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D 5.7. The sensitivity of reference basins using the balance between the demand and water resources and of flood events within the present and future conditions with or without climate change based on outputs from climate scenarios simulations.

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Part 1.

The sensitivity of reference basins using the balance between the demand and water resources

1.1. The vulnerability of Buzău and Ialomiţa rivers water resources to climate changes

The vulnerability can be defined as a set of conditions and processes as a result of some physical factors which increase the susceptibility of a community before the hazards effects.

In examining the vulnerability of water resources to climate change, there are taken into account the following aspects:

- the available water at source;
- time distribution of this availability
- water quality;
- the use of water resources on uses

1.2. The change of water resources as a consequence of climate changes

1.2.1. Natural hydrologic resources

The hydrological (natural) resources for Buzău and Ialomiţa rivers, calculated in the Racoviţă (Buzău River) and Ţăndărei (Ialomiţa River) sections established for the interval 1971-2000 and calculated based on the RegCM scenarios, regarding the climate changes influence on the water resources of the two water courses for the interval 2021-2050 are presented in the below table (*Table 1.1*).

Table 1.1. Present and forecasted, for the period 2021-2050, water resources in the Ialomiţa and Buzău river basins.

Period 1971-2000			
River	Section	Mean annual discharge (m^3/s)	Mean annual stock mil m^3
1. Buzău	Racoviţă	26.163	826.22
2. Ialomiţa	Ţăndărei	39.167	1237.00
Period 2021-2050			
1. Buzău	Racoviţă	23.944	756.00
2. Ialomiţa	Ţăndărei	35.412	1118.00

As you can see, the hydrological (natural) resource of Buzău River will decrease in the interval 2021-2050, from 826.22 mil m^3/year to 756.0 mil m^3/year, that is with about 8,5 %, while in the case of Ialomiţa River, the decrease is bigger, 9,6 %, that is from 1237.0 mil m^3/year to 1118.0 mil m^3/year.

1.2.2. The distribution of the mean monthly discharges

The simulations of the mean monthly water flow on the basis of the climate parameters resulted from the climate scenario, shows (*Table 1.2*) a decrease of the hydrological (natural) water resource of the two river basins, and also important changes in the seasonal distribution of the mean monthly discharges towards the period 1971-2000.

Table 1.2. Mean monthly discharges and the mean multiannual discharge on the outlet of Ialomiţa and Buzău river basins.

Racoviţă hydrometrical station on Buzău River														
	month	1	2	3	4	5	6	7	8	9	10	11	12	Mean annual
1971-2000	Present mean monthly discharge (m^3/s)	16.13	19.98	35.08	50.25	47.38	39.27	30.09	21.68	17.47	18.41	18.24	16.22	26.163
2021-2050	Changed mean monthly discharge (m^3/s)	18.38	18.38	26.32	31.49	29.95	39.51	34.23	30.30	23.23	18.14	18.36	17.42	23.944

Ţăndărei hydrometrical station on Ialomiţa River														
	month	1	2	3	4	5	6	7	8	9	10	11	12	Mean annual
1971-2000	Present mean monthly discharge (m^3/s)	28.61	34.16	50.88	63.78	66.36	56.28	45.74	34.59	29.03	30.58	29.99	28.01	39.167
2021-2050	Changed mean monthly discharge (m^3/s)	31.09	40.82	45.50	44.68	57.51	44.52	40.63	32.64	28.05	30.32	29.19	28.71	35.412

1.3. The water resources vulnerability

1.3.1. Vulnerability criteria quantification

To be able to quantify the vulnerability of water resources of Buzău and Ialomiţa Rivers it is necessary the particularization of some aspects relating to:

- The dependence of the population from the two rivers river basins upon the hydrological resource of those rivers;
- Constraints existing upon the water resources
- Existence or not of a water shortage, determined by the balance calculations, available - water requirement.

1.3.2. The population from Buzău and Ialomiţa river basins

From an administrative point of view the two rivers river basins are situated in several counties, so:

- Buzău river basin is situated in the Covasna, Braşov, Prahova, Buzău and Brăila counties;
- Ialomiţa river basin includes parts of the b Brăila, Prahova, Ilfov, Ialomiţa, Dâmboviţa and Buzău counties.

According to statistical data, the population from Buzău river basin is estimated (2005) to 363947 inhabitants, and in Ialomiţa river basin to 1423304 inhabitants. The weight of population connected to the centralized water supply is of 65.5% (238388 inhabitants) in Buzău basin and 59.8% (850788 inhabitants) in Ialomiţa river basin.

1.3.3. The criterion of the water dependency

After such a criterion, a certain area is even more vulnerable as the number of people reported to the unit of water resources measurement is bigger.

For the two river basins, the above criterion has the following values:

- For Buzău River at 1 million m^3/year hydrological resource are 482 inhabitants. From this point of view, according to Brouwer and Falkenmork classification, when at a million m^3 of water are between 101 and 500 inhabitants, then the main vulnerability problem is the one of water management.
- For Ialomiţa River at 1 million m^3/year hydrological water resource, are 1273 inhabitants. According to the classification above, with this indicator which in situated above the value of 1000 persons/mil m^3, the Ialomiţa river basin is situated in the category of the areas characterized by the lake of water.

1.3.4. Water deficit criterion

According to this criterion, the available hydrological resource is compared with the water requirement of the utilities on the considered time interval. As a forecasting period it has been chosen the interval 2010-2020, because the economical – financial situation in the world from present did not justify the choice of a longer period. For the application of this criterion, it is necessary to draw up a forecast of the water requirements evolution.

In *Table 1.3* present the evolution of water requirements of the utilities in Buzău river basin.

Table 1.3. The evolution of water requirements in Buzău river basin (mil m^3)

Year	2001	2002	2003	2004	2005
Population water supply	0	0	0	0	0
Industrial Water	0.011	0.011	0.015	0.004	-
Irrigation	0.10	0.10	0.10	0.10	0.1
Aquaculture	1.65	1.65	1.20	0.4	-
Total	1.76	1.76	1.31	0.5	0.10

The mean annual value of the surface water sampling for the utilities in the Buzău river basin was of 1.1 mil m^3.

The evolution of the surface water requirements of the utilities in the Ialomiţa river basin is presented in *Table 1.4*.

Table 1.4. The evolution of water requirements in Buzău river basin (mil m^3)

Year	2001	2002	2003	2004	2005
Population water supply	54.31	47.88	45.64	34.51	28.83
Industrial Water	110.28	97.25	93.47	64.75	54.01
Irrigation	2.46	2.46	10.85	4.42	1.79
Aquaculture	32.15	32.15	24.72	30.97	-
Total	199.2	179.74	174.68	134.65	84.63

The mean annual value of surface water sampling for utilities in Ialomiţa river basin was of 154.60 mil m^3/an.

