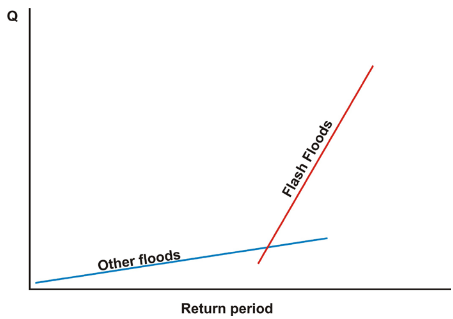

Fig. 1: A schematic description of difference of probabilities of flood return period based on the cause (type) of the flood.

4. Research and practice

There is a gap between science and practice. Hydrological Services cannot in many cases compete to Universities and research centers in grant programs. That unfortunately results in large number of research outputs that are not applicable in practice due to lack of knowledge on working practice of the Service. Sometimes it ends up with funny misconceptions: there was research on land-use changes impact on runoff from a small basin that found a change in regime in 1974. Authors tried to find all possible causes and lag times of its effect to explain it.

The true reason was the organizational change in the institute and a transfer of the responsibility for the gauging profile and the change the rating curve (while previously it remained unchanged for 20 years). The only solution is for the scientific teams to consult and/or include Hydrological Services to their research activities and teams in the preparatory phase to properly design the research, its output and to gain the knowledge about the data used for it. Same applies for the evaluation of data e.g. on the European scale - who measure the data knows the data and can add this knowledge to evaluation process.

5. Conclusion

However the major role for the National Hydrological Service today from my perspective is to keep doing the whole hydrology from observation trough educated and local knowledge based evaluation of data to modelling and research. There are increasing demands for data provision for processing, evaluation and modelling to be done by well financed programs and project on the pan-European scale. It is my deep believe that hydrologists who knows the basin, the gauging profile and the field work and uses his experience in data processing should not be replaced by an automatic data quality check procedure operated somewhere 1000 km away. The same applies for a local forecaster and automatic system from the distant research center.

Hydrology cannot survive without enthusiastic and experienced hydrologists.¨

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Measuring the hydrological snow storage in Alpine catchments with a new low-cost GPS technology

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Introduction

The retarded runoff from the seasonal snow cover in the Alps and its forelands plays an important role for entire watersheds like the Danube River Basin which is one of Europe's most important catchments reaching from the Eastern Alps down to the Black Sea. For hydrological purposes, such as discharge forecasts for hydropower generation (Koch et al. 2011), information about the snow water equivalent and the amount and temporal onset of meltwater release are highly important to estimate river runoff and water availability within a catchment. However, in mountainous areas it is still a problem to get these data due to no or only sparse in-situ snow measurements. Therefore, this study aims to develop a reliable low-cost technique which measures snow parameters continuously and which is globally applicable.

1. Measurement setup

Besides other snow parameters, the liquid water content of the snowpack is a key parameter to determine e.g. wet-snow stability and the spring meltwater onset. To continuously estimate the snow wetness, a new experimental low-cost GPS measurement technique was tested recently within an alpine catchment in winter and spring 2012/13. The measurements were situated at the high-alpine SLF test site Weissfluhjoch (46°49'47" N, 9°48'34" E) near Davos in Switzerland. Three low-cost GPS receivers connected with low-cost GPS antennas were installed. One antenna was mounted at a high pole (GPS_{pole}) which was always situated above the snow cover. The GPS signals received at this antenna serve as a snow free reference indicating atmospheric influences. Before the first snow fall in winter, two redundant antennas (GPS_{ground}) were brought out on the ground at an even place and were buried underneath the snowpack during the entire snow covered period. The signal losses registered at these antennas indicate the wetness of the snowpack. A schematic overview is given in Fig. 1. For validation, meteorological and snow-hydrological data were continuously recorded at the same site.

2. GPS data

The freely available GPS data are transmitted via L-band microwaves at a frequency of 1.57542 GHz. The signal strength for each of the 32 GPS satellites is expressed as carrier-to-noise-power-density ratio (CNo) and is continuously recorded with a temporal resolution of one second within the GPS raw data protocol. Per definition, CNo is a bandwidth-independent index and is used for assessing signal quality and quantifies the signal power of the received signal of each tracked satellite (Hofmann-Wellenhof et al., 2008). The data analysis is based on normalized CNo data considering a snow-free reference as well as elevation and azimuth information for each satellite at each time step. The microwave GPS signals interact as L-band microwaves with the snowpack, especially when it becomes wet (Hofmann-Wellenhof et al., 2008, Bernier, 1987). Thereafter, the CNo values received at GPS_{ground} indicate the degree of signal losses due to attenuation, reflection and refraction processes within the snowpack and its surface. The normalized CNo values are aggregated to half-hourly data showing the evolution of the wetness of the snowpack continuously by registering changes of the snowpack in a high temporal resolution.

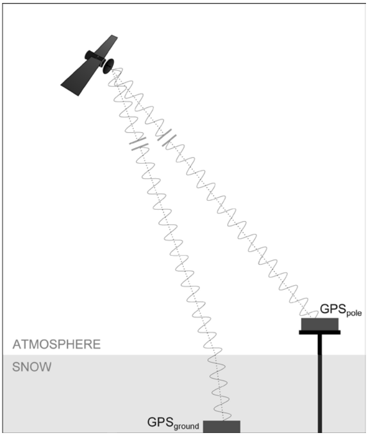

Fig. 1: Schematic of the experimental GPS measurement setup.

3. Start of the spring snow melt and daily melt-freeze cycles

In this study, the behavior of wet snow on the normalized GPS CNo signals was analyzed. At the test site Weissfluhjoch, GPS_{ground} was permanently covered with snow from the end of October 2012 until the beginning of July 2013. Until mid April, the snowpack was predominately dry, before the melt period started. The results cover exemplarily a period at the beginning of the spring snow melt. Fig. 2 gives an overview of the evolution of the normalized CNo values recorded with the GPS receivers as well as surface temperature, precipitation and snow lysimeter meltwater outflow measured at the SLF test site Weissfluhjoch for the time period 12-28 April 2013. In general, the lower the normalized CNo values, the wetter was the snowpack. The first two days of this period represented dry snow conditions without discharge at the lysimeter and constantly high normalized GPS CNo values. After 15 April, the air temperature reached values above 0°C during mid-day and the first meltwater outflow was measured. In accordance to the evolution of the temperature and the meltwater outflow, the normalized GPS CNo indicate with a clear decline the onset of the snow melt period as well as daily melt-freeze cycles with a minimum during mid-day and a peak during night-time. Shortly after reaching the GPS signal strength minimum, the peak discharge occurred at the lysimeter. A dry snowfall with air temperatures below 0°C led to an increase of the snow water equivalent on 19 April and interrupted the daily repeated melt-freeze pattern. During the following day no discharge at the lysimeter was recorded and the GPS CNo values showed no significant decrease. Less discharge was also measured on 22 and 27 April with colder air temperature around mid-day. In sum, Fig. 2 clearly shows the coincidence of the GPS signals and the meteorological recordings. In a further step, the GPS signal strength losses due to attenuation, reflection and refraction processes will be transformed into the bulk volumetric liquid water content considering the complex permittivity, by applying e.g. Tiuri et al. (1984).

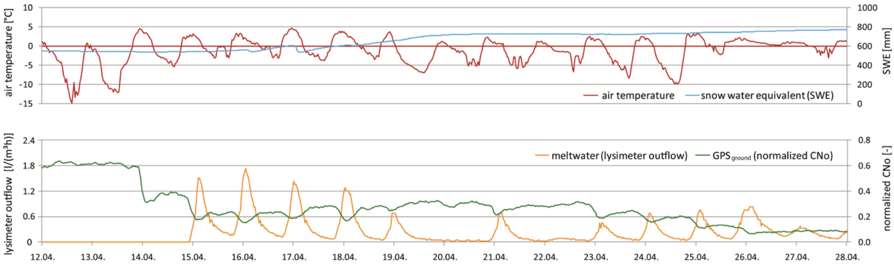

Fig. 2: Evolution of the normalized CNo values recorded with GPS_{ground} as well as air temperature, snow water equivalent and meltwater outflow at a snow lysimeter measured at the SLF test site Weissfluhjoch at the start of the snow melt period in 2013 (12-28 April 2013).

4. Conclusions

As a low-cost, globally applicable, low power consuming and non-destructive snow measurement setup, this approach might have the potential to be implemented in a basin-wide snow measurement network aiming at continuous data generation. Analyzing signal strength losses of GPS CNo data caused by wet snow has therefore a high potential for the determination of continuous measurements of the snow wetness with a high temporal resolution in basin-wide sensor networks for different hydrological applications. In general, a wider and more cost-efficient measurement network would improve e.g. low-flow and flood forecast models as well as water supply and hydropower estimates and would therefore also serve as a necessary basin-wide preparatory adaptation measure due to climate change impacts on snow which tend to cause an earlier runoff peak in spring.

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High flows regime analysis along the Danube

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Abstract
The aim of this paper is to analyze the occurrence of the high flows in the upper, central, and lower Danube basin based on time series of the daily discharge data. We identified the changes of the hydrological regime of the Danube downstream the Danube for the period 1876–2010 depending on the length of the time series in individual stations. The time series of the mean daily discharge were used from 23 stations along the Danube. For the individual stations we counted all floods over certain threshold value (from 4,000, to 16,000 m^3s^{-1}). The frequency of occurrence of selected high flows was counted for individual months.

1. Occurrence of the floods along the Danube
The time series of the mean daily discharge as well as maximum annual discharge series were used from 23 stations along the Danube River. The floods in the upper and lower parts of the Danube basin do not occur in the same years necessarily (Fig. 1). Generally, the high flows do not hit the whole area of the Danube basin. In the Upper Danube downstream Passau the highest instrumental floods occurred in 1862, 1897, 1899, 1954 and 2002 (Fig. 1a,b,c,d). In the Lower Danube reach those were the floods in 1897, 1940, 1942, 1970, 1980, or 1981. In 1897, 1965 or 2006 the flood hit the whole Danube basin (Fig. 1c). The highest discharge during the instrumental period in the Upper Danube occurred at Krems/Kienstock, 11,900 m^3s^{-1} in 2013, the second highest was 11,306 m^3s^{-1} in 2002 and the third one 11,200 m^3s^{-1} in 1899. At the Danube delta Bondar a Panin (2001) evaluated the discharge of 20,940 m^3s^{-1} during the flood in July 1897.

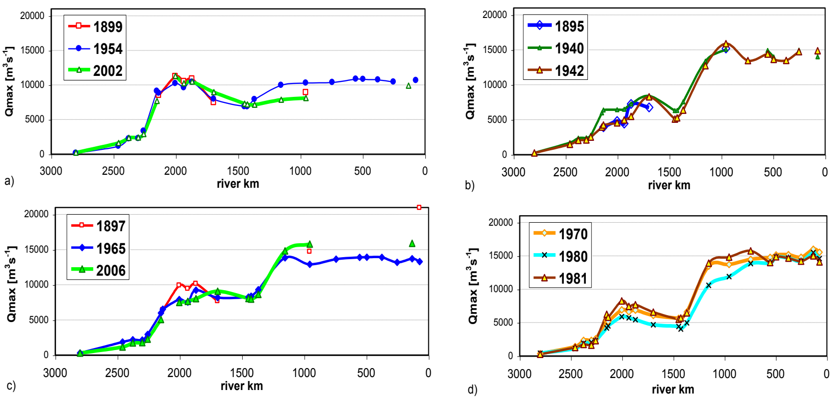

Fig. 1: Development of extreme floods downstream the Danube.

Between Stein-Krems and confluence with the Tisza river, there occurs transformation of the flood wave peak (see Fig. 2, 99th percentile p99). In Fig. 2 there is also the reconstructed discharge during the 1501 flood, according to Kresser (1957) the peak discharge was 14,000 m^3s^{-1} at Krems.

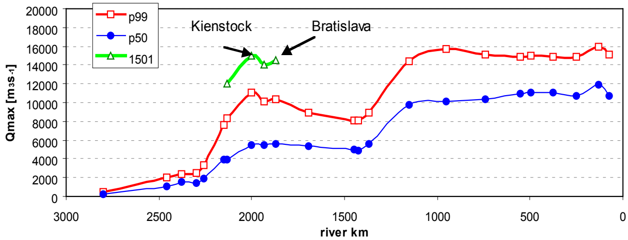

Fig. 2: Percentiles of the maximum annual discharge in selected stations downstream the Danube in the period 1876-2006. p99 – 99th percentile, p50 – 50th percentile and historic flood 1501.

1.1 Analysis of floods occurrence of the Danube at Bratislava, 1876–2013

From the whole 138-years series of mean daily discharge of the Danube at Bratislava 1876–2013 we counted all floods over 4,000, 5,000, 6,000, 7,000, 8,000, 9,000, and 10,000 m^3s^{-1} (Fig. 3). Five floods with peak discharge exceeding 10,000 m^3s^{-1} occurred during the 130-years period, once in May (2013), July (1954) and September (1899), and twice in August (1897, 2002). Totally we analysed 350 flood waves. In Table 1 there are listed the numbers of floods in individual classes during the whole 138-years period.

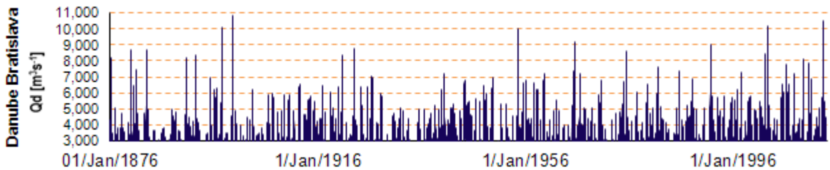

Fig. 3: Mean daily discharge, Danube: Bratislava, 1876–2013.

Table 1. Number of floods in selected discharge classes, and in months, Danube: Bratislava

Month/ discharge	4,000-5,000	5,000-6,000	6,000-7,000	7,000-8,000	8,000-9,000	9,000-10,000	10,000-11,000	**total**
I	19	3	4	1	1			**28**
II	8	7	2	1	3			**21**
III	14	11	6	2	1			**34**
IV	19	5	2					**26**
V	27	10	4	1				**42**
VI	30	12	2	3	2	1	1	**51**
VII	21	13	10	3	1	0	1	**49**
VIII	23	3	10	2	0	1	2	**41**
IX	19	2	1	1	2	0	1	**26**
X	4	1	1					**6**
XI	3	5						**8**
XII	11	4	3					**18**
total	**198**	**76**	**45**	**14**	**10**	**2**	**5**	**350**

The smaller Danube floods at Bratislava occur in May – June most frequently, the big floods above 9,000 m^3s^{-1} occur in June – September. According to some records, prior to the period of study, the 1787 "All Saints' Flood" at Bratislava occurred at the end of October and beginning of November with discharge 12,200 m^3s^{-1}.

The regime of floods was evaluated at Achleiten, Orsova and Ceatal Izmail in similar way to have a comparison with the upper, middle and lower reach.

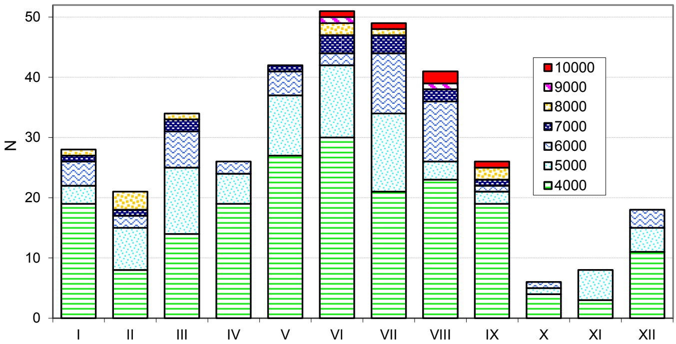

Fig. 3: Number of floods in selected classes and in individual months, Danube: Bratislava.

1.2 Analysis of floods occurrence along the Danube, 1901–2005

We assessed the occurrence of maximum annual discharge in four Danube stations in order to make basic comparison of the flood regime in individual parts of the river basin. The floods occur most frequently in June-August in the upper Danube basin, in April in the central part, and in April-May in the lower Danube basin (Fig. 4).

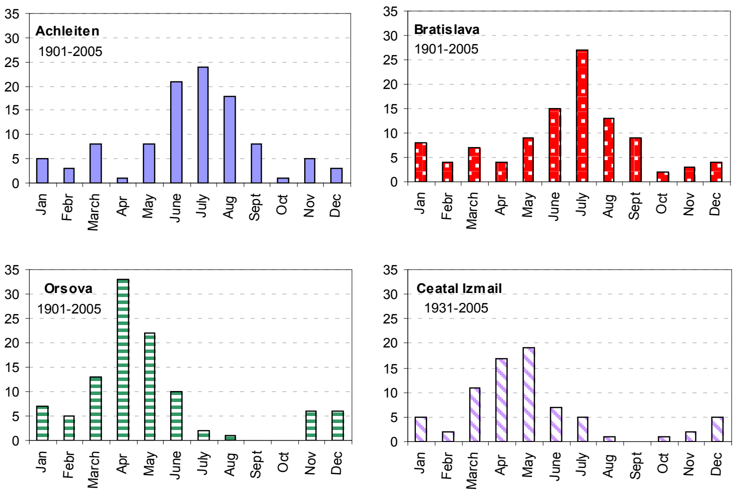

Fig. 4: Frequency of occurrence of the maximum annual discharge in individual months in selected stations downstream the Danube.

2. Conclusions

The occurrence of the high flows was evaluated in the upper, central, and lower Danube basin based on time series of the daily discharge data for the period 1876–2010. The regime of floods was evaluated at Achleiten, Bratislava, Orsova and Ceatal Izmail in similar way to have a comparison with the upper, middle and lower reach. Number of floods in selected classes and in individual months was counted. In each case the duration of the flood over certain threshold level was estimated as well. Due to limited extent of the only the results for Bratislava are shown mainly. The data will make possible to derive the typical flood shape and duration for each station.

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The Hydrological Service of Bavaria

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Bavarian Environment Agency

Introduction

The knowledge of the amount, distribution and quality of the available water is basic for water management and water research. In Bavaria this information in interest of public welfare is provided by a state service. The organization, main tasks and products of the “Hydrological Service” in Bavaria are presented here including current developments and challenges.
The state-run hydrology in Bavaria began about 200 years ago with the implementation of a network of river gauging stations. 115 years ago the “Royal Bavarian Hydro Technical Bureau” was established as a first professional authority. Today, hydrological services are the task of the Water Management Authority under the jurisdiction of the State Ministry for the Environment and Consumer Protection. Hydrological measurements are performed by the 17 regional state offices for water management. The Bavarian Environment Agency (LfU) as central technical authority is responsible for hydrological design, quality control and data management.
The Bavarian Water Act regulates the water surveillance by public law. The *legal supervision* of the waters lies with the county and municipal authorities. Only they can issue orders to water users. This has to be clearly distinguished from the *technical supervision* of waters by the water management authorities acting as official experts for the legal authorities. The technical water supervision in turn consists of two parts: the first part is the control of waters and installations with regard to legal proper conditions. The second part, which is presented here in more detail, is the hydrology of the natural water cycle and the quality of waters.

1. Hydrological measurements and investigations

Hydrological measuring of the water cycle comprises precipitation, rivers, lakes, seepage and groundwater. Thereby it has to be distinguished between quantitative and qualitative measurements. The measuring stations are organized in monitoring networks. Depending on their purpose these are statewide networks with uniform measurement programs for capturing the waters representatively or they are designed for specific parameters and regional issues.

The basic **quantitative measurement** in Bavaria records the variability of **water levels and flow rates** in rivers and lakes by about 560 stations of the state monitoring network. Water levels are measured continuously and digitally, but flow discharges usually only in time intervals. Given that discharge is often the decisive parameter for water management, continuous discharge hydrographs are derived from water level measurements by use of W / Q relationships. After the great “Pentecost flood” in Bavaria in 1999, hydrological metrology had been fundamentally revised. The focus was on fast and secure data availability for the needs of the flood forecasting service. The means to this end were digitalization, automation and redundancy. The water level is now being measured at all important stations with two different technical systems. Data are digitally recorded; automatically transmitted and stored and processed in central databases. Data transmission is also redundant via fixed and mobile networks. For discharge measurement, instead of traditional measuring vanes now the ultrasonic Doppler technology is used increasingly in order to measure and provide data quickly.

Monitoring of **water temperature** is of increasing importance, especially for low-water (drought) management and for monitoring of the impact of climate change on waters. Water temperature is measured at 113 sites once per hour and data are transferred remotely. In Lake Ammersee a measuring chain has been anchored at a buoy, which continuously records temperature profiles over a depth of about 80 m depth by a chain of 16 sensors.
Suspended sediments are monitored at 42 stations in Bavaria. Besides quantitative measuring of the transport of solids the results are used for other assessments like the effects of land erosion on silting the riverbeds and the water pollution caused by particle-bound pollutants.
Along the Main and Danube River six **automatic monitoring** stations are continuously measuring quality parameters and transfer them remotely. Along with continuous discharge measurements these stations are the backbone of emergency plans for aquatic ecology (see below).
Quantitative monitoring of **groundwater** includes groundwater levels, discharge of springs and groundwater temperature. The statewide monitoring network has about 600 measuring points for groundwater level and around 60 points for sources. The measurement of groundwater temperature provides important information for geo-thermal utilization and for the monitoring of climate change impacts. It is measured in the groundwater network and at sources.

The **qualitative measurement** of waters refers to physical, chemical and biological parameters. Nowadays the monitoring networks and programs are according to the obligatory three-tier approach of the Water Framework Directive (WFD) for the monitoring of water status. There are approximately 1.000 bodies of surface water in Bavaria. 37 sites for surveillance monitoring, and 1500 measurement points for operational monitoring cover them. The WFD also provides the ecological evaluation system with five classes from “high” to “bad” status. The **biological monitoring** for the WFD usually covers four quality elements of flora and fauna. This has led to an enormous expansion and differentiation of monitoring and assessment. This can be exemplified by a comparison: Previously, water quality was assessed by the saprobic system for benthic invertebrates, only one out of now four biological elements. Furthermore the former evaluation applied in equal manner to all types of waters, while now, evaluation according to WFD differentiates between 20 types of flowing water and 9 types of lakes in Bavaria.
The **chemical monitoring** for the WFD currently includes 162 river basin-specific substances and the 45 priority (hazardous) substances under the WFD. The 2013/39/EU Directive has now set Environmental Quality Standards for biota alongside those for water and sediments. An example is the concentration of mercury measured in fishes.
For 53 **lakes** in Bavaria with more than 50 ha surface area the chemical and biological monitoring has to be carried out according to the WFD as well. In lakes the biological sampling and analysis is particularly intricate and labor-intensive. Inter alia divers are deployed in order to detect the submerged plant growth.
For **groundwater quality** monitoring the statewide network has about 600 measuring points and is designed for the monitoring programs of the WFD of approximately 260 groundwater bodies. The standard parameters are nitrate, pesticides and heavy metals.
Integrated hydrological monitoring is established at 5 locations in Bavaria for a cross-media monitoring of the atmospheric deposition of substances into the water cycle. For this, the path of pollutants from rainwater or atmospheric deposition via seepage water into groundwater and further into adjacent rivers and wells of the public water supply is investigated.

2. Hydrological Services

2.1 Data Management and Data Services

The Hydrological Service is processing now about 500 million data records per year. The LfU manages the entire data processing from collection until provision of data and their quality management. The main instruments are integrated monitoring software and a system of primary and secondary databases. The Hydrological Service strives to publish all data to comply with the right of access to environmental information and at the same time to relieve the authorities from data requests. For this purpose a "**Hydrological Portal**" has been set up on the Internet, which is in constant expansion. This website currently contains 17 types of hydrological and meteorological data sets, which are available for free download.

Hydrography is another basic hydrological service, which is provided. The LfU maintains digital directories of waters collecting hydrographic features of rivers such as lengths of the river courses and extent of the catchment areas. On this basis, both analogue and digital maps are created. The digital cartography constitutes the basis of numerous GIS information systems. The archival long-term storage of measured data is important for scientific research issues.

All measurements and observations have to be analyzed and evaluated in order to extract useful information for **hydrological expertise and studies**. The LfU evaluates the measured data statistically in order to derive parameters of probability distributions and key figures for the design and control of engineering works. Another important task is regional analysis of data to generate synthetic hydrological variables for locations between gauging stations.

2.2 Warning and Information Services

Of particular public interest have always been extreme hydrologic conditions that pose special risks to society and economy. The Hydrological Service of Bavaria operates several warning and information services, which are disseminated via Internet and other media.

The **Flood Warning Service** in Bavaria operates flood alert plans with an information flow from the regional state offices for water management down to the affected communities. The operational core of this service is a flood forecasting service. Coordinated by the LfU five regional forecasting centers are providing forecasts of water levels and discharges for rivers and lakes. The predictions are calculated in rainfall-runoff models and hydrodynamic models based on measured data from 770 water gauging stations and 834 precipitation stations as well as future rainfall predicted by meteorological services. Other input is climatic parameters, such as air temperature, relative humidity and wind speed. Additional information sources are weather radar and satellite images. During a flood event frequent status reports and forecasts of water levels and discharges at around 100 gauging stations are permanently available on the Internet. Predictions are calculated for 6, 12 or 24 h and updated at least 4 times a day. At some stations a trend over 48 hours is displayed including an uncertainty range.

The **Low Water Information Service** on the Internet provides current values of six hydrological parameters that indicate critical situations in low water phases. The stations of the respective monitoring networks are displayed in maps with an assessment of the status by a color-coding. In times of low-water conditions additionally reports are published, describing the current situation and its effects together with a prediction of the further development.

Ecological Emergency Plans for the Bavarian river stretches of Main and Danube warn of critical conditions, which could cause damage for the river ecology, such as fish kills. These are especially periods of high temperature and low river flow. The system is based on real-time monitoring of water discharge, temperature, oxygen content, and the pH at automatic stations. At critical levels

a gradual alert and reporting system comes into force.
The **Avalanche Warning Service** for the Bavarian Alps publishes a daily status report in wintertime with a classified assessment of avalanche danger on the Internet. The alerts are based on data collected from automatic snow monitoring stations, snow measuring fields and reports of observers. The information benefits not only skiing tourists but also 35 avalanche commissions advising the local security authorities. An avalanche register serves the assessment of potential hazards in land-use areas and the planning of protective measures.

2.3 Hydrological Modelling and Planning

The Hydrological Service of Bavaria investigates the **impact** of **climate change** on the natural water cycle and aquatic ecology. For that purpose Bavaria conducts a research program together with other federal countries (KLIWA). Global and regional climate models are interlinked with water balance models or other impact models in order to calculate projections of future climatic and hydrological development in river basins. Sets of such projections are formed to ensembles, from which bandwidth of likely variations of climatic and hydrological parameters are derived. The objective is to develop adaptive measures in water management, such as a climate factor for the design of flood control works.
As already shown, water quality monitoring is now controlled by the **river basin management** of the WFD. At this stage monitoring primarily aims at the effects of pollution on the status of waters in order to planning measures. In future monitoring will increasingly aim at the effectiveness of measures taken. The logical frame for planning of the WFD has also preceded the monitoring by a systematic and comprehensive river basin analysis. These technical and economic investigations aim at an effective and efficient design of future water monitoring.
The EU-Directive on **flood risk management** is also based on a river basin planning concept, similar to the WFD. An important hydrological planning tool here are flood hazard maps and flood risk maps. They are based on different scenarios of flood risks driven by floods of low, medium and high probability. The results are processed in hydrodynamic models combined with digital terrain models for the design of floodplains classified by zones of water depth.

3. Developments and Challenges in Hydrological Services

Hydrological services currently show two sectors of “growth” yet with significantly different time reference. In the past hydrologic measurements typically were published annually. Meanwhile, acceleration has occurred. Operational services are expected to produce and disseminate information as soon as possible. In contrast, modelling calculations of the impact of climate change on the hydrological cycle are aimed on a time horizon of up to 100 years. Yet in both cases, hydrological data are used as input for intricate concepts or models of hydrological processes in order to emulate and predict them for warning or controlling services.
Hydrology is also driven by two external developments. Firstly, the continuous improvements of measurement and analysis open up new possibilities. Second, new environmental standards - mostly set up at European level - cause a further need for measurement, assessment and control of the state of the aquatic environment. The consequence for providers of hydrological service is an ever-increasing internal effort for data and quality management.

River discharge uncertainty estimation – a statistical approach

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Abstract
According to the complex workflow of river discharge estimation the quality assessment of this data is difficult. This fundamental working field of hydrometry is exposed to numerous uncertainties such as uncertainties in stage and discharge measurements as well as uncertainties in rating curve calculation. As a possible solution to handle this problem this study presents a statistical approach which combines the uncertainties of stage and discharge measurements as well as rating curves. The combined uncertainty values are assigned to daily mean and maximum discharge values to assess the quality of the discharge data. Based on this approach, corresponding quality criteria for low, mean and high ranges of water levels of 93 Bavarian gauges were obtained.

1. Uncertainty of stage measurements
The Guide to the expression of Uncertainty in Measurement GUM (ISO 2008) established general rules for evaluating and expressing uncertainty in measurement. According to this background the statistical GUM method type A was used to analyze the uncertainty in stage measurement.

First of all a plausibility check of available stage timeseries were carried out. For each gauge the correlation coefficient of the two redundant stage timeseries as well as the single control values and the according stage timeseries values were calculated (see Table 1). The standard uncertainty s_c for the 68% confidence interval derived from the combination of the calculated quasi systematic and random errors of stage measurements were assigned to three different ranges of water level.

$$s_c = \sqrt{s_{systematic}^2 + s_{random}^2}$$

To get the more significant combined standard uncertainty for the 95% confidence interval $s_{c,e}$ the extension factor k=2 for multiplication was used. As shown in Table 2 the combined uncertainty values estimated for 175 gauges are similar for low and mean ranges of water level and slightly higher for water level values greater than 75% quantile.

Table 1: plausibility check, systematic and random uncertainty and combined standard uncertainty (68% confidence interval) at gauge Ingolstadt Luitpoldstraße, Danube river

gauge station	river	ckd1	ckd2	cd1d2	s,sys	s,r1	s,r2	s,r3	s,c1	s,c2	s,c3
		-	-	-	mm	mm	mm	mm	mm	mm	mm
Ingolstadt Luitpoldstraße	Danube	1.00	0.99	0.99	4.5	4.1	4.6	5.3	6.1	6.4	6.9

ckd1	correlation coefficient between single control values (k) and stage timeseries W.DASA1 (d1),
ckd2	correlation coefficient between single control values (k) and stage timeseries W.DASA2 (d2),
cd1d2	correlation coefficient between the two redundant stage timeseries W.DASA1 (d1) and W.DASA2 (d2),
s,sys	quasi systematic uncertainty (68% confidence interval),
s,r1	random uncertainty (68% confidence interval) (water level values lower than 25% quantile),
s,r2	random uncertainty (68% confidence interval) (water level values between 25%-75% quantile),
s,r3	random uncertainty (68% confidence interval) (water level values greater than 75% quantile),
s,c1	combined standard uncertainty (68% confidence interval) (water level values lower than 25% quantile),
s,c2	combined standard uncertainty (68% confidence interval) (water level values between 25%-75% quantile),
s,c3	combined standard uncertainty (68% confidence interval) (water level values greater than 75% quantile)

Table 2: Combined standard uncertainty (68% confidence interval) for 175 gauges

low water level <25% quantile	mean water level between 25%-75% quantile	high water level >75% quantile
s_c (68% ci): 7 to 15 mm	s_c (68% ci): 7 to 15 mm	s_c (68% ci): 8 to 20 mm
$s_{c,e}$ (95% ci): 14 to 30 mm	$s_{c,e}$ (95% ci): 14 to 30 mm	$s_{c,e}$ (95% ci): 16 to 40 mm

s_c (68% ci) = combined standard uncertainty (68% confidence interval),
$s_{c,e}$ (95% ci) = extended combined standard uncertainty (95% confidence interval)

2. Uncertainty of discharge measurements

The standard method from DIN EN ISO 748 (DIN 2008) was used to obtain the uncertainty of discharge measurements. This method is similar to the uncertainty estimation method type B of the GUM (ISO 2008).

$$u_c(Q) = \left[u_m^2 + u_s^2 + \left(\frac{1}{m}\right)\left(u_b^2 + u_d^2 + u_p^2 + \left(\frac{1}{n}\right)\left(u_g^2 + u_e^2\right)\right)\right]^{\frac{1}{2}}$$

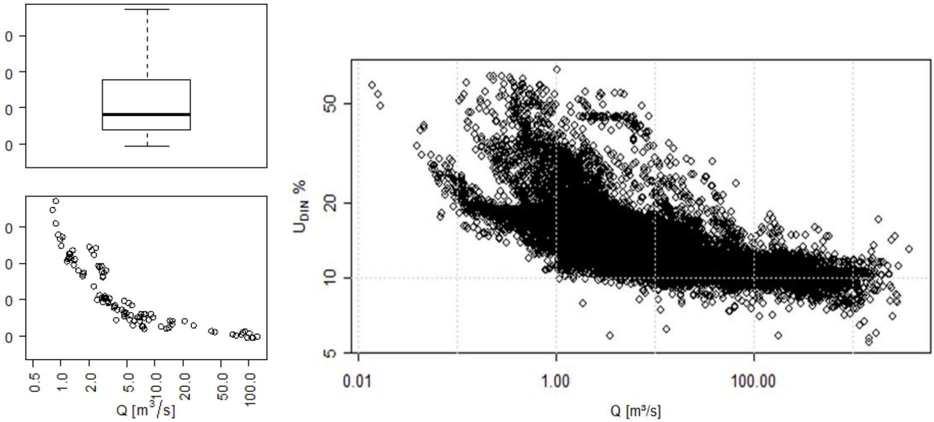
$u_c(Q)$	relative combined standard uncertainty (68% confidence interval),
u_m	uncertainty according to the number of measurement verticals,
u_s	uncertainty as a function of velocity, width and depth measurements (standardized 1%),
u_b	uncertainty of width measurement (standardized 0.5%),
u_d	uncertainty of depth measurement (d<= 0.3m u_d=1.5%, otherwise 0.5%),
u_p	uncertainty according to limited number of vertical velocity measurement points,
u_g	uncertainty depending on the velocity measurement tool,
u_e	uncertainty as a function of velocity variability during the measurement,
m	number of measurement verticals,
n	number of velocity measurements for each vertical

The extended uncertainty bound of the 95% confidence interval [U(Q)] of discharge measurements was derived from the following simple equation.

$$U(Q) = u_c(Q) \cdot 2$$

As displayed in Figure 1 there are generally increasing uncertainty values with decreasing discharge. The resulting average of the relative combined standard uncertainty [U(Q)] is 15% with a range from 5% up to 60%.

Figure 1: Relative combined standard uncertainty U_{DIN} as a function of discharge Q
a) gauge Unsleben at the river Streu b) relation between uncertainty and discharge based on 23.000 discharge measurements (1992-2011)

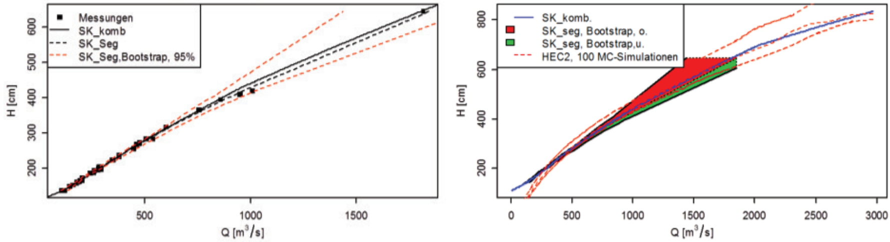


Uncertainty of rating curves

For the uncertainty estimation of rating curves within the range of measurements the statistical bootstrap method was applied. A basic requirement is the precise replication of rating curves represented by segmented potential functions (SegPot) (Willems and Stricker 2012). Applying the Lowess method from Cleveland (1979) and Cleveland et al. (1992), a weighted local-polynomial regression like a moving average technique in advance of the SegPot procedure, improved the adaptation in case of small numbers of discharge measurements at low and high water levels. Using a high number of varying discharge measurements samples the automatically parameterization of the segment specific functions with the bootstrap method carried out. Hence, it is possible to consider the uncertainty of discharge measurements as well as the uncertainties of the associated stage measurements in the uncertainty calculation of the rating curves.

Unlike some other studies, the uncertainty of the rating curves estimated not only within the range of discharge measurements but also the upper extrapolated part of the rating curves was considered. Therefore one-dimensional hydraulic recalculation of rating curves with the HEC2-model combined with a Monte Carlo simulation scheme was used. The main objective of the HEC2-model Monte Carlo simulation is to get rating curve uncertainty values within the range of discharge measurements which are similar to those received from statistical bootstrapping. The resulting 95% confidence interval (see HEC2 in Figure 2) represents a useful assumption of the rating curve uncertainty beyond the range of discharge measurements.

Figure 2: 95% confidence interval of the rating curve at gauge Ingolstadt Luitpoldstraße at Danube river within and beyond the range of discharge measurements



The left side of Figure 2 displayed the discharge measurements [■] with its related uncertainty (symbol size), the rating curve (SK_komb) and the adapted rating curve (SK_Seg) as well as the calculated 95% confidence interval at gauge Ingolstadt Luitpoldstraße, Danube river. The right handed picture in Figure 2 shows the 95% confidence interval of the complete rating curve, obtained from 1d hydraulic calculations (HEC2 model) within a Monte Carlo simulation scheme (100 simulations), in comparison with the related 95% confidence interval from bootstrap calculation.

To join the information obtained from statistical bootstrapping and that from one dimensional hydraulic modeling the 95% confidence interval values converted into separate relative standard uncertainties. The combination of the bootstrap uncertainty and the HEC2-model uncertainty were carried out by the application of inverse weighting factors. In case of low discharge values a weighting factor of 1 assigned to the bootstrap standard uncertainty was applied. While the weighting factor of the HEC2-model uncertainty increases from 0 to 1, a successive reduction of the weighting factor of the bootstrap uncertainty to 0 occurred until the rating curve discharge value similar to the highest measurement reached. Hence, the uncertainty values of the extrapolated part of the rating curves directly come from the HEC2-model simulation.

3. River discharge uncertainty

The combination of the standard uncertainty of the rating curve and the uncertainty of stage measurements was used to quantify the relative uncertainty U_{dm} of daily mean discharge after the method of Herschy (2009).

$$U_{dm} = \frac{\sum\left[\sqrt{(S_{mr}^2 + c_3^2 U^2 (H + c_2))} Q_h\right]}{\sum Q_h}$$

U_{dm} percentage standard uncertainty of daily mean discharge,
S_{mr}^{2} rating curve uncertainty,
$c_3^2 U^2 (H+c_2)$ uncertainty as a function of water level (Willems 2011),
Q_h hourly mean discharge

As displayed in Figure 3 there is a typical distribution of the relative standard uncertainty values with higher variations for low and high discharge values. The relative standard uncertainty at gauge Ingolstadt Luitpoldstraße, Danube river vary from a minimum of approximately 4% to the highest values of nearly 15%. The standard uncertainty values of daily maximum discharge are slightly bigger than that for the daily mean discharge.

Figure 3: Relative standard uncertainty (U) of daily mean and daily maximum discharge related to discharge values (Q) at gauge Ingolstadt Luitpoldstraße, Danube river (2003-2011)

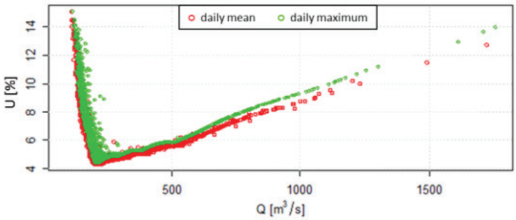
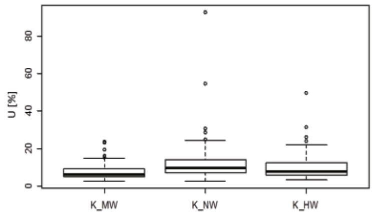


Figure 4: Uncertainty criteria K_MW and K_HW estimated as a func standard uncertainty values 93 Bavarian gauges



The following criteria are chosen to represent the discharge variation at lower, mean and higher water levels (see also Figure 4).

Mean water level („K_MW“): 5% quantile of the standard uncertainty of daily mean discharge
Low water level („K_NW“): 50% quantile of the standard uncertainty of daily mean discharge lower than the 25% quantile of discharge
High water level („K_HW“): 50% quantile of the standard uncertainty of daily maximum discharge higher than the 75% quantile of discharge

Especially the uncertainty criterion K_MW is a useful assumption of discharge variability at mean water levels. In cases of a small number of discharge measurements at low and high water levels a limited validity of K_NW and K_HW was observed.

4. Conclusion

The presented approach, based on a combination of the calculated uncertainties of stage and discharge measurements as well as uncertainties of rating curves was applied to obtain river discharge uncertainty for 93 Bavarian gauges. Combined uncertainty values assigned to daily mean and maximum discharge values are useful to assess the quality of discharge data. The new developed approach also provided corresponding quality criteria for low, mean and high ranges of water level.

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The use of copulas in hydrology: some useful case studies

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Abstract
Copulas have been used in several scientific fields and also applications of copulas have increased in the last decade. Copulas can be used to model multidimensional processes, however many hydrological processes, like floods and droughts, are multidimensional and therefore copulas seem to be an interesting option to carry out different multivariate analysis or perform bivariate and trivariate frequency analysis using copulas, which can be done as alternative to still mostly used univariate frequency analysis, where just one variable is considered in analysis. Bivariate and trivariate analyses were carried out for the Litija and Gornja Radgona gauging stations, which are booth part of the Danube river basin (Sava and Mura rivers, respectively). Different variables, as e.g. peak discharge (*Q*), hydrograph volume (*V*), hydrograph duration (*D*), hydrograph time ratio (*T*) suspended sediment concentration (*SSC*) were analysed and a methodology to estimate monthly sums of *SSC* is presented.

1. Theoretical Background
One of the main advantages of the copula functions compared to the classic multivariate distributions is that, different distribution functions can be used to model selected variables (this are marginal distribution functions). Therefore, one of the first steps is to fit classical univariate distributions to the selected variables and select the most appropriate distribution based on several graphical and statistical goodness-of-fit criteria and tests. The annual maximum method (AM) or the peaks over threshold method (POT) can be used to define sample in order to carry out analyses. In the presented case studies several parametric distribution functions, as e.g. log-normal (LN), Gumbel (G), generalized extreme value (GEV), Pearson 3 (P3), log-Pearson 3 (LP3), generalized logistic (GL), generalized Pareto (GPA), gamma (GAM) were used to model the selected variables. Distribution parameters were estimated with the method of L-moments (Hosking and Wallis, 1997). Graphical (e.g. QQ plot) and statistical (e.g. root mean square error (RMSE)) goodness-of-fit criteria and statistical tests (e.g. Anderson-Darling, Kolmogorov-Smirnov) were used in order to define the best fitting distribution function (Bezak et al., 2014a; Bezak et al., 2014b).

As a next step, one has to assess the dependence among the selected variables. This can be done using K-plot, Chi-plot or even with the calculation of different correlation coefficients, as e.g. Pearson's, Kendall's, Spearman's coefficients. Based on the dependence characteristics of the observed variables in the selected problem, at least two or three appropriate copula models are selected. Several symmetric and asymmetric copulas from different families are available and each copula has its own properties and it is more appropriate for specific problem. Some copulas are able to model just positive dependence between variables; while some other copulas are more flexible, meaning that can also capture negative dependence characteristics. However, e.g. Archimedean copulas are mostly used for modelling flood or high water events.

Copulas connect multivariate probability distribution and $F_{X_1}, \dots, F_{X_n}$ (univariate marginal distribution functions) (Sklar, 1959) and if these are continuous copula function (*C*) can be written with Eq. 2:

$$F(x_1, x_2, \dots, x_n) = C\{F_{X_1}(x_1), F_{X_2}(x_2), \dots, F_{X_n}(x_n)\}, \qquad (1)$$

$$C(u_1, u_2, \dots, u_n) = F\left(F_{X_1}^{-1}(u_1), F_{X_2}^{-1}(u_2), \dots, F_{X_n}^{-1}(u_n)\right). \qquad (2)$$

If a reader wants to find more theoretical information about copulas one should refer to: Joe (1997), Nelsen (2006) and Salvadori et al. (2007).

2. Results and discussion

In the next subsections results of three case studies using copula functions are presented. Bivariate and trivariate frequency analyses of *Q*, *V*, *D* and *T* were performed for the Litija station on the Sava river, trivariate frequency analysis of *Q*, *V* and *SSC* were done for the Gornja Radgona gauging station on the Mura river and estimation of the *SSC*'s monthly sums were done for the Ranca station on the Pesnica river (drains into Drava–Drau river). Table 1 shows some basic characteristics of the selected case studies.

Tab. 1: Basic characteristics of the presented case studies

Case study	Litija	Gornja Radgona	SSC's estimation
River	Sava	Mura	Pesnica
Stations	Litija (gauging)	Gornja Radgona (gauging)	Ranca (gauging), Polički vrh (rainfall station)
Analysed period	1953-2010	1977-2005	1970-1973
Sample	Annual maximum	Annual maximum	Monthly sums
Analysed variables	*Q*, *V*, *D*, *T*	*Q*, *V*, *SSC*	*Q*, *SSC*, Precipitation (*P*)
Catchment area [km^2]	4,821	10,197	84

2.1 Bivariate and trivariate analyses of data from Litija station on the Sava river

Šraj et al. (2014) presented results of bivariate frequency analyses of pairs *Q-V*, *V-D* and *Q-D* using copulas for 58 annual maximum events from the station Litija on the Sava river where graphical three-point method was used for baseflow separation. The procedure described in section 1 was used to carry out multivariate frequency analyses. However, some of the main conclusions were: correlation between *Q-D* is smaller than the correlation between the other two pairs, Gumbel-Hougaard copula from Archimedean family was selected as the most appropriate for modelling *Q-V* and *V-D* pairs, while Student-t copula was selected for the *Q-D* pair. However, differences among selected copulas were not significant and eventually some primary joint and conditional return periods were calculated (Šraj et al., 2014).
Trivariate analyses of variables peak discharge (*Q*), hydrograph volume (*V*) and hydrograph time ratio (*T*) were also done for the Litija gauging station on the Sava river. Hydrograph time ratio (*T*) is defined as a ratio between hydrograph's time of growth (D_g) and hydrograph's time of decreasing (D_d); which can be written as $T = D_g/D_d$. Based on the Kolmogorov-Smirnov test and QQ plot, LP3, P3 and Gumbel distributions were selected for modelling *Q*, *V* and *T* variables, respectively. Parameters of the marginal distributions were estimated with the method of L-moments. Then, based on the dependence assessment, which was done using K-plot, Chi-plot and correlation coefficients (Kendall's correlation coefficient for pairs *Q-V*, *Q-T* and *V-T* were 0.39, 0.04 and 0.11,

respectively), six copula functions were selected. Gumbel-Hougaard, Frank and Clayton copulas from Archimedean family were selected; however symmetric and asymmetric versions were used. Copula parameters were estimated with the maximum pseudo-likelihood method. All 6 six copulas were also tested with Cramer-von Mises test and none of the copulas could be rejected with chosen significance level 0.05. Using graphical goodness-of-fit test (Fig. 1) the asymmetric Gumbel-Hougaard copula from the Archimedean family was selected as the most appropriate for the presented problem. Primary OR and secondary Kendall's return periods were calculated and symmetric versions gave slightly lower return period values as asymmetric versions. These results can be interpreted as: symmetric copulas can underestimate the highest correlation, because all dependence structures are modelled with one parameter. However, this is not the case for the asymmetric copulas, where two parameters (in case of trivariate analyses) are used in order to describe dependence.

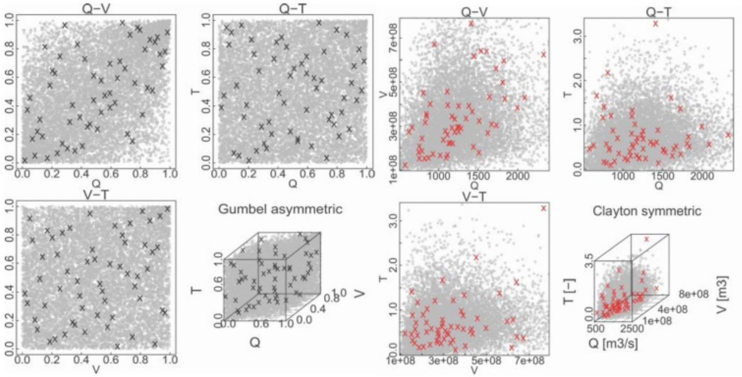

Fig. 1: Two types of graphical goodness-of-fit tests for the asymmetric Gumbel-Hougaard (left) and symmetric Clayton (right) copulas

2.2 Trivariate analysis of data from Gornja Radgona station on the Mura river

Bezak et al. (2014c) presented results of trivariate copula analyses for several gauging stations in Slovenia and USA where suspended sediment concentrations are also being observed. One of the analysed stations was also Gornja Radgona on the Mura river. Again, similar procedure as described in section 1 was carried out in order to perform multivariate copula analyses. Some of the main conclusions of the study were: Gumbel-Hougaard copula was selected as the most appropriate for modeling *Q-V-SSC* variables in case of all considered stations; asymmetric copulas are more flexible and can be used as an alternative to the symmetric versions of copula functions. Also, some primary and secondary return periods were computed and the results of the study indicated that copulas can be used for modelling peak discharges, hydrograph volumes and suspended sediment concentrations.

2.3 Estimation of *SSC* values

Copula functions can also be used for the estimation of different (missing) variables–variables. For the estimation of the monthly *SSC* data based on the *Q* series or based on the discharge (*Q*) and precipitation (*P*) data next equation can be used:

$$f_q(ssc) = P\{SSC \leq ssc | Q = q\} = \frac{\partial C_\theta(q,ssc)}{\partial q}, \quad (3)$$

$$f_{q,p}(ssc) = P\{SSC \leq ssc | Q = q | P = p\} = \frac{\partial^2 C_\theta(q,p,ssc)}{\partial q \partial p} / \frac{\partial^2 C_\theta(q,p)}{\partial q \partial p}, \quad (4)$$

where function $f \in [0,1]$, meaning that this can be replaced with values generated with uniform distribution (e.g. 1000 or 10000 values). Then Eq. 3 and Eq. 4 can be solved with the use of numerical methods (e.g. Newton method). As a results a distribution of possible values is obtained and then based on the most likely values (maximum of the density function), a final estimation is determined (empirical confidence intervals can also be easily constructed). In the final step of the estimation we transform the estimated values into real space using the inverse version of the selected marginal distribution function (*SSC* variable). However, the procedure of marginal distribution selection and copula definition is the same as in the all other presented case studies. Results obtained with the use of Eq. 4 were better as results of estimation of the *SSC* values just based on the standard *Q-SSC* curve, which is mostly used for the estimation of the *SSC* values (the analyses were performed for the monthly sums).

3. Conclusion

Results of the presented case studies show that copula functions are flexible and useful mathematical tool, which can be used for modelling different hydrological phenomena, as e.g. floods or sediment transport. Furthermore, a procedure for the estimation of the missing *SSC* values based on the *Q* and *P* series (monthly sums), using copulas, is also briefly described.

Acknowledgements

We wish to thank the Environmental Agency of the Republic of Slovenia (ARSO) for data provision. The results of the study are part of the Faculty of Civil and Geodetic Engineering (UL FGG) work on the Slovenian national research project J2-4096 and on the international research project SedAlp, which is financed by the European Union through the Alpine Space program.

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EFAS (European Flood Awareness System) – possibilities of system in the Danube river basin

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Floods belongs to the most dangerous and costliest natural disasters worldwide as well as in EU. Strengthening of actions for protection of these natural disasters becomes one of the main aims of actions of European Commission. EFAS (European Flood Awareness Systems) is focused on improvement of system of hydrological forecasts in European scale. EFAS is 1st operational hydrological network in Europe and belongs to the family of Copernicus emergency management service.

EFAS was developed on JRC (Joint Research Centre) in Ispra since 1999. Since 2012 EFAS is operated by operational services outside of JRC. 4 independent, but cooperating, centres are involved into the EFAS forecast´s issue and dissemination process. Data collection centre is divided into **Hydrological Data Collection Centre** and **Meteorological Data Collection Centre**. Rediam-Elimco consortium is responsible for hydro-data collection and management. JRC is still responsible for meteorological data collection and management. Computation process and management of EFAS – IS platform are provided by ECMWF – as **Computation Centre**. **Dissemination Centre (DC)** is responsible for output data analyses and communication with EFAS partners. DC was formed as consortium of 3 hydrological services from Netherlands (RWS), Slovakia (SHMU) and Sweden (SMHI).

Hydrological simulation is provided by LISFLOOD model. LISFLOOD is a GIS-based, distributed hydrological rainfall-runoff-routing model specifically designed to be used in large scale catchments. The model run in EFAS for all of Europe on 5km grid and either with a six-hourly timestep (Deterministic DWD and ECMWF forecasts, COSMO-LEPS forecasts) or daily timestep (Ensemble ECMWF forecast).

Results of computation process are visualised in EFAS – IS. All partner institutions have password protected account. EFAS outputs are available in the form of tabs, graphs and interactive maps. GIS based solution enables user to choose area, choose visible products (layers) and check outputs of model in chosen area (watershed). EFAS includes 38 partner institutions from 24 countries now. Most of partner institutions are hydro – meteorological service, some include Civil Protection services too.

EFAS is a system for early flood warning. It is based on probabilistic forecast with 48 hours – 10 days lead time. EFAS provides forecasts for whole river basins, across the borders, and allows sharing of information in the case of widespread incoming flood. Due to connections to Civil Protection, EFAS is able to help to harmonize help assistance before and during large flood crisis in Europe. EFAS warnings are issued in the form of EFAS alerts, watches and Flash flood watches, which are sent to partner institution by DC.

EFAS computation process is based on 4 main meteorological inputs. Two of them are deterministic forecasting models (DWD and ECMWF) and two of them are probabilistic models (COSMO – 16 ensembles and VAREPS – 51 ensembles). These meteorological forecasts enable forecast with 5 days (COSMO), 7 days (VAREPS and DWD), or 10 days (ECMWF) advance. Spatial resolution of meteorological models varies from 7 up to 30 km. Except of forecasts, EFAS is based

on measured data from more than 8 000 meteorological observation points and more than 500 hydrological stations.
EFAS starts its dissemination duty in 2010. Since that date, it was very helpful prediction tools in many difficult hydrological situations in hydrological operative on the field of SHMU. Its main advantage was longer time advance and international scope of view, which enables hydrologists to control the situation in the whole Danube river basin. Since 2012 is SHMU part of DC and is fully involved in EFAS operative. As a part of Danube region is SHMU responsible for Danube river basin. We would like to present two serious flood situation in Danube river basin. In the first case study, SHMU was not only EFAS DC, but affected area too – flooding on Danube in may – june 2013. Second case study presents SHMU in the role of forecaster – as part of EFAS DC.
2013 was very difficult for all parts of Dissemination Centre. Many river basins have been affected by serious flooding. 100 alerts and watches have been issued for 18 of partner states (all member states except of Finland, Belgium and the Netherlands). Many of them have been issued for the Danube river basin. Flooding in the Danube river basin in May – June 2013 was first important proof for new operational centres. It was caused by deep low pressure system with high rainfall accumulations (often more than 100 mm in 24 hours) in whole German and Austrian part of Danube river basin. Result of rainfall activity was flood affecting upper and middle Danube and its tributaries – mainly Inn and Enns.
First signs (forecasts) of possible flood activity did appear on 25th of May 2013. Although their probability was low, we started to monitor situation very carefully. Intensity of flood forecasts have increased in next days very significantly, but conditions for issue of EFAS alerts weren ´t fulfilled till 2nd of june, when first EFAS alerts have been issued for German part of Danube river basin. Another EFAS alerts related to this situation were issued for Austria, Slovakia, Hungary and Serbia in next days.
In this case, forecast of EFAS system was underestimated since the beginning of the flood situation. Also the expected peak time wasn ´t predicted very suitable. But EFAS has fulfilled its main duty – to issue early warnings for a possibility of flood situation in whole affected area.
The flood situation in Balkan part of Danube basin (Serbia, Bosna and Herzegovina, Croatia, Romania, Bulgaria) in May 2014, was the worst flooding in last 120 years in this area. Deep low pressure system called Yvette (Tamara) caused heavy rain in the south-eastern and central Europe. Rainfall accumulations in Bosna, Croatia and Serbia exceeded 400 mm nad were highest recorded ever. Most affected areas were Sava, Morava and Bosna river basins.
First signals of possible flood activity has occured at 10th of may and first EFAS flood alerts were issued for Serbia, Bulgaria and Romania for Morava, Timok, Olt, Jiu, Vedea and Arges rivers one day later. Next warnings have been issued for Romania, Croatia and Serbia in following days. Bosna is not a member of EFAS partnership, therefore no flood alerts could be issued from EFAS by usual way. Therefore warnings were sent to European Emergency Response Coordination Centre (ERCC) and Bosna was warned in this way. All in all 20 EFAS alerts and watches and 7 flash flood alerts were sent to 5 countries + Bosnia from 11th to 15th may.
EFAS is not a tool for prediction of water stage or discharge. It is just early warning system. And this function - as early warning system was fulfiled in both presented case studies. Due to developments in EFAS system, effectivity, accuracy and time advance of EFAS will increase in near future and we hope that its applicabillity in the system of flood prevention and protection will increase.

DEM-based Ukrainian Hydrography Dataset as part of Ukrainian National Spatial Data Infrastructure

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Introduction

Watershed and river network delineation, based on automatic feature extraction from a DEM is capable of creating a hydrography dataset (HD) for the *Ukrainian* National Spatial Data Infrastructure (NSDI). Well-integrated and topologically-consistent hydrography layers are required as a basic layers to perform GIS analysis, hydrologic modelling, sustainable landscape management.

Furthermore, this process will establish a cooperation between Ukrainian state and scientific institutions by means of standardized water resources data for all the stakeholders. Ongoing EU and USA (National Hydrography dataset 2 Plus) scientific projects should encourage Ukrainian authorities to adopt best practices in the HD development. Overview of the processing workflow and the input geodata quality needed described in this article.

1. Case study

The HD of Ukrainian NSDI consists of 9 main watershed regions (Grebin, 2013): Vistula (Western Bug and San) - I, Danube - II, Dniester - III, Southern Bug - IV, Dnipro - V, Don (Seversky Donets) -VII, Prychornomorya - VI, Pryazovya - VIII and Crimean rivers watersheds – IX.

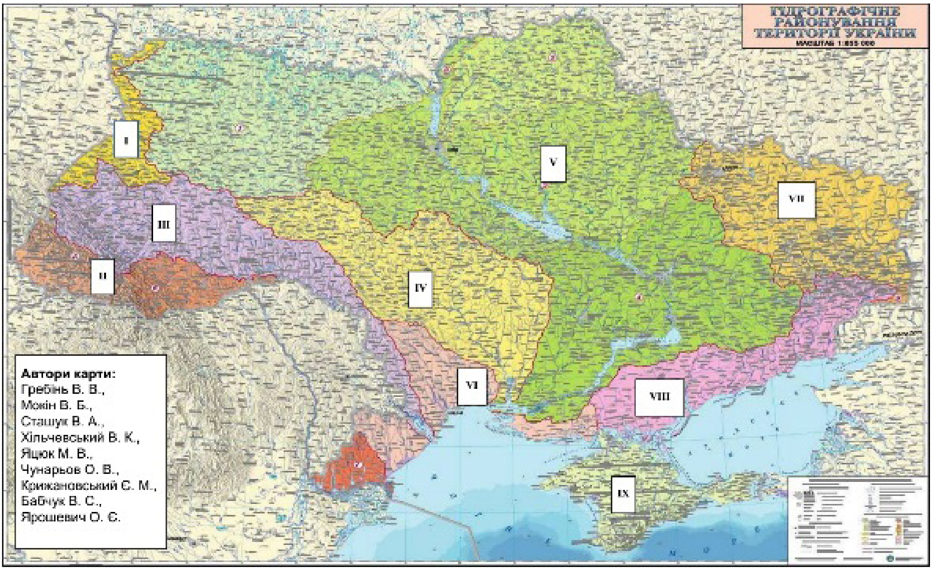

Fig. 1: Hydrographic delineation of Ukraine (Grebin, 2013)

This dataset was made based on a 1:250000 scale map regardless to the needs of hydrological modeling for the transboundary watersheds that also relies on the data from the rivers upper part.
We have also assessed the European catchments and River network System (ECRINS, 2012) compliant to the INSPIRE Directive, however this data has discrepancies with a real watershed configuration.

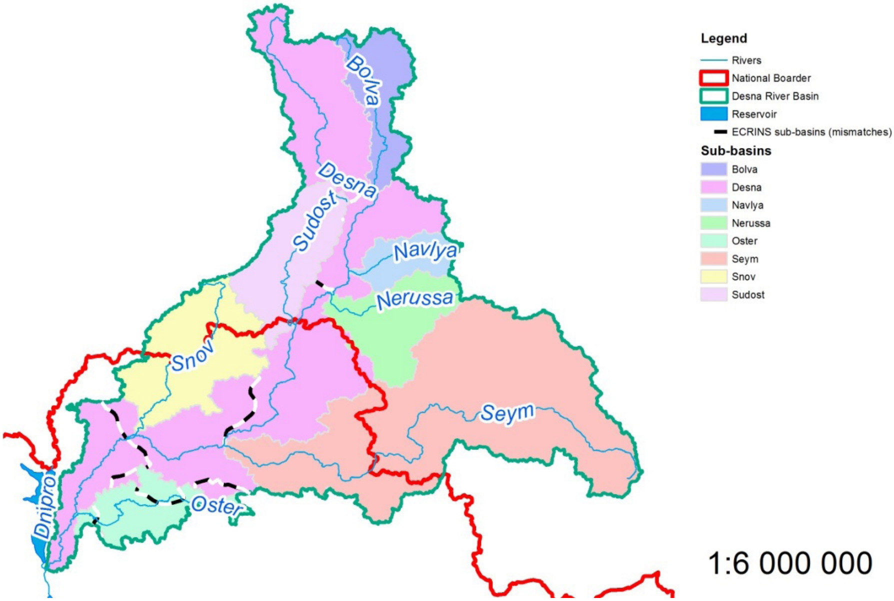

Fig. 2: An example how ECRINS data mismatches the general structure of the transboundary Desna river watershed.

2. Methodology approach

One of the solutions is to use a global scale DEM products to automatically delineate three layers of watersheds for: hydrological modeling purposes (divided by the stream gage network), general geographical overview (as seen on the map, divided by the junctions of the first-order tributaries) and for the water management purposes.
The DEM-based stream network delineation algorithm implements the cell-to-cell flow accumulation concept. This concept is widely used in GIS, HIS and modelling software, mainly as D8 and Dinf methods. In other words, it assumes that river is convergent to talweg and should be derived from DEM (raster representation), instead of being digitized from topomaps (vector representation) and enforced back into DEM.
Nevertheless, prior semi-automatic hydrological conditioning of DEM is needed to fill inland sinks, link the flow paths and form river valley with a minimum data alteration of heights, slopes and to obtain the river network that matches the real structure. Spatial resolution and scope of the DEM have a big impact on the derived data accuracy (Fig.3), not only by mismatching the optical image but also by overestimating the stream length when using too detailed LiDAR data without sufficient preprocessing (Charrier, 2012).

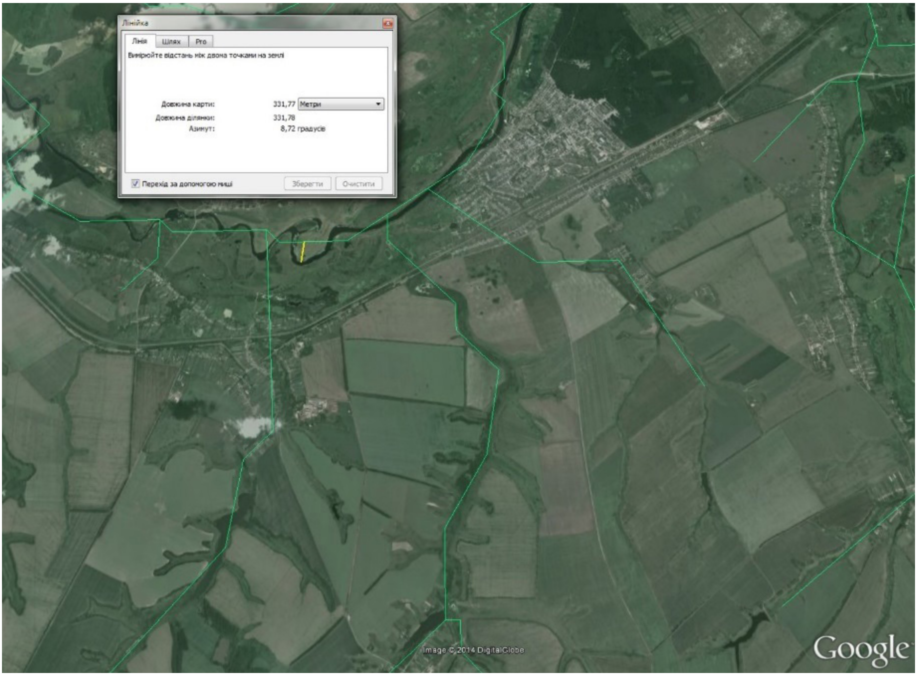

Fig. 3: SRTM HydroSHEDS 90 meter derived data mismatches river by approximately 300 m (© SPOT Image Copyright 2012, CNES)

Furthermore, the threshold parameter to determine streams, catchments and the scope of processing are interrelated with a variability of river density. To overcome this issue map algebra is advised to be used on the stage of the flow accumulation grid, to incorporate such parameters as river base level, average precipitation rates (Gartsman, 2013) or influence of the forest cover within the certain river buffer.

3. Conclusion

This paper examines the required input data and processing workflow to create hydrography dataset for the Ukrainian NSDI. Quality control of near-global scale Aster GDEM2 (30 m resolution), SRTM v.4 (90 m), USGS HydroSheds (90 m) and fine-resolution LiDAR (<2 m) data was examined to extract the most accurate and consistent stream network and watershed boundaries.

It became clear that Aster GDEM2 has many artifacts (sensor data errors) and does not represent real earth terrain even after filtering. SRTM and HydroSheds hydro-conditioned data is too coarse to represent river curvature, so derived river network positioning mismatch «true river» on fine-resolution satellite images, however this data is freely available for our case study and can be used in a pilot project to determine the watersheds for the Ukrainian NSDI. In addition, coordinates of stream initiation points should be clarified and topographic maps used to obtain a stream names.

LiDAR data might overestimate the stream length, reveal man-made features (bridges, dams) that terminate the flow, although, resampling LiDAR point cloud or SAR data to 8-10 m resolution represents the most accurate result and provide consistent spatial reference data for hydrological and hydro-chemical analysis. The most prominent result will be obtained with a new TanDEM-X WorldDEM 12 meter resolution data with the deriver DSMhydro by fusing in case of flood-prone areas with the LiDAR data to obtain a better river valley morphology for floods forecasting. Ukrainian Hydrometeorological Institute as science organization is interested in cooperation with the German Aerospace Center to design a pilot project for obtaining the hydrography dataset for the Desna river watershed or its part.

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http://www.projects.eionet.europa.eu/ecrins - European catchments and River network System

Detecting changes in annual maximum discharges in the Slana and Ipel River basins, Slovakia

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Abstract/Introduction

The study of changes in hydrological long-term time series has become a topic of rising scientific importance in connection with a number of large floods observed in recent years worldwide and also in the Slovak Republic. The aim of the study was to analyse changes in trend and seasonality of occurrence of the annual maximum discharge (AMD) series in South Slovakia. Catchments of Ipel and Slana Rivers where observations of annual maximum discharges were longer than 40 years were chosen for the study. Hydrological time series operate under the assumption of homogeneity and stationarity. Homogeneity of the time series was tested by a non-parametric Mann-Whitney-Pettit test (MWP, Pettitt, 1979) and Alexandersson test (SNHT, Alexandersson, 1986) for single shift at 5% levels of significance. Further calculations were evaluated with emphasis on the homogeneous stations. The Mann-Kendall (MK, Kendall, 1975) test is commonly used in engineering hydrology to detect trends, but when the data do not follow the normal distribution or are autocorrelated, the use of test corrections is suggested. Therefore corrected Mann-Kendall trend test (HR, Hamed and Rao, 1998) was used to assess the significance of detected trends at 5, 10 and 20% levels of significance in 40-, 60- and 80-year-long time periods. Seasonality studies of hydrological processes have also become a topic with renewed interest due to connection with floods and therefore with development of river basin management plans. Seasonality as seasonality concentration index and mean day of flood occurrence was computed to understand regime changes on the analysed rivers. Statistically significant decreasing trend was found in majority of these catchments. The results of the study can be helpful in future by mapping of flood prone areas in the Ipel and Slana River catchments.

1. Data

AMD from 10 gauging stations in the Ipel and Slana River basins, located in South Slovakia and mouthing into Danube River in Hungary, were obtained from the Slovak Hydrometeorological Institute. The AMD series for the trend analysis chosen are based on the length of the observations, which is more than 40 years, with a maximum length of 88 years. AMD represent the observed peak maximum values during hydrological year (starts on the 1.November), mean record length of data set was 76.3 years, median 81.5 years and mode 79 years. The catchment sizes vary between 57.38 and 685.67 km^2.

2. Results and Discussion

2.1 Homogeneity and Independence

The homogeneity was tested on all stations by the SNHT (Alexandersson and Moberg, 1997) method for a single shift and MWP test (1979) using AnClim software (Stepanek. 2007); only 3 stations were found not to be homogeneous at a 5% level of significance by both tests (Table 1.). We detected the year of change for non-homogeneous stations and re-evaluated homogeneity by shortening the time series, shortened the time series were found to be homogeneous. The causes of the non-homogeneity in the time series are unclear even after detailed analysis of the concerned time series and water structures constructions in the area.

Tab. 1: Stations tested at a 95% level of significance (p=0.05) according to the SNHT and MWP test (homogeneous stations are marked in bold, observ. – observation, stat. – statistics, val. - values)

		SNHT single series shift				MWP			
Station ID	Start year of observ.	Test stat.	Year of change	Critical val. p =0.05 (Khaliq and Ouarda, 2007)	Result	Test stat.	Year of change	Critical val. p=0.05	Result
7440	1931	16.31	1942	8.951	N	602	1981	508.7	N
7500	1962	8.65	1968	8.382	N	222	1985	244.8	H
7580	1931	13.32	1968	8.951	N	819	1968	508.7	N
7600	1931	9.53	2010	8.951	N	531	1978	508.7	N
7670	**1922**	**3.25**	**1930**	**9.047**	**H**	**286**	**1933**	**596.6**	**H**
7680	**1960**	**3.75**	**1976**	**8.432**	**H**	**140**	**1979**	**259.8**	**H**
7730	1925	16.59	1986	9.062	N	867	1986	566.8	N
7830	**1923**	**3.80**	**1998**	**9.047**	**H**	**522**	**1987**	**586.6**	**H**
7860	1926	9.07	1979	9.001	N	546	1980	566.9	H
7885	1926	9.848	1962	9.001	N	632	1962	556.9	N

Trend analysis

The Sen's slope (1968) and trend analysis tests were programmed and performed in the R free software programming language using the fume and Kendall packages (McLeod 2011, Santahter Meteorology Group 2012, R Core Team 2013). The trend was detected positive in station 7885 and was negative in the rest of the cases for the whole observed time period by Sen's slope. The corrected HR test for lag-1 autocorrelation was applied to the discharge series to assess the statistical significance of the trend for different observation lengths: 40 years from 1970 to 2010; 50 years from 1960 to 2010; 60 years from 1950 to 2010; and the whole period of time observed at all the stations. The results were evaluated at the significance levels of 5, 10 and 20% (Table 2.).

Tab. 2: Results of the significance analysis (decreasing trend –3= significance at 5%, -2= significance at 10%, -1 = significance at 20%, 0= no significant trend detected, rising rend 3 = significance at 5%, 2= significance at 10%, 1 = significance at 20%) Homogeneous stations marked in bold

Station ID	Whole time period	2010-1970	2010-1960	2010-1950
7440	-3	-3	-3	-3
7500	-3	-1	no data	no data
7580	-3	-1	-3	-3
7600	-3	0	-3	-3
7670	**0**	**0**	**0**	**1**
7680	**0**	**0**	**0**	**no data**
7730	-3	-3	-3	-3
7830	**0**	**-3**	**-2**	**0**
7860	-3	0	-1	-1
7885	0	-3	-2	0

The null hypothesis (no trend in the time series) could not be rejected at the 20% significance level in 2 cases in the 40-year-long time period, in 2 cases in the 50-year-long time period, in 2 cases in the 60-year-long time period. At the 10% level of significance, a trend was observed in 2 cases in the 50-year-long period. A trend at the 5% significance level was found in 4 cases in the 40-year-long time period, in 4 cases in the 50-year-long time period, in 4 cases in the 60-year-long time period, and in 6 cases for the whole available time series. In all cases but one a decreasing trend was detected. In the stations, which were found homogeneous by previous tests (7670, 7680, 7830), was found trend of weak significance or no trend.

2.2 Seasonality analysis

The seasonality analysis of annual maximum discharges (AMD) was based on the Burn index (1997). Mean date and variability of occurrence were computed for 4 decades (1971-1980, 1981-1990, 1991-2000 and 2001-2010) and also for the whole time period (Table 3.). With higher elevation the month of occurrence moves from spring (March, April, May) to summer season (June, July, August). The most significant decadal shift of two months was observed in station 7600. More than 6 months shift (f.e. 7730, 7830) of the mean date of occurrence between decades was observed, but in most of the cases the variability of occurrence reached less than 50%, therefore the AMD are likely to be more evenly distributed during the year. The causes of this can be the influences of weather patterns as indicated in Parajka et al. (2010).

Tab.3: Seasonality analysis, colour represents the month of occurrence, in bold are marked months with variability of occurrence stronger than 0.5

Station ID	Elevation (m a.s.l.)	1971-1980	1981-1990	1991-2000	2001-2010	Whole observed time period
7440	172.4	February	**March**	March	April	March
7500	166.25	March	**April**	**April**	March	April
7580	139.47	February	**April**	March	**February**	March
7600	142.02	**February**	**April**	April	**March**	**March**
7670	411.97	July	April	July	**May**	May
7680	324.04	June	June	June	**May**	June
7730	284.95	July	May	August	**May**	June
7830	411	September	**June**	September	May	July
7860	263.65	February	May	September	April	April
7885	157.98	March	April	**May**	**May**	April

3. Conclusion

The paper was focused on results of an analysis of changes in annual maximum discharges in the Ipel and Slana River basins. The quality of the data set was tested by the SNHT and MWP tests. The MK and HR trend tests were applied to different observation lengths – 40, 50, 60 and more than 40-year-long time series obtained from 10 gauging stations. The analysis of the trend significance revealed, that there is a strong decreasing trend of AMD present. Seasonality analysis revealed, that there is weak variability of occurrence present in the AMD. Significant decadal shift in the mean date of occurrence was more than two months. The results of analysis can help when mapping flood risk areas and developing river basin management plans in the Ipel and Slana River basins.

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Testing of the Drava River Water Level Periodicity

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Summary
This paper analyses the periodicity of time series of water level data of the River Drava next to Donji Miholjac, recorded from 1890 to 2012. For this purpose, the numerical model of harmonic function was used from the Mathematics programming package, as well as a suitable method for determining the initial approximations. The multiple periodicities of water levels (annual; 10-year and 40-year period) and their parameters have been established based on 36,524 data, as well as by application of a linear-trigonometry regression and a non-linear optimization. The procedure has been tested on three series of data (according to different adjustment - according to height, position and accuracy), with various fundamental data (daily, average monthly, average annual water levels, etc.), and different lengths of the periods observed. Results (periodicity parameters) are almost the same, with occasional distinguished deviations of the long period established.
The presented procedure is proven to be convenient for the analysis of time series data on natural characteristics. In view of the mathematically established characteristics of water levels of the River Drava, the options for practical application (forecasts) have to be considered further on.

Introduction
The river regime is a consequence of the various events in its entire (upstream) catchment area and represents a component of the hydrological cycle. Global hydrological cycles are largely dependent on climate change whose occurrence is mainly driven by the solar and ground influences. Global model of redistribution of waters can be analyzed by using various databases (Chapanov, 2010). In this sense, there is a utilization of data on the Earth rotation, data on solar radiance and ice thickness recorded at sea during last 400 years, then data on the sunspots phenomena, and data on the average sea level over the last 300 years, as well as other data. What has been detected in the process is the existence and effect of the 11-year cycles of sunspots and the 45-year equatorial asymmetrical solar cycles.
The knowledge of the river water regimes is widely applied in the field of environmental protection and hydromechanics. For example, the extremely low or high waters may have a significant impact on local ecosystems in rivers and wetlands (Bonacci, 2003; Swanson, 2011). Regular monitoring and studying of river water levels is important for many water management activities. In this context, the analysis of trends and short- and long-term forecasts of water levels are subject to a number of researches.
This paper introduces the application of an effective procedure for estimation of parameters of a linear- trigonometric regression based on the available information on the water level trends of a certain river. The procedure is based on the application of a well-known method of a non-linear optimization (Dennis, 1996; Wolfram, 2011), with application of complete modules of the Mathematica programming package. The knowledge of the optimal parameters of a linear-

trigonometric regression allows the identification of relevant periodic factors affecting the time horizon of water levels.

1. Observation of the River Drava water level next to Donji Miholjac

It is evident from the description of the occurrences of time series of characteristic water levels applied in the said analysis that this has not been such an easy job as may be expected.
With over 300 km, the River Drava flows through the territory of the Republic of Croatia. The last 50 kilometres of Drava (as far as Donji Miholjac) is influenced by the regime of the River Danube which it flows into. Due to a sufficient distance to have the Danube retardation disregarded, the water meter station at Donji Miholjac is the most representative when it comes to various upstream occurrences in the almost entire River Drava basin. The lower River Drava has started to be observed at the end of the nineteenth century. Donji Miholjac hydrometric station is one of the oldest in the Republic of Croatia. It was established by the Austro-Hungarian authorities, with data first registered on 1 January 1890. While developing this paper, there has been the utilization of water level data from the Donji Miholjac site in the period from 1900 to 2012, and most daily water level readings (from water meters; or gauge boards) in centimetres have been available. However, the missing data refer to the periods between 1913 and 1922, and between 1944 and 1945 (12 years in total).

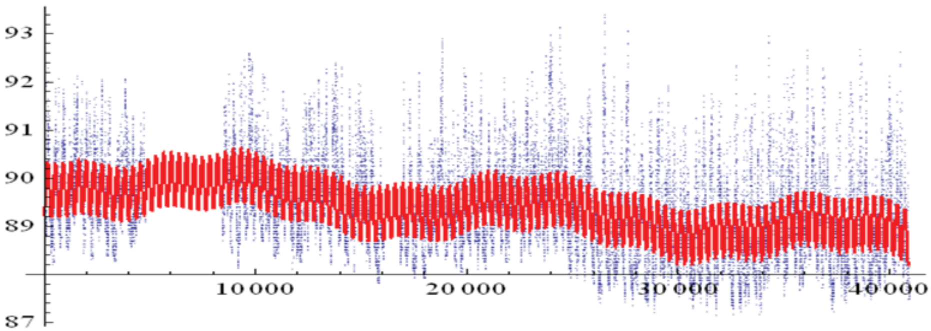

Figure 1: Details of the water level of the River Drava next to Donji Miholjac and a linear-trigonometric regression describing their trends

Given that the location of a meter of the monitored station has been changing over the time, and so has the absolute elevation of its "0", hence the data have been transposed into absolute elevations - metres above sea level (m a.s.l.) and therefore "equalized". Consequently, the basic B data series have been achieved. In this way, non-compliance caused by the water meter re-location has not been accepted because, in general, such recordings are not considered reliable. Unfortunately, this is the most common way of dealing with such information. In addition, no action is taken with regard to non-compliance related to parallel readings of both the old and the new gauge board. In this way, water levels (B) are expressed in meters above the sea (Trieste), taking into account, and according to relevant periods, water levels recorded at gauge boards at the elevations as follows: "0" = 88.54 m a.s.l. (1900-1970); "0" = 88.39 m a.s.l. (1971-1992); "0" = 88.57 m a.s.l. (1993-2011). In doing so, there have been some doubts.

Further data alignment was subsequently carried out by resuming it to an only one water level monitoring site, i.e. the old one at 77.00 r. km. At this point, the data on water table (VV) descending of 0.135 %o was used, for location next to Donji Miholjac (River Drava Hydrographic Atlas, 1972; plus Information based on the experience of professionals employed at Croatian Waters). In line with this, water levels between 1971 and 1992 have been corrected for + 8 cm, and water levels between 1993 and 2011 for -47 cm, which corresponds to the re-location of water meter 570 m downstream and 4 070 m upstream. Due to different data in parallel readings at old and new water meters, a new U2 data series has been formed. There, water levels between 1971 and 1992 were corrected for + 13 cm, and water levels between 1993 and 2011 for -37 cm. For the purpose of correction, the values of mean differences among data at old and new water meters have been used.

2. Analysis of the water level periodicity (Drava - Donji Miholjac)

For the purpose of this analysis we have used the data on the absolute values of water levels of the River Drava next to Donji Miholjac, for a period from 1 January 1900 to 31 December 2011. Since the data for a maximum of 12 years of the I and II world war are missing, observations altogether concern 100 years at that location, or 36,524 daily water levels recorded.

For the prepared data, a mathematical model is designed on the basis of the following assumptions: the information may have a linear component (of decline or decrease); their time horizon may be influenced by more periodic factors (whose characteristics include: basic period, i.e. angular frequency; amplitude and phase shift). This may define representative vectors, while their superposition may be described as linear-trigonometric regression. Finally, it is necessary to find the optimal parameters of such a regression. Addressing the optimization problem is a complex and numerically unstable process (Jarre, 2004), while the minimization function is a very sensitive to the choice of the initial approximation. As a consequence, the search for acceptable initial approximations should be given the utmost importance. The mathematical paper (Scitovski, 2012) is proposing and testing an acceptable method for determination of the initial approximation, and it is used in this analysis.

It has been assumed that the movement of water is affected by: a linear factor and 3 dominant periodic factors whose characteristics are the subject of this research. Optimum LS-parameters are derived by addressing the optimization problem, applying the modified Levenberg-Marquardt iterative process and obtained an initial approximation with the corresponding 95 % confidence intervals and the estimated $\sigma 2 = 0{,}61$ variance .

On the basis of the results obtained, it can be concluded that the water level of the River Drava next to Donji Miholjac is mainly affected by the following 3 periodic factors: Factor of the basic period of one year, amplitude ± 56.73 cm; Factor of the basic period of 10.32 years, amplitude ± 8.90 cm; Factor of the basic period of 39.37 years, amplitude ± 24.00 cm.

In addition, the linear component ($t \rightarrow 90{,}0276-0.000031\, t$) of the obtained model function may lead to an observation that the average water level of the River Drava next to Donji Miholjac in the period considered is around 90.03 m a.s.l. and has an average annual trend of decline by approximately 1.13 cm (Figure 1).

Furthermore, the additional analysis of the water level periodicity of the River Drava next to Donji Miholjac has been based on the average monthly, quarterly, semi-annual and annual data on the water levels. For example, the average monthly data are derived from daily measurement data as the arithmetic mean of all the data in the reference month. By analogy, the average ones are defined, too: quarterly, semi-annual and annual data. By way of comparison, the analysis has been carried out on the smaller data compilation, as well (for the period from 1946 to 2012). By applying the above methods and thus formed data, the optimal linear-trigonometric regression parameters have been determined. According to them, dominant periods in the data have been determined, as well. In all cases, the existence of the base dominant periods is noted as follows: from 1 year and slightly over 10 years. Less considered data reserves resulted in approximately one year longer period. The least likely period (because of the small data reserves) is the maximum period which for B series is close to 40 years, or some 47,5 years for the U series. It can be seen that in all cases the size of the amplitude of the annual periodic impact is about 55 cm; 10 cm of a 10-year periodic impact; and 25 cm of a 40-year periodic impact.

3. Conclusion

The proposed method of linear-trigonometric regression for the research of periodicity trends with river water levels can be an efficient tool in the hands of experts who research water levels and their applications. Notwithstanding the large number of data, the time of the computer operation necessary for identifying the optimal parameters is very short, hence absolutely acceptable (generally amounts to a few minutes).

The results of the research of the water level periodicity of the River Drava next to Donji Miholjac are in accordance with the existing findings when it comes to the global hydrological cycles, which mainly relate to solar activity cycles. Besides the options for applying the said method by means of the Mathematics programming package, this paper also points out the problems connected to collection and use of data on water levels. In the course of the analysis of the circumstances connected to observations of water levels next to Donji Miholjac, some data non-compliances have been found in the sense of location and altitude. The necessary equalization of the water level has been done, by the resumption of only one location and transposition into absolute altitudes. The issues encountered in connection to data have been a valuable experience that we should make other experts aware of.

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Bavarian information offers for hydrological service, flood- and low water information service

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Introduction

This extended abstract gives a short overview over the hydrological information services at the Bavarian Environment Agency, which offer hydrological and meteorological data in maps, charts, and tables, as well as additional relevant information.

1. The Bavarian flood information service online

In 1989 an online-platform (www.hnd.bayern.de) for the Bavarian flood information service has been developed at the Bavarian Environment Agency. Since this time it has been improved further continuously and today it is an essential part of the Bavarian flood warning system. It offers clearly arranged and comprehensive information about the current or an upcoming flood situation in Bavaria. Current data of water level, runoff, precipitation and snow is presented in maps, charts, and tables and is evaluated in regard to flood.
The map at the welcome page of www.hnd.bayern.de containing the gauges gives an overview of the spatial extent and the severity of an ongoing flood.
The severity of a flood is categorized by warn levels, ranging from no warn level (green) to warn level four (purple). Furthermore a status report summarizes the current situation as well as the expected future development and active warnings are provided for the administrative districts.
In charts the chronological evolution of water level and runoff is shown for every gauge. In addition for a large number of gauges forecasts are shown in the charts.

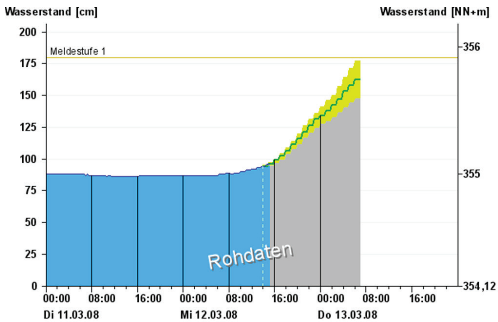

Fig. 1: water level chart at www.hnd.bayern.de

This online-platform is an important source of information for the public as well as public authorities and civil protection.

2. The Bavarian low water information service online

The drought-events in 2003 and 2007 have also show the necessity of a low water information service. Because of this the online-platform www.nid.bayern.de is operated since 2008. This low flow information service offers information about current and upcoming low flow conditions in Bavarian rivers, low groundwater levels, low spring discharge, high water temperature, and low oxygen saturation.

Measured data is classified in regard to drought and presented in maps, charts and tables in equivalent to the flood information service.
Precipitation is evaluated in maps as well as in charts. The map for precipitation shows the Standardized Precipitation Index, the measurement sites on the map show the duration of the ongoing drought.

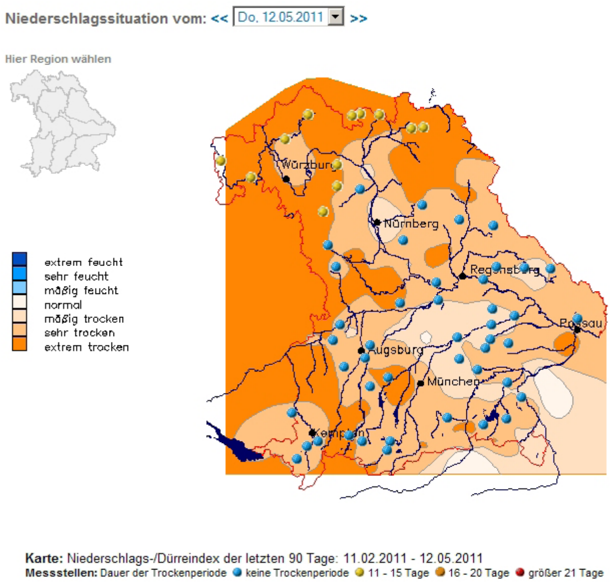

Fig. 2: Standardized Precipitation Index at www.nid.bayern.de

Daily discharge values are characterized by their statistical values: lower than the lowest daily mean (new lowest value), lower than the mean value of all lowest yearly values (very low) and lower than 75% of all values for the current month (low).

3. The Bavarian flood information service for smart phones

To meet the need of an increasingly mobile society, since 2010 the mobile web site (m.hnd.bayern.de) supplements the information offers of the Bavarian flood warning service. This web site is optimized for smart phones - it is easy to use and offers the important information of the online-platform of the Bavarian flood information service in a compact form.

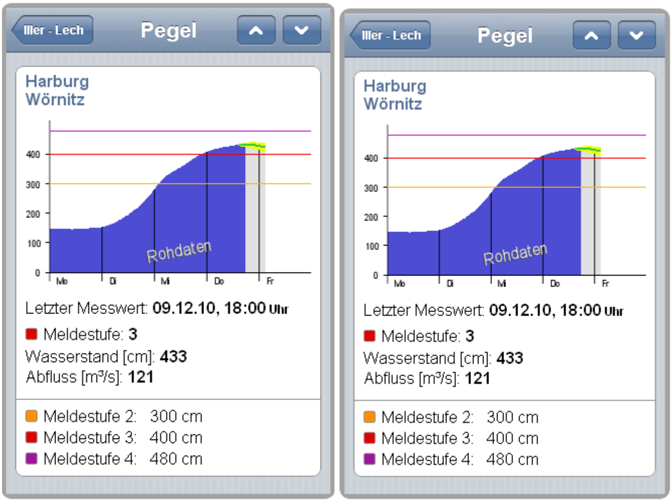

Fig. 3: welcome page and water level chart at m.hnd.bayern.de

4. The Bavarian hydrological service online

The latest innovation has been introduced last year: the information offer of the Bavarian hydrological service (www.gkd.bayern.de). The aim of this offer is to provide the public with longtime, reviewed hydrological data as simple and easy as possible.

