Chapter 5
Characterization of the Runoff Regime and Its Stability in the Danube Catchment

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Abstract The main purposes of this investigation were to typify the runoff regime (i.e., the typical timely distribution of their flow discharges within the year) in the various regions of the Danube Catchment, and to determine the areal distribution within the Danube Catchment of various indices, each of which characterize the stability of one selected (or integrated) element of the interannual distribution of the flow discharges in the rivers.

The present investigation was carried out as one of the projects of the hydrological co-operation of the 13 Danube Countries in the frame of IHP (International Hydrological Programme) UNESCO.

The computations necessary for the investigations were carried out by processing the series of monthly mean discharge values of 206 gauging stations operated on the river network of the Danube Catchment. Data series covering 51 years (1950–2000) or the only slightly shorter length of 42 years could be provided for the majority (95%) of the stations.

The identification of runoff regime types and stability is based on the probability of occurrence of six particular hydrological events: the first, second and third greatest monthly mean discharges of the year, symbolized with MAX1, MAX2 and MAX3, and the first, second and third lowest monthly mean discharges of the year, min1, min2 and min3.

The numerical results of the runoff regime type identification process can be seen in Table 5.5 and in Annex 3. They are graphically displayed on the map of the Danube Catchment in Annex 2.

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Eight main runoff regime types and 17 subtypes were found in the Danube Catchment. Various indices characterizing the stability of the runoff regime, *N*(MAX1), *N*(MAX2), *N*(MAX3), *N*(min1), *N*(min2), *N*(min3), along with the synthesizing indices *N*MAX, *N*min and N_R, as defined, after Nováky, by the formulae Eq. (5.2) and Eq. (5.6), were computed and displayed on the maps of Annexes 4–6.

Keywords Danube River Catchment · Runoff regime types · Runoff regime stability · Flow distribution · Flow discharges

5.1 Introduction

By size, the River Danube is only the second greatest river in Europe after the River Volga, but it is one of the most international rivers in the world. The Danube and its tributaries collect their waters from the territory of 18 countries, whose life and history – in spite of the different social and political traditions – are more or less defined by this river. Because of this geographical connection, it was a natural necessity that the countries sharing the Danube Catchment – despite political disagreements – had to co-operate in the field of hydrology. The first steps of this collaboration persisting today, were in 1971, when the – at that time – eight Danube countries began to co-operate for the development of the first Hydrological Monograph of the Danube River. This work was finalized in 1986 by the publication of the German-language version of the Monograph. Since 1987, the aim of the Regional Hydrological Co-operation of the Danube Countries has been to improve and update the Monograph by jointly compiled and published follow-up volumes on selected topics of common interest. The goal of the preparation of the present chapter was to investigate the runoff regime by using a uniform methodology in the whole Danube Catchment. The main points were to typify the runoff regime and the investigation of its stability on the rivers of the Danube Basin.

The runoff regime is the fluctuation of a certain hydrological event within the year. In the characterization of the runoff regime, selected events, first of all the extreme values play an important role. Although the realization of a selected hydrological event within a particular year may differ considerably from that of other years, the typical pattern of the runoff regime over a longer period can be detected. Regime stability is the measure of deviation between the runoff regime of individual years and the typical regime pattern.

Because of spatial variability of climate and prevailing physio-geographical conditions, the regime of the watercourses is also different and has variability in space. Moreover, the regime is influenced also by impacts from anthropogenic activities (e.g. land and water uses). When factors that determine the runoff regime do change in time (climate change, change in anthropogenic activities), both type and stability of the runoff regime will change. Thus, characteristics of the runoff regime can be used as indicators of climatic changes.

This chapter – besides the introductory and closing parts – has four main sections dealing with the investigation of the runoff regime. The first presents a general description of the Danube Basin, emphasizing those natural factors, which more or less affect the runoff regime (e.g. climatic and geomorphologic conditions). The second part contains the methodological description of the investigation and presents the data collecting procedure. The next section introduces the results of the typification of the runoff regime together with a colour map and detailed tables of the regime types. The fourth part deals with runoff regime stability. The stability values of the six hydrological events to be introduced later in Annex 3 are presented in a table, while from the nine stability indices (six original events and three derived) three are displayed on colour maps in Annexes 4–6.

The base map of charts presenting the results of the investigation is USGS HYDRO1k, which was developed from a 30 arc-s digital elevation model of the world, it provides a standard suite of geo-referenced data sets (at a resolution of 1 km) that will be of value to organize, evaluate, or process hydrologic information on a continental scale (USGS 2003).

5.2 Investigations Carried Out in the Past

Various regions of the Danube Catchment have been investigated several times in regards to runoff regime characterization and stability calculation, but the catchment was never analyzed as a whole system. The main projects involved in the regional analyses are noted below.