For the water requirements of utilities evolution there were used the results obtained in the NIHWM study: "Studies regarding evolution scenarios of water requirements of uses in order to underlie the actions and measures necessary to achieve the objectives of the sustainable management of river basins water resources" developed in 2008

We must emphasize that Buzău and Ialomiţa river basins are part of the basin unit of the water management resources Buzău-Ialomiţa, which comprise beside the two river basins mentioned above, surfaces belonging to other river basins.

In the mentioned study, there were drawn up evolution scenarios on water requirements on water resources management units for the interval 2010-2020. The year 2020 was chosen as the last year of the forecasting period, because this is the limit year comprised in "The projection of the main macroeconomic indicators" developed by the National Commission for Forecasting of Romania. At the basis of the water requirement of utilities evolution were used:

- Evolution of gross domestic product and gross added value obtained as a result of water use in industry;
- Objectives of the Operational Program "Environment" the Romanian Government which provides the objectives to be achieved in water supply to the population in the regional system;
- Data from the National Administration for Land Arrangements which provides for aquaculture, the evolution of water requirements having as a water source the Buzău and Ialomiţa rivers has been drawn from the study mentioned above.

In *Table 1.5* is presented the forecast of the surface water requirements evolution of the water utilities, in the two river basins.

Table 1.5. The forecast of the water requirements evolution

Year	**2010**	**2015**	**2020**
Buzău river basin	*(mil.m³)*	*(mil.m³)*	*(mil.m³)*
Population water supply	0	0	0
Industrial Water	0.020	0.020	0.025
Irrigation– 8628 ha	1.5	16.40	32.80
Aquaculture	2.0	9.0	14.0
Total	***18.41***	***25.42***	***46.83***
Year	**2010**	**2015**	**2020**
Ialomiţa river basin	*mil.m³*	*mil.m³*	*mil.m³*
Population water supply	51.0	59.0	68.0
Industrial Water	92.0	115.0	146.0
Irrigationi-25344 ha	6.0	12.0	65.0
Aquaculture	32.0	34.0	34.0
Total	***181.0***	***220***	***313***

The water requirements forecasted in the two river basins are far below the volume of water resources as it can be seen. As a consequence of that, from this point of view, there is a water surplus in both river basins.

1.3.5. Water balance criterion

According to this criterion, the available water resources per inhabitant are compared with the resource utilization degree, the vulnerability increasing from the water surplus to the lack of the water, as the degree of resource utilization grow.

According to Brouweri and Falkenmark, there are four types of characteristics regarding the vulnerability of water resources (*Table 1.6*)

Table 1.6. Characteristic types regarding the water resources vulnerability

The resource on inhabitants	The rate of the resource utilization (%)			
(m^3)	*< 40*	*40 - 60*	*60 - 80*	*> 80*
<1000	Marginal vulnerability	Pressure on water	Lack of water	Lack of water
1001-2000	Marginal vulnerability	Pressure on water	Lack of water	Lack of water
2001-10000	Excess water	Excess water	Marginal vulnerability	Lack of water
>10000	Water surplus	Water surplus	Marginal vulnerability	Lack of water

For the Buzău and Ialomiţa river basins, the water balance indicators are as follows:

<u>Buzău river basin</u>

Resource per inhabitant = 2077 m^3/year• inhabitant

<u>Ialomiţa river basin</u>

Resource per inhabitant = 786 m^3/year• inhabitant

With this resource and the data presented in *Tables 1.3* and *1.4* for the two river basins it results the following water utilization rate (%) (*Table 1.7*):

Table 1.7. Water utilization rates in Ialomiţa and Buzău river basins

Year	***2015***	***2020***
Buzău river basin	3.4	6.2
Ialomiţa river basin	19.7	28.0

As you can see, the water utilization rate of the two river basins is reduced. The rate is of 3-5% for Buzău River and of de 17 – 26% for Ialomiţa River. These rates are below the limit of 40%. In these conditions, according to Brouwer and Falkenmark scale (the water balance criterion) the situation concerning the vulnerability of the two river basins is presented in *Table 1.8*.

Table 1.8. Vulnerability degree of water resources in Ialomiţa and Buzău river basins

River	Resource per place (m^3/inhabitant year)	Resource utilization rate (%)	Vulnerability degree
Buzău	2077	3-6	Water excess
Ialomiţa	786.0	20-28	Marginal vulnerability

The application of the requirement – resource balance criterion in the case of the Buzău and Ialomiţa river basins, emphasize that in the Buzău river basin will exist a water excess in the following 15 – 20 years, and in the Ialomiţa river basin, there will be a marginal vulnerability, that is quite far from a possible pressure on this river basin water resource *(Figure 1.1).*

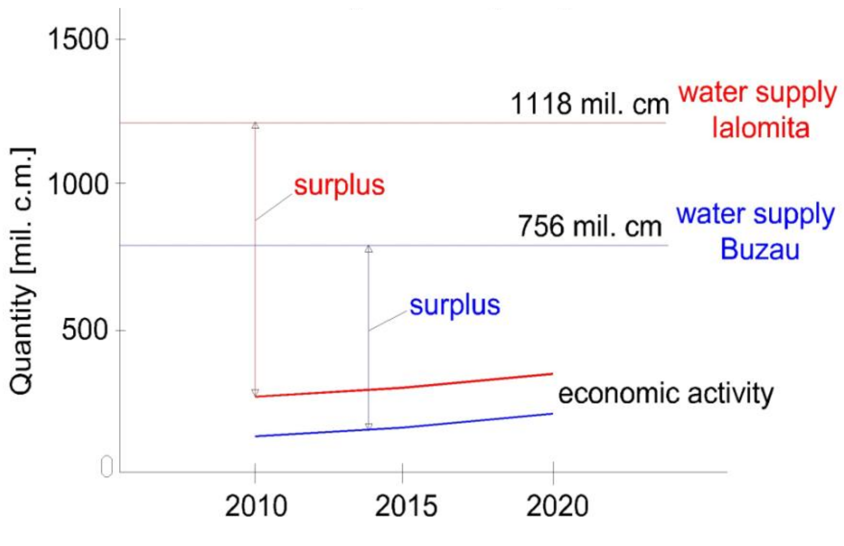

Figure 1.1. Water resources wulnerability in Ialomiţa and Buzău river basins -Normal year -

1.4. Hydrological resources of the Buzău and Ialomiţa river basins in draught conditions

It is well-known not only the seasonal variation of the Ialomiţa and Buzău river basins water resources, but also their great variability from year to year. Therefore on the two rivers there are the floods which cause human victims and great damages, but also the draught years, when the mean annual discharges don't exceed 14-20 m3/s and as a consequence of that, it takes place a hydrological resources reduction of up to 50% from those mean multi–annual. In those conditions is necessary the analysis of the water resources vulnerability of the two river basins in a drought year as well. In this purpose there was elaborated the hypothesis that the (natural) hydrological resources of the two rivers are *(Figure 1.2)*:

- For Buzău river basin at 500 mil m^3/year
- For Ialomiţa river basin at 700 mil m^3/year

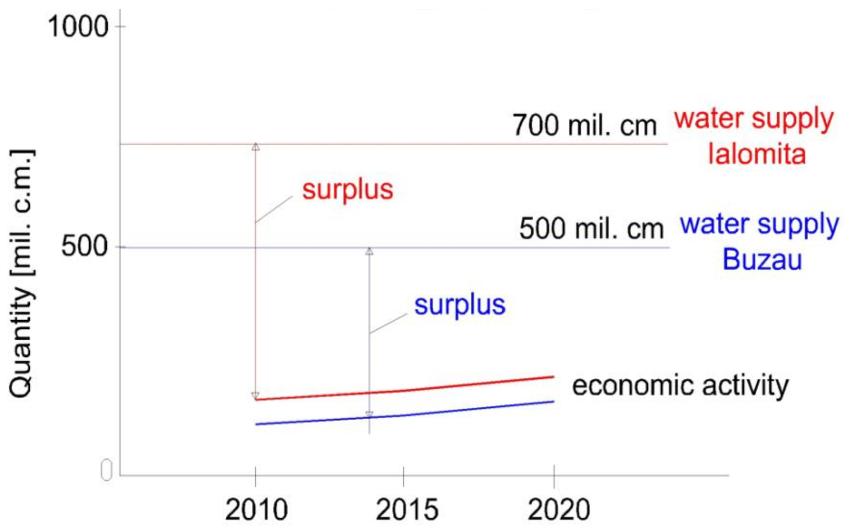

Figure 1.2. Water resources vulnerability in Ialomiţa and Buzău river basins - Drought period-

In those conditions it is obvious that it is necessary to initiate adaptation measures or discharge transfers from the joined river basins.

1.5. Conclusions

As a consequence of the scenario application regarding the climate changes in the Buzău and Ialomiţa river basins, for 2021-2050, it is forecasted a hydrological (natural) resource reduction of the two rivers as following:

- Buzău river basin from an mean annual stock of 826.22 mil m^3/year (1971-2000), at 756.0 mil m^3/year for 2021-2050;
- Ialomiţa river basin from 1237.0 mil m^3/year, at 1118.0 mil m^3/year for the same periods.

In order to establish the water resources vulnerability of the two rivers as a consequence of the climate changes in the stipulated scenario there were utilized several criteria for quantifying the vulnerability:

- Water dependency criterion;
- Water deficit criterion ;
- Water balance criterion.

After all these criterions it resulted that in the year 2020, the water resources from the two river basins are not vulnerable.

The vulnerability analysis was also analyzed for a drought year, when it was considered that the water resources of the two river basins, is reduced to almost half. In this situation, the water resource per inhabitant is reduced to half and the utilization degree of the water resources increases towards 50-60%. As a consequence of that, within the Buzău and Ialomiţa river basins might appear a pressure on the water resources, so it will be imposed the adaptation measures.

Part 2.

Flood events within the present and future conditions with or without climate change based on outputs from climate scenarios simulations.

The flood occurrence was calculated on the upper part of the Dyje catchment. Its area is 1756 km^2, the closing profile is watergauge station Podhradí. The catchment is proper testing of future flood occurrence, because there is no significant reservoir (*Figure 2.1*), which could influence strongly the hydrological regime. For the calculation the HYDROG rainfall-runoff model was used (this model is used for operation discharge forecast for Dyje catchment since 2003 in CHMI). The input data for the HYDROG model were divided into 20 Thiessen polygons – for each polygon the closest ALADIN calculation point was selected (*Figure 2.1*).

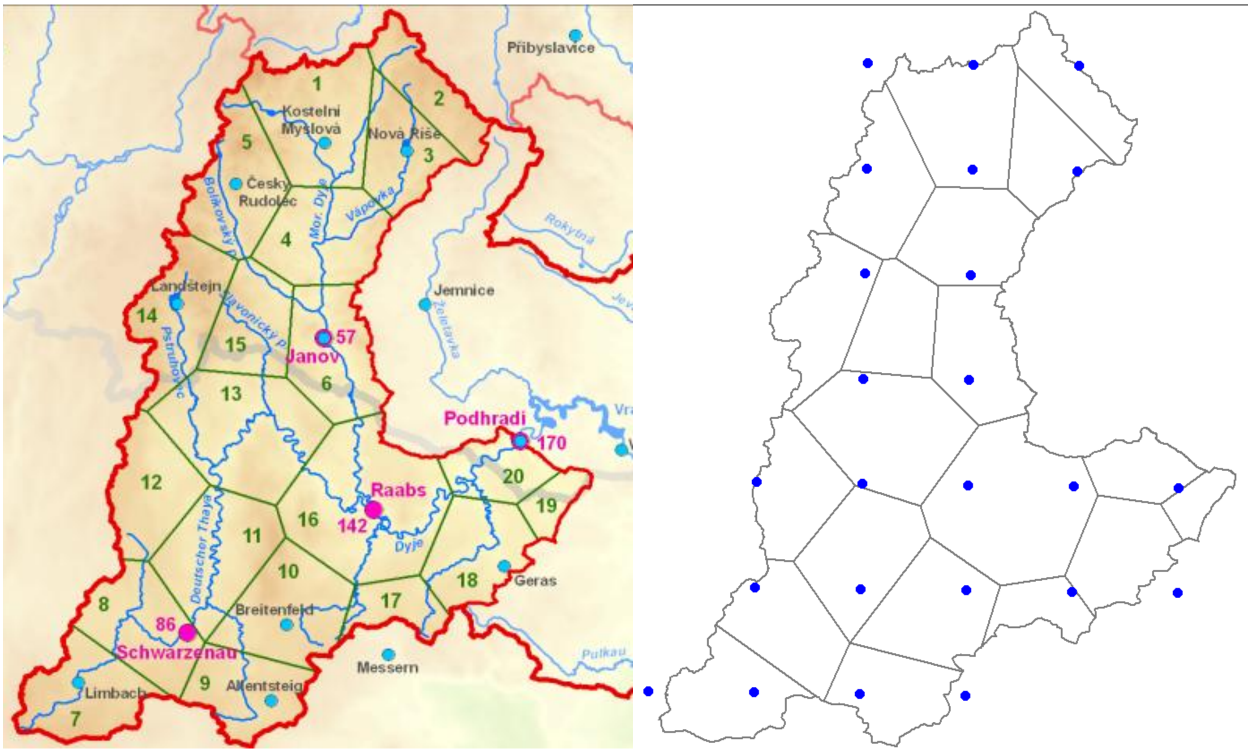

Figure 2.1. The map of the upper part of the Dyje catchment (left). The Thiessen polygons compared with the ALADIN calculation points (right).