In this web site not only data of water level, runoff, water temperature, ground water and spring discharge is available in charts and tables, but also all kinds of meteorological data and water chemistry indicators.

Fig. 4: download page for a measurement site at www.gkd.bayern.de

The data presented on this website can be downloaded in a simple csv-Format by choosing the download-link at the respective measurement site.

5. Conclusion

All these information offers serve a different aim and complete each other. It will remain a future task, to adjust and further develop the information offers according to the needs of the users.

At the moment the information offers for the flood information service and the low flow information service are revised – they will be published with a new layout and new functionalities in 2015.

The comparison of maximum annual and monthly discharge trends in Slovak's streams

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Abstract
The evaluation of trends in time series of average, maximum and minimum discharges is a part of the assessment of the climate change impacts on the hydrological regime. The Hydrological service of the Slovak Hydrometeorological Institute has processed an assessment of trends in mean yearly discharges and partitioned the territory of Slovakia in terms of the vulnerability according to the evolution of the mean water bearing. Similarly, the trends of minimum yearly discharges, monthly discharges and hydrological extremality assessment have been processed. As the extremality we consider the ratio between the highest and the lowest mean daily discharge in particular years and months.
In this article the trends of maximum discharges in the hydrological years and particular months are evaluated in selected 76 gauging stations, where the discharges have been evaluated since 1961 and earlier.
The mean daily discharge data series have been used as inputs, from which the selection of the extreme values has been done by existing database report tools. The obtained files of hydrological data have been processed and statistically analyzed using a non-parametric Mann-Kendall test, which is used to detect significant trends in time series. The main advantage of the Mann - Kendall test is that it is not affected by the current data distribution and is less sensitive to the appearance of the rare extreme values in the time series.
Particular trends have been categorized into the decreasing trends (significantly, medium and slightly) and increasing trends (significantly, medium and slightly), respectively without a trend.

Key words: Mann - Kendall test, maximum discharge, monthly discharge.

1. INTRODUCTION
The problem of occurrence of the extremity has been dealt with e.g. in the article of Pekárová et al. (2007), where the changes of maximum runoff volumes of Danube River were analyzed for two periods: 1876-1940 and 1941-2005. The authors have stated that the runoff volumes regime during last decades had practically been not changed. In the paper Holko et al. (2011) extremes have been evaluated using flood index, which had been set for 122 mountain basins in Slovakia and Austria. The statistically significant increasing trend has been found in 7 Slovak and 22 Austrian basins. In the paper of Pekárová and Pekár (2003) the authors tried to verify the hypotheses about the increase of extremes in the observed climatic and hydrologic data series by evaluation of climate change. The increase of trend was not confirmed.
In this article the maximum discharges are evaluated in 35 gauging stations for the whole observing (whole period available for concrete gauging station) period and in 76 gauging stations for the period 1961 – 2012. This study was applied on rivers and gauging stations of Slovakia's

sub-catchments (figure 1). The colors of sub-catchments used here are applied also in the tables 1 and 3, to show the relation of selected water-gauging stations to particular sub-catchments.

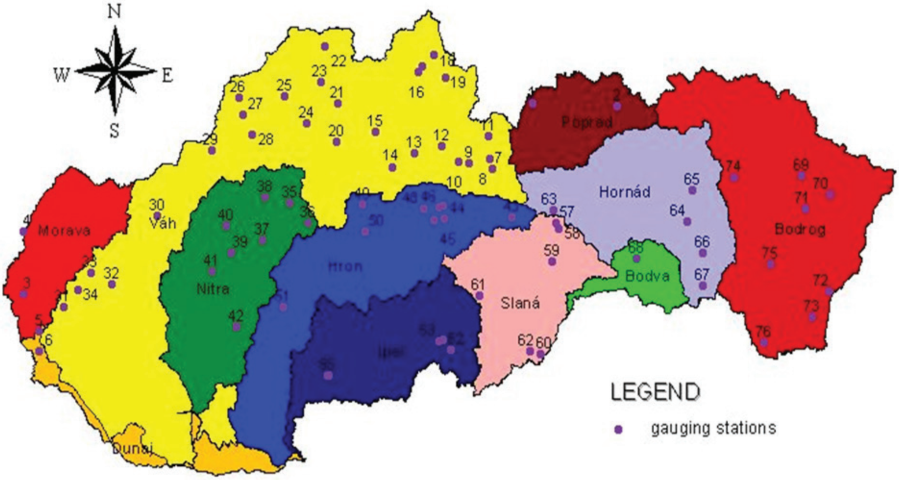

Fig. 1: Map of Slovakia sub-catchments

2. MATERIAL AND METHODS

The maximum discharge represents the highest mean daily discharge for the selected period, the maximum yearly discharge is the highest mean daily discharge of the particular hydrological year and the maximum monthly discharge is the highest mean daily discharge of the particular month (figure 2).

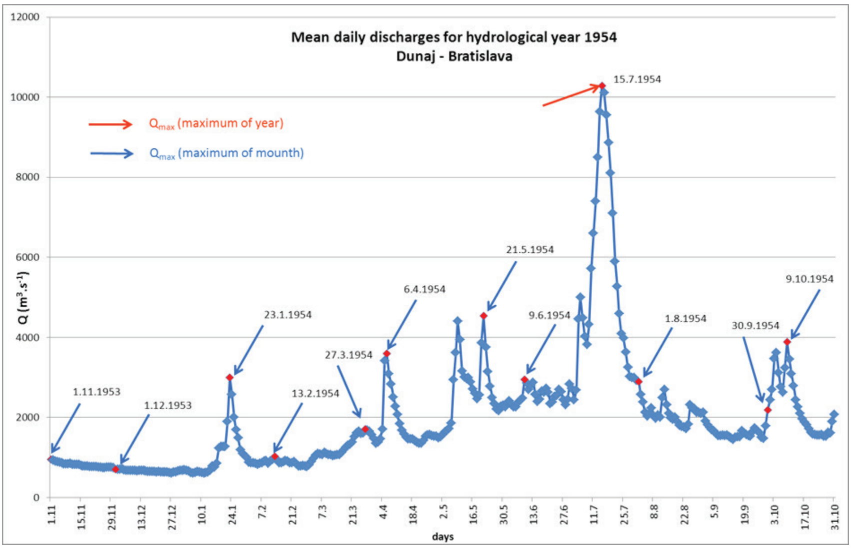

Fig. 2: Example of selection of maximum discharges in years/months

The direct outputs of these hydrological characteristics are provided by the hydrological information system of SHMÚ. The obtained hydrological data files have been processed and statistically analyzed using non-parametric Mann-Kendall test, which is commonly applied for detecting of significant trends in time series. The advantage of Mann-Kendall test is, that it is not affected by the current distribution of data set and it is less sensitive to extreme values in the time series. This test is especially suitable for larger-scale files with more than 40 data (WMO, 2008). Mann-Kendall test is based on the statistical values in the time series (Drápela and Drápelová, 2011).

3. RESULTS AND DISSCUSSION

The whole observing period:

The trends of maximum monthly and maximum annual discharges for the total observed time period have been evaluated in 35 gauging stations. The results are presented in the table 1. The observing periods for these stations are listed in the table 2. The situation of selected gauging stations is showed in figure 1.

Tab. 1: The resulting trends for the whole observing periods in 35 selected gauging stations.

number	flows	the gauging stations	catchments	11	12	1	2	3	4	5	6	7	8	9	10	year
2	Poprad	Chmelnica	Poprad	-3	0	0	0	-2	0	0	0	0	0	0	0	0
4	Morava	Moravský Ján	Morava	0	0	2	0	0	0	0	0	0	0	0	0	0
6	Dunaj	Bratislava	Dunaj	0	2	0	1	3	0	0	0	0	0	0	0	3
8	Biely Váh	Východná	Vah	-3	0	0	-2	0	0	0	-1	0	-2	-2	-3	1
9	Boca	Kráľova Lehota	Vah	-3	-2	0	-3	0	-1	-1	-3	0	0	-2	0	-3
11	Belá	Podbanské	Vah	-3	-2	0	0	0	0	3	0	0	0	0	0	0
12	Váh	Lipt. Mikuláš	Vah	-3	0	0	-3	0	-2	0	0	0	-1	0	0	-1
14	Revúca	Podsuchá	Vah	-2	0	0	0	0	-3	-3	0	0	-2	0	-1	-3
15	Ľubochnianka	Ľubochňa	Vah	-1	0	0	0	0	-3	-1	0	0	0	0	0	0
20	Turiec	Martin	Vah	-3	0	0	0	0	-3	-2	0	0	-2	-1	-3	-3
22	Kysuca	Čadca	Vah	0	0	3	0	0	0	0	0	0	-2	0	0	0
23	Kysuca	K.N.Mesto	Vah	-1	0	3	0	0	-2	0	0	0	-3	0	-1	0
24	Rajčianka	Poluvsie	Vah	-3	0	0	0	0	-2	0	0	0	-3	0	-2	-1
36	Handlovka	Handlová	Nitra	-3	0	0	0	0	0	0	0	0	0	0	-3	0
40	Bebrava	Biskupice	Nitra	-3	0	0	-3	0	-2	0	0	-2	-3	0	-3	-3
41	Nitra	N.Streda	Nitra	-2	0	0	-2	0	-1	-1	0	0	0	0	0	0
43	Hron	Zlatno	Hron	-3	-3	-2	-3	-1	0	0	0	0	0	-2	0	-3
44	Hron	Brezno	Hron	-2	-2	0	-3	0	0	0	0	0	0	0	0	-1
45	Čiemy Hron	Hronec	Hron	-3	0	0	-3	-2	-3	-2	0	0	0	0	0	-3
46	Bystrianka	Bystrá	Hron	-2	-1	-3	-3	0	0	0	0	0	-1	0	0	0
47	Štiavnička	Mýto	Hron	-3	-3	-3	-3	3	0	0	-3	0	-3	-3	0	0
48	Vajskovský potok	Dolná Lehota	Hron	-3	-2	0	-2	0	0	0	-3	0	-3	-1	0	-1
49	Starohorský potok	Staré Hory	Hron	-3	-3	0	-3	0	-3	-2	-3	-3	-3	-3	-3	0
50	Hron	Banská Bystrica	Hron	-3	-2	0	-2	0	-3	-2	-3	0	0	-1	0	-3
51	Hron	Brehy	Hron	-3	0	0	0	0	-1	-3	-3	0	0	0	0	0
52	Ipeľ	Holiša	Ipel	-3	-2	0	-3	-3	0	0	0	1	0	0	0	-3
54	Krivánsky potok	Lučenec	Ipel	-3	-1	0	-3	-3	0	-1	0	0	0	0	0	-3
55	Krupinica	Plášťovce	Ipel	-3	-2	0	-3	-3	0	-3	-3	0	0	0	0	-3
56	Litava	Plášťovce	Ipel	-3	-2	0	-3	-3	0	-3	-3	0	0	0	3	-3
57	Dobšinský potok	Dobšiná	Slana	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3	-2
59	Štítnik	Štítnik	Slana	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3	-3
61	Rimavica	Lehota nad Rimavicou	Slana	-3	-1	0	-3	-3	0	0	-2	0	0	0	-2	-3
62	Blh	Rinavská Seč	Slana	-2	-2	0	-3	0	0	0	0	0	0	0	0	3
66	Torysa	Košické Olšany	Hornad	0	0	0	0	-3	0	1	0	0	0	0	0	-1
74	Topľa	Hanušovce	Bodrog	-3	0	0	0	-1	0	0	0	0	0	0	0	0

Legend:

- increasing trend
- decreasing trend

1 -	slight trend
2 -	medium trend
3 -	significant trend

Tab. 2: The whole observing period in selected stations

Observing period	gauging station
1922-2012	Moravský Ján
1901-2012	Bratislava
1923-2012	Východná
1928-2012	Podbanské
1921-2012	Lipt. Mikuláš
1928-2012	Podsuchá
1931-2012	Others stations

The increasing trend of the maximum annual discharges has been identified as significant only in 2 water-gauging stations: in Bratislava on Danube River and in Rimavská Seč on the Blh River. The decreasing trend has been identified in 19 gauging stations and in 13 gauging station no trend has been manifested.

The assessment of the trends in the maximum monthly discharges has shown the significant occurrence of the decreasing trends, especially in the autumn and winter months. Decreasing trend is also visible duing the spring period, especially in the sub-catchments Hron, Ipeľ and Slaná.

4. Period 1961 - 2012

The trend assessment of the period 1961 - 2012 has showed the differences in trends in comparison with whole period observations. Among the 35 stations with long-term observation we have identified change of trends of annual maximum discharges in 18 gauging stations. The assessed trends in these stations have shown differencies mostly in the levels of significances and in one case (gauging station Blh – Rimavská Seč) even trend reverse.

Generally, for this period the significant number of decreasing trends of the maximum annual discharges has been identified (in 22 among 76 gauging stations). However, among 35 stations with long-term observation, the number of identified decreasing trends of annual maximum discharges has changed from 19 in whole period to 14 in period 1961-2012.

The increasing trends of annual maximum discharges have been identified in 4 water-gauging stations of 76 stations in this period.

The assessment of the evaluated trends of the maximum monthly discharges has shown the significant occurrence of the increasing trends in January (mostly in sub-catchments of Váh and Bodrog) and in period from July to October (in the sub-catchments of East Slovakia - Poprad, Bodrog, Hornád, as well as on Danube River), but most of monthly trends show decreasing and zero trends. When comparing the 35 stations with long-term observation, the change of monthly trends in the whole observation period and in the period 1961-2012 shows important change of decreasing trends for the months December, January, February and March to the zero trends or decreasing trends of lower significance, mostly in sub-catchments Hron, Ipeľ and Slaná.

Tab. 3: The resulting trends for the period 1961 - 2012 in 76 selected gauging stations

number	flows	the gauging stations	catchments	11	12	1	2	3	4	5	6	7	8	9	10	year
1	Javorinka	Ždiar.Podspády	Poprad	0	0	0	-1	0	0	0	0	0	0	2	0	0
2	Poprad	Chmelnica	Poprad	0	0	0	0	0	0	0	0	0	0	2	3	0
3	Močiarka	Láb	Morava	-3	-2	0	0	0	-3	-3	-2	-1	0	0	-1	0
4	Morava	Moravský Ján	Morava	0	0	0	0	0	0	0	-1	0	0	0	0	0
5	Vydrica	Spariská	Dunaj	0	0	1	0	0	0	-2	0	0	0	0	0	0
6	Dunaj	Bratislava	Dunaj	0	0	2	0	3	0	-1	0	0	0	3	3	3
7	Ipoltica	Čierny Váh	Vah	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Biely Váh	Východná	Vah	0	0	2	0	0	0	0	0	0	0	0	0	0
9	Boca	Kráľova Lehota	Vah	0	0	0	0	0	-3	-3	-3	0	0	0	0	-3
10	Váh	Liptovský Hrádok	Vah	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Belá	Podbanské	Vah	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Váh	Lipt. Mikuláš	Vah	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Ľupčianka	Part. Ľupča	Vah	-2	-1	0	-1	0	-3	-1	-3	0	0	0	0	-3
14	Revúca	Podsuchá	Vah	0	0	0	0	0	0	-1	0	0	0	-1	0	0
15	Ľubochnianka	Ľubochňa	Vah	0	0	2	0	0	-2	0	-2	0	0	0	0	0
16	Biela Orava	Lokca	Vah	0	0	3	0	0	0	0	0	0	0	0	0	0
17	Veselianka	Oravská Jasenica	Vah	0	0	3	0	0	0	0	0	0	0	0	0	0
18	Polhoranka	Zubrohlava	Vah	0	0	2	0	0	0	0	0	0	0	0	0	0
19	Oravica	Trstená	Vah	0	0	0	0	0	0	0	0	0	0	0	0	1
20	Turiec	Martin	Vah	-2	0	0	0	0	-2	-1	0	0	-1	0	0	0
21	Varínka	Stráža	Vah	0	0	1	0	0	-3	-2	-2	0	0	0	0	0
22	Kysuca	Čadca	Vah	0	0	2	0	0	0	0	0	-2	0	0	0	0
23	Kysuca	K.N.Mesto	Vah	0	0	2	0	0	-1	0	0	-3	0	0	0	0
24	Rajčianka	Poluvsie	Vah	0	0	0	0	0	0	-2	0	0	0	0	0	0
25	Petrovička	Bytča	Vah	0	0	3	0	1	-2	0	0	0	0	0	0	3
26	Petrinovec	Vydrná	Vah	0	0	2	0	3	0	0	0	0	0	0	0	2
27	Bielavoda	Dohňany	Vah	0	0	1	0	0	-2	-1	-2	0	0	0	0	0
28	Pružinka	Visolaje	Vah	-3	-3	0	0	0	0	-3	-3	-2	-3	-2	-3	0
29	Vlára	Horné Sŕnie	Vah	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Jablonka	Čachtice	Vah	0	0	0	0	0	-2	-2	-3	0	0	0	0	0
31	Blatina	Pezinok	Maly Dunaj	0	0	0	0	0	0	-2	-2	0	0	0	0	-2
32	Trnávka	Bohdanovce	Maly Dunaj	-3	-3	0	-2	0	0	0	0	0	0	0	-3	-3
33	Parná	Horné Orešany	Maly Dunaj	0	0	0	0	0	0	-2	0	0	-1	0	-2	0
34	Gidra	Píla	Maly Dunaj	0	1	2	0	0	0	-3	0	0	0	0	0	0
35	Nitra	Nedožery	Nitra	-2	0	0	0	0	-2	-1	0	0	0	0	0	0
36	Handlovka	Handlová	Nitra	-3	0	0	-2	0	0	0	-1	0	-3	0	-3	0
37	Nitra	Chalmová	Nitra	-2	0	0	0	0	-3	0	0	0	0	0	0	0
38	Nitrica	Liešťany	Nitra	0	0	3	0	0	-3	0	-1	0	0	0	0	0
39	Nitra	Chynorany	Nitra	0	0	0	0	0	-1	0	0	0	0	0	0	0
40	Bebrava	Biskupice	Nitra	-1	0	0	0	0	0	0	0	0	0	0	0	0
41	Nitra	N.Streda	Nitra	0	0	0	0	0	0	0	0	0	0	0	0	0
42	Žitava	Vieska	Nitra	0	0	0	-3	0	0	0	0	0	0	0	0	-3
43	Hron	Zlatno	Hron	0	0	0	0	0	0	0	-2	0	0	0	0	0
44	Hron	Brezno	Hron	-2	0	0	0	0	-2	-2	-1	0	0	0	0	0
45	Čierny Hron	Hronec	Hron	-3	0	0	0	0	-3	-2	-3	0	0	-2	0	-2
46	Bystrianka	Bystrá	Hron	-2	0	0	-1	0	-1	-2	-3	0	-2	-3	0	-2
47	Štiavnička	Mýto	Hron	0	0	0	0	0	-3	-2	-3	0	0	0	0	-3
48	Vajskovský potok	Dolná Lehota	Hron	0	0	0	0	0	0	0	-1	0	0	-2	0	-3
49	Starohorský potok	Staré Hory	Hron	-3	-2	0	0	0	-3	-2	-3	-3	-3	-3	-3	-3
50	Hron	Banská Bystrica	Hron	-3	0	0	0	0	-3	-2	-3	0	0	-1	0	-2
51	Hron	Brehy	Hron	-2	0	0	0	0	0	-1	-3	0	0	-1	0	0
52	Ipeľ	Holiša	Ipel	-3	0	0	-3	-1	-2	0	0	0	0	0	0	-3
53	Tuhársky potok	Lučenec	Ipel	0	0	0	0	0	0	0	0	0	0	0	0	-3
54	Krivánsky potok	Lučenec	Ipel	-3	0	0	-3	-3	-3	-2	-3	0	0	-3	0	-3
55	Krupinica	Plášťovce	Ipel	-1	0	0	0	0	0	0	-3	0	0	0	0	-3
56	Litava	Plášťovce	Ipel	-3	0	0	0	0	0	0	-1	0	0	0	3	-2
57	Dobšinský potok	Dobšiná	Slana	-2	0	0	-2	0	-1	0	0	0	0	0	0	0
58	Slaná	Vlachovo	Slana	0	0	0	0	0	0	0	0	3	3	0	0	0
59	Štítnik	Štítnik	Slana	-3	0	0	0	0	0	0	-2	0	0	-2	0	-3
60	Slaná	Lenartovce	Slana	0	0	0	-2	0	0	0	0	0	0	0	0	-2
61	Rimavica	Lehota nad Rimavicou	Slana	-2	0	0	-3	-3	-2	0	0	0	0	0	0	-3
62	Blh	Rinavská Seč	Slana	-2	-1	0	-3	-2	0	0	0	-1	0	-2	0	-3
63	Hnilec	Stratená	Hornad	0	0	0	0	0	0	-3	0	0	0	0	0	0
64	Hornád	Kysak	Hornad	0	0	0	0	0	0	0	0	3	0	1	0	0
65	Sekčov	Prešov	Hornad	0	0	0	0	-1	-2	0	0	0	0	0	0	0
66	Torysa	Košické Olšany	Hornad	0	0	0	0	-2	0	0	0	0	0	2	1	0
67	Hornád	Ždaňa	Hornad	0	0	0	0	-1	-1	0	0	1	0	1	0	0
68	Bodva	Nižný Medzev	Bodva	0	0	0	-2	-1	-1	0	0	0	0	0	0	-3
69	Laborec	Koškovce	Bodrog	0	0	3	0	0	0	0	0	0	0	0	0	0
70	Cirocha	Snina	Bodrog	0	0	0	0	-1	0	0	-2	0	0	0	0	0
71	Kamenica	Kamenica	Bodrog	0	0	0	0	0	0	0	0	0	0	2	0	0
72	Uh	Lekárovce	Bodrog	0	0	0	0	0	-1	0	0	0	1	0	1	0
73	Latorica	Veľké Kapušany	Bodrog	0	0	2	0	0	0	0	0	0	1	0	0	0
74	Topľa	Hanušovce	Bodrog	0	0	0	0	-1	0	0	0	0	0	0	0	0
75	Ondava	Horovce	Bodrog	0	0	0	0	0	0	0	0	0	0	0	0	0
76	Bodrog	Streda nad Bodrogom	Bodrog	0	0	1	0	0	0	0	0	0	0	0	0	-3

5. CONCLUSIONS

In our contribution the Mann-Kendall statistic assessment of the trends of the maximum annual and the maximum monthly discharges have been proceeding. The trends have been calculated for the whole time period in 35 gauging stations and for the chosen time period, 1961-2012 in 76 gauging station.

When we compare the stations in both periods, we can notice in many cases the change of significant trends in annual and monthly series from decreasing (whole period) to zero trend, or a decreasing trend with lower significance (period of 1961-2012). This change of annual trends is visible mainly in Váh catchment. The change of increasing trend to decreasing one in the station of Blh – Rimavská Seč is probably caused by water reservoir, operated on this river since 1980.

Only in one gauging station (Bratislava - Danube River) the increasing trend has been identified both in the whole observation period and period of 1961-2012. This station is in operation since 1901 (the longest period of observation in Slovakia). Since 2000 the frequency of floods with significant peak discharge on Danube River has increased (Poórova et al., 2013) and the increasing trend of annual maximum discharges in this station is in good correspondences with this statement.

Generally we can say that the assessed results has shown prevailing occurrence of the decreasing trends of the maximum monthly and annual discharges, in some cases significant.

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Stochastic modeling of time series of mean annual discharges in Serbia's part of the Danube River Basin to the end of the 21st century

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Abstract/Introduction

In this studyis discussed the modeling of time series of mean annual river discharges to the end of the 21st century. The initial assumption is that the time series of mean annual discharges represent a nonstationary stochastic process, which can be broken down into its deterministic and stochastic components. The deterministic component is usually a linear or nonlinear trend, with a periodic component characterized by macrocyclic and microcyclic variation in the time series of mean annual discharges. The stochastic component is a set of random numbers, whose basic feature is adherence to the normal distribution with parameters N(0,1).

The linear trend concept was used for trend detection and modeling, while the cyclic components were identified applying the spectral theory of random processes. In the specific case, the identification of the macrocyclic component was preceded by Loess smoothing of the basic time series, after trend elimination. Following elimination of the trend and macrocyclic variation from the basic time series, residuals of a different type were obtained and subjected to autoregression analysis, to determine the quantitative indicators of the macrocyclic component. The random component was derived after the deterministic component had been extracted from the basic time series.

The proposed analytical procedure for time series modeling is comprised of individual modeling of all the identified components: linear trend, macrocyclic and microcyclic variation, and the random component, as well as their superposition. The cyclic components were modeled by means of harmonic functions or autoregression (AR), while the moving average (MA) was applied for the random component.

The developed approach was used to model time series of mean annual discharges in Serbia's part of the Danube River Basin to the end of the 21st century. The time series of mean annual discharges recorded at the following gauging stations were examined: Orsova and Bogojevo at the Danube River, Senta at the Tisza River, Sremska Mitrovica at the Sava River and Ljubičevski at the Velika Morava.

1. Data

The object of the study was the Danube River, along with its major tributaries (the Sava River, Tisza River, the Velika Morava). The needed hydrologic time series were obtained from the Hydrometeorological Service of Serbia and the German Federal Institute of Hydrology in Koblenz. The considered gauging stations on the Danube River included the station at Bogojevo, where transboundary waters from the Danube River Basin enter Serbia. The exit station was the station at Orsova in Romania, which reflects water contributions from the catchment areas of the Sava

River, Tisza River and Velika Morava. The hydrological analyses were conducted for a synchronous period at all stations from 1931 to 2012.

2. The modified TIPS model

The time series were decomposed by extracting the deterministic and stochastic components. The deterministic component comprised a trend component and a long-term macroperiodic component. The stochastic component included a high-frequency periodic component and the remainder represented a random component. This approach is based on the TIPS method (Yevjevich, 1984), but was modified such that mean annual discharge time series were used instead of daily time series. The time series were composed of mean annual discharges, which did not contain a seasonal component. The reason for removing the seasonal component was an attempt to uncover the long-term stochastic structure of the time series. It was assumed that the time series included a linear trend that was removed from the time series. The remainder of the time series was characterized by the presence of a long-term macroperiodic component, and the Hurst coefficient was used to determine whether the time series had a long memory. The local-regression Loess technique (Stojković et al, 2013) was applied to better assess the macroperiodic component—to smooth the time series and thereby extract the long-term macroperiodic component. The part related to the determination of the long-term periodic component constitutes the modification of the TIPS method, while modeling was performed by spectral analysis. The remainder of the time series represented the stochastic component characterized by microperiodicity or high-frequency periodicity. The stochastic component was modeled applying the ARMA approach, founded upon the conventional method of Box and Jenkins (1976). The last segment of the time series represented the modeling error, which needed to have the characteristics of a random time series with zero mathematical expectation and constant variance. In addition, the random time series was subjected to a randomness test and the model was validated only after adopting the hypothesis that the time series was random.

2.1 Modeling of the deterministic component

In order to model the long-term macroperiodic component, the mean value trend needed to be removed from the discharge time series. It was assumed that the trend was linear and testing was performed by checking the slope of the regression coefficient β (Kendall and Stuart, 1966). Subtract the trend component Q_T from the time series Q produced residuals of the first order Q'. These residuals, Q', were then smoothed applying the local-regression Loess method, where the width of the smoothing window needed to be established. This was followed by spectral analysis, to determine the periods of mean annual and seasonal discharge time series. Significant periods determined on the basis of a relative cumulative periodogram (RCP) (Yevjevich, 1984), with a specified period significance level of 95%. Additionally, Fisher's test (Yevjevich, 1984) was applied to assess the significance, which showed that significant periods determined by the RCP were also significant according to Fisher's test. Once the significant periods were established, it was possible to model the long-term periodicity of the time series. The macroperiodic component Q_P had to be modeled using the amplitudes of the cosine and sine waves at significant frequencies (Yevjevich, 1984).

2.2 Modeling of the stochastic component

In order to analyze the stochastic component Q_{STOCH}, it was necessary to refuse the deterministic component Q_{DET} from the time series Q. This provided residuals of the second order Q''. The

degree of the remaining periodicity of the second-order residuals *Q''* was tested by the residual periodicity test (Yevjevich, 1984). This test requires the periodicity to be assessed using a normalized cumulative periodogram (NCP). In order to apply the apparatus of mathematical statistics to the stochastic component Q_{STOCH}, it needed to be transformed into a time series that belonged to normal distribution. The stochastic component was modeled by ARMA (p, q).
Autoregressive model parameters were obtained by solving the Yule-Walker equation (Box and Jenkins, 1976). It directly correlated the normalized covariate function with AR(p) model parameters. In other words, once the normalized covariate function of the time series was determined, the Yule-Walker equation yielded AR(p) model parameters ϕ_1, ϕ_2,..., ϕ_p. MA(q) model parameters were determined on the basis of the normalized covariate function value of the stationary stochastic process. The ARMA model was selected applying the AIC criterion (Salas et al, 1980), whose minimization ensured the best possible choice. Then the selected model needed to be validated. Both model selection and validation were based on the model error ε_t. In the ideal case, the model error represents white noise if it fulfills the conditions of mathematical expectation E(ε)=0 and variance Var(ε)=1. The most important feature of the model error is that it does not contain any hidden cyclical pattern, or, in other words, that it is a time-independent random variable. This model error ε_t feature was verified using the Porte-Manteau and Box-Ljung tests (Salas et al, 1976). The modeled deterministic Q_{DET} and stochastic components Q_{STOCH} were then aggregated to obtain the total modeled value of the mean annaul discharges time series applying the modified TIPS method. A comparison with observed time series yielded the values of the NSE objective function.

2.3 The Long-term projections of hydrologic time series

Mean annual discharge trends Q_T are generally assessed with regard to historic discharges. A future mean value trend is generated assuming that the parameters are estimated from the time series *Q* and that the linear regression equation is extrapolated in the future. Given that the linear trend determines the tendency of the entire time series, it is justifiable to extrapolate the linear trend over a longer time segment. This extrapolation method was applied to generate the long-term macroperiodic components Q_p of the time series *Q*. Significant periods, obtained using the discrete Fourier transform, estimated over the long-term period, were extrapolated in the present case. The trend and macroperiodic components were extrapolated for future periods N+1, N+2,..., N+L. The stochastic component was projected applying the minimum sum-of-squares error principle (Box and Jenkins, 1976). This method produced the confidence intervals of the generated values of the stochastic component.

2.4 Result

In order to establish whether the time series of mean annual discharges have a long memory, the Hurst coefficient *h* was determined on the basis of the widely used rescaled range (*R*/*S*) analysis. The range of the coefficient was 0.545–0.724, showing that the time series have a long memory. The significance of the trend was determined comparing the slope coefficient of the regression curve β to the critical value for a confidence threshold of α=0.05. The adopted hypothesis was that the linear trend was statistically significant at all stations for the time series of mean annual discharges. The linear trend of mean annual discharges was found to decline at all stations, excluding the station Senta at the Tisza River, which showed an upward trend. The significant level of periods (SLP) was specified at 95% of the periodic intensities sum. The RCP increment was greater in the time series of smoothed annual discharges than in the basic time series.

The significant periods at all the considered stations were also verified by Fisher's test, with a significance threshold of α=0.05. It was found that the macroperiods could be divided into four groups, whose average values were: 9.5, 13.5, 22.5 and 31.5 years. The significant macroperiods are consistent with the research of Pekarova et al. (2003), Labat (2006) and Stojković et al. (2014). The criterion AIC(p,q) was minimized to select the best model. To demonstrate these criteria, the stochastic components of the all time series showed that the best match was achieved from 6^{th} to 7^{th} degree autoregressive AR(p) models. The conclusion was that the aggregated modeled values of mean annual discharges Q_m matched recorded time series quite well, as demonstrated by the objective functions, where NSE was in the range 0.89–0.94.

3. Conclusion

When the modified TIPS model is verified, it is then used for long-term projections of annual time series of discharge. Long-term projections are compared with observed data (1931–2012) within the three time periods: I (2013–2040), II (2041–2070), III (2071–2100). During the I period average discharges of the Danube River are reduced at the interval of 3% to 8%, and at the Sava River reduction of discharges is 9% , compared with the historical period (1931–2012). Velika Morava shows stagnation while the Tisa River discharge increased (10%). During the period II, discharges of the Danube River and the Sava River reduced in the range from 8% to 10% and reducing reduction of the discharges of Velika Morava are 5%. Unlike them, Tisza River indicates an increase in discharges of 8%. Last III period is the driest the discharge reduction of the Danube River is in the range 8–10%, of the Sava River are 13%, of the Velika Morava are 21%. At the Tisza River is expected the increase in discharges by 17%.

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Long-term development of actual and potential evapotranspiration during the growing season on the Eastern Slovak lowland

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Introduction

Evaporation of water in nature from the physical point of view means the process of conversion of water into the steam. In nature it is a crucial regulator of energy flows. Evaporation from soil and plants is called evapotranspiration. Amount of evapotranspiration in time is influenced by energy required for a change of water into vapor and amount of water in this environment. It means that evapotranspiration has seasonal character. Crucial amount of water obviously evaporates in the vegetative period (VO) of year, from April to September. The maximum possible evapotranspiration under the given meteorological conditions is called potential evapotranspiration (ET_0). Its size is the result of energy balance on the active surface. Actually evaporated water from the soil and plants is called actual evapotranspiration (ET_a). It depends from positive energy balance, turbulent exchange between stands and atmosphere, the water supply in soil profile and from the ability of plants to regulate their water intake and outtake. In case of sufficient amount of water the actual evapotranspiration is the same to potential. The aim of this paper is to analyze the development of potential (ET_0) and current (ET_a) evapotranspiration during the growing season between 1970 and 2013 on Milhostov locality.

1. Materials and methods

The process of evaporation was examined in the central part of Eastern-Slovakian Lowland in the area of Milhostov (N 48°39,786´; E 21°43,298´; 100 m). The location is characterized by medium-heavy gleyed soils with clay particles of 18–39 % fig. 1. The site is located in the central part of the Eastern Slovak lowland. This site is in terms of evaporation typical for the whole lowland. Database for the analysis was obtained by numerical simulation on a mathematical model GLOBAL. The model GLOBAL is a simulation mathematical model of soil water transfer which enables the calculation of moisture potential distribution or soil moisture in real time [Šoltész, Baroková, (2006)]. Potential evapotranspiration ET_0 is calculated according to FAO, by Penman`s method of– Monteith [FAO, (1990)]. For determining the actual transpiration or evaporation intensities the method developed on IH SAS was used. According to this method the evapotranspiration structure depends on the value of leaf area index (LAI) [Majerčák, Novák, (1994)]. Daily totals of potential and actual evapotranspiration were calculated During the growing season. The results were analyzed statistically. Daily ammounts ET_0 and ET_a were gained for 44 year data series of vegetal periods. It is the data base for other statistical analysis of evapotranspiration.

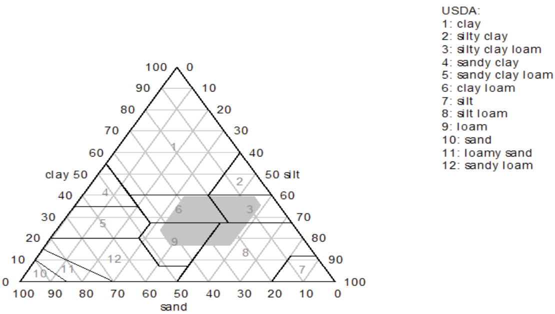


Fig. 1: Texture of the examined soil profile according to the triangular classification diagram USDA (sand 0,05–2,0mm, clay <0,002mm, silt 0,002–0,05mm)

2. Results and discussions

Table 1 shows the basic statistical characteristics of average long-term daily, monthly and growing season amounts of ET_0 and ET_a, average long-term amounts of precipitation and average long-term position of the groundwater level during growing seasons. From the above table the descriptive characteristics (position, shape and variability) are evident. From the long-term view there is actual evapotranspiration in average 60,1 % from potential and 84,3% from precipitation in the study area during the growing seasons. However, it should be noted that no influence of winter water storage was captured in unsaturated zone and in groundwater From statistical characteristics of GWL position can be concluded that ground water supplies by water root zone of plant cover [Šoltész, Baroková, (2006)].

Are shown in figure 2 long term values of average monthly amounts of ET_a a ET_0 during vegetal periods of the years 1970 - 2013. It results that the highest long term average actual evapotranspiration amount gains ET_a in june (66,6 mm). The highest values of ET_0 are achieved in july (105,8 mm). The highest evapotranspiration deficiency ($ED=ET_a-ET_0$) was identified in the august (53,1 mm). Root zone of soil profile is dried up the most during this month in long term view. Course of vegetal precipitation amount and average vegetal GWL position corresponds to course of evapotranspiration proces.

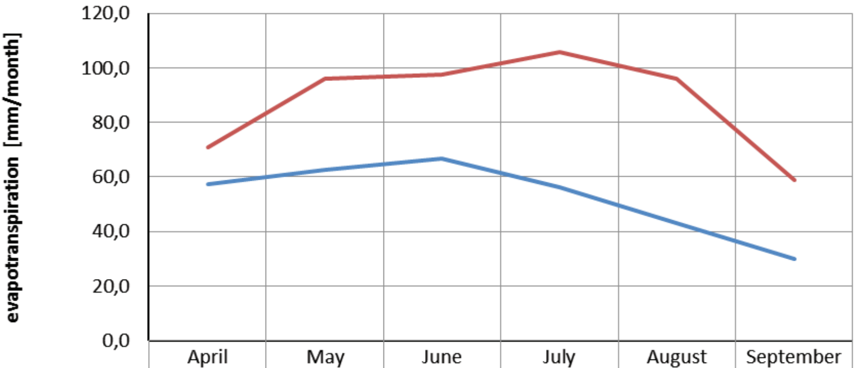
Figure 3 shows courses of potential evapotranspiration ET_0 during growing seasons, actual evapotranspiration ET_a and their linear trends for the period of years 1970–2013, course of precipitation P and course of the GWL. Precipitation in investigation period was stable. We could identify an increasing trend of ET_0 and ET_a values on the Figure 2. The difference between ET_0 and ET_a has increased. Potential evapotranspiration had greater increase according to ET_a. Increased values of ET_0 and ET_a can be observed mainly in the last 15 years of investigated period. Absolute highest and also smallest values of ET_0 and ET_a were identified for the whole observed period of years 1970–2013 during this period.

3. Conclusion

The aim of this paper is to analyze the development of long-term data series of potential and actual evapotranspiration. The period of years 1970–2013 was evaluated.

Tab. 1: Descriptive statistical characteristic for average long-term daily, monthly and growing season amounts of ET_0 and ET_a, average long-term amounts of precipitation and the average long-term position of the groundwater level under the surface during vegetation periods in 1970–2013

Descriptive	*Eta*	*ET0*	*Eta*	*ET0*	*Eta*	*ET0*	*precip.*	*GWL*
Statistics	vegetation period		month		day		veg. per.	veg. per.
Mean	315,86	525,20	52,14	87,15	1,73	2,87	374,50	-173,07
Standard Error	10,72	11,69	1,25	1,51	0,01	0,02	12,84	6,85
Median	295,98	527,86	51,09	87,00	1,65	2,78	360,85	-178,96
Standard Deviation	71,11	77,53	20,29	24,47	1,04	1,38	85,20	45,44
Sample Variance	5057,22	6010,65	411,62	598,75	1,08	1,89	7259,14	2064,92
Kurtosis	-0,66	0,48	-0,19	-0,22	0,00	-0,12	2,09	1,22
Skewness	0,60	-0,37	0,29	0,25	0,49	0,26	1,02	1,04
Range	266,19	372,87	106,33	131,94	5,57	9,30	444,40	208,70
Minimum	202,29	302,70	5,28	28,29	0,00	0,02	226,80	-239,04
Maximum	468,48	675,57	111,61	160,23	5,57	9,32	671,20	-30,33
Count	44	44	264	264	8052	8052	44	44



	April	May	June	July	August	September
Eta [mm]	57,4	62,6	66,6	56,1	43,1	30,0
ET0 [mm]	70,9	96,1	97,5	105,8	96,2	58,7

Fig. 2: Long term values of average monthly amounts of ETa and ET0 during vegetal periods of the years 1970 – 2013

The baseline data needed for analysis were daily amounts of potential and actual evapotranspiration. The values of ET_0 and ET_a were calculated on a mathematical model GLOBAL with one-day step. Modeling has been carried out in conditions of locality Milhostov on the East Slovakian Lowland. It was possible to assemble large-scale hydro-meteorological, hydrological and phenological databases and hydrophysical characteristics needed for the numerical simulation of evaporation of water in that area. The basic characteristics of descriptive statistics were calculated and long-term trends of ET_0, ET_a. Development of these trends (ET_0 and ET_a) had increasing character and their difference grew mainly in the last years. This shows the increasing intensity of the drying of investigated area. These results are still incomplete. The processes of water evaporation in connection to the water supply in the unsaturated soil zone and groundwater level are the subject of further research on the East Slovakian Lowland.

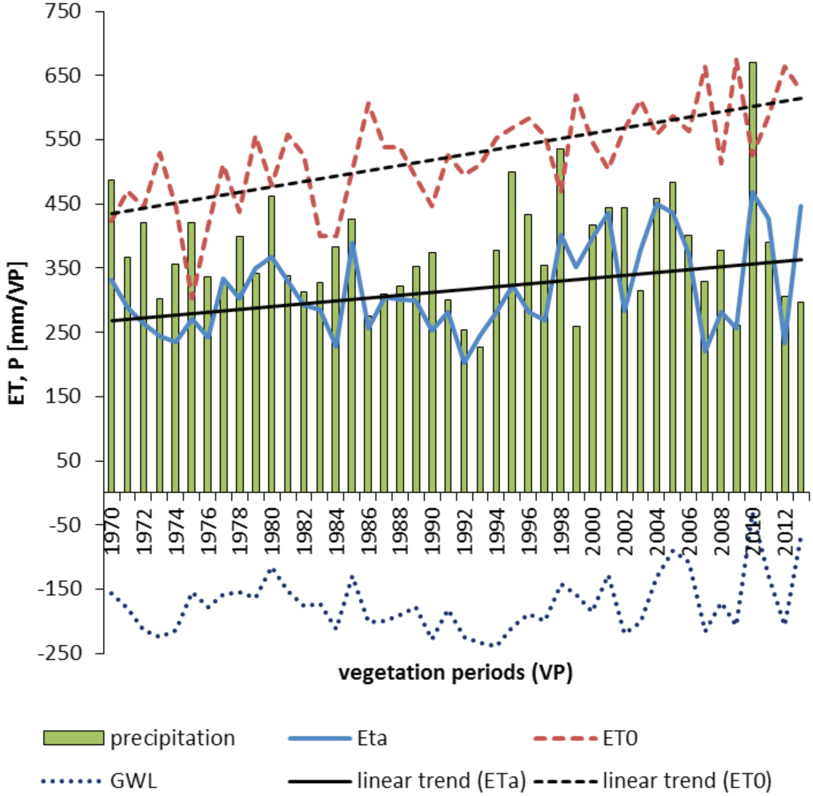


Fig. 3: Development of vegetation amounts of ET_0, ET_a, P and linear trends ET_0, ET_a during the period of years 1970 – 2013

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Acknowledgements

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HYDRO-GENETIC METHODS OF THE ANALYSIS OF THE AVERAGE ANNUAL RUNOFF IN THE DANUBE BASIN

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Introduction

The most spread methods of time series analysis is parametric and nonparametric statistical criteria (Fisher, Student, Terry, Spearman, Wald-Wolfowitz, Mann–Kendall, etc.). However, these methods do not take into account the peculiarities of hydrological series: dependence on time, the distribution laws that differ from normal and have the long-term cyclical fluctuations (SMH, 1967; GHP, 2009). From this, their application does not provide the reliable estimates (Gorbachova et al., 2012, 2013; Gorbachova, 2014). The present trends of hydrological researches are returning to using of geographical-hydrological method that was developed by Glushkov (Glushkov, 1933; Dmitrieva, 2000). For a while this method was forgot, due to intensive development and application of statistical methods. The geographical-hydrological method is the foundation of the genetic analysis the research of hydrological objects and phenomena.

The goal of this paper is the analysis of the average annual runoff in the Danube basin (within Ukraine) with hydro-genetic methods that allow to determine the physical causes of appearance inhomogeneity and nonstationarity time series

1. Data and methodology

The research was carried out for the data 11 hydrological gauges in the Danube River Basin that located on the territory of Ukraine. The basins that have a long series of observations of the average annual runoff and the natural conditions its formation were selected as the representative catchments.

Methodological approaches for assessing the homogeneity and stationarity of hydrological series with hydro-genetic methods by Gorbachova were developed (2014). So, the homogeneity of the time series is the absence of unidirectional changes of the hydrological characteristic (refers to a one genetic series - floods, rain floods etc.) over time against the backdrop its variability due to the long-term cyclical fluctuations. The stationarity of the time series is the constancy of average value hydrological characteristic over time if the time series has at least one full closed cycle (dry and wet phase) of the long-period fluctuations. These two definitions are the identical concepts, especially when the time series has the representative period for determining of the stable average value. In the absence of a representative period, the time series may be with quasi-stationary if it is homogeneous. Necessarily the following provision use:

- in the hydrological series need to restore the gaps in observations and bring them to a long-time period, that allows to trace the temporal dynamics of hydrological characteristics over a longer time interval;
- the homogeneity of the hydrological characteristic over time is researching with integral curve;
- the stationarity of the hydrological characteristic is researching with difference-integral curve.

For clarify the results obtained (if necessary) can be used the other hydro-genetic methods and approaches (the analysis of meteorological factors of the runoff formation, the combined graphics etc.).

In this research the integral and difference-integral curves, combined chronological graphs were used. The integral curve used to detect the influence of anthropogenic factors (hydraulic structures, canals) and of climate change (the presence of trends in the data series). If on the integral curve will not be found “jumping”, “emissions” or unidirectional deviation, then the process the forming of the runoff in the study area is homogeneous, and conversely. Integral curve is defining with formula

$$W = \sum_{t=1}^{T} w(t) \,, \qquad \textbf{(1)}$$

where W – the total runoff of river for period time T;
$w(t)$ – the runoff of t-th year.

The analysis of the difference integral curve allows to define the dry and wet phases of the long-period fluctuations of hydrological series. The difference integral curve is defining according to

$$\frac{\sum_{t=1}^{T}(k(t)-1)}{C_v} = f(t) \,, \qquad \textbf{(2)}$$

where C_v – the variation coefficients of runoff;
$k(t) = Q(t)/Q_0$ – the modulus coefficients;
$Q(t)$ and Q_0 – the discharge of t-th year and the average discharge for the period of time T.

A combined chronological graph of characteristics allows defining synchrony/asynchrony of long-term fluctuations in different rivers within the one hydrological homogeneous area. In turn, the synchronous fluctuations indicate on the homogeneous climatic conditions of formation runoff.

2. Results

The list of the rivers that were investigating in the Danube River Basin are shown in Tab. 1. For the 10 gauges the observations series of the average annual runoff were prolonged to the long-term period with linear regression. It allowed to follow the temporal dynamics of runoff on this gauges for longer time. Thus, the duration of the observations series ranged from 78 to 111 years.

Tab. 1: The list of representative catchments in the Danube River Basin (within Ukraine)

№	River - point	F, км^2	Period of investigating
1	Borgava river – Dovge village	408	1895-1918, 1921-39, 1944-45, 1947-2010
2	Rika river – Mizhgirya village	550	1895-1904, 1913-18, 1920-40, 1942-2010
3	Uhz river – Uhzgorod town	1970	1924-37, 1947-2010
4	Latorytsa river – Mukacheve town	1360	1907-10, 1913, 1916-18, 1922-23, 1925-38, 1944, 1947-2010
5	Teresva river – Ust-Chorna village	572	1907-10, 1913, 1916-18, 1922-23, 1925-40, 1944-2010
6	Tysa river – Vylok village	9140	1924-1937, 1946-2010
7	Tysa river – Rakhiv town	1070	1895-1918, 1920-29, 1931-38, 1942-2010
8	Siret river – Storozynetz town	672	1895-1915, 1918-23, 1940-42, 1945-2010
9	Prut river – Yaremcha town	597	1895-98, 1900-14, 1916-38, 1942-2010
10	Prut river – Chernivtsi town	6890	1895-1911, 1919-24, 1926-42, 1945-2010
11	Danube river – Reni town	811000	1921-2010

The graphs of the integral curves of the average annual runoff were created for representative catchments. Such graphs don't have any significant points of the fracture of the directions of the curves, i.e. the observations series are the homogeneous. Some examples of such curves are shown in Fig. 1.

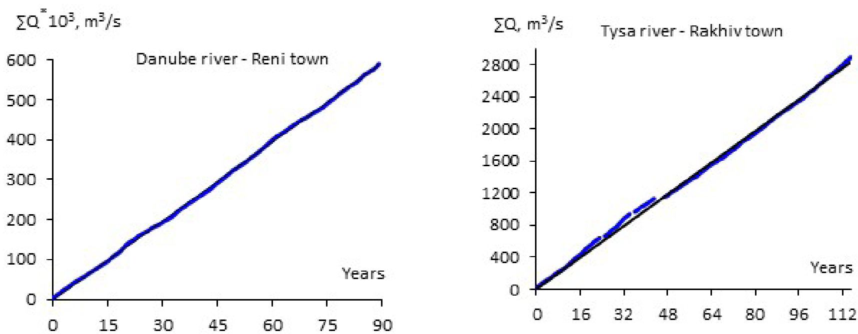

Fig. 1: The integral curves of the average annual discharges in the Danube River Basin

The difference integral curves of average annual runoff of the Danube characterized by the presence of cycles of varying duration. Some examples of such curves are shown in Fig. 2. Analysis of the graphs showed that at 3 gauges (Rika river - Mizhgiray village, Latorytsa river - Mukacheve town, Teresva river - Ust-Chorna village) the series of observations don't have of the full closed cycle. For such gauges, the observations data will be have the constant the average value with an increase of their duration. For the other gauges the observations series have the dry and wet phases of the long-term cyclical fluctuations, i.e. their average value is constant over time (Fig. 2 *a*). Analysis of combined graphs showed that for all time series are observed the synchrony of runoff fluctuations (Fig. 2). At the same time the cophasality of fluctuations runoff are not observed for all time series (Fig. 2 a). Therefore, the synchronous fluctuations of average annual discharges indicate homogeneity of the climatic conditions of their formation. The asynchronous phase of fluctuations runoff one can explained by feature of the rivers basins (relief, soils, forests, wetlands, lakes, etc.).

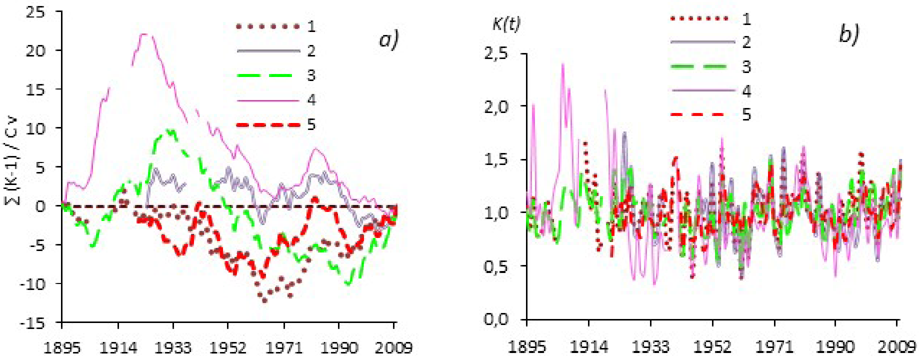

Fig. 2: The combined graphs of the difference integral curves *(a)* and chronological curves *(b)* of the average annual discharges in the Danube River Basin
(1 – Rika river - Mizhgiray village, 2 – Uhz river - Uhzgorod town, 3 – Tysa river - Rakhiv town, 4 – Prut river - Chernivtsi town, 5 – Danube river - Reni town).

3. Conclusion

Analysis of the temporal dynamics of average annual runoff in the Danube basin (within Ukraine) with hydro-genetic methods showed that the time series are homogeneous and stationary. Only on the three gauges the time series don't have of the full cycle of the long-period fluctuations and are characterized by quasi-stationary processes. All the time series have the synchronic of the runoff fluctuations.

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Identification of maximum flow changes in selected stations on the Danube River

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Topic 2 – poster presentation

Introduction

The aim of the paper is the thorough statistical analysis of daily discharge series, comparison of changes in floods occurrence, timing, duration and frequency, and evaluation of their long term variability. Due to increasing length of time series of hydrological and meteorological data and their better availability it is possible to work with the higher number of historical series. We use the database of the mean daily discharge of the Danube River in several stations. The first part of the paper describes the IHA (Indicators of Hydrological Alternations) software. Long term trends are evaluated as well as changes of various hydrological characteristics for different periods.

1. Methodology

To analyse changes of river flow regime we used software for identification of changes in hydrological series of daily data called IHA (Indicators of Hydrologic Alterations) Version 7. This software has been developed by the organisation for protecting the nature The Nature Conservancy. IHA is a tool for calculating the characteristics of natural and alterated hydrologic regimes. The method and software will work on any type of daily hydrologic data, such as streamflow, water stages, ground water levels, etc. The great advantage of the IHA method is that it can be used to summarize long periods of daily hydrologic data into a much more manageable series of relevant hydrologic parameters.

The IHA software uses daily data for its calculations. For the relevant and meaningful statistics it is needed to have input data from sufficiently long series of hydrological observations. It is necessary to work with a minimum of 20 years length range to evaluate before and after impact observations. More data was needed for more variable parameters and for extreme events such as large floods. The number of years of data needed may vary depending on the (1) degree of climate variability; (2) the frequency or variability of the particular parameter; (3) the severity of the hydrologic alteration that you are trying to detect; (4) and whether the goal is to characterize the central tendency or range of inter-annual variability. If there is doubt about how much data is enough, it is important to use some tests to see how different record lengths affect IHA statistics. The IHA will calculate a total of 67 statistical parameters. These parameters are subdivided into 2 groups, the IHA parameters and the Environmental Flow Component (EFC) parameters. There are 33 IHA Parameters and 34 EFC Parameters. This software has many options which can be used to control how these parameters are calculated. An important choice that we had to make was whether to compare two distinct time periods or analyse trends over a single time period. If the hydrologic system which we wanted to study had experienced an abrupt change such as construction of a dam, our settings were affected by computing the hydrologic parameters for two time periods, before and after the impact. IHA parameters can be calculated using parametric (mean/standard deviation) or nonparametric (percentile) statistics. For our study we used non-parametric statistics because it is a better choice, because of the skewed (non-normal) nature of hydrologic datasets. To the group of IHA parameters (33 parameters) there belong for example parameters of frequency changes of water level status, frequency and duration of pulses of small and large flows, duration and time of occurrence (date) of annual extreme flows, the intensity of monthly discharges, etc. (The Nature Conservancy, 2007).

2. Results

For statistical analyses in this paper we used data from database of average daily discharges processed in the framework of the international project (Project No. 9 IHP UNESCO – Flood regime of rivers in the Danube river basin). Analysis of the recorded annual maximum daily discharges for Central Europe was processed by Villarini et al. (2011) and Pramuk et al. (2013) evaluated the flood flows changes of the Danube River in Bratislava station. Taylor et al. (2003) focused primarily on the size and length of the input data series needed to reach relevant results. For this paper four water gauging stations were chosen, specifically Bratislava (1876–2008) Achleiten, Krems, and Orsova (1901–2007) (Fig. 1), but limited publication space caused that we had to show outputs only from gauging station Achleiten (Table 1, Fig.2-3).

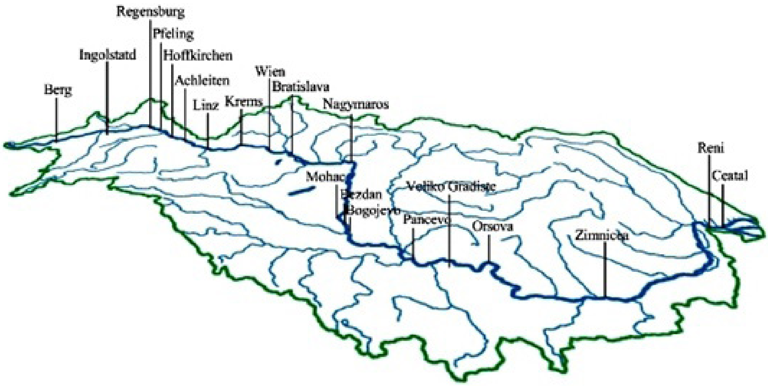

Fig. 1: Gauging stations on the Danube River.

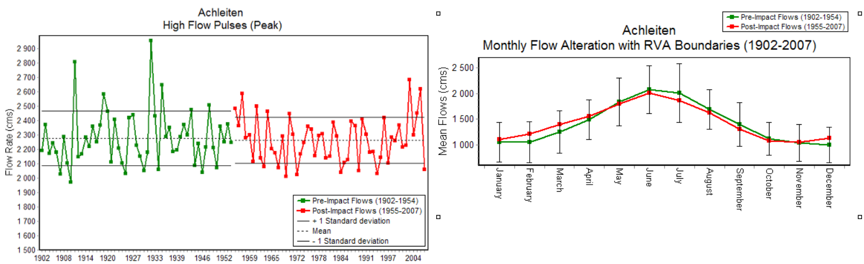

Fig. 2: Comparison of the peaks of high flow pulses - left; comparison of the duration high flow pulses – right (in the two periods: pre-impact 1902–1954 and post-impact 1955–2007), Danube: Achleiten.

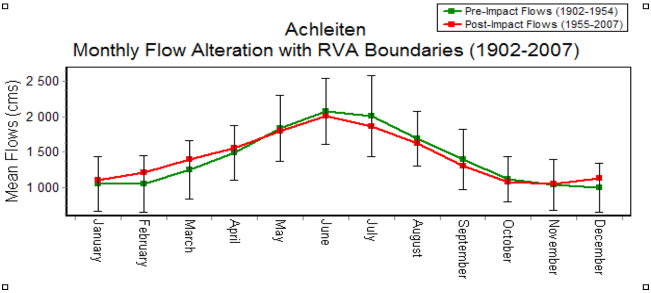

Fig. 3: Changes in long-term average monthly discharge of the Danube at Achleiten station in two periods: period I (1902–1954) and period II. (1955–2007).

Tab. 1 Comparison of the average values, duration, timing (the order of the day in the year) and frequency of extreme low peaks, high flow peaks, small floods and large floods, Danube: Achleiten, period I. (1902–1954), period II. (1955–2007)

EFC Parameters	I.	II.	**EFC Parameters**	I.	II.
Extreme low peak [m^3s^{-1}]	628	655.6	**Small Flood peak**[m^3s^{-1}]	4097	4136
Extreme low duration [days]	12.02	8.627	Small Flood duration [days]	42.64	26.89
Extreme low timing	9.068	357	Small Flood timing	161.8	168
Extreme low frequency	3.34	4.094	Small Flood frequency	0.6119	0.5849
			Small Flood rise rate	352.9	684
			Small Flood fall rate	-146.8	-215.8
High flow peak [m^3s^{-1}]	2276	2264	**Large flood peak** [m^3s^{-1}]	6134	5397
High flow duration [days]	7.331	6.476	Large flood duration	23.2	44.75
High flow timing	175.3	182.4	Large flood timing	155.4	199.9
High flow frequency	8.17	9.17	Large flood frequency	0.0943	0.2075
High flow rise rate	353.8	305.1	Large flood rise rate	1092	920.6
High flow fall rate	-166.7	-164.4	Large flood fall rate	-274.9	-258.8

When we were analysing the change between two time periods we used for the implementation of the IHA software the Range of Variability Approach (RVA). RVA analysis also generates a series of Hydrologic Alteration factors, which quantify the degree of alteration of the 33 IHA flow parameters. In an RVA analysis, the full range of pre-impact data for each parameter is divided into three different categories. The boundaries between categories are based on percentile values (for non-parametric analysis). The program then computes the frequency with which the "post-impact" annual values of IHA parameters actually fell within each of the three categories. Finally, a Hydrologic Alteration factor *RVAF* is calculated for each of the three categories as:

$$RVAF = \frac{(OF - EF)}{EF},$$

where: *OF*- observed frequency; *EF*- expected frequency.

A positive Hydrologic Alteration value means that the frequency of values in the category has increased from the pre-impact to the post-impact period, while a negative value means that the frequency of values has decreased (Fig. 4).

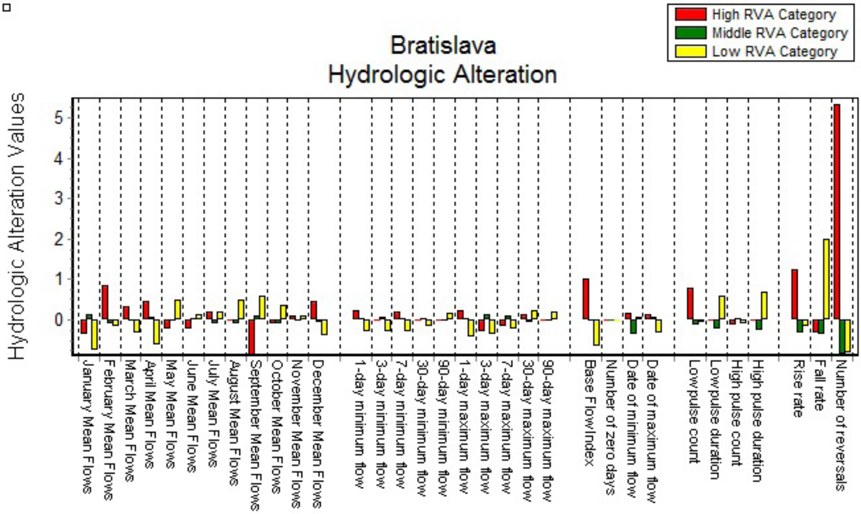

Fig. 4: RVA analysis, data series of daily discharge from Bratislava water gauge.

3. Conclusions

Our results suggest, proved by graphical outputs, that average annual discharges of the Danube River are stable. The number of small floods at Achleiten decreased, while at Bratislava (Pramuk et al., 2013) increased. At the same time there is a reduction of flood wave duration of small floods. Also the rise rate of the small floods is increasing. On the other hand, at Achleiten increase large flood frequency.

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GIS in hydrology at Surface Water Department of CHMI

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Introduction

Geographic information system (GIS) is reflected in many branches at daily work in Surface Water Hydrology Department of Czech Hydrometeorological Institute (CHMI).

1 Manage data base

Surface Water Hydrology Department keeps actual hydrological GIS data, where changes come from field survey and from other hydrological and water management institutions. It is mainly water gauging station layer, catchment divides layer etc. Map of water gauging stations, which measure water level and evaluate discharge, is at the Fig. 1.

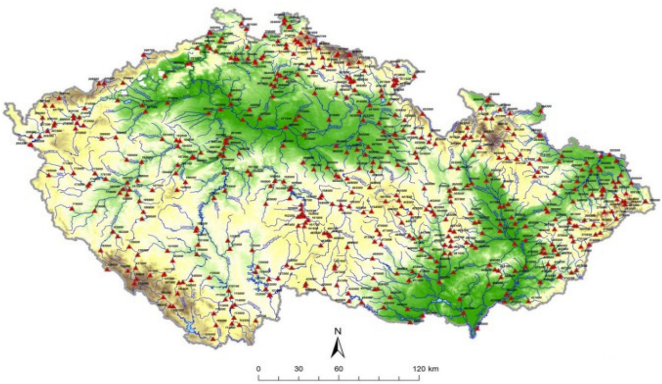

Fig. 1: Map of water gauging stations with discharge evaluation

2 Catchment divides

Our department finished catchment divides in scale 1:10000 at the end of 2012. It is more precise than catchment divides in scale 1:25000 and we have been working on it for five years in close co-operation with T. G. Masaryk Water Research Institute. This co-operation still continues. We have made systematic catchment divides for dams, river crossing and gauging stations. Each catchment has extended ID number, where numeral position reflects hydrological order and type of division (Fig. 2). New catchment areas were computed for Labe, Vltava and Odra rivers using equal area projection ETRS89/LAEA Europe.

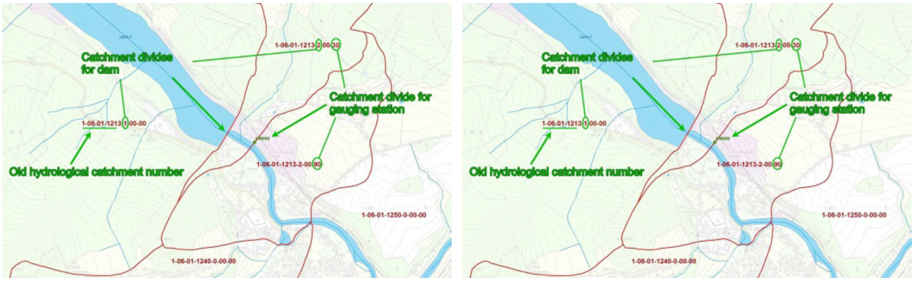

Fig. 2: Example of new catchment divides with extended hydrological number

3 Special scripts and applications

There are small scripts and commands to facilitate work in ArcGIS environment, for example script for projection transformation of radar precipitation data set. Large extensions and complete applications for specialized work or public presentation were developed, e. g. *FFG-CZ* (Czech Flash Flood Guidance), *AGPosudek* and *HydroHMS*.

FFG-CZ is a GIS application for computing a risk of potential flash floods occurrence in the Czech Republic. Results are presented on website of CHMI. Saturation index and potential risk precipitation with duration 1, 3 and 6 hours are obtained.

Saturation index is based on simple balance of precipitation, runoff and evapotranspiration in daily time interval and it is presented by six levels (from very low saturation to extremely high saturation, Fig. 3 left). The potential risk precipitation with duration 1, 3 and 6 hours is calculated from simple rainfall-runoff model. Values in the map at Fig. 3 (right) represent 1 hour precipitation, which can cause runoff with return period about 2-5 years.

Potential runoff is calculated from 15minutes radar precipitation and indicates direct runoff in the catchment layer or square polygon layer (Fig. 4). This procedure is still in testing phase.

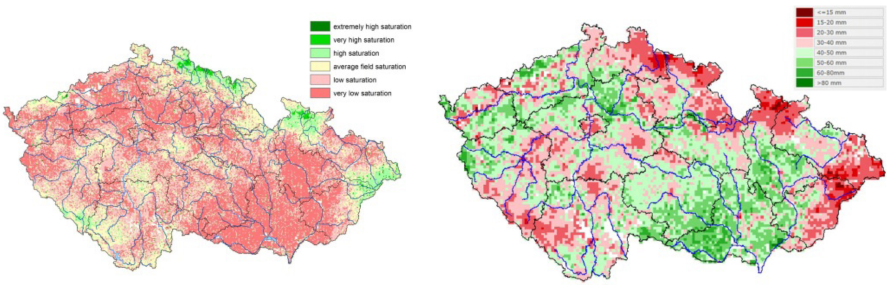

Fig. 3: Saturation index (left) and potential 1 hour risk precipitation (right) from 9. 7. 2014. Maps are presented on web CHMI.

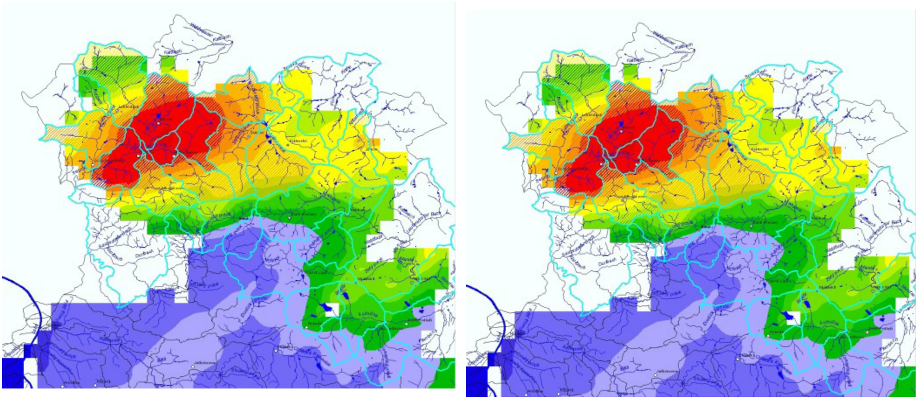

Fig. 4: Risk of potential runoff from radar precipitation

AGPosudek is a helpful application for basic hydrological and geographical data computation and estimation of rainfall-runoff model parameters, for example *N*–years precipitation, watershed slope, catchment area, Q_{100} estimation, *CN* values etc.
HydroHMS is a package of procedures collected in toolbox for ArcGIS. This toolbox allows complex operations to prepare data for rainfall-runoff modeling in *HEC-HMS* program.

4 Hydrological studies

Surface Water Hydrology Department made a lot of hydrological studies for design floods with return period *N* > 100 years. Use of GIS sources is necessary to define watershed and rainfall-runoff model parameters correctly (catchment area, precipitation).

5 Thematic maps

Our department prepares map outputs for different publications, for example Landscape atlas of the Czech Republic, Hydrological yearbook, Hydrological balance, flood reports etc. Many GIS outputs are available at CHMI website. Map of monthly average discharge´s regime at selected water gauging stations published in Landscape atlas of the Czech Republic is at the Fig. 5.

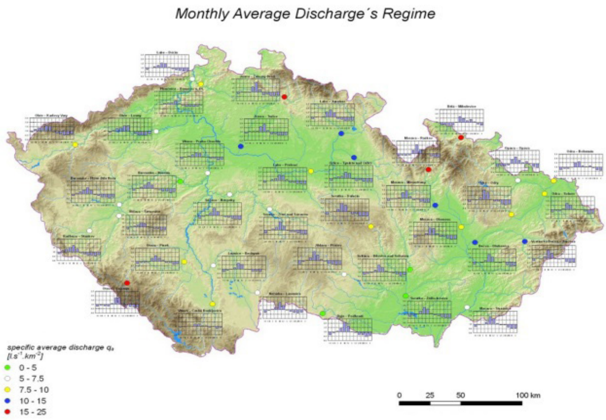

Fig. 5: Monthly average discharge´s regime at selected water gauging stations

6 Flood reports

Several catastrophic floods occurred in the Czech Republic during last decade. GIS was used for computing results (total precipitation, soil saturation) or making maps (return period of flow peak in gauging stations). Map of precipitation from period 1. 6. 2013 15:00 – 2. 6. 2013 15:00 is at the Fig. 6. Return period of peak discharges in gauging stations is presented in map as colored point.

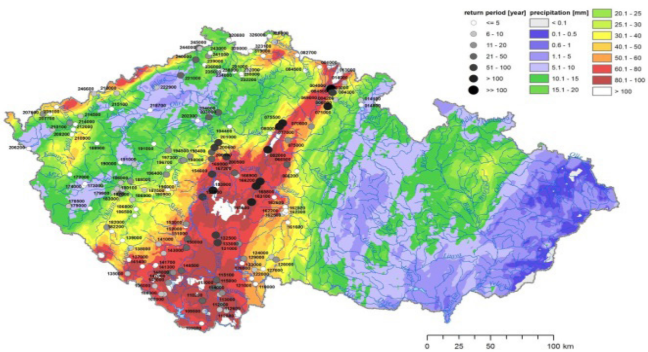

Fig. 6: Total precipitation from period 1. 6. 2013 15:00 – 2. 6. 2013 15:00

7 Used GIS software

ArcGIS software from ESRI Company is used in desktop and server sites, currently in version 10.2.2.

CLIMATE CHANGE AND ITS IMPACT IN WATER RESOURCES IN ROMANIA

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ABSTRACT
At the Danube Ministerial Conference in 2010, Ministers emphasised that the impacts of climate change will increase and develop into a significant threat in the Danube River Basin if the reduction of greenhouse gas emissions is not complemented by climate adaptation measures. Also the 1st Danube River Basin Management

The management Plan, adopted in 2009, draws first conclusions and identified future tasks in this regard. Romania is one area in the basin will be strong impacted by decreasing water resources CLIMHYDEX Project is a reaction to this facts, and focus in particular on a better understanding of the climate change mechanism at a regional and local scale, identifying the main impacts of climate change on water resources and sectors, potential adaptation measures, challenges as well as options for coordination with regard to the different impacts.

In this paper we show how it was applied the theory underlying the calculation of the Standardized Precipitation Index (SPI) to define a Standardized Flow Index (SFI), emphasizing in this way the extreme hydrological periods.

Keywords: Danube, climate change, hydrological indexes

1. INTRODUCTION
In 2000 the Water Framework Directive (WFD) established a legal basis to protect and restore clean water across Europe and ensure its long-term, sustainable use. The general objective of the WFD is to get all water — lakes, rivers, streams and groundwater aquifers — into a healthy state by 2015. The achievement of EU water policy goals is threatened by a number of old and emerging challenges, including water pollution, water abstraction for agriculture and energy production, land use and the impacts of the climate change.

The EU’s policy response to these challenges is the 2012 Blueprint to safeguard Europe’s water resources. The overall objective of the Blueprint is to improve EU water policy to ensure:

- good quality water,
- in adequate quantities,

for all authorized uses. This involved researchers to study the evolution of water resources: water’s vulnerability to climate change and man-made pressures such as urbanisation and land use; and in research studies for hydrologic parameterizations, as support for policy decision.

Different research studies were conducted for getting in-puts for climate change impact on water resources at the large basin level, getting the following results for Romania:

2010 – Methodology for CC estimation on the maximum discharges (case study Mureș)

2011 – CC assessment on maximum discharges (case study Siret)

2012 - CC assessment on maximum discharges Jiu and Ialomiţa”

2013 – 2014 CC impact on extremes in Bârlad Basin.

The financial instruments were different, research studies under FP6-FP7 financial instruments, as: CECILIA, http:/www.cecilia-eu.org/, CLAVIER [1], http://www.clavier-eu.org/, ENSAMBLES, http://www.ensembles-eu.org/, IS-ENES, https://is.enes.org/the-project, ECLISE, http://www.eclise-project.eu/, or the Romanian research Program financial instrument: CLIMHYDEX -"Climate change impact on hydrological extremes in Romania" [2], http://climhydex.meteoromania.ro/ and Danube WATER, for the Danube River study [3].

2. HYDROLOGICAL INDEXES

Data

- Annual and monthly values of the discharge at the 13 longest stations in Romania, on the main rivers were selected and analyzed for the period 1935 – 2012;
- Annual and monthly values of precipitation and of minimum and maximum temperatures at some representative meteorological stations, for a similar period

Methods

The monthly precipitation data sets were used to evaluate the trends and jumps in the series of data (Man-Kendall and Pettit Test were applied) and to calculate the value of standardized precipitation index SPI for the three stations.
For the summer season dry periods are identified for the years 1943, 1949, 1950, 1972, 1990, 1992, 1993, 2003, 2007 and 2011, while for the autumn season dry periods are identified for the years 1946, 1947, 1950, 1990, 1993, 2003 and 2011.
Looking at the monthly discharges on the main tributaries in South of Romania, anomalies were identified, as well as the droughty periods – figure 1 and table 1. God significance of the tendency was identified during summer months, for South of Romania (19 cases) and for the autumn-winter, for higher altitude stations (hilly and mountainous basins) [2].
Danube was considered as integrator of the Romanian conditions in water resources change and 2 stations were more detailed analyzes – the Romanian inflow, at Turnu Severin and after collecting all main tributaries of the Romanian floodplain, at Calarasi station [3]. To calculate the values of standardized precipitation and evapotranspiration index SPEI at the three stations, these data sets, as well as, the mean air temperature sets were used. Monthly mean discharge data sets were used for the value calculation of standardized flow index SFI, by the same method as in the case of standardized precipitation index. SPI and SFI do not show a clear tendency for Drobeta-Turnu Severin. In case of Calarasi, the trend (figures 2) shows a positive evolution for the whole analyzed period. For the early period droughts prevail on a wider range of years (1946 - 1954) and at the end of the observation interval wet periods are also prevailing (2005 - 2010). The trend is significant just only in case of climatic indices, for the observed period. The hydrological drought (SFI index) periods are clearly highlighted: moderate (-1.5 ÷ -1), severe (-2 ÷ -1.5) and extreme (≤ -2), but also periods of time with high discharges. In this way, the periods characterized by the hydrological drought have been recorded for the years: 1946, 1947, 1949, 1950, 1952, 1953 – 1954, 1964, 1972, 1974, 1983, 1987, 1989, 1990, 1993, 1994 - 1995, 2003, 2007 and 2011 (figures 2).

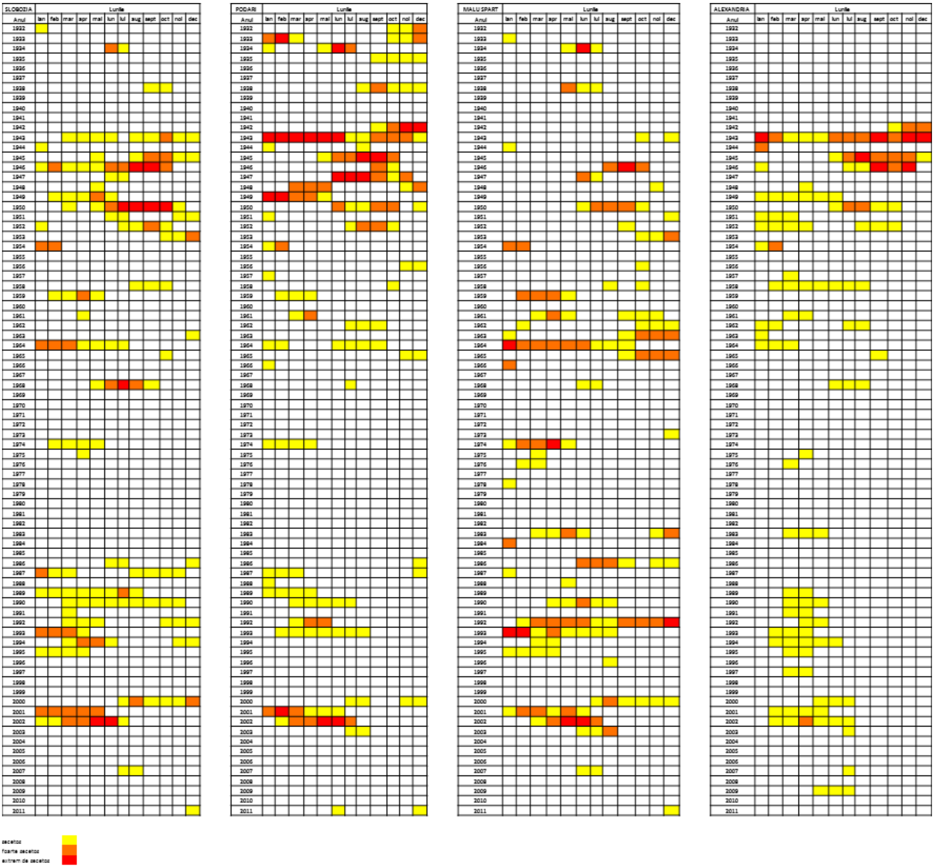


Figure 1 Monthly anomalies (1931-2012)

Tendency was computed for each month and its significance and results are presented in table. 1.

Table 1 Tendencies of the mean monthly discharges (dry and wet periods)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	AN	
***	8	5	5	0			0	2	12	10	2	5	4	53
**	8	3	6				1	2	6	7	3	5	1	42
*	6	6	2	5			2	9	7	7		8	6	58
+	3	2	0	2			2	2	3	3	4	1	4	26

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	AN	
***														0
**			2		1								2	5
*			2		5	1								8
+			1	2	2	5	1							11

Semnificatia notațiilor din tabelul 3 sunt:

Tendinta negativa

Tendinta pozitiva

Iar nivelele de semnificație sunt date de:

***	0.001
**	0.01
*	0.05
+	0.1

To study the seasonal variability, the SFI index was computed at Calarasi station, for the period 1931 – 2012. The trend was also computed for this station, but is insignificant in the case of the summer and autumn seasons, respectively. In figure 7 is presented the temporal evolution of the SFI index for summer and autumn, for the accumulated periods 1, 3 and 6 months, at Calarași station.

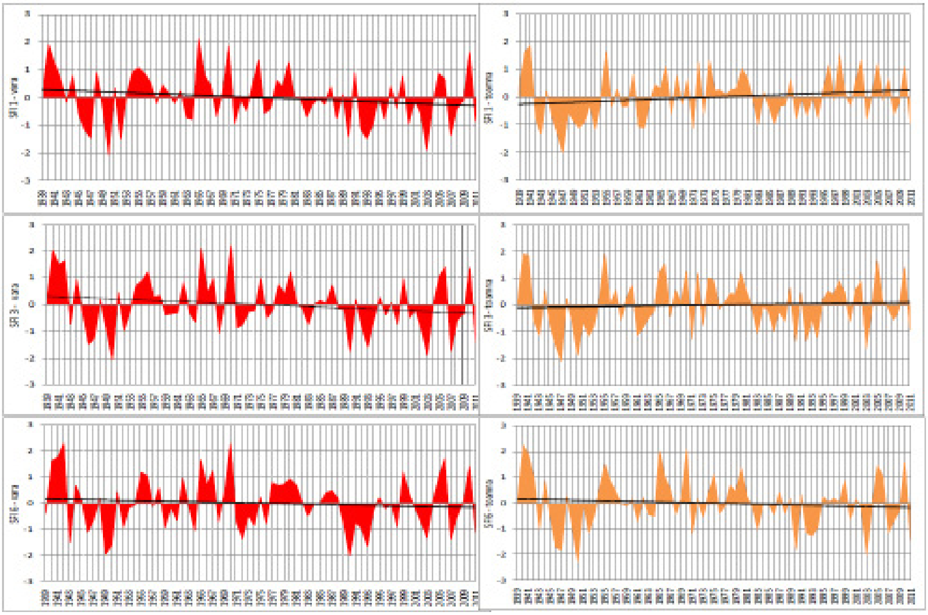
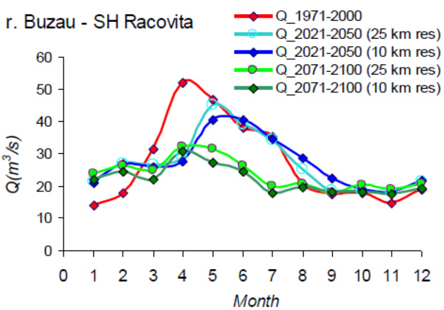
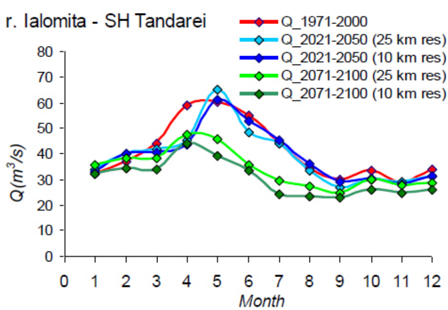


Figure 2. Seasonal evolution [summer (red) and autumn (orange)] and the trend of the SFI index for the accumulated periods of 1, 3 and 6 months at Calarasi station

Long term projection of hydrological tendency was calculated by discharge simulation for the three scenarios for Ialomita-Buzau Basin for 2021-2015 and 2071-2100. Precipitation is not changing very much, but temperature distribution change is important, inducing changes in discharges hydrographs [1].





3. CONCLUSIONS

Climate change leads to changes in the frequency, intensity, extent, duration and timing of extreme weather and climate events, and can result in unprecedented extremes;

Attention to temporal and spatial dynamics of exposure are particularly important when designing risk management policies that may reduce risk in the short-term, but increase long-term vulnerability (e.g. dike systems reduce flood exposure, but encourage settlement patterns that could lead to an increase in flood risk);

There is limited to medium evidence of climate-driven changes in magnitude or frequency of floods at regional scales – however, there is medium confidence that projected rainfall in-creases will lead to increases in certain catchments;

There is medium confidence that droughts will intensify in the 21st century, particularly in southern Europe, the Mediterranean and central Europe;

Extreme events will have the greatest impacts on sectors with close links to climate, such as water and agriculture (type of vegetation);

There is high confidence that changes in climate have the potential to seriously affect water management systems, however this is not necessarily the most important driver of change at the local scale.

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FREQUENCY ANALYSIS OF THE SYNCHRONOUS EXTREME FLOWS: CASE STUDY ON THE MORAVA RIVER

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Abstract/Introduction

The paper presents bivariate frequency analysis of the maximum discharges (Q_{max}) of flood waves synchronous occurred on mainstream and its tributary. We analyzed the daily discharges records, from 1969 to 2011, on the Morava River and its left tributary the Myjava River. As a mathematical method for determining a joint probability of two dependent variables copula functions were used. Finally joint return periods and conditional return periods of the maximum synchronous discharges (Q_{max}) were calculated. Results of the analysis provide comprehensive information how the hydrological characteristics may affect the size and course of extreme hydrological situations.

1. Methodology

Basic statistical analysis approach gives satisfactory results in the case of simple systems, for example where the main river does not capture major tributaries. These conventional approaches may not give satisfactory results for the evaluation of flood risk in situations where floods occur on two or more rivers and join together at the same time. Therefore the multidimensional approach to statistical analysis of flood events should be further developed and defined at neighboring profiles on mainstream and its tributaries. Bivariate (as well as multivariate) statistical modeling of hydrological characteristics is now fairly rapidly developing approach to hydrological analysis. The copula functions are now used frequently as a mathematical tool for determining joint probability of occurrence of the two dependent variables (e.g. maximum flow). The main advantage of this method is that the marginal distribution of the variables can be in any form and variables may be correlated. Therefore, copulas appear to be the most suitable tool for modeling dependencies between two or more variables. The word "copula" was first used in mathematical or statistical sense by Sklar (1959). Good introduction of the theory of copulas can be found in monographs of Joe (1997) and Nelsen (1999). Salvadori and De Michele (2004) studied the relation between univariate and bivariate return period in term of Archimedean copula. Karmakar and Simonovic (2009) present the bivariate flood frequency analysis with the copula functions for evaluating joint distributions with mixed marginal distributions. The very popular in empirical applications are the Archimedean class of copulas. Archimedean class of copulas includes a full suite of closed-form copulas which cover a wide range of dependency structures, including comprehensive and non-comprehensive copulas, radial symmetry and asymmetry, and asymptotic tail dependence and independence. This class of copulas is popular due to its flexibility and easy construction. For each copula, the value of θ (copula parameter) can be obtained by considering the mathematical relationship (Nelsen, 2006) between Kendall's coefficient of correlation and the generating function $\phi(t)$. Kendall's coefficient of correlation is a well-known nonparametric measure of dependence or association in multivariate statistics. Table 1 shows well-known and most used bivariate one–parameter copulas in hydrology. Some other distributions expressed as copulas are also listed, e.g., in Balakrishnan and Lai (2009).

Table 1 The most frequently used Archimedean copulas in hydrologyJoint return period for two variables can be written in the form of:

Copula	C (u, v, θ)	parameter space θ	Kendall's τ	Generator ϕ(t)
Clayton	$(u^{-\theta}+v^{-\theta}-1)^{-1/\theta}$	[−1, ∞) /{0}	$\frac{\theta}{\theta+2}$	$\frac{1}{\theta}(t^{-\theta}-1)$
Gumbel-Hougaard	$\exp\{-((-\ln u)^{\theta}+(-\ln v)^{\theta})^{1/\theta})\}$	[1, ∞)	$\frac{\theta-1}{\theta}$	$(-\ln t)^{\theta}$
Frank	$-\frac{1}{\theta}\ln(1+\frac{(e^{-\theta u}-1)(e^{-\theta v}-1)}{(e^{-\theta}-1)}$	(∞ , ∞)/{0}	$1+\frac{4}{\theta}[D_1(\theta^*)-1]$	$-\ln\frac{e^{-\theta t}-1}{e^{-\theta}-1}$

Debye function $D_1=\frac{1}{\theta}\int_0^{\theta}\frac{t}{e^t-1}dt$, $\theta^*=-\log(\theta)$

Joint return period for two variables can be written in the form of:

$$T_{x,y}=\frac{1}{\lambda(1-F_{(x)}-F_{(y)}+F_{(x,y)})}, \tag{1}$$

or

$$T"_{x,y}=\frac{1}{\lambda(1-F_{(x,y)})}, \tag{2}$$

Equation (1) represents the joint return period of X ≥ x and Y ≥ y. Equation (2) represents joint return period of X ≥ x or Y ≥ y. Symbol λ represents average events per year.
Conditional return period for X, given Y ≥ y may be expressed as:

$$Tx_{|Y\geq y}=\frac{1}{\lambda(1-F_{(y)})(1-F_{(x)}-F_{(y)}+F_{(x,y)})}. \tag{3}$$

An equivalent formula for conditional return period of Y, given X ≥ x can be obtained.