Stanescu and Ungureanu (1997) within the frame of the FRIEND-AMHY co-operation carried out a runoff regime stability investigation of the Tisza River Basin. For the analysis the data were collected from the FRIEND-AMHY database, from yearbooks and from the national co-ordinators of III-AMHY. Relying upon the available data from stations in Romania, Spain, Yugoslavia, Greece and Switzerland, the discriminating periods which define a particular river flow regime were determined. The existence of different zones expressed by their mean altitudes that from the stand point of physiographical properties are quasi-homogeneous, allows hydrological regionalization to be carried out. Stability investigations allowed the determination of very stable or stable mountainous zones, relatively stable zones in medium altitudes and unstable or relatively unstable zones in low territories (Stanescu and Ungureanu 1997). The investigation was continued later by the development of the methodological part (Stanescu and Corbus 2004).

In the framework of a bi-lateral hydrological co-operation between the Water Resources Research Centre (VITUKI, Budapest) and Technical University of Graz, 25 discharge-measuring stations of the catchment of the Upper Rába River (belonging to the section of Sárvár) were processed for typifying the runoff regime and to determine its stability (Bergmann et al. 2001). Runoff regime could be clustered, depending on climatic and hypsographic conditions, into three types. Stability investigations were carried out both on the basis of the index of Corbus and that of the Nováky index N. Mapping was carried out on the basis of the index of Corbus: one map was created for the whole runoff regime (six events), one for MAX1 event and one for min1 too. There was a definite clustering in the case of three events. For the Rába River, also the longitudinal profile of the stability index was plotted (Nováky et al. 2001).

In the framework of an investigation of 30 watercourses in Hungary, also a stability investigation was carried out (Nováky et al. 2001). It was determined that the most stable was the runoff regime of watercourses originating from karst regions. The least stable was the runoff regime of watercourses heavily affected by anthropogenic impacts. The runoff conditions of the western part of the country (Transdanubia) are more stable, due to climatic effects, than those of the eastern part (Tisza Catchment). With some exceptions (Lajta River/Hegyeshalom and Mura River/Letenye), the stability of the flood regime is higher than that of the low flow regime. This might be due in part to higher climatic stability, and partly because of special riverbed conditions of the two rivers mentioned. The Raba River originating in the Alps is the only exception with the lowest runoff regime stability among all the investigated watercourses.

As a first step of the evaluation of runoff regime in the whole Danube Basin, the hydrological regime in one of the most important subcatchments of the Danube River, the Tisza River Basin was investigated (Kovács and Nováky 2004). After the examination of 40 data series, it can be declared, that the runoff regime types of the area relate well to territorial climatic changes connected with elevation, while the runoff regime stability of the low flow events is higher than that of the flood events. The most stable part of the basin is the mountainous area around the springs of the Tisza and the most unstable territory is in the western part, the Zagyva River Basin. The results of this work were presented at the XXIInd Danube Conference, held in Brno, Czech Republic, 2004.

5.3 General Description of the Danube River Basin

The River Danube, crossing Middle and Southeastern Europe along its 2,857-km long course, with its multi-annual mean discharge of 6,855 $m^3 s^{-1}$ is the 21st greatest river of the Earth and – after the River Volga – the second greatest of Europe. Its catchment, covering an area of 817,000 km^2, is situated south of the European main continental divide, running from Gibraltar to the Ural Mountains, the central band of this southern part, between the springs of the Rivers Rhine and Dnepr (RZD 1986).

The Danube Catchment not only crosses the European continent geographically, but it also provides historical and political contact between its western and eastern regions too. At the beginning of the hydrological co-operation of the Danube Countries – in 1971 – 12 European states shared the Danube Catchment; moreover these states were separated by the Iron Curtain. Today, after political changes in East-Central Europe, 18 countries share in the Danube Basin. The most important data related to these countries are presented in Table 5.1.

A detailed general description of the Danube River Basin has been published in previous issues within the frame of the co-operation of the Danube Countries (RZD 1986, RCDC 1999), so in this publication only a short introduction to the most important geographical factors is presented. For every factor, the authors have tried to use the most recent maps, compiled on the basis of the latest databases at that time.