On the *Figure 2.2* the annual peak discharges since 1933 are depicted. It is obvious that since 2002 three significant floods occurred. Generally the winter floods prevail in this catchment (see *Figure 2.3*).

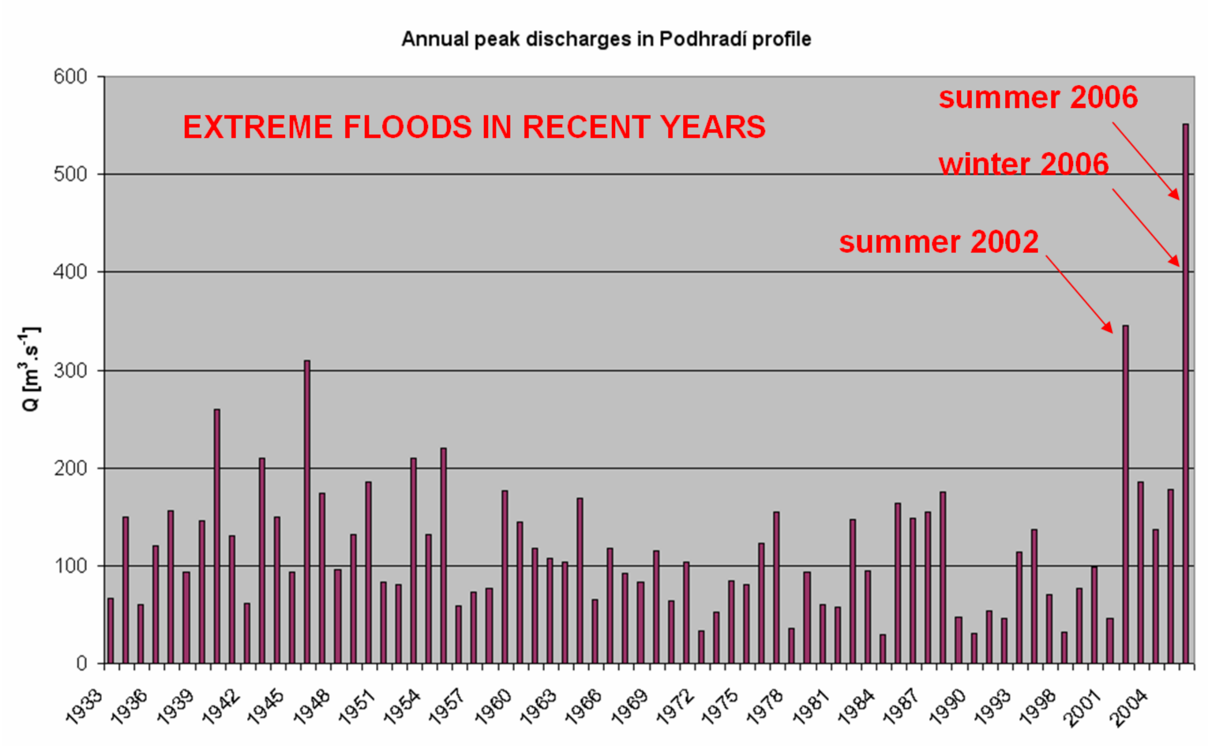

Figure 2.2. The annual peak discharges in Podhradí watergauge station since 1933.

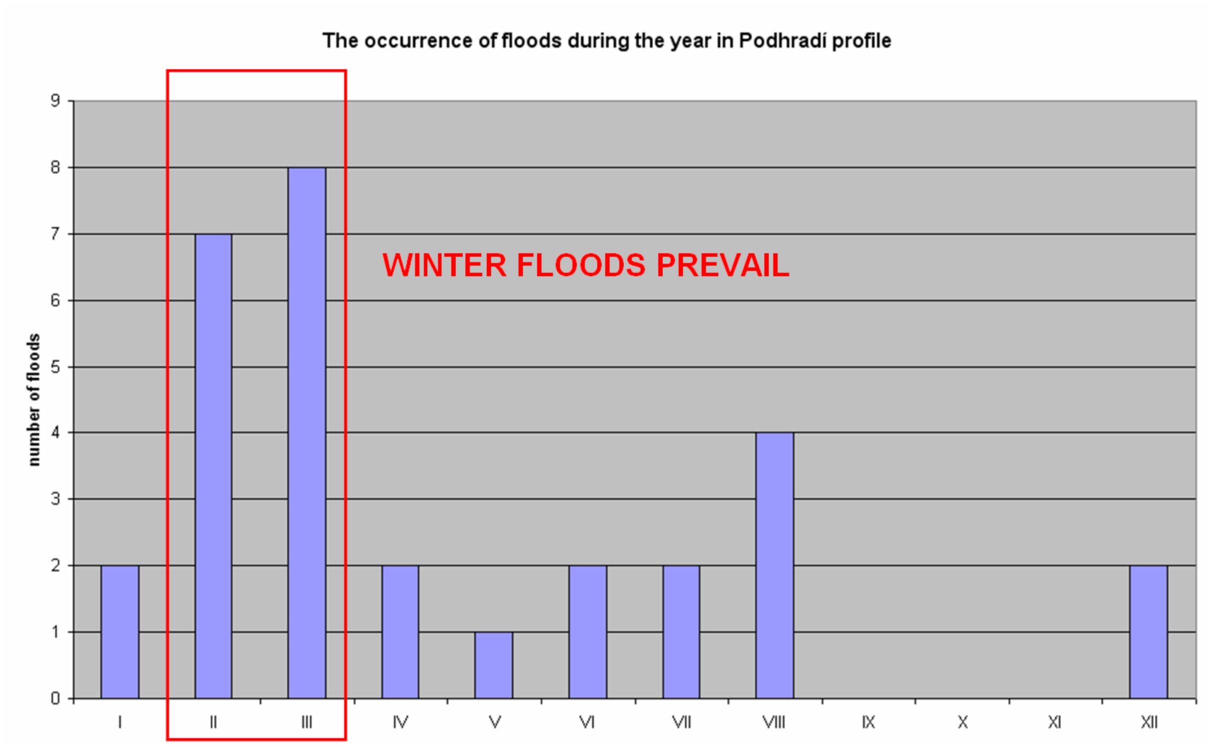

Figure 2.3. The flood occurrence during the year. The winter floods caused by snow melting prevails (during period 1961-2000).