2. Case study

To illustrate the bivariate frequency analysis of synchronous maximum discharges (Q_{max}), the Morava River and its left tributary the Myjava River were used (Fig. 1). Number of 104 synchronous maximum discharges was identified between the Morava and Myjava rivers during the period of 1969–2011. The identification of the marginal distributions of the hydrological variables is the first step of bivariate analysis. Knowing the marginal distribution, we are able to separate marginal behavior and dependence structure. The dependence structure is fully described by the joint distribution of uniform variables obtained from marginal distribution. As marginal distribution was estimated Pearson6 theoretical probability distribution for Q_{max} of the Morava River and JohnsonsB theoretical probability distribution for Q_{max} of the Myjava River. Two most popular Archimedean copulas in hydrology (Clayton and Frank) were employed to construct the joint distribution of the synchronous hydrological pairs of Q_{max}. The joint CDFs (Cumulative Distribution Functions) evaluated from copula method were compared with empirical joint probability (Fig. 2 a)) and AIC, MSE and HQIC information criteria were used to testing the goodness of fit of the model. Results showed that Clayton copula function is appropriate copula function for determining a joint distribution of synchronous maximum discharges (Table 2). Then, the simulation of 8 000 pairs of Q_{max} using the Clayton copula was done (Fig. 2 b)). The main purpose of the simulation using copula is to describe and to illustrate the interdependence of two hydrological variables. Kendall's coefficient of the simulated pairs from appropriate copula ranged value of 0.397. Fig. 3 a) and b) present joint return periods of synchronous pairs of Q_{max} of the Morava and Q_{max} of the Myjava. Conditional return periods of synchronous pairs of Q_{max} of the Morava and Q_{max} of the Myjava are presented in Fig. 4 a) and b).

Fig. 1 Map of the Morava River in Slovakia and its left tributary the Myjava River.

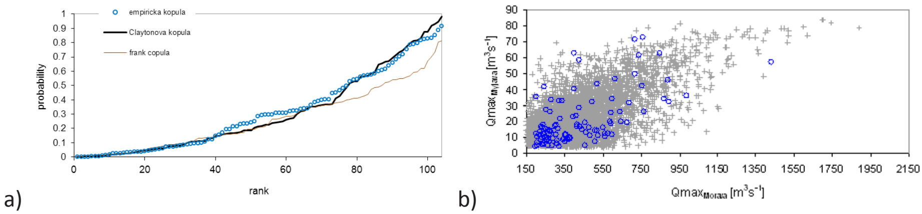

Fig. 2 a) Comparison of copula methods and empirical joint probability of synchronous Q_{max} of the Morava and the Myjava Rivers.
b) Simulation of the 8 000 pairs of the synchronous Q_{max} of the Morava and the Myjava Rivers generated from Clayton copula and measured data (Period of 1969–2011).

Table 2 Copula parameters and information criterions of the model

Copula	θ	SIC	AIC	HQIC
Clayton	1.178	23.75	28.92	26.9
Frank	3.772	27.51	32.68	30.65

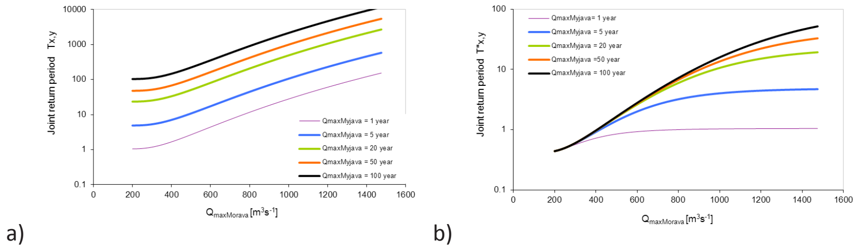

Fig. 3 Joint return periods of synchronous Q_{max} pairs of the Morava and the Myjava Rivers during the period of 1969–2011 (a) the joint return period of X ≥ x and Y ≥ y, b) joint return period of X ≥ x or Y ≥ y).

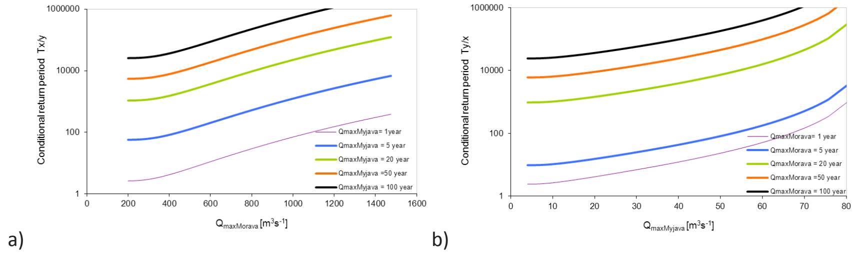

Fig. 4 Conditional return periods of synchronous Q_{max} pairs of the Morava and the Myjava Rivers during the period of 1969–2011: a) $Q_{maxMorava}/Q_{maxMyjava}$ and $Q_{maxMyjava}/Q_{maxMorava}$.

3. Conclusion

Results obtained by the bivariate frequency analysis of hydrological variables give an overview of the flood event as a whole and might be practically used in water management and in the design of flood protective systems. The choice of a particular copula might depend on the nature of the particular data set. This would be useful for further studying for more cases of selected data set and other copula functions.

Acknowledgements: This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0496-10 and results from the project implementation of the "Centre of excellence for integrated flood protection of land" (ITMS 26240120004) supported by the Research & Development Operational Programme funded by the ERDF.

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Methodology for Flood Hazard Delineation. Case study: Arges-Vedea basins (RO)

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Introduction

According to the requirements of the Floods Directive 60/2007/EU the Member States had to provide till the end of 2013 Flood hazard and Flood risk maps.

In the absence of an official or at least of a recommended methodology in Romania for flood delineation, each river basin authority used different approaches for hydrological and hydraulic modelling. In the usual approach used in Romania, the synthetic floods corresponding to the exceedance probabilities of at least 10%, 1% and 0.1% are obtained in a preliminary phase, being then used for hydraulic simulations. There are still some controversial issues in this approach: a) how to take into account the continuos hydrological input of interbasins; b) when to introduce the flood contribution of the tributaries; c) how to choose the scale factor of the tributaries floods in order to obtain the standard floods (10%, 1% and 0.1% probabilities of exceedance for the maximum discharge) at the downstream gauge station; d) how to keep constant the probability of exceedance of the maximum discharge along each river stretch.

The hydrological processes (occured on the hillslopes) and the hydraulic processes (main stream flood composition with the diffuse input from interbasins and the point input from sub-basins, followed by flood propagation on each river stretch) cannot be separated, since they take place simultaneously. The problem of obtaining the flood components (from upstream basin, interbasins and tributaries) by preserving at the same time a constant probability of exceedance on the river stretch between two gauge stations was solved using a coupled simulation of hydrological and hydraulic processes. The dynamics of the physical processes from the nature was thus better reproduced.

1. Main stages of the floods generation and propagation

The main stages of the floods generation and propagation include:

1.1 The topologic model of the river network and boundary conditions. The topological model is a graph, where the arcs represent river stretches or water diversions from one river to another. The most upstream nodes represent the points where the hydrological reaction of the upper basin is set as a boundary condition. The downstream node of each arc represents a gauge station, a reservoir, or a confluence. On each river stretch the coupled hydrological-hydraulic modeling is used. The sub-basins and inter-basins will provide the hydrological input (boundary conditions) for the flood propagation model. The surface of the modeled area should not be bigger than a few hundreds km2.

1.2 The DTM. The Digital Terrain Model (DTM) integrates both the river bed and the floodplain area. The extension of the model should be larger than the expected limits of the 0.1% flooded area. Lidar data corresponding to a vertical accuracy of 10-15 cm were used for the flood plain. The DTM included all dykes and hydraulic structures along the rivers.

1.3 Database creation. The database included detailed information related to the river basin, hydraulic network, hydraulic structures and their operation (if it is the case), meteorological and hydrological data, and the trace of the previous floods (where such data were available).

1.4 Setting up the hydraulic model and calibration of the hydraulic parameters of the river bed. During this phase the hydraulic model is set up for each river stretch for which the delineation of the flooded area is required. The calibration of the roughness coefficients from the river bed is performed in steady state, using a 1D hydraulic model. The hydraulic parameters have a unique value for each river stretch, but have different values from one stretch to another. When the downstream end of the stretch is represented by a gauge station, the rating curve will be used for calibration, by choosing some discharges below the limits of the river banks. When the downstream end is a confluence, discharge measurements for different water levels below the river banks are necessary and the downstream condition in the simulation will be hydraulic slope. Each discharge (either form the rating curve or obtained by measurements) will be split between the upstream basin, the tributaries and the interbasins proportional to their corresponding areas, followed by a hydraulic modeling of the flood propagation. The roughness parameters are well calibrated when the simulated discharges are very close to the rating curve at the gauge station or the rating curve computed by the software for the ungauged tributaries. The final result of this stage is represented by calibrated roughness coefficients of the river bed.

1.5 Choosing the most significant floods. This stage represents an important step for the calibration and validation of the hydrological parameters of the sub-basins and interbasins, as well as for the validation of the hydraulic parameters of the river beds and floodplains. It is recommended to choose recent floods, corresponding to the present situation of the hydraulic regime. In this way, less incertitude will exist during the synthetic floods propagation. If the considered floods are registered before the realization of some hydraulic structures (dykes, damd, diversions), the configuration corresponding to that period should be taken into account for the hydraulic simulations. Still, the flood delineation for the synthetic floods will be performed for the present state of hydraulic regime.

1.6 Analysing the precipitations which generated significant floods. The precipitations, which generated the floods selected at the step 2.5, can be obtained from the meteorological stations, or from the gauging stations. In the first case, hourly data are available, being consistent with the concentration time of the small catchments. However, when the meteorological stations are far away from some small catchments, the registerd data at the meteorological stations could be useless, due to the spatial variability of the rain. In this case, the data from gauge stations, even if they are daily data, should be used due to their proximity of the studied catchments. Of course, the daily data have to be dezagregated into hourly data using the temporal structure of the precipitation registered at the nearest meteorological station.

1.7 Calibration and validation of the hydrological parameters. Validation of hydraulic parameters. The simulations are based on a coupled modeling of hydrological and hydraulic processes, using the facilities offered by Mike 11 software. Due to the huge volume of work involved by the flood delineation at the level of river basins and the limited time for providing the hazard maps, the modeling was event based, despite the problems raised by the characterization of the soil initial humidity. The calibration of the hydrological parameters should be realized for 2-3 historical events, including the largest registered flood, using the corresponding precipitations for the same period, while the validation should use other 2-3 historical floods. Data both from the meteorological stations and from gauging stations were used. Due to the large number of sub-catchments and interbasins which intervene in flood hazard maps creation the most reasonable option is to use a very simple hydrological model, meaning SCS model having only 3 parameters: CN (Curve Number), Tlag (Lag time) and AMC (Antecedent

Moisture condition). In the hydraulic component, the roughness coefficients for the river bed were obtained during the calibration in steady state (Step2.4), while the same coefficients for the flood plain were derived based on land use from European Project CORINE Land Cover. For the floods generation and propagation, the hydraulic model set up at Step 2.4 is coupled with the hydrological module from Mike 11 software. The calibration becomes more difficult in the presence of reservoirs, when not only the flood at the downstream gauge station but also the water level in the reservoirs should be accurately reproduced taking into account the real operation rules of the reservoirs during the event. The main difficulties in the calibration process are due to the spatial and temporal variability of precipitation, as well as the initial soil humidity. The final results of this step are calibrated and validated hydrological and hydraulic parameters.

1.8 Statistical processing of the maximum annual precipitation registered at the meteorological stations. The following steps are used for the statistical processing of the registerd precipitation:

- The maximum hourly precipitations for each year are processed for each meteorological station, obtaining the values corresponding to different probabilities of exceedance (0.1%; 0.2%; 0.5%; 1%; 10%; 20%);
- The same procedure is used to process the maximum annual precipitations for the following rain duration: 3h; 6h; 12h and 24 h.
- The obtained values for the same probability of exceedance are interpolated, obtaining the cumulative rainfall curves for each probability of exceedance P%
- The derivative of the cumulative rainfall curves for an hourly step leads to a decreasing synthetic hyetographs. By starting with the maximum value as the central value and re-aranging the remaining one into a decreasing order alternatively to left and to the right of the central value the so-called composite hyetograph is obtained.
- For the coupled simulation one considers that the rain duration is equal to the concentration time of the catchment, which is approximately 1.67 Tlag.

If during coupled simulation the composite hyetograph leads to extreme values of the maximum discharge, other hyetographs can be proposed. For instance, exceptional precipitations structures occured in the past can be used as a template. The cumulative rainfall curves are normalized and then the ordinates are multiplied by the concentration time, and the precipitation P%. The derivative of the obtained curves are then used for the coupled simulation.

1.9 Identifying the components of the synthetic floods. For the beginning the syntetic floods in the requiered locations were provided by National Instituteof Hydrology and Water Management in Romania (NIHWM). The synthetic floods are obtained by the statistical processing of the registered floods or by regionalization studies can be in natural regime or in actual regime. No matter how the parameters were provided, the final simulations will be done according to the actual situation of the hydraulic works on the river. The maximum discharges of the synthetic floods usually correspond to the following probabilities of exceedance: 10%; 1% and 0.1%. Still, other probabilities like 0.2%; 0.5%; 2%; 5% or 20% can be considered. The components results after reaching a good agreement between the floods obtained by coupled simulation and the synthetic floods provided by NIHWM. The simulations for deriving the components will be performed either in natural regime, or for the actual situation according to the parameters provided by NIHWM. At the upstream end of each stretch the boundary condition is represented by the flood P%. Since for basins larger than 10 km2, the precipitation P% generates a flood whose maximum discharge corresponds to a lower probability of eceedance than P%, the scaling of the precipitation with a factor lower than 1 is compulsory. This value is obtained by a trial and error procedure until the flood resulted downstream as a result of upstream flood and the contribution of the sub-catchments and inter-basins is close enough to the syntehtic flood in the same section. One can notice that in this approach the components have both a point character (the tributaries) and a diffuse character (the input due to the interbasins). In the case of large basins, it could be necessary to consider a different starting point of the precipitation (meaning to take into account the rain travel, for instance from upstream to downstream). Establishing the scaling factor for the precipitation as well as the lag time for the precipitation start along the river basin supposes a good knowledge of the hydrological reaction of each sub-catchment, usually achieved during the coupled hydrological and hydraulic simulation.

1.10 Flood propagation in the modified hydraulic regime due to existing hydraulic structures. If the components were obtained in natural regime, they will be propagated according to the modified regime and observing the operation rules of the hydraulic works. If the components were derived for the actual modified regime, new simulations are not necessary, the propagation results for this regime being obtained in the phase 2.9. The main result of this phase is represented by the flood hydrographs as well as the water free surface along the whole river network.

1.11 The delineation of the flooded areas for each probability of exceedance P% of the maximum discharge. Following the intersection of the water free surface for each P% with the DTM the hazard maps are derived.

1.12 Modelling the backwater effect on the tributaries. If the flood is produced on the main river, the bacwater effect on the tributaries is obtained during the Phase 2.10 on the condition to consider a sub-sector sufficiently extended on the tributary upstream the confluence with the main river. One recalls that the boundary condition on the main river is the flood P%, while the flood on the tributary has only a compensation role in order to obtain the flood P% at the downstream section on the main river. If the flood is produced on the tributary, the floods on the main river and on the interbasins have the compensation role. After the hydraulic simulations, two flooded areas result, the maximum extension in both cases being considered.

2. Conclusion

The hydrological processes on the hilllslopes and the hydraulic processes in the river bed and floodplain take place simultaneously, being necessary to treat them coupled during the simulations. The methodology provided by the authors uses this approach, unlikely to the usual approach when the hydrological and hydraulic procresses are sequentially treated. Although the presentation was referring explicitely or implicitely to 1D modeling, the same considerations are valid for the quasi 2D or for the 2D simulations. The presented methodology was applied for Arges (12.500 km^2) and Vedea (5.400 km^2) river basins in Romania.

Numerical Modelling of morphological stability of proposed restoration measures along the river Havel

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Summary
Large and small scale combinations of different measure types are proposed for river restoration of the Lower Havel river between Pritzerbe and Gnevsdorf in order to satisfy safe navigation conditions and morphological stability. Detailed 2D numerical modeling has been used for evaluation of flow and sediment transport characteristics. DHI was contracted by NABU (Nature And Biodiversity conservation Union) to perform this modelling.
By applying a two-step approach using the in-house software packages MIKE21FM and MIKE21C, DHI was able to simulate in very detail changes of flow parameters as well as morphological processes and changes for a 14 km long stretch of the Lower Havel river.
A 10 years period has been used for "long-term" simulations to analyze trends in morphological processes, in particular in respect to the navigation channel.
The major benefit of this study was the identification of areas where morphological stability after implementation of restoration measures can be critical as well as long-term prediction of induced morphological changes by the measures. From the methodological point of view the study verified validity of applied distinct approaches for sand transport and fine-grained sediment remobilization assessment and identified limits for their application.

1. Introduction
The lower river Havel area has an outstanding importance as a natural river and floodplain in western Central Europe together with the adjacent lowlands, as it forms one of the largest contiguous wetland areas. Furthermore, for much of its length, the river Havel is navigable and acts as an important link in the European waterway connections. The NABU was commissioned as carrier to fulfill a directive concerning the riparian zones. The NABU planned and prioritizes 15 so called measure areas, each of them containing a set of typical restoring intervention measures to be implemented (PEP, 2009). DHI was engaged to carry out hydrodynamic and morphodynamic modelling to investigate the projected measures in terms of effectivity, effects on the hydrodynamic behavior of the river, effects on the actual river bottom, ensuring navigability and future stability of the river banks as a basis for the final approval procedure.

2. Model area and base data for modeling
The **model area** includes the river Havel between km 131,5 as upstream location (Untere Havel Wasserstraße, UHW) and the downstream location km 145,3 (position of the river gauge station Havelberg-Stadt) as well as the adjacent floodplains up to widths of 2.000 m. The model covers a total area of approx. 30 km². The boundaries to the northeast and southwest are formed by flood polders, which can be used to reduce peak flood water levels in the downstream river Elbe (WASY, 2008).

The river Havel represents the main dewatering structure of Brandenburg with mean discharges at the gauging station Havelberg of MQ = 89 m³/s. The discharges and water levels of the river Havel are not only dependent of the hydrological regime but are strongly affected by the river Elbe and many regulation weirs along the Havel. In case of flood conditions in the river Elbe backwater in the Havel occurs and causes extensive flooding in the floodplains. The model area includes some tributaries. The river Havel and the tributaries in the model area show river bottom gradients of less than 1‰.
The **topography** of the model is based on three Digital Elevation Models in 2 m resolution (DEM2). The river bottom elevations are provided with yearly shipping measurement campaigns and show a resolution from 0.25 to 1.0 m. A comprised DEM has been constructed. DEM - corrections have been necessary at dense reed vegetation areas. Additionally, over 50 **soil samples** have been taken along sections through the floodplain as well as the river bottom and have been evaluated. The mean grain size in the river is d_{50} = 0.284 mm and in the abandoned branches d_{50} = 0.037 mm. The grain sizes have been assigned uniformly in transverse direction but varying in longitudinal direction of the river Havel. Basis for the **roughnesses** has been a biotope mapping. A method to consider the effects of aquatic plants on the river bed roughness has been developed. The **hydrological input data** include long-term time series of daily water levels and discharges as wells as single water level fixations. Additionally ADCP – measurement campaigns have been carried out. 11 characteristic conditions ranging from NNQ = 2.8 m³/s to HHQ = 440 m³/s have been chosen for steady model runs, a 50 days flood wave with a moderate Q_{max} = 178 m³/s has been chosen for the transient model run.

3. Methodology

DHI has chosen a **two-step model approach**: Simulating the flow conditions with the hydrodynamic model MIKE21FM and the morphodynamic processes with the model MIKE21C.
MIKE21FM solves the 2D - depth integrated Navier-Stokes equations. The spatial discretization is provided by an unstructured finite volume element mesh comprising triangular as well as quadrangular elements. Results of MIKE21FM are for example water levels, discharges, flow velocities, Froude numbers and bottom shear stresses.
MIKE21C is using Saint-Venant equations solved by a finite difference numerical scheme and can be extended by computing secondary helical flows especially for bended river systems.
The methodological workflow is shown in fig. 1.

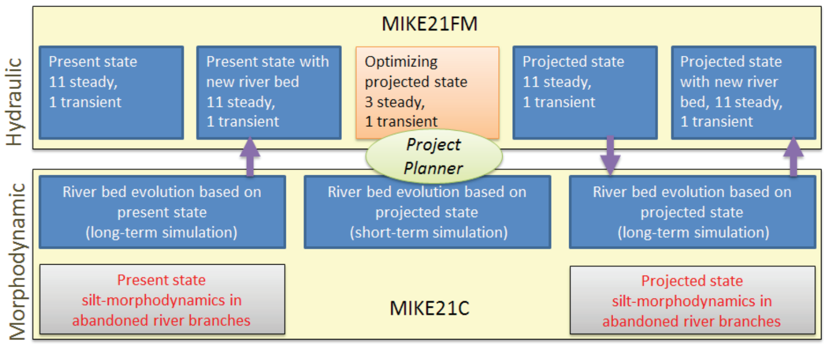

Fig. 1: methodological workflow

3.1 Model setup

Two models have been set up. The MIKE21FM unstructured mesh consists of more than 200,000 nodes and 340,000 elements. River and abandoned branches elements are quadrangular, elements in the foreland are mostly triangular. The element sizes range from 7 m² in the river and trenches to 1,950 m² outside the dikes. The MIKE21C – computational grid consists of over one million curvilinear cells and reflects the strongly bended river Havel course and guarantees fast and reliable numerical results. Bed load and suspended load sediment transport have been computed by the Engelund-Hansen formula, which have given best results in precalibration runs.

3.2 Model calibration and verification

Firstly, the hydrodynamic model has been calibrated for 12 steady events and 1 transient event. The calibration results have been compared with observed water levels at certain locations along the river Havel and, additionally, in transverse direction with the ADCP – measurements. **Secondly**, the morphodynamic model has been calibrated against observed river bed variations using the hydrodynamic results as input data. The results of morphodynamic model calibration have revealed that the long term differences in riverbed changes can be simulated with mean constant input data instead of dense transient input data in satisfying accuracy. This confirms results of a previous study in the region performed by Milbradt (2014).

4. Measures

In particular, the effects of the following measures have been investigated with several scenario runs: terrain works, flood depressions, bank protection, initialization and development of floodplain vegetation, reestablishment of abandoned river arms, groins, bed throats, impoundments, expected bed loads, flooded areas and waterway protection.

Exemplarily, the results of the scenario for restore and reconnect an abandoned river arm will be explained. Reestablishing the river arm has been carried out by virtually dredging the old river bed and constructing a groin to protect the bank and to redirect the main flow (Fig. 2). Furthermore, additional soil samples have been taken into account.

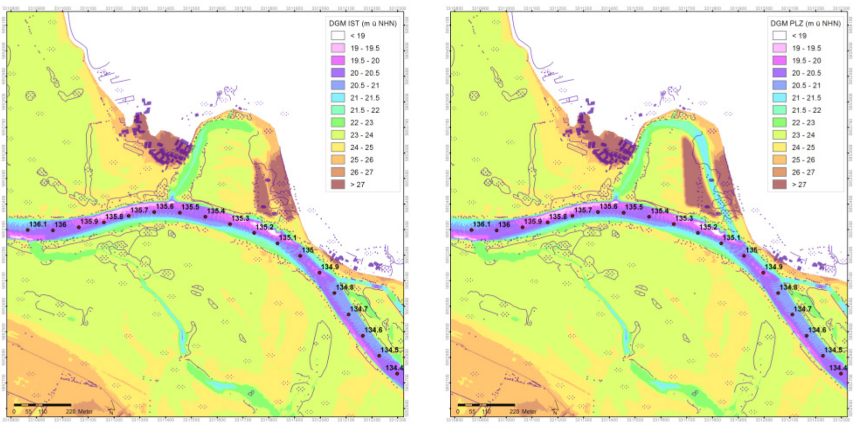

Fig. 2: actual surface (left) and future surface (right) with reconnected river branch.

The simulation-results have been documented as absolute values as well as differences from the projected to the actual state. Fig. 3 (left) shows the simulated changes in flow velocities (m/s). Due to the groin construction, the flow slows down directly upstream of the groin, while above the groin the flow is strongly accelerated. As parts of the discharge are diverted, velocity will decrease in the main river. Fig. 3 shows on the right side the river bed evolution (sedimentation in m). Thus, with the actual state, a future sedimentation of some dm has to be expected (Fig. 3, top right). Compared to that, the middle right figure shows that if the branch is reestablished, the morphodynamic regime changes significantly. Due to the lower flow velocity in the main channel, sedimentation increases. In contrast, downstream of the branch mouth deposition is less and will turn even into slight local erosion due to the less remaining bed load. The changes in river bed evolution with the different regimes are shown in Fig. 3, bottom right.

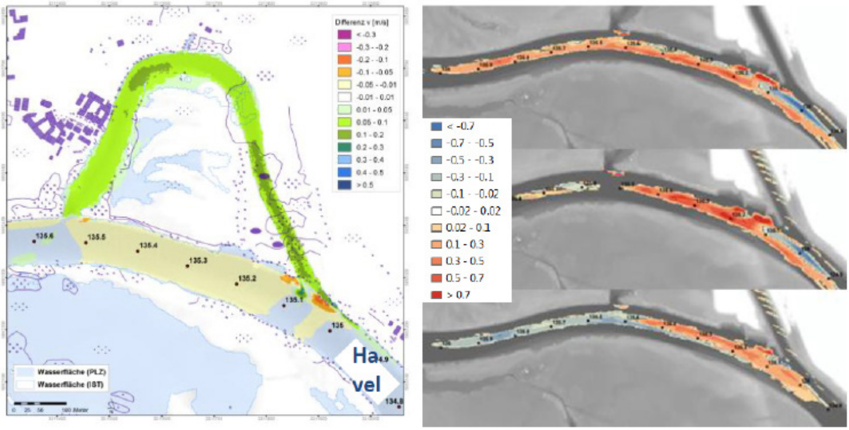

Fig. 3: differences of flow velocities (left) and morphological changes (right)

5. Conclusion

The overall simulation results show that the applied two-step approach is suitable to investigate the hydrodynamic and morphodynamic effects of measures along a river. The results of the applied approach can be used as reliable basis for approval procedures but also as a professional basis for conflict resolution strategies for different interests of river development.

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Determination of the maximum characteristic flows in the urbanizing territory

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Introduction

The present material considers the determination of maximum characteristic flows of Sofia Rivers reflecting the new hydrological conditions in the urban areas. Development of Sofia city as a Bulgarian capital enhances the processes of urbanization with significant increase of territory and population. Dynamics of these processes could be demonstrated with the next facts: in 1880 the territory of the town is 2.8 km^2 and the population is only 20500 people; in 1918 the urbanized territory reaches 7.5 km^2 and the population – 154 000 people; in 1934 respectively - 57 km^2 with 287 100 people; in 1985 – 150 km^2 and 1 114 800 people (Fig. 1). According to the last information from the National Statistical Institute in 2013 the territory of the city is 1134 km^2 and the population is 1 249 665 people representing 16.4% of the whole population in the country.

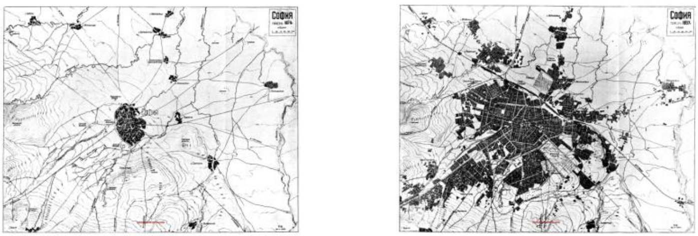
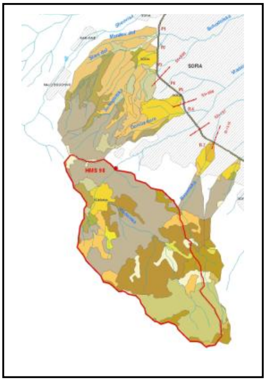


Fig. 1: Old maps of Sofia in 1878 and 1937

The rapid development leads to a constant alteration of topography, landuse and landscape of the city impacting strongly the conditions of formation and concentration of the surface flows. The local urbanization processes influence on the increase and the re-distribution of surface run-off changing its genetical structure. These processes are markedly visible during the maximum flows. The last years the rapid growth of the capital urgently imposes the new methodological issues for maximum flow determination necessary for new infrastructural constructions and flood protection activities. Sometimes the level of urbanization is changing so quick that the conditions of flow formation could be altered in the frame of several years. The determination of the maximum flows is additionally complicated in the case when there is not a suitable hydrological monitoring network or a lack of any observations.

In the present material is discussed the authors' experience with hydrological assessments of the maximum surface flow with a specified return period and at locations of flow concentration along the reconstructed South Motorway of Sofia crossing almost all rivers, which spring in the Vitosha mountain and flow through the whole city till their estuaries at the Iskar river in the frame of the Danubian catchment area (Fig. 2). All tributaries of the Iskar River in the studied region have a similar hydrological regime. But hydrological observations exist only in one hydrometric station (hydrometric station Kniajevo) located at the beginning of the city with a still low level of urbanization (5%). This active hydrometric station is located at the Vladaiska river one of the biggest ones flowing through the city area. But other sub-watersheds in the Sofia area are heavily impact on the urbanization (up to 100%). On the Fig. 2 left below is shown the landuse and urbanization level at the watersheds in the studied region with description of different used landuse classes for the Vladaiska River as an example on the right.



Landuse and urbanization (Vladaia station)	AREA ($km^{2)}$
Discontinuous Urban Fabric	1.498
Industrial or Commercial Units	0.278
Sport and Leisure facilities	0.410
Pastures	0.108
Complex cultivation patterns	0.540
Land principally occupied by agriculture with areas of natur	0.884
Broad Leaved forest	14.937
Coniferous forest	9.920
Mixed forest	3.127
Natural grassland	2.144
Transitional woodland scrub	2.302
Bare rocks	0.152
Sparsely vegetated areas	0.415
Peat Bogs	7.892

Fig. 2: Landuse and urbanization of watersheds with flow concentration to the project sector

1. Determination of the maximum precipitation and runoff coefficient of the station donor

Determination of the maximum daily precipitation with specified probabilities is based on the division into districts of the daily maximum rains on the territory of Bulgaria (Marinov and all, 1980). The Region of Sofia city is in XX region according to this zoning. In the Table 1 below are shown the daily maximum of rains with different probabilities for Vladaia watershed – Kniajevo area in mm.

Tab. 1: Daily maximum of rains with different probabilities for Vladaia watershed – Kniajevo area (mm)

Station	$\overline{H}$ (mm)	F (km^2)	Probability P %	
			0.1	1
Vladaia River - Kniajevo	44	44.61	137	99

The runoff coefficients at Kniajevo station could be determined using the known formula (1) according to the accepted methodology for calculation of maximum flows (Tab. 2):

$$Q_p = 16.67 * P_{p*} \varphi * \overline{\psi}_{(\tau_p)} * F \qquad (1)$$

Where:

Q_p– maximum flow with some probability (m^3/s); P_p – maximum daily rain with some probability (mm);

φ - runoff coefficient; $\overline{\psi}_{(\tau_p)}$ – reduction coefficient of maximum rains; F – area (km^2); τ_p – time for flowing down (min) shown in the Table 2 below.

Tab. 2: The runoff coefficients at Kniajevo station

Lp	J_p	Q_p	τ_p	$\psi(\tau_p)$	$\overline{\Psi}(\tau_p)$	F	P_p	φ	P
km	km	m^3/s	min		min^{-1}	km^2	mm		%
17.05	0.0909	83.56	243.72	0.674	0.002767	44.61	137	0.30	0.1
17.05	0.0909	52.79	273.38	0.693	0.002535	44.61	99	0.28	1

The runoff coefficients of the Vladaiska River at Kniajevo HMS for maximum length of drainage (Lp) and slope (Jp) are shown in the Table 2. The calculated runoff coefficients correspond to the calculated coefficients by other authors (Gergov, 2003). According to these studies the runoff coefficient in the region is higher than the average one for the country assessed as 0.25 and reaches values up to $\alpha \leq 0.48$.

It was mentioned above the donor Vladaiska watershed till the hydrometric station is less touched by the urbanization processes. If the process of urbanization might be accepted as fully completed and the average runoff could be increased till 0.8 the specific flow would increase significantly as can be seen on the Fig. 3. The figure represents a „very good forecasting and warning" for the future negative flood events if the process of urbanization would cover the whole area of investigated monitored sub-watershed. Obviously going into the heart of the city, with additional flow accumulations from another river stretches, the high flow magnitude and for flood risks would augment additionally. The forecast specific water flows increase very much – up to 2.67 times only as a result of higher urbanization.

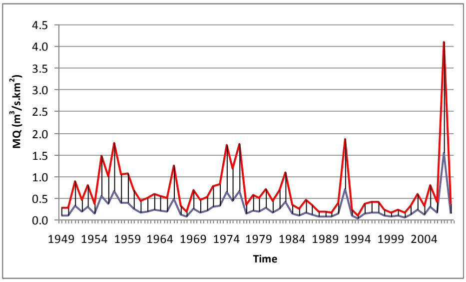


Fig. 3: Alteration of the specific flows accepting full urbanization of sub-watershed Vladaiska River at Kniajevo HMS

Considering changeable intermediate level of urbanization, at the same area with respectively changeable middle runoff coefficients, the characteristic maximum flows might change as it is shown in the Fig. 4 – Relationship between flows and return periods depending on urbanization level. Surely the level of urbanization is very decisive factor itself.

The analyses show that the usage of hydrological information from hydrometric donor station located at watershed with low level of urbanization for another watershed with higher urbanization might decrease the characteristic maximum flows even though in catchments with hydrological homogeneity. Some correction coefficients of reliability should be applied especially when the characteristics flows are required for important constructions menaced by potential floods.

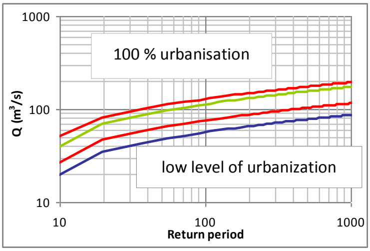


Fig. 4: Relationship between flows and return periods depending on urbanization level

2. Determination of maximum flows in unobserved urbanized watershed

For the maximum annual runoff determination, at the point of interest of the Sofia Rivers, a methodology of new data rows generation using the unique station donor at Kniajevo is accepted. Two different approaches are compared:

- Division of watershed as urbanized and non-urbanized and generation of two separate data rows with annual maximum flows. For the non-urbanized parts of watershed are accepted runoff characteristics of the hydrometric station donor. For the urbanized parts is render an account of the level of urbanization by correction of the runoff coefficient at the station donor
- Generation of a new data rows rendering an account of the level of urbanization and the landuses for different watersheds with correction of the runoff coefficient at the station donor using weighed coefficient corresponding to each watershed depending on its urbanization and landuses.

In our pilot area of Sofia the calculated characteristic maximum flows using the both approaches produce almost the same values with insignificant differences mainly because of the hydrological homogeneity of the region under natural conditions.

3. Conclusions

Using the methodological approach for generation of new rows of hydrological data rendering an account of the level of urbanization and the character of landuses by correction of runoff coefficients gives the opportunity to assess the characteristic maximum flows in different urbanizing territories and the flood risks with enlargement of urbanization processes and changes in landuses.

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Changes in hydrological extremes and climate variability in Slovenia

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Introduction

Hydrological extremes in Slovenia are more frequent, violent and destructive over recent years. Floods and droughts can occur even in the same year. The periods of low discharges are longer, leading to hydrological drought; on the other hand, high-intensity rainfall occurs frequently, usually leading to flash floods. The main reasons for these changes are climate variability and climate change. Climate change is increasingly noticeable in the changes of river discharges and flow regimes, which are largely dependent on climatic factors. Trends of river flows show a general reduction in water quantity and lengthening periods of low discharges leading to drought conditions. The differences between river flow regimes are less distinctive than in the past and the number of them is decreasing (Frantar and Hrvatin, 2008).

1. Climate variability and climate change in Slovenia

The interaction of three major climate systems (Continental, Alpine and sub-Mediterranean) in the territory of Slovenia strongly influences the country's precipitation regime. The spatial variability of precipitation is high (Dolinar, 2008). The annual precipitation sum varies from 800 mm in the NE part of the country to more than 3500 mm in the NW part of the country. The spatial distribution of precipitation is highly influenced by the country's diverse terrain.

Similarly to the most parts of the world measurements in Slovenia clearly indicate that the climate is warming up. The air temperature is rising in all parts of the country. A strong positive air temperature trend of 3.4 °C per century is identified in the analysed 51-year period (1961-2011) over the whole country (Dolinar et al., 2013). In the aspect of meteorological seasons (DJF-winter, MAM-spring, JJA-summer, SON-autumn) the highest trend for country mean air temperature is detected in summer (4.7 °C per century) and the lowest trend is detected in winter (3.3 °C per century). Trend in spring is 3.8 °C per century, while trend in autumn isn't statistically significant.

At the same time other climatic variables like precipitation and snow cover, which have a significant impact on the water regime and many human activities, are also changing. Changes in precipitation at annual level are not very obvious, but seasonal changes in precipitation are evident (Fig.1). The autumn peak is becoming more distinctive, while the quantity of precipitation in the other months is decreasing (Dolinar, 2008). Additionally, the accumulation of precipitation in the snow pack is reduced (Bertalanič et al., 2010).

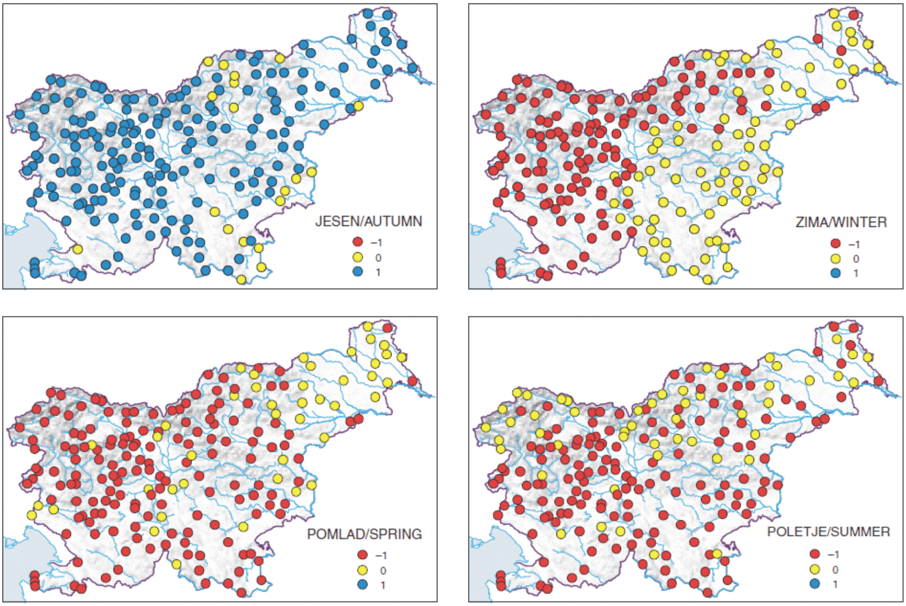

Fig. 1: Statistically significant trend in the seasonal precipitation for the period 1971-2000 (Dolinar, 2008)

2. Temporal variations of river flows

Analysis of the temporal variability of flows using available historical observed and measured data can show the changes in the hydrological behaviour of the river. The data from the hydrometric gauging station Litija on the Sava River show that there was a mostly wet period in the late 19th to the first half of the 20th century, until 1940 (Fig. 2). During this period, mean and also minimal annual flows were greatly above periodical average, with the exception of only individual years. Between 1940 and 1960 there was a very dry period, followed by an almost 20-year period with flows above periodical average. Continuous period with mean annual discharges mostly below the periodical average is lasting from the year 1980.

On the contrary, the distribution of annual flood peaks in comparison with the mean discharges is particularly uniform (Fig. 2). Annual flood peaks were below average only in the period 1940-1960. The distribution of annual flood peaks in the last three decades differs from the mean annual discharges and corresponds to the periodic average. We can observe frequent high peaks. Both extremes, floods and droughts therefore occurred in the same year. The reason is the uneven distribution of precipitation during the year, because most of the precipitation falls in the form of short-term and heavy rain. As a result, the periods of low discharges are getting longer. The trend of low flows, lasting for periods of over 30 days shows declining flows almost anywhere in the country (Kobold and Ulaga, 2012). A statistically significant decrease in flows is particularly recognizable in mountainous regions. The reason is less snow-abundant winters over the last thirty years. This contributes to reduced spring flows and consequently longer periods of drought.

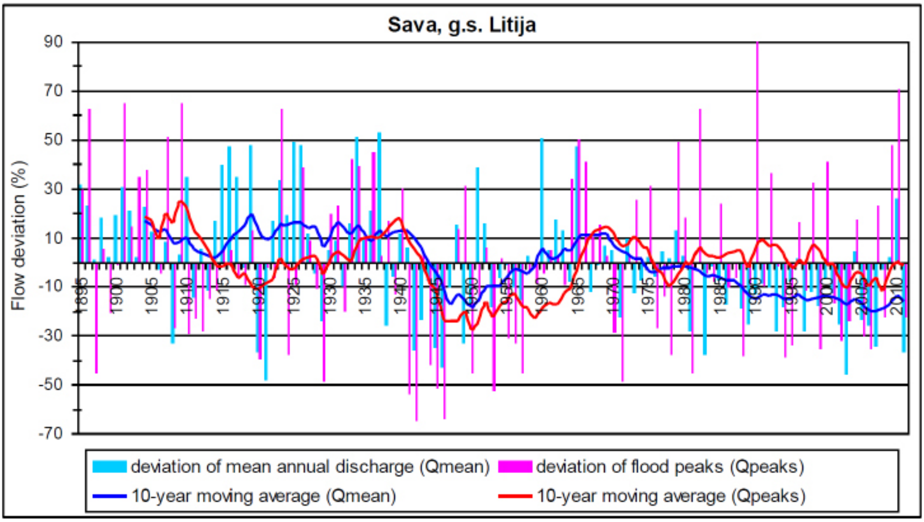

Fig. 2: Deviations of the mean annual and annual flood peak discharges from the periodical means

A high number of flash floods and large-scale floods occurred in Slovenia in last decade. The largest floods in recent years were floods in 2007, 2009, 2010 and 2012. The flood-peak discharge magnitude of the majority of the rivers has grown. The number of flood events shows an increasing trend in the period 1996-2012 (Fig. 3). On average nearly 60 high-water events occur per year when river flows exceed the flood warning level. Floods in Slovenia are regular phenomena occurring almost every year by rainstorms affecting different regions of the country, although the severity of the high water phenomena is increasing, especially on smaller streams in torrential and mountain catchments and also on the headwaters of major rivers.

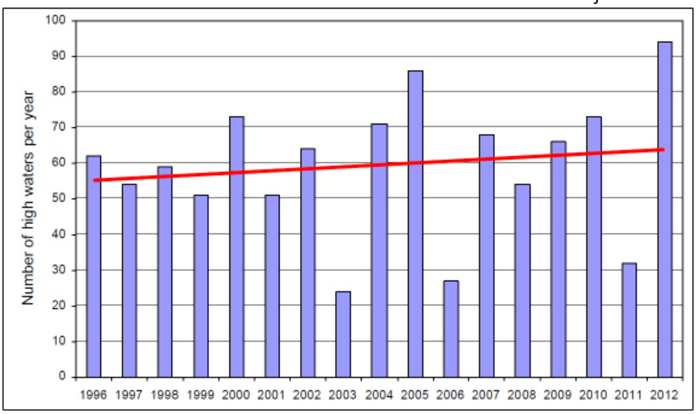

Fig. 3: The number and the trend of high water events on Slovenian rivers

Long lasting precipitation deficit indicates shortage of water and drought. The shortage of water especially affects agricultural crops in the summer. Summer droughts are more frequent; huge damage in agriculture has occurred twelve times since 1990, including nine times since 2000 (Fig. 4). But drought is a regional phenomenon with an unequal impact in a scale of the whole country.

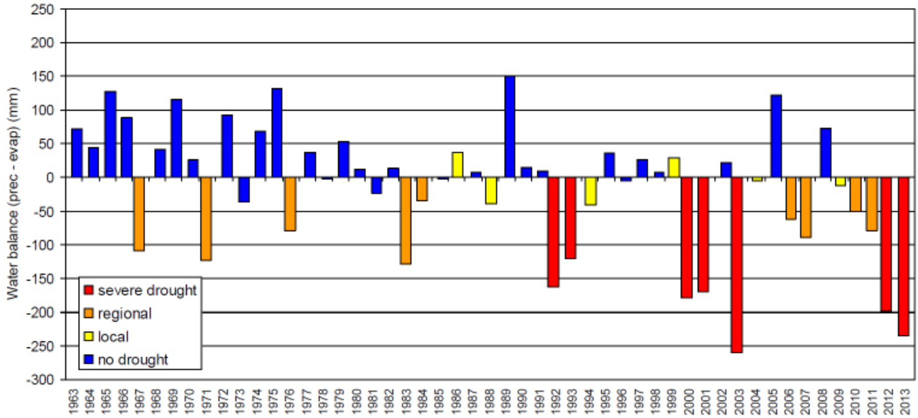

Fig. 4: Severe, regional and local droughts in Slovenia in the period 1963-2013 identified on the basis of the average water deficit (precipitation - evaporation) during the summer period (Sušnik et al., 2013)

3. Conclusion

Climatic and hydrological analyses and investigations of river flow regimes confirm the impact of climate change on the water cycle in Slovenia. Climate change is increasingly noticeable in the changes of river discharges and flow regimes which are largely dependent on climatic factors. Flood risk vulnerability is projected to increase in the future due to the combined impact of anthropogenic factors and climate change. Particularly worrying in the context of climate change is the already considerable risk of floods which is expected only to increase. Apart from direct risk to human life and health, floods also increase the psychological pressure on the population living in the regions at risk. The damage caused by weather related events in Slovenia is huge and rising in recent years.

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Water flow of rivers in modern and expected climate changes in basin Tisza (within the limits of Ukraine)

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Introduction

Climate changes include a set of oscillation climatic characteristics of different scales, but first of all, it changes in air temperature and precipitation. They have in the past decade with significant impact on the long-term fluctuations of many hydrological processes is reflected in changes in the components of the water balance areas and the hydrological cycle. Meteorological conditions some years form the features of the climate, which manifest themselves in modern terms the variability of the elements of the water regime of rivers. This includes snow cover, transpiration, and groundwater. Redistribution of precipitation within the year is reflected in fluctuations in river flow, groundwater regime in soil moisture reserves.

1. Materials, methods and results of research

Changes in the hydrological regime of rivers is directly related to two major factors - changes in thermal regime and regime moisture. Evaluation of modern hydrological consequences as a result of climate change was based on solving in principle water-balance relationships in the form of statistical dependencies between meteorological factors and flow, with particular emphasis sensitivity on the flow to changes in temperature air and precipitation.

Condition and nature of changes in of river runoff in the basin the Tisza (in Ukraine) in modern period (1991-2011 years) conducted the comparative estimate of runoff for the base period (climatic norm - 1961-1990 years). Also by similar periods revealed changing meteorological conditions (Fig., Tab. 1:).

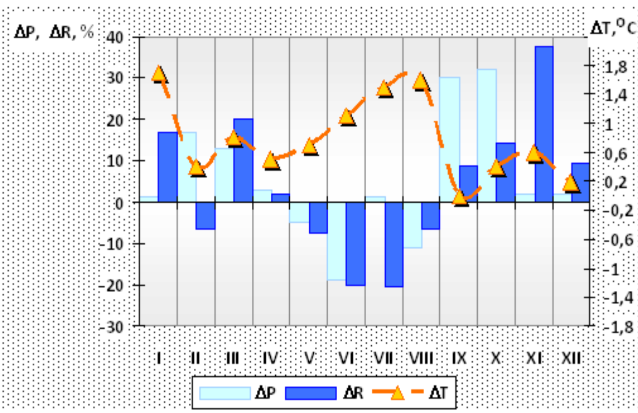

Fig. Changes in average monthly air temperature (*ΔT, °C*), the amount of precipitation *(ΔP,%)* and water flow *(ΔR,%)* in basin Tisza within the limits of Ukraine in 1991-2010 years period relative to the climate norm (1961-1990 years)

Tab. 1: Changes in the average, maximum, minimum monthly, seasonal and annual temperature (dT, C), monthly, seasonal and annual precipitation (dP,%) and the average monthly, seasonal and annual water flow (dR,%) in the Tisza in within Ukraine in 1991-2010 years relative to the climate norm (1961-1990 years)

Periods	Changes in the 1991-2010 biennium relative climatic norm (1961-1990 years)					
	temperature, oC			amount of precipitation,%	water flow,%	
	average	maximum	minimum		average	maximum
I	+1,7	+1,3	+2,2	+1	+17	-6
II	+0,4	+0,2	+0,6	+17	-6	-26
III	+0,8	0,0	+0,4	+13	+20	+11
IV	+0,5	+0,6	+0,2	+3	+2	+3
V	+0,7	+1,0	+0,4	-5	-7	-10
VI	+1,1	+1,4	+0,7	-19	-20	-22
VII	+1,5	+1,8	+1,3	+1	-20	-17
VIII	+1,6	+1,9	+1,3	-11	-6	-7
IX	0,0	-0,2	0,0	+30	-4	+1
X	+0,4	-0,3	+0,7	+32	+15	+37
XI	+0,6	+0,8	+0,3	+2	+38	+41
XII	+0,2	+0,1	0,0	+2	+10	-4
winter	*+0,8*	*+0,5*	*+1,0*	*+6*	*+6*	*-12*
spring	*+0,5*	*+0,5*	*+0,3*	*+2*	*+5*	*+2*
summer	*+1,4*	*+1,7*	*+1,1*	*-10*	*-18*	*-15*
autumn	*+0,4*	*+0,1*	*+0,4*	*+20*	*+5*	*+26*
year	***+0,7***	***+0,7***	***+0,7***	***+6***	***+3***	***0***

Based on the regional model REMO-ESNAM5 built projection changing climatic characteristics in the Tisza River Basin for the period 2021-2050 years for balanced scenario of society - A1B. Conversion of the expected impacts of climate change to the middle of XXI century in runoff water carried by the empirical dependences between changes in runoff and changes in temperature air and precipitation in 1991-2010 years relative to the climate norm (1961-1990 years).

Changes in average water flow during the warm season ΔR av. w. p.

$$\Delta R \; av.\; w.\; p. = 0.462\Delta P + 5.326\Delta T - 10.61, \quad (Rr = 0.877). \tag{1}$$

Changes in average water flow during the cold season ΔR av. w. p.

$$\Delta R \; av.\; c.\; p. = -1,268\Delta P + 1.834\Delta T - 23.52, \quad (Rr = 0.592). \tag{2}$$

Where ΔP= change in precipitation

ΔT= change in temperature conditions of air

Rr= multiple correlation coefficient dependence ΔR *av.* = $f(\Delta R, \Delta T)$ for warm and cold seasons

The equations of multiple correlation dependence ΔR *av.* = $f(\Delta R, \Delta T)$ allow appreciate in Tisza River Basin (in Ukraine) possible changes in average monthly, seasonal and annual runoff (Tab. 2). Moreover, predictive estimates of changes in runoff water years 2021-2050 are given relative to the climatic norm (1961-1990 years) and relatively modern period (1991-2010 years)

Tab. 2: Projections of changes average air temperature, amount of precipitation in the years 2021-2050 with respect to climatic norm (1961-1990 years) and evaluation prognostics of changes in water flow in 2021-2050 years

Periods	Projections of changes in the years 2021-2050 with respect to climatic norm (1961-1990 years) based on the regional model *REMO-ECHAM5*		Pprognostics evaluation of changes in water flow in 2021-2050 years			
			with respect to climatic norm (1961-1990 years) (with dependencies)		with respect to modern period (1991-2010 years)	
	average air temperature, oC	amount of precipitation,%	average	maximum	average	maximum
I	+1,3	-1,7	+28,1	+21,7	+11,1	+27,7
II	+2,1	+31,6	-12,7	-39,8	-6,7	-13,8
III	+1,3	+0,3	+25,5	+17,8	+5,5	+6,8
IV	+0,5	+1,4	-7,3	-4,5	-9,3	-7,5
V	+0,3	+13,5	-0,1	+6,3	+6,9	+16,3
VI	+1,1	-2,1	-5,7	-2,2	+14,3	+19,8
VII	+0,7	+11,1	-1,8	+3,8	+18,2	+20,8
VIII	+1,2	-10,9	-9,3	-7,5	-3,3	-0,5
IX	+1,2	+28,5	+8,9	+20,0	+12,9	+19
X	+2,3	-28,0	-11,3	-10,6	-26,3	-47,6
XI	+0,3	-4,1	+29,3	+23,6	-8,7	-17,4
XII	+0,4	+34,9	-20,0	-50,8	-30	-46,8
winter	*+1,4*	*+22,8*	*-4,6*	*-34.5*	*-10,6*	*-22,5*
spring	*+0,9*	*+6,2*	*+6,0*	*+6.5*	*+1*	*+4,5*
summer	*+1,0*	*-0,1*	*-5,6*	*-2*	*+12,4*	*+13*
autumn	*+1,3*	*-0,3*	*+9,0*	*+11*	*+4*	*-15*
year	*+1,7*	*+6,3*	*+2*	*-2*	*-1*	*-2*

Conducted the predictive estimates in change of maximum flow $\Delta R\ max$ on dependence $\Delta Rmax = f(\Delta Rav.)$

Changes the maximum flow of water in the warm season (3) and the cold season (4)

$$\Delta\ R\ max.\ w.\ p. = 1{,}5124 \Delta R\ av.\ w.\ p. + 6{,}4992,\quad r = 0.953 \tag{3}$$

$$\Delta\ R\ max.\ c.\ p. = 1{,}5078 \Delta R\ av.\ c.\ p. - 20{,}624,\quad r = 0.968 \tag{4}$$

Where r= pair correlation coefficient.

2. Conclusion

In the dynamics of water resource, in the space-time variability of runoff decisive role have climatic factors. According to the water balance equation, the river flow is the difference between precipitation and evaporation from the surface of the river basin, which gives reason to practice to assess changes in water flow to changes in thermal regime and regime moisture. The effect of these factors to some extent corrected by the peculiarities of the geographical position of the territory and its relief.

The impact of Hillslope Length parameter on SWAT streamflow prediction in the Upper Danube

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Introduction

A main challenge for eco-hydrological modeling at large scale concerns the identification of the best input data in order to assess hydrological processes and water quality efficiently. Model spatial input data are the primary sources of the uncertainty in hydrological modeling (Zhang et al., 2014). The impact of topographic data and the quality of spatial prediction is well documented (e.g. Chaplot, 2005, Zhang et al., 2014). In the SWAT model (Soil and Water Assessment Tool, Arnold et al., 1998), the topographic attributes of the sub-basins are all derived from Digital Elevation Models, DEM, (Chaubey et al., 2005; Jha et al., 2004). DEM resolution affects the watershed delineation, stream network and sub-basins classification (Cotter et al. 2003; Chaubey, 2005). A courser DEM resulted in decreased representation of watershed area, decreased slope, increased Hillslope Length, decreased streamflow, sediment, NO3-N and TP load predictions (Lin et al., 2010). However, Robison et al. (1995) and Jha et al. (2004) pointed out that after a certain threshold in the number of sub-basins was reached, few changes in streamflow outputs were observed. Among the topographic parameters, the sub-basin Hillslope Length parameter plays an important role in predicting runoff, lateral flow, and sediment yield through the peak runoff. Over the last 20 years several algorithms have been developed based on the geographic information system (GIS) technology for the Hillslope Length estimations. Recently, Zhang et al. (2012) proposed a GIS toolbox to estimate Hillslope Length based on flow accumulation. The objective of this study was to analyse the impact of DEM resolution (25 or 100 m) and Hillslope Length estimations on SWAT model streamflow output.

1. Materials and Method

1.1 SWAT model

The Soil and Water Assessment Tool (SWAT) is a physically based watershed-scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields with varying soils, land use, and management conditions. The SWAT model is widely used either to perform hydrologic assessment or to simulate nutrient diffuse pollution, losses and emission scenarios on river basins of different sizes. The model is demanding in terms of input data, assessment of processes and calibration efforts.

1.2 Study site

The study area is the Upper part of Danube Basin. The Upper Danube covers about 132000 km^2 across Austria, Germany, Czech Republic and Slovenia, extending from Danube sources down to the Gabcikovo Reservoir. The area was subdivided in 753 sub-basins with 180 km^2 of average area. The altitude ranges from 3873 to about 100 m. Major land uses within the watershed are forest (38 %) and arable land (34 %). The mean annual precipitation is around 900 mm.

1.3 DEM and Hillslope Length configurations

Six different SWAT configurations were defined to assess the best DEM resolution and Hillslope Length. Two pan-European DEMs, the Shuttle Radar Topography Mission (STRM, pixel size of 100 m), and the ASTER Global DEM (ASTER GDEM V2, pixel size of 25 m) were used. Three algorithms were applied to each DEM to calculate Hillslope Length: L1, calculated with the default SWAT method based on sub-basin slope; L2, calculated with a 3D flow accumulation algorithm (Zhang et al., 2012); and L3, by setting a default value equal to 50 m in all sub-basins. In all six cases the watershed delineation in sub-basins was kept constant. Malagò et al. (2014) reports the other common spatial input data used in SWAT (land use, soil, climate data). Mean, min, max and standard deviation of altitude (m) did not differ significantly between the two DEM, and slopes decreased from DEM 25 to DEM 100.

Large differences could be observed for Hillslope Length distributions (Tab.1). The mean Hillslope Length L1 increased by 12% from DEM 25 to DEM 100. With flow accumulation (L2), DEM25 gave values that were approximately the half of those of DEM 100.

Tab. 1: Hillslope length (m) and Slope statistics (%) for the different configurations

	DEM 25 L1 (m)	DEM 25 L2 (m)	SLOPE (%) 25	DEM 100 L1 (m)	DEM 100 L2 (m)	SLOPE (%) 100
Min	9.15	20	0.9	9.15	50	0.6
Max	121.95	45.12	62.7	121.95	63.81	59.5
Mean	52.45	32.87	15.1	58.61	58.05	13.7
StDev	31.07	3.01	15.4	34.10	1.14	14.6

1.4 Streamflow calibration and regionalization

A step-wise calibration approach was developed in order to calibrate the streamflow. This methodology involves sensitivity analysis, multi-variables calibration and regionalization of the calibrated parameters (Pagliero et al., 2014; Malago` et al., 2014). The methodology required the selection of the headwater sub-basins, whose calibration was performed using SUFI-2 (Abbaspour, 2008) method through sequential steps that focused on different hydrological processes. The final calibrated parameters set of “sub-basins donors” was transposed to ungauged sub-basins using the hydrological similarity approach (regionalization technique). In the Upper Danube, each SWAT configuration was calibrated using monthly and daily streamflow data of about 25 monitoring-points covering the period 1995-2004.

1.5 The evaluation of the impact of DEM and Hillslope Length

The impact of DEM resolution and Hillslope Length on uncalibrated SWAT outputs was quantified using the percentage bias between monthly rescaled outputs of each model, assuming the DEM 25-L2 as the finer and most realistic of the six configurations. The impact of Hillslope Length on calibrated SWAT streamflow was assessed using the bR^2 and Nash-Sutcliffe coefficient (NSE) between the monthly calibrated and observed streamflow of 150 gauged stations. The percentage bias (PBIAS %), bR^2 and NSE were performed using the R package “hydroGOF” (Zambrano, 2010). The period of these monthly analyses cover the years from 1995 to 2009.

2. Results and Discussion

2.1 The impact of DEM resolution and Hillslope Length in the uncalibrated models

Table 2 shows the percentage bias (PBIAS, %) of uncalibrated monthly outputs (753 sub-basins) in the six SWAT configurations. Note that monthly outputs were rescaled by the upstream area (km^2). DEM resolution and Hillslope Lengths did not impact uncalibrated streamflow significantly. Similar to flow, total N and P changed little with DEM resolution. Conversely, the impact of DEM resolution on sediment yields was large, probably due to the combined effect of slopes and Hillslope Length changes. However, uncalibrated models can misrepresent the realistic impact of DEM resolution and Hillslope Length on the outputs, as hydrologic calibration is essential to achieve realistic estimations of sediment yields.

Tab. 2: PBIAS (%) of monthly outputs of SWAT configuration compared to DEM 25-L2

VARIABLE	DEM 100 L1	DEM 100 L2	DEM 100 L3	DEM 25 L1	DEM 25 L3
STREAMFLOW	0.5	-0.2	-0.2	0.5	-0.1
SED	-40.3	18.9	8.4	-32.2	27.8
N	-5.9	1.2	-1.1	0.3	6.1
P	-7.4	2.5	-0.4	-0.4	8

2.2 The impact of DEM and Hillslope Length in the calibrated models

In order to assess the performance of the six configurations, Fig.1 displays the cumulative frequency curves of bR^2 and NSE between calibrated and observed streamflow of 150 gauged stations. In all cases the goodness of fit improved with the transposition of calibrated parameter sets to hydrologically similar sub-basins. After calibration, the six configurations reached approximately the same good performances, albeit the DEM 25 L1 and DEM 100 L1 seemed slightly better performing.

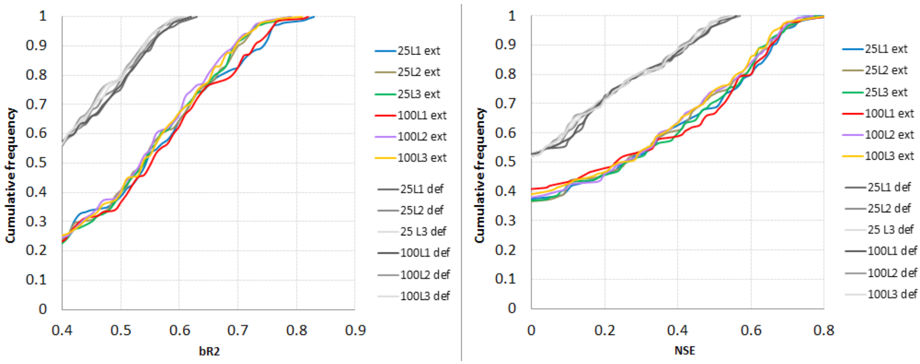

Fig.1. bR^2 and NSE cumulative frequency curves for the six uncalibrated (def) and calibrated (ext) models

3. Conclusion

The analysis showed that the DEM resolution and Hillslope Length algorithms did not influence streamflow predictions significantly. All configurations reached good statistical performance after calibration. The coarser DEM resolution and default Hillslope Length algorithms (DEM100-L1) can be used to predict streamflow in the Upper Danube efficiently. These results needs to be further verified after more gauging station data are used for calibration and regionalization. The large impact of DEM resolution and Hillslope Length on uncalibrated sediment yields suggests that further research should focus on the impact of these configurations for water quality predictions.

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Experiences from the use of the Curve-Number Method in selected case studies in Slovakia

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Introduction

The Curve-Number method is one of the well known modeling methods in hydrology. The original equations and calculation were developed by Soil Conservation Service (SCS). This method was developed initially for computing the amount of storm runoff, taking abstractions into account. It was intended to model the daily runoff as affected by land-use practices; nowadays it is used for modeling the continuous hydrologic situation too.

Case studies

Like every mathematical calculation of natural processes, the SCS CN method has its advantages and limits too, which are major under different conditions. For testing the model we have made three case studies in different parts of Slovakia. They represent river basins of Domanižanka, Smrečianka and Svacenický jarok. The location of mentioned watersheds is shown in fig.1.

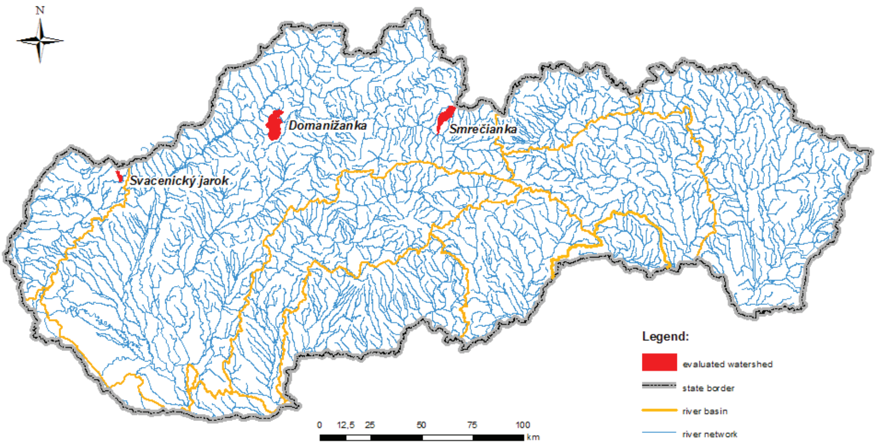

Fig. 1 watershed location

In case study evaluating Domanižanka river basin we have used SCS CN method first of all for modeling its precipitation – runoff conditions up to the water gauging station Prečín. The selected river basin area is 74,05 km^2, and the river length is 13,3 km. The elevation difference between spring and water gauging station is 166 m.

After detailed data analyses we have used SCS CN method for modelling three selected floods on Domanižanka river, as follows: the summer flood in July 1997, the autumn flood in November of the same year and the spring flood in the end of March and beginning of April 2006. All these

floods occurred during different synoptic situations with different precipitation amounts and weather conditions. According to this, the flood wave parameters were different too. So we have made specific individual consecution during modelling of all these floods.
The flood in July 1997 occurred under dry antecedent moisture condition (AMC) and November flood in the same year occurred under normal antecedent moisture condition. For such purpose we have used CN curves AMC II for normal initial conditions and AMC I for dry initial conditions.

Table 1 difference between real and modeled volumes of the selected flood waves.

Duration of the flood wave	CN	Real volume	Modeled volume	Volume difference [%]
30.6. – 31.7.1997	AMC I	6 175 526	6 794 892	10
7.11. – 23.11.1997	AMC II	2 162 160	2 345 413	8

Without moving the curve value from normal to the dry position it has been impossible to model the precipitation-runoff conditions causing the flood wave in July 1997. Than we can achieve that the modeling conditions resemble the real conditions in the river basin during occurrence of the evaluated floods. We have a had a problem with modeling the spring flood in March 2006. The SCS CN method has been unable to model this flood, as during the flood an intensive snowmelt had occurred and this method couldn't be used for such type of runoff modeling. Explicitly we improved one of the main limits of this method.
During next step we have used SCS CN method for modeling the effect of hypothetic land use changes for these floods. We have simulated both versions of the land use changes; it means deforestation as well as afforestation. We have simulated naturally looked changes, like change of land principally occupied by agriculture, with significant areas of natural vegetation turns for example to natural grasslands, or natural grasslands turn to the pastures. This theoretical calculation we have made for some partial river basins of Domanižanka tributaries (Hodoň, Lednický potok and Bodianka) and for the whole evaluated river basin. In case of partial river basin with high percentage of forest we have calculated just the deforestation possibility.
The differences in the outflow volumes between real land-use and changed land-use by afforestation have varied between 1 to 8 %. In case of deforestation the differences have been up to 15 %. The differences have been even higher in case of flood in November than in case of July flood. It was caused due to the different antecedent moisture conditions.
The second case study describes the influence of changes in the way of land use on run-off in a catchment area of Smrečianka creek. For the runoff computation there has been used the CN method in this case too.
Important step in the process of achievement of defined goals has been the correct calibration of model. It has been necessary to choose couple of real rainfall – run-off processes. Three rainfall situations have been chosen: first one from 5th to 9th of September 1996, another one from 5th to 10th of July and last one from 17th to 29th of July 2001. The modeled run-off represents 99.96 % from real one, which means that it's only slightly underestimated. The calibration has been successful and the model produces satisfactory results.

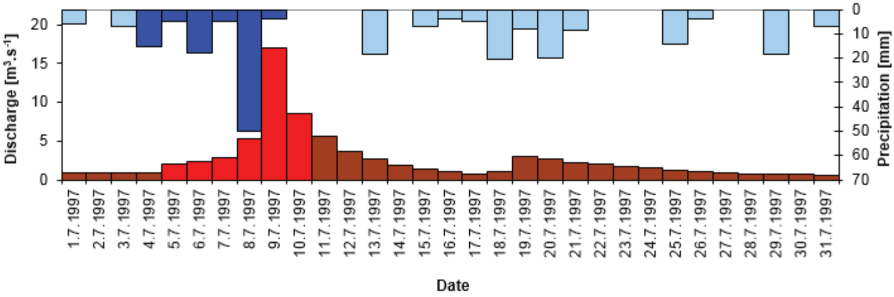

Fig. 2 Precipitation - runoff conditions for the flood-wave in July 1997 in Smrečianka basin

It should be mentioned that due to the absence of water-gauging station at the outfall of the Smrečianka, it has been not possible to calibrate the model for whole catchment area, but only for its upper part. It means that mentioned 99.96 % accuracy of achieved results we can consider only for the simulation of land cover changes for upper part of the catchment area. 5 scenarios of land cover changes have been evaluated in this part, particularly: afforestation, deforestation, replacement of alpine meadows by scrub, replacement of scrub by alpine meadows and replacement of scrub by forest. Four scenarios would result into decreasing of run-off and only one would result into increasing of run-off volume.

Lowest run-off has been simulated for assumption of presence of conifer forest almost in the whole upper part of catchment area. In this case, the volume of run-off would be 5.58 % lower. Deforestation would lead into 1.93 % lower run-off. Replacement of natural meadows by scrub would be the only one from evaluated scenarios which would lead into higher run-off from catchment area (4.64%). Scenario of replacement of scrub by natural meadows would result into 3.52 % decrease and spreading of forest in the areas currently covered by scrub would lead into 4.41 % decrease in run-off from catchment area.

In the terms of run-off production, the most dangerous land cover classes are clear-cut areas with sparse or no vegetation. Significant volume of precipitation drains away also from areas covered with the scrub. On the other end of chart there is conifer forest which in terms of run-off production represents an example of land cover with much better attributes.

Simulations on the fields presented in the lower part of catchment area have been also performed besides the ones mentioned above. The real utilization of soil in respective years and also way of cultivation has been taken into account. Computations have been made for all 15 fields located in the catchment area of Smrečianka. Generally we can say that the lowest run-off can be achieved by temporary grassing of the fields. On the other hand, worst impact on run-off has been showed by growing of potatoes and corn in the fall line.

In the third case a methodology for a post-event analysis of a flash flood and estimation of the flood's peak and volume has been developed and tested. The selected flash flood occurred on the 6th June, 2009 in the Svacenický Creek Basin. To understand rainfall-runoff processes during this extreme flash flood, the runoff response was simulated using the KLEM (Kinematic Local Excess Model) spatially-distributed hydrological model. The distributed hydrological model is based on the availability of raster information about the landscape's topography, soil and vegetation properties and radar rainfall data. In the model, the SCS-Curve Number procedure is applied to a grid for the spatially-distributed representation of the runoff-generating processes. A description of the drainage system's response is used to represent the runoff's routing. The simulated values achieved by the KLEM model were comparable with the maximum peak estimated on the basis of the post-event surveying. The consistency of the estimated and simulated values by the KLEM model was evident both in time and space, and the methodology has shown its applicability for practical purposes.

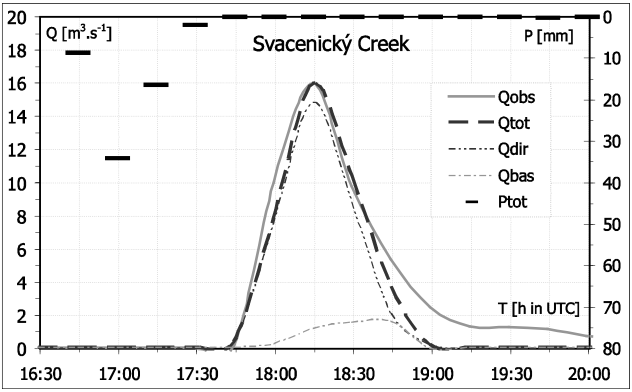

Fig. 3 Simulation of the flood wave's cross section at Svacenický Creek 0,77 km from mouth by the KLEM model

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Flood forecast systems for the catchment of the Inn and the Danube until Passau

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Introduction

Like many other rivers the catchment of the Bavarian part of the Inn and the Danube extends over different countries. As flood forecasting is only possible for the entire catchment an intensive cooperation of the flood warning organizations in different countries is essential.
This paper is about the flood forecasting systems and agreements for the production of flood forecast for the river Inn and the Bavarian part of the Danube until Passau. It also shows experiences from operational flood forecasts, mainly in the Inn catchment, during the flood in June 2013.

1. Catchment of the Danube until the confluence with the Inn

The catchment of the Danube until Neu Ulm is situated in Baden-Württemberg. From Neu Ulm to Passau the catchment lies for the most part in Bavaria. A part of the upper catchment of the rivers Lech and Isar also lie in Tyrol and are included into the Bavarian flood forecasting models.
Between Bavaria and Baden-Württemberg an *Administration agreement about flood forecasting cooperation* was signed, which contains the exchange of discharge measurements and flood forecasts. The Flood Forecasting Centre (HVZ) Baden-Württemberg provides hourly updated forecasts for the Danube at gauge Neu Ulm with a forecast horizon of 7 days, calculated with the rainfall-runoff model *LArSim*. These forecasts are further used by the Bavarian Flood Warning Service (HND). They also run the rainfall-runoff model *LArSim* for the catchment of the Danube and its tributaries and the hydrodynamic model *Flux* for the calculation of the flood routing along the Danube from Regensburg down to Passau.

2. Catchment of the Inn and Danube from the confluence

The Inn catchment lies mainly in Germany and Austria, a part of the uppermost catchment also belongs to Switzerland. As flood warning in Germany and Austria falls within the competence of the federal states, the Bavarian Flood Warning Service and the Hydrographic Services of Tyrol, Salzburg and Upper Austria are involved in the flood forecasting system for the catchment of the river Inn. The part of the Danube from gauge Hofkirchen down to Passau (about 30km downstream) is included here, because the peak flow of the flood wave in and downstream from Passau is mainly formed by discharge of the Inn.

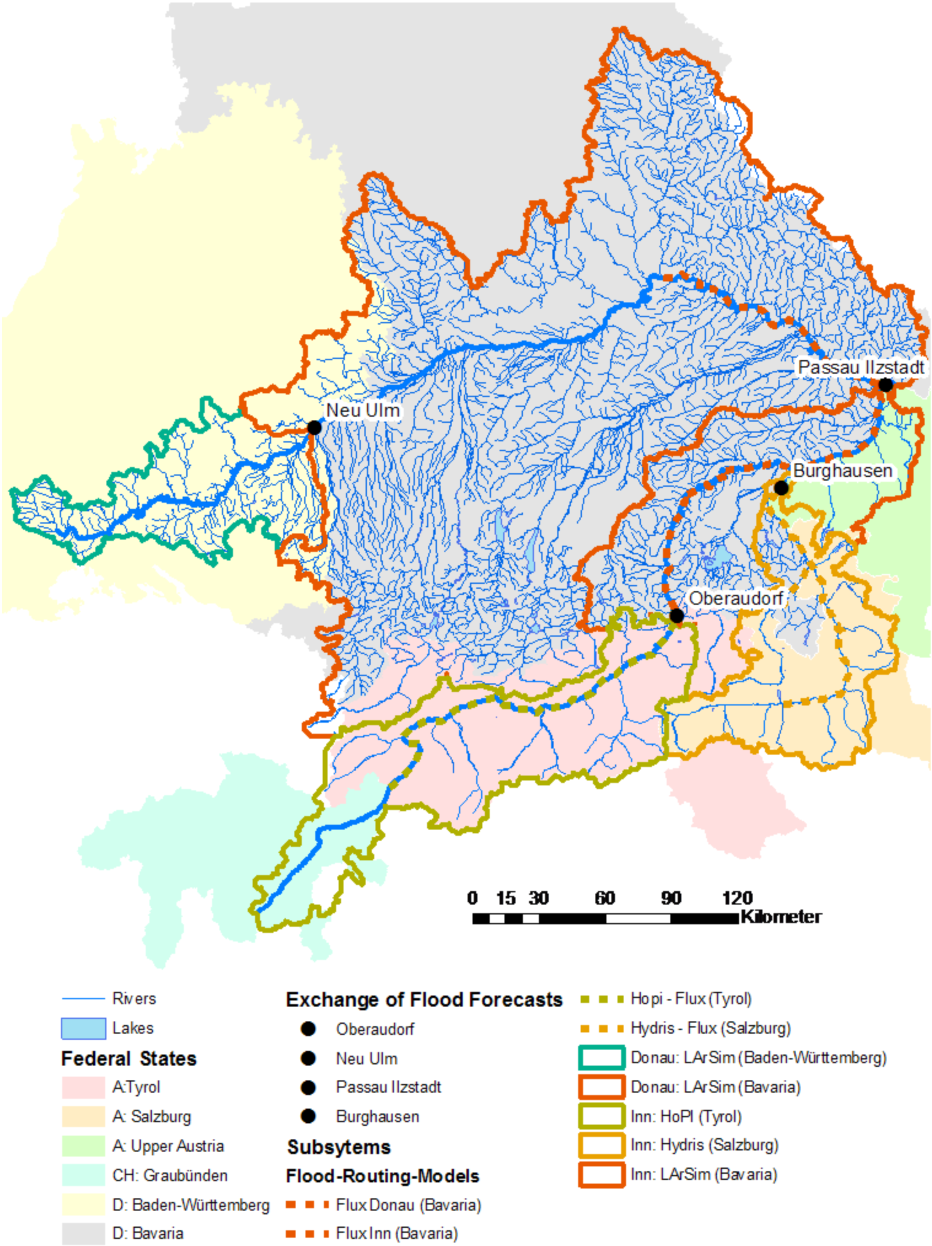

Fig. 1: Flood forecast system for the catchment of the Inn and the Danube until Passau

2.1 Cooperation Agreement about flood forecasting

A *Cooperation Agreement about flood forecasting* was signed in autumn 2011 within the framework of the *Regensburg Treaty*. This agreement rules the handing over of flood forecasts and the assignment of flood-forecasting models for the different sections. An exchange of discharge measurements and data from meteorological stations already existed before.
The agreement includes the catchment of the river Inn and the Danube downstream from gauge Hofkirchen on German and Austrian territory. However, in this paper only forecasting systems for Inn and Danube until Passau are described.
For the different sections of the Inn different flood forecasting models are run as subsystems by the responsible countries. Every country runs the forecast model and publishes the outcome on his own responsibility. Forecasts for a minimum of 48 hours are calculated automatically and delivered every hour. These forecasts have the status of unchecked data.
The upper Inn until gauge Oberaudorf is modelled by the Hyrographic Service (HD) Tyrol. They use the *HoPI* flood forecasting system which consists of the *SES* model for glacial areas, the rainfall-runoff model *HQsim* and the hydrodynamic model *Flux* for modelling of the flood routing of the Inn. Flood forecasts for gauge Oberaudorf are handed over to Bavaria.
Flood modelling for the entire Salzach catchment, including the Bavarian areas, is done by the HD Salzburg with the system *HydRIS* which has a model for glacier areas, a rainfall-runoff-model and the hydrodynamic model *Flux* for the routing of the flood wave along the Salzach and lower part of the Saalach. Flood forecasts are delivered to Bavaria at gauge Burghausen.
The section of the Inn from Oberaudorf to the river mouth in Passau, without the Salzach catchment but including areas in Upper Austria, is in charge of the Bavarian Flood Warning Service (HND). The rainfall-runoff-model *LArSim* is used and the hydrodynamic model *Flux* along the river Inn. Flood forecasts, which consist of both the discharge from Danube and Inn, are passed over to Upper Austria at gauge Passau Ilzstadt.

3. Operational forecasts during flood in June 2013

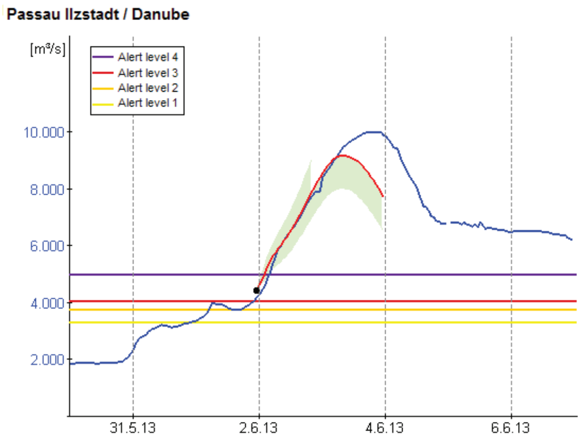

Fig. 2: Example for operational forecasts (red line) at gauge Passau Ilzstadt issued on 2nd of June 0 am with uncertainty range (green area) and the later measured discharge hydrograph (blue line).

Generally, the forecasts for gauges at the rivers Inn, Salzach and Danube calculated during the beginning of the flood wave (for example 2nd June 2013 0 am) met the rising limb of the flood wave relatively well. The prediction of the flood peak for the Danube upstream the confluence of the Inn was satisfying. For the Inn and the Salzach, the flood peak was generally predicted too low and too early. Considerable differences between predicted and the later measured peak discharge occurred at the lower Salzach and the Inn downstream the confluence with the Salzach. This was partly caused by precipitation forecast. But also recalculations of the flood routing from Oberaudorf to Passau with measured discharge and precipitation data simulate the peak for about 6 hours too early.
The example in Fig. 2 shows the forecast for 48 hours at gauge Passau Ilzstadt issued on the 2nd of June 0 am. A peak of ca. 9200m³/s is predicted for 3rd of June about 8 am. The measured data show a peak flow of about 10.000 m³/s on 3rd of June at 7 pm. The green area is the uncertainty range which represents the deviation between measured and predicted data from experiences with former flood events. A part of the upper margin is missing because water level values exceeded the rating curve.

3.1 Experiences and conclusions

In the whole the exchange of flood forecasts and measured discharge as well as the communication worked well between the Hydrographic Services respectively Flood Warning Service of the different countries. Main problems were caused by a temporary failure of the Salzach forecasts that showed that it is necessary for the countries at the lower reach to have an alternative model. With the very high water levels differences in the stage- discharge-relations for nearby gauges in Bavaria and Salzburg at the lower Salzach, and for gauges in Bavaria and Upper Austria at the lower Inn, caused greater differences in determination of discharge. Here the stage-discharge-relations have to be adjusted which has partly already been put into practice. Missing water level and discharge records at gauge Passau/ Ilzstadt caused problems passing over the flood forecast. A second gauge has to be defined within the forecasting models for each exchange point of flood forecasts.

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Estimates of the spatial variability of parameters of the mathematical model of the formation of rainfall floods

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Introduction

For the development of theoretical hydrology and solve practical problems related to the calculation and to the forecast regime of water flow of rivers and its characteristics successfully applied mathematical modeling of the formation of river flow. Prospects for modeling the processes of runoff - is the prospect of hydrology in general. Future hydrologic modeling is related to how well the true transition to universal modeling systems for pools of all sizes and located in any geographic environment. Such attention is because the mathematical modeling facilitates of complex detailed study of the conditions and the processes of river flow based features landscape on water catchments and their spatial diversity.

1. River runoff and its modeling

River runoff is formed under the influence of meteorological factors and underlying surface river catchment. Performance of the last (topography, soils, vegetation) is not only the most influence on the formation of water flow, but also determine the degree of influence of meteorological conditions. In its turn, river basin perceives, re-distributes, accumulates, disperses and directs the matter and energy flows, and performs a double function: on the one hand, it determines the relation of precipitations, runoff and evaporation (water balance) together with the climate conditions and weather, on the other hand,–it re-distributes runoff in time (transformation).So you need to solve theoretical and practical problems that reflect the processes of water flow by spatial heterogeneity of the landscape and meteorological conditions in river catchments.

A characteristic feature of rainfall floods is their genetic heterogeneity. This implies various conditions of their formation, and the dynamics of the flow regime. Although the physics of the formation water flow of the rivers in the mountains to the plains of is the same. However, in the mountains, all these processes are more intensified and expressed more clearly.

Development of mathematical models of the flow is accompanied by a simultaneous systematization, generalization and normalization parameters. Latest designed to reflect the objective physical characteristics water catchments. A question of generalization parameter is inextricably linked to the hydrology of landscapes. Information support modeling of a system of parameters for all natural areas is a prerequisite for the practical use of models.

2. Structural and functional peculiarities of mathematical model

To solve and perform basic tasks of the study used a mathematical model of the formation of rainfall floods DOSHCH. The choice is because there is a significant long-term experience of successful use for the study of the processes of rainwater, calculation and forecast of floods ***in the plains*** *(the right bank of the Pripyat),* ***foothills*** *(Western Bug),* ***mountain rivers*** *(catchments Carpathian region - Tisza, Dniester and Prut).*

Mathematical model DOSHCH is based on the following fundamental provisions:
- Precipitation (rainfall) intensity is taken as water input of the watershed
- Water formation is calculated by means of water balance solutions
- Watershed moistening takes place by the moisture balance in soil layers
- Water formation is transformed into water flows in the river network with the help of application of influence functions.

The structure of the model DOSHCH includes a priori information about basic processes of rainfall runoff formation on the basis of general theoretical and physical notions. They are fall-out of precipitations, evaporation, surface detention, infiltration, filtration, water detention in the draining layer of soil, surface and subsurface water formation, hydrographs of surface, subsurface and basis runoffs, and of common runoff in the outlet of the watershed.

3. Complex of model parameters

Upon making, implementing mathematical models of runoff, reliable determination of parameters is one of the central tasks. The complex of parameters of DOSHCH includes areal and model parameters.

Areal parameters determine the spatial structure of prognostic system. Variety of rainfall runoff formation conditions requires separation of such structural elements as particular basins and particular areas within the territory of research, where rather homogeneous landscape conditions and hydrometeorological situations are observed.

Model parameters are the basis for methodical solutions of the development. They are numerical factors in the algorithmic system of the model for description of elementary processes of rainfall runoff formation. Complex of model parameters is constant for each spatial facility, but the values of parameters vary from basin to basin, depending on their peculiarities.

The model itself, its algorithms are arranged in the similar way, and the interaction between its structural elements is established. There are 13 parameters “working” in its mathematical expressions. They display with certain accuracy averaged characteristics of soils, morphometric and hydraulic characteristics of the watershed as a transforming system. This is the model with distributed parameters, which take into account spatial changeability of factors and landscape conditions, with different detailing required for practical purposes. Source information is represented in the model in the form of time functions, as a sequence of average values of respective meteorological quantities in the watershed, which are precipitation intensity, air humidity deficiency, and wind speed.

Thus, the landscape conditions of any catchment accounted for by parameterization. The level of variability of these parameters varies. Some of them are evaluated according to meteorological observations. The values of other parameters are defined initially only in a certain range, and then refined in modeling flood by applying optimization procedures.
Uncertainty when replacing particular values of the initial parameters of their optimal values

should be compensated for more information. If the processes of the flow depends on the physiographic conditions, and parameters of the mathematical model of the flow depends on the individual performance for a particular catchment these conditions.

4. Generalization of the values of model parameters depending on landscape characteristics of the river basins

Parameters shall reflect objective characteristics of specific watersheds, and it is desirable to have specific physical content. Therefore, special attention was paid to the accuracy, stability and physical relevance of parameters evaluation.

Therefore, the structures of the model DOSHCH and in the result of water balance calculations it was established that parameters k_3, W_m, η have important influence on the water formation of rainfall flood and on the end results of simulation. Parameter W_m determines ability of subsurface soil layer to infiltration and water drainage. Parameter W_m – maximal water-absorbing capacity of the existing soil layer, in which subsurface runoff is formed. Parameter η – relative indicator of existing watershed area and capacity of hollows in the watershed without runoffs. Particular attention is paid to just these three parameters because their values depend on the intensity of the loss of water on the surface detention and surface runoff and subsurface runoff.

The dependences between the said parameters and morphometric parameters of watersheds (average slope (I, ‰), the average height of the catchment (H, m abs) and coverage ratio of forest (F_f, %)) showed good relation, approximation coefficients vary in the range R^2=0,68÷0,94 (fig 1-3).

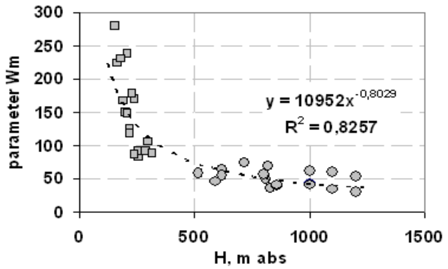

Fig. 1. Dependences of model parameters W_m of the average height of river basins (H, m abs.)

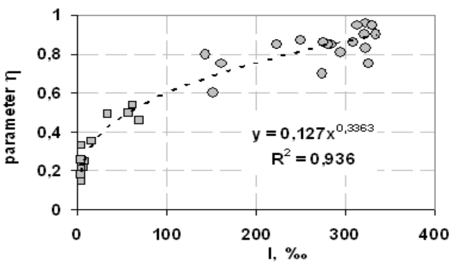

Fig. 2. Dependences of model parameters η of average weighted inclination of river basins (I, ‰)

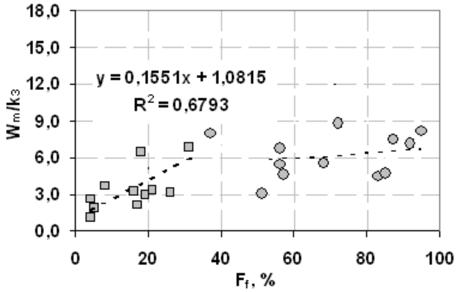

Fig. 3. Dependences of model parameters W_m/k_3 of percentage of forest land of river basins (F_f, %)

With increasing average height of river basins (H, m abs.) - maximal water-absorbing capacity of the existing soil layer W_m decreases.

Relative indicator of existing area runoff of river basins and capacity of area in river basins without runoffs (η) increases with average weighted inclination of river basins (I, ‰)

Also increases value W_m/k_3 with increasing coverage ratio of forest (F_f, %). Moreover, this relationship for mountain basins not clearly defined.

5. Conclusions

Thus, the model parameters for the plains, foothills, mountain basins rivers were systematized, generalized and made part of an information database for the simulation of runoff and use to the forecast rainfall floods. These dependencies can be used to unexplored territories (rivers basins) in hydrological sense.

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Low flow forecasting for the Austrian Danube

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Abstract/Introduction

Most of the Austrian Danube reach is influenced by river runoff power plants and hence the water level is regulated and shipping no problem. Only two sections are not influenced by power plants, which can cause problems for cargo convoys in the case of low flow: the Wachau and east of Vienna. To give the shippers a better possibility to plan their cargo, a low flow forecasting system with a lead time of up to 168 hours has been developed.

1. Area and data

To provide forecasts for the reference gauges Kienstock (Wachau) and Wildungsmauer (east of Vienna), the entire Upper Danube Basin from the Black Forest to the Austrian-Slovakian border is accounted for. The total catchment area (104.000 km²) includes tributaries in Germany, Switzerland and Austria and is quite diverse: elevation ranges from 180 to 3798 m a.s.l., with high mean annual precipitation (MAP) in alpine areas (up to 3000 mm/yr) and low MAP in the eastern lowlands (< 400 mm/yr). Low flows occur mainly in the winter season during cold spells. Snow melt in spring and glacier melt in summer contribute to runoff so that extreme low flow usually does not happen during these times of the year.

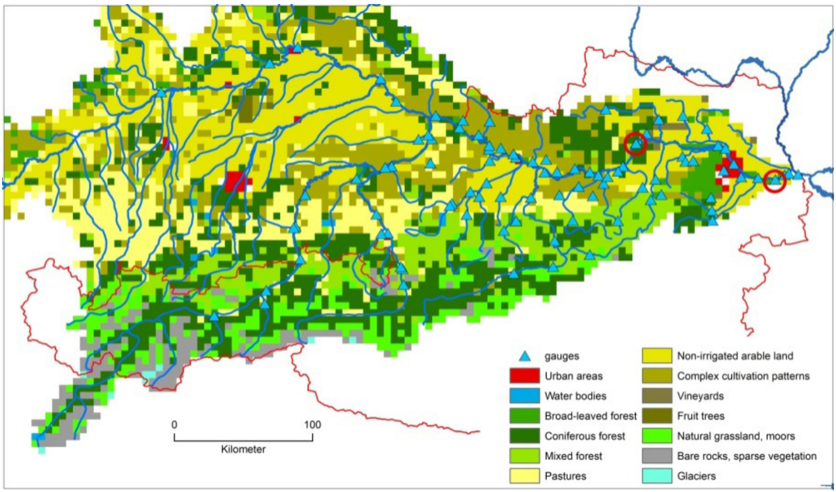

Fig. 1: Corine Land Cover map of the model area. The shown area is the extent of the meteorological model which comprises almost the entire Upper Danube Basin. Blue triangles indicate gauges used for calibration, red circles indicate the sites for which forecast are issued (left Kienstock, right Wildungsmauer)

For the model development, runoff data on an hourly time step were available for 91 gauges; meteorological data were available from 2003-2012 based on the INCA system (Haiden et al., 2011) which is a combination of rain gauge and radar data. Figure 1 shows the spatial extent of the area which is covered by meteorological data, only small parts of the Upper Danube Basin are not covered by the INCA system.

2. Hydrological model and model calibration

The rainfall runoff model used in this study is a conceptual hydrological model (Blöschl et al., 2008) which is applied in a distributed mode. The structure is similar to that of the HBV model (Bergström, 1976) and includes a snow model, a soil moisture accounting model and a routing model. However, several modifications were made including an additional ground water storage, a bypass flow (Blöschl et al., 2008; Komma et al., 2008) and a modified routing routine (Szolgay, 2004). An Ensemble Kalman-Filter method (Komma, 2008) is implemented to update the model states (e.g., soil moisture) prior to the forecasts. The temporal scale is 1 hour, the spatial scale is a 5x5 km raster.

Based on the Corine land cover data set, a priori parameters were assigned to each pixel, the routing parameters were estimated using observed runoff data. Several simulations were used to adjust the a priori parameters, so the model estimates snow melt, the timing of floods and recession curves well. Figure 2 shows the calibration result at the gauge Kienstock (95.970 km²) for the period July 2006-July 2007. The model estimates runoff in the winter well, during snowmelt the model is somewhat overestimating the runoff.

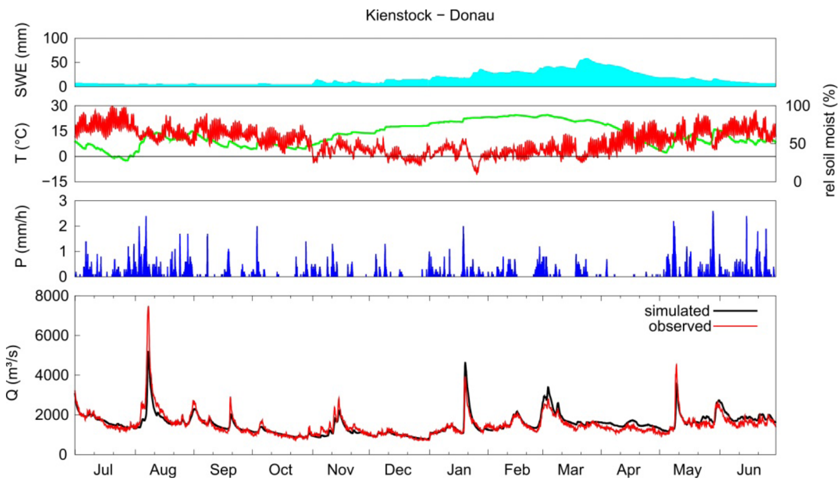

Fig. 2: Calibration results for the gauge Kienstock (95.970 km²), July 2006-July 2007. Panels show mean values of (from top to bottom) snow water equivalent(SWE, light blue), temperature (red) and soil moisture (green), precipitation (blue) and observed (red) and simulated (black) runoff.

3. Low flow forecasts

Deterministic and ensemble forecasts for 168 hours are used operationally to forecast runoff. However, currently the forecasts are published for a lead time of only 72 hours if the water level is below the mean water level. Flood forecasts are generally associated with errors, which can be attributed to uncertainties in the meteorological forecasts and the hydrologic simulations, and ensemble spreads are usually considered capable of representing them (Nester et al., 2012). In the case of a low flow situation, the ensemble spread is small as the uncertainty in the meteorological forecasts is small. To account for the hydrological model errors, a statistical model has been implemented to estimate the uncertainty in the case of low flow periods. This statistical model is based on an evaluation of forecasts using observed meteorological data, assuming that the observed meteorological data is perfect and the resulting errors can be attributed to the hydrological model alone. The operational testing period of the forecasting system has started in summer 2013. Starting in December 2013, a period of very low water levels started which lasted until the end of April 2014. Figure 3 shows an example of a forecast for a lead time of 72 hours for the gauge Kienstock on April 4, 2014.

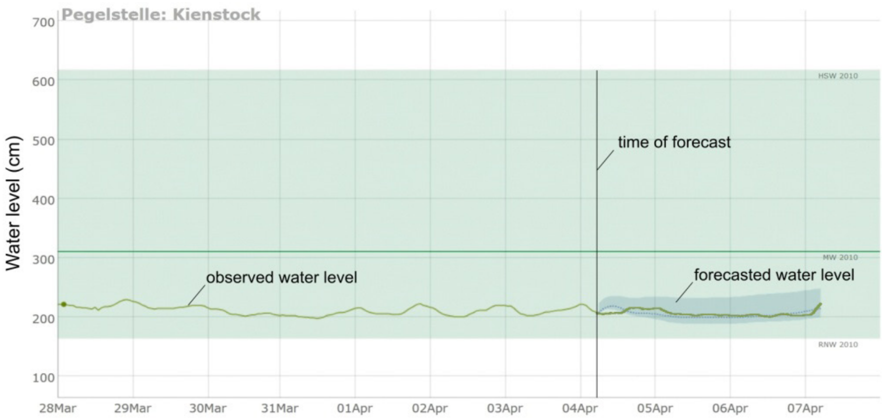

Fig. 3: Low flow forecast (modified screenshot) published online on April 4, 2014. Green line is observed water level, light blue area is the range of navigable water level, dark blue area is forecasted water level for the next 72 hours. (Source: http://www.doris.bmvit.gv.at/pegel_und_seichtstellen/pegelstaende/)

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Hydrological Forecasting System in the Morava River Basin

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Abstract/Introduction

In central Europe floods are the natural disasters causing the greatest economic losses. One way to partly reduce the flood-related damages, especially loss of lives, is a functional objective forecasting and warning system that incorporates both meteorological and hydrological models. Success of the hydrological forecast is strongly depended on the success of the precipitation forecast obtained usually as output from numerical weather prediction models.

Hydrological model HYDROG is used in routine for the calculation of discharge forecasts for the whole Morava river basin within the Flood Forecasting Service of Czech Hydrometeorological Institute - Brno Regional Office. Paper describes the process of the discharge forecast creation, including trans-boundary cooperation (Czech Republic, Austria and Slovakia).

Hydrological forecast is created under the conditions of significant uncertainty. The error of (not only) predicted data can be great. Especially in the case of flash floods, using of the precipitation nowcasting is essential. The precipitation nowcasting, which is derived from the extrapolation of radar echo, can improve first hours of the precipitation forecast significantly.

Probabilistic approach in hydrological forecasting has been implemented in Czech Hydrometeorological Institute recently. Probabilistic discharge forecasts result from the set of different weather forecasts. The probability of limit discharge exceeding can be then estimated. Both deterministic and probabilistic discharge forecasts are issued daily and are presented on the web sites.

1. Trans-boundary cooperation

Czech Hydrometeorological Institute (CHMI) – the national hydrological service – issues daily deterministic hydrological forecasts with lead time of 48 h for more than one hundred water-gauge stations. Within the Morava River catchment there are 25 forecasting profiles in Czech Republic and 3 forecasting profiles in Austria. The forecasts end in the gauging station Hohenau an der March under the junction of Morava and Dyje Rivers. For operation of flood forecasting service the international cooperation is necessary because significant part of upper Dyje catchment spreads in Austria and also there is Myjava River basin in Slovakia, see fig. 1.
Closer partnership between Czech and Austrian side starts after wasting flood event which hit Dyje River basin in spring 2006. Current data measurement turned out to be insufficient especially concerning snow cover. Observation in boundary area was widened and the exchange of data was established. Current hydrological model was extended up to gauging station Hohenau.

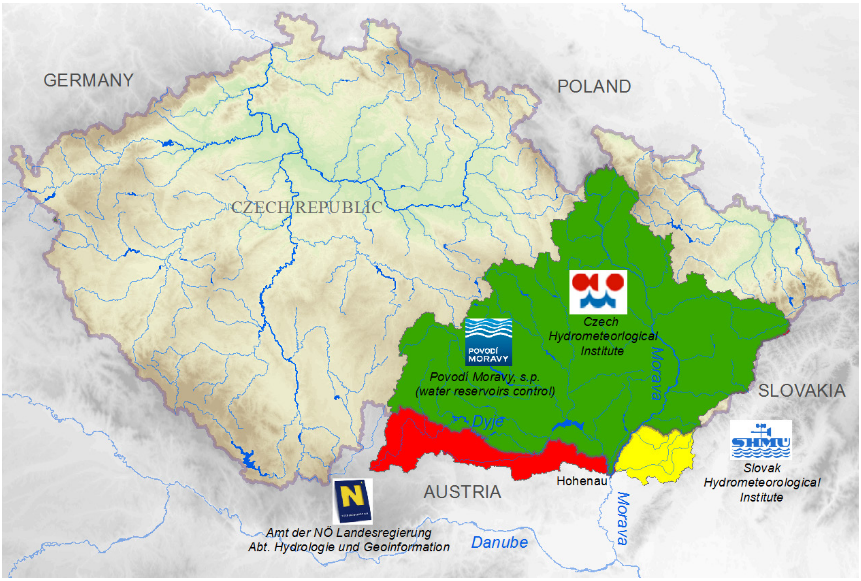

Fig. 1: Area of interest

2. Hydrological modeling

The distributive rainfall-runoff model HYDROG (Starý, 1991-2014) is used for hydrological forecasting in area of interest. The distributive rainfall-runoff models are able to involve both temporal and spatial distribution of the input data (i.e. precipitation, temperatures and snow cover). The exact input data are the fundamental term for the successful simulation and consequently the discharge forecast in the given catchment. There are always some errors of the measurements. These errors must be taken into account in the model calculation. The other requirement is to keep the input data transparency so that it would be possible to edit it where appropriate (e.g. at the underestimating of snow stores in the catchments based on measurement)

For the above mentioned reason the catchments of interests are divided into subareas (polygons) – in the mountain areas the maximum polygon area is dozens of km^2, in lowlands it is possible to think of larger ones. The input quantity is than considered as the mean value. The time step of the input data is one hour.

The input data are automatically prepared by means of GIS. The measured precipitation are combined with radar data estimation in more variations (Šálek et al., 2004), temperatures and snow cover are area interpolated following the point measurements, whereas altitude dependence is taken into account. The forecasting values are considered according the outputs from various NWP models e.g. ALADIN (ALADIN International Team, 1997), in some case the corrections are curried out based on the consultation with meteorologist. The precipitation nowcasting by the method COTREC (Novák, 2007) or by the method INCA (Haiden et al., 2004) is

used for the first three hours of the precipitation forecast.
Process of input data producing and model calculation is automated which enables frequent updating of discharge forecast (every hour if necessary).

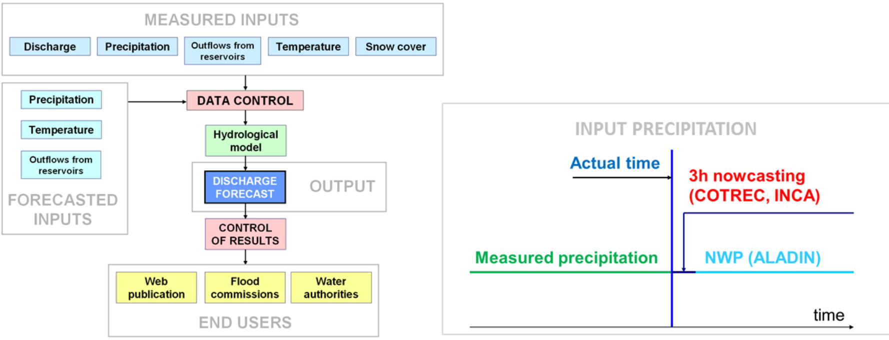

Fig. 2: Input data

3. Probabilistic approach

The error of the precipitation forecast is usually the main factor that influences the accuracy of the final flow forecast – at least when we speak about the forecasting of summer floods caused by heavy precipitation. The deterministic discharge forecast based on one rainfall scenario is a great simplification of the real situation – the indeterminations, which influence the whole calculation process, are not expressed in the final discharge forecast. When significant decisions are to be made according to an actual discharge forecast (e.g. evacuation of inhabitants in the flood-threatened area), it is necessary to estimate the hazard factor.
The probabilistic hydrological forecasts are provided by CHMI since 2012 in addition to deterministic forecasts. Input data comes from ensembles of NWP model ALADIN-LAEF (precipitation and temperature). ALADIN-LAEF produces 16 different weather forecasts with resolution of 18 x 18 km. Hydrological output consist of 16 variants of future discharge in every forecasting profile. The results in form of hydrograms (see fig. 3) are provided only for experts. In order to make results understandable, the outputs for public are presented as probability of limit discharges exceeding during given time interval.

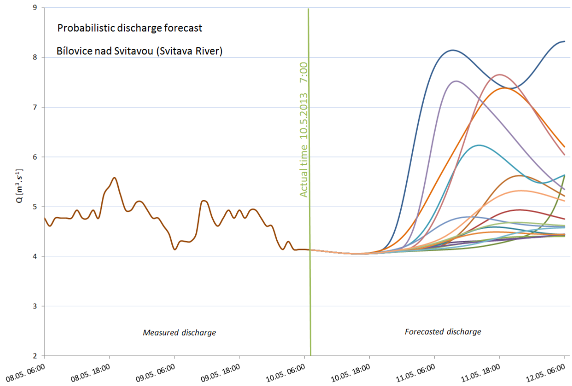

Fig. 3: Probabilistic forecasts

4. Conclusion

Hydrologic forecasting system must be able to react quickly to dynamically changing conditions in the catchment. Therefore the discharge forecasts have to be frequently updated using latest measured data and the most actual weather forecast. To apply the discharge forecast effectively, it is necessary to interpret it well. Therefore we should put the accent on the training of the people involved in the flood-protection, especially in the case of probabilistic forecasts.

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Evolution of the Water Budget in the Danube basin: A multi-perspective View

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Introduction

Water storage in soils, groundwater, and surface water bodies is poorly constrained by direct measurements. As a consequence, we find that hydrological models have difficulties in representing the spatio-temporal water budget in the Danube basin. Complementary information is necessary in order to assess their realism. To this end, we evaluate remote sensing observations of water storage variations provided by the Gravity Recovery and Climate Experiment (GRACE) mission. Additionally, we derive water storage variations via the terrestrial water budget equation, i.e. we combine the atmospheric-terrestrial flux precipitation minus evapotranspiration ($P - E$) from numerical weather models and measured river discharge (R).

1. GRACE and Hydrological Models

Hydrological models simulate fluxes between and the amount of water stored in soils, groundwater and surface water bodies. Adding up all compartments, total water storage (TWS) S is obtained, a quantity most relevant for the water budget but hard to measure directly. An independent reference of TWS is provided by the NASA/DLR satellite mission GRACE, which measures the Earth's time variable gravity field since 2002. With release 05 (Dahle, 2012) GFZ Potsdam provides improved monthly gravity solutions in form of spherical harmonic coefficients, which are corrected for atmospheric and oceanic signals. Applying a thorough post-processing including spatial filtering we computed monthly TWS variations according to the approach described by Wahr (1998).

The realism of TWS estimates from the following models is assessed: The Large Area Runoff Simulation Model (LARSIM) is a German water balance model that simulates processes of the water cycle in catchment and river networks at small spatial scales (Ludwig, 2006). LARSIM-ME covers middle Europe and is available for upper and middle Danube down to the gauging station Nagymaros. In particular, it is used for forecasts of low flow and floods. The WaterGAP Global Hydrological Model (WGHM) represents a conceptual model of the water cycle with the main objective to monitor freshwater availability world-wide (Döll, 2003). The Community Land Model (CLM) simulates hydrological processes at the land surface (Oleson, 2008). We evaluate

output from CLM2.0 from the Global Land Data Assimilation System (GLDAS) (Rodell, 2004). Furthermore, first results from running CLM3.5 with high spatial and temporal resolution for the European CORDEX area, utilizing the simulation platform TerrSysMP (Terrestrial Systems Modelling Platform, Shresta, 2014), are considered.
In Fig.1 monthly estimates of TWS from GRACE and from the different models are area-averaged for the catchment of upper and middle Danube down to the gauging station Nagymaros. While the annual amplitude of about 45 mm month^{-1} of LARSIM and GLDAS-CLM agrees well with GRACE (47 mm month^{-1}), WGHM and CLM3.5 overestimate the annual signal with 75 mm month^{-1} and 110 mm month^{-1}. Furthermore, we observe a phase shift of the time series of GLDAS-CLM and LARSIM of 11 days with respect to GRACE. Further analyses (not shown here) indicate that, in particular, GRACE and LARSIM show similar month-to-month TWS variations.

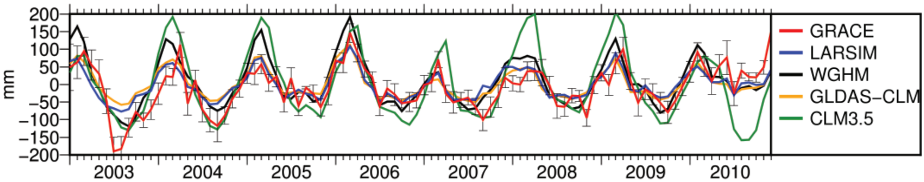

Fig. 1: Total Water Storage (TWS) from GRACE and different hydrological models for the area of upper and middle Danube down to the gauging station Nagymaros

2. The Water Budget Equation

In what follows, we will derive estimates of total water storage (TWS) change in the Danube basin independent of hydrological modelling, based on evaluating area-averaged fluxes from NWP models and atmospheric reanalyses. Via the terrestrial water budget equation TWS changes ΔS are linked to precipitation P, evapotranspiration E, and river discharge R according to

$$\Delta S = P - E - R. \tag{1}$$

Integrating Eq. (1) leads to a TWS estimate, comparable to GRACE but based on the fluxes P, E, and R according to

$$S(t) = \sum_{i=1}^{m} (P(t_i') - E(t_i') - R(t_i')), \tag{2}$$

where t_i' represents monthly intervals and $P(t_i')$, $E(t_i')$, and $R(t_i')$ monthly sums. Yet, in particular $P - E$ is contaminated with large errors which sum up due to integration. Analyzing the residuals (non-closure) of Eq. (1) we derive an error model (considering a constant offset and annual and semi-annual components) that is applied to $P - E$ in order to obtain error corrected fluxes. Finally, a flux-based basin-integrated TWS estimate is computed.

2.1 The components of the Water Budget Equation

TWS change ΔS in Eq. (1) is obtained by numerically differentiating the GRACE-derived time series of TWS, S. The fluxes P and E are obtained from global and regional Numerical Weather Prediction (NWP) models and observational data sets. We evaluate data from the *European Centre for Medium-Range Weather Forecasts* (ECMWF) reanalysis ERA-Interim (Berrisford, 2011) and the NASA reanalysis MERRA (Rienecker, 2011). Furthermore, output fields from the recently established high-resolution COSMO-EU analysis developed by the *German Meteoro-*

logical Service (DWD) are evaluated. COSMO-EU is a non-hydrostatic regional atmospheric model that covers the Eastern Atlantic and Europe with a grid resolution of 7 km. In comparison to model outputs, we also assess observational precipitation data from *the Global Precipitation Climatology Center* (GPCC) in combination with evapotranspiration data from global monthly latent heat flux grids provided by Jung (2011). Monthly river discharge R is available to us for the (most downstream) gauging station at Ceatal Izmail until December 2010.

2.2 TWS change and TWS

In a first step, the bias of terrestrial-atmospheric flux $P - E$ was quantified by analyzing the non-closure of Eq. (1). COSMO-EU and the combination of GPCC and MPI were found to be nearly unbiased. In contrast, we obtained large biases for the global NWP models, with 10 mm month^{-1} for ERA-Interim and 17 mm month^{-1} for MERRA (Springer, 2014). Next, error-corrected flux-derived TWS change in the (total) Danube catchment according to Eq. (1) is compared to the GRACE based estimate (Fig. 2a). In Fig. 2b likewise TWS according to Eq. (2) is compared to GRACE. After correction, the annual amplitude of TWS change amounts to 35 mm month^{-1} for all the data sets. Furthermore, a positive trend of TWS change of 1 to 2 mm month^{-1} year^{-1} is found. During the integration in Eq. (2), residual errors in the model accumulate, therefore, the differences between GRACE and models are larger in Fig. 2b. The GRACE derived annual amplitude of TWS of 64 mm is overestimated by flux-derived TWS with differences of about 10 mm. The annual amplitude of WGHM differs from GRACE by 20 mm. Finally, we find that the RMS between GRACE derived TWS and the flux-based estimates is smallest for ERA-Interim (25 mm) and the observation based data sets (25 mm) and particularly large for MERRA (57 mm).

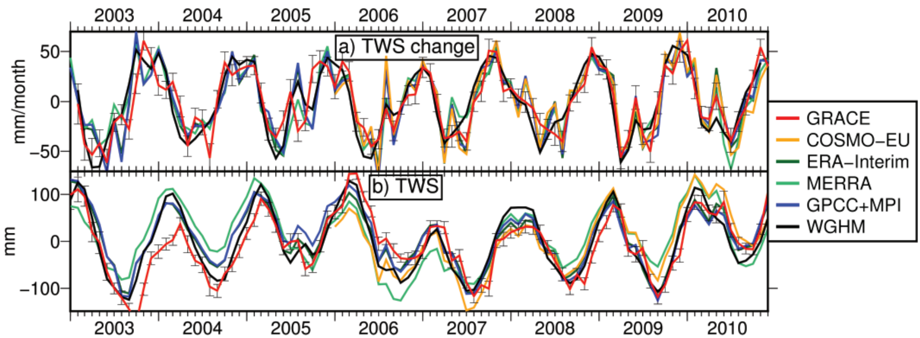

Fig. 2: Evolution of a) TWS change and b) TWS in the Danube catchment (down to the gauging station of Ceatal Izmail) derived from GRACE data and fluxes $\boldsymbol{P - E - R}$

3. Case Study: Flood 2013

The evolution of TWS during the exceptional flood in 2013 was evaluated in the area of upper and middle Danube (defined in Section 1), using GRACE data. Fig. 3 pictures TWS since 2003 for April to June. In April and May 2013 a relatively large amount of water was stored in the basin with its maximum in May. This shows that the soils were already exceptionally wet before the record of extremely high precipitation rates at the transition from Mai to June. Then, in June, storage is notably high compared to the previous years and exceeds the normal storage in June by 18 km^3, which corresponds to a water layer of 10 cm thickness covering the whole catchment area of 180000 km^2.

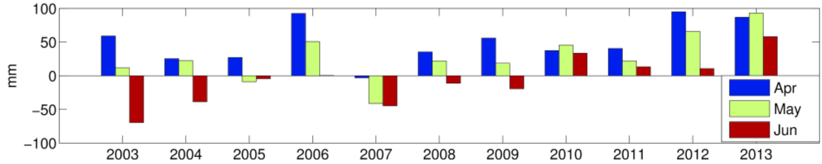

Fig. 3: Evolution of TWS as perceived by GRACE since 2003 for April to June

4. Conclusion

The total volume of water stored in the Danube basin was evaluated a) from hydrological models b) from atmospheric-terrestrial fluxes via the water budget equation and c) as perceived by GRACE. We found GRACE being a valuable tool for determining the drift in NWP prediction models and for constraining long-term storage. Furthermore, we validated seasonal signals of different hydrological models. The currently developed land-surface model CLM3.5 needs some further adjustments, while LARSIM-ME generally provides good estimates of TWS. Finally, taking the flood 2013 as an example, we showed how GRACE perceives specific weather-related flood events. Future work will include the assessment of monthly variations of TWS.

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Advanced modelling framework for estimating design-flood peaks in the Upper-Tisza Basin

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Introduction

Reliable estimation of design-flood characteristics (DFC) for a given return period is required to design structural and non-structural measures to reduce or avoid flood disaster losses. In practice, this information is obtained through the use of one of the flood frequency estimation techniques based on the principle of analysing series of observed events to infer a probabilistic behaviour, which is then extrapolated to provide estimates of the likely magnitude of future extreme events (i.e., flood magnitude associated with the recurrence interval T, T-year flood). By nature, extreme flood events are seldom observed locally and hydrologists have little or no chance of gathering an adequate sample of catastrophes. This raises the question of how best to extrapolate to extreme events when <u>no or only short series of recent events are available</u>, or – as is often the case – <u>the land uses of the watershed and/or the morphology of stream channels and floodplains has been changed (drastically/slightly) in recent decades</u>, or <u>in the case of changing climate</u>.

Design flood techniques (flood frequency estimation methods) can be divided into two basic categories: the so called traditional "*streamflow-based"* (statistical processing of station data) and, the newest generation, the "*rainfall-based"* (convert rainfall into streamflow using either, discrete event modelling, or continuous simulation modelling (CSM) approach) methods. Estimation of design floods using CSM has emerged as a very active research topic across academic institutions in Europe and in everywhere in the world. CSM is based on the use of precipitation-runoff models (lumped or distributed), of various complexities, for transforming precipitation data into river flows. By coupling a precipitation-runoff model with a stochastic weather-generator model, Monte Carlo simulations can generate very long series (even more thousand of years) of synthetic daily weather data which can be transformed into river flow from which the flood frequency characteristics can be deducted.

Recognizing the importance of problem and the inadequacy of the traditional methods in determine DFC, a methodology-development has been achieved in our company in order to determine reliable flood frequencies, and it has been developed the "DIWA" (DIstributed WAtershed) modelling "family".

1. The framework of our modelling concept

As a result of this work, an integrated modelling technique (and its computer realisation as well) has been developed based on continuous, distributed simulation of the river system response subject to stochastically generated meteorological forcings. This approach allowed to overcome the limitations of conventional statistical analyses "at site" or regional analyses, it provided design values for virtually any level of risk, and supplied in addition to the peak flows also other key variables such as the flood volume and duration associated with each simulated peak, thus allowing to assess the risk of failure of engineered dykes due to prolonged submersion times and the design of retention basins.

This integrated modelling framework stands on three basic pillars.

I. *A stochastic weather generator* ("DIWA-SWG") to simulate the meteorological forcings at daily temporal resolution over a spatially distributed domain (Szabó, 2007). The DIWA-SWG model is a generation of the temporal process by a multi-level modelling approach, according to the following basic steps:
   1. First the alternating process of storm-interstorm process is modelled by simulating the length of the dry and wet spells respectively using the daily scale as reference.
   2. For each storm period a randomly generated precipitation amount is simulated for the length of the wet spell.
   3. Finally, a disaggregation procedure is applied to the wet spell to simulate the daily precipitation.

   The length of the storm-interstorm process is modelled on the basis of a seasonally parameterized Markov chain approach, to account for the significant differences characterising the precipitation patterns across the year. The precipitation amounts can be sampled from random values generated by probability distributions fitted to the daily precipitation amounts available from historical series.

II. *A distributed precipitation-runoff model:* With most emphasis on the recent years of extensive scientific development HYDROInform Ltd. developed the large-scale high resolution distributed hydrological model DIWA (DIstributed WAtershed) which is a dynamic water-balance hydrological model that distributed both in space and its parameters, and which was developed along combined principles but its mostly based on physical foundations (for fundamentals see Szabó, 2007. and its appl. Szabó et al. 2011.). The fundamental processes that are simulated by the model include interception of rainfall, snow accumulation/melt, soil frozen, surface runoff, infiltration, evaporation, transpiration, exchange of soil moisture between the soil layers (percolation and capillary rise) and drainage to the groundwater, sub-surface flow, and flow through river channels.

III. *An integrated 1D hydraulic model* ("HEC-RAS"), which allows to compute the key hydraulic variables associated with the hydrologic design values and used in the design of the flood protection measures.

Such modelling framework allowed a much higher flexibility than conventional (streamflow-based) flood frequency analyses based on the use of statistical models and complied with the requirements needed to achieve our objectives.

2. Applying the model framework on the Upper-Tisza Basin

As a consequence of the floods occurring in recent years, large scale and ever accelerated embankment development works were initialised in Transcarpathia (Ukrainian part of UTB). As an additional consequence of this large scale embankment development works, that the return periods of extreme hydrological events and its volume will change into an adverse direction in the lower part of the River Tisza.

With regard to design efficient flood management strategy, answering the questions like: what are the present (modified by the embankment development works) characteristics of floods, or will climate change lead to more flooding, are one of the major problems facing flood experts of the UTB Regional Water Directorate. The Upper-Tisza Regional Water Directorate recognized the gravity of the problem, and at the autumn of 2008 applied for the calls for proposals announced within the framework of the Swiss Hungarian Cooperation Programme as agreed by the Swiss Federal Council and the Government of Hungary with an application entitled "*Development of*

the flood prevention information system in the catchment area of the Upper River Tisza" that application has won subsidy.
In accordance with the winner proposal of the HYDROInform Ltd., one of the specific aim of our researches was to develop and implement an adequate modelling framework to estimate the distribution of the extremes of different return period (100 and 200 years) flood events for both present and future climate variability, referring to the Tiszabecs outlet gauging station of the UTB.

3. Results

We ran the calibrated DIWA-SWG and DIWA models using 900 times 100 years independent synthetic, stochastically generated daily sequences of weather conditions on the basis for both present and future climatic conditions, referring to the Tiszabecs outlet gauging station of the UTB, with the purpose to estimate the frequency of the extreme flood events for the return periods of 100 and 200 years. The scenarios are evaluated.

A.) Present conditions:
- current conditions of the riverbed and the overbanks,
- current land-use,
- meteorological data for the past 30 years.

B.) Predicted climatic condition:
- current conditions of the riverbed and the overbanks,
- current land-use,
- projected climate data for the future period of 2021-2050.

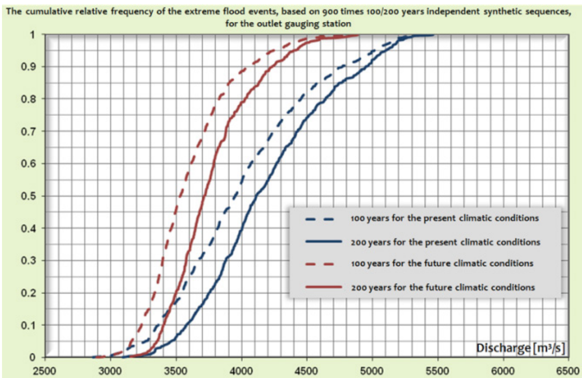

Fig. 1: The cumulative frequency of the extreme flood events for the outlet gauging station of UTB. Blue/Red line indicates the present/future. Dashed/ Continuous line indicates the 100/200 y.

A.) Evaluation of the simulation for present conditions:
As a result of the integrated simulations the cumulative frequency curve of the extreme flood events for the outlet gauging station of UTB of 100 and 200-year recurrence interval were made, which was considered as reference for the evaluation of scenario B.). The results are shown in the Fig. 1.
B.) Evaluation of the simulation for predicted climatic conditions:
According to the results of the simulations we can conclude (see Fig. 1.), that the flood threat in

the region will significantly decrease on the UTB according to the applied climate change scenario (A1B). This can be happen in spite of the fact that the increase of 10% of the winter precipitation is predicted. Our conclusion can be explained by two essential conditions mentioned below (a more detailed conclusion of our results can be find in (HYDROInform, 2012), and (Pongrácz et al., 2013)):

C-1. Firstly, it is important to point out that nearly 60% of the maximums of the 900 runs of 100 years were given by flood waves originating from conjoint rainfall and snowmelt. In spite of the fact that the increase of 10% of the winter precipitation was predicted by the climate models, through the predicted average increase of 4°C of the daily mean temperature the rate of rain/snow in winter will be increased on the project area. Hence the majority of the precipitation in winter will fall as rain, not snow that leads the snow accumulation to drop and the winter run-off to increase. As a result the volume of flood waves originating from conjoint snowmelt and rainfall will significantly decrease and so will the frequency of the extreme flood events.

C-2. The relative invariability of the annual precipitation and the increase of the intensity of the precipitation will result in the increase of the rate of the dry/wet days. As a result of the longer period of days without rain the riverbeds will be filled with less water when the rain begins to fall. The conditions mentioned above will result in a situation where the frequency of flash-floods on the area of the foot of mountain will increase due to the increase of the intensity of the precipitation, while the flood waves in the bigger rivers (like River Tisza) will run down with lower water levels.

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Modelling of suspended sediments in the Upper Danube with SWAT

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Introduction

Suspended sediments pollution threatens the good ecological status of the Danube River. Integrated watershed modelling can help prioritization and planning of management activities to achieve water quality targets set in the European Water Framework Directive. The aim of this study was to calibrate and validate the Soil and Water Assessment Tool (SWAT) model to simulate suspended sediment loads in the Upper Danube, thus enabling management scenario assessment.

1. Materials and methods

1.1 Study area and SWAT model set-up

The Upper Danube Basin, stretching from its sources down to the Gabickovo Reservoir, covers approximately 132000 km^2 and comprises the German, Austrian, Czech, and Slovakian part of the Basin (Fig. 1). Altitude ranges from 3980 to about 100 m; annual rainfall is 900 mm on average. In this section, the Danube River has a mountainous, alpine character, but its sediment regime has been heavily modified by anthropogenic activities (Habersack et al., 2013).
The Soil and Water Assessment Tool (SWAT) is an integrated watershed model that is increasingly used for ex-ante assessment of management scenarios world-wide. Details of the model can be found in the vast literature (e.g. Gassman et al., 2014). The spatial data comprised a land use map based on different databases (CAPRI, HYDE3, SAGE, GGLC 2000) and adjusted for crop statistics; the European Soil Map; a Digital Elevation Model of 100 m pixel size; pan-European climate data with ground resolution of 25 km^2; large reservoir and point sources data (Malagó et al., these proceedings). The Upper Danube Basin was subdivided in 753 subbasins with a median area of 143 km^2. For each subbasin, the dominant land use – soil type combination was used to identify a single Hydrologic Response Unit (HRU). The only exception was for urban areas, which were maintained as separate HRUs, for a total of 822 HRUs. The simulation period was 1990-2009, inclusive of five years of model warm-up. A regionalized calibration and validation of streamflow ensured that monthly water balance and streamflow components were correctly represented (Malagó et al., these proceedings).

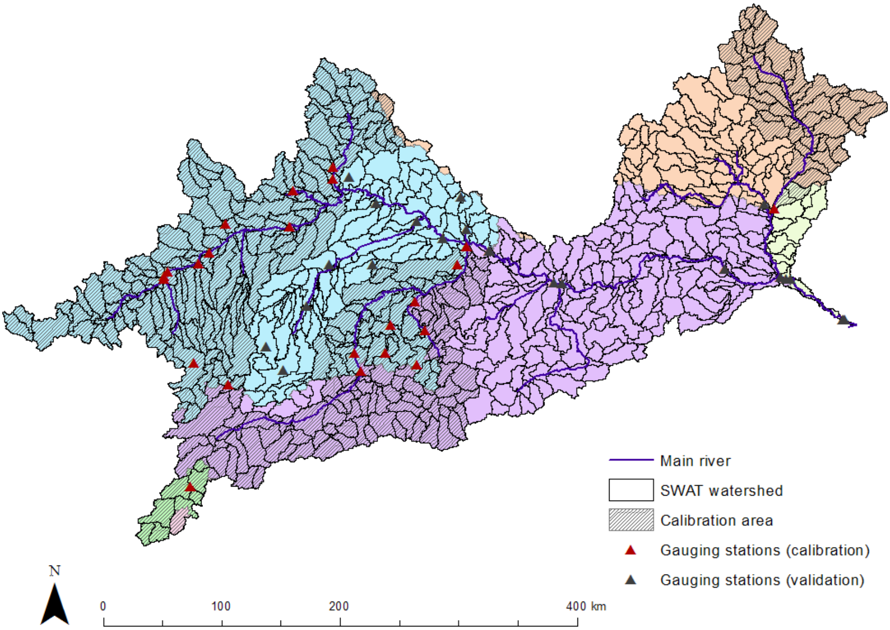

Fig. 1: SWAT delineation of the Upper Danube study area with location of gauging stations used for sediment modelling. The area selected for calibration purposes is in grey; colors indicate country borders.

1.2 SWAT sediment modelling and parameterization

SWAT sediment module comprises a land phase, where hillslope erosion is assessed through the Modified Universal Soil Loss Equation (MUSLE), and a stream phase, where aggradation or degradation in the main stream reaches is simulated. Several changes to SWAT default options were adopted in this study to improve the simulation of sediment processes as outlined below.

The MUSLE assess daily sediment yields for small catchments, and in SWAT it is applied at HRU level. The main inputs are daily surface runoff, vegetation cover, and the Universal Soil Loss Equation (USLE) factors of soil erodibility (K), crop type (C), soil conservation management (P), topography (LS), and HRU area. Soil erodibility K was based on HRU climate, stoniness, and topsoil texture. The topography factor LS was calculated according to the Revised USLE (RUSLE). No spatial distribution of current conservation practices (factor P) in the region was considered at this stage. MUSLE sediment yields increase more than linearly with HRU area (Chen and Mackay, 2004). In large HRUs, this may result in large and unrealistic sediment yields. To correct for this scale-dependency, the MUSLE was applied to a standard area of 1 ha, then multiplied by the HRU area (in ha).

In the stream phase, the streamflow shear power is simulated with a modified Bagnold's equation that regulates the maximum transport capacity of sediment load in the reach. When sediment in the reach exceeds its transport capacity, the excess sediment is deposited in the reach. Conversely, when transport capacity exceeds the carried sediment load, degradation of the reach banks and bed can occur. In this study, a physical approach that used a shear stress resistance threshold of the reach was selected for simulation of reach degradation. The approach

is conceptually appealing and has been found to improve model sediment simulations in lowland areas compared to SWAT default setting (Lu et al., 2014).
A two-step, multi-site, and spatially-split calibration and validation approach was pursued to improve the sediment budget assessment. The calibration and validation zones are depicted in Fig. 1. In the first step, the MUSLE C and P factors were calibrated so that sediment yields generally matched erosion measured in temperate area plots of Europe (Maetsen et al., 2012) and rates reported in erosion maps of Germany, Austria and Slovakia (Panagos et al. 2014). In the second step, stream shear power and shear stress parameters were calibrated against monitored data at annual time steps with the SUFI-2 method. Suspended sediment concentration (mg/L) time-series from 19 monitoring stations were used in the calibration zone and 14 in the validation zone. Monitored data comprised suspended sediment published in national water quality databases or in ICPDR Trans-National Monitoring Network.

2. Results and discussion

The USLE C factor of some crops (barley, wheat, silage corn, orchards, and a 'generic' crop) was adjusted to 0.1, so that C values for cropland varied in the range of 0.03-0.2. The factor P for pastures was lowered to 0.15 to counteract an underestimation of grassland biomass that resulted in poor vegetation cover. With this calibration, MUSLE sediment yields matched well literature erosion rates (Table 1), albeit erosion in forest area may be underestimated.

Tab. 1: SWAT calibrated sediment yields (t/ha) vs. Hillslope erosion data: med= median value; μ = mean; CV= Coefficient of Variation. Erosion maps = Panagos et al. (2014); Erosion plots = Maetsen et al. (2012).

Land use class	SWAT			Erosion map rates			Erosion plot rates		
	med	μ	CV	med	μ	CV	med	μ	CV
Forest	0.04	0.1	1.5	0.09	0.09	0.2	0.0	1.3	3.6
Grassland	0.1	0.4	1.8	0.14	0.80	1.7	0.1	1.0	2.0
Cropland	1.0	4.0	2.8	1.2	1.4	0.8	1.1	4.1	2.1

In the stream phase, stream power default parameters were kept unchanged (SPCON = 0.0001; SPEXP = 1; PKR = 1). Shear stress parameters (reach vegetation cover, sediment bulk density and sediment median size) were set at median values of the admissible range. With this parameter set, sediment concentrations at some gauging stations were satisfactory (e.g. Fig 2). However, sediment concentrations were generally overestimated in downstream stations of the validation dataset, indicating that stream phase parameters require further refinement.

3. Conclusion

The initial calibration of the Upper Danube yielded good estimates of hillslope erosion (table 1), and of sediment concentrations at some gauging stations (Fig. 2). However, further work is required to improve sediment concentration measured at gauging stations. Inclusion of detailed spatial information to define reach conditions (vegetation, sediment characteristics, engineering interventions, e.g. Habersack et al. 2013) is expected to improve SWAT predictions further.

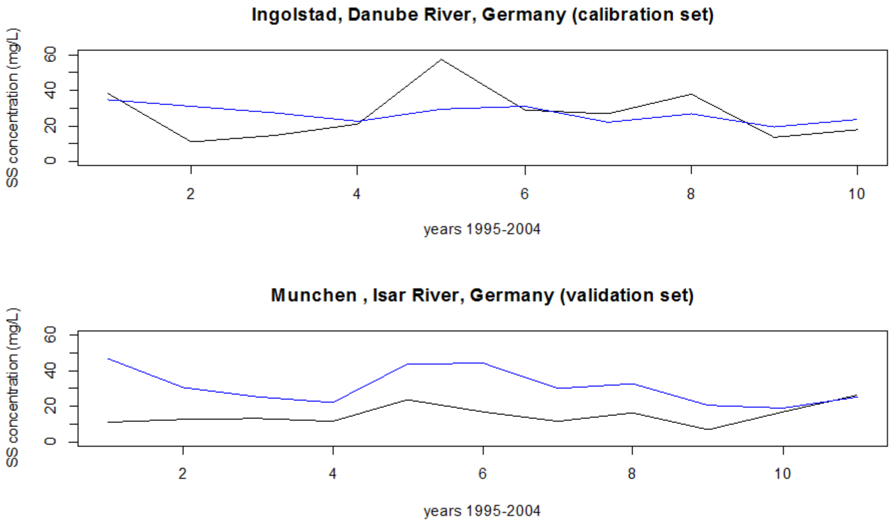

Fig. 2: Observed mean annual Suspended Solid concentrations (mg/L, in black) compared to SWAT predictions (blue line) for a station of the calibration dataset, and one for the validation dataset.

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Analysis of the periods without rainfall in the central part of the East Slovakian lowland between years 1961 and 2013

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Introduction

Precipitation are within hydrologic cycle determining natural source of water in the catchment. Analysis of rainfall (their temporal and spatial distribution in the catchment) is therefore fundamental assumption for water balance in the system of atmosphere - plant cover – unsaturated zone – groundwater. During shortage of rainfall meteorological drought starts. In general, the drought may be defined as a precipitation deficit due to the expected rainfalls (normal). Long periods without rainfalls lead to a deficit of available water in the unsaturated zone of soil (3rd water source) and then to the reduction of groundwater. Thereby assurance of water in 3rd water source decreases. 3rd water source determines source of water for the plant cover. Therefore it is necessary to evaluate rainfall, as a natural source of water, not only in term of quantity but also in term of their temporal distribution [Pálinkášová, Z. - Šoltész, A., (2012), Šoltész, A., (2008)]. In this regard it is necessary to analyze statistically significant periods without precipitation. This periods has a great influence on hydrological processes and water balance in the catchment.

1. Materials and methods

Methodology of research consists of identification of rainless periods (RP), analysis of RP in terms of its duration in days, analysis in terms of its occurrence in studied periods, quantification of statistical characteristics and interpretation of the results.
Climatic station Milhostov (N 48°39,786´; E 21°43,298´) was chosen for the identifikation of rainless periods. Station is located in central part of East Slovakian Lowland (ESL) fig.1.
Daily precipitations measured in the station were studied during years 1961-2013.

Fig. 1: Localization of the observed area

19,358 daily precipitation amounts (including null) were analysed in this period. Duration of rainless periods during the growing season was identified in two ways. Periods with null daily precipitation amounts were taken into account in the first selection (f0). Daily precipitation amounts of up to 2 mm were understood as null in the second selection (f2). It is supposed that such precipitations will be intercepted by plant cover and consequently evaporated with no impact on soil water storage. Rainless periods were selected only from those which occurred during vegetal periods (VP) April – September. However, rainless periods which had started before VP and overlapped with a vegetal period, were also taken into account as well as periods which started in vegetal period and ended after VP had finished. Periods with no precipitations during the vegetal periods in 1961 - 2013 were probabilistically evaluated in each selected group.

2. Results and discussions

Selection of rainless periods is based on analysing daily precipitation amounts during years 1961 – 2013. 11723 days (60,60%) out of 19358 studied days were without rainfall in this period. Days without precipitations were grouped in 3290 periods. Only 32.90% of days lasted 1 day and 53.30% lasted for 1 or 2 days. Periods which have null daily precipitations and last for 10 or more days form 6.40% from all RLP. There is shown relative frequency distribution of rainless periods by the number of days without precipitation evaluated for entire years (DWPy) and for vegetal periods (DWPvp) of the years 1961-2013 in the fig. 2. Frequency distribution of rainless periods reduces significantly with the growth of time duration. Deviations of variability and median are not statistically significant for vegetal periods and for entire years.

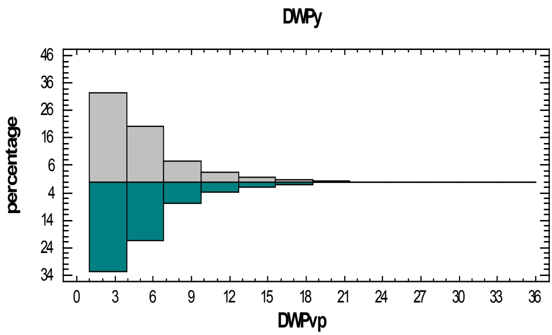


Fig. 2: Relative frequency distribution of rainless periods occurrence by the number of days without rainfall. DWPy- rainless periods in days evaluated for entire years 1961-2013, DWPvp – rainless periods evaluated for vegetal periods (april – September) of the years 1961 – 2013

There is shown occurence of rainless periods in particular years and VP of examined period 1961 – 2013, their temporal duration and linear trend of development. Figures shows that significant trends in time lengths of rainless periods are not identified in the fig. 3 and 4.

Tab. 1 illustrates probability characteristics of both selections in a form of duration curve of maximum yearly rainless periods. Theoretical curve and empirical points of "f(0)" are created from rainless periods with null daily precipitations. Course of theoretical duration curve and empirical points of "f(2)" were created from rainless periods with max. daily precipitations of 2 mm. The course of both curves shows that they are comparable in development though their position is different. Duration of rainless periods with probability of reaching or exceeding p = 1% is 35 days and 57 days for f (0) and f(2) respectively.

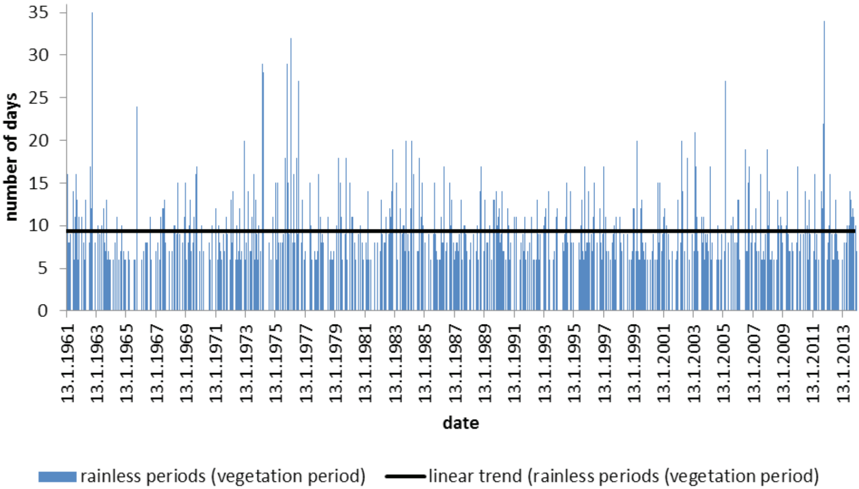


Fig. 3: Occurence of rainless periods and its duration in years 1961 – 2013 and trend development of their time length duration.

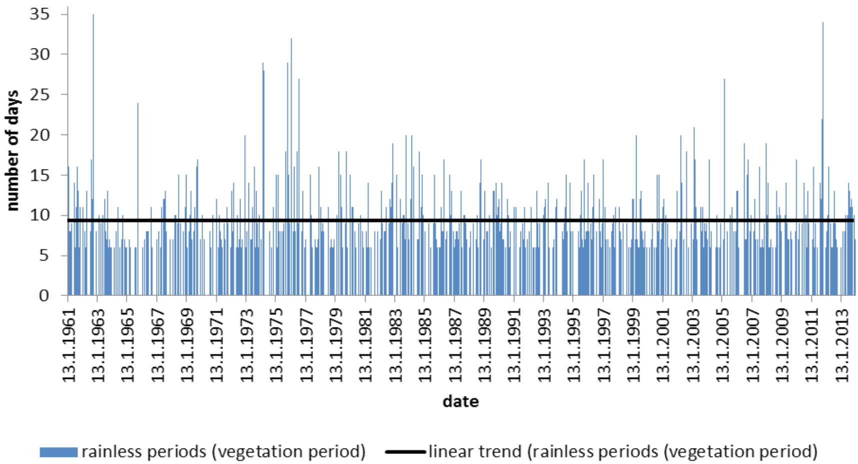
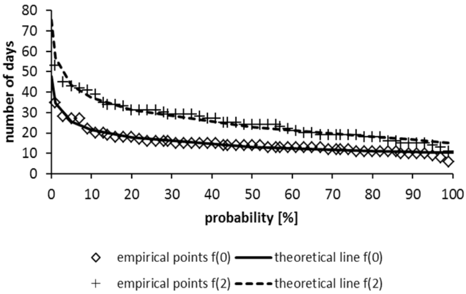


Fig. 4: Occurence of rainless periods and its duration in vegetal periods of the years 1961 – 2013 and trend development of their time length duration.

Tab. 1. shows five longest rainless periods identified in the selections f(0) and f(2), their duration in days and probability of occurrence. In f(0) the longest period with null precipitations was indentified in 1962 and lasted for 35. Probability of occurrence of similar dry period is once in 100 years. In f(2) the longest rainless period was identified in 1967 and lasted for 53 days. Probability of occurrence of such period is once in 48 years.



Summary Statistics			
Evaluated per.	years	VP	VP
Filter	f(0)	f(0)	f(2)
Count	3290	1689	1352
Average	3,6	3,7	6,1
Standard dev.	3,5	3,5	6,2
Coeff. of var.	1,0	1,0	101,6
Minimum	1	1	1
Maximum	35	35	53
Range	34	34	52
Skewness	2,7	2,1	2,5
Kurtosis	11,4	10,0	8,8

Fig. 5: Theoretical curves and empirical points of reaching or exceeding max. duration of RLP between year 1961 – 2013 for selections f(0) and f(2) and statistical characteristics of the studied selections

Tab. 1: Identification of five longest rainless periods in vegetal periods between 1961–2013 for f(0) and f(2)

Daily precipitation totals to 0.0 mm					Daily precipitation totals to 2.0 mm				
period		number	probability	periodicity	period		number	probability	periodicity
start PWP	end PWP	of days			start PWP	end PWP	of days		
from	to	[days]	[%]	[years]	from	to	[days]	[%]	[years]
25.9.1962	29.10.1962	35	1,0	100	19.7.1967	9.9.1967	53	2,1	48
18.3.1974	14.4.1974	28	3,9	26	9.9.2006	23.10.2006	45	4,5	22
5.8.1976	31.8.1976	27	4,3	23	19.9.1962	31.10.1962	43	5,4	19
14.3.2005	9.4.2005	27	4,3	23	8.9.1961	19.10.1961	42	6,2	16
15.9.2011	6.10.2011	22	9,4	11	12.8.1974	21.9.1974	41	7,0	14

3. Conclusion

The aim of this paper is the analysis of rainless periods in central part of East Slovakian Lowland in Slovak republic. Daily precipitation measurements meassured in meteorological station Milhostov during the years 1961 – 2013 were the database for analysis. Rainless periods were examined for entire years and for vegetal periods. Duration of rainless periods during vegetal periods was identified in two different ways: first selection, f(0), comprise only the periods with null precipitations; second selection f(2) comprised periods when also precipitations up to 2 mm were considered null. Multiplicity of rainless periods occurrence significantly decreases with time duration increment in year and vegetal evaluation. Deviations of variability and median during relative multiplicity identified fore vegetal periods and for entire years are not statistically significant. Different course of duration curves for selections "f(0)" a "f(2)" was identified. The longest rainless period last for 35 days. It has periodicity of 0.01. Rising or decreasing trends do not manifest in the long term in time length of rainless periods.

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The forecasting of the mean monthly water levels of the Danube River on the water gauge Reni

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Introduction

Smooth fluctuations of the water levels that are observed on the Lower Danube are caused by the transformation of the floods that are formed on the Upper and Middle Danube. These floods can be formed in the different parts of the catchment area of the Danube and in any season of the year that leading to the constant fluctuation of the water levels throughout the year and the formation of the hydrographs of the different shapes (DB, 1989). The forecasting of the mean monthly water levels of the Danube River on Ukrainian part is necessary for the national navigation and the effective management of the water resources and softening of the consequences of the dangerous natural phenomena: floods and droughts. The complexity of this type of forecasting is related to the absence of the reliable forecasts of the rainfall in the Danube basin in the period of the lead time of the forecast. That is why the technique of the forecasting of the mean monthly water levels on the water gauge Reni is based on simple empirical relationships.

1. Data and method

The water gauge Reni situated on the Lower Danube at the distance 127.2 km from Sulina. The graph of the mean monthly water levels on the water gauge Reni for the period of observation 1921-2010 years has the form of a sinusoid (fig. 1).

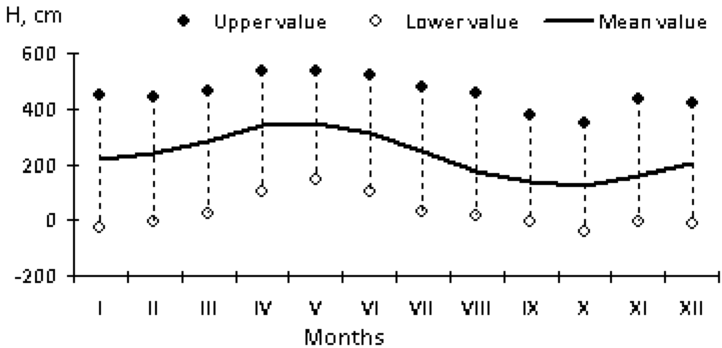

Fig. 1: Mean monthly water levels of the Danube River on the water gauge Reni, (1921-2010)

The highest mean month water levels are observed during the spring and summer flood (April-June) and the lowest - during the autumn low water period (September-October). The variability of the mean monthly water levels are the lowest during the spring and summer flood (C_V = 0.26-0.31) and the highest - during the autumn low water period (C_V = 0.63-0.67). The amplitude of the mean monthly water levels are within 382 (September) - 471 cm (January) (tab. 1).

Tab. 1: Mean monthly water levels (H, cm) of the Danube River on the water gauge Reni (1921-2010) and its parameters

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
H, cm	220	238	283	339	345	310	250	176	137	128	158	206
Cv	0,45	0,38	0,33	0,29	0,26	0,31	0,41	0,55	0,63	0,67	0,61	0,47
Upper value	447	445	466	537	533	524	475	455	378	345	432	418
Lower value	-24	-2	25	103	144	101	32	14	-4	-41	-9	-14
Amplitude	471	447	441	434	389	423	443	441	382	386	441	432

Different simple relationships are usually used for the forecasting of the mean monthly water levels (H^{t+1}) (GHF, 1989)

$$H^{t+1} = f(Q^t) \qquad (1)$$

$$H^{t+1} = f(W^t_{24}, x) \qquad (2)$$

$$H^{t+1} = f(W^t_{24}, x) \qquad (3)$$

$$H^{t+1} = f(H^t_{24}) \qquad (4)$$

where Q^t – the mean monthly discharge of the last month or last ten-day period
x – the rainfall forecast for the next month
W^t_{24} – the water storage in the river-bed network on 24-th date of the last month
H^t_{24} – the water level on 24-th date of the last month

We proposed to use the relationships that improve the results of forecasting of the mean monthly water levels of the Danube River on the water gauge Reni

$$H^{t+1} = f(H^t_{24}, I_h) \qquad (5)$$

where I_h – the index which takes into account the change of the water levels in the first part of the next month. This index we can determinate by difference of the water levels on the begining and middle of the next month (ΔH).

If -30 см $\le \Delta H \le$ 30 cm, then we consider that I_h index is a constant;
if $\Delta H <$ -30 cm, then we consider that I_h index is a decreased;
if $\Delta H >$ 30 cm, then we consider that I_h index is a increased.

The I_h index should be evaluated before the forecasting. For this purpose the data on the water levels in the water gauges which are situated on the Danube River from Ingolstadt town to Reni town are used. The rainfall forecast for 6 days period in the Danube basin is used also. All this information is on the websites of the national hydrometeorological services of the countries of the Danube River basin. The assessment of the homogeneity of the time series of the mean monthly water levels on the water gauge Reni was carried out by the hydro-genetic methods (Gorbachova, 2014). The assessment of the quality of the forecasting equations was carried out by criterion $\overline{S} / \overline{\sigma}$ (MOH, 2012).

2. Results

The construction of the hydroelectric power stations Iron Gate I (1972) and Iron Gate II (1984) did not affect on the homogeneity of the time series of the mean monthly water levels on the water gauge Reni (fig. 2).

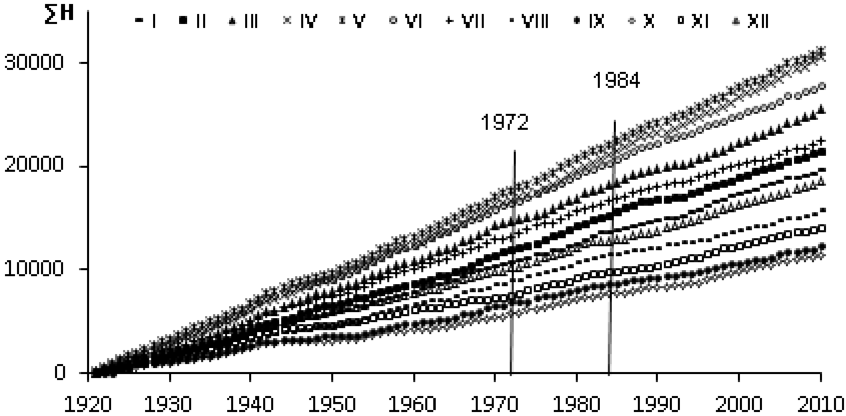

Fig. 2: Integral curves of the mean monthly water levels on the water gauge Reni, 1921-2010

The relationships (5) for every month of the year and for three possible value of the I_h index were determined on the data of the water gauge Reni (fig. 3). Equations for the forecasting of mean monthly water levels of the Danube River on the water gauge Reni and R-squared values and criterions $\overline{S} / \overline{\sigma}$ are presented in tab.2.

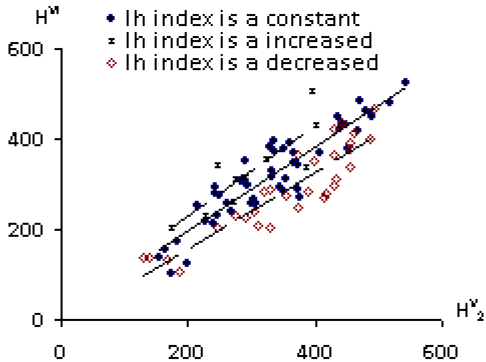

Fig. 3: Plot of June mean monthly water levels versus water levels of the Danube River on the water gauge Reni on May 24th. Regression lines are for different I_h index value

The forecasting equations for January, February and August are classified as «satisfactory» (0.50< $\overline{S}/\overline{\sigma}$ ≤0.80) while for the remaining months of the year – «good» ($\overline{S}/\overline{\sigma}$ ≤0.50) (MOH, 2012).

Tab. 2: Equations for forecasting of monthly water levels of the Danube River on the water gauge Reni

Month	I_h index is a increased	R^2	I_h index is a constant	R^2	I_h index is a decreased	R^2	$\overline{S}/\overline{\sigma}$, (*/**)
I	$H=0{,}72H_{24}+117{,}3$	0,76	$H= 0{,}90H_{24}+33{,}1$	0,87	$H= 0{,}70H_{24}+12{,}4$	0,61	0,69/0,54
II	$H=0{,}81H_{24}+98{,}7$	0,77	$H= 0{,}69H_{24}+66{,}2$	0,67	$H= 0{,}51H_{24}+97{,}4$	0,58	0,78/0,65
III	$H=0{,}71H_{24}+141{,}7$	0,79	$H= 0{,}90H_{24}+41{,}3$	0,94	$H= 0{,}63H_{24}+52{,}8$	0,76	0,71/0,43
IV	$H=0{,}57H_{24}+216{,}8$	0,61	$H= 0{,}88H_{24}+50{,}3$	0,87	$H= 0{,}90H_{24}-14{,}6$	0,93	0,66/0,46
V	$H=0{,}48H_{24}+206{,}2$	0,74	$H= 0{,}84H_{24}+65{,}1$	0,85	$H= 0{,}91H_{24}-40{,}1$	0,81	0,60/0,38
VI	$H=1{,}01H_{24}+27{,}5$	0,74	$H= 0{,}94H_{24}+8{,}7$	0,85	$H= 0{,}84H_{24}-11{,}7$	0,82	0,54/0,42
VII	$H=0{,}83H_{24}+37{,}0$	0,88	$H= 0{,}96H_{24}-10{,}1$	0,93	$H= 0{,}80H_{24}-27{,}0$	0,74	0,58/0,44
VIII	$H=0{,}79H_{24}+91{,}9$	0,76	$H= 0{,}74H_{24}+14{,}5$	0,79	$H= 0{,}85H_{24}-55{,}4$	0,86	0,67/0,51
IX	$H=0{,}62H_{24}+102{,}3$	0,70	$H= 0{,}84H_{24}-1{,}6$	0,88	$H= 0{,}72H_{24}-14{,}1$	0,67	0,62/0,44
X	$H=0{,}78H_{24}+102{,}4$	0,56	$H= 1{,}06H_{24}+3{,}7$	0,83	$H= 0{,}61H_{24}+18{,}2$	0,62	0,70/0,49
XI	$H=0{,}92H_{24}+80{,}2$	0,85	$H= 0{,}96H_{24}+22{,}7$	0,79	$H= 0{,}37H_{24}+56{,}7$	0,62	0,68/0,50
XII	$H=0{,}62H_{24}+160{,}0$	0,56	$H= 0{,}91H_{24}+33{,}7$	0,83	$H= 0{,}66H_{24}+41{,}2$	0,72	0,65/0,49
						Mean value:	0,66/0,48

Note: * - without I_h index ; ** - with I_h index

3. Conclusion

The new predictor (I_h index) was proposed for the forecasting of the mean monthly water levels of the Danube River on the water gauge Reni. The data for the period 1921-2010 were used and the assessment of the homogeneity of the time series was carried out. The forecasting equations for every month of the year were defined and the assessment of the quality of these equations was carried out. The I_h index has improved the forecast of the mean monthly water levels of the Danube River on the water gauge Reni by 27% on the average in comparison with the relationships (4).The using of the I_h index is improving the results of the forecasting of the mean monthly water levels of the Danube River on the water gauge Reni on the average on 27% in comparison with the relationships (4). The best is a forecasting equation for the May ($\overline{S}/\overline{\sigma}$ =0.38), and the worst - for the February ($\overline{S}/\overline{\sigma}$ =0.65).

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The method of forecasting maximum spring water discharges by using regression coefficients for specific exceedance probabilities

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Abstract

Applying the method of forecasting maximum spring water discharges with regression coefficients $k_{Q(P)}$ using for specific exceedance probabilities allows taking into the account the forecast errors directly, as there are probable diversions of water discharges within the confidence intervals.
Forecasting values of maximum waters discharges are presented as interval estimates which have more real expression than using the relative measure of the mean square error. The probability of acceptable error exceeding depends on the value maximum water discharge.

1. Methodological foundations

The purpose of the research is the theoretical and practical implementation of scientific and methodological basis for long-term forecasting of maximum spring flood runoff as the interval estimates for certain probability values and is also the determining approaches for these calculations on the example of the river Desna.

The proposed scheme of interval assessment forecasting values of maximum water discharges $Q_{\max}$, (m^3/s) is based on their communication with depth of runoff h (mm) from the basin for the flood period $Q_{\max} = f(h)$.

There is a possible expression form of the forecast when the expected value is given next to its values indicating the availability (probability) of each of these values occurrence.

The expected value of the maximum water discharge exceeding at the appointed probability $Q_{\max(P)}$ consists of the value of this quantity , calculated according to the methodology or with the middle line $\overline{Q}_{\max}^{\,forecast}$ and random component δQ_P , through which the forecast error (deviation of maximum water discharges from the middle line communication) can be expressed for certain probabilities $P\%$ depth of runoff h .

$$Q_{\max(P)} = \overline{Q}_{\max}^{\,forecast} + \delta Q_P \quad (1)$$

There are four variants of calculating this value for the determination probability of various forecast errors and presentation of forecast in the probability form.

Patterns of distribution forecast error ΔQ are considered in a field of correlation

$Q_{\max} = f(h)$ in these variants to determine the parameters of conventional functions:

$$\Delta Q = Q_{\max}^{fact} - \overline{Q}_{\max}^{forecast} \tag{2}$$

Where $Q_{\max}^{fact}$ = actual water discharge

$\overline{Q}_{\max}^{forecast}$ = forecasting water discharge

Forecast error can be represented as random variables with δ_P probability exceeding $P\%$. Then the maximum water discharges $Q_{\max(P)}$ of the certain probability $P\%$ for the assessment runoff depth h can be calculated in this way:

$$Q_{\max(P)} = \overline{Q}_{\max}^{forecast} + \delta_P \tag{3}$$

where $\overline{Q}_{\max}^{forecast}$ = the value of the expected water discharge, which is obtained from the forecast equation $Q_{\max} = f(h)$ (evaluated at an average line in a field of correlation)

δ_P = probability forecast error.

In the course of compiling long-term forecast of maximum water discharge of spring flood on the scheme above, the input value of a runoff depth is its value according to the forecast.

In the development of the forecasting method there are cases where forecast errors ΔQ are dependent to some extent on the initial argument from the predicted value. Each case requires a special analysis taking into account the dependence of the desired variable from its arguments. After analyzing these dependences their deviations ΔQ can be distributed by the normal law or have a skewed distribution. It is necessary to identify forecast errors and establish a correlative communication between these errors (values of an error in the absolute value) and the variable $|\delta_i| = f(y')$ received from the forecast for the probability forecast errors determination.

Then the relative errors of forecast ($\varepsilon = |\delta_i / \delta_i'|$) are calculated taking into account the error sequence. Each forecast error δ_i should be divided into appropriate error value δ_i', removed from the graph $|\delta_i| = f(y')$ and compared with the expected value. If there are no connection between relative forecast error $\varepsilon = |\delta_i / \delta_i'|$ and forecast values y' (in our case $\overline{Q}_{\max}^{forecast}$), then the relative errors ε can be considered as random .

Normal $\overline{\varepsilon}$ and standard deviation $\overline{\sigma}_{\varepsilon}$ are calculated for the new sequence of relative errors ε (random variables).

The expected value of given probability $Q_{\max(P)}$ in this case is defined as follows:

$$Q_{\max(P)} = \overline{Q}_{\max}^{forecast} + \delta_P \tag{4}$$

$$\delta_P = K_P\, S, \tag{5}$$

$$S = \delta' \overline{\sigma}_{\varepsilon}, \tag{6}$$

$$Q_{\max(P)} = \overline{Q}_{\max}^{forecast} + K_P\, \delta' \overline{\sigma}_{\varepsilon} : \tag{7}$$

where $\overline{Q}_{\max}^{forecast}$ = predicted values of water discharge (predicted at an average line $Q_{\max}$ = *f(h)*)

δ_P = prediction error of a probability

K_P = value of the normalized deviation according to a given probability at a normal distribution of forecast errors [1]. If the forecast errors are distributed asymmetrically, normalized deviations K_P - are determined by the binomial law taking into account subject coefficients of the variation C_V and asymmetry C_S sequence $|\Delta Q| = |\delta| = |Q_{\max}^{fact} - \overline{Q}_{\max}^{forecast}|$ for any value of the depth of runoff .

S = mean square forecast error

δ' = error with graph communication $|\delta_i| = f(y')$ of the absolute forecast errors $|\Delta Q| = |\delta| = |Q_{\max}^{fact} - \overline{Q}_{\max}^{forecast}|$ with the predicted values of water discharges $\overline{Q}_{\max}^{forecast}$

$\overline{\sigma}_{\varepsilon}$ = standard deviation of relative forecast errors

$\delta_i = Q_{\max}^{fact} - \overline{Q}_{\max}^{forecast}$ = errors of forecast

$\varepsilon = |\delta_i / \delta_i'|$ = relative forecast error.

We have analyzed two variants of forecast error distribution in this paper. The values were similar so it was decided to use normal distribution of forecast errors in subsequent calculations.

The regression coefficients $k_{Q(P)}$ for the 11 hydrological stations for the river basin Desna were obtained during forecasting of the maximum water discharges to certain probability of exceeding (10, 20, 25, 50, 75, 80, 90 %)

Free term b in the regression equation should be considered for the hydrological stations where the non-linear dependencies $Q_{\max} = k \cdot h + b$.

It is useful to represent water discharges in the form of interval estimates for the probability β for the practical purposes, thus it is guaranteed that the value of forecast water discharge $Q_{\max}^{forecast}$ will be within the confidence interval I_β :

$$I_\beta = \{ Q_{\max(P2)}, Q_{\max(P1)}, \} \quad (8)$$

$$\beta = P_2 - P_1,$$

where P_1 , P_2 = probability

Thus, the confidence probability P will be as follows:

$$P \{ Q_{\max(P2)} < Q_{\max}^{forecast} < Q_{\max(P1)} \} \quad (9)$$

Example of maximum forecast spring water discharges into interval estimates $Q_{\max(P)}$, m^3/s

	Confidence limits	Confidence probability
r. Desna – c.Schernigiv - $Q_{\max(P)}$,	$P \{1660 < Q_{\max}^{forecast} < 2661\}$	= 80%
$Q_{\max(P)}$,	$P \{1827 < Q_{\max}^{forecast} < 2492\}$	= 60%
$Q_{\max(P)}$,	$P \{1895 < Q_{\max}^{forecast} < 2426\}$	= 50%

Evaluation criteria are that the forecast is regarded as justified if the actual water discharge is demonstrated in the confidence interval of forecast corresponding probabilities.

The values of maximum water discharge granted on the basis error of prediction, depending on the value of the maximum water discharges for different probabilities.

2. Conclusion

The technology of presentation of the long-term prediction of maximum spring water discharges in the form of interval estimates is methodical and it can be applied for other rivers in different physiographic zones. Using predictive values of maximum water discharges with appropriate confidence limits is considered to be useful.

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Regional water balance modelling by GROWA in Slovenia

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Abstract

GROWA is a grid based regional scale model with modular architecture for estimating long term annual averages of main water balance components. It has been developed at Forschungszentrum Jülich in Germany for use on regional scale for river basins and Länders. In 2009 cooperation has been established with Slovenian Environment Agency to upgrade it for use on national scale for the country with physiogeographic features different from German regions. GROWA has been successfully adapted for use in Slovenia. It is regularly implemented for modelling regional water balance of long term periods as well as on annual time scale. Outputs of GROWA are now widely used in Slovenia for water management purpose, for nutrient flow modelling and for sequential coupling modelling. Modular structure of the model proved to be highly flexible, enabling use in Alpine and karst regions as well as encompassing regions with different climate types.

1. Introduction

Slovenian Environment Agency ARSO has a long history of calculating national water balance, dating back to the nineties of the last century. From the climate data on precipitation and evapotranspiration, there has been derived mean total runoff by river basins for different 30 years periods. However, even the last published water balance for 1971-2000 long term period did not separate total runoff into hydrological components of direct runoff and groundwater runoff (Frantar ed., 2008). The need for calculating regional groundwater recharge on national scale by groundwater bodies led to search for the proper tool, i.e. a spatially distributed water balance model to derive groundwater runoff.

2. Regional water balance of Slovenia

The initial use of the GROWA model in Slovenia was intended primarily for reporting on quantitative groundwater status to the EU Commission. Since in the GROWA process of deriving groundwater runoff all other water balance components have to be determined, GROWA soon found many other uses. Transfer of the model to Slovenian practice proved to be quite a challenge, taking into account different physiogeographic characteristics from those in Germany. Slovenian territory is highly varied, encompassing at an area of just 20,273 km^2 four major macro regions: Alps, Dinarides, Pannonian Basin and Mediterranean.

2.1 GROWA model in a nutshell

GROWA is an empirical, spatially distributed regional model for calculating water balance components for long term periods, the lowest time unit being one year (Kunkel and Wendland, 2002). The model uses grid of input data on climate, hydrography, land use, soil, topography and geology. From the precipitation amount it calculates water balance components at modelled territory. In the first step is from input data calculated actual evapotranspiration for each grid cell 100 m x 100 m, which is then subtracted from precipitation to derive total runoff. In the final step groundwater recharge rate is determined through baseflow index BFI, by separation of calculated total runoff into direct runoff and groundwater runoff components.

2.2 Water balance 1981 – 2010

In initial cooperation project of GROWA model transfer to Slovenia, water balance for long term period 1971 – 2000 was performed (Andjelov et al, 2014). Later, water balance calculation was done for the next 30 years period 1981 – 2010. This proved model consistency by showing similar spatial distribution of all water balance components.

The mean annual precipitation amount in Slovenia in long term period 1981 – 2010 was 1431 mm/a. The mean actual evapotranspiration ratio was 45 %, which means that 641 mm/a returned back into atmosphere. So, on average nearly half of the precipitation amount did not contribute to surface water and groundwater quantity. Total runoff at ratio of 55% amounted to 790 mm/a. The direct runoff at ratio of 35 % amounted to 501 mm/a, and groundwater recharge at 20 % amounted to 289 mm/a.

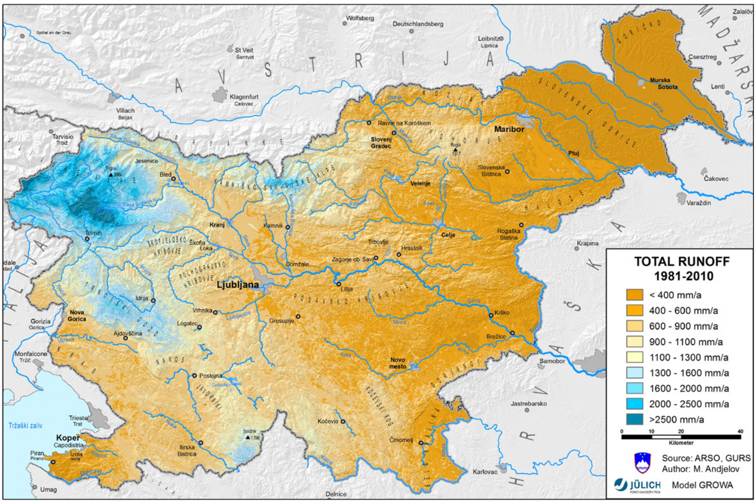

Fig. 1: Mean annual total runoff for long term period 1981 - 2010

In the regional pattern of water balance components, the dominant influence of area precipitation distribution could be discerned. The high precipitation belt of amount exceeding 1500 mm/a is in the western part of Dinarides increasing in NW direction into Alps region, where in Julian Alps has a maximum exceeding 3500 mm. Adjacent to this belt is low precipitation area in the SW of the country in the Mediterranean region and further away in the NE in the Pannonian

Basin, where precipitation rate drops below 900 mm/a. Central parts of Slovenia have in general precipitation in the 1000 to 1200 mm/a range.
Total runoff has area pattern similar to precipitation, with highest rates in the Alps and western parts of Dinarides (Figure 1). In Julian Alps total runoff is more than 2500 mm/a. Low total runoff is in the Mediterranean and in the Pannonian Basin where in the latter in far NE it amounts to less than 400 mm/a. In the rest of the country it is in general in the range of 400 to 1000 mm/a.
Groundwater recharge, is however strongly influenced by hydrogeology. Still, the highest amount is in the Julian Alps, exceeding 1200 mm/a and the lowest in the Pannonian Basin in far NE being below 100 mm/a, while the majority of the country in general is in range of 100 to 300 mm/a (Figure 2). Locally, the influence of hydrogeology is most explicit in the Mediterranean region where in the karstiftied carbonate rocks recharge is strikingly higher compared to neighbouring flysch area. Similarly in the Pannonian Basin, gravel filled alluvial plains have double amount compared to the adjacent hard rock area.

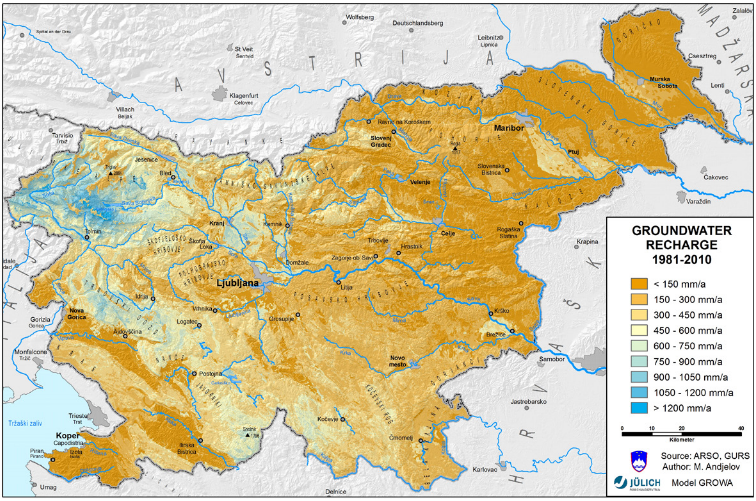

Fig. 2: Mean annual groundwater recharge for long term period 1981 – 2010

Modelled water balance for two 30 years periods 1981 – 2010 and 1971 – 2000 revealed decrease in water quantity in Slovenia. Mean annual total runoff decreased by 38 mm and groundwater recharge by 15 mm. The latter is very important for the country, since groundwater is a major source for drinking water supply. Groundwater recharge decrease of 15 mm corresponds to discharge 9.64 m3/s, which is almost double the amount of total annual groundwater abstraction for the drinking water.

2.3 Annual water balance

Apart from long term periods GROWA has been used to calculate annual water balance for all years from 1971 onwards (Figure 3). It allows good qualitative comparison of all water balance components. Years 1972, 1979 and 2010 stand out as especially water abundant, with total runoff exceeding 1000 mm. Dry years were 1971, 1983, 2003 and 2011, the last one being extremely dry, having precipitation hardly above 1000 mm and actual evapotranspiration 56 %.

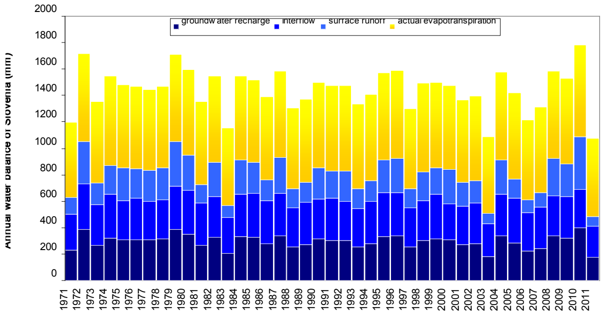

Fig. 3: Water balance components by GROWA model

2.4 Extended applications of GROWA model in Slovenia

GROWA model products have been extensively used for different applications at Slovenian Environment Agency ARSO. Water balance component values have been yearly fed into WISE system of European Environment Agency. Products have been also used in national water legislation implementation: annual groundwater monitoring and quantitative status assessment reports as well as for river basin management plans. GROWA has been implemented in climate change assessment studies as well as for deriving environment indicators published by ARSO. So far the model was also used in nitrate pollution assessment of groundwater and surface waters, and last but not least to derive upper boundary condition in sequential coupling modelling of groundwater.

3. Discussion

In Slovenian territory with physiographic highly varied regions GROWA proved to be a reliable tool to calculate long term water balance components on regional scale as well as by river basins, the year being the smaller time unit. Accuracy on annual time scale is diminished due to the effect of water retention, but the model is still very good for qualitative assessments of change in water quantity between years and of long term trends. Modular architecture of the model enables upgrading for various uses. The first one DENUZ WEKU already completed, will be used for nutrient flow modelling, while the new mGROWA in fine time scale will be transferred to Slovenia in the next cooperation round. The new model will be applied for studies of water quantity variation on seasonal time scale.

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Impacts of Danube-Sava Canal on Ground Water Dynamics

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Abstract

The Government of the Republic of Croatia passed the *Decision on preparatory works for the Danube-Sava Canal construction* in 1991. There is no doubt that the future multifunctional Danube-Sava Canal (MDSC) would have a strong impact on natural potentials and agricultural ecological systems, primarily on the soil water regime, mainly in its lower course, which would be constructed in the wider area of Biđ-field.

The main research objective was to design a model for adequate appraisal of the possible impact of MDSC on groundwater dynamics in the agrological profile of agricultural land situated in the immediate vicinity to the canal.

Continuous monitoring of groundwater dynamics was carried out in the period 2001- 2013 on an area of 6 600 ha, focusing on groundwater level fluctuations in the profile to 4.0 m solum depth, using hydropedological piezometers as well as automatic Orphimedes limnimeters.

Piezometers (40 piezometers to 4.0 m depth) were laid out in four lines – cross-sections (I, II, III and IV), perpendicularly to the longitudinal axis of MDSC. Ten piezometers were installed at each cross-section according to the scheme: 200, 500, 1000, 1500 and 2500 m on both sides of the canal. Piezometer lines were about 3.5 km apart from each other.

Program VS2DTI Ver.1.2 was used to model the groundwater flow in the agrological profile of agricultural soils in the immediate vicinity to MDSC as well as the possible impact of the canal on groundwater level fluctuation (dynamics).

The obtained indicators confirmed the regular pattern of marked horizontal communication of groundwater in the studied region within two levels: shallow, in the profile covering layer (soil) to 4.0 m depth, and deep, gravely water-bearing aquifer below 15.0 m depth, as well as vertical interconnection between these levels.

It was also confirmed by modelling that the future MDSC would continuously drain the surrounding area on locations of the selected cross-sections - profiles (I, II and III) in years of average climate.

The width of the draining zone under the influence of MDSC, in which a lowering of groundwater level in agricultural soils from 1 to 50 cm at groundwater depth of 0 to 4 m relative to the ground surface is expected, would be in the range of minimal values from 370 m to 170 m and maximal values from 970 m to 390 m (that is, in the width from 485 m to 195 m to the left and right of the longitudinal canal axis).

The model also indicated that in the conditions of a very deep groundwater level (>3 m from the ground surface), in profile IV (Babina Greda – Konjsko – Kladavac), MDSC would feed the agrological profile of agricultural soil through water infiltration from the very basin. According to calculations, the width of the zone of the influence of canal feeding would range from 90 m to 250 m from the canal axis.

In the hydrological conditions of dry years (e.g. the years 2011 and 2012), especially during summer months, with prevalence of very deep groundwater levels (>3.0m), MDSC would feed the adjacent soils with water from the very basin, thereby reducing the drought "effect" in its bank area even without irrigation.

Morfogenesis of Sacalin Island- an 'L' system

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Keywords: Danube Delta, Sacalin Island, L-system, morphogenesis

Abstract

The morphohydrological complex Sacalin Island, whose history dates from the mid- nineteenth century, enables a pilot study and thorough analysis of its evolution due to the amount of existing information in libraries, that describes sub processes in different stages that contributed to the development of morphohydrographic network.

A morphogenesis model of the Danube Delta- Sacalin Island developed in axiomatic form is represented by a tree fractal type – L-system, a higher stage in the simulation of this complex genesis. It is a formal system due rigor, and diminish considerably elements of intuition. Confronting the created L-system with historical maps, photogrammetric and satellite images as well as the reality on the ground (measuring with JAVAD Triumph V1 GPS) was observed that this model can provide a method for morphohydrographic network analysis in the Danube Delta. The practical character of the 'L' system creates premises for a tool in spatial planning and ecological systems. A sequence of iterations has been developed through Fractal Grower software of the University of New Mexico corresponding to each stage.

Examination of time marks of L-systems provide helpful knowledge on the possibilities of ecosystems services created by morphohydrographic network and can predict environmental flow regime. If the terms of the similarity between fractals tree as defined by Lindenmayer systems, capable of generating complex structures of biological development, and morphohydrographic network of Sacalin Island Complex, framing, it is clear that in the same time are taken place processes regarding climate change, which condition the system development (in particular the Black Sea level rise and intensifying of extreme weather events, or reducing the period between extremes). Rigorous mathematical formulation of the situation in Sacalin Island morphogenesis through the L-system models lead to very large size and complex models for Danube Delta, providing efficient holarchic and heuristic solutions.

1. Introduction

For an overview of the research object - Fractal analysis of morphogenesis Island Sacalin it is considered useful to briefly describe the fractals discipline emerge and evolution.

The concept of L System (Lindemayer) was introduced in 1968 by biologists Aristid Lyndenmayer to define the systems capable of generating complex structures from small data sets, the basic designs for the development of biological axiomatic theory. (Mandelbrot, 1982) They have proved useful in digital graphics as a new method of tracing the fractal and used, especially in biology, for modeling proper the plant growth. Applicability of systems-L was extended to drawing landscapes and shaping land morphology, such as Sacalin Island. Basically it is a parallel system rewritten by a set of rules and symbols (grammar formal recursive definition of branching symmetric and binary). Central concept of systems-L is the substitution of re-writing the basic idea and consists in building complex objects by successive replacements of parts made of simple

objects using recursive generating a set of rules (called productions).
A system-L naturally fits into the theory of formal languages: based on an alphabet and a set of productions, iteratively generating a certain number of words, starting from an initial word. The deepest study of a rewriting system is operational formal grammar of Chomsky, considered the father of formal languages. (Chomsky, 1957)
The essential difference to Chomsky grammars type consists in the method of application the rules generation: instead of being applied sequentially, one by one, in the L-systems case, they are applied in parallel, simultaneously replacing all letters of the chosen word. This difference was driven by the development of such systems. Productions are intended to model cell divisions of multicellular organisms, which can occur a number of divisions at the same time. (Necula , 2014)

2. Method

L-Systems describing fractals

In generalized terms, a fractal demonstrates the limit. Fractals model complex physical processes and dynamical systems. The basic principle of fractals is that a simple process that goes through several iterations infinite becomes a very complex process. (Dogaru-Ulieru & Draghicescu, 2011)
Fractals are trying to model the complex process of multiplication of a simple process initiator. Most fractals work on the principle of feedback loops. A simple operation is carried out on a sequence of data and then restored again. This process is repeated infinitely many times. The limit of the manufacturing process is the very fractal. Almost all of fractals are self-similar at least in part. This means that some of the fractal itself is identical, except the whole fractal which is to a smaller scale. Fractals can look very complicated. However, usually they are very simple processes that produce complex results. This comes from chaos theory. (Fractali, 2012)
Colloquially, a „fractal“ is „a fragmented geometric shape that can be split or broken into parts so that each of them is (at least approximately) a miniature copy of the whole“ (Mandelbrot, 1982)
The term was introduced by Benoît Mandelbrot in 1975 and is derived from the Latin „fractus” meaning broken or fractured and suggests two main differences of the fractal objects compared to classical mathematical objects: they are not completely smooth, but irregular edges and they are not in one piece but consist of an infinite number of parts, all reduced-size copies of the whole. (Falconer, 2003)
There is no universally accepted definition of the term fractal, the one that Mandelbrot proposed - metric space for which the Hausdorff dimension does not coincide with the topological dimension - just proved too restrictive because of the difficulty of calculating it. Many fractal (or at least their final approximations) are comprised of sequences of elementary shapes - such as the sequence of segments, for example. This sequence can be described by strings generated by L-systems, if we each character of the alphabet each geometric interpretation. (Necula , 2014)

Material

The above topology is very relative, there are similarities and also intersections between the groups mentioned. We now turn to the practical processes of development and use of L- systems for Sacalin Island (Danube Delta).
First, it must be stressed that the Sacalin island evolution is closely related to the hydrology of Sf Gheorghe branch of Danube Delta.