2.1. The simulation of period 1961-2000

As the input data for the hydrological model the precipitation, temperature and snow level (water equivalent) from the ALADIN-CE model were used. All the resulting flood waves were simulated – see example on *Figure 2.4*. Then the annual peak discharges were evaluated and compared with the measured values (*Figure 2.5*). It is obvious that the simulated peak discharges reached higher values than the measured ones – when we speak about period 1961-2000. But in 2002-2006 three extreme floods occurred in the Dyje catchment as it was specified in previous part. The problem is that, in simulated period, summer floods prevail (*Figure 2.6*), which is not coinciding with the reality.

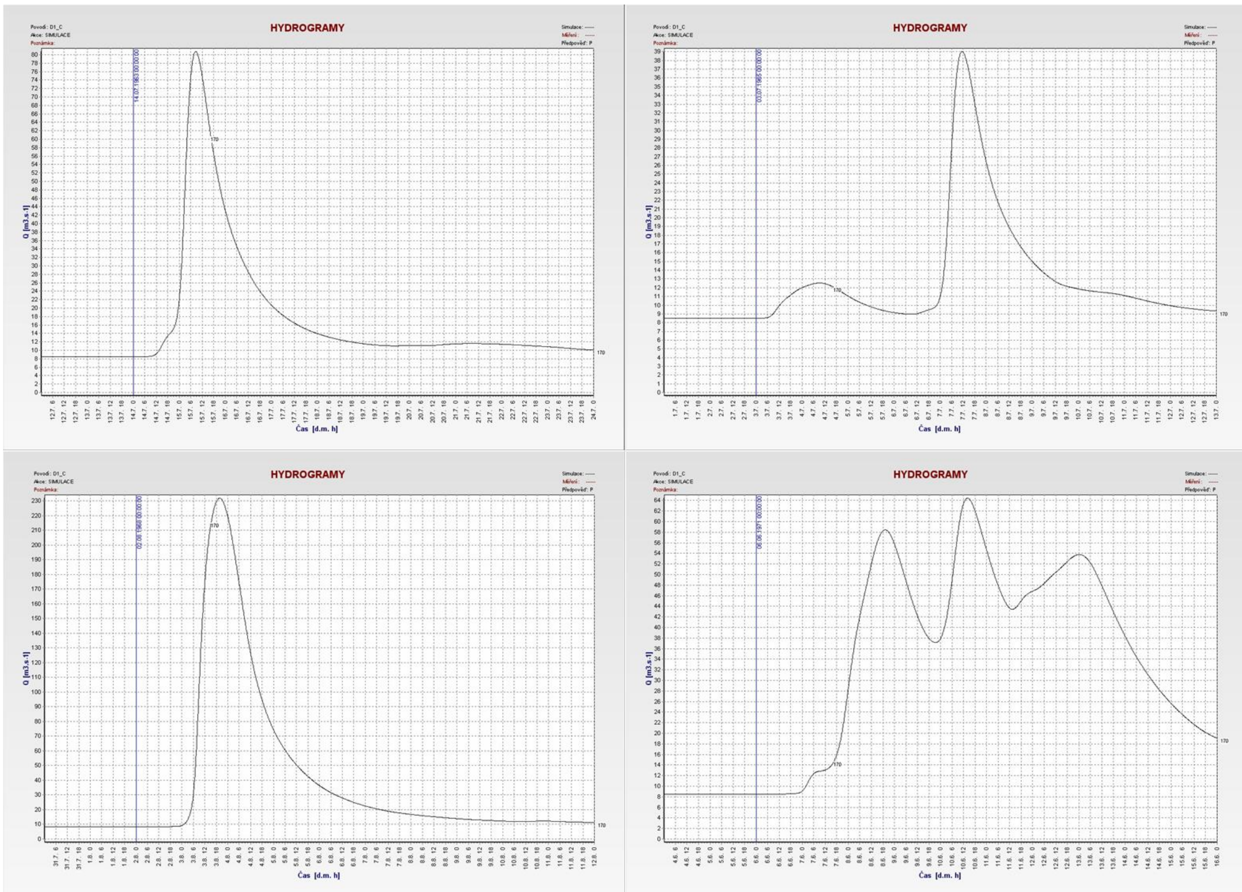

Figure 2.4. Examples of simulated flood waves from period 1961-2000

For the better comparison the return time period peak discharges were calculated (with the use of three-parametric log-normal distribution) in such a way that in the whole available series of measured maximum year discharges (1933-2008) the values from 1961-200 were substituted by simulated maximum year discharges. The results are presented in *Table 2.1*. The difference between measured and simulated return time period peak discharges is only several percent – we can assume that the simulation of period 1961-2000 was quite successful.

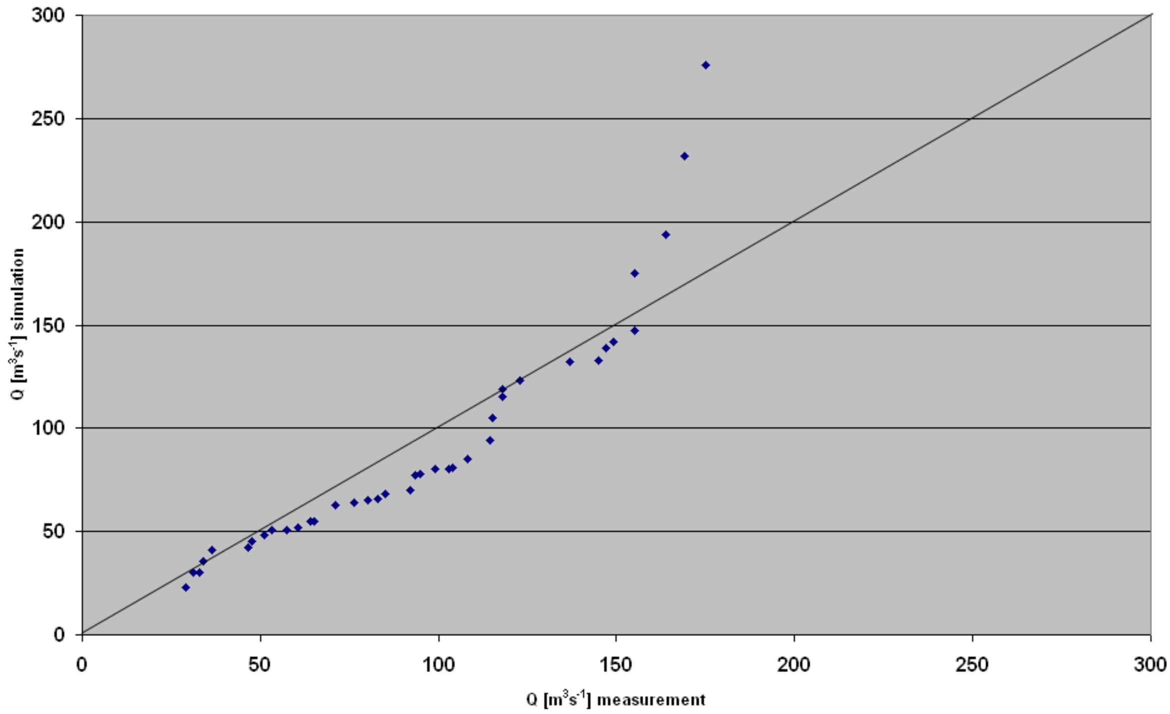

Figure 2.5. Comparison of measured and simulated annual peak discharges for period 1961-2000.

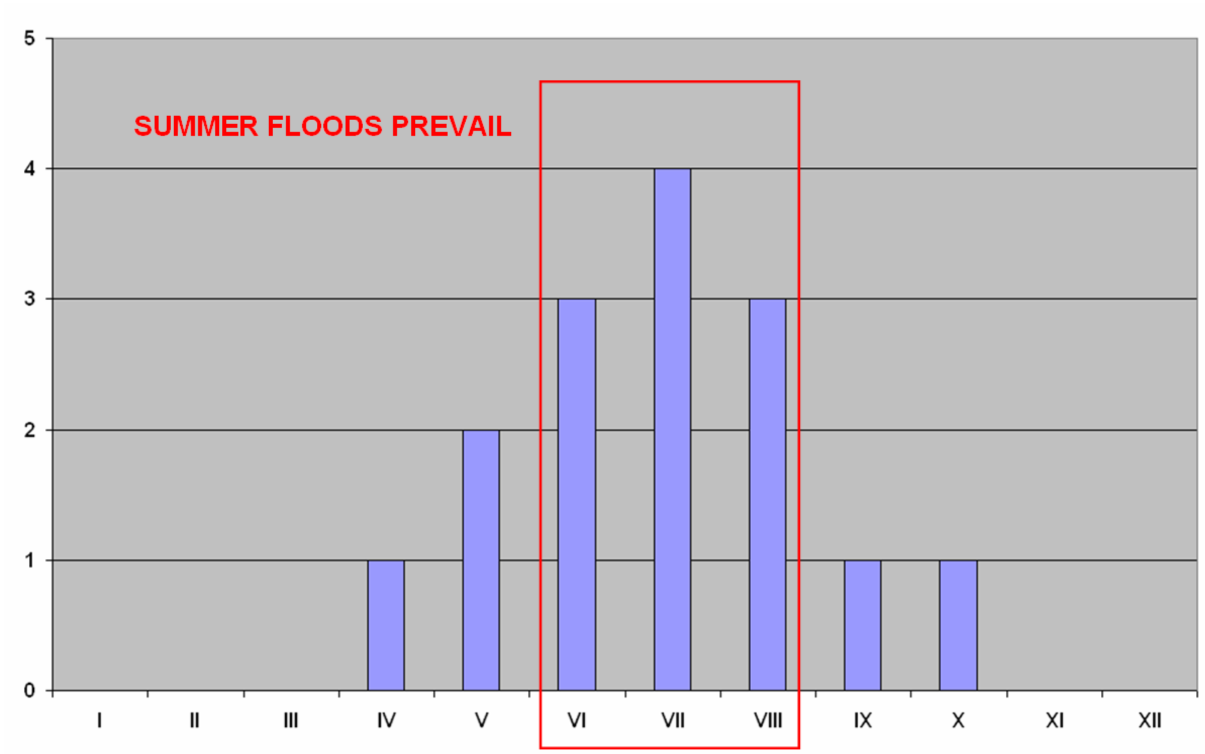

Figure 2.6. The flood occurrence during the year – simulation of period 1961-2000.

Table 2.1. Comparison of measured and simulated return time period maximum year discharges.

Return period [year]	Measured maximum year discharges [m^3/s]	Measured and simulated year maximum discharges [m^3/s]	Difference [%]
1000	681	685	0.5
500	595	602	1.1
200	491	500	1.9
100	419	429	2.4
50	353	363	2.8
20	274	282	3.1
10	220	227	3.0
5	172	176	2.3

2. 2. The simulation of period 2021-2050

The simulation of a period 2021-2050 was done in the same way as the simulation of 1961-2000. Again all the floods which occurred in simulated period were evaluated (see examples of flood waves on *Figure 2.7*). The summer floods prevail (*Figure 2.8*).