Sacalin island surface appearance dates from 1897, after the catastrophic floods, most known and recorded in the Danube hydrological archive. Obviously, the appearance of the island after the flood, when were transported large amounts of silt, was prepared long before.(Gâștescu & Driga, 2002) (Panin, 1983) We will further show the main phases of bifurcation of the Sf. Gheorghe arm at the mouth to the Black Sea.

Figure 1 Mouth of the Sf. Gheorghe branch into the Black Sea – detail on the Russian map 1771 (Source: University Leiden Library)

In a study on the Black Sea water circulation, published in 1937, R.Ciocârdel mentions that since 1854 as a result of surveys made before Sf. Gheorghe arm mouth had two sandy banks at 0.5 m below water.(Ciocârdel, 1937)

This is confirmed later by more frequent surveys of Charles Hartley, made after the establishment of the European Commission of the Danube (1856) in order to choose one of the arms for maritime navigation and then by Gr.Antipa in the hydrographic map of the Danube Delta in 1909 -1911 (survey made in the 1909-1911 Service of Fishermens' Party under the leadership of eng I. Vidrascu. (Antipa, 1941)

Fractal nature of morphogenesis is confirmed by Col. M. Ionescu-Dobrogeanu who analyzed the evolution of the islands, presenting in an article („Notre Sachaline" published in Romanian Royal Geographical Society Bulletin 1938(Ionescu Dobrogianu, 1938)), the elongation stages, and noting that in 1924 the island was already 10km length. Based on GPS measurements conducted in 2013, it was observed that Sacalin Island has reached the 19km length.

Data on the length and pattern of morphological evolution differ because this formation is fragile and can be easily subject to changes caused by waves, especially during storms, as happened in the spring of 2013, when the island was divided over a length of 3 km, however, morphological and hydrological network maintain the fractal active.

Overlapping the L-system theory tree fractal on the topographic maps selected to follow the evolution of this island, we find two important aspects:

• First, that the island was only gradually elongated southwest, reaching in 2013, 19km in length, direction and growth imposed by the fractal nature of river system and river silt deposited both arm and St. George as those coming from the north east by sea currents;

• Second, the island supports a translational movement westward trend due to the angle given by the pressure wave fractal. This phenomenon annealing deltaic area, especially in the north-east, at the mouth of St. George arm contributes primarily to the increase of flows on the main arm of the mouth.

In this context, the north-eastern part of Sacalin is very close to the Delta, the mouth of the 'Garla de mijloc' lake is locked, and „Meleaua" (Bay between them) just gradually reduced by decreasing the fractal scale in each iteration.
This process of evolution is Sacalin island formation model for the suite of islets in the southern arm St. George, from Crasnicol to east.

3. Results and discussions

Based on these assumptions, we can construct a method to describe this dynamic system, using the theory of fractal trees, system-L. Also, we can use analogies with topographic maps, and simulation is used as a method to describe the evolution of Sacalin Island.
Generaly, we seek understanding the state of the system with fractal depicting inputs, transformations and outputs of the system. It's about finding the response functions of the system. From this description it can be done computer simulation, eg. „By playing" Fractals Foundation website, or using more advanced software in Java or C, as well as software New Mexico University - Fractal Grower 2010.03 - Joel Castellanos, whose results we will refer below. Although construction is pure mathematics, system-L Islet of Sacalin can be discovered in the picture below.

Figure 2 Aspects of the L-System formation of the Sacalin islet (Foto Cristian Trifanov)

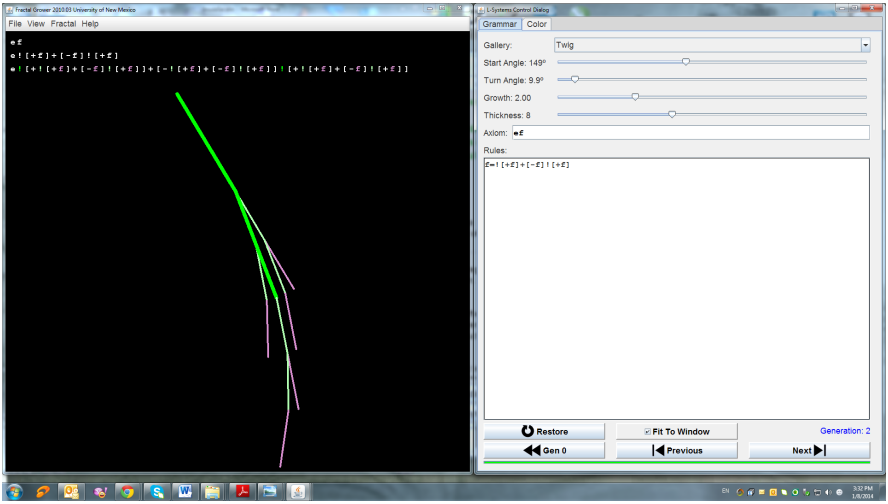

Figure 3 Ramification of the Sf. Gheorghe branch in the Turkish arm, Middle arm, Small Sacalin and main Arm

4. Conclusions

Adopting the perspective of interpretation of the fractal tree morphogenesis for Sacalin Island - system-L, is an outstanding theoretical gain and it is likely that the rules of multiplication fractal on deltaic systems can be considered as an element in the spatial planning process of socio-ecological systems as well.

Despite its limited perspective, trough schemes of specific phenomena morphogenesis, L-systems help develop ideas to explain structural and functional complexity in delta binomial.

Merge-integration processes, appearance / river erosion morphological structures with ecological consequences, lake/ geographic complexes of Danube Delta, this are just some of the issues that can be decoded by applying fractal theory.

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The assessment of the hydrological drought and the proposal of the forecast in real time

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INTRODUCTION:

The assessment of surface water hydrological situation is based on the data from the water-gauging stations of the state hydrological network. The data from 418 gauging stations have been used for the assessment of the hydrological regime and hydrological processes. 268 stations from the total number of 418 water-gauging stations are operative stations, from which transmission of data is provided in 15-minute and 1-minute step (water level, water temperature, air temperature and precipitation total).

The hydrological data from the water-gauging stations with natural hydrological regime (without human influence: e.g. water usage, water manipulation in water reservoirs, water transfers, etc.) are considered for hydrological drought and water scarcity assessment. Another necessary condition for real-time assessment is to use the data from operative stations.

For the assessment of the development of hydrological regime including the development of drought indicators 77 gauging stations with natural hydrological regime have been selected. There have been selected the stations, where the discharges have been monitored since 1961 and earlier. The hydrological forecasting is performed in 26 of 77 selected gauging stations (Fig. 1 - red points = operative stations; colors of main river basins are matching with Table 2).

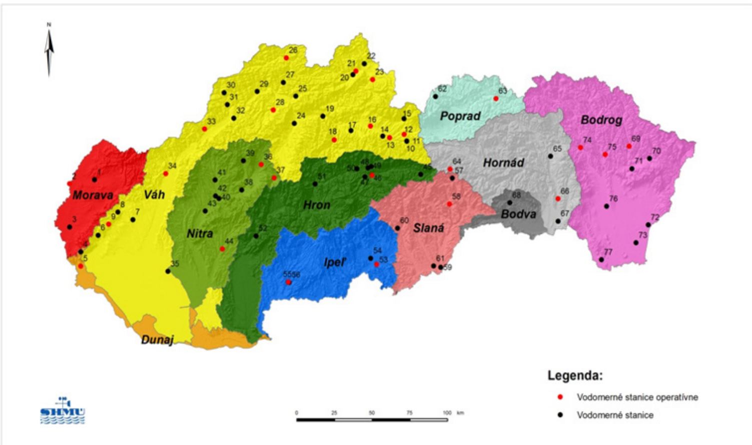

Fig. 1 Selected gauging stations with natural hydrological regime in the main river basins in Slovakia.

1. ANALYSES OF HYDROLOGICAL SITUATION IN 2011 and 2012

Hydrological balance in calendar year 2011.

The precipitation total in particular river basins and its distribution during the year show the following issue: The higher values of annual runoff than the long-term value have been assessed only in the Danube and Poprad river basins (103 % and 117 % of normal). In other river basins these values have been assessed in range 40 % to 93 % of long-term runoff only.

Hydrological balance in calendar year 2012.

The period from December 2011 to February 2012 was rich in snow, but the precipitation scarcity and the abnormally high air temperatures in March and in April caused the beginning of the dry hydrological situation. During the months June and July, according to the missing precipitation, the runoff was minimal. The situation with low precipitation and high air temperatures continued in August and September as well.

The specific distribution of rainfall during the year has caused that the annual runoff of particular river basins has not exceeded the long-term values. The values of annual runoff have varied in range from 26% to 89% of long-term values. In spite of the fact, that precipitation total of the year in Slovakia was about the long-term value according to the runoff from Slovak territory, the year 2012 was assessed as a dry one (155 mm, 59 % of long-term runoff).

2. HYDROLOGICAL YEAR 2012 IN POINT OF VIEW OF LONG-TERM ASSESSMENT

Hydrological year 2012 is one of the driest years since 1931. According to the results of the long-term assessment of the annual runoffs, the runoff of the year 2012 was evaluated as the fifth lowest.

Analyses of the hydrological year 2012 in the particular river basins

Year 1931 is assumed as the beginning of the systematic continuous evaluation of the discharges on the rivers in the Slovakia. The systematic evaluation of discharges has started in the year 1931 in 81 gauging stations. That is why we have assessed the water bearing of the years 2011 and 2012 in context of the period 1931 -2012.

Table 1. The key gauging stations.

Stream	Station	Hydrol. number	River log (km)	Catchment area (km2)	Discharge evaluation since
Myjava	Šaštín - Stráže	4-13-03-073	15,18	644,89	*1931
Morava	Moravský Svätý Ján	4-17-02-001	67,15	24,129,30	1922
Dunaj	Bratislava	4-20-01-006	1868,75	131 331,10	1901
Váh	Ša¾a	4-21-10-057	58,5	11 217,61	*1921
Nitra	Nitrianska Streda	4-21-12-017	91,1	2093,71	1931
Hron	Brehy	4-23-04-110	93,9	3821,38	1931
Ipe¾	Holiša	4-24-01-058	157,2	685,67	1931
Krivánsky potok	Luèenec	4-24--01-078	5,4	204,2	1931
Krupinica	Pláš□ovce	4-24-03-058	11,8	302,79	1931
Litava	Pláš□ovce	4-24-03-071	0,9	214,27	1931
Slaná	Lenartovce	4-31-02-098	3,6	1829,65	1931
Rimavica	Lehota nad Rimavicou	4-31-03-046	2,9	148,95	1931
Torysa	Košické O¾šany	4-32-04-151	13,0	1298,3	1931
Ondava	Horovce	4-30-10-001	29,2	2885,8	1931
Poprad	Chme¾nica	3-01-03-088	60,1	1262,41	1931

* - observation period interrupted

According to the assessment of the discharge time series from the selected key stations it was assumed that the driest year in whole territory of Slovakia since 1931 was the year 1933, the second was the year 1993 and the third one was the year 1947. These years follows the hydrological year 2012. (Tab. 2, Fig.1).

Table 2 Long-term discharge and average annual discharges in dry years in selected stations.

10 - 29	dry years
30 - 49	
50 - 69	
70 - 89	
90 - 110	normal year
111 - 130	wet years
131 - 150	
151 - 170	
171 - 180	
a viac	

No.	Stream	Station	Catchment	1961-2000	Q_{2012}	$Q_{r2012}/Q_{(61-00)}$	Q_{2011}	$Q_{r2011}/Q_{(61-00)}$	Q_{2003}	$Q_{r2003}/Q_{(61-00)}$	Q_{1993}	$Q_{r1993}/Q_{(61-00)}$	Q_{1947}	$Q_{r1947}/Q_{(61-00)}$	Q_{1933}	$Q_{r1933}/Q_{(61-00)}$
1	Myjava	Šaštín - Stráže		2,71	1,621	60	4,462	165	1,901	70	1,128	42	1,568	58	0,965	36
2	Morava	Moravský Ján	Morava	106,37	66,9	63	111,2	105	90,863	85	54,245	51	106,953	101	44,796	42
3	Moèiarka	Láb		0,201	0,073	36	0,171	85	0,123	61	0,091	45				
4	Vydrica	Spariská	Dunaj	0,06	0,026	43	0,104	173	0,051	85	0,031	52				
5	Dunaj	Bratislava		2061	2018	98	1782	86	2007	97	2030	98	1463	71	1800	87
6	Blatina	Pezinok		0,225	0,124	55	0,29	129	0,123	55	0,108	48				
7	Trnávka	Bohdanovce		0,411	0,141	34	0,455	111	0,261	64	0,205	50				
8	Parná	Horné Orešany		0,373	0,113	30	0,68	182	0,150	40	0,223	60				
9	Gidra	Píla		0,297	0,148	50	0,441	148	0,224	75	0,215	72				
10	Ipoltica	Èierny Váh		1,49	1,563	105	0,898	60	0,906	61	0,899	60				
11	Èierny Váh	Èierny Váh		3,547	1,764	50	3,811	107	2,137	60	2,146	61	2,303	65	2,633	74
12	Biely Váh	Východná		1,491	1,15	77	1,658	111	1,441	97	1,149	77	0,930	62	1,112	75
13	Boca	Krá¾ova Lehota		1,892	1,076	57	1,855	98	1,168	62	1,052	56	1,384	73	1,772	94
14	Váh	Liptovský Hrádok		8,738	5,668	65	8,806	101	6,413	73	5,845	67				
15	Belá	Podbanské		3,481	2,703	78	3,272	94	2,709	78	3,187	92	2,528	73	3,266	94
16	Váh	Liptovský Mikuláš		20,134	13,76	68	20,892	104	15,525	77	15,143	75	13,107	65	16,293	81
17	¼upèianka	Part.¼upèa		1,704	0,895	53	1,544	91	1,334	78	1,483	87				
18	Revúca	Podsuchá		4,711	2,82	60	4,283	91	3,081	65	4,123	88	2,722	58	2,762	59
19	¼ubochnianka	¼ubochòa		2,323	1,852	80	2,488	107	2,067	89	1,927	83	1,335	57	1,760	76
20	Biela Orava	Lokca	Váh	6,751	5,94	88	5,769	85	5,191	77	5,499	81				
21	Veselianka	Oravská Jasenica		1,574	1,199	76	1,309	83	1,177	75	1,221	78				
22	Polhoranka	Zubrohlava		3,295	2,711	82	2,673	81	2,713	82	2,495	76				
23	Oravica	Trstená		2,687	1,628	61	2,522	94	2,104	78	1,745	65				
24	Turiec	Martin		9,828	7,553	77	10,512	107	7,953	81	6,233	63	5,943	60	7,026	71
25	Varínka	Stráža		3,139	2,445	78	2,532	81	2,335	74	2,191	70	1,094	35		
26	Kysuca	Èadca		8,552	7,162	84	8,142	95	6,252	73	6,351	74	4,731	55	5,190	61
27	Kysuca	K.N.Mesto		16,603	10,009	60	14,497	87	11,466	69	12,546	76	9,463	57	10,609	64
28	Rajèianka	Poluvsie		3,465	1,893	55	2,856	82	2,061	59	2,242	65	1,729	50	1,582	46
29	Petrovièka	Bytèa		0,72	0,764	106	0,79	110	0,607	84	0,492	68				
30	Petrinovec	Vydrná		0,109	0,084	77	0,115	106	0,122	112	0,054	50				
31	Biela voda	Dohòany		1,99	1,32	66	1,342	67	1,434	72	1,186	60				
32	Pružinka	Visolaje		1,248	0,615	49	1,155	93	0,842	67	0,568	46				
33	Vlára	Horné Sènie		3,242	2,269	70	3,082	95	2,240	69	2,087	64				
34	Jablonka	Èachtice		0,903	0,418	46	1,001	111	0,715	79	0,408	45				
35	Váh	Ša¾a		141,962	103,095	73	135,222	95	113,361	80	98,399	69	87,966	62	90,379	64
36	Nitra	Nedožery		2,125	1,135	53	1,636	77	1,483	70	1,373	65	1,416	67		
37	Handlovka	Handlová		0,578	0,348	60	0,323	56	0,403	70	0,302	52	0,373	65	0,158	27
38	Nitra	Chalmová		6,075	3,522	58	6,271	103	4,313	71	3,841	63	3,302	54	2,325	38
39	Nitrica	Lieš□any		1,908	1,013	53	1,563	82	1,182	62	1,201	63				
40	Nitra	Chynorany	Nitra	9,75	5,398	55	9,278	95	6,881	71	6,374	65	5,546	57		
41	Bebrava	Biskupice		1,964	1,127	57	1,96	100	1,148	58	0,946	48	1,640	84	0,758	39
42	Bebrava	Nadlice		3,266	2,022	62	4,044	124	2,368	73	1,765	54				
43	Nitra	Nitrianska Streda		14,624	8,994	62	14,93	102	10,108	69	8,880	61	8,638	59	5,233	36
44	Žitava	Vieska nad Ž.		1,6	0,656	41	1,56	98	0,822	51	0,781	49	1,349	84	0,903	56
45	Hron	Zlatno		1,337	0,759	57	1,668	125	0,810	61	0,763	57	0,720	54	0,903	68
46	Hron	Brezno		7,416	4,082	55	8,811	119	4,558	61	4,133	56	4,309	58	4,210	57
47	Èierny Hron	Hronec		2,898	1,137	39	2,856	99	1,697	59	1,279	44	1,912	66	1,251	43
48	Bystrianka	Bystrá	Hron	0,916	0,577	63	0,852	93	0,545	59	0,569	62	0,632	69	0,635	69
49	Štiavnièka	Mýto		1,017	0,692	68	1,075	106	0,650	64	0,621	61	0,552	54	1,089	107
50	Vajskovský potok	Dolná Lehota		1,342	0,76	57	1,263	94	0,932	69	0,972	72	0,764	57	0,996	74
51	Hron	Banská Bystrica		25,526	13,234	52	26,049	102	18,239	71	14,738	58	16,179	63	14,897	58
52	Hron	Brehy		45,898	23,14	50	50,195	109	30,749	67	25,077	55	28,016	61	20,268	44
53	Ipe¾	Holiša		2,877	0,56	19	4,211	146	1,552	54	0,730	25	2,630	91	0,930	32
54	Krivánsky potok	Luèenec	Ipe¾	1,332	0,305	23	1,623	122	0,673	51	0,425	32	0,584	44	0,317	24
55	Krupinica	Pláš□ovce		1,589	0,46	29	1,757	111	0,904	57	0,581	37	1,339	84	0,440	28
56	Litava	Pláš□ovce		0,952	0,267	28	1,338	141	0,504	53	0,267	28	0,848	89	0,295	31
57	Dobšinský potok	Dobšiná		0,442	0,189	43	0,492	111	0,271	61	0,198	45	0,310	70	0,522	118
58	Štítnik	Štítnik		1,138	0,351	31	1,604	141	0,622	55	0,333	29	0,686	60	0,865	76
59	Slaná	Lenartovce	Slaná	12,693	4,678	37	17,413	137	7,370	58	4,747	37	6,905	54		
60	Rimavica	Lehota nad Rim.		1,437	0,327	23	1,667	116	0,732	51	0,468	33	0,920	64	0,631	44

Methodology of the assessment of hydrological drought in real time:

When making the real-time assessment, it is necessary to focus on evaluation of the actual hydrological situation as well, including the actual flow depression (deficit volume) under certain threshold value. Therefore it is necessary to know the initial status, in addition to the precipitation also to the air temperature, evaporation and water content of snow pack, which would help to evaluate comprehensively the origin and the course of the hydrological drought.

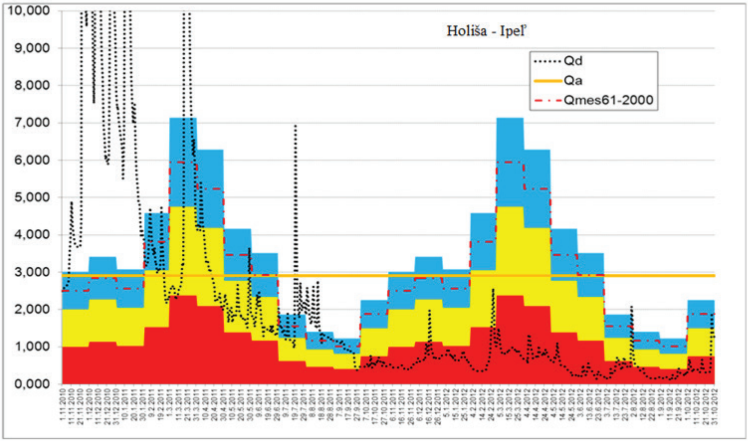

Fig. 2 Actual status of the low flow.

Legend:

$Q_{mes61-2000}$ – mean long-term monthly discharges for the period 1961-2000 ($m^3.s^{-1}$),
Q_d – mean daily discharges ($m^3.s^{-1}$), in real-time assessment – operative discharge values,
Q_a – mean long-term discharge for the period 1961 - 2000 ($m^3.s^{-1}$).

The variability of the hydrological regime (distribution of the monthly discharges) during the year is higher than the variability of annual discharges. Therefore, for the operational evaluation of the occurrence of the hydrological drought as a part of the hydrological regime of selected period, the evaluation of the operational discharge according to the annual long-term discharge is not sufficient. For this reason the monthly long-term discharges have been chosen as the benchmark line and the scaling range for the evaluation of drought has been increased, at 40%. (Note: this value is still the first estimation based on historical measurements in the same month of reference period and requires even more analysis.) This way, 3 reference quantiles are proposed:

	1.	quantile (120 to 80 % of $Q_{mes61-2000}$ - normal status of water bearing)
	2.	quantile (80 to 40 % of $Q_{mes61-2000}$ – subnormal status of water bearing)
	3.	quantile (less than 40 % of $Q_{mes61-2000}$- critical value of water bearing status)

For the evaluation the following should be taken into account:

- During the months that are typically aqueous (e. g. spring months), where Q_a is lower than the values of the particular long-term monthly discharges ($Q_{mes61-2000}$), the evaluation of actual discharge to the Q_a irrelevant, it is therefore necessary to monitor the operational discharge with respect to the proposed 3 quantiles of long-term monthly discharges. During this period, the climatic factors play also an important role, such as actual water supply in snow cover, actual and forecasted precipitation total and air temperature.
- In the case where the long-term monthly discharge ($Q_{mes61-2000}$) is lower than Q_a, the assessment with respect to Q_a is reasonable. It can represent the first indication after the actual value falls below Q_a that it is necessary to follow the development of hydrological situation, including the development of climatic indicators.

3. CONCLUSION

In 2012 was occurred above the average air temperatures, above the average values of sunshine and relatively windy weather at the end of winter and in spring 2012, causing sublimation of water content of snow pack. These factors has caused the low amounts of surface runoff during the spring in 2012, which was also reflected in the hydrological flow regime during the year, and it affected the annual runoff values.

When assessing the hydrological situation in real time, it is necessary to focus on the evaluation of the current hydrological situation, mainly discharges, including the assessment of current flow depression (deficit volume) below a certain reference value. To do this, it is necessary to know the initial state of climate conditions, precipitation and evaporation also the air temperature and the water content of snow pack during the relevant period, which will help to comprehensively evaluate the occurrence and the development of the drought. The assessment of the years 2011 and 2012 and their place in historical observations have shown that it is necessary to evaluate the occurrence of drought in smaller time units than year and in the individual sub-basins.

To reduce the impacts of drought it is necessary to integrate the current state of the hydrological network by more stations. It needs to integrate the existing gauging stations in profiles with unaffected hydrological regime with online data transfer.

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The Plan for the Prevention, Protection and Minimizing of the Flood Effects Inside the Somes – Tisa Hydrographical Area Study regarding delineation of flood hazard zones in hydrographic basin of Somes river, border area

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Introduction

The Plan for the Prevention, Protection and Minimizing of the Flood Effects inside the Somes – Tisa Hydrographical Area is made according to the Romanian Government's Decision, regarding the approval of the program for the implementation of the National Plan for the Prevention, Protection and Minimization of the Flood Effects and for the financing of this plan, starting from 23 October 2007, according to the provisions of the European Union's Flood Directive, for the assessment and management of the flood risk.

The National Plan for the Prevention, Protection and Minimization of the Flood Effects will be applied on the Somes, Crasna and Tisa river basins**.**

The paper is a brief presentation of the case study which is part of this program, undertaken in Satu Mare city, up to the border area.

1. Project objectives

Someş River**,** is one of the most important in Transylvania, northwestern Romania, with more than 465 km lenght, and 15.740 km² surface of hydrographic basin.

The main objectives followed by the project are:

- identification of the river basins or river sub-basins with flood risks;
- regionalization of the flood hazard;
- presentation of the main flash floods occurred during the last 30 years, which induced floods;
- description of the flood vulnerability inside the flood risk areas;
- use of the charting equipment for the making of the flood risk assessment;
- causes of the floods, with the description of the anthropic factors contributing to the urging of the flood phenomenon;
- assessment of the influences / modifications over the hazard regionalization of the flash floods and assessment of the vulnerability;
- estimation of the tendencies regarding the future floods occurrence
- assessment of the consequences of eventual flood over the population, properties and environment;
- the establishment of the protection degree, accepted for the human settlements, for the

economic and social objectives, for the farm areas, etc.;

- preliminary assessment of the flood risk (for discharges higher than the calculus discharge);

- presentation of the necessary measures and actions for the reduction of the flood risk, the financial assessment for that and the identification of the necessary projects;

- cost analysis for the potential structural and non-structural measures, in an alternative manner, by using the 2D flood map analysis;

- analysis of the flood risk, for the evacuations and for the contingency plan (number of evacuated people, size of the forces assigned for the evacuation activities, logistics and technique available for the authorities);

2. Main stages of the project

In order to make the plan, first of all, we needed a detail analysis of the main floods occurred inside the Somes – Tisa hydrographical area during, at last, the last 30 years, in order to identify the area exposed to such phenomenon.

After this analysis, we established the main stages of the eventual project, inside the priority areas.As a consequence, the hydrological and the topographical studies are the foundation on which the entire project would be built. The quality of these studies will define the superior results output.

2.1 Topographical studies

Topographical studies will encompass situation plans, cross-section profiles, longitudinal profiles, topographical studies, altimetry control points and the digital model of the terrain (DTM) with an altitudinal accuracy of 15 cm in the priority areas and 20 cm in the rest of the river basin. The DTM will be integrated with the plans and the DTM vector maps or similar items, at the existing scale for the urban (inhabited) areas. We will use the most detailed available scale, and for the river basin we will use the informational plans made according with the 1:50.000 and 1:25.000 maps, where these maps are available.

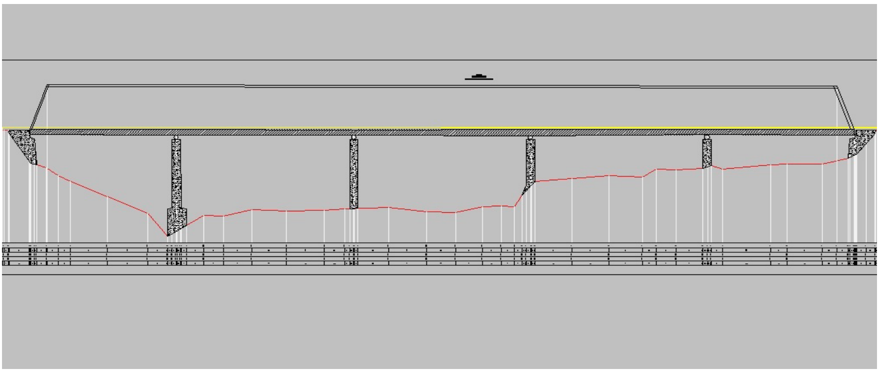

Fig. 1. Cross section example – bridge in Satu-Mare city

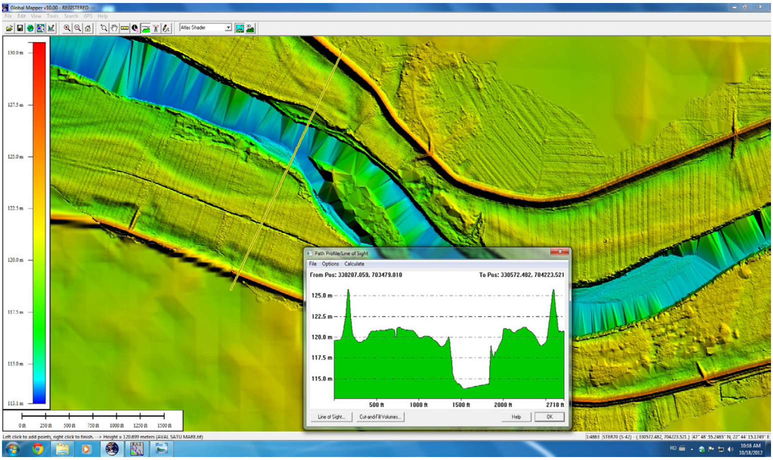

Fig. 2. The Digital Terrain Model – Somes River in the border area

2.2 Hydrological studies

The hydrological studies will provide the characteristic parameters for the floods occurred for the calculus discharges with overflow probabilities of 0,1%; 1%, 5%, 10%.

The hydrologic and hydraulic models will be made by using the hydro-meteorological data base and the topographical measurements on site; them calibration will be done according to the records of the historical floods.

The studies on the hydrologic and hydraulic models will be necessary for the establishment of the carrying capacity of the riverbeds, for the delimitation of the flood plains and for the detection of the transit discharges at the hydro-technical installations, but also for the establishment of the parameters needed for the structural measures' projects. These will be based on the 1D and 2D unstable hydro-dynamic models.

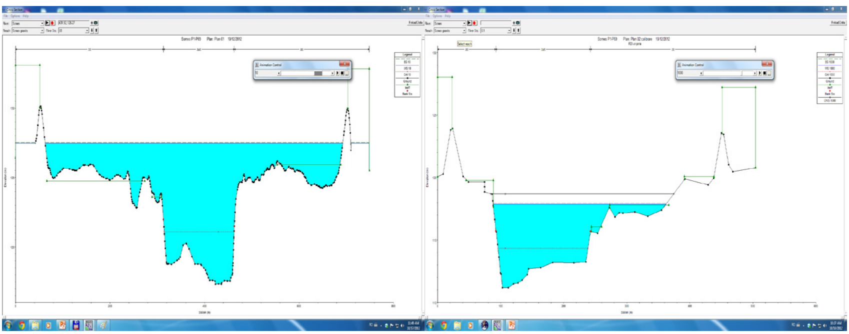

Fig. 3.Hydraulic modelling(cross section example) - Somes river (Romania and Hungary)

Fig.4. Flood hazard map(example)

3. Conclusions

In developing policies referring to water and land uses Member States and the Community should consider the potential impacts that such policies might have on flood risks and the management of flood risks.

Throughout the Community different types of floods occur, such as river floods, flash floods, urban floods and floods from the sea in coastal areas.

The damage caused by flood events may also vary across the countries and regions of the Community.

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GEODATA BASE FOR DANUBE FLOOD HAZARD AND RISK MAPS ATLAS

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ABSTRACT
A transnational, interdisciplinary and stakeholder-oriented approach was key for adequately assessing and mapping flood risk. And due to the many actors involved in flood risk management, harmonization was a key feature of the project. This “common interpretation” of events covered the specification of the goals and tackled key technical questions. DANUBE FLOODRISK has resulted in better socio-economic conditions in the Danube basin and less flood damage to its floodplain. The project has also improved the common geodatabase for flood and risk mapping along the Danube floodplains.
Keywords: Danube, floods, hazard, risk, geodatabase

1. INTRODUCTION
Flooding is the most widely distributed of all natural hazards across Europe with floods from rivers, estuaries and the sea threatening many millions of people in Europe. Floods cause distress and damage wherever they happen and insurance company data show that the financial impact of flooding has increased significantly since 1990.
In April 2007, the Parliament and Council of the European Union agreed the wording on a new European Directive on the assessment and management of flood risk. The Integrated Project Danube Floodrisk is listed as one of the European actions which support the Directive, as well as the Joint Danube Strategy.
Danube Floodrisk was active in stimulating the uptake of research advances through manuals, guidance for professionals, stakeholders involvement, public information and educational material, leaflets and newsletters.
Danube Floodrisk was a flagship project for the Interreg IVB - SEE Programme of the European Commission. It commenced in 2009 and ran to 2013. The Danube Floodrisk consortium includes 24 partners in 8 countries along the Danube, leading institutes, universities and NGOs in the basin, and the project involves managers, researchers and practitioners from a range of government, commercial and research organisations, specialising in aspects of flood risk management.

2. HARMONIZATION OF REQUIREMENTS ON THE FLOD MAPPING PROCEDURES FOR THE DANUBE RIVER
Danube Floodrisk Project has the main results the Hazard and Risk Maps Atlas in a harmonized methodology for the Danube floodplains, environmental, ecological and socio-economic aspects of floods along the Danube and Danube Delta. It considers flood risk as a combination of hazard sources, pathways and the consequences of flooding on the “receptors” – people, property and the environment, stakeholders’ involvement being one of the most important issues. A common geodatabase was provided as support for maps production, as well as a database of the main stakeholders in the Danube Floodplain.

Harmonization was the central activity of the project; harmonization is not only needed regarding different nations but also regarding different user groups. So each user group might expect different map content and is going to use it in a different way. The bottom line is that the river is being conceived like a system which does not respect any border. Flood risk management has to be one piece of this puzzle. The national requirements are summarized in the "Report on national requirements on the flood mapping procedures for the Danube River", and the „Manual of harmonized requirements on the flood mapping procedures for the Danube River" (see the project site www.danube-floodrisk.eu).
In the harmonization manual not all aspects of the EU Floods Directive could be handled, as the Danube Floodrisk project only covers the hazard and risk mapping part and some examples of flood risk management plans in certain pilots. The focus is on the production of maps on the scale of a large river catchment (scale 1:100 000). Still it is considering as much as possible also the needs and problems of the tributaries.
The harmonisation process covers the specification of the goals and tackles technical questions referring to the scenario definitions, methods used, accuracy threshold and so forth. Basis for the harmonized product description are the national laws of the project members, the European Floods Directive and good practice results from different flood risk mapping projects as well as existing maps or atlases.

3. HYDROLOGICAL AND HYDRAULIC MODELING

The hydrological processing was performed at different degrees of complexity, depending on the future utilization of the results. Synthetical hydrographs were generated, under the volume conservation hypothesis. For hydraulic simulations in steady state either a unique value of the maximum discharge corresponding to a probability of exceedance P% or an uncertainty interval of the maximum discharges was obtained if taking into account the hydrologic uncertainty; in the latter case instead of a well defined inundation line, a strip of inundation was obtained for each probability of exceedance P%. The inundation strip is also justified by the uncertainties related to the DTM. For unsteady state simulations, a family of hydrographs corresponding to the same probability of exceedance P% is obtained. The floods corresponding to the maximum discharges which could lead to the dyke overtopping was considered for hydraulic simulations. The floods having the maximum volumes represented boundary conditions for transient computation of the water flow through the dyke and its foundation. The critical gradients were computed, showing the (possible) sensitive parts of the hydraulic structures. 1D for mountainous regions and in Croatia and Serbia was applied, and coupled 1D-2D or pure 2D simulations for plain areas was considered for urban areas (pilot areas) or for the Danube Delta. The flowchart of the hydrological methodology is presented in Figure 1 Flowchart of the hydrological methodology1.

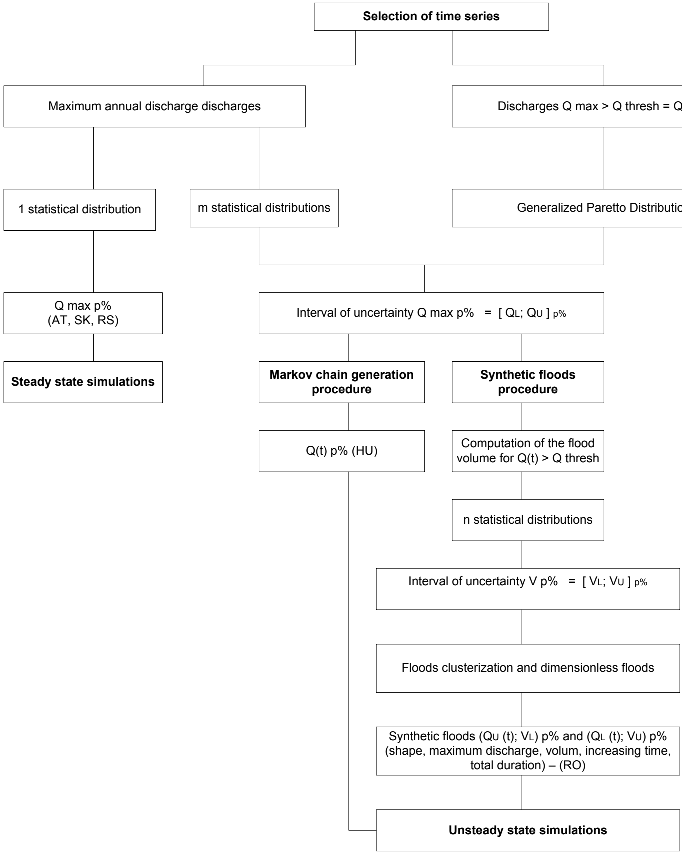

Figure **1** Flowchart of the hydrological methodology

4. VULNERABILITY MAPPING

The methodology for vulnerability index / indicators determination was considered that vulnerability indicators must be developed based on some well defined criteria; this methodology has been provided by the FP7-project SAFER and was adequately transferred for the Danube Floodrisk Project (BEAM Methodology). The damage functions are not part of the BEAM product itself; but was taken in an adjusted version from other large scale risk projects i.e. Rhine and JRC database (Ad de Roo Lisflood model application for flooding areas in Europe).

5. COMMON GEODABASE ALONG THE DANUBE FLOODPLAIN

In the context of flood hazard and risk modelling data was collected in a central database. This relates especially to input data not acquired with DFRP funds such as DTM, cross-sections, roughness coefficients, hydrological data, but also to input data for risk considerations (as hydraulic infrastructures, economical, social and environmental objectives). The main data sources for flood risk maps are digital terrain data, land use information, hydraulic data and for the damage assessment also statistics. Especially linear structures were considered as they have high impacts for Q30 and Q100. A metadatabase content of the geodatabase of the Danube Floodplain, as: projection information, height system used, Data Source, way of data generation, processing, accuracy information, owner of the data, copyright limitations, detailed description of the classes used, preferable already adjusted to INSPIRE, is available on project site access (www.danube-floodrisk.eu), together with the Hazard and Risk Maps Atlas [4] at scale 1:100.000, as an output of the geodatabase.

6. CONCLUSIONS

In building the geodatabase along the Danube floodplains the relevant project partners work on the compilation and acquisition as well as processing and storing of all necessary data. The process follows the agreed harmonized methods and requirement, to serve for the mapping actions; for this purpose was linked to the EU Floods Directive initiative framing, the ICPDR Danube River Basin GIS platform requirements - Cooperation beyond regional and national borders the Danube Floodrisk project developed a web global system for topographical, hydrological and socio-economic data, with main objectives:

- support Floods Directive (and others – WFD, Natura 2000, European Strategy for Landscape Conservation) reporting and map making
- integration of existing and future information data sources to increase usage effectiveness
- optimization of costs
- anticipate analysis and modeling functionality.

The main results which partners got during the project implementation for data collection are:
- Reports on data availability, area covered by each data set, accessibility conditions and quality check results, homogeneous terrain data set and river cross section data set that has been quality checked and adjusted to neighbor data sets, land use data set and statistical dataset that has been quality checked and has comparable content than neighbor data sets and data compiled by the partners, processed as far as necessary and ready to be used for the mapping actions
- Common data base is now available for ICPDR data platform, as well as the Atlas [4].

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Understanding Flood Problems Among Decision-Makers and General Public Should be Improved: Case Study from Ukraine

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Introduction

According to the statistics presented by the State Service of Ukraine on Emergencies, river floods have imposed the most severe damages to the sectors of economy and the human communities in Ukraine. The frequency and intensity of floods as well as the magnitude of the damage caused, have increased in the country during the past three decades. Researches have shown that the climate change and irrational economic activities in river basins (deforestation, flood-plain building, and so on) are major reasons of increasing the frequency and intensity of flood hazards. But, adaptability and vulnerability of the Ukrainian society to floods are still poorly understood. The Ukrainian water management and protection authorities have faced the difficult task of developing suitable prevention and mitigation strategies, and strengthening the resilience of the population. Feasible strategies must satisfy political, social and technical requirements, and be justified in economic sense. In this context it seems interesting to study the social aspects of preparedness of Ukrainian society to the flood management problem.

In order to study this issue, the paper is devoted to a research of: a) public opinion on preparedness of the Ukrainian society to extreme river floods; b) awareness among decision-makers and general public about a role of the Hydrometeorological Service in the flood management. The study is based on: a) the long-term experience of working in the Hydrometeorological Service of Ukraine; b) results of social surveys of residents who live in flood dangerous regions; c) analysis of information which has been published in the Ukrainian professional literature and in the mass media.

The aims of this study include: a) to explore the main sources of information on water-related hazards and the level of knowledge useful in a flood crisis situation in different groups of peoples; b) to learn what various population groups think of the most significant causes and consequences of flood damages and the role of various central and local authorities in the elaboration and implementation of adaptation measures; c) to assess the level of knowledge among decision - makers and general public in the area of hydrometeorology and methods of flood assessment and forecasting.

Communities which live in different flood risk areas have been included in the researches, including: a) high-risk areas (Tisza and Dnister river basins), b) low -risk areas (some tributaries of Dnipro river).

The following results have been revealed for various groups of respondents.

1. Results

1.1 Decision-makers with tertiary education, but having no special qualification in the hydrometeorology, geography or other related sciences

As a rule, these persons work in the central and local governments. Duties of these persons are often limited by purely administrative functions during flood periods. The information and forecasts of the Hydrometeorological Service are often the only source of their knowledge about natural factors of flood formation. The most of them understand that floods present significant economic and environmental problem. But, a lot of them have insufficient level of awareness on: a) natural and anthropogenic factors of flood runoff formation, for example, about an impact of climate change on increasing flood frequency in Ukraine; b) the role of hydrometeorological information and forecasting in the flood management policy. As a result, interaction between organizations of the Hydrometeorological Service and local authorities could be complicated in some cases at time of floods. In turn, it reduces the effectiveness of anti-flood measures.

1.2 Decision-makers with qualification in the field of hydrometeorology, geography or other related sciences

As a rule, these persons work in the central and local branches of the Ministry of Environment Protection, the State Service of Emergencies, the State Agency of Water Resources or others water-related authorities. On the one hand, the most of them understand the hydrometeorological nature of floods origin and significance of hydrometeorological information and forecasting in the flood management. In conditions of economical difficulties they try to support the system of hydrometerological observation and forecasting. On the other hand, a lot of them have point of view that such non-structural flood control measures as hydrometeorological forecasts and warnings are of secondary importance in comparison with structural methods of flood control. They also insufficiently understand a necessity to take into account the issue of climate change in the flood management policy. But, in general, in this case, the interaction between organizations of the Hydrometeorological Service and the central and local branches of water-related authorities, can be described as highly effective.

1.3 Public views on flood problem

In order to learn what various population groups think of the flood problem in Ukraine the responses from 1275 residents living in areas of high- and low-risk of floods have been analyzed and summarized. The following results have been obtained.

Sources of information about problem. About 65% of population living in both types of flood risk areas get information from local official bodies - local governments and local branches of central water-related authorities. About 25% of population get information from other sources - central and local mass - media, non-governmental organizations.

Causes of increasing of flood losses. The responses of people living in areas of high - and low - flood risk differed significantly. People living in the high - risk areas have indicated following main causes of increasing flood losses: deforestation (indicated by about 85% of respondents), unauthorized building in floodplains and river channels (about 80%), insufficient activity of central and local water management authorities (about 65%), impact of climate change on flood formation factors (about 30%); low accuracy of hydrometeorological forecasts (about 20%); insufficient private mitigation measures (about 10%). Another data were obtained for respondents living in the low-risk areas: deforestation (about 55%); unauthorized building in floodplains and river channels (about 70%); insufficient activity of central and local water management authorities (about 45%), impact of climate change on flood formation factors (about 20%); low accuracy of hydrometeorological forecasts (about 25%); insufficient private mitigation measures (about 5%).

Negative consequences of flood disasters. Both groups of respondents indicated the same most serious negative consequences of flood disasters: destruction of private property (about 75%); impossibility of agrarian and household work (about 70%); destruction of economic infrastructure (about 70%); deteriorating social conditions of life (about 60%); deterioration of sanitary conditions (about 55%); threat of environmental pollution (about 55%).

The most effective flood protection measures. It was noted the difference in estimates of the most effective measures to protect flood between the two groups of respondents. Interviewing the population living in the high-risk areas provided the following results: about 80% of respondents named the flood control levees among the most effective measures for reducing flood losses; about 70% of respondents indicated preventing construction in high - risk areas; about 65% respondents named the reforestation and development of the national system of flood hazards prevention; particularly, flood forecasting and the public's information about flood risk. The following results were revealed for other group of respondents: the flood control levees – about 75%; preventing construction in high - risk areas - about 50%; the reforestation – 35; development of the national system of flood hazards prevention – about 60%.

Financing for the flood management activity. About 70% of population living in the flood high -risk areas estimates the level of financing for the flood management activity as insufficient. In the areas of low flood hazard this opinion was shared by only about 45% of respondents.

Public participation in the flood management policy. In the high-risk flood areas about 70% of population was satisfied by the present level of public participation in flood management policy, among respondents living in the low-risk flood areas this percentage is lower, making about 55%.

2. Conclusion

The results of this study have been rather unexpected for Ukrainian central and local governmental bodies responsible for flood management policy. These underline: a) importance of having the alternative flood risk management policies studied not only from aspects of technical and economic rationales, but also from that of social acceptability, before any decision is made; b) importance of using these results by the Ukrainian water-related authorities in their plans of development of flood management policy.

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Comparison of the 1895 and 2006 Danube floods

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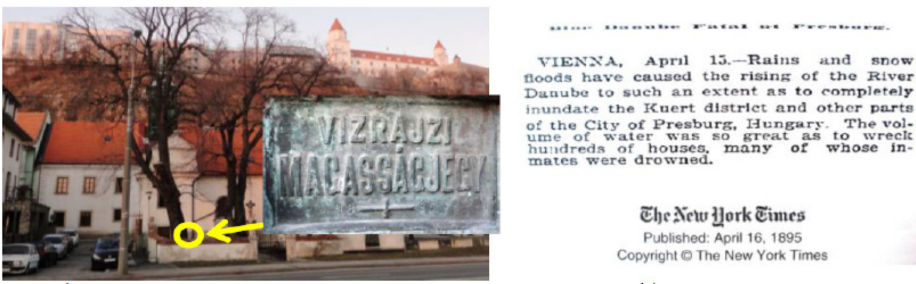
Abstract
The occurrence of the catastrophic floods over the Upper, Central, and also over the Lower Danube River in the last fifteen years (2002, 2006, 2010, 2013) have drawn our attention to study information concerning the Danube floods. When studying and reviewing the flood regime at present, it is necessary to pay attention to historical hydrology and to the data in archives. The aim of this study is to describe the 1895 flood in the river reach between Bratislava and Turnu Severin, and to compare this flood with the 2006 Danube flood.

1. Introduction
In the year 2012 we have discovered an unreferenced flood mark of the 1895 flood in the old city of Bratislava. This flood mark was found in the garden on the wall of the Holy Trinity church in Zizkova street no.3 (Fig. 1a) in the former quarter called Zuckermandel (below the Bratislava castle near Danube). The flood mark indicates the water level dated 1895 below the Hungarian inscription "VIZRAJZI MAGASSÁGJEGY" (translation: "hydrographic level mark"). The flood in spring 1895 was one of the biggest floods in the Lower Danube basin. However, there exist no descriptions of the flood occurrence in year 1895 at Bratislava in the official documents of the hydrographic service.
The study is divided into two parts. In the first one, we tried to sum up information on the 1895 Danube flood based upon the historical records study. In the second part the 1895 and 2006 floods are compared on base of the preserved observed Danube daily discharge data from five stations along the Danube. It is striking how similar are the both floods - in their meteorological and hydrological origin aspect, particularly their peak discharges, or their flood wave travel times.



VIENNA, April 15.—Rains and snow floods have caused the rising of the River Danube to such an extent as to completely inundate the Kuert district and other parts of the City of Presburg, Hungary. The volume of water was so great as to wreck hundreds of houses, many of whose inmates were drowned.

The New York Times
Published: April 16, 1895
Copyright © The New York Times

a) b)

Fig. 1 a) The 1895 flood mark in the garden of Holy Trinity Church in Bratislava (photo: P. Miklánek, 2012), **b)** Report on the 1895 Danube flood at Pressburg in the newspaper "The New York Times".

2. Results

2.1 Data

We studied the information from newspaper articles dealing with the flood on the Danube and its tributaries in 1895 (Fig. 1b), according to Preßburger Zeitung, Wiener Zeitung, or „Komáromi Lapok". during the period since the end of February to the end of April 1895.

We extracted the mean daily discharge data (as well as maximum annual discharge) from the database of the project „Flood regime of rivers in the Danube basin" for five stations: Danube: Bratislava; Danube: Nagymaros, Danube: Veliko Gradiste, Danube: Turnu-Severin (Orsova), and Danube: Ceatal Izmail of the years 1895 and 2006. In Fig. 2 there is the mean daily discharge in selected stations in 1895 and 2006. In other stations there are no data available for the year 1895.

In 1895 the flood wave at Bratislava station culminated on 31 March 1895 with discharge of 6979 m^3s^{-1}. In 2006 the flood wave at Bratislava culminated on 31 March 2006, as well, with discharge of 7824 m^3s^{-1}.

At Orsova the flood wave in 1895 culminated on 14-18 April (about 16 days later than at Bratislava) with discharge of 15200 m^3s^{-1}. In 2006 the flood wave at Orsova culminated on 15–18 April (also about 16 days later than at Bratislava) with discharge of 16258 m^3s^{-1}.

There are no differences in the travel times of both floods. Even when the smaller flood waves have shorter travel times due to channel training at present, it is not valid for larger floods. The travel time of the large flood is the same as 111 years ago. The development of the flood waves is remarkably similar in 2006 and 1895 (Fig. 2), but the discharges were more variable in 2006.

2.2 Maximum annual discharge at Bratislava and Orsova

In this part we concentrated on assessment of the 1895 flood significance at stations Danube: Bratislava, and Danube: Orsova. We used the log-Pearson III type distribution for assessment of the flood significance. In Fig. 3 there are the maximum annual discharge series at stations Bratislava and Orsova. The return period of the flood at the Bratislava station was about 5-10 years (Fig. 4), at Orsova station it was the biggest flood ever measured with the return period of about 80-100 years.

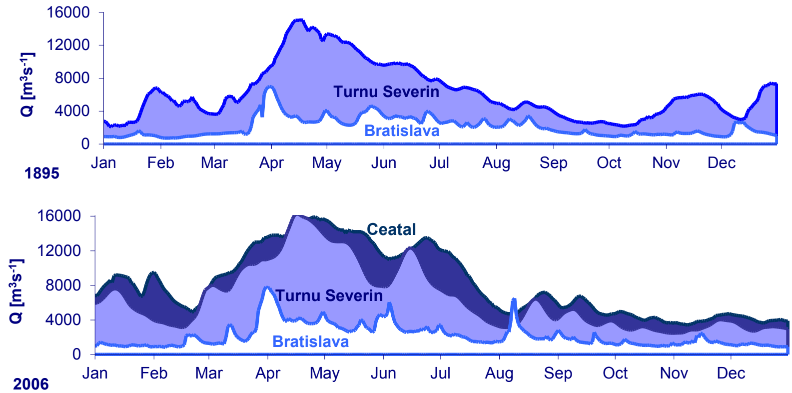


Fig. 2: Mean daily discharge hydrographs from Danube, gauging stations Bratislava, Turnu Severin/Orsova, and Ceatal Izmail, (years 1895, 2006).

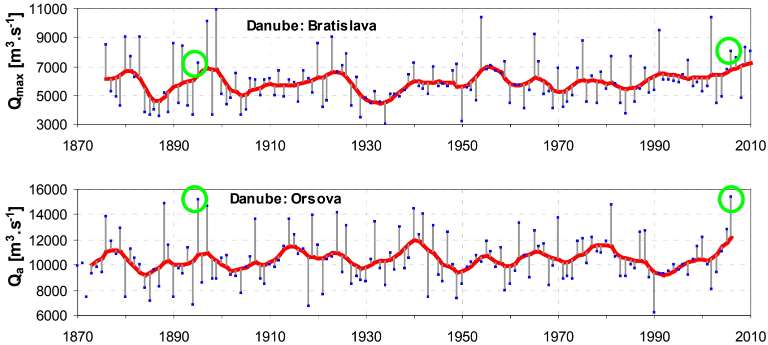


Fig. 3: The Danube maximum annual discharge time series. Marked by the circle are those of the year 1895 and 2006, at Bratislava and Orsova.

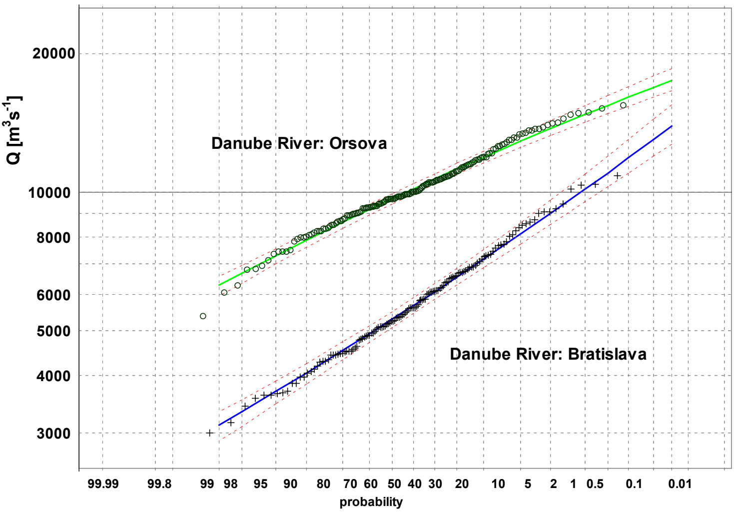


Fig. 4: Empirical and theoretical exceedance probability curves of the Danube maximum annual discharges at Bratislava and Orsova, from the whole observation period. q(5) and q(95) are the probability confidence limits, the log- Pearson type III. probability distribution.

3. Conclusions

There can be found many flood marks of the historical floods in cities located on the Upper Danube (e.g. Passau, Linz, Melk, Krems, or Hainburg). Such marks are not so frequent on the Danube downstream from Bratislava. But it is still possible to find out new information on flood history over the Danube territory; enabling us to better evaluate the flood peak exceedance probabilities (N-years flood peaks).

The 1895 March flood at Bratislava was apparently an ice and rain one. In Bratislava it occurred between the 26th to 31th March, 1895. It is interesting to compare this historical 1895 flood

shape with that of the year 2006. It is striking, how similar are the both. From their hydro-meteorological origin aspect, particularly their peak discharges, or their flood wave travel times. This similarity confirms our assumption, that by the structural river channel interventions (river training), the river wave travel times are changed only in cases of the minor floods. In case of the high floods, with vast inundation areas flooded, the flood wave travel times have not been changed significantly.
Instructive is a fact, that also such catastrophic Danube flood, can after 111 years fall into oblivion. Instigation to search for this flood information was an incidental discovery of the flood mark from 1895, in garden of the Bratislava (down the castle) Holy Trinity church, when searching for flood marks from the other years.
When studying and reviewing the flood regime at present, it is necessary to pay due attention to historical hydrology and to the data in archives. It is still possible to find out new information on flood history over our territory, enabling us to better evaluate the flood peak exceedance probabilities (N-years flood peaks). There is also necessary to closely cooperate within the Danube countries (Brilly, 2010; Bondar and Panin, 2001). In their national archives, there are many valuable documents helping in the Danube flood regime evaluation in the Danube river catchment as a whole.

Acknowledgements
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Fig. 5: Left - ice on the Danube in Bratislava around 1900, right - frozen Danube before the WWII. (Bratislava City Gallery, Joseph Hanák archive).

The increase of water levels and change of floods travel times on the Upper Danube

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Abstract
Important changes of transport and transformation capacities of the Danube River channel occurred, due to anthropogenic activities in last century. This refers to the flood travel times and also flow behaviour changes during flood wave propagation through the channel. In the last decades extreme water situations increasingly occurred on the Danube catchment area. In June, 2013 the highest flood wave since 1876 on the German, Austrian, Slovakian and Hungarian sections.
The aim of the paper is to analyse changes of the Danube rating curve at Bratislava gauge, and changes of travel times of the biggest floods above discharge of 10,000 $m^3.s^{-1}$ at Bratislava water gauge.

1. Increase of water levels
The transformation properties of the Danube river channel are changing due to anthropogenic activities. This refers to the flood travel times and also flow behaviour during flood wave propagation through the channel. During the 2013 flood, the hydrologists were surprised by high peak water levels in almost all stations in the Danube River basin. We are interested in floods above discharge of 10,000$m^3.s^{-1}$ at Bratislava water gauge (Table 1).

Tab. 1. Peak water level of the biggest instrumental floods at Bratislava (1868.8 river km), discharge at Bratislava water gauge, water levels at Hainburg (1883.9 river km), Nagymaros (1694.6 river km), Budapest (1646.5 river km), and Mohacs (1446.9 river km).

Date, Bratislava	Discharge [$m^3.s^{-1}$]	Hainburg [cm]	Water Bratislava [cm]	level Nagymaros	Budapest [cm]	Mohacs [cm]
06. 06. 2013	10,640	980	1034	751	891	964
16. 08. 2002	10,370	952	991	705	848	926
15. 07. 1954	10,400	906	984	641	807	924
19. 09. 1899	10,870	862	970	600	770	878
04. 08 1897	10,140	854	940	622	780	900

The water level in Bratislava reached the historically highest measured value on 6 June 2013. In Bratislava the 1899 flood culminated with discharge 10,870 $m^3.s^{-1}$ at water level 970 cm. In 2013 the discharge was 10,670 $m^3.s^{-1}$ and the water level was 1034 cm. In 114 years the water levels were increased by more than 60 cm in Bratislava at the comparable discharge. The rating curve is slowly changing in its upper part. In the neighbouring Hainburg the 1899 flood culminated at water level 862 cm and in 2013 the water level was 980 cm, what gives the increase of more than 1 m.

The similar situation is also in stations Nagymaros, Budapest or Mohacs (Konecsny and Nagy, 2013). The biggest difference in water level between floods in 2013 and 1899 was recorded at Nagymaros station. The increase of water level is about 150 cm.

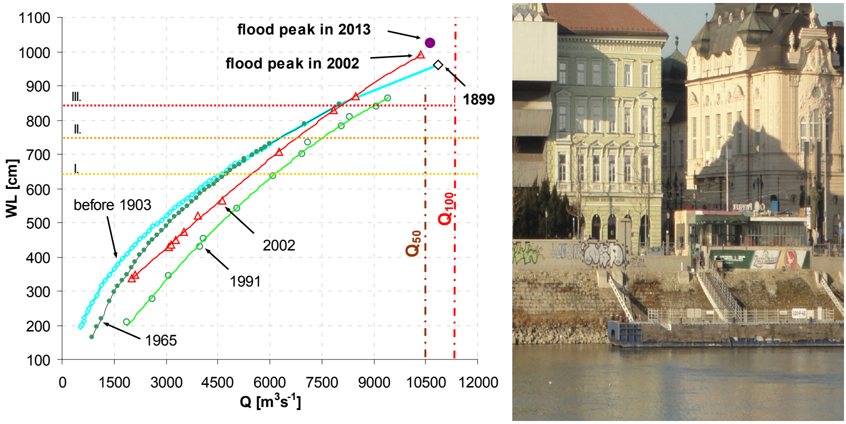

Fig. 1. Changes of the Danube rating curve at Bratislava gauge (Foto: Pekarova, 2013) (related to the present gauge zero water level WL).

2. Analysis of the flood wave travel time changes in the upper Danube

In the previous studies (Miklanek et al., 2002, Mitkova et al., 2005, Pekarova et al., 2001) authors showed that the medium floods travel times between Kienstock and Bratislava of 1991–2002 period are shorter by about 41% compared to 1923–1966, and by about 11% compared to 1975–1991. The travel times of the big 1991 and 2002 floods did not change significantly. The second part of the paper deals with the floods above discharge of 10 000 $m^3.s^{-1}$ at Bratislava water gauge (Table 1). In Figure 2 we can see the scheme of the Austrian and Slovak/Hungarian part of Danube.

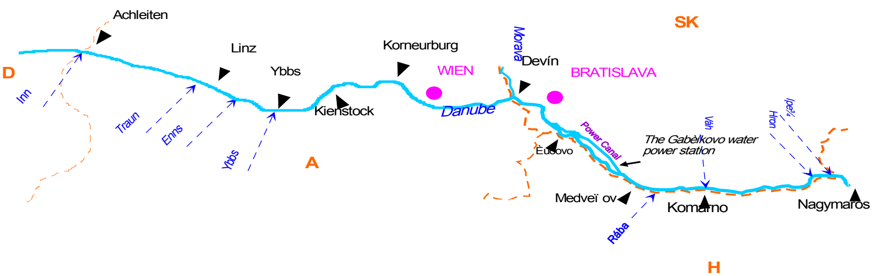

Fig. 2. Scheme of the Austrian and Slovak/Hungay part of Danube.

We completed the input data with the last flood wave from 2013 and we assessed the changes of the flood travel times in the Passau–Bratislava–Sturovo sections (Figure 3). The travel times of the important floods in the reach Passau–Bratislava were between 65 and 130 hours. The travel times of the important floods in the reach Bratislava–Sturovo were between 50 and 70 hours. During the 1954 flood the travel time Ybbs–Bratislava was 78 hours and in 2013 the travel time was only about 45 hours in the same section; and travel time between Bratislava and Sturovo was about 50 hours in 1954 and about 60 hours in 2013. The differences between flood travel times in the upper Danube are bigger than in section Bratislava–Sturovo.

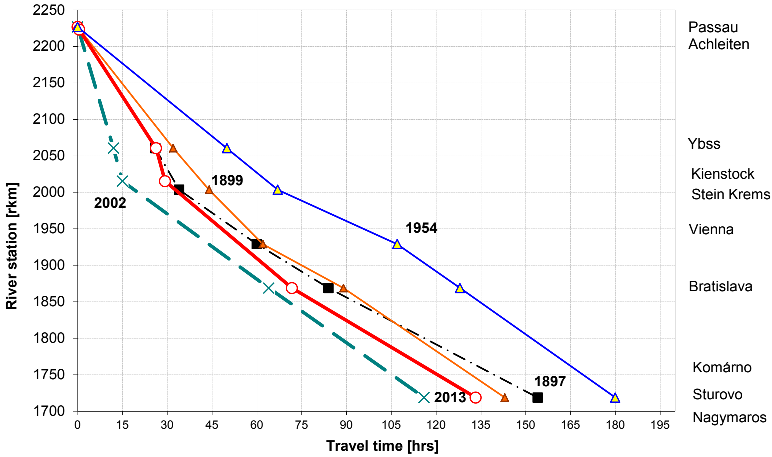

Fig. 3 Travel times of selected floods in 1897–2013.

Blöschl et al. (2013) analysed the meteorological and hydrological characteristics of the June 2013 flood, compared to the 2002, 1954 and 1899 floods, and discussed the implications for the hydrological research and flood risk management. Konecsny and Nagy (2013) prepared a hydrological analysis of the June 2013 flood on the Danube along the Hungarian reach.
In the future, it is necessary to adapt the forecasting methods to the recent conditions in the basin taking into account the continuously changing conditions of flood wave propagation on Danube. At the same time it is necessary to find the mathematical expression of the graphical relations in order to develop mathematical models of the travel times.

3. Conclusions

Channel training resulted in shortening of the floodwave travel times. This fact was indicated by several authors, e.g. Hajtasova et al. (1995), Zsuffa (1999). Hajtasova indicated that the travel times on the upper part of Danube decreased by 25-30%. Zsuffa analysed the daily water stages before and after 1976 concluding the increase of small and middle floods. It may happen due to channel training of the upper Danube, which changed the superposition of floods on main stream and tributaries.
The volume of transported suspended and bed load gradually decreased in the middle reach of Danube due to construction of the reservoirs on German and Austrian reach. The deepening of the channel below Devin (Slovakia) and the consecutive fall of the groundwater level resulted

in unfavourable conditions. The gravel excavation below Bratislava was stopped after 1980. The new Danube dam near Cunovo increased the Danube water level at Bratislava after November 1992. Decrease of flow velocities and stream turbulence caused the sedimentation of bed load (originally transported by the stream into lower profiles) in Danube channel in Bratislava. According to Opatovska (2002) it caused the expected planned sedimentation and channel bottom rouse and increase of the water level in Bratislava. According to our analysis, the average difference of peak water level of the floods in 2013 and 1899 at selected stations was about 100 cm, and of peak water level of the floods in 2013 and 1954 was about 70 cm. This increase could be attributed to the riverbed silting.
The changes that have occurred and are still occurring in the Danube Basin will require modification of the forecasting methods for station Danube: Bratislava used in operational service. In this respect the Institute of Hydrology SAS especially in cooperation with the Slovak Hydrometeorological Institute has developed several projects. Comparative flood analysis studies are an essential basis for developing more efficient strategies for integrated flood risk management. In forecasting such disastrous floods with a reasonable lead time, the travel times in all relevant sections of the Danube would play a vital role in any of the forecasting methodologies.

Acknowledgements
This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0015-10 and MVTS project Flood regime of rivers in the Danube River basin. This publication is the result of the project implementation ITMS 26240120004 Centre of excellence for integrated flood protection of land supported by the Research & Development Operational Programme funded by the ERDF.

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St. Magdalena flood July 1342

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Introduction

The probably most catastrophic flood in the middle of Europe since the year 1000 AD, perhaps even the year 700 AD has been the so-called "St. Magdalena flood" (or St. Mary Magdalene's flood) in July 1342. There are about 100 written documents about this event. There also exist flood marks and topographic traces like erosion-gullies in the surface (max. depth about 14 m) and soil which had been washed down from the hills to the bottom (e.g.in the Spessart). Until now there has been no study making a real critical inter-disciplinarian analysis (historians, meteorologists, hydrologists, geomorphologists, geographers) of the original sources including the morphological traces and summarizing the results. Research has still to be continued.

1. The Flood, the Morphological Traces and the Climate

The above mentioned material allows answers and comments to following points:

1.1 The weather before the flood

There was a long and cold winter with a winter flood in February, and then it was cool and rainy until the beginning of July. Than there has been a very short hot period which made the surface of the soil dusty and crusty. Due to the long and wet period before the catastrophic flood there had surely been a high base flow in the water courses.

1.2 The regions and rivers which had been affected by the flood

The areas of today's Germany (Fig.1 shows the most affected rivers), Austria (especially Carinthia), Switzerland, the northern part of Italy, the Netherlands (only by river Rhine or also by rain?) and in France the central and eastern regions and the Provence.

1.3 The maximum water levels and the dating of them (Julian Calendar)

There are water marks (photos available) in Hannoversch-Münden/Weser (21 or 24 July) and Limburg/Lahn (25 July), also exactly reconstructed water levels in Würzburg/Main (21 July), Frankfurt/ Main ("Eiserner Steg"/22-24 July) and in Basel ("the Fish Market and Grain Market, including the two fountains", were flooded - 29 July). Reports about approximate levels exist from Mainz ("up to the belt of a man in the cathedral", but where did he stand?), from Cologne (24 - 25 July) "one could go by boat over the city's fortifications" (only those along the river?)", from Zurich ("the water level of the lake even reached up to the steps of the Fraumünster Church" - no dating). In Avignon one could go by boat in the city (no dating).
In Würzburg it had been possible to transfer the levels of all watermarks into discharge [3].

1.4 The peak levels of 1342 compared with the other ones in flood history

In Würzburg, Frankfurt, Limburg/Lahn and Hannoversch-Münden (also in Mainz and Cologne) it is the biggest flood in flood history together with an extraordinary fact: All the other big floods are winter floods **<u>and just the biggest one is a summer flood!</u>** In Basel it is a "catastrophic" flood among the biggest ones.

1.5 Period and intensity of the rainfall

The rain began on 19 July in the middle of Germany (about the region Limburg - Frankfurt - Würzburg - Hannoversch-Münden - Dresden - Prague) and it has than extended. It lasted about one week (until 25/26 July?). No information could be found about the south of Germany, Austria (Carinthia), the north of Italy and from France. If one compares the dates of the peaks - between

19 July and about 24 July in the middle of Germany - and 29 July in Basel it seems that it **had not been everywhere** the same week. Question: Had it been been only a single event or had there been perhaps a chain of (two?) closely connecting events?
There are two similar reports which describe the intensity of the rainfall very drastically. One is from Würzburg and the other is from the monastry Loccum near Hannover: There was a "two days cloud burst which initiated a deluge. It seemed that the water came from everywhere, even from the peaks of the mountains and out from the soil and it covered areas where it was not usual".

1.6 The damages caused by the flood

Direct damages: Every bridge, many "houses and towers", whole villages and nearly all the mills (for grinding cereals, situated at the smaller water courses) had been destroyed. Thousands or even ten thousands lost their lives. The agricultural damages caused a big crop failure and a famine. Large areas had been damaged so severely that an agricultural use was no more possible, e.g. the whole area of the "Spessart".

1.7 The morphological traces of the flood

Many erosion gullies in the soil (down to 14 m depth) prove that there had been a very intensive surface flow. Dating (e.g. by 14C) proves that they had been formed in the middle of the 14th century (e.g. Fig.2). Such erosion-gullies are distributed in a large area which begins in the west near Stuttgart and around Limburg. Many gullies are in the Upper Main area and between the rivers Weser (Werra) and Elbe. In the north the area goes until Berlin.
In hilly areas - mostly in agricultural use - the very intensive surface flow had washed away huge quantities of soil partly totally and partly downhill to the bottom of the slopes. At the bottom the material accumulated as it happened e.g. in the Spessart. It is now a famous wooden region because after the flood there was not enough soil for agricuture.

1.8 The Period between 1310 and 1353 and the climate in Europe

The years between 1310 and 1350 had been very rainy in Europe. Wet summers and floods caused in the years 1315 - 1318 bad harvests and a catastrophic famine known as the "Great Famine". During the years 1347 - 1353 the "Black Death" (Great Pestilence) was peaking in Europe. About one third of the population of Europe died by this terrible disease.
The years after about 1310 became cooler and cooler with harsher winters , shorter vegetation periods and reduced harvests. Agriculture had to withdraw to lower areas, viticulture had to withdraw to more southern regions. Fig. 3 shows the up and down of temperature (climate) since the last (Würm-) ice age. One can see that at the beginning of the 14th century the "Medieaval Optimum" ended and was changing into the "Little Ice Age" which ended in about 1865. Checking the floods since about the year 900 one can get the impression that there are more summer floods in the "Optimum-periods".

2. What about Precipitation and Weather

There is a study which tries to analyse the possible precipitation for the catchment area of the river Main (about 20000 km^2) for the flood 1342 [1]: Estimations of the maximum possible 24hour precipitation for an area of 25 km^2 are about 360 - 400 mm, for an area of 1000 km^2 are about 300 - 320 mm and for an area of 20000 km^2 are about 260 mm. For a time of 48 hours the figures are about 10% more.
But the historic reports, the flood marks and the morphological traces prove that the area of intense rainfall had been essentially larger. Yet it is not known if the very intense rainfall had been exactly within the same two days at every place of the large area. Could it have been that two or

even more zones of very heavy rain had been moving around? The total duration of the rainfall had been according to the reports about one week, but possibly not everywhere the same week. Which of the until now observed meteorological/climatic weather systems could have caused such a huge downpour in such a large area? There are only the most important systems:
Big floods in summer are mostly caused by a "van Bebber Vb" cyclone. The genesis of such a (sub-) tropical Mediterranean cyclone is shown in Fig. 4. Such a low can be formed everywhere in the Mediterranean Sea. If it is in the western part it causes heavy flooding in France as it had been probably also in 1342. If it is more in the eastern part it causes such heavy flooding as it has been in Serbia, Bosnia and Croatia in May of this year 2014. In July 1342 it seems that there had been perhaps two or more huge van Bebber Vb cyclones closely one after another
And last but not least: In the background could have been the jetstream (Fig.5). A jet stream loop can also cause or increase extreme weather conditions [2]. There is a discussion how far a jetstream loop has been the reason that storm after storm has rolled across UK in January/ February 2014 causing the heaviest flooding since about 250 years.

Résumé from these until now observed most important weather systems: Nature has a powerful toolbox of possibilities to produce heavy, plentiful and long lasting downpours.

3. Conclusion, proposal to prepare against such a flood nowadays.

St. Magdalena flood July 1342 had been an extremely big disaster which had affected a very large area in Europe.
Now a horror scenario: What will happen if nowadays such a flood affects the densely populated countries in such a large area? Cities, towns and many other settlements, industrial and municipal plants, roads, railways, bridges, barrages, reservoirs, weirs, flood protection works etc. will be highly endangered. I propose to make a study in cooperation of meteorologists and hydrologists about the precipitation, the discharges and the endangered area of such an event. In Germany: German Weather Service together with the hydrological services (BfG and Länder) and also specialised universities. The next step is to check the safety of the (above mentioned) endangered objects. A further step should be to prepare the services responsible for risk prevention and disaster control for such a horror scenario.

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Sources of the Figures:

Fig.1: First Draft of this Fig: Bork H.R.: Landschaften der Erde unter dem Einfluss des Menschen. Darmstadt 2006, p. 120. (Map: Bundesamt für Kartographie und Geodäsie, Frankfurt am Main).
Fig.2: The Wolfsschlucht near Pritzenhagen/Oberbarnim, Brandenburg(Foto: Lienhard Schulz, Lizenz: CC-BY-SA, Source: Wikimedia Commons).
Fig.3: from Schönwiese, C.: Klimaänderungen (1995).
Fig.4: Pattern of a "van Bebber Vb" cyclogenesis. (from http://undine.bafg.de).
Fig.5: Jetstream. Credit: NASA/Goddard Space Flight Center.

Fig.1: Affected Rivers by the flood in 1342 (dotted rivers: no reports, but without them there could not have been a big flood in Regensburg, Passau and Basel.)

Fig.2: The Wolfsschlucht near Pritzenhagen/ Oberbarnim/Brandenburg

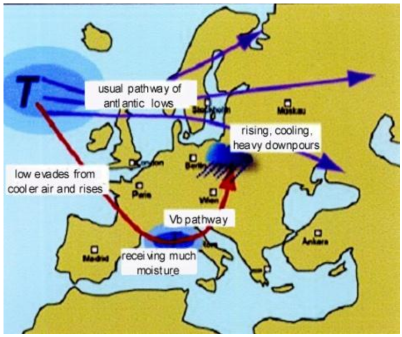

Fig. 4 : Genesis of a van Bebber Vb track.
A mediterranean tropical cyclone can be formed at any place of the Mediterranean Sea Sea and also with variations (e.g. medicane).

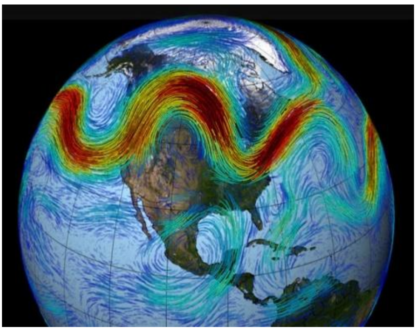

Fig 5: Highly idealised computerized view of the polar jetstream on the northern hemisphere with its meanders.

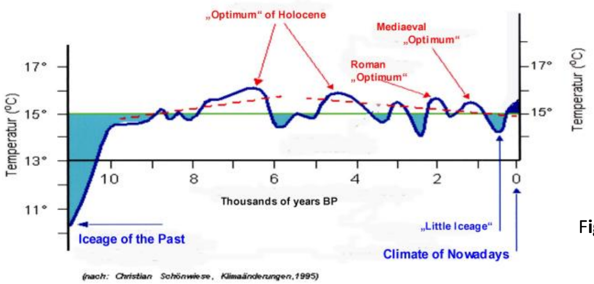

Fig. 3: Climate from the last (Würm-) Iceage until 1995

Extrapolation of Flood Volumes by using the Method HMxQ

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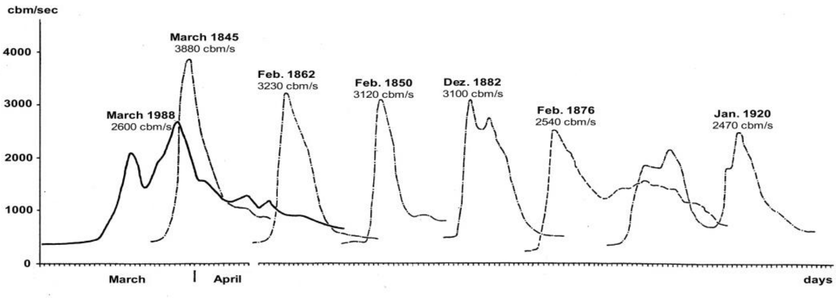
Introduction

The methods of extrapolating flood peaks – based on the maximum annual flood peaks of an observation period – are very well known. The methods of low flow statistics – using the smallest daily means NMxQ of x days (e.g. x = 1, 2, 7, 14, 30, 60 connecting days of one period within every year of the observation period) are also well known [1] . In order to extrapolate flood volumes one has to take only the **biggest daily means HMxQ** in the same manner.
The method will be shortly shown by an elaborated example.

1. Extrapolation of flood volumes at the station Regensburg/Danube

(Since 1924 Regensburg-Schwabelweis, 35399 km^2 , Mean Annual Flood MHQ = 1540 cbm/s)
The available values for this paper had been the annual flood peaks for the period 1845 - 1988, the computerized daily means for the period 1924 - 1988 and the peaks and daily means of the biggest floods - see the flood hydrographs in the following **Fig.1:**



1.1 Extreme Value Analysis

The first step is to calculate the biggest means HMxQ of x = 1,2,3, etc. connecting days for these hydrographs. These means can be transformed into graphs (Fig.2) beginning with the peak, then the biggest one-day mean, two-day mean etc. These graphs are helpful if one wants to get practical results out from the theoretical results.
The second step is to calculate the annual HMxQ (the biggest means for x=1 and then 2, 7, 14, 30 and 60 connecting days) for every single year of the computerized observation period 1924 - 1988.
The third step is the extreme value analysis (Fig.3).
There are the annual peaks of the period 1845 - 1988, the calculated annual HMxQ for the period 1924 - 1988 and then the HMxQ of the big floods (Fig.2) in order to get a partial duration series HMxQ for the period 1845 - 1988. In addition to the annual flood peaks 1845 - 1988 there are 5 families of the annual values HMxQ 1924 - 1988 and 4 families of the partial duration series HMxQ 1845 - 1988 for making a combined (graphical) extreme value analysis HMxQ for the period 1845 - 1988 - see Fig.3.

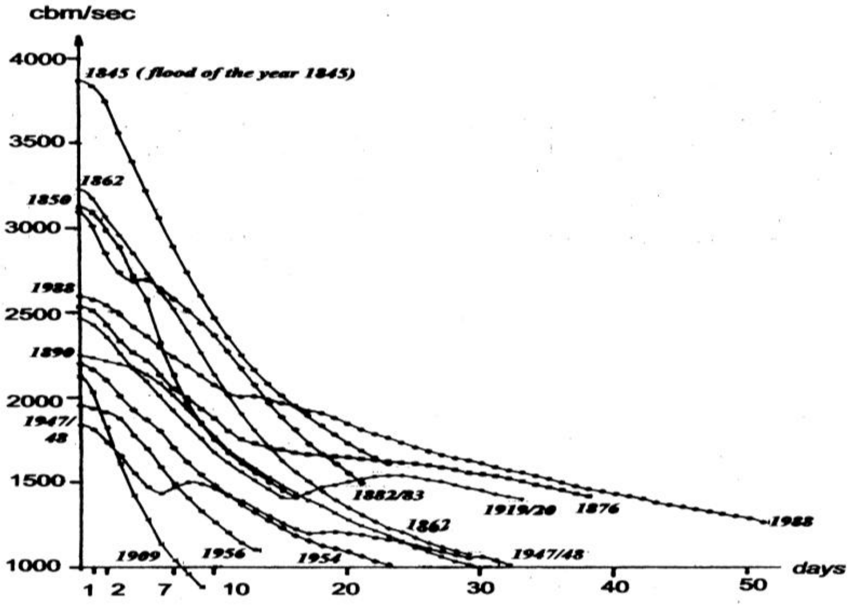


Fig. 2: Graphs HMxQ (x= 1,2,3, etc. connecting days) for the floods of Fig. 1 and other big floods

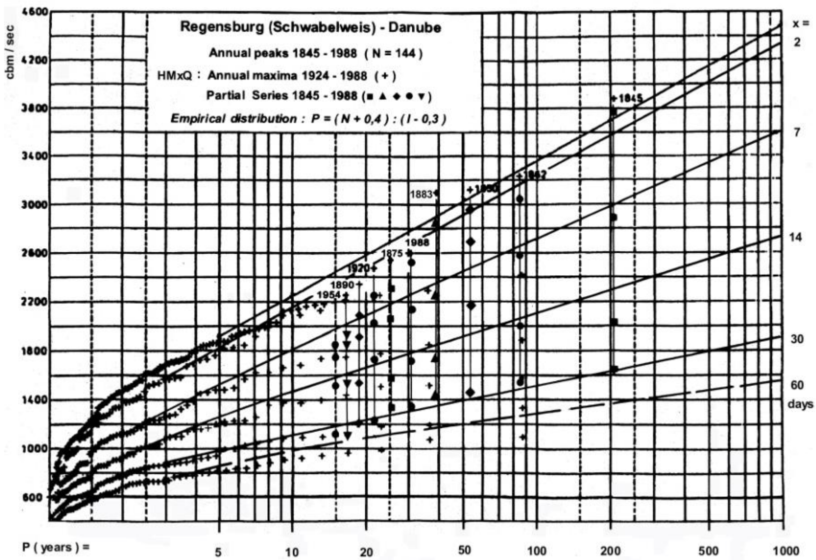


Fig.3: Combined Floodpeak and HMxQ Extreme Value Analysis

2. Results

The results (Probability of HMxQ) are in the following table 1 (only a part can be shown here).

(Catchment Area :35399 km², Mean Annual Flood MHQ = 1540 cbm/s)

Prob.	5	10	20	50	100	200	500	1000	Years
Peak	1900	2250	2600	3050	3400	3700	4100	4500	cbm/sec
	1,23	1,46	1,69	1,98	2,21	2,4	2,66	2,92	Q/MHQ
HM7Q	1530	1800	2100	2450	2700	3000	3300	3600	cbm/sec
	0,99	1,17	1,36	1,59	1,75	1,95	1,95	2,34	Q/MHQ
	925	1089	1270	1482	1633	1814	1996	2177	hm^3
	26,1	30,8	35,9	41,9	46,1	51,3	56,4	61,5	mm
HM30Q	1000	1130	1250	1400	1550	1650	1800	1900	cbm/sec
	0,65	0,73	0,81	0,91	1,01	1,07	1,17	1,23	Q/MHQ
	2592	2929	3240	3629	4018	4277	4666	4925	hm^3
	73,2	82,7	91,5	102,5	113,5	120,8	131,8	139,1	mm
HM60Q	870	980	1100	1200	1300	1400	1480	1560	cbm/sec
	0,56	0,64	0,71	0,78	0,84	0,91	0,96	1,01	Q/MHQ
	4510	5080	5702	6221	6739	7258	7672	8087	hm^3
	127,4	143,5	161,1	175,7	190,4	205	216,7	228,4	mm

The ratios Q/MHQ (Mean Annual Flood) are added to the discharges Q and the volumes are additionally transferred into mm (runoff from the catchment area) in order to make the values comparable to other stations.

The graphical representation of the results makes it possible to develop design floods by making combinations of the graphs.

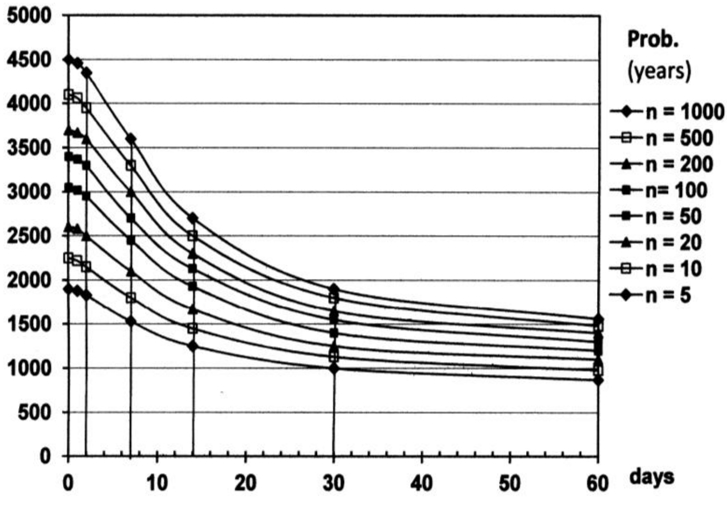


Fig.4: Probabilities of HMxQ

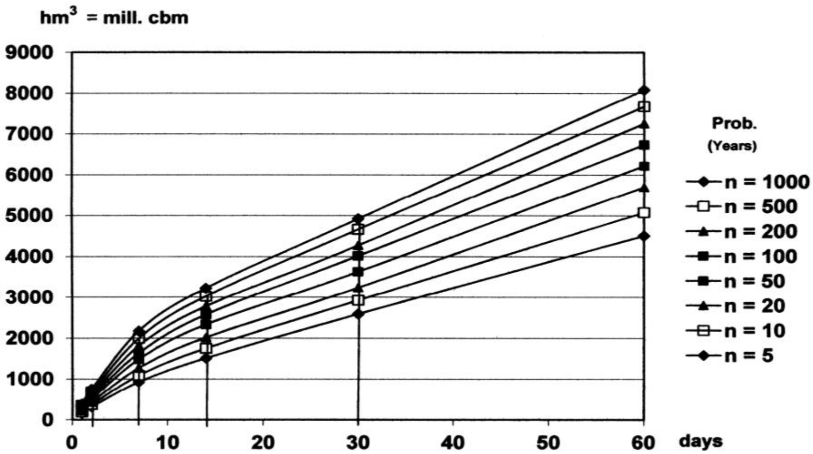


Fig.5: Probabilities of Volumes HMxQ

And finally the probabilities HMxQ of Fig.4 will be represented together with the hydrographs HMxQ of Fig.2 within one graph - see Fig. 6. This combination makes it possible to develop graphs HMxQ of various probabilities and similar to recorded big floods. In order to transform these graphs HMxQ backwards into flood hydrographs it is at first necessary to construct the ascending part below the peak similar to recorded big floods. By this way one can get the hydrographs of design floods for various purposes.

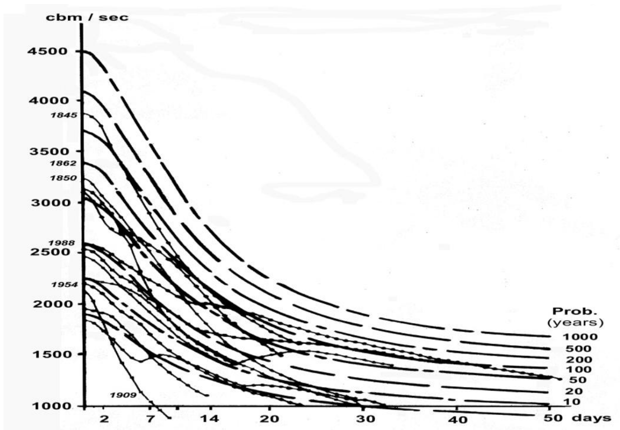


Fig. 6: Probabilities of HMxQ together with the graphs HMxQ of the big floods

References:

[1] DVWK-Regeln Niedrigwasseranalyse No 120 (1983) and No 121 (1992).

Lessons learned from disastrous floods: the case of Tecuci City (Romania)

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Abstract/Introduction

Learning from catastrophic flood events is a fundamental starting point for understanding future flood risk and for taking appropriate measures in order to mitigate this risk (Chorynski et al., 2012). The lessons derived from the catastrophic floods that affected Romania in the early '70s (1970, 1972) and in 2005 - 2006 led to the enforcement of new policies and strategies in the field of water and flood risk management. However, the flood-related damages recorded in recent years have shown that there still is a lot to be learned, especially at regional and local scales.

This paper presents the disastrous flash-flood that hit Tecuci City in September 2007, the main lessons learned from this event and the actions that were or should be taken in order to mitigate the flood risk in this city.