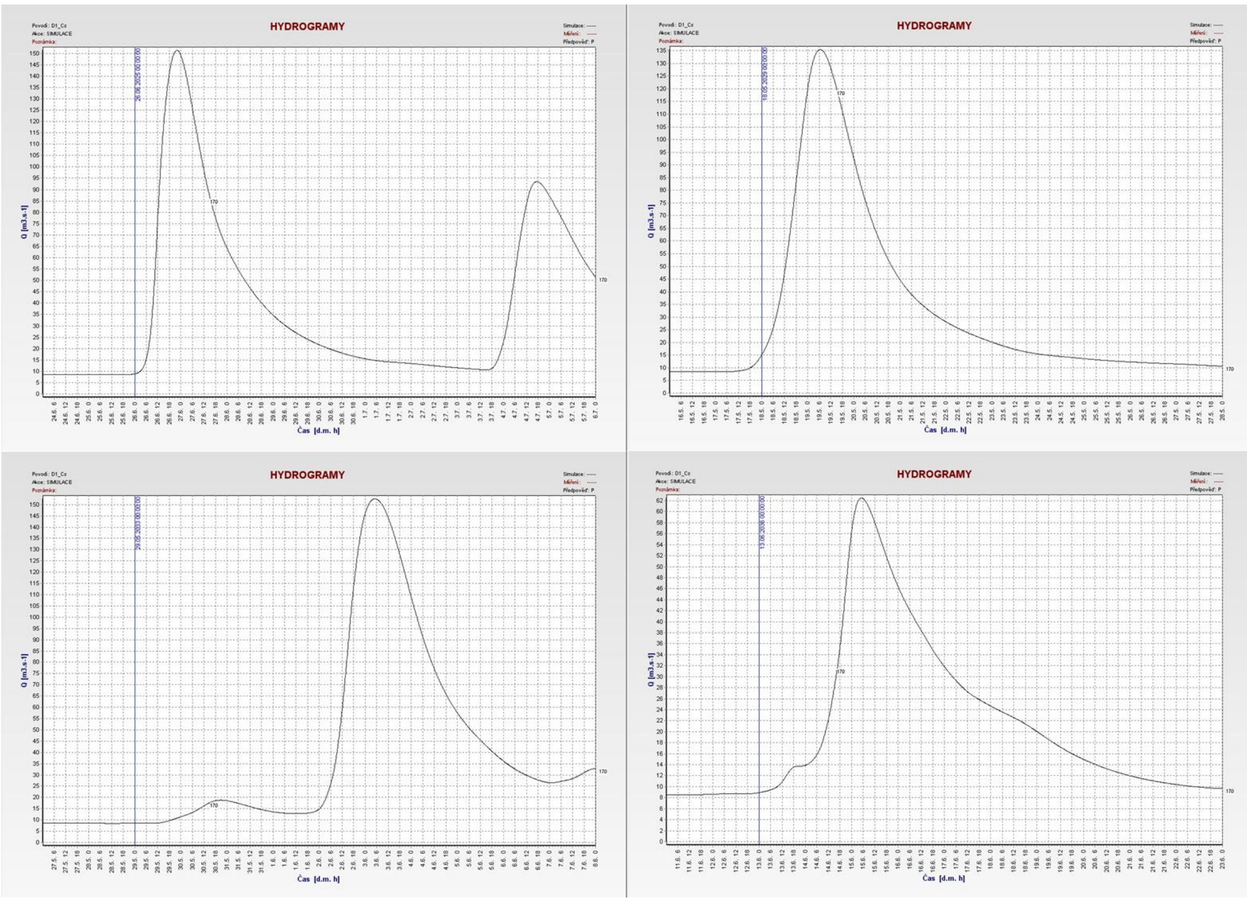

Figure 2.7 Examples of simulated flood waves from period 2021-2050

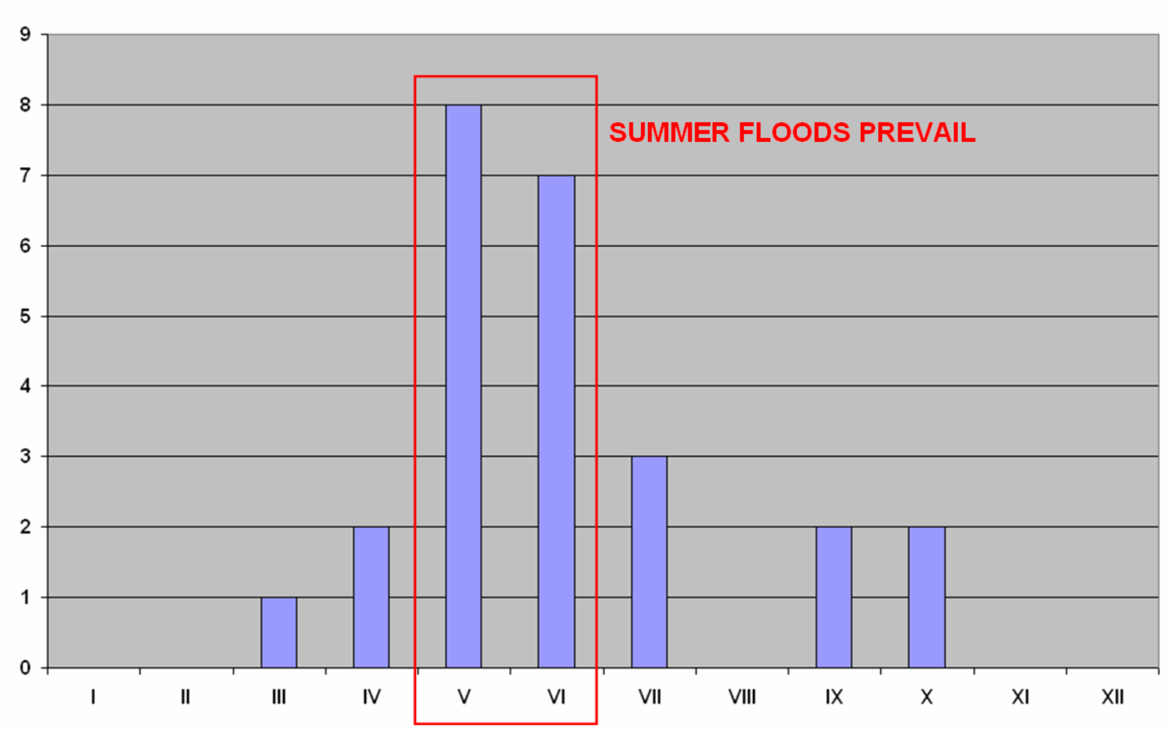

Figure 2.8. The flood occurrence during the year – simulation of period 2021-2050.

The series of maximum year discharges occurring in 2021-2050 was created. Based on this series a new return time period maximum year discharges were calculated, the missing data (maximum year discharges from 2009-2020) were selected randomly from measured data. The several variants of random substitution were calculated and then the resulting return time period peak discharges (presented in *Table 2.2*) were obtained as an average values. The difference between return time period peak discharges based on measured values (1933-2008) and both measured and simulated values (1933-2051) is more than 10 percent.

Table 2.2. Comparison of measured and simulated return time period maximum year discharges.

Return period [year]	Discharge based on measurement [m^3/s]	Discharge based on measurement and simulation (1961-2000) [m^3/s]	Discharge based on measurement and simulation (2021-2050) [m^3/s]	Difference [%]
1000	681	685	805.6	18
500	595	602	702.5	18
200	491	500	577.6	18
100	419	429	491.3	17
50	353	363	411.5	17
20	274	282	315.7	15
10	220	227	250.2	14
5	172	176	190.8	11

2.3. The simulation of period 2071-2100

The simulation of a period 2071-2100 by the HYDROG model was done in the same way as the previous simulation. The example of several flood waves is depicted on *Figure 2.9*. Again the summer floods prevail in this period (*Figure 2.10*).

All the flood waves were evaluated and the series of maximum peak discharges were created. Then the return time period peak discharges based on measured and simulated data (1933-2100) was calculated using three-parametric log-normal distribution. The missing data (2051-2070) were randomly selected from the measured maximum year discharges (1933-2009). Several variants of random substitution were done and then calculated the average return time period peak discharges (see *Table 2.3*). Again the return time period peak discharges derived from measured data are about more than 10 percent lower than return time period peak discharges derived from both measured and simulated data (1933-2100).