1. Study area, data and methods

The study focuses on Tecuci City (about 43,000 inhabitants), which is located in eastern Romania (in the north-eastern extremity of the Romanian Plain) (Fig. 1a), at the confluence of Bârlad (L = 207 km; A = 7220 km^2) and Tecucel rivers (L = 24 km; A = 112 km^2) (Fig.1b); the altitude ranges from 30 to 60 m a.s.l. The Rateş channel (L = 13 km) was achieved in 1980 along a tributary of Bârlad River, east from the built city area, as a safety measure against floods. This channel regulates Bârlad River's flow, through derivation, especially during high discharges. Almost 1/3 of the city area (and about 2/3 of its built perimeter) is located in the Bârlad River floodplain, which highly exposes it to flooding. In the past, local flooding events have mainly been caused by the Bârlad River overflowing. While its average multiannual discharge is of 8.33 m^3/s (between 1950 and 2007, at Tecuci gauging station, controlling 97% of the total catchment area and 92% of the river's length), the maximum discharges recorded during the largest floods have exceeded 300 m^3/s. Such events took place in 1972 (331 m^3/s), 1973 (322 m^3/s), 2003 (460 m^3/s) and 2004 (579 m^3/s), and caused significant flooding and damages in Tecuci City. Following the events of the '70s, major engineering works were implemented on the Bârlad River: channel regularisation, embankment on both banks (Fig. 1b), water derivation in the Rateș channel (with an average multiannual discharge of 4.32 m^3/s between 1984 and 2007, and a maximum flow capacity of 350 m^3/s).

Tecucel River has a very low multiannual discharge (0.15 m^3/s, during the 1950 – 2007 period). Annual flood peaks have a large variability: between 1968 and 2007, they ranged from 0.230 m^3/s (in 1994) to 183 m^3/s (in 2007). The highest flood peaks were recorded in 1971 (122 m^3/s), 2005 (99.4 m^3/s), 2006 (98.8 m^3/s) and 2007 (183 m^3/s). As until 2007 it hadn't caused considerable flooding in Tecuci city, no embankment operations were attempted, except for the inferior sector where, on the upstream left bank, a 500 m-long levee was built (Zaharia *et al.*, 2009).

Economically, the city is important due to its role of transport ways junction (railways and roads), as well as to industrial, agricultural and commercial activities, most of which of local importance.

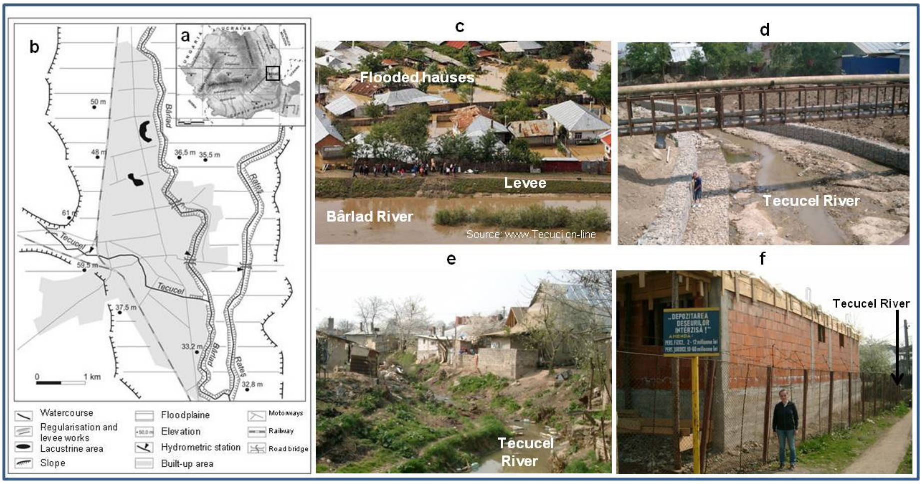

Fig. 1. Study area location in Romania (a). Tecuci city area and the main engineering works (b). Houses flooded in September 2007, behind the levee on the right side of the Bârlad River (c). Engineering works on Tecucel River in August 2009 (d). Buildings close to Tecucel River channel (e). New house adapted to the flood risk (with an elevated foundation) and a billboard for banning the waste storage on the river bank (f).

The study is mainly based on hydrologic and fieldwork-generated data. The hydrologic data comprise average, maximum and minimum monthly and annual discharges recorded at 3 gauging stations located on the Bârlad and Tecucel rivers, and on the Rateş channel, and hourly discharges of the 3 watercourses recorded during the September 2007 flash-flood. The data were provided by the "Romanian Waters" National Administration– Water DirectoratePrut. The field investigations were performed in many campaigns, between September 2007 and May 2014, which included observations and questioning of city residents affected by the September 2007 flood. The main method was the statistical analysis of hydrologic data and survey answers.

2. The flood event of September 2007 and its disastrous consequences

In September 2007, Tecuci City was severely affected by a flood with significant social and economic damages. It originated from an exceptional rainfall event for this region: in the afternoon of September 5th, in the central part of Bârlad catchment and in the upper sector of Tecucel catchment, rainfall amounts exceeded 100 mm in 3 hours, while the 24 hour total precipitation exceeded 200 mm (almost 40% of the region's annual rainfall amount) (Zaharia et al., 2008). As a result, a flash-flood occurred on Tecucel River, with a 6 hour rising time and a total duration of 26 hours. Between 3:00 p.m. and 9:00 p.m. on September 5th, the discharge increased from 0.54 to 183 m^3/s. This was the highest discharge recorded on Tecucel River, since 1968 (when Tecuci gauging station was installed), with a return period of 500 years (Zaharia et al., 2009). The September 5th heavy rainfall also generated flash-floods on the other 2 rivers in the Tecuci City area, as well: Bârlad's discharge has grown in 20 hours from 1.40 m^3/s to 245 m^3/s, and that of the Rateş channel, through an important water volume of Bârlad River was derived, increased from 0.09 m^3/s to 326 m^3/s in 22 hours. While the Tecucel River flash-flood was the main cause of the Tecuci City flooding, its expansion and consequences were amplified by local factors, including morphological features (specific for a floodplain) and the dam role that the transport infrastructure and the levee on Bârlad's right bank played. Tecucel River's flow was therefore blocked at the entrance in Tecuci City by the undersized road and railway bridges and by the embankment-structure for railway elevating; the water subsequently

overflowed these "barriers" and flowed through the city, heading, according the slope, towards the Bârlad River, and accumulated in a layer of over 2 m behind the levee along Bârlad's right bank (Fig. 1c) (Zaharia et al., 2009). As the flooding affected approximately 70% of the built city area (with water layer thickness exceeding 1 m), the consequences were disastrous: 3 fatalities, 2210 houses were damaged (of which 392 were completely destroyed, and 425 suffered serious structural damage), and the city's infrastructure was gravely deteriorated. The total cost of the damage amounted to approximately 6 million euro (Zaharia et al., 2008).

3. Learned lessons and measures already adopted or necessary for flood risk mitigation

In the case of Tecuci City, the most important lessons learned from the disastrous September 2007 flash-flood were:

1. Small and apparently harmless water courses (such as Tecucel River) may generate catastrophic damages, in the context of favorable circumstances (natural and anthropogenic). As a consequence, since 2008, engineering and maintenance works were set up on Tecucel River (re-calibration and dredging works, levees, bank protection and consolidation, vegetation clearing) (Fig. 1d).
2. Not only natural hazards are responsible for flooding and its consequences, but an important role can also be played by the human factor: in this case, mainly by the transport infrastructure built in an embankment-like manner, undersized bridges, the inadequate maintenance of river channels (the watercourses, especially the Tecucel River, were used for the riverine population as a garbage deposit), buildings located in the immediate vicinity of the Tecucel's channel (Fig. 1e), sewerage system dysfunctions, etc. After 2008, some measures were taken, such as: riverbed vegetation and waste clearing, banning waste storage on river banks and riverbeds (Fig. 1f), razing certain buildings located very close to Tecucel River (which obstructed the river flow).
3. The levees cannot always guarantee protection against flooding, but, on the contrary, can become one of their causes and can aggravate the damage. In order to avoid such situations, engineering techniques allowing a faster drainage of the water which is blocked by levees should be envisaged (e.g. spillways, drainage systems).
4. For the improvement of flood risk management in Tecuci City, special attention should be paid also to non-structural measures. In this respect, we deem it necessary to:

- Appropriate information and training of the population with regard to flood risk. The May 2014 survey (when 101 persons were interviewed) revealed that 59% of respondents have considered they were insufficiently trained and informed about the flood risk, and expressed their desire to know more in this respect. As opposed to an August 2009 survey (totalling 163 respondents), an increase in population informing and training levels can be noticed, as the 2009 share was of 92% (Zaharia et al., 2009). This rising was partly due to local information campaigns. Thus, at the end of May 2013, the Tecuci City Hall completed the *Analysis and Risk Coverage Plan in Tecuci City)*, which comprised potential risks locally identified (out of which flooding is representative), as well as the measures, actions and resources needed for properly managing these risks (Tecuci City Hall, 2013). This information is available online on the City Hall's website. Moreover, several public disaster alarm exercises were scheduled in Tecuci.

- The buildings located in flood prone areas must to be structurally adapted (elevated building). The houses that were rebuilt after the September 2007 flood have high foundations, sometimes exceeding 1 m (Fig. 1f).
- Insurance policies need. After the September 2007 flooding experience, the percentage of residents with life and asset protection insurances increased from 19% (in 2009) to 31% (in 2014). It is however noteworthy that a large share of the population (69%) is not covered by any type of insurance, which is mainly due to the lack of trust in the insurance system, and the dissatisfaction with the compensation fees (only 22% of respondents insured before 2007 were satisfied with the compensation, 36% were dissatisfied, and 42% were partially satisfied).
- Necessity for improving the organizing and activity of institutions responsible for flood risk management, from national to local scale. Although significant progress has been made, a higher efficiency of these institutions' activity is required.

4. Conclusion

Learning from past catastrophic floods is an important factor in building the social capacity for these natural hazards (Komac et al., 2010). In the case of Tecuci City, the lessons learned from the September 2007 disastrous flood led to the implementation of a series of both structural and non-structural local measures, for a better adaptation of the community to similar future events. Although in the meantime significant improvements have been made in the field of flood risk management, many measures must be translated from theory to practice when switching from national to local scale.

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The Flood on Slovak part of the Danube River in June 2013

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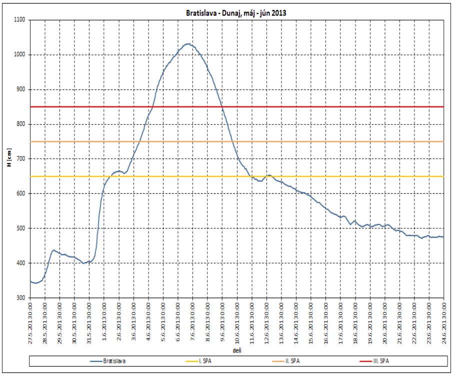
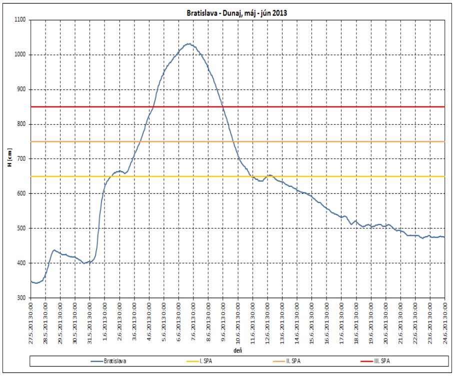
Abstract/Introduction
The flood represents an extreme phenomenon of hydrological regime, which can cause the damage in the natural environment. The origin and the character of floods are a subject of the climatic conditions; they are the result of the atmospheric processes in a certain geographic environment. Therefore it is necessary to observe and evaluate the flood situations, so that on the basis of the knowledge of them or by analysis of certain flood events, the measures can be taken to help the situations to be foreseen or at least to mitigate the negative consequences of it. This is as well the goal of this paper about assessment of the genesis and evolution of the flood on the Danube River in June 2013 and its place in flood history at Slovak reach of the Danube River.

1. Meteorological and hydrological development of flood
At the end of May 2013 an emergency flood situation on the Danube started to develop. The weather was under the influence of low pressure alternately over the German part of the Danube river basin, southwestern Poland and Slovakia.. Flood situation caused by extremely high precipitation in the upper basin of the Danube River in Germany and in the Inn basin began on 29.5 2013. It was caused by heavy precipitation nearly evenly distributed across the basin. The biggest amount of precipitation felt in Bavaria on average 120 mm, in the catchments of the Inn river and the Salzach river 150 mm, in the catchment of the Traun, the Enns and the Ybbs 120 mm and in the Danube catchment under the Ybbs down to the March/ 60 mm

Rainfall activity resulted into a flood of exceptional historic significance. Water level on Slovak territory in the profile Devin began to increase on 31.5. in the morning from water level corresponding to the average annual flow and we have seen a significant increase of 280 cm in 24 hours. Rainfall in Germany temporarily ceased, water level was stabilized, but the next day (2.6. 2013) it rose again. Flood wave reached a culmination in Devin on 6.6. 2013 at 3:15 p.m. on level 974 cm and in Bratislava about two hours later on level 1034 cm Such a water level was not reached in Bratislava since 1889. The total wave height in Devin was 632 cm. Flood wave progressed throughout the Slovak section of the Danube to Štúrovo, and the middle and lower sections also achieved record water levels, the level corresponding to the 3rd flood activity degree was exceeded in all profiles. Culmination occurred gradually over the coming days, namely 7.6. in Gabčikovo and Medveďov, 8.6. in Komárno and finally 9.6. at 7:00 a.m. in Štúrovo .The water levels achieved in all gauging stations broke so far measured values. The values of peak flow in Devin and in Bratislava reached 50-100 year return period, in Komárno 100- year return period and in Medveďov and Štúrovo were higher than the 100- year return period.



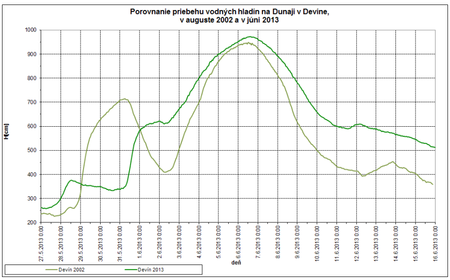
Graph1 Devín – Danube, May – June 2013



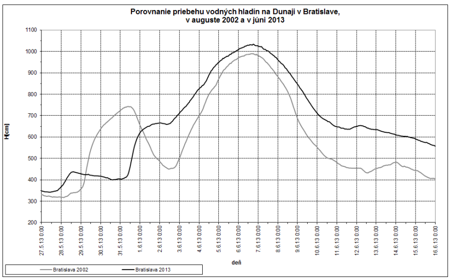
Graph 2 Bratislava – Danube, May – June 2013

High water levels of the Danube influenced also the tributaries Morava, Váh, Nitra, Hron and Ipeľ. Backwater was reaching few kilometres upstream. Water level recorded 2nd and 3rd flood activity degree in gauging stations on tributaries of the Danube. 3rd flood activity degree was exceeded on the Morava river in the station at Vysoká pri Morave 2nd flood activity degree was exceeded on the Vah river in Kolárovo and level peaked at just below 2nd flood activity degree on the river Ipeľ, station Salka,. The lower part of the river Hron was not so greatly affected by the flood situation on the Danube, which was caused by physical-geographical circumstances of the Hron valley.

Hydrological situation on the Danube in June 2013 was developing very similarly to the situation in 2002, although it was uprising from different baseline situation. In August 2002 a first lower flood wave was caused by two-day extreme rainfall, which had stopped, but after five days came back two days with significant rainfall totals of 30 to 50 mm, which led to a second, higher flood wave. The start of the wave at the end of May 2013 in Germany with the continuation in Austria was also affected by heavy rainfall. Occurrence of heavy precipitation indicated that the height of flood wave should be very similar to the wave of 2002. The travel time and height of wave increased by gradual transition passing through Austria and exceeded the historical value.



Graph 3 Devin – Danube, August 2002, June 2013



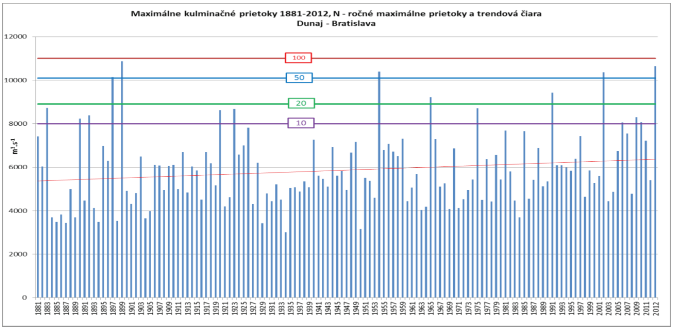
Graph 4 Bratislava – Danube, August 2002, June 2013

Flood Forecasting Service at Slovak Hydrometeorological Institute was monitoring the situation on the upper Danube and its tributaries and issued warnings against flood to the responsible Slovak authorities 5 days in advance before estimated culmination. Water managers began

preparing for the protection of Devin, Bratislava, and gradually the whole Slovak section of the Danube. Hydrological warnings for the Slovak section of the Danube were issued based on the evaluation of the development of hydrological and meteorological situation in the German and Austrian parts of the Danube basin in sufficient advance, which proved as an advantage, in connection with preparation of flood protection..
The situation was also monitored through the EFAS (European flood awareness system). EFAS forecasted possibility of significant floods on the Danube since 27.05.2013.
The first hydrological warning of level 1 for the district Bratislava was issued on Saturday, 1.6.2013 with validity from 10:30 a.m. to unlimited time. Hydrological warnings were continuously updated depending on the development of hydrological situation. Regional flood hydrological warnings were gradually issued for all districts in the Danube basin. Hydrological warnings of level 2 were issued for the entire Slovak section of the Danube already on Sunday 2.6. and hydrological warnings of level 3 on Monday 3.6.
SHMU issued total of 16 hydrological warnings in respect of the situation in the Slovak section of the Danube for the period from 1.6. to 12.6.2013., Flood forecasting service issued calculated expected heights and times of culminations since Monday 3.6. 2013. The upper section of the Danube in Germany and Austria was not culminated at that time.

2. The flood from the point of view of regime hydrology

All meaningful floods on our part of the Danube have their origin in alpine tributaries of the Bavarian and Austrian Danube.
The oldest written records about flood on the Austrian part of the Danube are from the 1012. Next known floods are in the years 1210, 1344, 1402, 1466, 1499. Parameters of these can compare with floods from 1899 and 1954. The greatest flood (for the last 600 years in Germany, Austria and Slovakia) was in august 1501. Flood marks of this flood have been preserved for instance at City Hall in Passau or Austria's Linz and Ybbse. In Linz gauging station was the flow estimated 12 000 m3.s-1 and in Vienna 14 000 m3.s-1 (Kresser, 1957).
Great floods of July 1670, of June 1682 and of November 1787 can compare to floods in years 1899, 1954, 2002. The flood that came in June 2013 is classified (as regards the culmination) to the largest flood on Danube, which were recorded after 1899.
In June 2013 in gauging station Bratislava – Donau was recorded extraordinary significant flood wave. The peak of flood flow is reached to the 100-year design flow. Parameters of this flood wave are as follows:
Date and time of peak discharge: 6.6.2013 at 16,30 (SELČ)
Peak water stage: 1 034 cm
Peak discharge: 10 641m3.s-1
T-year of peak discharge (return period): 50 – 100 years
Time of rise of discharge wave: 11 days
Time of recession of discharge wave: 39 days
Discharge wave volume (above the value of Qa): 9,884 mld m3
Total water volume (pass by discharge cross section) during flood wave: 18,609 mld m3



Graph 5 Maximum discharge peak on Danube in Bratislava, T-year maximum discharges and their trend.

Since 2000 to up to now were occurred in five years high discharge peaks of Danube River that exceed discharge value 8000 m3.s-1 (Q10), in year 2002 two (March and April), in year 2006, 2009, 2010 and 2013.

Total for the period 1901 – 2013 discharges exceeded the annual culmination Q10 value in 11 years, including 2013. Floods occurred for this period in the summer (July to September, in June four times) and only two times in winter

The flood situation on the Danube River was measured by the employees of SHMÚ (Slovak Hydrometeorological Institute) since its start in Devín on 3rd June 2013 until the passing of the flood wave through Štúrovo on 11th June 2013. The discharge has been measured by the ultrasound device ADP. During the flood on Danube in June 2013 there were made 59 direct measurements on Danube River, its tributaries and chutes. As a very positive is considered the fact that all water-gauging stations in which the discharge is evaluated by SHMÚ, resisted the blast of the flood and did perform the recording of the water stages unfailingly

3. Conclusion

Despite the significance of floods and high material damage in the German part of the Danube river basin, flood damages were only minimal on the Slovak section of the Danube thanks to new flood protection measures-mobile walls. This fact confirms the high cost effectiveness of amount incurred on flood protection comparing to possible material damages that would arise without such protection.

Due to the fact that flood protection has been built not only in our country but also in the upper basin of the Danube in Germany and Austria, and it´s expected to be built in other sections, we can expect that higher values of culmination water levels will be achieved by the same flow.

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Comparisons of spatial and temporal patterns of the June 2013 flood in the Upper Danube Basin with the 2002, 1954 and 1899 floods

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Abstract/Introduction
The four largest flood events in the Upper Danube basin in the last 150 years occurred in June 2013, August 2002, July 1954 and September 1899. Maximum flood discharges of the Danube at Vienna were about 11000 m³/s, 10300 m³/s, 9600 m³/s and 10500 m³/s, respectively. Analyses of the large-scale atmospheric conditions before the events show similar large-scale stationarity situations prior to the events in 1954, 2002 and 2013, whereas prior to the 1899 flood there was no atmospheric stationarity. The events in 1954, 2002 and 2013 were caused by two blocks of large scale precipitation; the event in 1899 was caused by a single block of large scale precipitation.

1. Spatial and temporal precipitation patterns
The flood in September 1899 followed after a very dry winter 1898/1899 with very little snow and an unusually dry summer 1899 (e.g., in Waidring near Lofer, 1899 August precipitation was 114 mm, long-term mean over previous decades was 201 mm). Hence, groundwater levels were low (Lauda, 1900) at the beginning of the event. The event precipitation was enormous, e.g., in Weißbach (Salzach catchment), 515 mm were recorded in 6 days. The spatial extent of the precipitation was exceptionally large with 48 h precipitation totals exceeding 200 mm over an area of 1000 km² (Kresser, 1957). Snow was recorded above 1400 m a.s.l. which reduced the liquid water input to the event. Most of the precipitation fell in the Inn, Salzach, Traun and Enns catchments. The contribution of the Bavarian Danube to the event was small (Lauda, 1900).
The three months before 1954 flood were wetter than the mean. A first block of precipitation during 1-2 July increased antecedent soil moisture and a second, more extreme block during 7-12 July caused the main flood event. At the northern fringe of the Alps, in Lofer, 257 mm of precipitation were recorded in the same period, with a two-day maxima (7-8 July) of 233 mm. Snow accumulated down to 800 m a.s.l. and hence did not directly contribute to flood runoff. For example, in Dienten (1200 m a.s.l., some 20 km southeast of Lofer) snow depths increased from 20 to 77 cm on 8 July and little melt occurred on the following days (HZB, 1955).
Also the August 2002 flood was caused by two blocks of precipitation. The two rainfall blocks (7 August and 11-12 August) were separated by four days. Less precipitation was recorded in the catchment of the Bavarian Danube, but significantly more over the northern tributaries to the Austrian Danube such as the Kamp. In the 620 km² Kamp catchment there were 200 and 115 mm of precipitation during the two events, respectively. The first event substantially increased the antecedent soil moisture for the second event. Air temperatures were rather high and the catchments most affected do not exceed 1000 m in elevation, so snow did not play a significant role during this event.

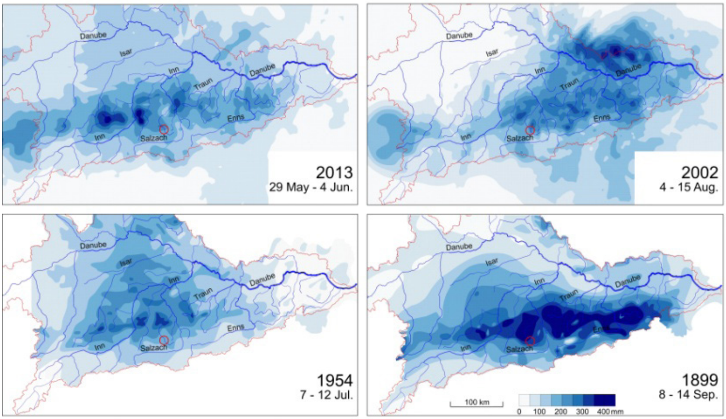

Fig. 1: Observed precipitation totals of four large flood events in the Upper Danube Basin. 2013 and 2002 are based on rain gauge data interpolated by the INCA method using radar (Haiden et al., 2011). 1954 and 1899 are based on rain gauge data interpolated manually from about 600 stations within the Danube Basin (HZB, 1955; Lauda, 1900). Red line indicates the Upper Danube catchment boundary above Wildungsmauer, red circle indicates Lofer. After Blöschl et al. (2013a)

The north of the Upper Danube Basin was particularly wet at the end of May 2013. At the station Lofer, 209 mm of precipitation were recorded in May 2013 as compared to the long-term May mean of 140 mm (period 1976-2011). Lower than average air temperatures resulted in low evaporation rates, which resulted in high soil moisture values throughout the catchment. Heavy precipitation started on 29 May in the northern part of the Bavarian Danube catchment around the city of Regensburg, where a precipitation total of 95 mm was observed from 29 May to 4 June. Further south, precipitation started on 30 May and lasted until 2 June 2013, with smaller intensities on 3 and 4 June. For example, from 29 May to 4 June a precipitation total of 232 mm was observed in Lofer. Precipitation was highest along the northern ridge of the Alps in Austria (Tirol, Salzburg and Upper Austria). Precipitation interpolated between the rain gauges based on weather radar exceeded 300 mm during this time period, however, snowfall at high altitudes reduced the runoff volume produced.

Figure 1 shows the observed precipitation totals leading to the four flood events. The 1899 and 1954 precipitation totals are based on daily records (07:00 to 07:00), the 2002 and 2013 are based on hourly records.

2. Temporal runoff patterns

The flood in 1899 occurred after a long period with little precipitation indicating that the soils were dry. However, the maximum flood peak in September 1899 was almost as high as in June 2013 due to precipitation values exceeding 500 mm in 7 days in large parts of the Danube catchment. Similarly to the 2013 flood, the flood events in 2002 and 1954 were caused by two blocks of precipitation separated by a few hours or days, respectively. The first block of precipitation caused saturation of the soil moisture and a smaller flood wave, whereas the second precipitation block caused the main flood wave. Figure 2 shows the runoff hydrographs of the Danube at Vienna for the four events.

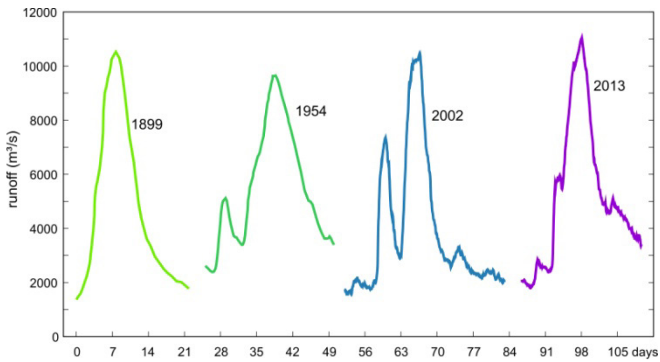

Fig. 2: Runoff hydrographs of the Danube at Vienna (101.500 km²) for the 1899, 1954, 2002 and 2013 floods. After Blöschl et al. (2013b)

Figure 3 shows the evolution of the 2013 flood. At the Bavarian Danube, the flood response was delayed with relatively flat peaks, similar to previous floods (e.g. 2002, 1954, 1899). However, the total volume of the 2013 flood along the Bavarian Danube was large. The flood wave along the Inn built up through Bavaria, merged with the flood coming from the Salzach and produced a very steep wave at Schärding. At the confluence in Passau, the fast and slow contributions of the Inn and Bavarian Danube are clearly visible. During the propagation of the flood wave along the Austrian Danube, it changed shape due to retention in the flood plains, which is apparent by the kink of the rising limb about a day before the peak.

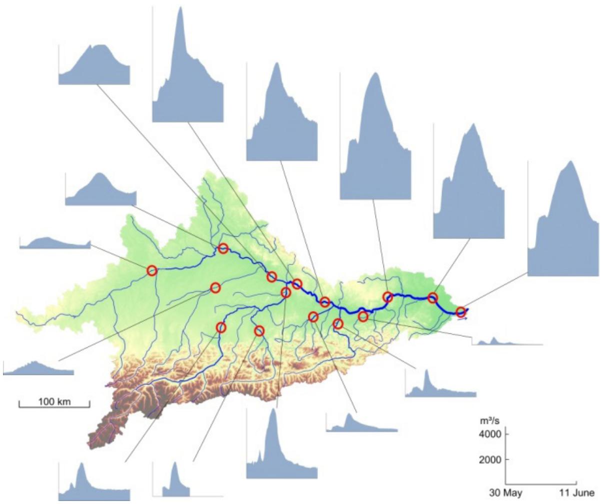

Fig. 3: Propagation of the June 2013 flood along the stream network of the Danube Basin. The scale shown on the bottom right relates to all hydrographs (light blue areas). From Blöschl et al. (2013a)

3. Conclusions

Even though the spatial distribution of precipitation, runoff generation and the spatial evolution of the four floods were different, the maximum runoff values along the Austrian Danube were quite similar.

The analysis showed that the combination of extreme factors has a high impact on the magnitude of regional floods. Indeed, in 2013 a number of characteristics contributed to increase the flood magnitude, e.g., relatively high antecedent soil moisture, little shift between the flood peaks at the confluence of the Bavarian Danube and the Inn, and rainfall blocks close together resulting in a single, large volume flood wave with relatively small peak attenuation.

While statistical analyses are important when estimating design flood discharges, particularly in large catchments with long flood records, it is equally important to address the problem from a process perspective and understand what combinations of factors could plausibly be expected to occur during extreme situations.

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Hydrological aspects of the flood in June 2013 in Bavaria

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Abstract
In the Bavarian part of the Danube catchment the flood in June 2013 led to extreme discharge and extensive inundation. The most affected rivers were the river Isar downstream from Munich, the Danube from Deggendorf to Passau and the river Inn, especially the tributaries Salzach, Saalach and Mangfall. For almost all tributaries to the Danube down to Passau – including the river Inn – and the Danube itself the flood in June 2013 was an extreme event. Fig. 1 shows the return periods for the rivers of first and second order in the German part of the Danube catchment.

1. Meteorological Conditions
Meteorological characteristics of this flood event were a wet month which led to high soil moisture content already before the event and continuous rainfall over a period of four days from 30 May to 2nd June with a short rain break during the morning of the 1st June. High rainfall quantities regarding the four-days-sums (up to 406 mm at rain gauge Aschau-Stein) occurred in an extensive area, especially in the eastern alpine part of Bavaria and the adjacent Austrian regions.

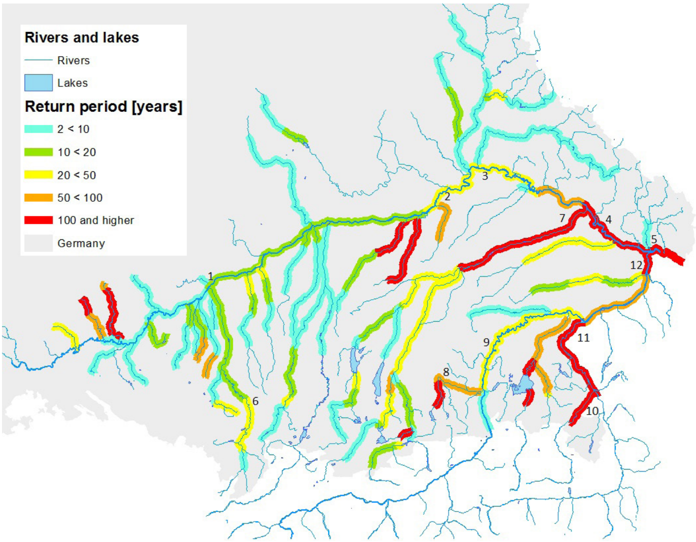

Fig. 1: Return periods of peak discharge form 30.5. – 5.6.2013

2. Evolution of the flood

2.1 Iller and Lech

The river Iller run a minor flood with peaks of 10-20 years return period and 20-50 years in the upper parts of the catchment. The peaks of the river Lech reached a return period of only 5-10 years reduced by additional retention in the lake Forggensee. The peak of the Iller reached the Danube 1 a.m. at 3rd June.

2.2 Isar

In contrast to former floods, where rainfall in the Alps dominated, this time precipitation was distributed relatively homogenous over the catchment of the river Isar and other southern tributaries. Therefore return periods were highest at the lower reach of the rivers. Here, peak discharges with return periods of 100 years were recorded at gauges of the river Isar while the upper parts south of Munich reached only return periods of 10-20 years. The peak of the Isar reached the Danube 9 p.m. at 4th June.

2.3 Inn

The flood wave of the river Inn was formed by its tributaries. Along the Bavarian section return periods rose from 2-5 years in Oberaudorf near the frontier to Tyrol to 50-100 years after the confluence with Salzach and about 100 years near Passau. Return periods of more than 100 years also occurred at the rivers Mangfall, Tiroler Achen and Alz. Especially at the river Salzach and its tributary Saalach extremely high discharges were observed with return periods of over 100 years.

Tab. 1: Peak Discharge of selected Stations corresponding to the Numbers in fig. 1

No	Station / River	Date & Time of Peak PePeak Litija	Q Peak m³/s	Return Period y
1	Neu Ulm / Danube	3rd June 0:45 a.m.	900	10
2	Kelheim / Danube	4th June 3:00 p.m.	1,800	20-50
3	Schwabelweis / Danube	4th June 4:45 p.m.	2,660	20
4	Hofkirchen / Danube	4th June 9:45 a.m.	3,500*	
5	Passau-Ilzstadt / Danube	3rd June 9:45 a.m.	10,000	> 100
6	Kempten / Iller	2nd June 7:45 a.m.	650	20-50
7	Plattling / Isar	4th June 8:30 p.m.	1,190	100
8	Feldolling / Mangfall	2nd June 7:30 p.m.	288	50-100
9	Wasserburg / Inn	2nd June 7:00 p.m.	2,300	20-50
10	Siezenheim / Saalach	2nd June 1:30 p.m.	1,100	> 100
11	Burghausen / Salzach	3rd June 4:00 a.m.	4,000	> 100
12	Passau-Ingling / Inn	3rd June 6:00 p.m.	6,800	100

* reduced by dike breach

2.4 Danube

Along the Danube the flood situation worsened continuously from return periods of about 10 years at gauge Neu Ulm near Baden-Württemberg to about 100 years from the confluence of Danube and Isar downstream to Passau. Because of the persistent rainfall the flood wave had a broader peak than in the former flood events in August 2005 or May 1999. In Passau, the peak discharge was mainly formed by the peak-discharge from the Inn, with a maximum of about 6,800 m³/s at gauge Passau Ingling on June 2nd. At the Danube a peak discharge of about 3,500 m³/s was measured two days later at gauge Hofkirchen, 30 km upstream from Passau. After the confluence of Donau and Inn a peak discharge of about 10,000 m³/s was measured on June 3rd at gauge Passau Ilzstadt, which is the highest recorded value since the historical flood mark of the 16th century. In comparison to the flood in July 1954 the peak of the river Danube and the river Inn were nearly the same but the time distance between the peaks was shorter and the river Inn hit the Danube at a higher discharge than in July 1954.

3. Water and Discharge Measurement

Water level recording worked without interruption at most stations during the event. Only the instruments of two gauges in Passau / Danube were flooded and lost their energy supply. They have to be replaced by hourly eye observations. At several stations the calibrated waterlevel-discharge curve was exceeded by the event resulting in gaps at the peak discharge. Considerable deviations in peak discharge were observed at neighbored gauges at the Salzach on the German and Austrian river banks.

4. Forecasts

The flood forecast system is based on different hydrologic forecast models covering all catchments in Bavaria. The rainfall-runoff model predominantly used is LARSIM. It is applied as an event-based flood model as well as a water balance model with soil moisture accounting (Vogelbacher, 2011). At the river Inn propagation of the flood wave is fast. Thus forecast lead-times of more than 8-12 hours for Passau depend on the precipitation forecasts with greater uncertainty especially in the areal distribution of the rain.

In the water balance model the soil storages were filled up at 1th June. The following forecasted rainfalls are transformed completely into runoff resulting in an overestimation of the discharge peaks. The models were not able to calculate the observed runoff at these extreme conditions and they have to be recalibrated with the data of this event. Blöschl et al. (2014) reported similar overestimation in the forecasts of the Austrian models in the Inn basin.

For the event-based model a runoff-coefficient has to be estimated in advance of the event. The estimated runoff-coefficient used during the event was to low resulting in an underestimation of the peaks. Simulation after the event showed good results by applying the unreduced original coefficients from calibration for the different subbasins.

The hydrodynamic model at the river Inn calculated the time of the peak as to early in comparison to the observation (fig. 2). Probably the extent of the flooded areas and the backflow of tributaries resulting in retarded flow at these extreme conditions were not included in the 1-dimensional model.

The 24h-forecasts of the Danube upstream of Passau gave good results. Even the 48h-forecasts were reliable and a good base for early warnings and the preparation of mobile protection measures.

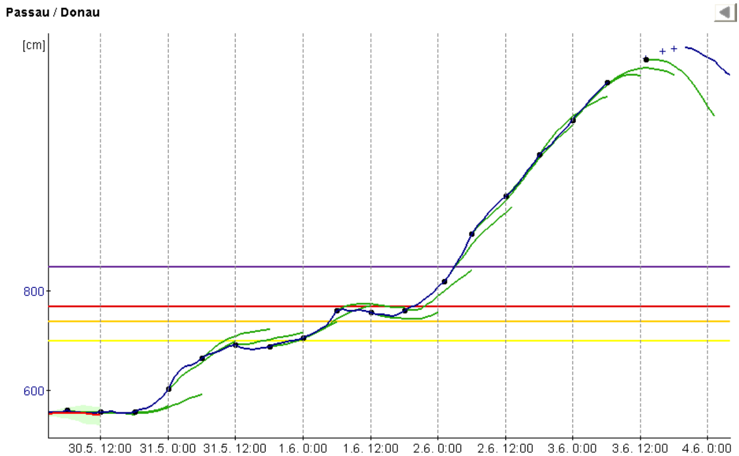

Fig. 2: 12h-forecasts for gauge Passau/Donau

5. Damages

In Bavaria the flood event caused damages of about 1.3 billion Euro. Along a lot of rivers extensive areas where flooded, at most river gauges in the Danube catchment water levels exceeded alert level 3 or the highest alert level 4, which means that some buildings or extensive build-up areas are flooded. High inundations on urban areas partly caused by dyke breaches happened for example in the surroundings of Rosenheim, Freilassing, Deggendorf and in Passau.

6. Conclusions

The exchange of flood forecasts and measured discharge as well as the communication worked well between the Hydrographic Services respectively Flood Warning Service of the different countries. Information in the internet www.hnd.bayern.de was available without interruption during the event despite the enormous number of site visits reaching 15 million a day. Improvements are possible by recalibrating the forecast-models using the data of this extreme event, including the simulation of dyke breaches, extrapolating the waterlevel-discharge curves to extreme waterlevels and providing a sufficient personal equipment at flood-warning centers.

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Analysis of flooding situations in 2013 in the territory of Central and Eastern Slovakia

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Abstract/Introduction

The beginning of the 2013 was characterized by the winter rich in precipitation. Changing of several periods of snow accumulation following by snow melting was observed. And just snow melting often accompanied by continuous precipitation resulted in January-April to several flooding situations just in the south of central and eastern parts of Slovakia. In the months May and June also precipitation from thunderstorm cloudbursts affiliated, generating numerous local flash floods especially on smaller streams. In our contribution we therefore focused on hydrometeorological analysis of flooding events in the first half of the 2013 in the central and eastern parts of Slovakia.

1. River basins of Central and Eastern Slovakia

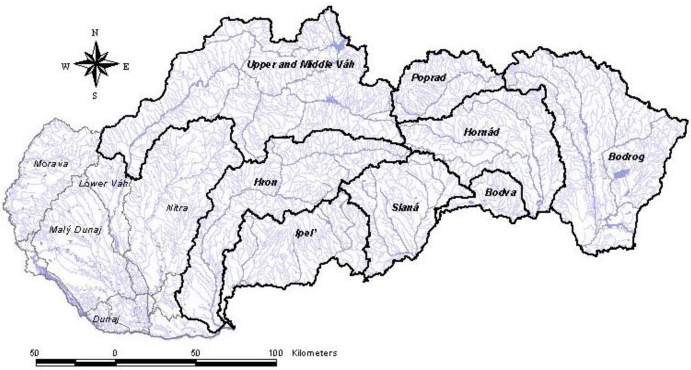


Fig. 1: River basins of Central and Eastern Slovakia

The territory of Slovakia is situated mainly on the Black Sea drainage area (about 47086 sq. km, i.e. 96 %), a small portion of the north belongs to the Baltic Sea drainage area (approx. 1950 sq. km, i.e. 4 %, the Poprad river basin). The Black Sea drainage area is represented by the Danube basin, while our country is conventionally divided into collecting area of tributaries of the Danube in the west (the Morava, Váh, Nitra, Hron and Ipeľ river basins) and the Tisza collecting area in the east (the Slaná, Bodva, Hornád and Bodrog river basins).
This study presents an analysis of flooding situations in the territory of Central and Eastern Slovakia, i.e. in the Upper and Middle Váh, Hron, Ipeľ, Slaná, Poprad, Hornád, Bodva and Bodrog river basins (Fig. 1).

2. Precipitation

In the first half of the 2013 there was high variability of precipitation in space observed. The highest rainfall amounts were recorded in the mountains in the middle of Slovakia – Low Tatras, Poľana and Slovak Ore Mountains. But in comparison with long-term mean precipitation the most affected were areas in southern parts of Slovakia – mainly in the Ipeľ, Slaná and Bodva river basins. Rainfall total for the first half year reached the value of normal annual precipitation, occasionally was also exceeded (Fig. 2).

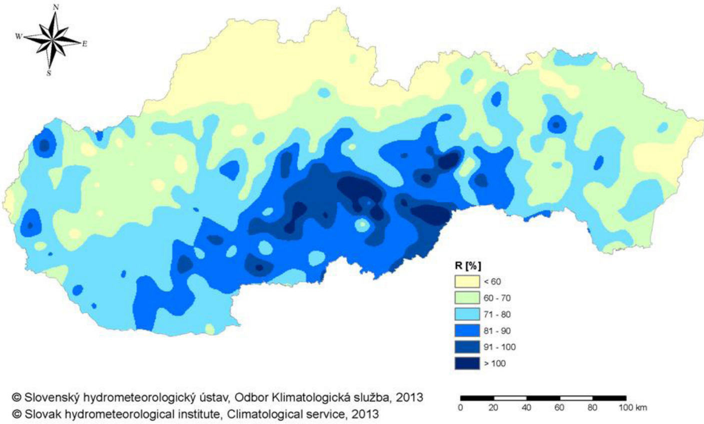


Fig. 2: Precipitation totals in the first half of 2013 expressed as % of normal annual precipitation

In January-March there was abundance of precipitation in the whole territory of Slovakia. During the cool periods the snow systematically accumulated in the snowpack. In February the highest snow water storage for the period of its evaluation was calculated in the Upper Hron, Slaná and Bodva river basins. Although changing of the cool periods accompanied by snowfall and melting periods with intense distinctive temporary warming and liquid precipitation was frequent, in early April runoff influencing snow water supply was evaluated in some Slovak river basins. April itself was classified as dry with average deficit of precipitation 36 mm, resp. 18 mm in Central, resp. Eastern Slovakia.

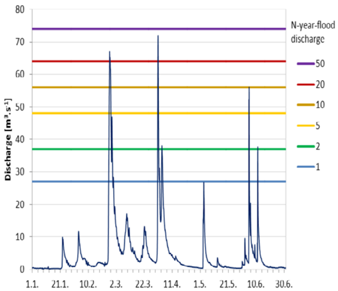
During May and Jun rainy periods caused by both multi-day frontal and intense convective precipitation were alternating with short dry periods without any precipitation. This variable weather was completed by heavy precipitation associated with storm activity on cold front in the June last decade (24th-25th).

3. Hydrological situation

As a consequence of climatological and meteorological conditions there were numerous flooding situations in the first half of the 2013 in basins of Central and Eastern Slovakia.

In winter, namely during the first three months of the 2013, the weather in our region was influenced by prevailing cyclonic situations. This brought cloudy and rainy weather. Solid precipitation accumulated in snow cover. However our region was very often lying on the boundary of different air masses. Due to temperature gradient over the territory of Slovakia and neighboring countries was very high. This synoptic situation produced intense causal precipitation.

Several floods caused by snow-melt with precipitation occurred nearly in all monitored catchments. From hydrological point of view the most significant were recorded in the Lower Ipeľ river basin. The most extreme situations were at the end of February and at the turn of March and April. On tributaries of the Lower Ipeľ River basin (Litava in Plášťovce, Štiavnica in Horné Semerovce) the values of 20-year flood discharges were observed (Fig. 3).



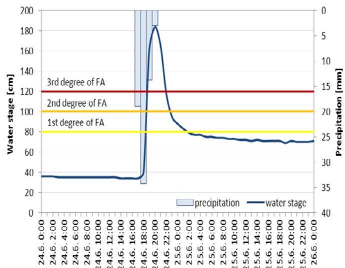


Fig. 3: Discharge on Litava in Plášťovce (Ipeľ) with marked levels of N-year-flood discharge in the first half of the 2013 (left), hourly rainfall totals from rain-gage station Lom nad Rimavicou and hourly water levels on Rimavica in Kokaka nad Rimavicou in June 24-26, 2013 with marked degrees of flood activity (FA, right)

During May and Jun rainy weather accompanied by both long-lasting frontal and heavy convective precipitation was alternating with short dry periods without precipitation. Following high landscape saturation the hydrological response of catchments to heavy several hours lasting rainfall was very quick. Considerable local water level rises were recorded in all river basins, but especially in small ungaged catchments. These flash floods together with sediments of mud and stones caused large material damages in many municipalities.

Occurrence of local extreme events culminated in late June (June 24). Evening rainstorm produced heavy rainfall that lasted only few hours. Mostly in 4 hours more than 70 mm of rain fell over the Čierny Hron river basin (the Upper Hron river basin) and more than 60 mm over Rimava river basin (tributary of the Slaná river). Total rain amount in 4 hours reached nearly value of normal June precipitation. The maximum peak discharges of significance 20-year flood discharges were assessed (Fig. 3).

Not typical flooding situation occurred in early June. Catastrophic flood on Danube River caused flooding of municipalities located on the lower parts of Hron and Ipeľ river basins (Danube tributaries) due to backwater (Fig. 4).

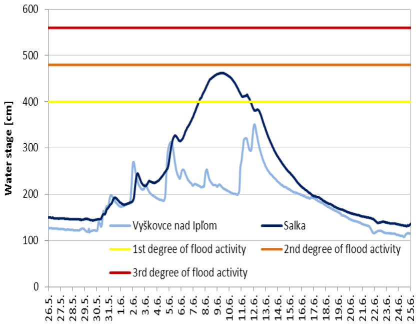


Fig. 4: Water stages in hydrological stations Vyškovce nad Ipľom (unaffected by Danube backwater) and Salka (affected by Danube backwater)

4. Conclusion

In winter 2012/2013 changing of cool periods accompanied by snowfall and melting periods with intense distinctive temporary warming and liquid precipitation was frequent. During the cool periods the snow systematically accumulated in the snowpack. When cool period has been changed for melting, the issue of snowmelt runoff was highlighted. Frozen soil or ground prevented snowmelt from infiltrating into the soil. Therefore the runoff of the water released by the melting of snow accelerated. Several flood situations from melting snow and rain occurred in all catchments in Central and Eastern Slovakia. From hydrological point of view the most significant flooding was recorded in the Lower Ipeľ river basin.

After the unusual winter in the Central and Eastern Slovakia also extreme months May and June appeared with local occurrence of flash floods that flooded many municipalities and together with sediments of mud and stones caused large material damages.

Increased frequency of occurrence of extreme meteorological phenomena during the past few years indicates that dangerous rainfall-runoff events can occur almost at the whole territory and in any season taking into account the physical-geographical conditions of Slovakia.

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The Bosna River flood in May 2014

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Abstract/Introduction

The catastrophic flood, in May 2014 develops in the lower reaches of the River Sava, which have affected Croatia, Bosnia and Herzegovina and Serbia. The Slovenian government has decided to help the affected areas of Bosnia and Herzegovina with analyzing the event, making hydrological model of the river Bosnia and establishment of a program of further measures for mitigating the impact of flooding. It has been designed by the expert group composed of representatives from the Environmental Agency of RS, Institute for Water of RS and the University of Ljubljana. The expert group visited flooded areas in June and July. Event analysis was carried out on the basis of data that are delivered to us by colleagues from of the Federal Hydrometeorological Institute of Bosnia and Herzegovina and the Hydrometeorological Institute of RS.

1. Description of The Bosna River catchment

The catchment area of Bosna River from its headwaters to the mouth in the Sava River, covers area of 10.836 km^2. The river flows from south to north direction. Headwater is in the Dinaric mountains with peaks exceeding 2,000 meters, the central part of the basin covers a mountainous area of central Bosnia and lower part of catchment takes place through the flat inundated area the Sava river. The catchment has also extremely varied geology with typical karst areas and extensive floodplains in the lower reaches of the main river and its tributaries.

The area was equipped with water stations and hydrological data are available from the end of the 19th century. Currently working in the area for more than 27 gauging stations, which measure the water levels and flows along the main river and its tributaries. The hydrological study prepared in 2012 (Zavod za vodoprivredu“ d.d. Sarajevo in Federalni hidrometeorološki zavod, 2012) discussed in detail data measurements and description of the basin. The analysis based on the data from the periods between 1961-1990 and 2001-2009. Due the war in the area of the basin has an interruption of the observations on most water stations between 1991 and 2000th.

Flood waves move along the river Bosna relatively quickly. Top of the flood wave reaches the river Sava in less than 24 hours. The probabilities of the maximum flows in m3 are presented in Table 1.

Table 1 Probability of occurrence of peak flows in m^3 / s

return period in years	WS Modriča	WS Doboj	WS Maglaj	WS Zavidovići	WS Dobrinje	WS Reljevo
10	2214	2091	1508	1164	600	345
20	2551	2420	1764	1320	717	400
50	2990	2795	2120	1520	880	464
100	3318	3087	2479	1673	1058	510
2014 flood			3578	2525	1608	440

2. Flood in May 2014

Flood in May 2014 is a historic event in the lower reaches of the river Sava. The discharges are a large number of meters beyond the hitherto largest measured values. The first results of measurements and analysis of developments already made (RHZ, in 2014; Abdulaj et al., 2014; Kupusović, 2014).
Before flood there was very humid period in the month of April, which continued in May. The worst was during the period from May 13 to 16, Table 2. Maximum rainfall is measured in rainfall station Tuzla on thiss in Gradačac and Olovo. In the Sarajevo, Zenica and Zavidovići were measured slightly less rainfall, Table 2. At very high flow rates have been established already in the headwaters of the river Bosna, only flows are not already exceeded the values measured in the sixties, Kupusović 2014 The highest measured water levels occur from Dobrinje water station (upstream from the Zenica town) and down to the confluence with the Sava River. Due to the high inflows of rivers Kupa, Una and Vrbas is also the Sava River reached the highest levels measured downriver from water station Slavonski Kobas, Abdulaj et al., 2014. The main discharges the Sava River receive from Bosna River.

Table 2: The sum of the daily and multi-day rainfall at individual rainfall stations in mm..

Sum	Sarajevo-Bjelave	Olovo	Zenica	Zavidovići	Gradačac	Tuzla	Modrac
April	97	136,5	19,6	170	0	192,6	
1-11 May	32	27,1	16,5	25,8	91,8	55	
12. May	14,1	15,3	4,4	0,8	3,3	4,9	
13. May	34,6	5,5	30,2	12,3	21,1	20,6	52
14. May	71,3	72,9	53,7	57,1	68,3	92,3	79,5
15. May	18	65,8	38,7	33,1	85,1	103,8	76,6
16. May	4,6	8	11,4	9	13,6	28,6	14,4
17.maj	2,4	4,4	3,3	2,4	3,3	2,5	
13.05 16:00 - 16.05 6:00	116,5	150,4	127,1	107,8	178	229,2	
12.-17. May	145	171,9	141,7	114,7	194,7	252,7	222,5
1.-17. May	177	156,6	274,6	113,9	382,8	247,8	
April-17. May	274	335,5	177,8	310,5	286,5	500,3	
Average yearly 1961-1990	932		782			894	

Precipitations cover the entire basin with a relatively moderate intensity. The data of rainfall measured hourly in the Zenica rainfall station between May 13 and May 16 fluctuate between 0.7 and 10.7 mm per hour. The highest intensity was observed in Sarajevo where May 14 fallen 11.4 mm per hour of rain. It was raining all the time continuously without significant stop from May 13 in the afternoon until May 16 in the morning. After the mayor event there was moderate rain on May 16 and May 17 during the day even with the rain very moderate intensity. In Tuzla is

overdue 229.9 mm of rainfall in 62 hours of continuous rainfall. We must also note that in some places in the area poured much more water, and that is part of the preceding rainfall in April and May are detained in the mountains in the form of snow, which is fully melted during the event.
View the basin in the vicinity of Sarajevo showed that the flow streams in the headwaters very high, but not the river overflows its banks, so that only the damaged lining and eroded the riverbed. The event can be estimated in this work, with an incidence in the 50-100 year return period (WS Reljevo), which were designed arrangement of watercourses, Table 1. A similar situation is also evident in the some tributaries. From WS Dobrinja downstream, on the Bosna River, were discharges well beyond flows with return period of hundred years. Signs of catastrophic rainfall observed in the valley of Željezno Polje and down the river from Zavidovići, where are the confluence of the tributary of The Krivaja River. The most affected area is the valley and the village Željezno, where landslides and debris flows transformed the area landscape.
Flooding has reached extremely high flow rates, which far surpassed the previous measured value. In the Zenica was the previous maximum level at the flood exceeded 70 cm and in town Doboj even 150 cm. In this context we should note that the large amounts of water spilled at flood-prone areas and thus reduce the tip of the flood (Kupusović, 2014). More surprising than the amount of water its duration of flood event. Thus, in town Doboj flow greater than the previous maximum lasted two days, and three hours.
To create a flood wave is very valuable information to the dam Modrac on the Spreča River. Namely catchment area of the storage Modrac, which takes 1200 km^2, gave more than 1m^3 per second per km^2 of specific flow. The data show maximum inflow to the reservoir Modrac of 1,600 m^3/s (5/15/2014 at 15 pm) and the outflow from the reservoir 1,137 m^3/s (at 16/5/2014 at 13.00). The storage is decreased maximum flow rate by 29% and delayed for 22 hours. Maximum flow of the river Spreča thus came to the confluence with the river Bosna, when the water level in Doboj already started to decline, but they grow bold duration of flooding. Down the river, the river spilled in a flood inundation area and slowed its flow. The Sava River at the outlet of the Bosna river began to rise from May 14 and reached a maximum at May 17 (Abdulaj et al., 2014), where was measured the Sava River measured flow of 6000 m^3/s. We must warn that this was not measured in the flow of the flood area on the right side of the river. At the same time was at the Gunja vilage, down the river is measured for 1400 m^3/s less discharge, which means that the flooded area of the river Sava downstream continue filling with water.

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2014 karstic inundation of the Planina polje, Slovenia

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Introduction

Planina polje is a typical karst polje in Ljubljanica river basin with steep surrounding hills from limestone in NE side and dolomite in SW side. Typically there are two annual inundations of the polje usually lasting for some weeks, higher annual inundation lasts about a month and extreme inundations last even for over 6 months. On average the polje is flooded 3 months annually.

The ground level of karst polje is on approximately 450 m asl and has an area of 10 km^2. Hydrologically it has typical dinaric hydrological regime with prime maximum in autumn and secondary in spring. The main 2 tributaries to the polje are karst springs, Unica spring and Malni spring. The rest of the water inflow is through smaller springs and estavelles. The direct surface drainage basin is small, only a few square km while the karst watershed is estimated of well over 500 square km (Gams, 1980), but cannot be precisely derived due to underground water bifurcations. The outflow of the polje is mainly through the limestone contact zone on the north-eastern edge of polje.

The February and March 2014 high water event is an extreme situation with extreme high water level after decades. There were over 40 flooded objects in the traditional settlements on higher grounds. Two communities were cut off.

The formation of a karstic lake in Planina polje begins when the inflow exceeds the outflow, which is at discharge of about 60 m^3/s at Hasberg water gauging station.

The extreme inundation can be connected to combination of numerous causes: high precipitation with snowmelt in the whole karst watershed of Ljubljanica river caused high karst groundwater levels also in the outflow direction of the Planina polje that blocks the outflow.

1. Weather situation

In the Planina polje watershed end of January brought significant amounts of rain and snow with precipitation values from 50 to 100 mm in the last week of January. The discharges were already above average, mostly in high discharge values. The rain continued throughout the February with amounts of rain being at around 400 % of monthly average, of which 3/4 were received in the first two weeks of the month. On average February precipitation is some 90 mm, in February 2014 360 mm were received.

2. Hydrological situation

The percolation of precipitation water into karst has increased the piezometric water levels of it and therefore the outflow was at its peak. Since the outflow is limited the consequence was the further increase of karst groundwater levels. In Planina polje the inflow into the karst polje increased, the outflow was at its maximum and it was further blocked by high karst groudwater levels at its discharge site (by Hotenjka and Rak river).

The water levels at water gauging stations in Planina polje began to rise higher from the 7th of February. The first week the water level was rising near 50 cm/day than the rise grade decreased to some 20 cm/day. The maximum was set on 24th of February with water level at 453,24 m asl.

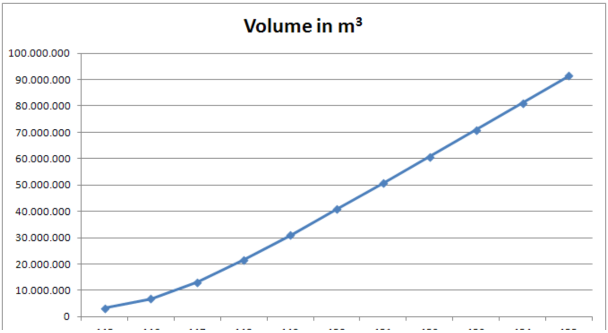

Fig. 1: Absolute water levels at 3 gauging stations and average high water level at Hasberg station.

The volume of water that was "stored" in a lake at the maximum was about 7,5 mio m^3. When the rise was the fastest, between 7 - 14th February, the surplus of inflow over outflow was 6-7 mio m^3 per day or 70-80 m^3/s.

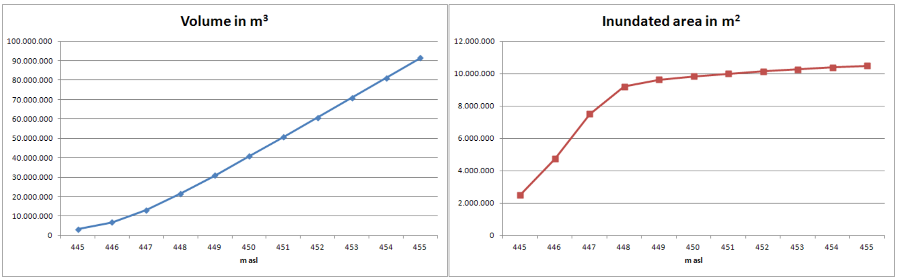

Fig. 2: Storage volume in cubic meters (m^3) and inundated area (in m^2) of Planina polje at terrain levels above the sea.

The decrease of water levels was slower and steadier, at first some centimetres per day, than 8-9 cm per day and below the 451 mark up to 20 cm per day.

The size of inundated area grows fast at the start and it is capsized above 448 m asl due to steep surrounding terrain. At its maximum the size of inundated area was 10,3 km^2.

3. Planina polje inundation history

The inundation of Planina polje is a typical karst event and the community used to live along with this phenomenon. There is over 2 centuries of written history of mayor inundations (Gams, 1980; Peternelj, 2009):
1801, 1802, 1820, 1844, 1851/52 big flood, 1876, 1878/79 several events, near big flood height, 1892, 1923, 1947, 1979, 2000/01, 2008/09.

Fig. 3: Planina polje on 22.2.2014 by Copernicus EMS (left) and the photo of the area (Photo: © Franjo Drole).

4. Post inundation events and lessons learned

After the February's inundation Slovenian Environment Agency in cooperation with Association of Slovenian Geographers organised the set up of inundation high water marks. The purpose of the project is to raise the awareness of high water events, so that the memory of these events is kept alive with local population and that the knowledge of past events can be used by proper land use planning. The high water marks can also be seen as a soft measure of flood planning as proposed also in the Flood directive (Directive 2007/60/EC).

Fig. 4: 2014 high water mark in the town of Planina (Photo: Marjan Bat).

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The new Hydrological Data Management in Serbia Improved Services during 2014 Kolubara and Sava Floods

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Abstract/Introduction

The Republic Hydrometeorological Service of Serbia (RHMSS) implemented the software package WISKI (Water Information System KISTERS) during the last years to renew their complete hydrological data management. In parallel the RHMSS developed a hydrological forecast environment based on the Swedish HBV model for small and medium catchments in Serbia.
This presentation will show system architecture, functionality, and usage of the system. Actual results, advances and successes from the 2014 Sava and Kolubara floods will be presented. Future opportunities linking several hydrological information systems, to get a better river basin and flood management in the Danube basin are shown.

1. System architecture and integration concept

All data types in the WISKI 7 system are stored in a structural relational database. Hierarchical metadata structure where the monitoring network and measured or computed parameters are defined. This approach allows adapting the system for various types of monitoring programs and easy to define parameters of quantity of surface and ground water, climate, air and water quality, sediment loads, seismic activities, human activities and measuring equipment's as well. The system hierarchy is based on station/measurement site concept, which represents core of the WISKI 7 data structure. A station typically consists of a set of metadata that are type-specific and at least one or more parameters/variables while each parameter can hold one or more data time series. The time series can be linked together through a number of operands, specifying different procedures for data handling and processing. For example, in the case of surface water hydrological station, stream flow time series are derived from stage time series through a set of rating curves and the generated stream flow time series are then used for calculating various statistical parameters, such as max, mean, minimum, standard deviation, etc. All these and similar data processing procedures can be specified using various operands/agents for linking the time series in a required manner.
The core technology, which provides the backbone of key services for environmental management data processing is called KISTERS Time Series Management (KiTSM). KiTSM is combining interdisciplinary demands on time series processing with regard to mass data capabilities, scalability, modular design and flexibility to work in diverse specialist areas, high level of automation, reliability, security, integration potential, broad platform independence, redundancy and resilience. Standard time series data structure contains time stamp, value, quality, and interpolation type. Time interval of time series can be regular or flexible, with possibility to add time offset. Between two points is clearly defined the interpolation type, which could be changed over the time.
WISKI as a client application is a strong, modern desktop tool connected to all metadata and time

series data. Effective data management is performed by default and user defined explorer views and time series graphs with sophisticated data editing and quality control capabilities.
There are two more modules integrated within the WISKI 7– BIBER and SKED. BIBER is a modern tool for management of hydrometric discharge measurements; it includes utilities for management of measuring devices and hydrometric measurements, and for processing, storage and evaluation of measured hydrometric data. SKED is a module for editing/analysis and management of rating curves. Rating curve editor generates stage-discharge relationships and operates also generally on the basis of source and target parameters. It has also proved useful in construction of the storage capacity curves for reservoirs. SKED rating curve management is based on the proven WISKI station model. Any number of rating curves and versions can be generated and managed for a station and its associated parameters. All modules are integrated so that, for instance, SKED has full access to all BIBER measurements and search possibility for selection and filtering those measurements which are required for generating a specific rating curve. Methods for analysing and computation of rating curves include linear regression, power law function, shifted power law function, logarithmic regression, polynomial of 1st to 5th order and exponential function. A separate regression process for fitting a rating curve could be run for each selected Q and/or H range, while the ranges can also overlap.
Integration process of HBV/IHMS conceptual hydrological model and WISKI hydrological information system started in 2009 in frame of project Hydrological Flood Forecasting System for Small and Medium Sized Catchments in Serbia, in cooperation of Hydrology Department of the RHMSS, Norwegian Water Resources & Energy Directorate (NVE) and KISTERS AG. The HBV version installed at the HD/RHMSS is a semi-distributed conceptual catchment model in which the spatial structure of a catchment area is not explicitly modelled. Instead, the sub-basin represents a primary modelling unit while the basin is characterised by area-elevation distribution and classification of vegetation cover and land use distributed by height zone. Such a “lumped” version of the model is computationally more efficient compared to its gridded versions, thus making operational real time model runs - and not the least pre- and post-processing operations such as data assimilation, calibration and forecast error estimation - less time consuming; it is well known that computational efficiency is of overriding importance for issuing timely flood warnings and forecasts in the catchments experiencing swift rainfall-runoff processes and fast occurring floods, including flash floods. The HBV model structure consists of three main components: a module for snow accumulation and snowmelt, soil moisture accounting, and the catchment response module. The model can be considered as conceptual since the processes within, and fluxes between, each module are governed by simplified expressions that conceptualize the underlying physical processes; these processes are represented in the model by linear or simple non-linear relationships.
During the following period the HBV model has been calibrated, tested and fine-tuned at several pilot basins in Serbia and results can be characterized as acceptable and in some cases good. Based on KiTSM core solution, the module of automated services (KiDSM) acquires real hydrometeorological data as water level, air temperature, precipitation, snow and forecast data for meteorological stations and catchment representative stations, consequently the data are being processed sent in HBV input formats to operating machines where HBV model is running. Data Import, model performance, computation and export of result data as evaporation, inflow and outflow, soil moisture, snowmelt, etc. is in HBV/IHMS environment fully automated. Finally, WISKI system automatically grabs the HBV result data and imports them back into the database.

2. Operational regime during flood period in May 2014

2.1 Meteorological and Hydrological Conditions in May 2014

In the period between the 14th and the 18th of May 2014, the advection of the cold Atlantic air across the Alps into the Mediterranean region led to the formation of the extensive cyclone, which influence was prevalent across most of the Balkan Peninsula. During that period, the territory of western and central Serbia received record high amounts of precipitation, exceeding 200 l/m² at places, even above 300 l/m² locally. This event was preceded by the period characterized by heavy precipitation between 14th of April and 5th of May, when most of the Republic of Serbia received between 120 and 170 l/m², in south-western areas exceeding 250 l/m², which contributed to significant saturation of soil with water. Consequently, catastrophic flooding was recorded on the medium and small catchments in western, south-western, central and eastern Serbia along with torrents, erosion and activation of number of landslides. Floods were characterized by instant and intensive increase and equally sharp drop of water level which is a distinct characteristic of flash floods and new historical maximum water levels were recorded. During whole flood period there were collected all characteristic data as precipitation, water levels from loggers and control observations, results of discharge measurements from the field, through automated processes and manual input were stored in integrated information system. High operability regime included continuous data control, validation and corrections. Forecast and measured data were reported and published several times per day via RHMSS internet page, regular reports and interviews. Scheduled automatic processes provided hydrological data in frame of international data exchange.

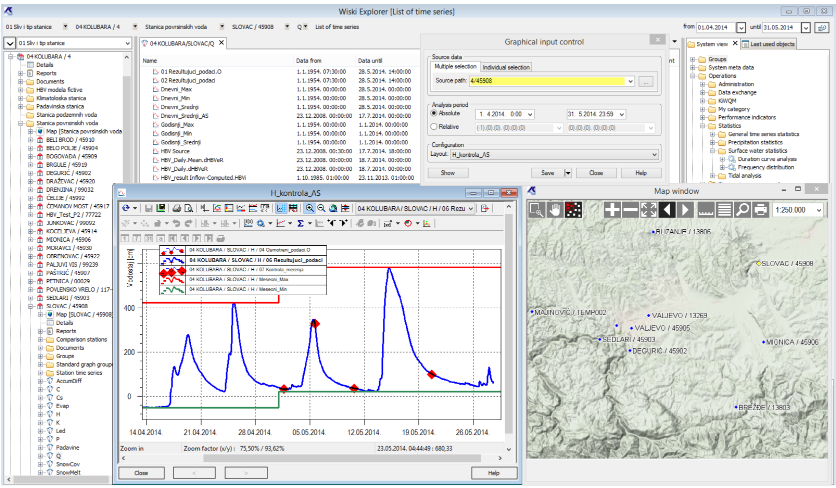

Fig. 1: Graphical input control in WISKI using selection from map

2.2 Kolubara River

Kolubara with its 3600 km2 catchment area and length 123 km is located in western part of Serbia. Main hydrological stations are Valjevo, Slovac Beli Brod, Drževac and Obrenovac, important stations on tributaries are Bogovađa on Ljig, Ub on Ub and Ćemanov Most on Tamnava.

Meteorlogical data are provided from station Valjevo. In short period of one month there were 4 rainfall events in duration 2-5 days while the maximum daily total rose up to 110 mm. Saturated basin reacted almost immediately with rapid runoff. In the evening hours on the 13th of May the water levels on the upper Kolubara River increased, moderately at first, and more significantly later on. At the Valjevo, Slovac, Beli Brod, Draževac and Obrenovac hydrological stations, new historical maximum were recorded.

Maximum discharges achieved in lower part of main course more than 950 m3/s with return period of more than 1000 years.

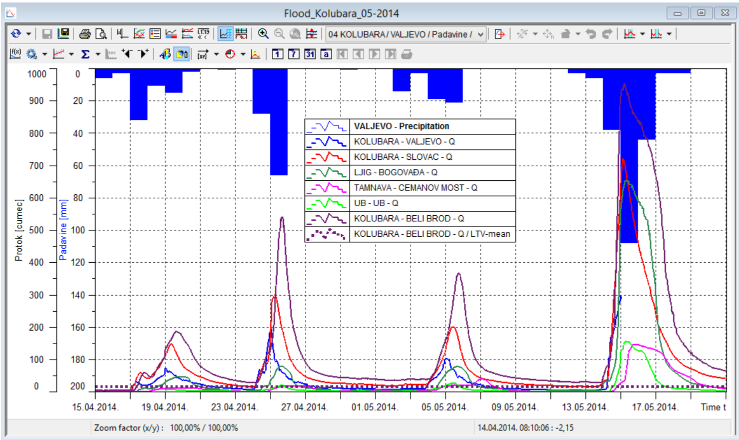

Fig. 2: Precipitation daily totals and high resolution discharge values during the flood period

2.3 Sava River

The main volume of catastrophic flood wave on Sava River was supplied from upper and middle part of the basin, mostly from tributaries located in Bosnia i Herzegovina. Heavy precipitation in the territory of western, central and eastern Bosnia, in the Croatian Posavina region, as well as in Montenegro, led to a sudden increase in the water levels of the right tributaries of the Sava River: the Una River, the Sana River, the Bosna River and the Drina River, which caused a major increase of the water level in the Croatian, Bosnian and Serbian section of the Sava River. On 16th and 17th of May, the Sava River broke the embankments on a part of its stretch through the Republic of Srpska and Croatia, causing the wave peaks to decrease downstream, but it also triggered the flooding of protected area in Srem from the hinterland. The peak of this wave was registered on the Sava River stretch during 17th of May and that peaks have been the highest since the beginning of measurements.. During the flood all discharge measurements were done by ADCP method. Doubled flood wave with massive initial volume and extremely rapid rising limb of second wave reached culmination in station Jamena at 3500 resp. 4600 m3/s and in station Sremska Mitrovica at 4300 resp. 6600 m3/s. The return period of the peak discharge on the Sava River at hydrological station Sremska Mitrovica is estimated at 100 years. Timely and appropriate management of the Iron Gate reservoir enhanced flow conditions reducing the backwater effect on the critical section of the Sava and Kolubara River. Also, Danube flood wave was significantly reduced and as a consequence of that, there were no floods downstream from the Sava River confluence into the Danube.

3. Conclusion

During the recent Sava and Kolubara floods the RHMSS data management system WISKI and the HBV forecast model worked fully operational and contributed to better flood management, providing all needed data, forecasts and information during that days. For statistical evaluation of the flood and rainfall data the basic statistic as min, mean, max, envelopes and long term values were computed automatically and immediately after data input or correction. Implemented wide range of statistical methods as Frequency analysis, Storm analysis, Duration curves, etc. run easily as configurable operation and allow very effectively to test various reference periods. Overall the new system gave the RHMSS all the data and information needed for its flood management in reliable quality and on time.

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Meteorological and Hydrological Analysis of May 2014 Floods In Serbia

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Abstract/Introduction

The disastrous May 2014 floods in Serbia caused human casualties and huge material damage to property and buildings, threatened a large number of settlements, critical infrastructure, water supply and sanitation, damaged energy and road infrastructure, triggered numerous landslides, and caused great losses in agriculture. A significant part of the territory of the Republic of Serbia was affected, particularly western and central Serbia.

1. Meteorological conditions in May 2014

The advection of the cold Atlantic air across the Alps into the Mediterranean region led to the formation of the extensive cyclone, developed at all altitudes, the influence of which was prevalent across most of the Balkan Peninsula in the period between the 14th and the 18th of May 2014.

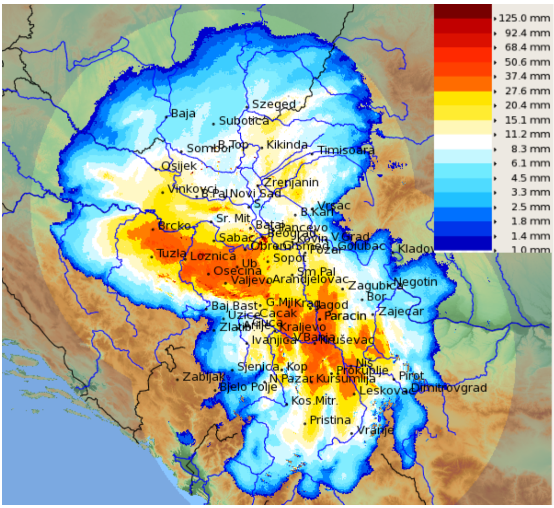

Fig. 1: 15th of May, estimated accumulated rainfall, radar Fruska Gora and radar Jastrebac

During that period, the territory of western and central Serbia received record high amounts of precipitation exceeding 200 mm, even above 300 mm locally (see Figure 1). This event was preceded by heavy precipitation between 14th of April and 5th of May, with totals from 120 up to 170 mm, in southwestern exceeding 250 mm, contributing to high saturation of soil.

1.1 The synoptic situation over Europe

On the 14th of May, the advection of cold air continued across the Alps in the area of central Mediterranean, causing further deepening of upper air trough and finally cyclone cutoff, centered over the Balkans and Pannonian Basin. Simultaneously, the cyclone collected additional moisture originating from the Mediterranean and the Black Sea, dragging cold air from north with increasing of wind. On the 15th of May, the cyclone reached the culmination of its development, with the center placed above western Romania and the lowest ground value pressure of 996 hPa (Figure 2).

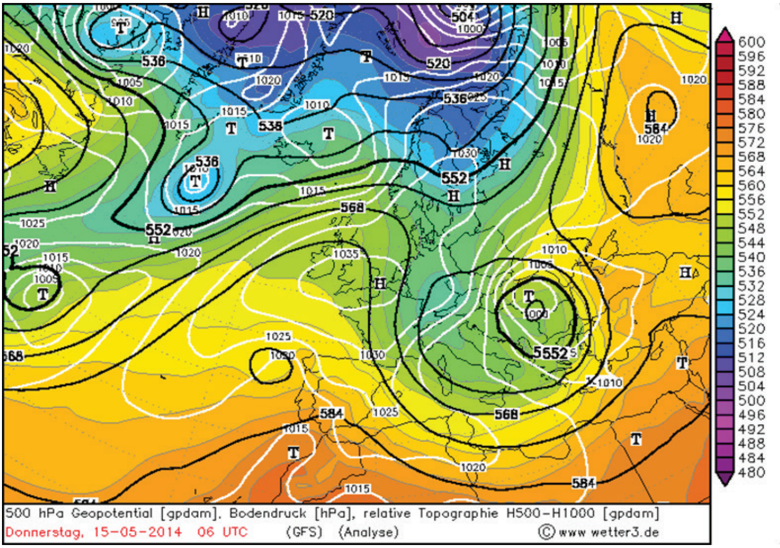

Fig. 2: Analysis of the synoptic situation at 500 hPa height, 15th May 2014 06 UTC, Source www.wetter3.de

Northerly and northeasterly wind in the lower and southwesterly in the higher atmosphere layers caused heavy windshear in the direction and speed.

The cyclone centered in the ground was moving from Genoa Bay across the Apennines, southern Adriatic Sea, southern parts of the Republic of Serbia, Bulgaria and Romania and then made a path in a shape of elliptical "arc" above the southeastern parts of the Pannonian Basin (area of northern Serbia, eastern and southeastern Hungary and northwestern Romania). This time cyclone has stepped away from the usual track of the Genoa cyclones toward the Black Sea, where it would dissipate.

Intensive processes within the cyclone have caused the formation of the thick cloudy layer (up till 8 km) and heavy and long lasting precipitation. During that period, the territory of Bosnia and Herzegovina, Republic of Srpska and the most of the Republic of Serbia (central and western areas) were under the influence of cold and windy weather, heavy and continuous rain and snow in the mountains higher than 1500 m, forming snow cover (Bjelasnica 45 cm, Kopaonik 56 cm). The 16th and 17th of May were characterized by weakening of the cyclone, directing precipitation toward north, producing brief rain and local showers above the Republic of Serbia. It remained on the area of the Balkan Peninsula until the 18th of May 2014, when it moved northward.

2. Hydrological conditions in May 2014.

Due to extreme precipitation episode instant and significant increase of water levels was recorded on the medium and small catchments in western, south-western, central and eastern Serbia (Figure 3.). The flood waves were recorded on the Sava River, the Kolubara River, the Tamnava River; on the Jadar River and other tributaries of the lower Drina River; in the upper basin of Zapadna Morava River and its tributaries; on the Velika Morava River and its tributaries; on the Mlava River and the Pek River and new maximum water levels have been recorded.

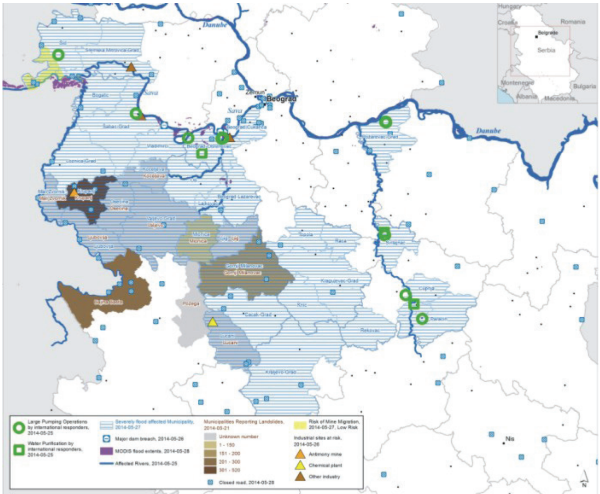

Fig. 3: Areas affected by floods in the Republic of Serbia, Source: OCHA MapAction

The flood waves that occurred on the small and medium catchments were characterized by instant and intensive increase and almost equally sharp drop of water level which is a distinct characteristic of flash floods.

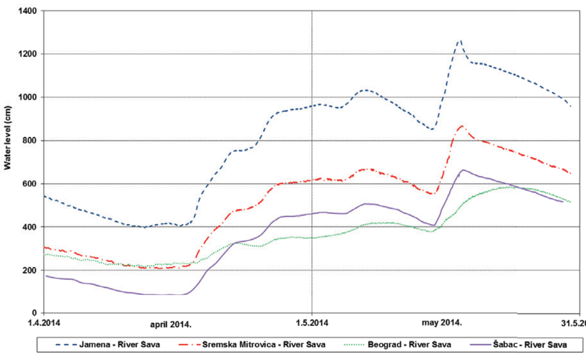

Fig. 4: Stage hydrographs – Sava River

In the middle of April 2014, a complex flood wave was formed on the Sava River (Figure 4). Major increase of the water levels on the Sava River's right tributaries: the Una River, the Sana River, the Vrbas River, the Bosna River and the Drina River was recorded in the middle of May 2014, as a result of heavy precipitation over the territory of western, central and eastern Bosnia and the Croatian Posavina region. In the Republic of Srpska and Croatia, embankments collapsed and Sava River flooded large areas, and in Serbia in Srem region water appeared in the protected area from the hinterland.

Fig. 5: Municipality of Obrenovac, 19th of May 2014, Source: Republic Geodetic Authority

Precipitation over Austria, Slovakia and Hungary caused a significant increase of the water level on the section of the Danube River through Serbia. By management of the Iron Gate reservoir the backwater effect was reduced on the critical section of the Sava and Kolubara River near Belgrade (Figure 5), and as a consequence impact of Danube flood wave was significantly reduced.

3. Conclusion

The precipitation amount registered in May 2014 in Serbia ranged between 92.8 mm in Kursumlija (south) and 317.6 mm in Valjevo (west). Belgrade received 278.5 mm of rainfall which is four times higher than the average for the month of May.

The highest daily precipitation were recorded on 15th of May 2014 when the record-breaking maximum daily precipitation amounts were recorded on three main meteorological stations since the establishment (Belgrade since 1888, Loznica and Valjevo since 1925).

The highest 3-day precipitation sums, above the average for the month of May, were recorded in the period between the 14th and 16th of May 2014 in western and parts of central Serbia. Precipitation amount in the area affected by floods of Podrinsko-kolubarski region, Macva and Tamnava exceeded 1000-year 3-day rainfall.

The return period of the peak discharges on the Kolubara River is estimated at more than 1000 years. The return period of the peak discharges on the Sava River and on the Zapadna Morava River are estimated at 100 years. Finally, the return periods of the peak discharges on the Drina and Velika Morava River are estimated from 10 to 20 years.

The Impact of Climate Change on Flood Hazard in the Sava River Basin and Adaptation Measures

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Abstract/Introduction

To evaluate the flood discharges in future the predicted precipitation data by climate change modelling were prepared for three different time periods in advance. For the transformation of extreme precipitation data to flood discharges a hydrological model was developed and then the precipitation data for different projections incorporated in simulation of historical flood event. The probability analysis of impact of climate changes for different water stations along the main stream of the Sava River was estimated. A Programme of adaptation measures was also suggested.

1. Introduction

The potential impact of climate change on floods is discussed in numerous scientific papers which have been peer relieved by Wilby R.L. and Keenan R. (2012). Most of those papers about the impact of climate change on floods are based on trend analysis from trends of the existing data. More advanced procedures are now using the hydrological models to analyse the impact in which also the uncertainty analysis of maximum discharge prediction is executed. Booij (2005) found out that the HBV model for numerous sub basins has a high impact on the model structure which influences the simulation results of the climate change impact on floods.

To evaluate the discharge in future we can use the predicted precipitation data by climate change modelling. The downscaling of results is estimated using E-OBS which is taking into account the climate change impact. E-OBS is a gridded data set of daily precipitation and temperature values from all around the Europe and is based on data which have been gathered during the European project ECA&D - European Climate Assessment & Dataset project. It was carried out by the Royal Netherlands Meteorological Institute (KNMI, 2013).

Our analysis based on data from meteorological report presented by Rakovec and Ceglar (2014). The precipitation and temperature data are taken from the raster data set based on the position of rain gauge stations and used for the hydrological model. The E-OBS dataset was defined on the same 0,25 degree grid resolution and the data collected between 1961 and 2010 were used in this study. Meteorological data from simulations of 16 different ENSEMBLES GCM-RCM model runs were used for preparation of projections. The prediction of the climate changes was prepared for three different time periods (2011–2040, 2041–2070 and 2071–2100). They have been referred to air temperature changes and to total rainfall amount with 20- and 100-year return period. The increments of the rainfall amounts have been specified for every season.

In this paper we used the complex HBV model for the Sava River Basin.

2. The Sava River Basin Case Study

The Sava river watershed from its source to the discharge into the Danube extends over an area of around 95.000 km2. To ensure the rigidity and robustness of the model the sub-basins were generated to be as large as possible while covering not more than one major tributary stream. As a result the watershed was divided into 13 sub-basins with areas ranging from 2.000 to 14.000 km2 (Table 1, Figure 1).
All the sub-basins were divided into elevation (3 were chosen) and two vegetation zone: forest and field (non-forest). The following input data are required to calibrate/run the model:

- precipitation (32 measurement stations were chosen),

- temperatures (8 measurement stations were chosen),

- discharge data (12 measurement stations were chosen),

- potential evapotranspiration (8 measurement stations were chosen).

Table 1: List of sub-basins.

#	Sub-basin number	Sub-basin name	Stream	Sub-basin area [km^2]
1	I.	Sava I	Sava	10.073
2	II.	Sava II	Sava	3.481
3	III.	Kolpa/Kupa	Kolpa/Kupa	9.501
4	IV.	Sava III	Sava	6.701
5	V.	Una	Una	9.907
6	VI.	Sava IV	Sava	1.880
7	VII.	Vrbas	Vrbas	5.295
8	VIII.	Sava V	Sava	4.403
9	IX.	Bosna	Bosna	10.261
10	X.	Sava VI	Sava	5.021
11	XI.	Drina I	Drina	13.781
12	XII.	Drina II	Drina	5.979
13	XIII.	Sava VII	Sava	8.424
			All sub-basins	94.708

For the calibration purposes and simulation of the impact of climate change we collected input data: precipitation, temperature, evapotranspiration, and discharge for the period from June 1 to December 31, 1974. An important characteristic of the 1974 flood event was major rainfall that moved with time from the east to the west part of the Sava River Basin and almost hundred year floods occurred over the basin at all. Also in year 1974 a lot of hydraulics structures: dams, levees systems, detention ponds were not in function.

The hydrological model was used for modelling of the impact of climate change forecasts on the Sava River discharges at selected stations. For modelling the impact of climate change the same input data as those for the calibrated model for the 1974 flood were used. Only the rainfall data were changed for the day with maximum precipitation and temperature increases. Instead of using the measured maximum daily precipitation, we used the predicted maximum daily precipitation and calculated peak discharges for precipitation of the E-OBS to day and predicted data with 20- and 100-year return periods. The flood discharges for precipitation with one hundred return period are in table 2.

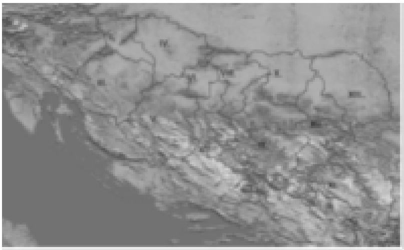

Figure 1: Modelled Sava river watershed – from its source to its confluence with the Danube – with orographic sub-basins and watershed borders.

Table 2: Results of modelling climate change flood peaks using the E-OBS data of the 100-year return period (in m^3/s).

Sub-basins	Water station	E-OBS m^3/s	2011-2040 m^3/s	2041-2070 m^3/s	2071-2100 m^3/s
Sava I	Čatež	2780	3297	3770	4134
Kolpa/Kupa	Šišinec	1522	1595	1664	1722
Sava II	Crnac	2510	2670	2817	2929
Una	Kostajnica	1407	2060	2245	2188
Sava III	Jasenovac	2718	2863	2993	3086
Vrbas	Delibašino selo	707	813	845	825
Sava IV	Slavonski Brod	3573	3895	4062	4142
Bosna	Doboj	767	985	1025	1103
Sava V	Županja	4227	4699	4957	5270
Drina I	Bajina Bašta	2474	2683	3087	2719
Drina II	Kozluk	2407	2639	3059	2686
Sava VI	Sremska Mitrovica	6603	7143	7580	7409
confluence		6715	7253	7695	7509

The probability analysis in the report was derived from the data collected in the period 1926–1965 for the last hydrological study of the Sava River Basin (Prohaska, 2009). The analysis does not consider the impact of flood protection measures in the Central Posavina as they were developed later. The data about 10, 1 and 0.1 percentage of probability were used as the basic relations for water stations. Probability of discharge values calculated from the E-OBS data with the 20- and 100-year return periods were estimated based on probability from the report. We assumed that predicted discharges calculated by model and by predicted maximum E-OBS precipitation have the same probability as today discharges. We then determined the new probability curves of maximum discharges for each period by the Gumbel probability function.

3. Adaptation measures

Uncertainty of results is very large but calculated impacts are significant and we can not simply dismiss them or not take them into account. We have to consider with due diligence to take measures to protect against flooding. In any case, it makes sense to rise on the higher level of protection of densely populated areas and even though tomorrow we establish that the forecasts are not fulfilled, we will have well-protected urban areas. In fact today the Netherlands is protected against the phenomena with 10,000 years return period and same is protection of Vienna against Danube flooding. In Japan, as well as measures in densely populated areas, apply the so-called giant levees. Also we have to raise the protection of critical infrastructure (roads, railways, electricity supply, hospitals and the like at a higher level. Agriculture land but not the farms do not look for any special extra protection.

In any case, we need to develop tools with which we can successfully simulate various scenarios of the origin and development of floods in the Sava River Basin, as the basis for successful warning system for flood protection. The above mentioned models are also the basis for the further development of flood protection systems, which will not endanger downstream areas.

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Climate Variability and Change Impacts on Hydrology

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Abstract/Introduction

The human society and welfare depends highly on water resources. Our vulnerability to floods and droughts decreased from previous centuries due to adaptation such as construction of flood protection measures, flood and drought planning etc. However a room for adaptation still remains either under current or any potential future climate conditions.

Climate with no doubt determines a hydrological regime. Significant flood events that occurred in recent decades in the Danube basin and Europe in whole might give an impression we live in the period of increased flood frequency that might be similar to 15th and 16th century or 19th century. Climate variability and change is one of the factors that (together with e.g. land use change) have to be considered in hydrology and water management especially in the field of planning and design. However the proper use of climate data and products on one hand and its correct interpretation in hydrological application seems to remain a great challenge for hydrologists and water management.

1. Seasonal forecasting in moderate climate

The predictability of the hydrological variables by the extended hydrological prediction differs in space and time. Shukla et al. (2013) assessed the relative contribution of the initial condition and climate prediction to the skill of the EHP in a global scale. They have found that in cold regions (e.g. Siberia, Canada), deserts and dry regions the contribution of the initial condition outweighs the climate forecast for up to 6 months lead time. On the other hand the in the moderate climate (e.g. Central Europe) or tropics the importance of the initial conditions prevail for the first month only. In general the regions with a well-developed division between a dry and wet season (or season of accumulation of water resources) may benefit from the knowledge of the state of the basin as an important driver of runoff in coming seasons.

In addition the regional differences also exist in the climate prediction skill. For example the El Nino Southern Oscillation ENSO phase impacts the occurrence of dry or wet periods in Australia or Southern America.

Although above mentioned findings are not very optimistic for most of the Europe because of small importance of initial conditions combined with relatively low climate prediction skill comparing to ENSO region, still there is a value in climate information available for the hydrological application. Fig. 1 shows evaluation of ECMWF monthly sum precipitation forecast transformed to below-/above-/normal categories of prediction and measurement. It is obvious that there is a skill in the forecast that enables us to condition the probability of occurrence of dry or wet period based on it.

Similarly Šípek (2014) has found similar dependencies between few large scale atmospheric and oceanic indices and meteorological parameters (namely Mean Areal Temperature and Mean Areal Precipitation) for small basin in 7 calendar months during the year (fig. 2).

CHMI has developed and implemented for testing operation seasonal forecasting system MESP The system is based on the generated ensemble of 1000 years of precipitation and temperature based on the historical observation and expected above/below/normal monthly climate outlook from ECMWF. Forty five ensemble members are selected and distributed in space and time in order to input hydrological simulation. Initial hydrological conditions are based on short term deterministic run of AquaLog system. System outputs are daily forecasts of discharge up to 30 days in advance.

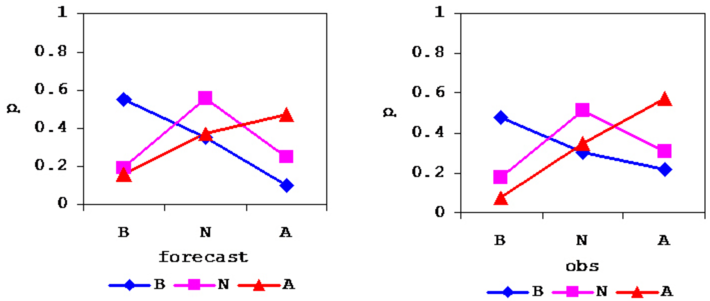

Fig. 1: Discrimination (left) and reliability (right) graph for the ECMWF monthly precipitation sum forecast for the Czech Republic (2007-2010).

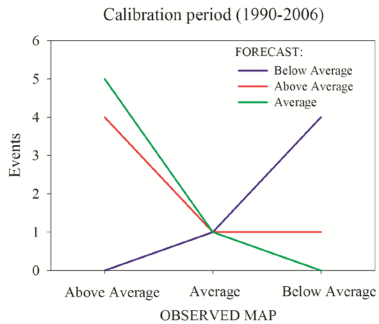

Fig. 2 Climate forecasts of January MAP based on December GHT850 (the lines are representing the number of the forecasted category corresponding to the observed category) from Šípek (2014).

2. Climate change impact on floods

Current climate models do not provide robust inputs for the hydrological modelling of extreme events (Kundzewicz, 2011) but demand for it prevails.

2.1. Methods

Pretel et al. (2011) presented the evaluation of various climate simulations (GCM and RCM) performance for the area of the Czech Republic. Based on their results we have used a set of the best performing models (MIROC3_2_M; MPI_ECHAM5; UKMO_HADCM3; ALADIN-CLIMATE/CZ and median of 8 best performing GCMs) and their simulations for 3 most common emission scenarios (A1B, A2 and B1). In addition a “colder climate” scenario was developed to reflect the conditions of the end of the 19th century. The aim was to demonstrate the sensitivity of flood regime to wider range of climate conditions for the selected basins including Bečva

River basin (1 592.7 km²) belonging to Danube basin. Disastrous floods are results of a causing precipitation event and the initial conditions of the basin. To reflect the wide range of possible combination of these two factors we have prepared a 1 000-years long time series of daily precipitation and temperature range (daily Tmax, daily Tmin) using stochastic weather generator LARS-WG (Semenov 2008). It was done based on expected monthly changes of precipitation and temperature (mean and variability) for three target periods (2010-2039, 2040-2069, 2070-2099). Precipitation was further distributed to 6h using the random selection of analogues from historical datasets. Spatial distribution of precipitation to sub-basins was done using a modification of Schaake shuffle method (Clark et al. 2004) based on random selection of analogue from observation data.
SAC-SMA (coupled with SNOW17 and Muskingum-Cunge) was used for runoff modeling of long time series as well as for following detailed ensemble simulation of selected flood events using different random spatial and temporal distribution of precipitation.

2.2. Results

Simulation results were processed by a standard flood frequency analysis used in the Czech Republic. Its evaluation (comparison of simulation under changed climate conditions to simulation done for reference period) suggests slight decrease or no change in value of 100y flood (fig. 3). However the spread of ensemble was very large. It was found that MIROC3_2_M based simulations provided significant increase of flood risk due to expected increase in summer precipitation. But in fact, a decrease of summer rainfall total is expected by other GCM simulations in the Central Europe. On the other hand ECHAM5 based simulations suggested the decrease of flood risk in all basins during the 21st century. Simulations of colder climate conditions indicated generally increase of the flood hazard.

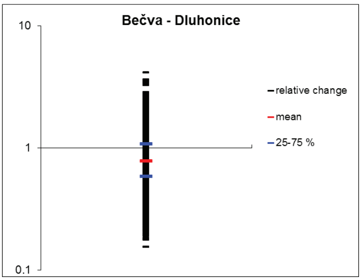

Fig. 3. Result of all simulations of future scenarios with respect to current climate.

3. Discussion on use of climate change scenarios in hydrology

Many studies attempted to assess the potential impact of climate change on flood regime. unfortunately some fail in the methodology - e.g. Dankers and Feyen (2008, 2009) modelled expected response of the whole Europe, however they failed in callibration of model but more importantly they did not downscale the climate scenarios and they estimated a change of 100y flood from 30y simulations (!) based on GCM uncorrected outputs. Such approach cannot guarantee the reliability of water cycle ballance in basins nor the plausible statistical certainty of estimates of extreme value from such short time series.
Hydrological response to precipitation is highly dependent on the initial saturation of the basin. Therefore the reliable precipitation and temperature simulation is critical to ensure the correct estimation of initial conditions. As GCMs nor regional RCMs are not able to simulate observed

climate parameters in regional and local scale, downscalling and/or bias correction is needed (nevertheless it does not remove the uncertaint).

Meteorological and hydrological methods differ. While meteorologists use 30y periods for statistical evaluation, hydrologists, for obvious reasons, use time series as long as possible when evaluating flood regime. Therefore the dirrect coupling of GCM and hydrological models for tis task should be avoided.

4. Conclusion

Climate is very important factor of hydrological regime. Hydrology might benefit from climate information especially in seasonal forecasting and long term scenarios. However the correct interpretation of the climate information and its reliability is absolutely critical to avoid errorneous hydrological applications and outputs.

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Impacts of climate change on the water regime in the Bavarian Danube basin

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Abstract
The impacts on the hydrological cycle related to climate change are investigated in Bavaria in several projects. For the Upper Danube region, within the project KLIWA the Bavarian Environment Agency aims to extend the existing ensemble of regional runoff projections for a better assessment of the future hydrological changes in the region. For this, several issues had to be solved (e.g. existing uncertainties, bias-correction and selection of regional climate projections). The present methodical approach, current results and the planned tasks still in progress are presented here.

1. Introduction
Since climate change, on a regional scale, can already be observed in Bavaria e.g. by increasing mean temperatures with impacts on the water cycle in Bavarian catchments, questions arise, how to deal with future impacts of climate change. For water management, robust estimates about possible changes of water regimes including a clear description of the inherent uncertainties are important in order to develop appropriate adaption and mitigation strategies.
The Bavarian Environment Agency (LfU) participates in several research projects (AdaptAlp, BIKLIM, KLIWA) and collaborations with various German environmental agencies. These projects deal with climate change and its impacts on the water cycle on the regional scale. During recent years, the main tasks were to asses and cope with uncertainties in the model chain, the use of available ensembles and to test different types of bias-correction methods.

Impacts of climate change on the water regime are quantified by generating a model chain consisting of a emission scenario, a global climate model (GCM), a regional climate model (RCM) and a hydrological impact model (Figure 1). Each step in the model chain has its own specific uncertainties. With the help of RCMs, the GCM results of coarse spatial resolution are downscaled to the regional or local scale. Two different approaches are used: statistical and dynamical downscaling. Dynamical RCM, in principle use the same process descriptions as the GCM but in most cases contain systematic errors (bias) when compared to reference datasets on the regional scale. This lack of plausibility can be tackled by Bias-correction of climate variables that turned out to be most sensitive in modelling the water balance. But also this step in the model chain has its own drawbacks and uncertainties that have to be considered when interpreting the model results.

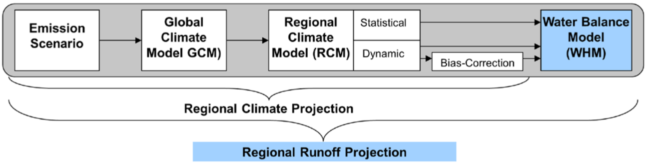

Figure 1: Model chain for regional runoff projections

Based on findings of projects like AdaptAlp, the current focus of impact analysis is to enlarge the existing ensemble of climate and runoff projections for Bavaria to achieve robust estimates of possible future development of the water regimes in Bavaria.

2. Impact analysis - current status

The Bavarian part of the Danube catchment covers about 48000km², most important tributaries with regard to discharge intensities are the rivers Iller, Lech, Isar and Inn with discharge regimes dominated by their alpine head catchments with maximum discharges in summer and minimum discharges in winter. The northern tributaries (e.g. Naab, Regen) have pluvial discharge regimes with snowmelt influenced by high flow conditions in winter and spring and low flow conditions in summer. Figure 2 gives an overview of the water balance models used for climate change impact analysis for the Upper Danube basin.

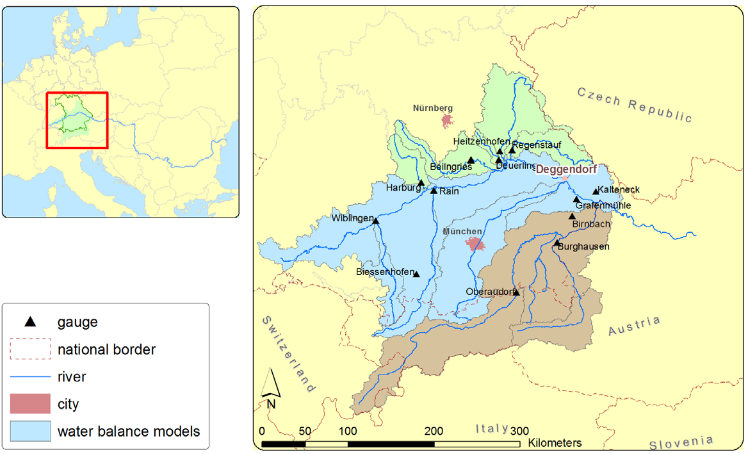

Figure 2: Danube catchment, spatial extend of water balance models and selected gauges

2.1 Observed trends of climate change

Analyzed long-term observations of temperature showed a significant trend of increased temperatures in Bavaria. For areal precipitation and intense rainfall, only in the hydrologic winter half year (November - April) an increased trend has been observed, whereas for the hydrological

summer half year (Mai – October) no clear trends have been detected.
Observed discharge time series showed weak (but not significant) trends of increased annual floods. Characteristic values for low waters have not changed significantly, but at many gauges in southern Bavaria a shift towards an earlier occurrence of winter low flow periods can be detected. Cautious interpretation of these results is essential, a change of discharge characteristics is not necessarily due to climate change, it can also be caused by hydraulic structures, water management, land use changes, etc. Otherwise, impacts of climate change on the water regime can be masked for the same reasons.

2.2 Possible future changes of the water regime

An example of projected changes on the water regime is given in Figure 3 where the deviations of the mean annual runoff for the near future 2021-2050 relative to 1971-2000 show a clear tendency of most statistical projections towards decreasing discharges. In contrast, most of the dynamical projections show slightly increasing discharges. Deviations calculated for the far future (2071-2100 vs. 1971-2000) show unique signals of decreasing runoff (not shown). The number of projections differs for the various gauges, i.e. hydrologic models therefore robust estimates of

future runoff are difficult to assess in cases where few projections are available.

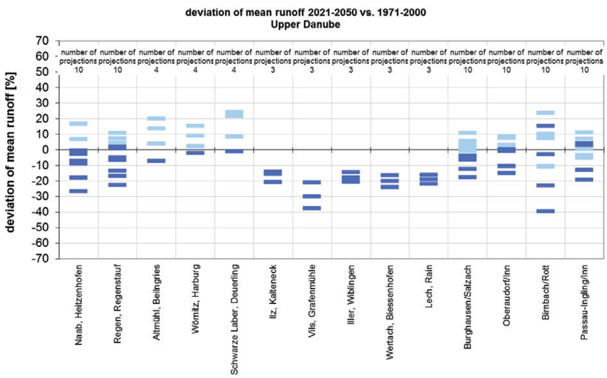

Figure 3: deviations of mean annual runoff for selected gauges in the Bavarian part of the Danube basin; statistical Projections in blue, dynamical projections in pale blue

3. Analysis - future plans

Ensemble simulations for the Inn basin showed a considerable bandwidth of changes in runoff regimes using 10 projections (Figure 3, gauges Passau-Ingling, Oberaudorf, Birnbach, Burghausen). Since there are fewer - and most of them statistical - projections available for the remaining tributaries in Upper Danube, one objective now is to enlarge the ensemble of runoff projections to get a comparable basis for the development of suitable water management strategies.
Within the BI-KLIM project, besides methods for bias-correction an audit strategy for climate projections is developed. It focuses on the ability of climate projections to be used as driving

variables for hydrological models. The audit is meant as a helping procedure for the impact analysis to select climate projections by objective measures and scores. This is necessary due to limited capabilities, e.g. computational resources etc. to run hydrological simulations.
First step is the development of a robust approach for bias correction. As a basic requirement the climate signal and its variability has to be preserved. With respect to diverse orographic regimes and catchment behaviors in different regions of Bavaria (Alps, mid-range mountains, etc.), the method should be equally applicable for entire Bavaria. Analysis of different climate datasets of the past for the Inn basin showed deficits when compared with modelled water balance in alpine head water catchments (AdaptAlp, 2011). Since the Bias-correction method is meant to be applied for all Bavarian river catchments, a uniform reference dataset for all climate variables was created by combining multiple climate datasets. Finally, to put the different spatial resolutions of reference dataset and RCM on a comparable scale, and to bridge the gap between relatively coarse spatial resolutions of RCMs and the finer scale of the hydrological impact model, a spatial disaggregation procedure was implemented into the Bias-correction procedure. As a result, the "quantile mapping" method by applying monthly correction factors was proved to perform best for bias correction. For disaggregating RCM grid sizes, it is recommended to use an adequate size of the area of interest to overcome the effect of spatial variability and, when disaggregating the spatial resolution of the RCMs, small differences in scale should be used to avoid scaling effects like smoothing (BI-KLIM, 2013).
Second step is the evaluation of an ensemble of (dynamical) climate projections with regard to the main meteorological forcing of hydrologic models: precipitation and temperature. Simple indicators, e.g. mean absolute error, are used to test the climate projections against a reference dataset for temporal and spatial plausibility. Further, the change signal of the projections can be considered during the selection process. As a result, the selected climate projections will be used for hydrological simulations to estimate possible impacts of climate change on the water regime.

4. Summary

The current ensemble of runoff projections for most catchments of the Upper Danube basin is not large enough to allow robust estimates of possible changes in the water regime. Based on results from several research projects (AdaptAlp, Bi-KLIM, KLIWA) methodologies are in development to enlarge the ensemble of runoff projections in order to quantify the impacts of climate change as well as the uncertainties connected to the model procedure.

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Water level information for inland navigation on the Austrian Danube

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Abstract

Water level information is an important basis for decision-making in inland navigation as it determines fairway depth and passage height under bridges (viadonau, 2013). Especially fairway depths influences loading of inland vessels and thus their competitive position versus alternative transport modes (Beuthe et. al., 2012). Furthermore providing precise water levels is essential for safe navigation as it contributes to prevent accidents like vessels running aground. Shippers and forwarders address these issues repeatedly in stakeholder meetings and thus confirm the need to improve water level information. viadonau supports inland navigation providing statistical analysis of historical water level data, real time water levels and low flow forecasts. Such a portfolio helps shippers and forwarders in long-term financial planning and risk assessment, navigating safely during transport, planning their journeys and determining the optimal loading of their vessels.

1. Introduction

The navigable length of the Danube available to international waterway freight transport is 2415 kilometres (viadonau, 2013). At the 350 kilometres in Austria we operate more than fifty gauge stations measuring water level and other hydrologic parameters following the guidelines and regulations of the World Meteorological Organization (WMO, 2006) and of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW, 2007). Collected data is validated, analysed and processed in line with international policies and according to the needs expressed by stakeholders and decision makers in inland navigation.
Our analyses focus on the gauges of reference and on the two free flowing stretches in Austria, namely “Wachau” and “East of Vienna”. These two bottlenecks are presumed to be crucial for cost efficient inland navigation. Here shallow sections may limit navigation as water levels are not regulated by power plants but natural variability plays an important role (viadonau, 2013).

2. Analysis of historical water level data

We employ a set of innovative methods to statistically analyse historical data (1981-2010). The analysis reveals monthly and annual means, the expected range of water levels during the course of a year as well as fluctuation patterns. Water levels decisive for inland navigation on the Austrian Danube are determined by analysing framework conditions for typical vessels and goods frequently transported on this stretch. Typical vessels include motor cargo vessels, tankers and barges with a stowage of 1500 to 2200 m³ and a draught of 2.5 to 2.9 meters. Typical goods are agricultural commodities like corn or sugar beet with a specific weight of about 0,6 t per m³, fertilizer (about 1 t per m³) and ore (about 2.5 t per m³). Statistics on the probability of occurrence of water levels decisive for these vessels and goods are calculated on seasonal and monthly basis for the above mentioned 30-years period and presented in self explaining charts (see Fig. 1).

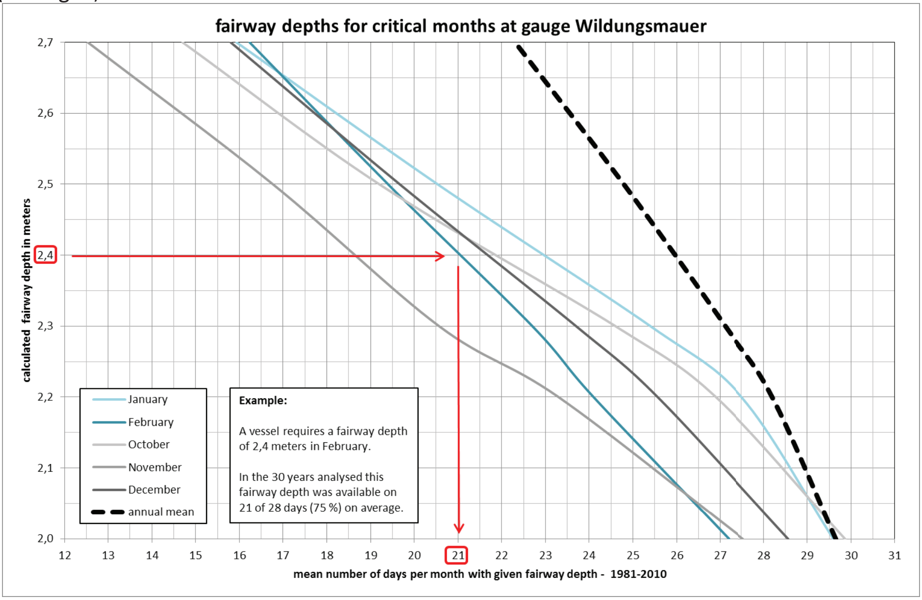

Fig. 1: mean availability of fairway depth at gauge Wildungsmauer (km 1894,7) for critical months

We present a set of more than 100 charts to companies which either want to enter the market of inland navigation or expand their position in transport on the Austrian Danube. Due to their comprehensive design these charts provide a basis for newcomers but the analyses also reveal interesting details for experienced forwarders and logistic providers.

3. Real time water level information

We present real time water levels for the nine gauges of reference which are relevant for certain sections of the Austrian Danube at viadonau homepage (see Fig. 2).

2014-07-09 Datum/Uhrzeit (MEZ)	Pegel								
	ACHL	WILH	MAUT	GREI	KIEN	DUER	KORN	WILD	THEB
13:00	341 (+2)	381 (+2)	451 (+2)	750 (+2)	299	376 (+2)	288 (-2)	265 (+6)	229 (+3
12:00	339 (+2)	379 (+9)	449 (-1)	748 (+4)	299	374 (-2)	290 (+3)	259 (+5)	226 (+3
11:00	337 (+6)	370 (+15)	450 (+2)	744	299 (-1)	376	287 (+2)	254 (+2)	223 (+2
10:00	331 (+4)	355 (+3)	448 (-2)	744 (+1)	300 (+3)	376 (+2)	285 (+6)	252 (+2)	221 (+2
09:00	327 (+4)	352 (+7)	450 (+2)	743	297 (+10)	374 (+7)	279 (+5)	250 (+1)	219 (+2
08:00	323 (+6)	345 (+5)	448 (-2)	743 (+2)	287 (+8)	367 (+4)	274 (+3)	249 (+2)	217 (+2
07:00	317 (+3)	340	450 (+2)	741 (-2)	279 (+3)	363 (+1)	271 (+4)	247 (+2)	215 (+2
06:00	314 (+3)	340 (+6)	448 (+3)	743 (+1)	276 (+2)	362 (+3)	267 (+1)	245 (+2)	213 (+2
05:00	311 (+2)	334 (+4)	445 (-2)	742 (+2)	274 (+3)	359	266 (-1)	243 (+2)	211
04:00	309 (+1)	330 (+5)	447 (+2)	740 (+1)	271 (+3)	359 (+2)	267	241 (+2)	211 (+1
03:00	308 (+2)	325 (+2)	445 (-2)	739	268 (+2)	357 (+2)	267 (+2)	239 (-1)	210 (-1)
02:00	306 (+3)	323 (+2)	447 (+1)	739	266 (+1)	355	265 (+4)	240 (+1)	211 (+2
01:00	303 (+3)	321 (-2)	446	739	265 (+3)	355 (+2)	261 (+3)	239	209 (-2)
00:00	300	323	446	739	262	353	258	239	211

Fig. 2: source: viadonau homepage: hourly water level information and deviation to last measurement for the nine gauges of reference which are relevant for certain sections of the Austrian Danube

State of the art measuring equipment and periodic services by viadonau staff guarantee accurate values within +/- 2 cm. Redundant data transfer systems help to avoid data gaps and hydrological software on several servers ensures a 24/7 service. Our recently developed app “DoRIS mobile” gives water level information of the nine gauges of reference updated every 15 minutes. Additionally a 3 days low flow forecast is provided for gauges Kienstock and Wildungsmauer. The app has been selected among the top 10 best applications in the “ITS in your pocket - App Contest 2014” at the ITS Europe Helsinki 2014 Congress.

Fairway depth and passage height under bridges are the most important parameters for loading of vessels and security of inland navigation. viadonau aims at providing these parameters as real time information in Inland Electronic Navigational Charts (Inland ENCs). Therefore we apply a 1D hydrodynamic model to calculate a real time (15 min interval) water surface for the two free flowing stretches “Wachau” and “East of Vienna”. Model calculations are based on actual riverbed surveys and real time water level and discharge data. So we are able to provide water levels every 100 m. Pilot tests have shown that it is possible to import these data together with actual high resolution riverbed surveys into Inland ENCs (see Fig 3.). Data is transferred via existing base stations of river information systems (RIS). Fairway depth is then calculated as the difference between water surface and riverbed; bridge clearance as the difference between the lower edge of the bridge and the water surface. This service is planned to be provided to all vessels via Inland ENCs after the successful pilot tests. In the future this will assist skippers with actual fairway depths and bridge clearances.

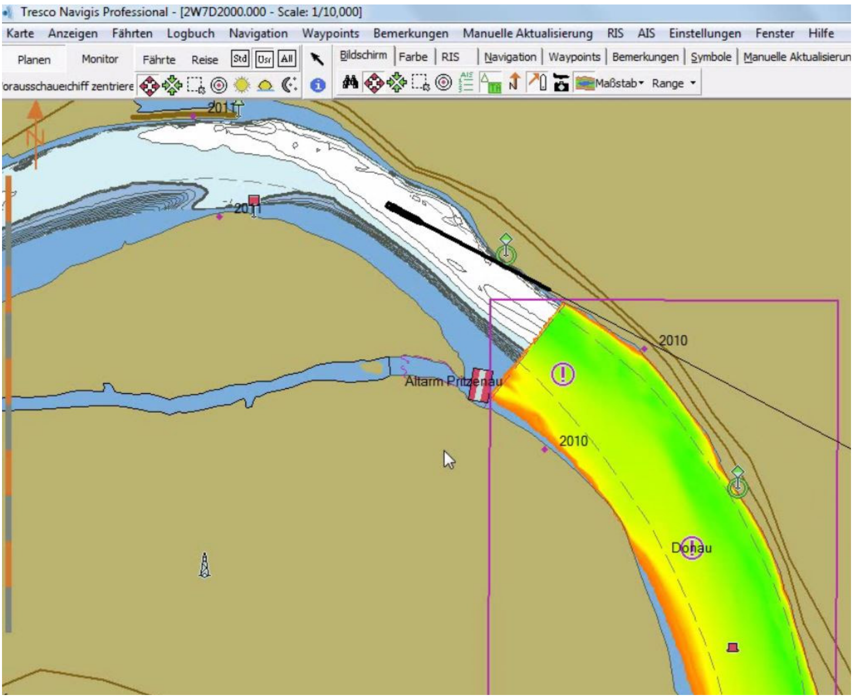

Fig. 3: screenshot of Inland Electronic Navigational Chart with actual bathymetric data at shallow section “Haufenrand Dürnstein rechts” (km 2010.2 - 2008.9)

4. Low flow forecasting

A recently established low flow forecasting system allows us to publish 72h forecasts on the homepage which are recalculated every four hours. 7-day meteorological forecasts and real time measured data of more than 90 gauges spread over the whole catchment serve as input into a rainfall-runoff model simulating future water levels for two gauges (Kienstock at km 2015,2 and Wildungsmauer at km 1894,7). We use measurements during the latest low flow period (December 2013 to March 2014) to further improve the system and finally extend the forecast interval up to 7 days. A detailed description of the low flow forecasting system is provided by Nester, Th., Kirnbauer, R. and Kickinger, P., (2014) in the book on hand.

5. Conclusion

Viadonau is committed to bring forward water level information. We provide statistical analysis of historical water level data, real time water levels as well as low flow forecasts. Such a portfolio supports shippers and forwarders in long-term financial planning and risk assessment, navigating safely during transport, and determining the optimal loading of their vessels. We are dedicated to refine our services by supplying real time fairway depth and bridge clearances as well as extending the low flow forecasting interval.

Acknowledgements

Part of this work was done within the EU-projects NEWADA duo and IRIS Europe 3. NEWADA duo is co-funded by the European Union (ERDF and IPA) under the South-East Europe Transnational Cooperation Programme. IRIS Europe 3 is a multi-beneficiary TEN-T project supported by the European Commission within the TEN-T funding programme.

The author would like to thank all the colleagues within viadonau who contributed and are still working on the mentioned topics related to water level information. These are especially colleagues from the teams Hydrology, Transport Development, DoRIS Operations and Development Traffic Management.

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ITS in your pocket - App Contest 2014: http://www.itsineurope.com/its10/index.php/app-contest

Inland Electronic Navigational Charts: http://www.doris.bmvit.gv.at/en/inland_ecdis/

NEWADA duo: http://www.newada-duo.eu/

IRIS Europe 3: http://www.iris-europe.net/

Evaluation of flow alterations and sequential influence on the riverine ecosystem under climate change in the Mures River Basin, Romania

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Introduction

The structure, functionality and the state of the aquatic ecosystems are heavily dependent on the hydrological regimes in a river basin, and their seasonal variability, which is of great importance for the normal life-cycle of the local species. Projected climate change is expected to impose mainly negative pressure on all regions in Europe (IPCC 2007b), altering directly and indirectly the hydrological cycle and, therefore, influencing negatively the state of aquatic ecosystems (IPCC, 2007a, 2008; World Resources Institute, 2005).

Being a part of the Danube River Basin, the rivers in the Carpathian Region are hosting unique aquatic ecosystems, including many endangered species. Recently, several studies were conducted (CARPIVIA Project Report 2011; CEU 2008; Danube Study Report 2012), investigating the impacts of the projected climate change on agriculture, water resources, tourism, wetlands of the region and possible adaptation strategies. However, no detailed information about potential hydrological impact in Mures River basin was available. This study aims to provide assessment of possible future changes in hydrological regimes triggered by projected climate change in this river basin and to link them to possible consequences on the aquatic ecosystem of the river.

1. Methods

To obtain the future discharge projections for Mures River the eco-hydrological, process-based, semi-distributed basin-scale model SWIM (Krysanova et al. 1998) was set-up, calibrated and validated until the Alba-Julia gauging station, with total catchment area of approximately 18 000 sq.km. The future climate projections over period 1971 - 2050 were obtained from simulations of nine sets of coupled GCM-RCM runs under one emissions scenario A1B (“ENSEMBLES” Project, van der Linden and Mitchell, 2009) and were introduced into set-up SWIM model. The resulting nine future discharges were separated into two periods: reference 1971 – 2000 and future period 2021-2050. These two periods were compared to each other in terms of alteration of intra-annual hydrological variability. To achieve it, the IHA – Indicators of Hydrological Alterations method after Richer et al. (1996) - was applied. Sixteen biologically relevant hydrological indicators were selected - percentage deviation in median monthly flows (relative change in percentage), low and high pulse duration (number of days during which flow below 25 percentile (low pulse) and over 75 percentile (high flow) occurs), low and high pulse counts (number of low flow and high flow events per year). To enable the spatial assessment of the relative percentage of change between the reference and future period for all nine climatic projections for the same set of indicators was calculated. Results were averaged and plotted at the sub-basin level. For the assessment of inter-model uncertainty among the nine projections, the standard deviation was calculated for each sub-basin and plotted in the same manner as the deviations in the indicators.

1.1 Study area

The Mures River with a total length 789 km and an average discharge of 184 m^3/s is one of the most important rivers in the Carpathian Region. The hydrological regime of the Mures River consists of two main periods: the wet period from April to August and a long, dry period from September to March. The annual mean precipitation varies from 1200 mm/year in the mountains to 600 mm/year in the lowlands (Hamar and Sarkany-Kiss 1995; UNECE 2002).

1.2 Model set-up, calibration and validation

The SWIM model is a basin-scale, ecohydrological model, incorporating number of sub-models: hydrological, vegetation and bio-geochemical model for nitrogen and phosphorous. SWIM model was based on the SWAT 95 (Arnold et al., 1993 & 1994) code, introducing the disaggregation scheme basin - sub basin - hydrological response unit HRU from MATSALU (Krysanova et al. 1989) model. The SWIM model is able to simulate river discharge, erosion, nutrient flows and vegetation growth on the daily-time step.

SWIM was set-up using agricultural, topographical, climatic and soil data as forcing datasets. The calibration and validation were performed with split-sample method on a daily time step over period 1986 - 2001, resulting in Nash Sutcliff Efficiency of 0.68 and relative volume difference of 3.9 % for calibration period and 0.6 and 9.6 % for validation period, respectively.

1.3 IHA Method

The IHA method was developed to assess rate of changes in hydrological regimes triggered by dams introduction. It calculates the intra-annual hydrological pattern of a river and compares changes in those for two periods pre- and post-impact basing on 32 biologically relevant flow indicators (Richter et al. 1996).

2. Results and discussion

All nine climate projections suggest an increase of flow in winter and more than half of all models project a decrease in summer flow of the Mures River basin by year 2050.
For the duration of the high flow event (discharge exceeds 75 percentile), in more than half of the scenarios (five out of nine) a slight increase in median and maximum values for the number of days was found. The same trend was observed for the duration of the low flow event (discharge less than 25 percentile): five scenarios showed an increase in the median and in the maximum number of days (see Fig. 1).
Spatially-distributed results showed a significant agreement over the whole basin area regarding the increase of flow in winter and drop in summer and the associated low standard deviation values indicate a high certainty of results. The maps with the relative percentage change in duration of the low flow events show that in the mountainous areas of the region low flow events might become more prolonged comparing to the valley. The same spatial distribution was observed also for seasonal changes. The relative change of discharge is projected to be higher in mountainous areas compared to the valleys in winter and in summer, a slight increase in the valley and a decrease for the higher altitudes were observed. As for the other indicators - low pulse count, high pulse count - no clear trend was found.

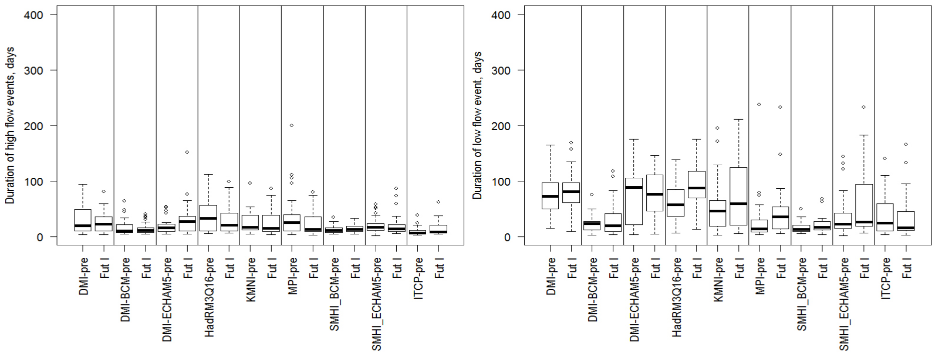

Fig. 1: Duration of high flow (left) and low-flow (right) events for the 1971 - 2000 and the 2021 - 2050 periods**.**

3. Conclusion

The future trend projected for Mures River Basin under A1B socio-economic development scenario could be seen as robust: an increase in the discharge for the winter months, a decrease for late spring, summer and early autumn, and the potential prolongation of high and low flow events, on what majority of models agreed. The prolonged duration of the low flow events and projected decrease in summer discharge may decrease the minimum required water depth, resulting in lowered habitat areas, necessary for fulfilment of aquatic organisms' life-cycles. It also could increase temperature of the water and lessen the dilution rate of contaminants in the water, leading to threating of ecosystems health. Projected increase of discharge during winter and the prolongation of high-flow events may result in the increased water velocities, leading to a change of morphology in the river reach, displacement of small organisms like plankton or fish eggs, increased turbidity and disturbance of photosynthesis (Richter et al. 1998).

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Trends and future development of Bavarian stream water temperature - Results of the KLIWA project

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Abstract
Water temperature controls numerous biological and physiochemical processes in rivers and streams. Hence, water temperature is used as a key quality measure. In analogy to the increased air temperature in Bavaria by 1°C for the previous decades, a similar trend in water temperatures can be expected. As a partner in the cooperation project KLIWA, the Bavarian Environmental Agency focuses on questions corresponding to climate change and its impact on the hydrological cycle and the water budget. Based on statistical analyses of 53 long-term water temperature measurements, we found a significant increase in temperature for 75% of all monitoring points, which was more pronounced in May and August. For the assessment of future water temperatures, statistical models accounting for the relationship between air and water temperature were developed and coupled with regional climate model projections.

1. Introduction
Water temperature is used as a key quality measure for streams. Numerous biological and physiochemical processes such as the metabolic rate of aquatic organisms are controlled by water temperature. Hence, water temperature determines aquatic biocoenosis, the rate of photosynthesis, mortality of fishes, aquatic metabolism as well as the solubility of gases or the toxicity of multiple environmental chemicals.
Aside the impact of shading, the distance from the spring or solar radiation, water temperatures show a delayed respond to the course of air temperature (Morrill et al. 2005). In Bavaria the air temperature increased by 1°C for the previous decades. This trend is in line with the development of global temperature and is expected to continue. To evaluate the impact of climate change on different aspects of the water budget the three German federal states Bavaria, Baden-Württemberg and Rheinland-Pfalz (Rhineland-Palatinate) implemented the cooperation project KLIWA. The common goal of this cooperation is to find options for sustainable actions in terms of climate change adaption. According to water temperature the following questions are in the focus of this analysis:

a) Whether and to which extend did water temperatures increase in Bavarian streams in the past?
b) How will the water temperature change in the future decades?

2. Methods

2.1 Study site and data

This study focuses on water temperature development within the political borders of the German federal state Bavaria, located in the southeast of Germany. Bavaria comprises sub-catchments of the three European river basins Elbe, Rhine and Danube in which the sub-basins of the Danube cover more than two thirds of the total area.

The data analysis is based on continuous daily water temperature measurements of 53 measurements points which are distributed over the complete study area. First measurements were logged beginning in 1951 (12 gauges) while the majority of the time series begin in 1980 (31 gauges).

2.2 Data analysis

In the trend analysis (Willems, 2011) the following temperature related parameters were considered: mean annual and monthly water temperature, maximum annual water temperature, duration of high temperature periods and seasonal changes in water temperature development. Trends for the complete period of measurements were identified by applying the Mann-Kendall-test, the seasonal Mann-Kendall-Test and the t-test as measure for significance. Trends of shorter periods of time were identified by the application of local weighted regression analysis, multiple trend tests and segmented probability distributions. Analysis of seasonality changes was done by trigonometric and circular-linear regression analysis.

The development of gauge based water temperature models as well as methods for water temperature regionalization and the incorporation of climate projections will be presented in chapter 3.2.

3. Results and discussion

3.1 Water temperature trends in the past

The statistical analysis of 53 data sets (Willems, 2011) revealed a significant increase in 75% of the long-time water temperature records (Fig. 1). Since 1980 the average warming of all measurement points accounted for +0.5°C per decade and was mainly observed in the period between May to August. Furthermore, seasonal shifts of warm periods were detected.

Besides the increasing air temperature in the past decades, also land use change und water management measurements affected water temperature. Although, a very strong relationship in the past between air- and water temperature was proved for most of the measurement points based on the results of a multivariate statistical analysis, the magnitude of climate change related increases could not be clearly verified.

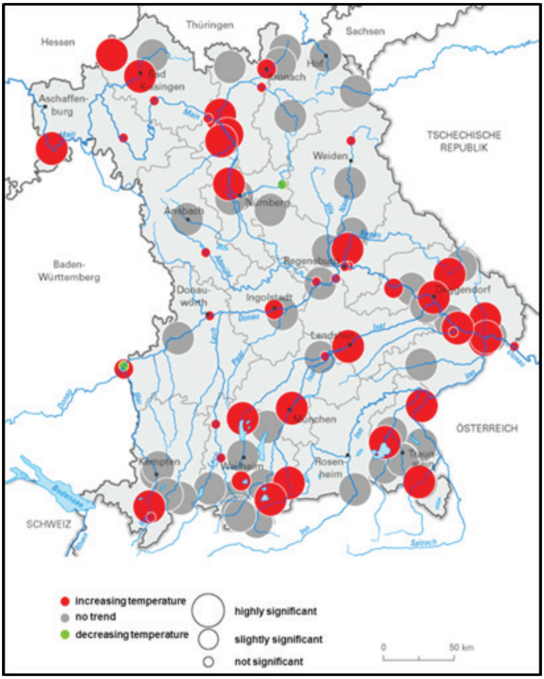

Fig. 1: Trend of the mean annual water temperature between 1980-2010

3.2 Approach to water temperature projections for the future

Based on the past trend in water temperature severe impacts on future water quality and thermal load capacities of rivers and streams might be expected. To produce water temperature projections based on regional climate projections, the Bavarian environmental agency developed the following approach. In 2008, a pilot study (Pöhler et al., 2009) was conducted as a first step, in the result aiming for the application of a statistical approach for water temperature modelling and a stepwise procedure for further tasks as shown in Figure 2. The subsequent blocks, namely the development of a statistical water temperature model focusing on individual gauges and the development of a statistical disaggregation model for the entire course of rivers have been already realized. Recently, the analysis of water temperature projections based on regional climate projections is in progress.

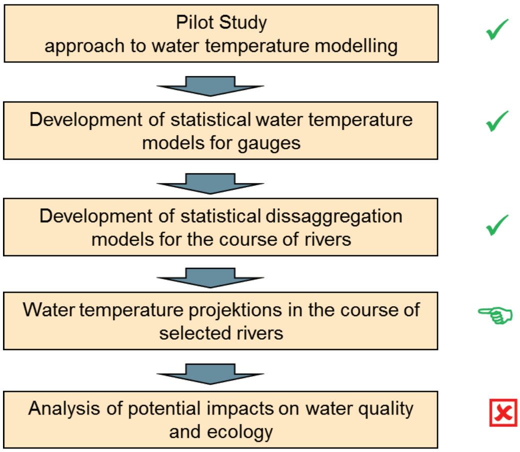

Fig. 2: Approach to assess the impact of climate change on water temperature and consequently on water quality and ecology

Within the second block in Figure 2 different statistical approaches for the gauge based modelling of water temperatures were tested (Willems & Stricker, 2011) and resulted in the development of so called „custom made" models for 130 Bavarian gauges. This approach is based on a refined method after Almon (Distributed-Lag-Model), employing subsequent time steps of air temperature as the core element. At each measurement point an optimized set of explanatory variables (humidity, precipitation, wind speed, discharge etc.) was defined.

In the following step (block 3) various regression models and regionalization methods were tested to delineate the water temperature along the course of the rivers (Willems, 2013). The resulting modelling of approximately 15.000km flowlength of Bavarian rivers is based on equidistant grid points of 5km applied for first and second order streams and 2km for a selection of third order streams, respectively (Fig.3). After the evaluation of the different regression models via cross validation the principal component analysis revealed best results (RMSE: 1.5°C, Nash-Sutcliffe coefficient (NSC): 0.88, BIAS: 0.1°C). Nevertheless, the more simple regression model based on the relation of air and water temperature already reached very good results (NSC > 0.95, BIAS of 50 % of the measurement points < 1°C & 75% <1.2°C).

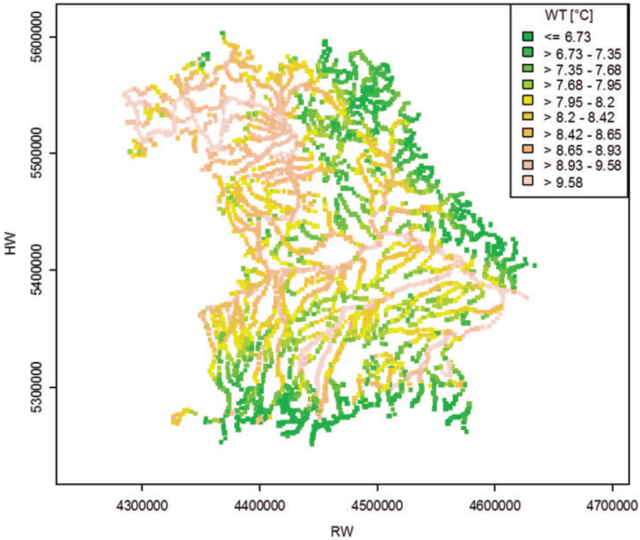

Fig. 3: Regionalized water temperature (8:00 am) in the course of Bavarian rivers and streams

4. Conclusion

The quality of the developed statistical water temperature-models is clearly sufficient for the application of input-data from regional climate projections. Thus, the derivation of climate change signals in water temperature is the next step and actually in progress. Therefore, three dynamical regional climate projections were selected, representing an upper, middle and lower scenario of the published signal range of air temperature change. These results are the basis for further analysis and modelling of the future water quality and ecology.

In addition, the gauge based statistical models are practicable for an operative water temperature forecasting system. As a further useful output, the regionalized mean water temperature in the course of rivers and streams of present time series are actually used as a database for ecological issues and input data for heat capacity modeling of streams.

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Transboundary collaboration on a Global Change Atlas of water resources, agriculture and renewable energies in the Danube Region

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Abstract
A newly founded networking project is working on the establishment of a collaborative research network to develop a digital Global Change Atlas of the Danube Region (GLOCAD) that will mainly focus on issues relevant to the macro-regional EU Strategy for the Danube Region (EUSDR). Therefore, our project aims at the improvement of the cooperation between institutions in the region and the exchange of knowledge on land and water management, potential changes in land use, climate as well as ecosystems and their services to society. The network shall develop common methods to monitor, map and model the actual and future state of water resources, agriculture, energy production and ecosystems in the Danube Region, using state-of-the-art remote sensing, simulation models and information technologies. This shall also lead to the assessment of communities' vulnerability and adaptation potentials to Global Change. Ultimately, common ways to analyze, communicate and disseminate information, from both own research and other sources, via a spatially explicit, digital and integrative platform will be developed and applied.

1. Introduction
The Danube Region, through its diversity and complexity offers as many possibilities for development as many challenges. Different patterns of economic development, social contexts, legacies and cultural identities, along with long standing or on the contrary, unstable political and institutional settings have been generating significant regional disparities between the affluent upper and the lower part of the Danube River Basin (DRB).

The particularities of the countries in central and eastern part of the DRB are mainly given by the structural changes in economy, social life, politics and institutions, during the transition and post-transition period. Although, these countries share some common pillars of the transition process, (e.g. privatization, institutional reforms, economic sectors restructuring, readjustment of foreign investments, etc.), they did not evolve equally during this process, on the contrary, each being characterized by different development contexts. For instance, in Romania, the industrial restructuring and privatization process and the newly emerging sectors, such as tourism or IT, have imposed new patterns of development. Likewise, Romanian agriculture has undergone different dynamics, passing from highly fragmented family-owned farms, in the first part of the transition period, to larger, commercially-oriented agricultural holdings, although spatial differences do exist. These types of changes have led to new governance forms of land resources and rural development policies.

Under these circumstances, the governance of water resources, land and renewable energies, at regional and national levels needs to be flexible, innovative and robust enough in order to cope with and adapt to external and endogenous drivers of global change and to respond to peoples' demands for well-being and economic growth. UNEP (2011) has introduced the term of 'green economy' to define the necessity to progress toward sustainable development by "improving human well-being and social equity, while significantly reducing environmental risks and ecological scarcities". Such a process calls for transformative policies and strategies in the management of natural resources.

2. Main issues

The scope of the GLOCAD network is to seed the establishment of integrative research projects to assess pressures and chances driven by Global Change in the Danube Region. Moreover, transdisciplinary research practices will make the core of a deliberate collaborative framework between academia/research institutes and different levels of stakeholders that share interests for resource management and economic and societal development in the DRB. This approach enables the co-design of the research objectives to target societally-relevant questions, followed by the co-production of knowledge which ultimately forms the solution-oriented answers to the societal problems. (Lang et al., 2011; Mauser et al., 2013). To this end, the key research question that steers the discussions within GLOCAD refers to the impacts of Global Change on the availability and use of natural resources and ecosystem services along with the associated societal implications in the DRB. Hence, we focus on building a) a transboundary collaborative research team, b) knowledge production through integrative models, methods and analyses, and c) information communication and dissemination.

2.1 Collaborative research

Interdisciplinary research along with an active involvement of stakeholders from regional to local level into the production and development of the knowledge needed is a prerequisite for assuring equitable and sustainable future development trajectories. In this respect, the Danube Region could benefit from a strengthened cooperation among various profile institutions in order to tackle in an integrative way, the key problems of water and land management, changes in the ecosystem functions and service, consequences of climate change on society, etc.

Increasing the competitiveness of the Danube Region is strongly related to the improvement of the cooperation among countries in many priority areas, such as assuring a viable and sustainable ***agriculture***, preserving ***biodiversity***, implementing effective water management and governance, reducing ***pollution*** and danger from ***floods***, lowering dependency on ***energy*** providers from outside the Region, designing sustainable ***urban development patterns*** or addressing ***demographic change*** (European Commission, 2010). All these areas could not be addressed from a standalone point of view; they need to be connected with one another through the existent flows at the DRB level (e.g. environmental flows, material flows, mobility of people, etc.). In order to do so, GLOCAD participating members aim at developing sound and reliable development scenarios for the next 50 years by integrating expertise and available methods from different disciplines and countries (Tab. 1).

Moreover, addressing the priority areas and plausible futures of the region through scenarios and storylines, and subsequently through management options and intervention strategies, implies a close collaboration with interested groups of stakeholders from the very beginning. Such a condition is particularly necessary to identify key problems that have to be addressed and to find common potential solutions in order to envision sustainable development patterns. Additionally, country-specific knowledge and understanding of particularities impose a tight collaboration of all the partners in the network. Likewise, harmonizing different disciplines' concepts and ideas, as well as dealing with methodological integration can be a challenge. This requires finding mutual grounds of scientific communication and developing common frameworks for problem evaluation and methods applicability.

Tab. 1: Current GLOCAD network project partners.

Romanian Academy of Sciences, Institute of Geography	Bucharest	Romania
Academy of Sciences, Department of Geography	Sofia	Bulgaria
University of Zagreb, Faculty of Agriculture	Zagreb	Croatia
Technical Univ., Land & Water Resources Management	Bratislava	Slovakia
Univ. of Life Sciences, Department of Land Use & Improvement	Prague	Czech Republic
Szent István University, Institute of Environmental Sciences	Gödöllő	Hungary
Jaroslav Cerni Institute for the Development of Water Res.	Belgrade	Serbia
University of Natural Resources & Life Sciences	Vienna	Austria
Ludwig-Maximilians-University, Department of Geography	Munich	Germany
University of Hohenheim, Faculty of Agriculture	Stuttgart	Germany
Leibniz Supercomputing Centre	Garching	Germany

2.2 Knowledge production

The use of complex simulation models to anticipate the impacts of changes and the trade-offs between the development of different sectors of activity and the use of resource/ecosystem services is crucial. In this sense, datasets availability and integration, scale issues, calibration/validation and (parameter) uncertainties are important topics for discussion among the partners of the GLOCAD network.

The methodological approach will be based partly on the OpenDanubia system developed for the Global Change Atlas of Upper Danube (www.GLOWA-Danube.de) – a flexible framework to couple various models of different disciplines with the help of software tools such as UML (Unified Modelling Language) and PDC (Parallel Distributed Computing). On this basis, methods and models developed by project partners from the network can be integrated in a unified system (Mauser & Muerth, 2008). This integrative modelling and analysis approach will lead to a regional assessment of global change impacts on the availability and use of natural resources and potentially relevant adaptation strategies for society (e.g. Barthel et al., 2012). Undeniably, the complexity of the approached research themes represents a methodological challenge that requires sound assessment frameworks in order to deal with the integration of a broad variety of biophysical and anthropic indicators of different environmental and socioeconomic contexts (Turner et al., 2003; Balteanu & Dogaru, 2011).

2.3 Information dissemination

A Global Change Atlas of the Danube Region is not only a tool for decision-making and the general public, but also a product that highlights the benefits of integrating scientific knowledge and expertise for sustainable and efficient management of water, land and energy resources. At the same time, it will raise awareness upon the positive and negative consequences of global changes on natural resources. It is innovative in the way that it offers potential development scenarios to guide stakeholders' decisions considering multiple factors. In this respect, the focus should be given to the effects of climate and land use change on economic activities and society, as well as on the occurrence and intensity of natural hazards, taking into account the significant regional differences of adaptability and resilience within the Danube Region. Stakeholders' input is an important aspect in the co-creation of knowledge. This is done at an early stage of project development through a dissemination strategy adapted for professional and non-professional stakeholders, while the specific outcomes will be tailored for their use and applicability. In this respect, the research outputs will be synthesized as summaries for policy-makers, taking into account the requirements for effective addressed policies, the particularities of the governance system (e.g. structure of the institutions and agents, governance principles, etc.), as well as the co-produced intervention or management strategies.

3. Conclusion

The "Global Change Atlas of the Danube Region" will provide Spatial Scientific Services (SSS) for a wide variety of socially and environmentally pressing issues related to water, food and energy, in accordance with the priority domains of the EU Strategy for the Danube Region. These services consist of detailed standardized tools and digital maps of the Danube Region, which make accessible the scientific analysis not only of the current state and use of natural resources like water and soil, but also of potential future developments. In this respect, scenarios of climate change, economic and demographic development, as well as different existing and expected EU regulations will be considered along with specific needs of different stakeholders groups. The refined, spatially explicit information will be accessible to politicians, heads of the EUSDR priority areas and decision-making stakeholders from local, regional and national level, but also to the general public. Similarly, the Global Change Atlas initiative concurs with the new research agenda of Future Earth on Global Change, emphasizing research on transformative scientific knowledge and sustainability.

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RESTORATION OF DANUBE FLOODPLAIN, A DELICATE PROBLEM

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AQUAPROIECT

Abstract

The paper reviews the way Danube Floodplain was in the past and how it was developed 40-50 years ago. The paperwork shows the way the hydraulic parameters of Danube water flow changed in the last approx. 25-30 years as a consequence of the massive anthropic impact on the hydrographic basin and the impact on the minor riverbed. The change of meteorological regime parameters and their impact over the surrounding environment are also analyzed.

An overview of their problems is made based on the simulation, on mathematical model of floods spread in 1970, 1981, 1999, 2000, 2005 and 2006 and on operative technical reports regarding the behavior of these hydrotechnical works during floods, and also the main issues raised by floodable objectives on the left Danube shore and some analyzed solutions for diminishing the damages are shown within the paperwork.

1 General aspects of Danube Floodplain scheme in Romania

The Danube Floodplain in Romania was embanked during 1960-1966, on 1.500 km, and protecting approx. 425.824 ha divided in 53 enclosures. The dikes have an average height of approx. 4m. Depending on enclosures size and protected objectives, the calculus debits correspond to some probabilities of overflowing of 10% (31 enclosures with a surface of 47816 ha), 5% (17 enclosures with surface of 213031 ha), 2% (4 enclosures with surface of 93127 ha) and 1% (an enclosure of 71850 ha surface). The crown level was established on approx. 1.5m above calculus level. Protected objectives are: approx. 12500 households, 145 social and economic objectives, approx. 900 km railroads and approx. 80 km of road. As proportion, 40% of embankment surface are located on sector Iron Gates II (km 863.4)- Calarasi (km 379.5) and approx. 60% downstream of Calarasi. The current use for Danube Floodplain: land for agriculture increased approximately twice, lakes and ponds surface decreased of 7.5 times, unproductive lands and those with constructions decreased approx. 3.5 times and the forests decreased from 64332 ha to 1727 ha. At the beginning of last century the forests represented approx. 25-30% of Danube Floodplain surface and at the middles of '60s they were 12-14%.

The works in dammed enclosures were irrigations (211772 ha.), draining (324574 ha.), fishery (14702 ha.) and rise plantations (28871 ha). In current conditions, the restoration issue on a surface of 75439 ha (8 enclosures) and/or using 12 enclosures with a surface of 193111 ha for flood mitigation show several aspects which question the practical utility of such actions.

In any case, the new regime must be controlled because it shall consider the followings:

- Annual average temperatures increased in the last 50 years (accentuated in the last approx. 20 years) with $0.5^0 – 1^0$ C and precipitations decreased with values between 38 mm at Turnu Severin (km 931) and 152 mm at Tulcea (km 71.6), draughts frequency increased (more than half of the years) and the forests disappeared. This led to an alarming tendency of the area to turn into a desert one;

- Important morphological modifications occurred in major riverbed by covering (levelling) most lakes and ponds, loss of water circulation ways between Danube and lands (ponds and lakes) within the Floodplain;
- In minor riverbed: low flows period increased, there is a tendency of dropping the riverbed and the deposits increased (the dredging intensified). This fact determines a difficult circulation of water between river and major riverbed;
- Soil structure in enclosures changed due to work technology in agriculture;
- Currently there is the possibility for irrigation in favorable conditions of soil within the Danube Floodplain;
- Construction areas of localities have expanded, unauthorized, within floodable area of Danube Floodplain. Inadequate materials were used (clay mixed with hay and manure) for houses construction;
- There is a habit of local population to intensively use the dikes crown for circulating with tractors and trucks;
- Inutility of using most of these enclosures for mitigating maximum debits of floods for the following reasons:
  - The only objectives which rise some problems of flood protection are Braila (km 169.7) and Galati (km 150) municipalities, but only under hypothesis where there are high floods on Siret and Prut rivers and there is an accordance with floods on Danube(see flood of 2010). The enclosures with high potential of flood mitigation (and with mitigation effects over the two objectives) are “Insula Mare a Brailei” and “Balta Ialomitei”. “Insula Mare a Brailei”(approx. 72000 ha) located right upstream of the two objectives, was provided since technical design for floods mitigation of the two objectives. The dammed enclosure can’t be used at the moment because is an important agricultural area. “Balta Ialomitei” (approx. 59300 ha) is located downstream of Calarasi and just upstream of “Insula Mare a Brailei”. It can’t be used because in it is a protected area and numerous strategic objectives such as railways, high tension lines and gas pipes networks.
  - The large volumes and periods of flood on Danube which can reach several months (flood of 1970), impose serious issues regarding security and utility of using these enclosures for flood mitigation 1% because: floods volumes can be much higher than their storage capacities, there are high risks of infiltrations through and under dikes, frequent erosions occur on shores and dikes. Also there is a very high probability that after flooding the water will remain in the enclosure up to 1 year (see 2010);

- In judgment of those who militate for a more “substantial” change of actual scheme of Danube Floodplain one can’t find the preoccupation for resolving two of the vital world issues: water and food sources.

2 Issues followed within the paper works

2.1 Damages caused by flood of 2006

The flood in 2006 on Danube downstream of Iron Gates was one with maximum flow according to a constant overflow probability of approx. 1% on the entire route of Danube to Galati locality (16000-16500 m^3/s). The average debit from which starts the flooding in natural regime is 9000-11000 m^3/s. Over this average debit (approx. 10000 m^3/s), floods volume from 2006 at Iron Gates was approx. 12-13*10^9 m^3 and its duration of approx. 3 weeks. Considering the design and execution of enclosures, the maximum flow value, the relatively short period of flooding and the fact that the 4 enclosures (Ghidici- Rast-Bistret, Dabuleni-Potelu-Corabia, Oltenita-Surlari-Dorobantu and Ostrov-Frecatei) ceded due to infiltrations, the entire flood's damages were reduced. Along the approx. 1500 km of embankment, the highest recorded damages were: 340 houses of which 200 destroyed in Dolj county (km 738-666), 130 houses in Constanta county (km 340) and 150 houses damaged in Tulcea county (km 100-1). In Braila (km 170), Galati (km 150) and Tulcea (km 72) municipalities the damages were minor and were caused by sewage repression.

2.2 Modifications of some hydrologic parameters of water flow on Danube River

The main modifications of some hydrologic parameters of water flow on Danube refer to reducing the value of solid flow in percentages varying from 90% downstream of Iron Gates to approx. 60% at Ceatal Izmail, reducing the dimensions of alluvia from riverbed ($d_{50\%}$), increasing the degree of torrential water leak on the Danube and the tendency of decreasing the liquid average annual debits in minor Danube riverbed.

2.3 Modifications of some morphological parameters of Danube riverbed

After massive scheming some water courses in Danube basin in the last 60 years, the high development of navigation on Danube with a maximum of approx. 60*10^6 tone/an during 1975-1985 and after obvious changes of climatic regime parameters it occurred important modifications of morphological parameters in Danube riverbed, among which we mention: the tendency of lowering the levels on which are found usually low debits $Q \leq Q$ multi-annual average (5500-6500 m^3/s), an alarming increase of shore erosion phenomena leading to a diminution of distance dike-shore (with average distance shore- dike of 250m) and a tendency of accentuation the alluvia deposit phenomena, especially around cogging, which demands an increase of drain operation on the navigable channel. For example is mentioned that in section Giurgiu (km 492.8) the corresponding level to flow of 3500 m^3/s dropped during 1953-2002 with approx. 1m and at Calarasi the correspondent level to the same flow dropped during 1970-2003 with approx. 0.5m.

2.4 Simulating the flow propagation in 1970, 1981, 1999, 2000, 2005 and 2006 on Danube river and the effects of various planning scenarios of Danube Floodplain over debits and levels regime

For verifying the effects of embankment on Danube and effects of some re-planning of Danube Floodplain over maximum flood debits and levels, a 1D model in propagation of a number of 6 real floods (1970, 1981, 1999, 2000, 2005 and 2006) was used. The simulation was conducted both in several scenarios: current situation (floodable enclosures), total elimination of dike enclosures, using the enclosures as temporary lateral accumulations (controlled mitigation) and using the enclosures both for mitigation in uncontrolled regime (similar to the way the 4 enclosures on Danube ceded during 2006 flood). The main observation is that the large enclosures "Insula

Mare a Brailei" and "Balta Ialomitei" weren't used for simulating flood mitigation. The simulation results indicate that the de-mitigation produced by these dikes over the flow and levels regime are the following: increases of approx. 0.8-0.9 m at Galati and approx. 0.5m at Calarasi. The de-mitigation produced by embankments over maximum flow at Calarasi is of maximum 10% (approx.. 6% in average). The effects of total dike elimination on sector downstream of Iron gates- Calarasi show a mitigation of current maximum flows of approx. 10%. Thus at Calarasi the flood debit of 2006 will drop from 16.500 m3/s to 15.300 m3/s.

3 Conclusions

- The issue of restoration the Danube Floodplain on Romanian territory is a very delicate one and must approached with great attention in the context of new climatic, morphological and hydrological conditions and not the least in the context of new problems existing worldwide: water and food. All these aspects shall modify profoundly, in a realistic way, the simplistic and full of enthusiasm thinking of returning, at any cost, to the "natural regime"

- The only objectives which may have issues when occurring a debit with overflow probability of 1% on Danube river are Braila and Galati municipalities and that's only in case there is a coincidence of floods on Danube river with floods on Siret and Prut rivers. The issue of protection against floods of these objectives would require an update because at technical design phase of Danube Floodplain by embankment (1960-1962), the accepted solution was the one using Insula Mare a Brailei.

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Sustainable Water and Land Management Strategies for Avoiding Water Stress in Agro-ecosystems

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Abstract
In the majority of world agro-ecosystems water relations in the soil-plant continuum are not optimal during the vegetation period. Hence, agricultural crops are usually exposed to one or both (at various times of a growing season) of the water imbalances such as water scarcity (deficit) and/or waterlogging/inundation. Both water stresses endanger food production, often contributing to various additional constrains (soil salinity/alkalinity, organic matter depletion). Managing the optimal water relations in the root zone in the agro-ecosystems is becoming increasingly challenging due to global climate change and variability, deterioration of environmental resources, as well as insufficient investments in the management of the land and water resources in croplands. Under waterlogging conditions crop production can be efficiently improved by implementing an adequate drainage system(s), currently in existence on ~200 Mha world-wide (mostly on hydromorphic and/or halomorphic soils). Given the complexity of waterlogging and the related constrains (e.g. shallow groundwater table, non-uniform soil stratigraphy, poor soil permeability), one of the most promising remedial strategies was shown to be a combined drainage system (open drainage channels and tile drainage, e.g. central and south-eastern European agro-ecosystems) with additional periodic land measures (mole draining, deep ripping). Modern sustainable agricultural strategies for water-deficient conditions, either in irrigated or rain-fed agriculture, are directed at managing the natural potential of agro-ecosystems, with the aim to improve the efficiency of water resource usage. Irrigation and conservation agricultural practices are currently implemented world-wide on around ~300 Mha and ~120 Mha respectively. Even though irrigation is one of the most effective strategies against the water deficit, it is unlikely it will be implemented on increasing acreage in the future because of strong competition for good-quality water, but there are opportunities for improved efficiency of water usage (e.g. transition from traditional to more efficient modern irrigation systems).

1. Introduction
In agriculture water scarcity is often equalized with drought. However, while drought implies a temporary decrease in water availability, water scarcity assumes that water demands exceed the sustainable exploitation of available hydro-resources in the long-term. In agricultural production, water scarcity assumes dysfunction (stress) in accessing (readily available) rhizosphere moisture, its uptake and transport through the plant and finally through stomata to the atmosphere, i.e. evapotranspiration (ET) (Ondrasek, 2014). A difference between effective precipitation and potential ET of crops represents the irrigation (crop) water requirements (Table 1) (Bos et al., 2009). Conditions for obtaining the potential ET can be achieved under well-watered rhizosphere (with enough readily available soil water), whereas in other cases, the actual value of ET will be lower than the (maximal) potential, and as a direct consequence will be obtained a certain yield reduction (Table 1).

Tab. 1: Crop (irrigation) water requirements and yield reduction for the average and the dry (25% probability of precipitation) conditions (1981-2000) in continental (based on 9 official meteorological stations) and Mediterranean (based on 6 official meteorological stations) Croatian ecosystems. Yield reductions (in the case without irrigation practice) were calculated for two soil types: texture-lighter (total available soil moisture = 80 mm up to 1 m depth) and texture-heavier (total available soil moisture = 140 mm up to 1 m depth)

Ecosystem	Crop	Irrigation requirements mm		Yield reduction %			
				Texture-lighter soil 80 mm/m		Texture-heavier soil 140 mm/m	
		Average	Dry	Average	Dry	Average	Dry
Continental ETo=690-820 mm Peff=521-890 mm	Corn	81-191	168-314	9-36	33-67	2-28	24-61
	Sugar beet	116-260	226-383	10-38	34-64	3-30	26-58
	Tomato	98-191	174-286	14-39	35-59	8-30	28-54
	Apple	59-196	164-328	3-27	24-55	0-23	19-48
Mediterranean ETo=883-1390 mm Peff=650-1085 mm	Corn	219-511	306-634	38-75	59-95	31-70	53-92
	Sugar beet	286-606	381-725	39-71	58-87	33-66	53-83
	Tomato	229-478	294-578	41-69	56-85	35-65	49-82
	Apple	214-503	315-644	28-54	47-71	24-51	42-67

2. Perspectives for avoiding water stress in agriculture

Irrigation is one of prerequisites for stable and high-quality crop yields, principally during drought seasons and for arid areas (FAO, 2012). Among traditional and modern irrigation systems there are many significant differences in their operational (technical) and environmentally-related characteristics, as well in water consumption, i.e. water-use efficiency (WUE) (Fairweather et al., 2002). Traditional surface gravity-flow methods in comparison to modern irrigation systems (e.g. drip and/or low-pressure sprinklers; Figure 1, 2) have substantially lower (up to 2-fold) WUE for instance. Also, Improved WUE in the irrigated fields can be obtained by choosing optimized irrigation management strategy, which assumes maintenance of the rhizosphere moisture: 1) close to the range of readily-available water (around the field capacity) to meet the full crop ET demands or 2) at relatively low soil water potential, i.e. below the full crop ET. For instance, regulated deficit irrigation (D) and partial rootzone drying (PRD) irrigation strategy (Figure 1) can improve WUE by 45-50% compared to irrigation strategy where soil water was maintained >80% of the field capacity. These two strategies are based on different concepts: in DI water application is manipulated temporally, and in RDI spatially. In humid to temperate areas supplemental irrigation strategy is used as a tactical measure to complement reasonably ample rainfall and stabilize production, and generally may be one of precautions ensuring stable and continuous yield in next vegetation (e.g. irrigation during the drought period at time of initialization of generative buds will positively impact the yield in fruit crops next year).

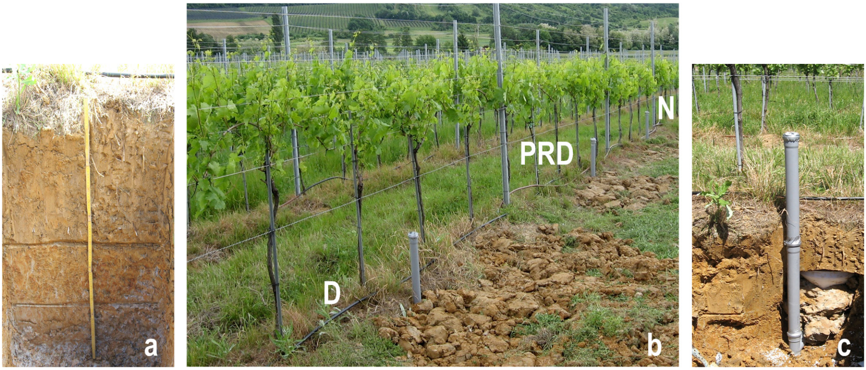

Fig. 1: Implementation of different irrigation strategies in vineyard on Luvisol (a, b) (D – deficit irrigation, PRD – partial root zone drying, N – non irrigation) and tracing of their impacts over the soil profile by lysimetric observation (c) (Petrovina, Zagreb County, 2013)

Some improvements in land management or shifting to new cropping systems is another possible and widely used strategy in combating water stress and some other accompanied soil constrains (low water retention capacity, high ET demands) or land degradations (organic matter depletion, desertification, salinisation) on (non)irrigated areas (Figure 2; Ondrasek et al. 2011). Implementation of some land conservation practices (from reduced or minimum to zero tillage) are increasingly used worldwide with an aim to restrict loses of topsoil water and/or alleviate some other soil constrains (>70 Mha) (Ondrasek and Rengel 2012). By leaving at least 30% of the crop biomass on the soil surface, conservation tillage (Figure 2) prevents soil wind/water erosion and positively impacts most soil characteristics important for the soil water retention.

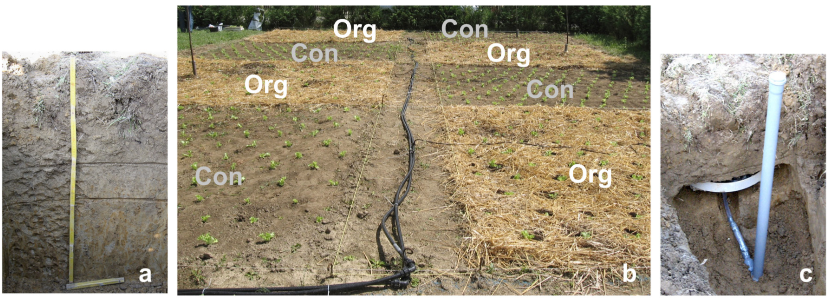

Fig. 2: Implementation of micro-sprinkler irrigation on Pseudogley (a, b) in different cropping systems (Org – organic and conservation agriculture with straw mulch; Con – conventional agriculture) and tracing of their impacts over the soil profile by lysimetric observation (c) (Novaki, Zagreb County, 2013)

Namely, stable soil structure (crucial for subsurface water flow) and medium soil texture (crucial for good water-holding capacity) are key determinants of water infiltration rates and the amount of readily-available water within the root zone. Organic matter generally improves soil structure and water-holding capacity, but also its functions in food safety/security as well protection of hydro-resources from metal contamination might be of great interest (Ondrasek and Rengel, 2012).

3. Conclusion

Over the last several decades the availability of freshwater in many rainfed/irrigated agro-ecosystems decreased to critical levels. In the next few decades, given the global climate variability (likely to comprise more frequent and more severe droughts and heatwaves, higher variability in precipitation distribution), accompanied by growing human population, the most relevant projections predict altered hydrological regimes in the terrestrial ecosystems, i.e. reduced availability of freshwater for agro-ecosystems. Besides numerous water and land management strategies for alleviating water scarcity (stress) in food production (implementation of the most efficient irrigation systems, land conservation techniques, precise farming), a great potential also exists in 1) enhancing the capacity for food handling and 2) serious reconsidering (changing) market-consumer relations.

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Impacts of Climate Change on the Water Resources and Adaptation Measures in the Danube River Basin – the ICPDR Strategy on Adaptation to Climate Change

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Introduction

Global Change is expected to have various impacts on the water resources of the Danube River Basin (DRB). Consequently, water use will be affected in the DRB which provides water resources for 83 million people in 19 countries. In order to provide a basis for the development of appropriate adaptation measures and strategies to be prepared for future changes in the DRB, the International Commission for the Protection of the Danube River (ICPDR) already adopted a Strategy on Adaptation to Climate Change in 2012 (ICPDR 2012), following the Danube Declaration (ICPDR 2010). The data base and the methods of assessing the regional impacts of climate change and adaptation activities in the Danube River Basin on the way to the ICPDR Adaptation Strategy will be explained.

1. Climate Change Impacts in the DRB

In order to identify climate change impacts on the different fields of the water sector for the entire DRB and its sub-regions, ongoing and finalized research and development projects as well as studies dealing with climate change in the DRB or parts of the basin were analyzed (Prasch et al. 2012). Firstly, the spatial coverage, the studied time period and the applied methods were considered in the analysis. Mainly the periods from 1961 to 1990 and from 1971 to 2000 were studied as reference period. As future period mainly the near-time period from 2021 to 2050 and the far-time period from 2071 to 2100 were chosen, but also the period from 2010 to 2039 was considered by some projects.

Next, the water-related impact fields were analyzed. Future trends of climate parameters were compiled, followed by possible effects on extreme hydrological events, on water availability and quality. Possible impacts on different types of water use and land use like water supply and demand, agriculture, irrigation, navigation, water related energy production and forestry were considered. Finally, impacts on biodiversity, ecosystems, soils/erosion, limnology and marine coastal zones were composed in the field of ecology.

In the scenarios of all analyzed studies, a temperature increase until the end of the century is to be expected for the entire DRB with low uncertainty, differing between 0.5 and 2 K under SRES IPCC A1B and A2 conditions. Particularly the south-eastern DRB is expected to become much warmer than in the past. The increase is most pronounced in the second half of this century, so that the increase rises to values between 2 an 5 K. The annual and the summer increases are likely to be larger than the winter increase. In summer, the changes are more distinct and are likely to reach values up to 6 K in the south-eastern DRB at the end of the century.

The DRB is located in the transition zone between expected increasing (in Northern Europe) and decreasing (in Southern Europe) future precipitation, which results in a medium agreement in certainty of the analyzed studies. Although the mean annual precipitation amount will almost remain constant, the northern DRB will gain more precipitation while in the southern parts less precipitation is expected. However, seasonal changes in future precipitation will be large according to the analyzed projects. While in summer a decrease is projected, in winter an increase of precipitation is likely to happen. Higher temperatures in winter will also affect the amount of rain and snowfall. Instead of snow, it might rain more often and, together with an earlier beginning of snow melt, the snow cover is expected to decrease and the snow season thus becomes shorter at all altitudes. However, some findings for mountainous areas state no trend or even a slight increase of snow fall due to a possible increase in winter precipitation.

For the whole DRB a future increase of extreme weather events is expected. The study results show both a future increase in intensity and frequency of dry spells, hot days and heat waves, and local and regional increases in heavy rainfall.

The potential future climatic conditions in the DRB will impact on the water resources and on the water-related fields. Reduced water availability in general, reduced groundwater recharge and a reduced soil water content are likely consequences. Furthermore, the seasonal runoff regime is expected to change. Future changes in rainfall distribution, evapotranspiration and reduced snow storage trigger a decrease in summer runoff and an increase in winter runoff. While there is no clear picture for changes in flood magnitude and frequency, more intense, longer and more frequent droughts, low flow and water scarcity situations are expected. A likely increase of water temperature together with reduced water availability is likely to cause a decrease in water quality.

Climate change also will cause changes in water use. A rising water demand of households, industry and agriculture is expected and will lead to higher water stress in the water dependent sectors such as agriculture (irrigation!), forestry, navigation and water related energy production. Changes in ecosystems and biodiversity with shifts of the aquatic and terrestrial flora and fauna are also likely. Besides all the negative effects, positive effects are also possible consequences of climate change as for example the reduction of ice days on rivers or longer vegetation periods.

2. Adaptation measures in the water sector of the DRB

Based on the likely climate change impacts in the DRB possible win-win and no- / low-regret adaptation measures are extracted from existing adaptation activities in the DRB such as National Adaptation Strategies, which were analyzed to find communalities, options for cooperation and challenges among the countries of the DRB. Suggested adaptation measures for the DRB, focusing on basin-wide measures, where transboundary cooperation seems to be useful, are presented for different categories following UNECE (2009) and EEA (2010) in Table 1.

The smoothly formulated measures allow various realizations. However, the measures not only have overlapping fields and linkages between the categories, but they are also linked between affected sectors and other relationships such as upstream – downstream dependencies. Positive and negative effects among them might arise and conflicts might occur, even though the selected measures are no- / low-regret or win-win-options, so that they have positive effects whatever the extent of future climate is, or other social, environmental or economic benefits are also met (UNECE 2009). Besides the presented measures, there are almost innumerable options for adaptation to climate change, particularly for distinct sectors. Coordination among the Danube countries could be useful, but is not required in several cases, so that the implementation on the national or regional level might be sufficient.

Tab. 1: Suggested adaptation measures in the DRB (ICPDR 2012, p. 23f).

Category	Adaptation measures
Preparation measures	Additional, intensified monitoring activities to follow and assess climate change and climate change impacts
	Homogenous data production, digital mapping and a centralized database for data exchange and comparability among regions and countries
	Identification of potential risk areas and hot spots
	Implementation of forecasting and warning services (e.g. for extreme events such as floods and droughts)
	Development of action plans or integration of specific issues into ongoing planning activities (e.g. to deal with water scarcity and flood situations)
	Further research to close knowledge gaps, determine vulnerability or reduce uncertainty
Ecosystem-based measures	Taking environmental implications and the conservation of biodiversity into consideration in all other measures
	Sustainable management of land use practices for improving resilience, and for enhancing the capacity to adapt to climate change impacts
	Implementation of green infrastructure to connect bio-geographic regions and habitats
	Protection, restoration and expansion of water conservation and retention areas
	Rehabilitation of polluted water bodies
Behavioral / managerial measures	Support education, capacity building, awareness raising, information exchange and knowledge transfer
	Establishment of and support for an integrated risk management
	Support of a water saving behavior
	Propagation of best practice examples
	Application of sustainable methods (e.g. good agricultural practices)
Technological measures	Adjustment of (existing) infrastructure, e.g. construction and modification of dams and reservoirs for hydropower generation, agriculture, drinking water supply, tourism, fish
	Development and application of water-efficient technologies
	Efficient waste- and sewage-water treatment and water recycling
Policy approaches	Support of an institutional framework to coordinate activities
	Harmonization of international, basin-wide legal limits and threshold values
	Implementation of restrictions (e.g. for development in flood risk areas)
	Expansion of protection areas (e.g. for drinking water resources)
	Adaptation of policies to changing conditions

3. Discussion and Conclusion

Climate change will impact on the water resources in the DRB following the analysis of existing studies and research and development projects. Although there are several uncertainties in the analyzed studies, in their results and in scenario results in principle, this should not be a reason for doing nothing. There are possibilites to consider uncertainty in choosing adaptation measures of a different level and detail (e.g. more general measures, no-regret measures, win-win measures). In preparing an adaptation strategy to climate change impacts, further issues should be considered known from experience in preparing the Danube Adaptation Strategy. It is essential to create a common understanding among the people, organizations and administrations involved. Therefore stakeholders should be continuously integrated in the preparation process and an international and interdisciplinary team should work on the development of such a cross cutting issue. If already existing, an acknowledged, transboundary organization can take over the coordination to foster a joint action. Furthermore, the implementation of an adopted strategy should be a step-wise approach, considering upcoming changes and growing knowledge. Therefore a strategy can be seen as a living document with the aim to regularly update it.
The ICPDR Strategy on Adaptation to Climate Change was adopted in December 2012 and is available at http://www.icpdr.org/main/activities-projects/climate-change-adaptation together with the Danube Climate Adaptation Study.

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Ensemble simulations of climate change impacts on river flow characteristics of the Danube River and its tributaries

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Introduction

The Danube River is the second largest river in Europe with a catchment area of 817000 km^2. Climate change might not only alter long term average flows, but also affect the hydrologic regime and river flow characteristics on smaller scales. The future development of the river runoff conditions, as a consequence of climate change, is of great interest for stakeholders and decision makers in the riparian states. In many regions of the Danube catchment, like the Western Balkan states, not many studies using future scenario projections have been carried out so far. The goal of this study is to gain robust scenario information about future river flow characteristics in the whole Danube catchment using a uniform modeling approach.

1. Materials and Methods

For this study the eco-hydrological watershed model SWIM (Krysanova et al. 1998) was applied for the entire Danube river catchment considering 1224 subbasins. The SWIM model (Soil and Water Integrated Model) is a continuous-time semi-distributed watershed model, which combines hydrological processes, vegetation, erosion and nutrient dynamics at the meso to macro scale. As the Danube river basin is climatically heterogeneous, it is characterized by a changing-complex river runoff regime varying from nival regimes in the alpine parts to mainly rain feed regimes in the lowlands. To account for the climatically heterogeneous river regimes of the Danubian tributaries, the SWIM model was calibrated separately for the major river subbasins (see Tab. 1 for selected calibration and validation results). After calibration and validation of the model, this study uses a set of high-resolution climate change projections until the end of the 21st century performed by several state-of-art GCMs and RCMs, from the ENSEMBLES project (EU FP6) (van der Linden and Mitchell, 2009). They serve as meteorological drivers for the SWIM model to simulate future daily time series of river discharge under different climate scenario projections. The analysis was carried out with regard to the “climate change signal” focusing on the changes between the reference period 1971-2000 and the scenario period 2031-2060.
The Indicators of Hydrologic Alteration (IHA) (Richter et al. 1998) describe the environmental flow characteristics in a section of a river. Hence, different hydrologic aspects of the flow regime can be assessed. The hydrologic data series were statistically analyzed by using selected hydrological indicators to evaluate changes in flow variability and to characterize within-year variations in the stream-flow regime and in riverine habitat suitability. The first indicator set comprises the long-term changes in the magnitude of monthly water conditions (mean value for each calendar month). Additionally the frequency and duration of low and high flow pulses as well as the rate and frequency of water condition changes have been evaluated. The results are used to quantify the range of predictive uncertainty and to allocate robust trends.

Tab. 1: Results of Calibration and Validation for selected gauging stations

Gauging station	Calibration	Validation
Inn - Wasserburg	1961-1975 NSE 0.68	1976-1984 NSE 0.66
Danube - Achleiten	1961-1969 NSE 0.73	1970-1979 NSE 0.63
Morava/March –Moravsky Jan	1961-1969 NSE 0.74	1970-1979 NSE 0.73
Sava/Save – Catez I	1961-1969 NSE 0.63	1970-1979 NSE 0.65
Szamos/Somes – Satu Mare	1961-1969 NSE 0.68	1970-1979 NSE 0.55
Velika Morava – Lubicevsky Most	1992-1995 NSE 0.64	1996-1999 NSE 0.65
Siret/Sereth - Lungoci	1966-1974 NSE 0.63	1975-1983 NSE 0.63

2. Results

2.1 Hydro-climatic conditions

All applied climate projections show a clear warming trend for the whole Danube basin under the A1B Scenario towards the middle of the 21^{st} century. In the summer months the warming trend is less distinct in the upper basin and most pronounced in the southern parts of the lower Danube basin (more than 2°C in the mulit-model-average). For precipitation the multi-model mean indicates for the summer months a slight reduction in the alpine region and a stronger reduction in the middle and lower basin, most distinct in the Mediterranean parts. In contrary, winter precipitation is projected to increase, mainly in the northern areas of the Danubian basin as well as the Pannonian Basin, the Carpathians and the Transylvanian Plateau. A slight reduction in winter precipitation is projected for the Romanian lowlands. The Climatic Water Balance for the summer months indicates a reduction of water availability in the next decades all over the Danubian basin, the strongest in the Pannonian Basin, the Carpathians and the Transylvanian Plateau as well as the Mediteranean parts of the Western Balkans. For the Climatic Water Balance a slightly higher surplus is projected in the winter months, except in the lower basin where a slight reduction becomes visible.

2.2 Selected river stations

Out of the results for the 1224 simulated subbasins for the whole Danube, in this abstract the modeling results for a selection of runoff stations are presented below. Besides these selected examples, maps showing the whole multi-model-mean trends as well as the inter-model variability for the whole catchment have been produced.

Inn (Wasserburg):
For the nivo-pluvial regime of the Inn River (Switzerland, Austria, Germany), the simulated long-term changes in the magnitude of monthly water conditions indicate a significant increase in runoff, especially in winter (Dec, Jan, Feb). For the months April, May and June the model projections do not show a clear signal. The IHA-analysis shows a model agreement for a decrease in the high pulse counts, a slight decrease in the low flow durations as well as a clear increase of the fall rate.

Upper Danube (Achleiten):
For the Danube river station Achleiten (Switzerland, Austria, Germany) the scenario projections show a clear increase in winter runoff and a decrease in the summer months for the mid of the 21st century. The IHA-analysis reveals a reduction in the number (median) of low pulses while the high pulse counts show no changes in the median, but an increase in inter-annual variability. For the other IHA-indicators there is no clear agreement in the model projections.

Morava/March (Moravsky Jan):
For the Morava River (mainly Czech Republic and Slovakia) the SWIM-Model results project an increase in the mean discharge for the winter months and in the late autumn. Due to a projected increase in winter precipitation a more intense snow-melt driven spring runoff is simulated. The IHA-analysis shows a reduction in the low pulse counts (median and variability) as well as an increase in the inter-annual variability in the high pulse durations.

Sava/Save (Catez I):
For the Sava (Slovenia, Croatia), as pluvio-nival regime the modeling results indicate an earlier snow-melt and an increase in river runoff for January as well as a decrease in summer runoff in the multi-annual average. While the IHA-analysis shows no changes for the high and low flow duration the scenario projections agree on an increase in the number of low pulse in the multi-annual median and in the inter-annual variability.

Szamos/Somes (Satu Mare):
For the Transylvanian river Szamos/Somes (upper part of Tisza catchment) the multi-model projections indicate a clear increase in average winter runoff, earlier and stronger snow melt and a runoff decrease in April and May. The IHA-analysis reveales an increase in low flow duration variability, but no clear trend in low pulse count has been visible among the different climate projections.

Velika Morava (Lubicevsky Most):
For changes in the monthly water conditions the modeling results show a low agreement among the climate projections for the eastern Serbian river, but indicate a decrease in average spring runoff. The IHA-analysis exhibits no clear change sign in the projections for most indicators. But, the model projections agree on an increase in the low flow durations an increase in the median and the inter-annual variability.

Siret/Sereth (Lungoci):
The Siret River rises from the eastern Carpathians in the Northern Bukovina region. For the Siret the modeling projections show nearly no coherent signs or directions in the changes in the magnitude of monthly water conditions. However, the model projections agree in a projected increase in mean runoff for January and February. Most similar, the model projections disagree in the results for the other IHA-indicators.

3. Conclusions

Projected changes in temperature, precipitation and, hence, snowmelt regime influence spatially diverse the river flow regimes in the Danube catchment depending on regional hydro-geographical conditions. While a warming trend is robust among all climate models, regional precipitation projections are afflicted with a higher of inter-model uncertainty. As snow responds rapidly to slight variations in temperature, snow influenced catchments are robustly projected to experience earlier spring flood and in some cases higher winter runoff. The study indicates a progressive decline in water availability in the summer months for the mid of the 21st century for most of the areas, most pronounced in the Carpathian region, the lower Danube basin and the Western Balkans. The inter-model comparison of the different climate projections reveals which aspects of climate impacts to runoff regime are projected more robustly and which are affiliated with high uncertainties. The IHA-Analysis can give a deeper insight to changes in characteristic runoff patterns, like changes in annual low flow durations. In future, climate change is projected to become an additional driver altering river flow regime influencing presently known natural flow patters over larger scales and will interact with other anthropogenic alterations of river flow. In a next step, the recently available climate projection of the CORDEX project (COordinated Regional climate Downscaling Experiment) will be applied in the hydrological modeling framework to compare the results to the here applied ENSEMBLES-projections under the A1B scenario.

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Climate change in Ukraine and its impact on hydrological regime of rivers

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Introduction

There are shown the main changes of climatic characteristics which are observing on the territory of Ukraine and adjacent regions of neighboring countries. The most important among them is the increasing of air temperature during period from January till March. It causes the decreasing of thickness of frozen ground. In ones term it influences on water regime of rivers: there are observing the decreasing of discharge during spring flood and its increasing during dry seasons.

1. Climate change

Climate change in Ukraine and Belarus (on its territory are forming a large part of runoff of the largest Ukrainian Dnipro river) actually concerns all climatic characteristics: air temperature, precipitation, air humidity, wind velocity etc. [1–2].

The most famous is the change of air temperature. During observation period from the end of XIX century till nowadays the increasing of annual temperature makes up from 1.5 C^0 on the South of Ukraine to 2.0 C^0 on its North and in Belarus. The most essential increasing is observing during last two decades. The most worm year during observation period in Ukraine was 2007, in Belarus 2008 (fig. 1).

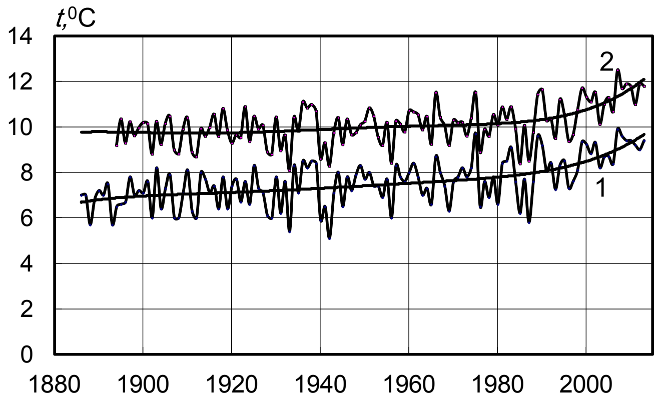

Fig. 1. The increasing of air temperature in Kyiv (1) and Odessa (2) during observation period from the end of XIX century

During period from 1990 the was only some years, when the annual temperature was less than norm. Thus, on the territory of Belarus in occurred only once – in 1996. In Ukraine it was observing some times, but previously in 80-th.