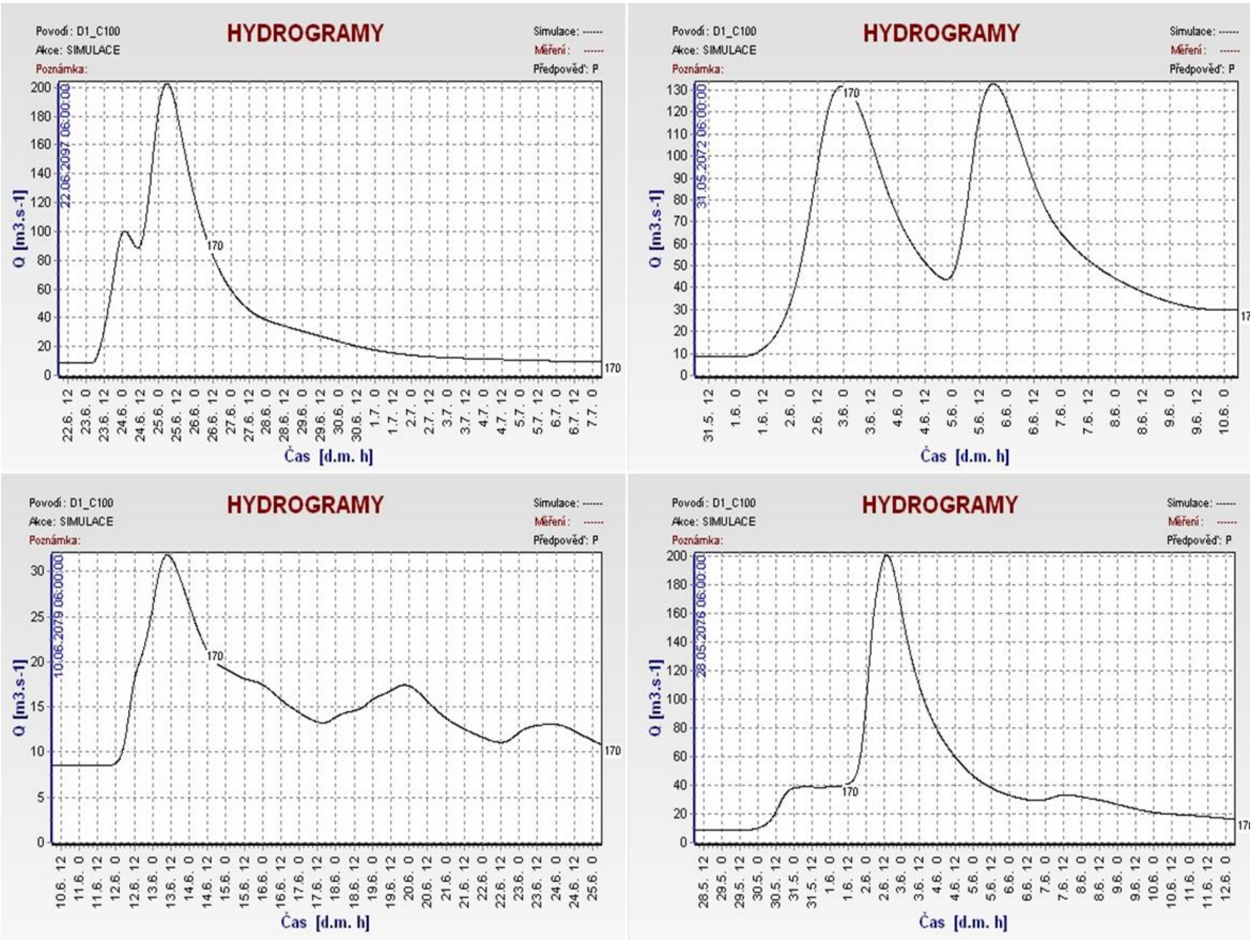

Figure 2.9. Examples of simulated flood waves from period 2071-2100

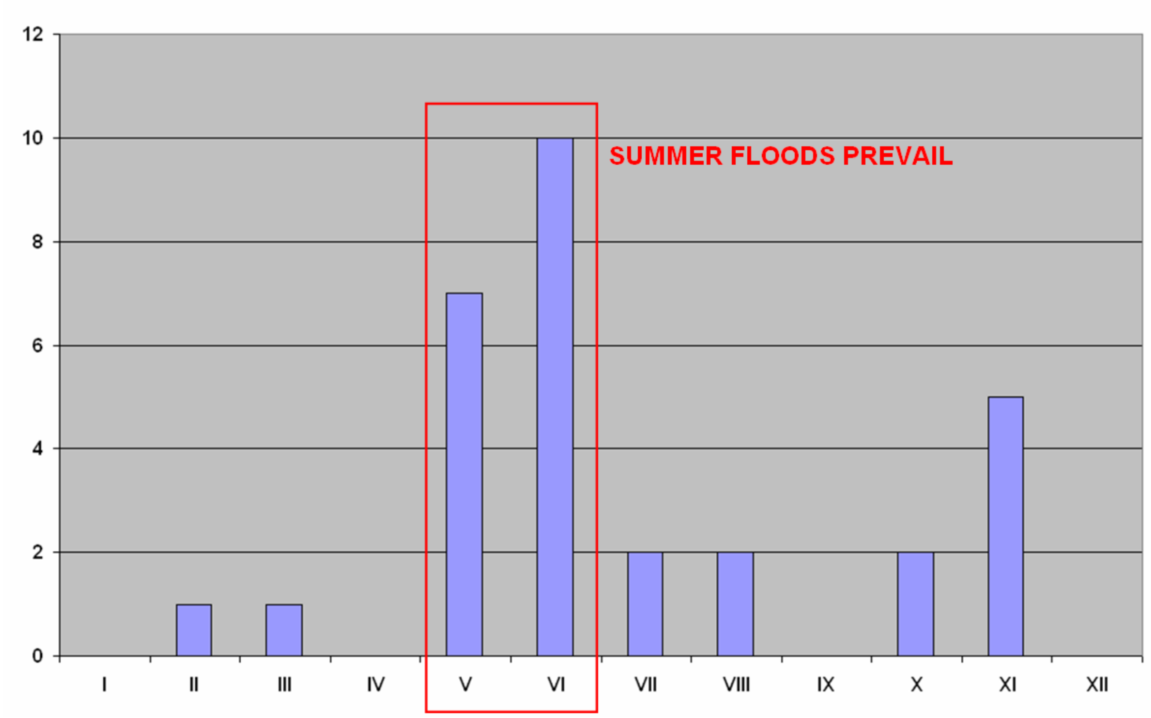

Figure 2.10. The flood occurrence during the year – simulation of period 2021-2050.

Table 2.3. Comparison of measured and simulated return time period maximum year discharges.

Return period [year]	Discharge based on measurement (1933-2009) [m^3/s]	Discharge based on measurement and simulation 1961-2000 [m^3/s]	Discharge based on measurement and simulation 2021-2050 [m^3/s]	Difference [%]	Discharge based on measurement and simulation 2071-2100 [m^3/s]	Difference [%]
1000	681	685	805.6	18	755.72	11
500	595	602	702.5	18	663.46	12
200	491	500	577.6	18	550.68	12
100	419	429	491.3	17	471.94	13
50	353	363	411.5	17	398.55	13
20	274	282	315.7	15	309.36	13
10	220	227	250.2	14	247.63	12
5	172	176	190.8	11	190.82	11

2.4. Conclusion

The whole process of flood simulation is highly uncertain. There exists an uncertainty of ALADIN-CE input data, the simplification of input data for the need of the hydrological model, and finally the uncertainty of the hydrological model itself. Despite this fact it is possible to assume that the peak discharges with the same return time period could increase if we take into account the future climate scenarios.