The largest increasing of air temperature is observing during period from January till March. Until 1990-th the increasing of summer temperature wasn't registered, but nowadays it is also observed. During two last decades from time to time are registering the meanings of highest temperature that had not been measured before. Thus, the modern meaning of the highest temperature in Ukraine is equal to 42.0 ^{0}C – it was measured in Luhansk city on August 12, 2010. At the same time the records with low temperature practically aren't observing (fig. 2)

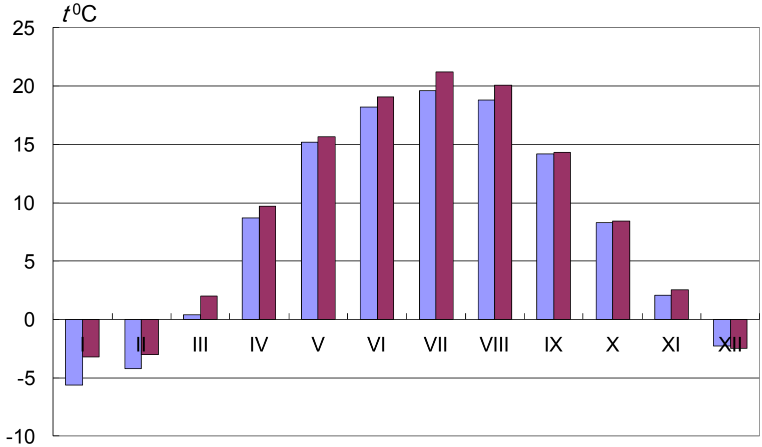

Fig. 2. The changes of air temperature in Kyiv city: left columns – during 1961–1990, right columns – during 1991–2013

The increasing of air temperature in winter is the main reason of dimension of thickness of frozen soil – it became 1.5–2.0 times less than in the middle of XX century.

Another characteristic, that changed greatly, is wind velocity – during last decades it becomes much less than before. In ones term the decreasing of wind velocity causes the dimension of evaporation: both from water surface and surface of ground.

2. Changes of hydrological regime

The climate change is the reason of correspondent changes in hydrological regime of rivers. The most obvious one is the changes runoff during some seasons: the maximum discharges of spring flood become less, simultaneously the minimum discharges (both winter low water and summer one) – become much greater [2].

The increasing of air temperature in spring is the reason the changes of date of maximum discharges – it became two-three weeks yearly than on the beginning of observation.

It is observing the essential changes of duration of ice cover and thickness of ice on the water objects. In both events they became much less than they was before. The main reason of it is the essential dimension of sum of negative temperature.

At the same time the temperature of water has the tendency to increasing. The most obvious increasing is observing during period of spring flood that is caused both dimension of discharges of water and increasing of air temperature.
Nowadays the highest water temperature in river can reach 38–40 ^{0}C. The highest meaning, that was measured, is equal to 40.3 ^{0}C.

The increasing of water temperature impacts on the quality of water. The content of dissolved oxygen during summer period very often has meaning 3–4 mg/dm^3 and less. But in November and December owing to absence of ice cover it has tendency for increasing and can reach 12–13 mg/dm^3.

3. Conclusion

There are observing the noticed changes of climatic characteristics on the territory of Ukraine and adjacent territory of neighboring countries. The main of them is the increasing of air temperature – the annual temperature increased on 1.5–2.0 C^0, that twice larger than in total on the Earth. The largest increasing of air temperature is observing during period from January till March. The climate change caused the decreeing of maximum discharges in spring and the increasing during dry periods (both in summer and winter). The increasing of air temperature during cold period caused the dimension of duration of ice cover and the thickness of ice.

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Spatial planning and sustainable approach in the case study of the river Drava floods 2012 near Duplek and Dogoše

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Introduction

The analysis of hydrogeographical characteristics of the landscape is the basis for the spatial planning in order to include also the flood protection in the planning process. The results of the hydrogeographical analysis allow us to delineate river's and the riparian areas directly from the field and it helps to determine the optimal land use and co-existence of water and society. The flood preventive measures significantly reduce the risk and these require only estimated 3% of the investment that would otherwise be used for the after-flood repair works and measures.

Long-time successful sustainable spatial planning is not based on hard construction approaches but rather on letting the water its natural space. When planning in the sustainable way, there is more space for water and more space for the society with less stress after unexpected flood events. The spatial planning in flood plains must take into consideration these natural-geographical characteristics to optimize the land use with flood adapted activities that can also economically withstand occasional flooding.

In the case study of the river Drava floods in year 2012 near towns of Duplek and Dogoše the visual analysis of land use over the last 2 centuries was made. Outlined are the land uses that in the last decades more or less ignored the hydrogeographical facts of flooding, mostly due to imaginative security that with the dams the river is fully controllable.

In the figures below the blue line shows the approximate high water line of fall 2012 floods. The lines are approximation also due to different scale and projection.

1. Situation around year 1770

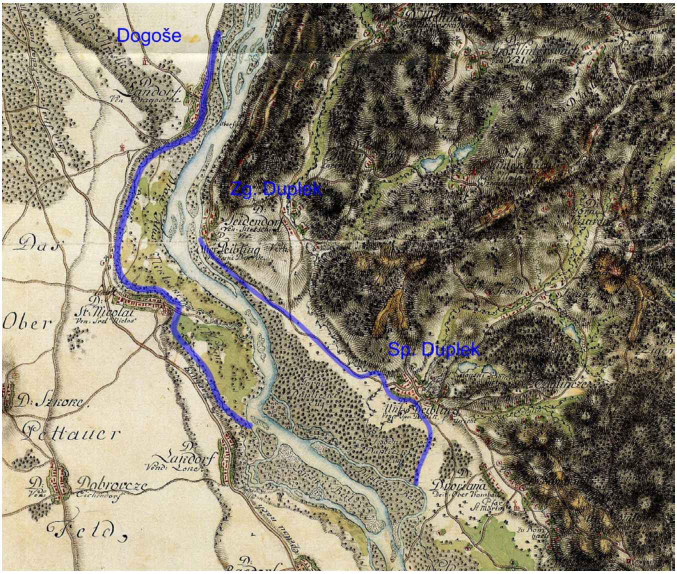

Fig. 1: Settlements are on the terrace above the floodplain, floodplain is still (Austrian military map).

2. Situation around year 1850

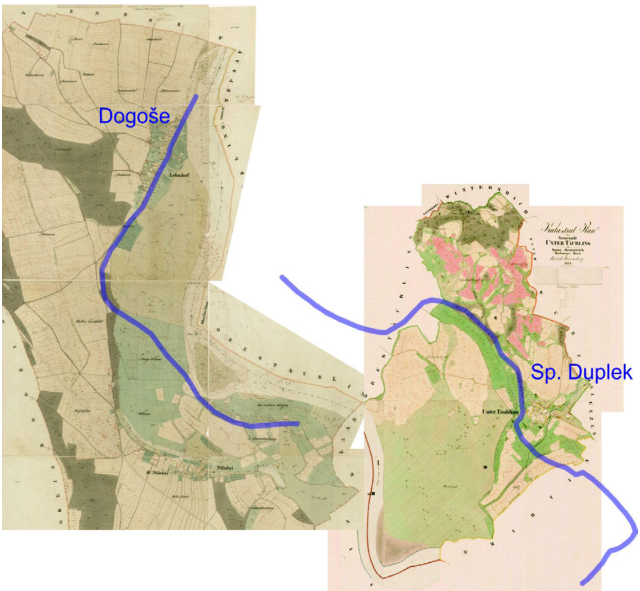

Fig. 2: Settlements are still above the floodplain, floodplain is already cultivated by meadows, first gardens are appearing at edges (Franz 1st Cadastre).

3. Situation in year 1954

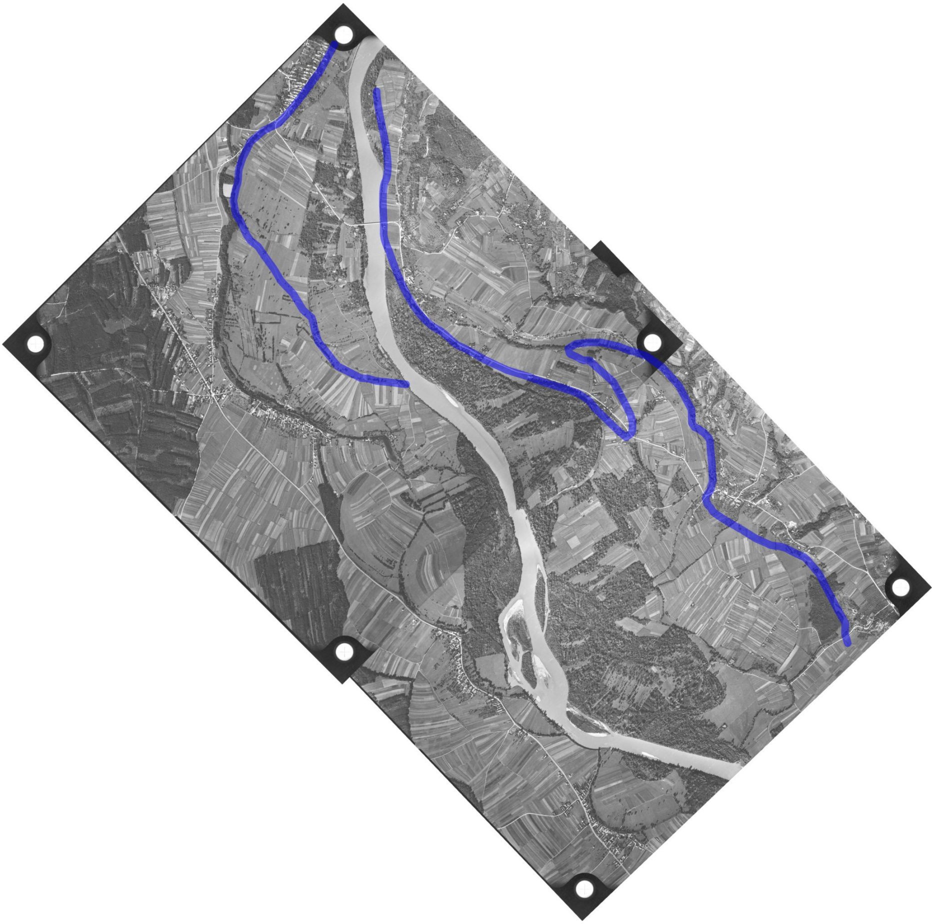

Fig. 3: Colonisation of floodplain starts with expansion of towns Dogoše and Duplek (Aero photo, Geodetski Inštitut, Slovenia).

4. Situation in year 2010

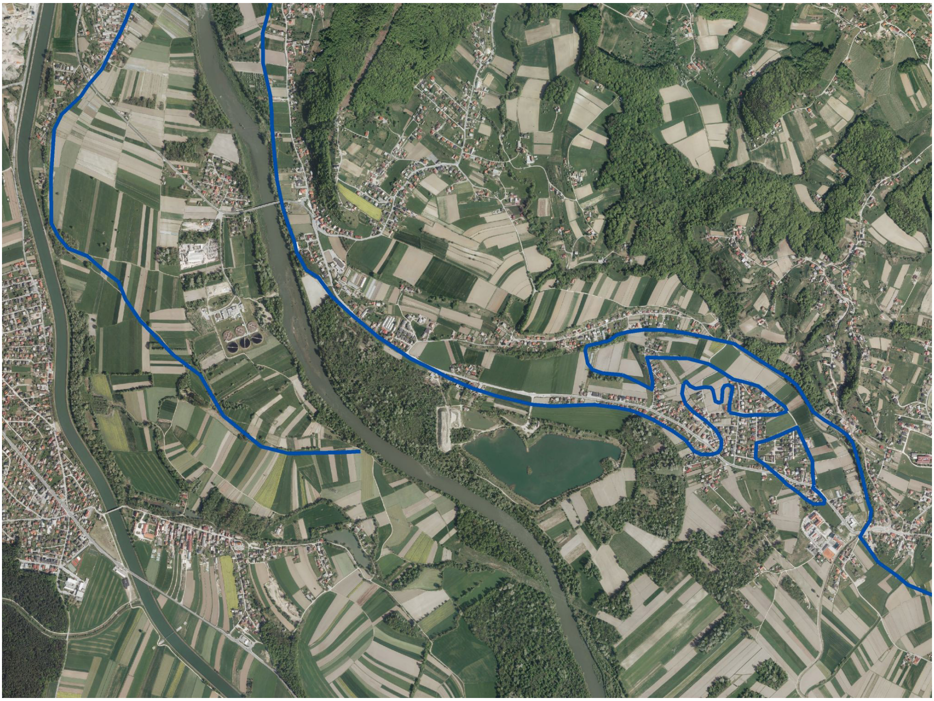

Fig. 4: Land use intensification and expansion of settlements in the Drava river floodplain. The supply channel of the Zlatoličje power plant (built 1964 - 1969) probably stimulated the idea that floodplain is safe from flood waters (Digital ortophoto 2010, Geodetska uprava RS).

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Problematic Issues of Implementation of the European Water Legislation in Ukraine

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Introduction

River floods and related inundations are the most widespread and dangerous natural phenomena in Ukraine. The frequency and intensity of floods as well as the magnitude of damage caused, have increased in many regions during the past decades. Taking into account the fact that river floods affect large areas with intense economical development and high density of population, the development of flood management is among the most urgent task of the Ukrainian water-related policy. The implementation of norms of the Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on assessment and management of flood risks (EFD) will contribute to the success of this activity. The problematic issues connected with implementation of the Directive's norms which are under a responsibility the State Hydrometeorological Service of Ukraine are considered in the paper.

Discussion

The objectives of the EFD is to establish a frameworks for the flood risk assessment and management which will reduce the adverse of consequences of flood in regards to human health, environment, cultural heritage and economic activity. In addition, it requires the EU Member States to coordinate the implementation of the EFD with the implementation of the European Water Framework Directive (EWFD), which focuses on water quality and ecology. In general, the EFD reflects the new thinking in the flood management policy - from the protection against floods to managing the risk of floods.

The Directive requires undertaking of a unifying process which include three stages:

- preliminary assessment of flood risks in river basins and identification the areas with a potential of significant flood risks. In these areas, further actions can be taken only if a significant flood risk is observed at the present or is expected in the future.
- developing flood hazard maps and flood risk maps for areas with potentially significant flood risks. These maps should include: the delineation of areas with medium and low probability of flooding by indicating also expected inundation depths; the number of inhabitants, the level of economic activity and the environment damage potential in flood risk zones;
- preparation of flood risk management plans at the river basin or sub-basins of a special scale. Plans have to consider different aspects of flood risk management, including flood forecasts and early warning systems.

It is obviously that the EU Flood Directive's implementation requires:

- a large volume of information about: a) past, relevant and expected hydrological conditions and a number of hydraulic parameters of rivers; b) estimation of

flood probabilities; c) determining flooding zones; d) estimation of water quality deterioration in rivers under impact of floods;
- development of non-structural flood control measures, in particular, flood forecasting and warning systems.

According to the Ukrainian legislation, the State Hydrometeorological Service is responsible for providing above mentioned activities. But, at present the Hydrometeorological Service can't provide these activities properly to meet to requirements of the EU Flood Directive. The major problematic issues are following.

Hydrological observation and forecasting system. The density of the observational network and its technical equipment lag behind the level of the EU countries. This density of observation points does not allow forecasting of flash floods in mountain river basins, especially, distribution of low in time, with the essential accuracy. The absence of automatic hydrological stations, technologies of remote hydrometeorological measurement and digital maps are reasons of impossibility to use the hydrological forecasting methods which are based on the modern mathematic models and GIS-technologies which give a possibility to estimate the flooding zones.
Hydrological studies. Much of them have the applied character and can be used for implementing the EFD. But a number of important directions in scientific researches should be strengthened. It is necessary to strengthen researches on the following issues: a) the exact estimation of floods probability needed for a creation of flood hazards maps and flood risks maps; b) consideration of impact of climate change within methods of hydrological calculations as well as in the models of hydrological forecasting; c) multidisciplinary studies to assess the possible economic, social and ecological damages caused by floods of different probability of exceedance.

Water quality monitoring system. The water quality monitoring system in Ukraine, including, the State Hydrometeorological Service should be reorganized according to the requirements of the EU Water Framework Directive. The European norms of ecological status estimation of surface waters should be introduced in the Ukrainian practice.

Logistic issues. In our view, implementing the EFD directive in Ukraine can face some difficulties, as there is no proper coordination of these activities between different water-related authorities. In particular, the national action plan which includes the calculation of necessary financial resources for this aim is not prepared. It is the reason of the absence of relevant action plan in the State Hydrometeorological Service.

Conclusion and Recommendations

The problematic issues discussed in the article have both sectoral and national character.
Their successful solution is possible in the case of solving a number of organizational, scientific and financial issues. Given the unsatisfactory preparation to the implementation of the EFD on the national level, it is advisable to recommend the State Hydrometeorological Service to start development of its action plan. In this regard, it was recommended to strengthen the international cooperation with such transboundary countries as Slovakia, Poland, Romania and Hungary, which have the experience in implementing the European water legislation.

Water management of Ukraine

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Introduction
Water management of Ukraine is the important sphere of human activity, that responsible for the providing of population and national economy by water, land reclamation, flood protection, minimization negative consequences from underflooding etc.

1. Regulation of flow
Uneven distribution of water recourses in Ukraine by space and time has led the requirement in regulation of runoff and transportation of water on large distance. The total quantity of reservoirs and ponds in Ukraine correspondingly is equal to 1,100 and 40,000. Among them the main role plays the Dnipro cascade, which consists of 6 large reservoirs with total volume 43.7 billion cubic meters and area 6,900 square kilometers. The main tasks as to cascade are the generation of energy, simplification of water intake, regulation of floods, shipping, fishing, recreation.

The total power of 6 HPP, built on the Dnipro river, makes up 3.8 mln kW, annual generation of electricity is equal about 10 billion kilowatt hours. The increased water level made it possible to simplify the water intake and to transport it on large distance. The effective volume of reservoirs gives possibility to reduce maximum flood discharges and to avoid flooding. After the creation of Dnipro cascade the guaranteed depth for shipping increased to 3.65 m. Some thousands ships pass through the gateways annually [2].

Except the Dnipro river the cascades of reservoirs were created on some other rivers: Southern Bug, Ross and others. In some invents their quantity exceeds 10 on one river.

2. Water intake and water transportation
Nowadays the total annual water intake in Ukraine makes up 13.7–13.8 billion m^3. Almost half of its quantity is being taken from the Dnipro cascade. The largest objects, those transport water on large distance, are Northern-Crimean canal, canal “Dnipro–Donbas”, Main Kakhovskyi Irrigation canal and canal “Dnipro–Kryvyi Rig”. The length of these objects reaches 400 km and ability 300 m^3/sec. On the East of Ukraine is operating canal “Siverskyi Donets–Donbas”. The last one provides by water a large industrial and populated Donbas region [3].

In addition to that is under operation a large quantity of pipelines, those transport water previously for drinking water supply. Thus, the providing by water of Odessa city is organized from Dniester river, Mykolaiv city – from the Dnipro river. The Lviv city, located on highland, also is provided by some pipelines. The main of that has its beginning from the Stryi river and has the length 109.6 km.

There are large quantity of industrial enterprises, located on banks of Dnipro river, those use water from it. Among them – the most powerful NPP in Europe – Zaporizka NPP, that has total power 6.0 mln kW.

3. Land reclamation

Until last time the total area of irrigated and drained lands was correspondingly 2.2 and 3.3 mln hectares. Nowadays actual area became much less. During some last years the actual area of watered lands was equal to 0.6–0.8 mln ha. Among others two regions are the leaders: Kherson region and Crimea, where in 2013 had actually was watered correspondently 291.5 thousand and 136.8 thousand ha. The rest irrigated area is located in other southern regions: Zaporizka Odeska and Mykolaievska. Although the area of irrigated land decreased, it is observing the essential improving technology of irrigation. Every year the area, were are used drip irrigation, became larger and nowadays it reaches 76.5 thousand ha.

The largest areas of drained lands are located on the North-Western part of Ukraine. The leaders are Lvivska and Volynska regions.

4. Flood protection

A large part of the territory of Ukraine is under risk of flooding. First of all it concerns the region of Carpathian mountains, where the annual sum of precipitation can exceed 1500 mm. One part of this region belongs to basin of the Danube river, another one – to the basins of the Dniester and Prut rivers. The last one is the tributary of the Danube river also.

During last decade in basin of Tysa river, that belongs to the basin of the Danube river, created complicated system of flood control, that includes about 40 automatic meteorological and gauging stations. This system also includes modules of flood forecasting and creation recommendation as to safe flood passing. In the basin of Tysa river also was constructed some hundreds kilometers of dams, was made the clearing of river channel, etc. The similar system is under creation in river basins of Dniester and Prut rivers.

5. Water management complex in Crimea

The Crimean Peninsula is the most southern part of Ukraine with area 27.000 square kilometers and population 2.4 mln. The luck of precipitation (in general it makes up about 400 mm) and southern location caused deficit of available water recourses. For the solving of water problem in 60-th was built very large Northern-Crimean canal, that has its beginning from Dnipro river (more exactly – Kakhovske reservoir) and the end near Kerch city, located on the eastern side of Crimea. During last decade until 2013 the canal transported to peninsula about 0.9 billion m^3 of water. The main part of this quantity was used for irrigation, particularly for growing of rice. Some water had been taken for industrial and drinking water supply also. Since the canal in winter is not operated, the consumption of water during this time was arranged from some reservoirs, those were filled from the canal during operation period.

Till nowadays the supply of water to the consumers was arranged on the base of contracts with Water management administration of Northern-Crimean canal, that located near its beginning.

After Russian aggression this mechanism was destroyed – Water management administration became unable to carry out its functions in Crimea. Until now Crimean authority didn't gather information about its need for water and didn't formulate it to Ukrainian side. Under these circumstances, without any legal basis for supplying of water to Crimea and having many responsibilities for consumers in Kherson region, Ukrainian side had to build a new regulatory structure near the boundary of the Crimea. Nevertheless some water to Crimea having been transported – in a quantity that is sufficient to provide the drinking water needs of local population. Nowadays is considering the project of building a new regulatory structure on the border between Kherson region and Crimea.

6. Water management complex in the downstream of the Danube river

Another water management complex was created in the downstream of the Danube river. Some decades ago – in the middle of XX-th century on the left bank of this river existed some large floodplain lakes, those reached the largest dimension during floods on the Danube river. During 60-th on left bank of river was built a long dam, that defended this area from the flooding. Simultaneously for the connection of lakes with river were built some canals, equipped by gates. In such way the lakes were transformed into reservoirs. Their total volume is 1.4 billion m^3 and total area 527 km^2 (fig. 1)

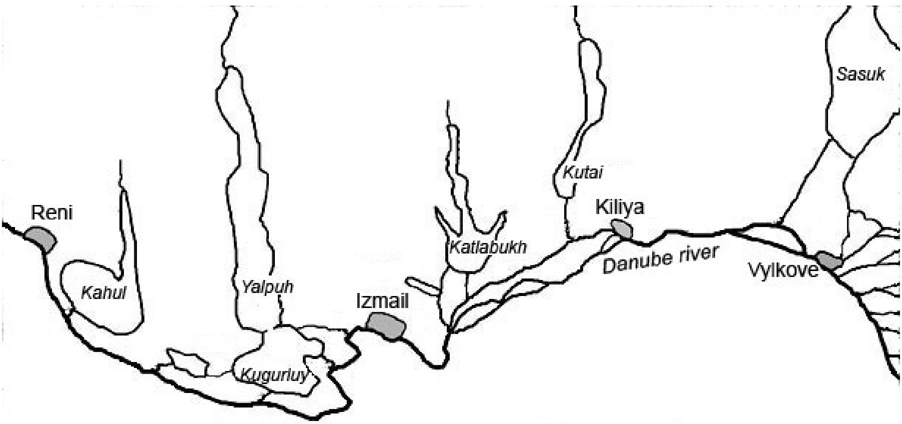

Fig. 1. Location of lakes, transformed to reservoirs in the downstream of the Danube river

The filling of reservoirs is organized during floods on the Danube river, when the water level in river exceeds water level in reservoirs. The rest time, when water level in reservoirs is less, than in river, the gates usually are locked [1].

The water, those had been taken from reservoirs, first of all was used for irrigation, in particular for the growing of rise. A large part of water, that had been taken from the Danube river, caused a good water exchange and satisfactory water quality in reservoirs. But even in the past sometimes were observed conditions when mineralization of water reached 1 g/dm^3 and more. The main reason of it – the water runoff of small rivers, those have high mineralization (up 4–6 g/dm^3) and flows into reservoirs (generally in their northern parts). Another one reason – the additional evaporation from the water surface. These factors caused the essential differences in mineralization of water by water area – in northern part of reservoirs it was much larger, than in southern ones [1].

Nowadays the water intake for irrigation became much less than early. In once term it caused the dimension of volume of Danube water that goes to reservoirs and is being taken from theirs. As a result of it the mineralization of water in reservoirs has the tendency to increasing and it causes further dimension of water intake and deterioration of water quality.

Another problem, that is observing in the downstream of the Danube river is the shore erosion. This problem is complicated by large depth of river (it can reach 20 m), large speed of flow and significant slope of shore. This problem in a whole was solved by use of new kind of bank protection by flexible geotextile casing. Briefly, it consists of two stitched textile fabric between which is pumped liquid concrete.

7. Conclusion

Water management complex of Ukraine is a complicated system that provides of population and national economy by water, land reclamation, flood protection, minimization from underflooding etc. There are some separate parts of water management complex, those were created in different part of country.

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Hydrologic Effects of Beaver Activities on Some Embanked Watercourses from Brasov Depression

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Introduction

Beaver (*Castor sp.*) represents part of riparian ecosystems, in the entire Palearctic region, in North America, as well as in Eurasia. In Europe beaver populations were practically eliminated, at the end of 19-th century in all Europe 1200 individuals still remained (Halley, Rosel, 2002). Starting from 1920 due to its protection beaver effectives increased, but areas occupied now by beavers are much smaller.

In Romania 182 beavers were imported in 1998 and were used to establish several cores on three Danube tributaries (Olt, Mures and Ialomita). The beaver population is estimated now at 1,600 individuals (Ionescu et al., 2010), but its natural habitat was altered by humans during the last century and some beaver families settled on embanked watercourses.

Beaver lives in the riparian area were stream shores are forested or wood vegetation covers at least 10 m wide stripes (Angst, 2010). Except humans, beaver is one of the very few species able to modify significantly watercourses geomorphology with direct impact over the hydrology (Butler, Malanson, 1995; Rosell et al., 2005). Building dams is the most important beaver activity leading to important physical changes of streams.

Beaver dams consist in overcrowding of branches, twigs and even logs, generally 1m height (Curry, 1967; Medweka-Kornas, Hawro, 1993), and can reach 20 m length (Medweka-Kornas, Hawro, 1993).

1. Methodology

The research was conducted in south-eastern Transylvania, in the upper Olt catchment, on 6 streams that flow through Brasov depression. The study area falls into a grid of coordinates E 26° 01 ' longitude/ N 45° 48 ' latitude (lower left corner) and E 26° 18 ' longitude and N 46° 06 ' latitude (upper right corner).

In order to achieve the objectives, on these populated by beavers stream sectors surveying measurements were performed. Sectors length is between 280 m and 640 m, totalling 2100 meters. On each sector 3 to 5 beaver dams were identified (20 on all watercourses), having a height between 0,3 m and 2,3 m. The analysed watercourses have a low gradient (generally less than 1%) and a double profile cross section (riverbed sized to discharge current flow and flood plain bounded by earth embankments, sized to discharge outstanding flows). Measurements focused on the longitudinal profile of the valley, significant cross sections and geometry of beaver dams.

To estimate the effect of beaver dams on the spill channel regime, hydraulic simulations were performed using Mike 11 application taking into account the presence of beaver dams or removing them. In order to achieve simulations, beaver dams were treated as waterproof construction provided with weirs and the spillway was assimilated to land line. Analyses were

done by comparing the two situations, namely "with beavers" and "without beavers".
The objective of the research presented in this paper is to analyse maximum discharge capable to be evacuated and to identify critical cross sections for each sector. In order to find critical cross sections and to emphasize the impact of beaver dams, hypothetic hydrographs have been adopted as input data for hydrological simulation. Those hydrographs reconstruct an hourly increase in flow from 1 m^3 s^{-1} to a maximum value determined according to hydraulic characteristics of the downstream cross sections

2. Results

Beaver dam influences hydraulics of embanked river beds in two ways (Woo, Waddington, 1990): on one hand beaver dam diminishes the leakage section where it is built and, on the other hand, beaver dam leads to a decrease in flow rate due to blockage occurred which causes a rise of water level upstream. These interrelated processes form critical sections not in sections were dams are, but upstream of them.
Simulations allowed us to compare each of 99-th cross section hydraulics with or without beaver dams built on river beds. Using Mike 11 the maximum peak flow able to pass through all studied cross sections was determined in both scenarios.
Cross sections were classified taking account their relative position to the beaver dam as follows: sections with dams (C), sections placed immediately (2-5 m) upstream dams (C-), sections placed immediately (1-3m) downstream dams(C+) and neutral cross sections (N) placed at different distances from dams.
The results can be summarize as follows:

- the maximum discharge able to pass through studied cross sections is 28% (average value) smaller in the scenario "with beaver";
- in 9 (from 99) situations a slight increase (less than 1.5%) of the maximum discharge is observed;
- in one case the discharge able to be evacuated is significantly bigger (23%) when beaver are present;
- all positive figures are reported at the end of studied sectors in cross sections placed immediately downstream the last beaver dam (C+ section);
- critical cross sections of analyzed sectors are C- type for three rivers, N type in two cases and C+ type for one situation, but this particular section is placed at a short distance upstream another dam;
- all sectors, with one exception, are able to evacuate the discharge having 100 years return period;
- in this particular case even in the scenario "without beaver" the 100 year return period flow will generate floods, but the critical cross section is not the same in both scenarios;
- in 19 from 20 situations maximum discharge in upstream dam cross section (C-) is lower than the discharge in corresponding dam cross section (C);
- value of the discharge in C- cross sections represents 49%-105% of corresponding C cross section;
- for C- cross section the ratio between maximum discharge "without" and "with beaver" is statistically dependent (for 19 freedom degrees) on the dam height;
- for the rest of the cross section types the reduction in capable discharge is not explained by dam height.

3. Conclusion

Beaver dams change the longitudinal profile by raising the thalweg and modifies the cross sections by reducing their active area. The presence of dams causes flow slowdowns due to reduced riverbed gradient and to the buffer effect of lakes created behind dams. As a result, the flow discharged by the sectors of riverbeds with beaver dams diminishes with 28% (average value), but the capacity to exhaust even large floods (generating discharges with long return period - 20-100 years) is not affected.

Generally the placement of critical section is related to the presence, downstream, of a dam. The capable discharge of cross sections placed immediately upstream a dam is significantly correlated to the corresponding dam height.

The risk of flooding along these embanked rivers is low, only one river could trigger floods, which could occur even if beavers will be removed.

Acknowledgements

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River hydro-morphological assessment – Romanian approach

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Introduction

At European level, there are clear requirements of the European Directives in the field of water quality, in particular the Water Framework Directive (WFD/60/EC). Romania must meet these requirements by developing a set of hydromorphological indicators for the assessment of the river ecological status. This is a complex process aiming to guide in a judicious way the aquatic ecosystems management.

The development of a complete methodology (which include all the elements required by the WFD), for assessing river hydro morphology and especially the correlation with the biotic quality component, in order to achieve an integrated approach in the assessment of the ecological status for water bodies (rivers) is part of the national and international scientific concerns.

Taking into account that the hydromorphological elements are supporting the biological elements in order to achieve good status, **the Romanian approach covers all hydro-morphological elements required by the Water Framework Directive**, as follows: hydrological regime (quantity and dynamics of water flow, connection to groundwater bodies), river continuity and morphological condition (river depth and width variation, structure and substrate of the riverbed, structure of the riparian zone).

1. Methodology for river hydro-morphological assessment

The methodology assesses the hydro-morphological pressures on rivers aiming at the elaboration of a 5-classification system depending on the degree of alteration.

The approach relies on the work already carried out in the River Basin Management Plans, namely the classification of surface water bodies using abiotic criteria (criteria which define also the significant hydro-morphological pressures) that have been detailed and included in the methodology.

The methodology developed within National Institute of Hydrology and Water Management takes into account the basic principles for classification of ecological status, according to CIS Guidance Document No. 10. It tries to quantify the deviation of current conditions from reference conditions. The reference is given by "undisturbed" conditions showing no or only "very minor" human impacts. Thus, considering the observed values and reference values, **each indicator is expressed as a deviation of current conditions to the reference conditions** (in percentage).

The establishing of the reference conditions for hydro-morphology is problematic and there are many approaches concerning this issue (Rinaldi et al., 2013). Within the paper, the reference conditions are based on historic information, from the period before the construction of hydro-technical works or slight deviation from this status, namely, the natural hydrological regime and the natural riverbed morphology.

Regarding the assessment and classification of rivers ecological status in terms of hydromorphological conditions, this approach is relying on a **scoring system and a classification system into five classes**. Thus, for each indicator, the reference status / natural or a slight

deviation from this is class I. The scores for each indicators, for class I are maximal. For the other cases (classes II-V), the score is lower depending on the severity of anthropogenic pressures and preliminary the class boundaries are set equidistantly.
Regarding the assessment of all hydromorphological elements required by the WFD, it is known that for some indicators the international experience does not exist (e.g. connection to groundwater bodies) or is limited (e.g. only few methods analyze bed width and depth variations, most of them relying on the width and depth measurements of the current situation). However, the Romanian methodology assesses these elements required by the WFD.
In addition, concerning the spatial scale of application**, the hydromorphological characteristics of the Romanian rivers are assessed at the water body level**, mentioning that for the water bodies that are too long, the assessment should be done on shorter river sectors (approach found in the majority of international methods).
Further, brief explanations of the hydromorphological indicators are presented.

1.1 Hydrological regime

Regarding the hydrological regime assessment, many European methods take into account the flow, but most of them analyzes only the flow during field investigations and only few methods analyzes the hydrological regime alteration (Rinaldi et al., 2013).
For the international scientific community, the flow regime that represents support for creating optimal habitat for biota still remains a challenge (Jowett et al., 2006).
In Romania, the analysis of flow regime alterations highlights some gaps related to the lack of long series of hydrological data in natural flow regime (before the pressure impact) and the fact that not all streams are monitored (insufficient gauging stations).
The flow value that provides optimal habitat for aquatic species it is not unique and varies from one species to another; in addition, the extreme flows (floods and droughts) are natural phenomena in which case biota will continue to survive, whether such phenomena do not happened frequently (Jowett et al., 2006). Given these issues, the Romanian approach considers that **the multiannual average flow create an optimal habitat for most aquatic species**. Thus, the “multiannual average flow” was selected as indicator to express the quantity and dynamics of water flow.
Another element which influences the hydrological regime is the connectivity of the river with groundwater bodies. Although the literature recognizes that groundwater plays an important role in the functioning of river ecosystems, none of the international methods includes such an indicator (Rinaldi et al., 2013). In order to analyze the flow between the river and groundwater aquifer, the **average annual values of water levels** measured in wells, located closest to the river, on both sides of the water body are analyzed, before and after the construction of dykes and dams. The indicator allows classification of the water body into one of the five quality classes depending on the **variation of the relative deviation of the water level in wells**.

1.2 River continuity

In assessing river continuity two indicators are proposed, namely: “longitudinal continuity of the river bed” (ensuring continuity for migratory biota) and “lateral continuity of the riparian zone/ floodplain “(the capacity of the floodplain to store water).
The “longitudinal continuity of the river bed” Indicator was developed to characterize the impact of dams or other structures on the mobility of fish species and to determine whether within the analyzed water body the continuity for fish fauna is ensured.
The “lateral continuity of the riparian zone/ floodplain” Indicator is proposed in order to

characterize the lateral connectivity of the water body with riparian floodplain which is reflected both in terms of quantity, by the capacity of the floodplain to take over the floods and of quality, by creating habitats for the aquatic species, sediment retention and nutrient recycling. In assessing this indicator, the presence of hydro -technical works carried out on the banks or in the floodplain area is essential.

1.3 Morphological conditions

The river morphological conditions are assessed by the following elements: river depth and width variation, structure and substrate of the riverbed, structure of the riparian zone. The river depth and width variation are frequently omitted by the most methods; issue taken into account by the Romanian approach. In addition, the multiannual average flow helps create optimal habitat for the most aquatic species. The present methodology considers that these optimal habitats may be expressed by an **average depth and average width corresponding to multiannual average flow**.

Regarding the substrate conditions, most methods provide some information on the composition and particle size, while very few methods assess the degree of substrate modification compared to the natural status. Thus, in order to assess composition of the riverbed the **average particle size fraction ($D_{50\%}$)** is proposed.

The **"channel/minor riverbed morphology and shape" Indicator** aims to assess the deviation from the natural status of the minor riverbed in terms of shape and morphology, namely, riverbeds deviations, riverbeds closures, artificial filling of abandoned riverbeds, reducing the number of arms of braided riverbeds. In order to quantify the pressures, the length of the water works (on both sides of the riverbeds) out of the total length of the water body is used as indicator (expressed in percentage).

The **"banks and the lateral mobility of the minor riverbed" Indicator** aims to outline the constraints in the natural evolution of the river banks and the dynamic of riverbed generated by channeling the riverbed, by banks protection, etc. The alteration is quantified as length (for both river banks) related to the total length of the water body.

Characterization of **"riparian zone"** starts from the idea that in the natural status, the riparian zone/vegetation was continuous over the entire length of the water body on both sides of the minor bed/channel according to the geomorphology of the valley. The riparian zone became discontinuous due to anthropogenic pressures having impact on its ecological function. Criteria for assessing the continuity of the riparian zone are the percentage of the natural zones out of total surface of riparian zone, corresponding to the water body. **The new element in assessing the riparian zone is the delineation of it (**type-specific width**), based both on valley geomorphology and water bodies' typology, accepting that the riparian zone width under natural conditions is different, increasing from upstream to downstream**.

1.4 Example of a proposed indicator

Average depth corresponding to multiannual average flow

Class I	Class II	Class III	Class IV	Class V
Whether the relative standard deviation depth deviates from the reference status between:				
± 0% and ± 20%	± 20% and ± 40%	± 40% and ± 60%	± 60% and ± 80%	±80% and ± 100%
Score				
13	**10**	**7**	**4**	**1**

$$\frac{depth_{average}^{obs} - depth_{average}^{ref}}{depth_{average}^{ref}} \cdot 100$$

where: $depth_{average}^{obs}$ = the measured depth;

$depth_{average}^{ref}$ = the reference depth.

2. Conclusions

The paper highlights the Romania's efforts within the National Institute of Hydrology and Water Management, to implement the requirements of the WFD in practice, recognizing that the deviation from the natural status of river hydro-morphology can lead to the failure in achieving the good ecological status. The methodology is intended to be a tool to characterize the rivers hydro-morphology and it can efficiently assist the policy makers: to identify and to quantify the degree of alteration of water bodies and to propose restoration or mitigation measures.

The development of hydro-morphological indicators and their integration in the evaluation and classification system of the rivers ecological status is an important step in the development of the second River Basin Management Plans.

This method is in the testing phase, in Romania and it will be validated by the end of the year after the correlation with ecological status given by biological, chemical (specific pollutants) and physico-chemical (temperature, oxygen, salinity, etc.) elements. The proposed type specific width for riparian zone also will be reviewed.

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Assessment of heavy metal compounds discharge of the Danube in the modern period

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Introduction

The most significant sources of water pollution by heavy metals are enterprises of the mining industry and ore processing, heat and metal production.
According to the IAEA (International Atomic Energy Agency) [6] there are many “hot spots” in the Danube basin causing water pollution by heavy metals, mainly by compounds of Ni, Pb, Zn, Cu, Al and Hg. Most of “hot spots” are located downstream of the Danube, at Romanian and Bulgarian section of the Danube. The major accidents inflict particularly great environmental and financial losses, last of them occurred in 2000 and 2010.
Research presents results of studying of heavy metals dissolved forms which are physiologically most active. Suspended metal forms should be regarded as potentially less hazardous to aquatic organisms, due to their ability to sedimentation, which causes self-purification of water environment [2, 4, 5]. Content of suspended heavy metals is directly related to water turbidity. For the Danube it is extremely important, as the water of the Danube is characterized by high values of this parameter. Content of suspended matter ranges from 50 to 199 mg/l with a maximum during floods and minimum during low water [2, 3].
Objective of presented study is to investigate current levels of heavy metals and the value of their discharge to Ukrainian section of the Danube.
The initial data were obtained from observation stations of State Hydrometeorologycal Service of Ukraine and international expeditions of 1988, 1990 and 2002. Station of Reni city that locates above a mouth of the Danube and under the last tributary is chosen for calculation.

1. Assessment of heavy metal compounds

Taking into account average concentrations of heavy metals for the period of 1990-2010 and concentration of fulvic acid in the Danube water we have performed thermodynamic modeling of heavy metals coexisting forms in the water of the lower section of the Danube assuming that the main migration forms of heavy metals are complex compounds with dissolved organic matter (Table 1).

Iron, copper and zinc are characterized with high degree of complex forming with fulvic acid. In contrary, manganese migrates mainly in the form of hydrated ions. Among the majority of metal only manganese was found with insignificant complexation with organic substances [4].

Tab. 1: Coexisting forms of heavy metals in the water of the Danube River (Reni) according to results of thermodynamic modeling (% of total content)

Metal	Form	Metal	Form
Mn	Mn^{2+} – 84,4%	Cu	Cu^{2+} – 4,1%
	$MnHCO_3^{+}$ – 8,6%		$CuOH^{+}$ – 9,8%
	$MnSO_4^{o}$ – 3,7%		$Cu(OH)_2^{o}$ – 7,4%
	MnFA – 2,1%		$CuCO_3^{o}$ – 16,1%
Zn	Zn^{2+} – 58,8%		$CuHCO_3^{+}$ – 3,3%
	$ZnCO_3^{o}$ – 8,5%		$Cu(OH)_2FA^{2-}$ – 59,0%
	$ZnHCO_3^{+}$ – 11,7%	Fe	$Fe(OH)_2FA^{-}$ – 83,0%
	$ZnSO_4^{o}$ – 3,2%		$Fe(OH)_2FA_2^{3-}$ – 16,4%
	ZnFA – 17,0%		

Our study has shown that metal complexes of anion origin were dominant among other complex compounds.

In spite of the low content of humic substances in the water~~s~~ of the Danube~~,~~ (on average, 0.26 mg/l for humic acid and 3.2 mg/l to fulvic acid)~~,~~ these natural organic acids play a major role in binding of heavy metals.

Dissolved heavy metals could be arranged in the following order regarding their content: Fe (content from 0,11 to 0.66 mg/l (average - 0,29))> Zn - 8,8 - 183,7 µg/l (average - 43.6)> Mn - 6,0 - 50,8 µg/l (average - 24,3)> Cu - 2,4 - 16,2 µg/l (average - 6,2)> Cr - 0,2 -7, 4 µg/l (average - 3,1).

Tendency of concentrations decrease was observed for Fe, Mn, Zn, Cu and increase for Cr [4].

Suspended form dominates for Al and Fe and dissolved form for Zn, Mn, Cu, Cr, Co, Ni, Pb and Cd [2, 5, 7].

Content of dissolved and suspended forms of heavy metals at the lower section of the Danube has decreased significantly (Table 2).

Tab. 2: Content of dissolved and suspended forms of metals in the Ukrainian section of the Danube (Reni) during the low water period, 1990 and 2002

Station	Concentration of heavy metals, µg/l							
	Forms of heavy metals	Fe*/Al*	Cd	Cr	Cu	Pb	Ni	Zn
1990								
Reni, Ukraine	total	470 (Fe)	2	20	17,9	14,1	15,8	75,8
	suspended	394	1	6,2	2,9	10	10,6	20,8
	dissolved	76	1	13,8	15	4,1	5,2	55,0
2002								
Reni, Ukraine	total	607 (Al)	0,2	2	6	1	6	13
	suspended	596,8	0	1	2	0	3	6,39
	dissolved	10,2	0,2	1	4	1	3	6,61
* Fe – the measurements were taken in 1990, Al – 2002								

No study of the composition of aluminum in waters of the Danube had taken place before, although the metal is considered as priority toxicant.

List of heavy metals was wider, so in 1990, the content of suspended forms of Mn equaled to 25.4 µg/l, dissolved forms - 8 µg/l; Co - 3.1 µg/l and 1.5 µg/l respectively.
There were changes in dominant forms of Pb, Cd and Ni: suspended forms have changed to dissolved. This was caused possibly by the low content of the metals (Table 2).
The relative content of suspended forms of heavy metals (percentage of the total content) the heavy metals in the Danube decreases in the following order: Al> Fe> Mn> Pb> Ni> Co> Cr> Cu> Zn> Cd [2,5].
Heavy metals in the Danube water could be ranged in the following order by the relative content of suspended forms (percentage of the total content): Al> Fe> Mn> Pb> Ni> Co> Cr> Cu> Zn> Cd [2, 5].

2. Study of metal discharge

Research of metal discharge was dedicated to a significant increase of water runoff and precipitation. During the period 1990 - 2010 water runoff increased by 24%, precipitation increased mostly during the summer-autumn low water, (26% compared to the mean annual) [3].
Thus, according to Clarke number (mass %), heavy metals are arranged in the following order: Fe (7.57)> Mn (0.085)> Cr (0.019)> Zn (0.012)> Cu (0.01)> Pb (0.002). At the same time we obtained a sequence of elements in the runoff of the Danube: Fe (5,9 -134,1 thousand tons / year)> Zn - (2,2 - 23,1 thousand tons / year)> Mn - 1,3 - 9.1 tons / year)> Cu - (0,6 - 4,3 thousand tons / year)> Cr (0,0 - 1,7 thousand tons / year) [4] which is different from the general trend of their distribution in the Earth's crust. In our opinion, this is due to significant differences in migration ability of individual elements.
Close correlation between the discharge of heavy metals and Danube runoff has not been found which indicates that heavy metals content is dependent on the frequency of wastewater inflow and heavy metals content.
The main sources of their inflow are domestic and industrial wastewater. Over the past 10 years, the total volume of water drained into the surface waters of the Danube decreased 1.3 times, polluted wastewaters - 1.9 times; Tisa drained - 1.5 times, polluted - 5.4 times; Prut drained increased in 1.1 times as polluted decreased to 3.6 times [8]. The European community in the upper and middle sections of the Danube has successfully implemented strategy aimed at wastewater drainage decrease [5, 6].

Tab. 3: Mean annual and permissible under PEL discharge of heavy metals by the Danube waters in Reni cross-section for 1990 - 2010.

	National standards (PEL)	Discharge of trace elements tons / year			
		Mean annual	Allowable according PEL	Multiplicity of exciding	
				Mean annual	The maximum for mean annual
1.	Iron, (0,10 µg/l)	58,26	20,9	2,79	6,41
2.	Copper, (0,001 µg/l)	1,46	0,209	7,00	20,43
3.	Manganese, (0,010 µg/l)	4,44	2,09	2,12	4,35
4.	Zinc, (0,010 µg/l)	9,21	2,09	4,41	11,09
5.	Chromium (VI), (0,001 µg/l)	0,81	0,209	3,88	8,04

PEL - Permissible Exposure Limit

In this anthropogenic impact is possible the transformation and transition of aquatic ecosystems to a new trophic status with a modified natural background for the lower Danube. Ecosystem in the Lower Danube (delta region) is under the influence of moderate anthropogenic impact (Table 3).

3. Conclusion

Trend of heavy metals dissolved forms content and discharge decrease most likely is attributed to economic restructuring in Eastern European countries and Ukraine in that time. In turn that caused decrease in anthropogenic pollution load to the Danube basin.

It has been shown that heavy metal discharge in lower Danube closely correlated with concentrations of corresponding elements and did not correlate with water flow which could be considered as an evidence of significant anthropogenic contribution.

At the last Ukrainian cross-section Reni mean annual discharge of copper, manganese, zinc, chromium and iron exceeded national quality standards by several orders of magnitude. For the maximum discharge that exceeding reached several dozens of order of magnitude.

Analysis of information has shown that new anthropogenicaly modified natural background has been taken place for the Danube during past two decades. This fact should be considered while assessing current and future anthropogenic impact on the Danube River and Danube Delta ecosystems.

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Analysis of 18 elements in liver and gills of three Danubian predatory fish species

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Abstract
In this work 18 elements (Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Se, Sr, Zn) were analyzed using inductively coupled plasma optical spectrometry (ICP-OES) on liver and gills of three predatory fish species (pikeperch – *Sander luciopreca*, European catfish – *Silurus glanis*, pike – *Esox lucius*) caught in the Danube River at river kilometer 1170th. Post-hoc tests showed that pike had significantly higher level of Cu, Se, and Zn in liver, compared to other species ($p<0.05$) while concentrations of As, Mn, and Zn in liver of pikeperch were significantly higher than those in liver of catfish. For gills, statistical tests showed that pike had significantly higher level of Ba and Zn, compared to pikeperch and catfish, but pikeperch had significantly lower level of Mn, Sr, and Zn in gills than other species. Obtained results showed that differences in concentrations of elements in liver and gills exist even in top predators which inhabit same area, which could be explained by their food preference and behavior. Results from this work could help making better plans for monitoring of large river pollution.

1. Introduction
Serbian part of the Danube River is polluted mainly because of number of industrial centers such as Novi Sad, Belgrade, Pancevo and Bor (Stanic et al. 2016) as well as due to untreated communal wastewaters and runoff from agricultural areas. As other large rivers, which pass through numerous cities, the Danube also face a problem of heavy metal pollution, which is confirmed by work of Babic-Mladenovic et al. (2003) where elevated concentrations for As, Cu and Hg were found in sediments of Danube in vicinity of Belgrade. Accumulation of elements in metabolically active fish organs such as liver and gills, especially in piscivorous fish species could be good indicator of large river pollution.
Three piscivorous fish species (pikeperch – *Sander luciopreca*, European catfish – *Silurus glanis*, pike – *Esox lucius*) were sampled from the Danube River in vicinity of Belgrade and analyses of elements in liver and gills were performed to find out how it could improve monitoring of large river pollution.

2. Materials and Methods

This work represents comparison of already published data prepared by Subotić et al. (2013a, 2013b) with data obtained for pike (*Esox lucius*) caught on the same sector of the Danube River.

2.1 Sample collection, preparation and element analysis

Pikeperch, European catfish and pike were sampled in the Danube River at 1170th kilometer of the river, from October to December 2010 and total length (TL) and total weight (W) was measured. Samples included 10 pikeperch (TL = 38 cm -59 cm, W = 437 g – 2000 g), 11 European catfish (TL = 55 cm – 100 cm, W= 1095 g – 6620 g) and 6 pike specimens (TL = 51 cm -65 cm, W = 940 g – 1680 g). Collected individuals were dissected and with a plastic laboratory set samples of liver and gills quickly removed, washed with distilled water and stored at -18^{0}C prior to analysis. Analyses were performed in accordance with procedure described in Subotić et al. (2013a, 2013b).

2.2 Statistical analysis

The principal component analysis (PCA) was used as an unsupervised statistical method that summarizes the variation of a data set between samples to a set of uncorrelated components, each of which is a particular linear combination of the original variables, in order to assess the differentiation among the analyzed liver and gills samples, based on the elemental level.

One-way ANOVA and post-hoc tests (LSD, TAMHANE) were used to show if differences in elements concentrations in liver and gills among analyzed fish species exist.

3. Results

Concentrations of Li, Ni and Pb were below the detection limit in all investigated samples. Concentration of Cd was above the detection limit only in liver of pikeperch (0.04 – 0.091 μg/g dry weight) while concentration of Co was above the detection limit in pikeperch liver (0.01 – 0.11 μg/g dry weight) and catfish gills (0.01 – 0.31 μg/g dry weight). Data relating to other elements are presented in Table 1.

Table 1. Concentrations of Al, As, B, Ba, Cr, Cu, Fe, Hg, Mn, Mo, Se, Sr, and Zn in liver and gills ($\mu g/g^{-1}$ dry weight) in pikeperch, catfish and pike

Tissue		Pikeperch	Catfish	Pike
Liver	Al	4.84 ± 3.46	3.91 ± 2.46	4.36 ± 4.85
	As	0.50 ± 0.11[a]	0.23 ± 0.14[b]	1.71 ± 0.90[a]
	B	0.53 ± 0.40	1.10 ± 1.00	1.03 ± 0.96
	Ba	0.26 ± 0.35	0.07 ± 0.08	0.20 ± 0.36
	Cr	0.04 ± 0.04	0.04 ± 0.03	0.07 ± 0.12
	Cu	6.20 ± 2.81[a]	8.28 ± 3.80[a]	36.34 ± 19.28[b]
	Fe	241.54 ± 157.32	392.83 ± 328.18	265.41 ± 237.13
	Hg	1.66 ± 0.42	1.52 ± 0.55	1.25 ± 0.67
	Mn	3.52 ± 1.56[a]	1.64 ±0.73[b]	2.86 ± 2.10[a,b]
	Mo	0.22 ± 0.10	0.25 ± 0.07	2.40 ± 3.51
	Se	0.84 ± 0.56[a]	0.68 ± 0.36[a]	3.32 ± 0.45[b]
	Sr	0.72 ± 0.88	0.39 ± 0.10	0.12 ± 0.07
	Zn	58.53 ± 10.51[a]	41.19 ± 12.00[b]	81.74 ± 35.25[c]
Gills	Al	13.28 ± 9.26	9.67 ± 9.235	3.03 ± 2.50
	B	0.18 ± 0.18[a]	0.34 ± 0.48[a]	0.50 ± 0.12[b]
	Ba	0.93 ± 0.295	1.60 ± 1.28	4.02 ± 0.50
	Cr	0.03 ± 0.02	0.18 ± 0.38	0.06 ± 0.07
	Cu	1.01 ± 0.365	1.88 ± 1.43	1.39 ± 0.725
	Fe	73.01 ± 31.23	72.46 ± 33.34	109.25 ± 57.90
	Hg	1.52 ± 0.48	1.48 ± 0.38	0.96 ± 0.42
	Mn	5.71 ± 2.45[a]	16.99 ± 10.42[b]	19.16 ± 2.63[b]
	Se	0.60 ± 0.58	0.60 ± 0.47	0.70 ± 0.25
	Sr	29.31 ± 11.20[a]	77.21 ± 13.36[b]	73.11 ± 13.97[b]
	Zn	40.11 ± 12.36[a]	58.00 ± 5.26[b]	437.24 ± 89.09[c]

[a,b,c]The values with different letters in the same row are significantly different (LSD, TAMHANE)

Principal Component Analysis (PCA) showed that based on investigated elements in liver, pike showed higher values for Cu, Se and Zn and separated from the other two groups while pikeperch and catfish partly overlapped (Figure 1). One-way ANOVA showed that As, Cu, Mn, Se, and Zn concentrations in liver significantly differed between species.

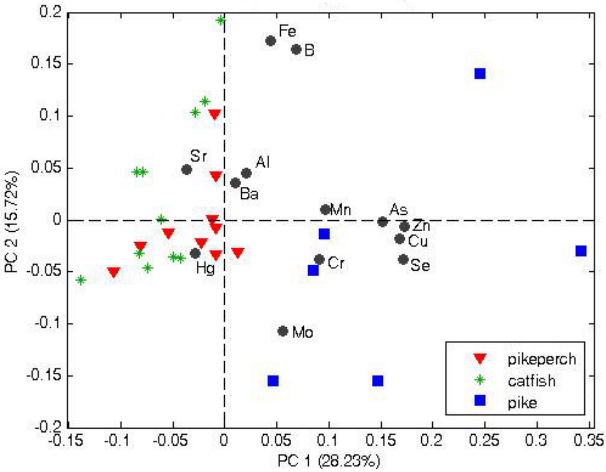

Figure 1. The PCA plot of elemental concentrations in liver of three investigated fish species

Each investigated fish species formed separate groups, based on the PCA results of element concentrations in gills where pike was grouped with higher values for concentrations of Ba and Zn (Figure 2). One-way ANOVA showed that Ba, Mn, Sr, and Zn concentrations in gills significantly differed between species.

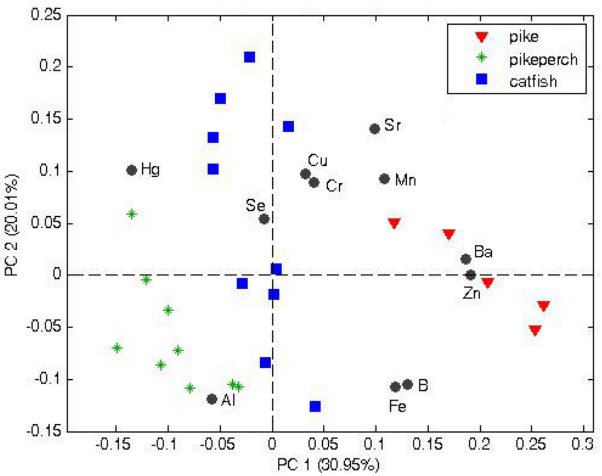

Figure 2. The PCA plot of elemental concentrations in gills of three investigated fish species

4. Conclusions

Three investigated piscivorous fish species in this work showed statistically different concentrations of As, Cu, Se, Mn, and Zn in liver as well as different concentrations of Ba, Mn, Sr, and Zn in gills. These differences could be explained by different food preference and behaviour. Results obtained could help in better organization of large river pollution monitoring.

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Vegetation response to a more natural water regime: case study of a restoration project from the upper Danube

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Abstract
The restoration project along the upper Danube near Ingolstadt aims to bring back water and sediment dynamics back to the floodplain notwithstanding the still existing hydropower barrages. The comprehensive monitoring project MONDAU is able to evaluate the effects of the project. Here, we present the results of the five year vegetation monitoring. Vegetation is changing to target habitat types, but only in a small corridor along the new created floodplain river, big parts of the floodplain remain unaffected.

1. Introduction
The upper Danube between Neuburg and Ingolstadt (Germany) was more or less separated from its floodplain as many other rivers in Europe already in the 19th century. In the 1970ies the last water and sediment dynamic was cut-off by the construction of a chain of several hydropower plants: the groundwater showed almost constant conditions (an amplitude of 50 cm in contrast to several meters in earlier years) and only high floods reached the floodplain (only three times in 40 years). Nevertheless, due to the extensive land use in the area, a large forest of high value for nature conservation could be maintained. But investigation in 1999 showed that the typical floodplain vegetation is suffering the important regular water dynamics both regarding flooding but also low water conditions (Margraf 2004). Therefore, a restoration project was implemented in 2010. Here, the project, but also the short-time results will be presented.

2. Restoration Project “Dynamic development of the Danube floodplain”
The investigation area is situated between Neuburg and Ingolstadt near the two hydropower plants Bergheim and Ingolstadt (river kilometer marker 2470 km), the project area has a size of 1.200 ha. The project aims to bring back the natural water dynamics to the floodplain as a key determinant for the development of the typical floodplain vegetation and fauna. It was conducted to the main part by the Bavarian Water Management Authority Ingolstadt from 2006 to 2010, a smaller part of the project was financed by the German Federal Agency for Nature Conservation and conducted by a local working group of the nature conservation authority. Depended on the discharge of the river Danube, different amounts of water were diverted into the floodplain or were drained out of the floodplain by the following three measures (see also Fig. 1):

1. New floodplain river of 8 km running partly in former oxbows with a fluctuating permanent water flow of 0.5 - 5 m^3/s according to the discharge amount of the Danube; it functions as a bypass river of the hydropower barrage, but also as a new habitat for aquatic organisms; the water has been running since June 2010.
2. Controlled "ecological" flooding of the riparian forests during natural floods with low annuality, approx. 2 - 3 times per year for a period of up to 5 days with a maximum discharge of 25 m^3/s along the new floodplain river; until now 10 flooding periods of different intensities and length passed.
3. Ground water draw-down in the floodplain by temporary drainage at low water discharge in the Danube River; works in areas, where the groundwater level was constantly high due to the barrage Ingolstadt; it has been conducted twice: in autumn 2011 for 2 month, in summer 2012 only for few weeks.

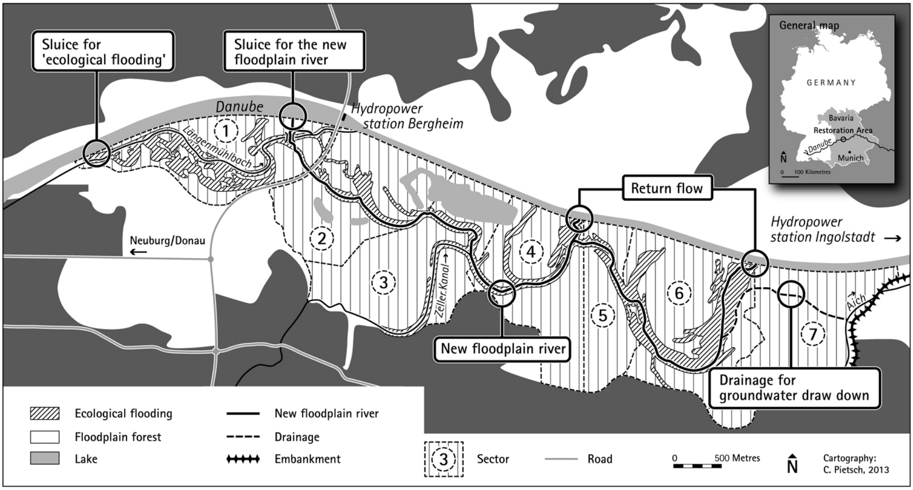

Fig. 1: Study area with the location and spatial extent of the three restoration measures; sectors: division of the investigation area into seven sectors for vegetation monitoring.

3. Methods of the Vegetation Monitoring

The restoration project was accompanied by a research project to monitor the changes of the abiotic parameters and the effects on vegetation and fauna (www.mondau.de, Stammel et al. 2012). Due to the expected spatial differences of the effects on floodplain forest and aquatic and semi-aquatic vegetation, two monitoring designs were implemented, both regarding the same sectors according to the pre-restoration conditions of surface water and groundwater (see Fig. 1). The forest vegetation was investigated by a stratified random sampling design (3 parameters regarding height, distance to the measures and flooding probability) on 117 plots of 200 m^2. The riparian vegetation was investigated both by stratified random plots (99 plots of 1 m^2 in three habitat types) and by 19 transects of 1 m^2-plots crossing the new river (length between 20 m and 110 m). Vegetation recording was done before the onset of the new floodplain river (2007 -2009), in the year after water diversion (2011) and in the following years (2012 - 2013).

4. Results

4.1 Riparian vegetation

The aquatic and semi-aquatic riparian vegetation along the new floodplain river showed a quick response to the changed abiotic conditions. 10 species disappeared after 2009, but 67 new species re-appeared originating both from the soil seed bank and through seed dispersal by the new water course. More than half of them were indicator species for enhanced water dynamics (Fig. 2). There were significant differences in vegetation response due to the initial water regime on the development and the re-establishment of target vegetation types. The former dry oxbows where many ruderal soils and gravel banks were created due to construction works showed the strongest increase in species: 64 new species, thereof 31 target species, but also the number of neophytes increased both in number and abundance. In the former temporary waters, 10 of the 17 new species were target species, but also 5 new neophytes could establish. In contrast, in the broad permanent backwaters no significant changes in species number and composition could be observed as also the abiotic conditions did not change significantly.

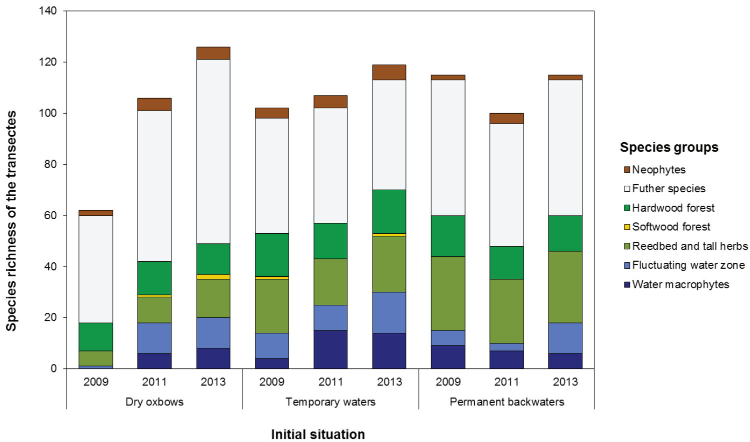

Fig. 2: Effects of the restoration project from 2009 to 2013 on species number, number of target species (in blue and green), neophytes (brown) and further species (grey) for the observed transects in different pre-restoration conditions.

4.2 Vegetation of the floodplain forest

The actual flooded area was much smaller than the one predicted by a model and so, 72 of 117 plots were not affected at all by the restoration measures. Therefore, the forest vegetation showed only in a small corridor the attempted reaction. In low-lying plots which were temporarily inundated by an increase of the groundwater level (11 sites) or were directly influenced by the new floodplain river (8 sites) vegetation responded to the changed hydrological conditions. An analysis of the time series showed a directed development in vegetation in these highly dynamic plots (blue and black sites in Fig. 3): species number increased significantly, many of the new species were typical for floodplains and therefore target species. But in most parts of the project area and therefore the biggest part of the floodplain, the vegetation has not shown any reaction, yet.

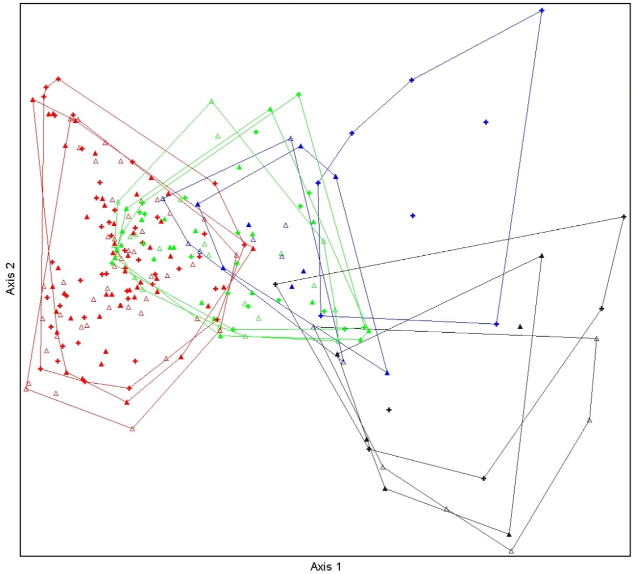

Fig. 3: Detrended Correspondence Analysis of the relevés from 2008 (△), 2011 (▲) and 2012 (✚); plots of different inundation frequencies enfolded by a convex hull for each year illustrating the time-shift in ordination space; red: not flooded at all; green: only flooded for a few days in 2011 by ecological flooding; blue: flooded for ca. 150 days a year since 2010; black: inundated up to 150 days a year by groundwater.

5. Conclusion

We conclude that a dynamic water discharge also in a small floodplain river can initiate the re-establishment of typical floodplain plant communities, but the effects are restricted to a small corridor. Changes in the riparian vegetation and in parts in forest vegetation have taken place in a few plots, but it is still unclear whether these are self-sustaining (e.g. long-term establishment of softwood forest) or only the first step of succession. To restore the whole former floodplain of the river Danube more water (it is actual 1 % of the Danube discharge) has to be diverted, regularly, and considerably larger parts of the floodplain must be flooded (for further information see the final report to be published in 2015). Therefore, protecting the last remaining natural floodplains is the key task to maintain biodiversity in floodplains, not till then degraded floodplains have to be restored.

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AIM for Rivers (Austrian Index Macrophytes for Rivers), RI-HU (Reference Index Hungary) and IBMR-SK (IBMR Slovakia) – three macrophyte-based Water Framework Directive compliant assessment systems in comparison, using the example of the Danube

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Abstract
In this study three principally different macrophyte-based Water Framework Directive-compliant assessment systems for rivers are compared. The Austrian, the Slovakian (= adapted French system) and the Hungarian system (= adapted German system) are applied on data of the whole Danube stretch and their performance is critically discussed. The results confirm the applicability of macrophyte metrics for large rivers but underline the need of river-type- and region-specific specifications of the systems.

1. Introduction
The main environmental objective of the EU Water Framework Directive (WFD, European Commission, 2000) is the protection of inland surface waters. The WFD aims to provide the mechanisms to protect and enhance the status of aquatic ecosystems with the goal to achieve at least "good ecological status" of all water bodies within the European Community by 2015.

Status monitoring has to be done by the individual member states. Therefore the WFD allowed the development of assessment methods on national levels. Since the initiation of the WFD as many as 300 new methods for assessing the ecological status of water bodies in Europe were developed (Birk et al, 2012), more than 20 dealing with macrophytes in rivers.

This variety of methods caused criticism, too, especially with regard to the big efforts which had to be made to ensure comparability of assessment results. In order to check all the developed methods for consistency with the normative definitions of the WFD and to ensure a common understanding of "good ecological status" the so called "intercalibration exercise" (Heiskanan et al., 2004; European Communities, 2005) was stipulated.

In this study data from the Joint Danube Survey (JDS) are used to test the performance of three intercalibrated macrophyte-based assessment systems on data of the whole Danube stretch.

2. Results and Discussion

The three assessment systems are principally different. The Slovakian system (Baláži & Tóthová, 2010), which is an adaption of the French IBMR (Haury et al., 2006), solely is based on the trophic indication of different species. The Austrian system (Pall & Mayerhofer, 2013) respects furthermore the indicative value of some species concerning hydro-morphological alterations as flow velocity or embankment. Both systems include only Hydrophytes (submersed or floating-leafed species) and Amphiphytes (species which can live as well submersed as occasionally in the dry at the banks). The Hungarian system (Lukács, 2009), which is an adaption of the German Reference Index (Schaumburg et al., 2004) assigns the species to the three groups: A = reference species, B = indifferent species and C = degradation indicators, independent of a specific pressure (eutrophication or hydro-morphological alteration). In difference to the German original version the Hungarian adaption includes also Helophytes (reed-vegetation) which enhances the explanatory power of the system especially with regard to hydro-morphology.

The Slovakian and the Austrian assessment systems show a decrease of ecological status from the source to the mouth of the Danube. This finding cannot be interpreted by the typical pressure data macrophytes are regarded to be indicative for. Neither the nutrient concentrations (Phosphorus- and Nitrogen-compounds) nor hydro-morphological impairments show a significant increase along the Danube stretch. These results demonstrate clearly that the indicative value of species, especially concerning trophic conditions, changes within different regions and river-types and underline the necessity for type-specific specifications of assessment systems.

The results of the Hungarian system generally show only small differences along the course of the Danube. However, in spite of delivering the most balanced results along the river course, even in the Hungarian system region- and river-type-specific adaptions would have to be made to achieve a sound assessment of ecological status of the whole Danube in the sense of the WFD.

3. Conclusions and Future Perspectives

Whether macrophytes should be used for large river assessment according to the WFD or not recently is under discussion. There are controversial points of view within the European Union. Whereas e.g. the Austrian and the Slovakian systems are officially used for the Danube in the respective countries, the Hungarian system officially is regarded to be not applicable for large rivers (Lukács, pers comm.).

The results of this study on the one hand clearly demonstrate that a macrophyte-based quality assessment of large rivers is possible. On the other hand it could be shown that the systems deliver plausible results only for the river-types or regions they were developed for. For enabling an assessment on a larger scale in all systems tested river-type and region-specific adaptations would have to be performed.

As a further outcome of this study the importance of including Helophytes in a macrophyte-based quality assessment could be shown, especially with regard to hydro-morphology.

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Application of AIM for Rivers (Austrian Index Macrophytes for Rivers) in the Danube River in Bavaria, Germany

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Abstract
EU Water Framework Directive (WFD) requests the ecological evaluation of surface waters based on community composition of different aquatic animal and plant groups. At present, no evaluation system exists for Macrophytes in big streams in Germany. Therefore, AIM for Rivers was adapted to the river conditions in Bavaria. The results are in accordance to the evaluation results of aquatic algae in the Danube River. However, as the River is strongly changed in its hydromorphology, it is complicated to collect enough species on one measuring spot to achieve a secure evaluation.

1. Introduction
WFD requests the assessment of the ecological status of surface waters. Hereby, community composition of different groups of aquatic organisms is evaluated based on the expected community composition in rivers not exposed to human pressures. Organism groups used for evaluation are fish, benthic invertebrates, aquatic algae and aquatic macrophytes. For the latter, no evaluation system exists for big streams in Germany. Therefore, the AIM for Rivers (Austrian Index Macrophytes for Rivers) was adapted to the conditions of the Danube River in Bavaria.

2. Theoretical Background
2.1 The Danube River in Bavaria
The Danube River in Germany is shaped by the central highlands. After junction with the River Iller, it shows the characteristics of a big stream. Without human pressure, the River would be winding in broad and narrow valleys. The Entering of the River Inn changes the appearance of the Danube River again: The amount of the Inns primarily alpine, nutrient poor water is almost equal to the amount of its own water and dilutes nutrient concentrations of the River. The Danube section in Bavaria is classified as “Western Alpine foothill Danube section” in Robert et al., 2003.

2.2 Macrophytes as bioindicators
Aquatic Macrophytes can be used for assessing nutrient pollution of Rivers and Lakes. Especially their longer life – spans give them an advantage compared to other autotrophic bio – indicators, as they integrate environmental conditions over a period of several months to years. Macrophyte evaluation is based on indicative values for certain Macrophyte species. If a species is usually found in natural conditions, but never found when human pressure is high, the species gets a good indicative value. If a species usually occurs when human pressure is high, it obtains vice versa a bad indicative value. For assessing the ecological quality of a river section, on a representative survey of approximately 100 m, all Macrophyte species found are collected and determined. Based on their abundance and their indicative values, the ecological status of the Macrophyte

community is calculated. However, in big streams, Macrophyte assessment is problematic. This is mainly due to the fact that natural conditions of big streams differ widely between each other and also within the river itself.

The Implementation of the WFD lead to the development of an evaluation system for Macrophytes of the Danube River in Austria, called “Aim for Rivers” (Pall, K. & Mayerhofer, V., 2013). The developer of the method, Dr. Pall, edited the indication of Macrophyte species and adapted it to the Bavarian Danube (Pall, K., 2013). As the Danube River water in Austria is diluted by the nutrient – poor alpine water of the Inn River, natural conditions in Bavaria are slightly more nutrient rich. Therefore, the same Macrophyte species can indicate a “good” ecological status in Bavaria, but a “moderate” ecological status in Austria.

3. Results and Discussion

Community composition of Macrophytes in the Danube River in Bavaria has been investigated on approximately 20 measuring points during the last 10 years. However, sampling of Macrophytes is difficult, primarily due to the depth and current velocity of the Danube River. Further, shoreline stabilization destroys large parts of the natural Macrophyte habitat. Although the Austrian evaluation system calculates the ecological status from a number of two indicative Macrophyte species, results based on a higher number of Macrophytes clearly enhance the plausibility of the calculated ecological status.

The aggregated ecological status of the Danube River in Bavaria is “moderate” (Figure 1). However, planktonic and benthic algae indicate a “good” status in the upper part of the Bavarian Danube (Figure 2 & 3). The ecological status based on Macrophytes seems to alternate between “good” and “moderate” in the whole Bavarian Danube, showing a tendency to “moderate” (Figure 4). Contrary to benthic and planktic algae, Macrophytes utilize nutrients from the sediments. Although nutrient concentrations in the Danube River are decreasing since the 1980s, they are probably still elevated in the sediments.

Average phosphorus concentrations per year are still leveling at 100 µg P/l/year. For this river type, a phosphorus load of 100 µg P/l/year needs to be undershot to be able to reach the “good ecological stage” (Länder Arbeitsgemeinschaft Wasser, Ausschuss Oberirdische Gewässer und Küstengewässer, 2014). Phosphorous loads in the Danube River are still dangerously close to this value.

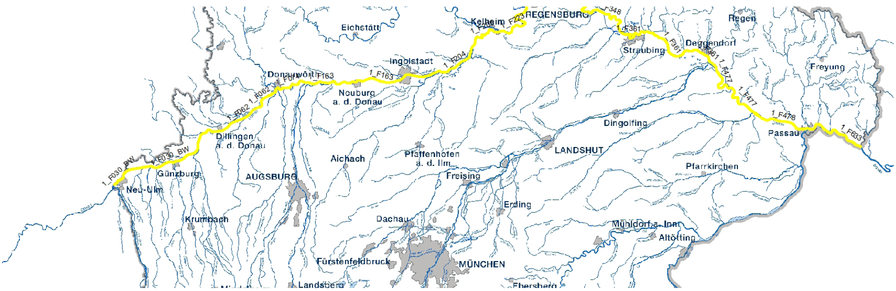

Figure 1. Aggregated ecological status in the Bavarian Danube Section
yellow = moderate ecological status

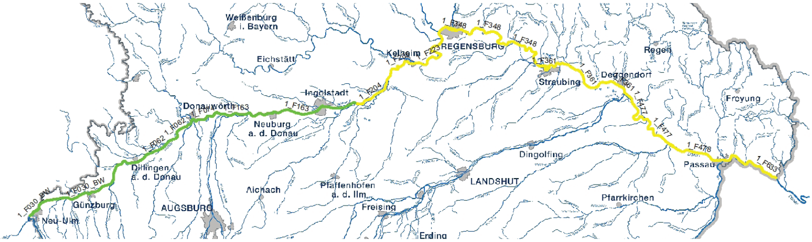

Figure 2. Ecological status of benthic algae in the Bavarian Danube Section
Green = good ecological status, yellow = moderate ecological status

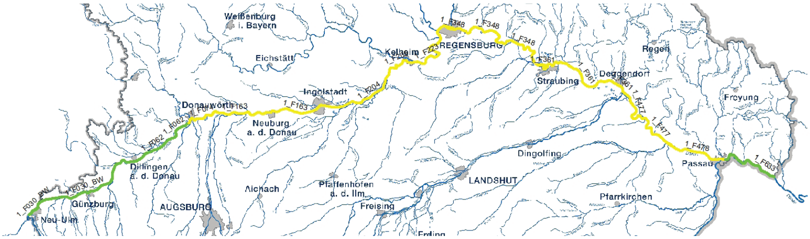

Figure 3. Ecological status of plankton algae in the Bavarian Danube Section
Green = good ecological status, yellow = moderate ecological status

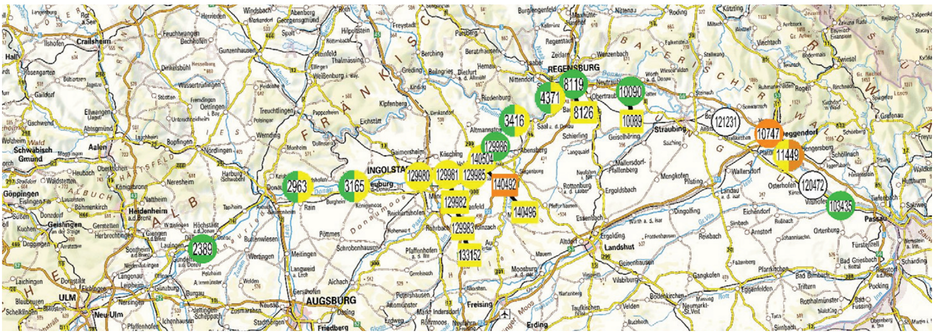

Figure 4. Ecological status of Macrophytes in the Bavarian Danube Section
Green = good ecological status, yellow = moderate ecological status, orange = poor ecological status

4. Conclusions and Future Perspectives

The evaluation of the ecological status of Macrophytes in the Bavarian Danube is possible and its results are in accordance to the ecological status of other autotrophic organisms. However, hydromorphological deterioration and plain sampling methods result in poor Macrophyte species numbers and a more elaborated sampling technique could affect the results of Macrophyte evaluation. It is necessary to further investigate the plausibility of the valuation procedure. At present, the evaluation system is tested by using Macrophyte data from the "Joint Danube Survey 2013".

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Groundwater drought in Northeast Bulgaria and the SPI index

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Abstract
Groundwater is a valuable resource yet vulnerable to long-lasting droughts. One of the drought indices is the Standardized Precipitation Index (SPI) that allows monitoring of droughts at different time scales. For the study area from the Northeast Bulgaria (Dobrich region) the impact of drought on the groundwater system is investigated based on the SPI indices. The results show that the decline of the groundwater levels is in conformity with low values of the SPI especially for longer time scales. This fact indicates the importance of the drought monitoring. In general, the impact from the short-term wet and dry events is superposed on the long-term influence described by SPIs.

1. Introduction
According to many climatic scenarios, more frequent droughts for Southeastern Europe are expected with enhanced negative impact on the freshwater resources. Groundwater in Bulgaria is rather vulnerable to long-lasting droughts, based on the groundwater regime data (Benderev, et al., 2008).

The shortage of precipitation propagates trough different elements of the eco-hydrological system. Mishra & Singh (2010) introduce groundwater drought as an additional important type of drought in addition to the known types (meteorological, hydrological, agricultural and socio-economic). This type of drought generally occurs on the time scale of months to years and affects groundwater recharge, levels and discharge.

Drought in the northeastern part of Bulgaria is normal and a relatively common phenomenon (Nikolova, 2013). Long-lasting drought episodes affect groundwater systems. The aim of the study is to assess the impact of droughts on the groundwater regime in the Dobrich region (Northeast Bulgaria) based on the SPI indices.

2. Study area
The Dobrich region is located in Northeast Bulgaria, in the eastern part of the hilly Danubian Plain (Fig. 1). Low plateaus up to 150-200 m high are the typical relief of the area. The climate is temperate. The annual rainfall averages between 500-550 mm. Precipitation is characterized with maximum in June and minimum in February. The snow cover stays for up to 2.5 months. The main soil types in the area are: typical Chernozems and leached Chernozems. Agricultural landuse is widespread in the area.

The lithostratigraphical units of Sarmatian age (Neogene) that outcrop in the study area are: the Odarska Formation (detritus-shell and oolite limestones with sandy and clayey layers) with a thickness of about 20 m that overlays the Frangen formation (sands). Quaternary is represented by the Loess Formation with a thickness of 5÷15 m (Fig. 1).

Groundwater is accumulated in the Neogene limestone and sands. This Sarmatian aquifer, which is the most important source for water supply in the area, is vulnerable to pollution – mainly from the agricultural activity and settlements without wastewater treatment plants. Hydrogeological setting in the Dobrich region is described by Danchev et al. (1981) and Pulido-Bosch et al. (1997). Pavlova and Benderev (2014) identified several types of the groundwater regime for the region.

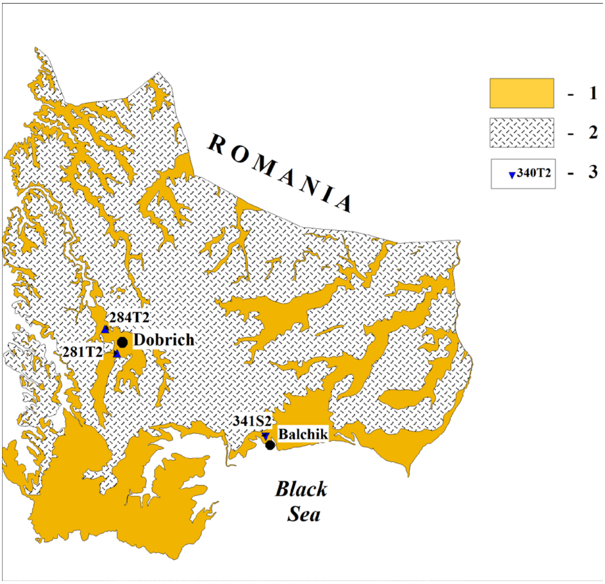

Fig. 1: Study area: 1- outcropping of the Sarmatian limestone; 2 – loess cover; 3 – well

Four observation wells are used in this study – two in the town of Dobrich and others – near the Black Sea coast (Fig. 1, Tab. 1). The individual number of each well includes symbols that mean as follows: “T” – borehole, “S” – dug well, and ”2” – karst aquifer.

3. Method and data

The Standardized Precipitation Index (SPI) proposed by McKee et al. (1993) allows monitoring of droughts at different time scales – generally from 3-month to 24-month. The values of the SPI from -1.50 to -1.99 indicate severe drought, and SPI below minus 2 – extreme drought. The Standardized Precipitation Index (SPI-n) is a statistical indicator comparing the total precipitation received at a particular location during a period of n months with the long-term rainfall distribution for the same period of time at that location. SPI is calculated on a monthly SPI for a moving window of n months, where n indicates the rainfall accumulation period, which is typically 1, 3, 6, 9, 12, 24 or 48 months. The corresponding SPIs are denoted as SPI-1, SPI-3, SPI-6, etc. (SPI, 2012). A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. A 6-month SPI may be associated with anomalous streamflows and reservoir levels. SPIs of longer time scales are most probably tied to streamflows, reservoir levels and groundwater levels (according to http://drought.unl.edu/

MonitoringTools/ClimateDivisionSPI/Interpretation/6month.aspx). The Program to calculate the SPI value is downloadable from the National Drought Mitigation Center at the University of Nebraska - Lincoln (http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx, 19 Sep 2013).

Tab. 1: Average depth to the groundwater table (Hav) and standard deviation (s). Coefficient of correlation of the groundwater level with the SPI indices

Station	Location	Period	Hav, m	s, m	SPI-24	SPI-36	SPI-48
s341S2	Balchik	1987-2011	31.94	0.97	**0.62**	0.58	0.44
s332S2	Tsarichino	1986-2011	32.04	2.13	0.65	**0.77**	0.70
s281T2	Dobrich – park	2006-2011	18.32	0.56	0.57	-	-
s284T2	Dobrich	2006-2011	19.51	0.61	**0.74**	0.48	-

The time series used in this study are from the meteorological and hydrogeological networks at the National Institute of Meteorology and Hydrology at Bulgarian Academy of Sciences. To compute the indices SPI, a long-term time series of monthly precipitation sums are necessary. The monthly precipitation data is from the synoptic station at the town of Dobrich (period 1981-2011). The groundwater levels are from the four observational wells in the Dobrich area (Tab. 1). The wells are measured on monthly or daily basis.

4. Results

According to the annual precipitation sum in Dobrich, the identified dry years are as follows: 1983, 1986, 1990, 1992, and 2001, and the wet years are: 1995, 1997, 2002, 2005, and 2010. The SPI values are calculated based on monthly precipitation data for the synoptic station Dobrich. The results for SPI-24, SPI-36 and SPI-48 presented in Fig. 2 for the period 1989-2011 reveal the long-term wet and dry episodes.

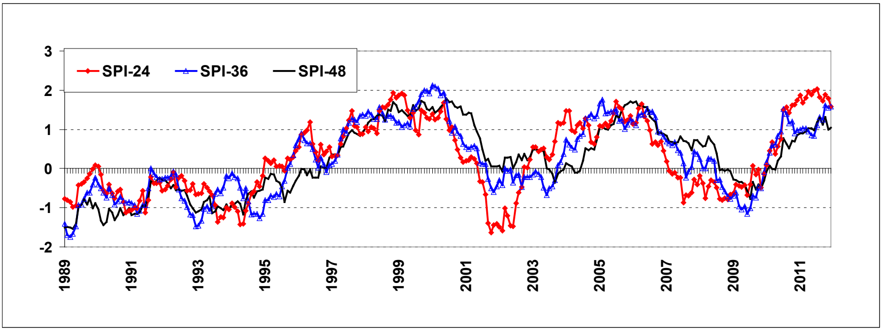

Fig. 2: Evolution of the 24, 36 and 48 months SPI for the study area

The groundwater regime for the wells is compared with the SPI indices. The highest correlation is observed for SPI-24 and SPI-36 (Tab. 1). The results give evidence that the groundwater levels are generally in conformity with the values of the SPI indices, especially for longer time scales (Fig. 3). Large precipitation amount in Dobrich in December 2009 and January 2010 that exceeded the respective monthly norms three to four times, contributed to the additional groundwater level rise in the beginning of the 2010 in addition to the long-term influence indicated by SPIs.

5. Conclusion

The groundwater regime in Northeast Bulgaria gives evidence to respond both to short-term and long-term fluctuations of the precipitation input. The succession of wet and dry years results in the respective variations of the groundwater levels. To assess the impact of the variable precipitation amount on the Sarmatian aquifer in Northeast Bulgaria, the groundwater regime in the Dobrich region is compared with the SPI indices. The results show that the fluctuation of the groundwater levels is in conformity with the SPI values mostly for longer time scales. Evidently, the Sarmatian aquifer is prone to droughts and is characterized with large temporal variation in groundwater recharge. Under the circumstances, its quantification on a regular basis is necessary along with monitoring of the groundwater drought. In general, wet and dry cycles of precipitation input alternate and further propagate into the groundwater system.

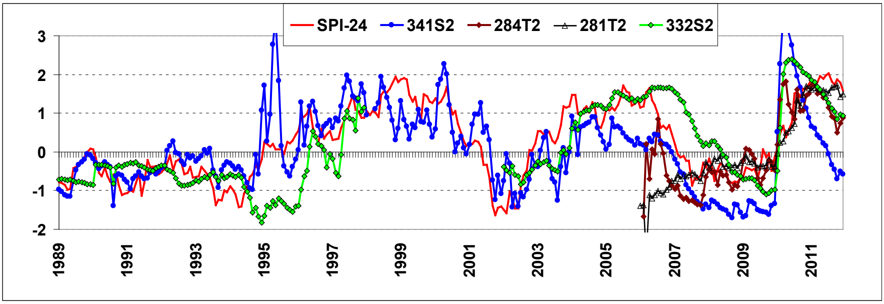

Fig. 3: Comparison of the groundwater levels in relative deviations (Hav-H)/s and the SPI-24

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