Table 5.1 Countries sharing the Danube catchment in 2005

	Country's		Area (1,000 km^2)		Share of		Inhabitants (2003)		
					Country in the catchment	Catchment in the country		In the catchment	
No.	Symbol	Name	Total	In the catchment	%		Total (10^6)	(10^6)	%
"Danube countries" (with major areal shares), approx. in hydrographic order									
1.	D	Germany	357.0	59.6	7.30	16.8	82.1	9.1	11.1
2.	A	Austria	83.9	80.7	9.88	96.4	8.1	7.7	9.4
3.	CZ	Czech Republic	78.9	24.5	3.00	31.1	10.3	2.8	2.5
4.	SK	Slovakia	49.0	48.5	5.94	99.0	5.4	5.2	6.4
5.	H	Hungary	93.0	93.0	11.39	100.0	10.0	10.0	12.2
6.	SLO	Slovenia	20.3	18.0	2.19	88.8	2.0	1.7	2.1
7.	HR	Croatia	56.6	35.4	4.33	62.5	4.8	3.2	3.8
8.	BIH	Bosnia and Herzegovina	51.1	38.3	4.66	74.9	3.8	2.9	3.5
9.	SCG	Serbia and Montenegro	102.2	91.4	11.19	90.0	10.4	9.0	11
10.	RO	Romania	237.5	232.2	28.43	97.6	22.6	22.6	27.6
11.	BG	Bulgaria	110.9	48.2	5.90	43.6	8.3	3.9	4.8
12.	MD	Moldova	33.7	12.0	1.46	35.6	4.3	1.1	1.2
13.	UA	Ukraine	603.7	32.5	3.96	5.4	50.9	3.1	3.7
"Peripheral countries" (with minor areal shares)									
14.	CH	Switzerland	41.3	1.8	0.22	4.4	6.7	0.3	0.4
15.	I	Italy	301.3	0.5	0.06	0.2	57.5	0.1	0.1
16.	PL	Poland	312.7	0.3	0.03	0.1	37.8	0.04	
17.	AL	Albania	28.7	0.1	0.01	0.01	3.2		
18.	MK	Macedonia	25.7	0.4	0.05	0.2	2.1		
1–18.	Danube Catchment total			817.0	100.00			82.74	100.0

5.3.1 Topography and the River Network

The springs of the Danube are in the Black Forest, in Western Europe, while its mouth at the Black Sea is in Southeastern Europe. The northernmost point of its divide is, near the springs of its tributary Morava/March, while the southernmost one is in the Rila Mountains, at the origin of its tributary Isker. The length of the longitudinal axis of the catchment is 1,630 km, that of its watershed 6,320 km. The orography of the latter however is uneven: while it reaches on the southern stretch a height of 4,052 m above sea level (Piz Bernina), the highest point on its northern stretch is the peak Krivan, in the High Tatra Mountains, at only 2,496 m a.s.l. The average elevation of the catchment is 475 m above sea level (RCDC 1999).

The mountain ridges articulating the surface of the Danube Catchment – the Alps, the Carpathians, the Dinarides and the Balkan Mountains – subdivide it into three characteristic units. Its upper part between the riverhead and the Devín Gate is the Upper Danube Region. Within the latter, the Uppermost Danube Region, between the springs and the town of Ulm, is crossed by the non-navigable stretch of the Danube.

The most outstanding tributary in the Upper Danube Region is the River Inn, due not only to its catchment area, but also particularly to the fact that it collects the waters of the highest part of the Danube Catchment.

The Central Danube Region is the subcatchment situated between the Devín Gate and the Iron Gate. This area is sometimes referred to as the Carpathian Basin, although the inclusion of the area south of the River Sava into that Basin is – partly for political considerations – not generally accepted.

The two most important tributaries reach the Danube in this region, not so far from each other, the Tysa/Tisza and the Sava. The River Tysa/Tisza collects the most runoff from the eastern part of the Carpathian Basin, including Transylvania, while most of the discharges of the River Sava are supplied by its southern tributaries originating in the Dinarides.

The Lower Danube Region is between the Iron Gate and the mouth into the Black Sea. This territory can be divided into two parts. Above Brăila, the Danube and its tributaries cross the basin in wide, terraced valleys; this is the area called the Romanian Lowland. The Danube Delta follows downstream Brăila, and this is sometimes also called the Maritime Danube Region (RCDC 2004).

The left side tributaries of the Danube, in this region, collect their waters from the southern slopes of the Southern Carpathians. Numerous watercourses originating in the Eastern Carpathians are collected by the two greater north-eastern tributary streams, the rivers Siret and Prut. The southern tributaries of the Danube originate from the northern slopes of the Balkan Mountains. An overview of the most important parameters of the main tributaries of the River Danube is presented in Table 5.2.

5.3.2 Climatic Conditions, Hydrometeorology

Because of the elongated shape of the Danube Basin in the west–east direction and diverse relief features the climatic conditions are variable. The Danube Catchment

Table 5.2 Overview of the main tributaries of the River Danube (RZD 1986)

River	Catchment area (km^2)	Partial discharge from subcatchment ($m^3\ s^{-1}$)
Danube (from the spring to the mouth of Lech)	15,654	184
Lech	4,398	107
Naab	5,645	52
Isar	8,369	163
Inn	26,976	742
Enns	5,940	191
Morava/March	27,633	124
Raab/Rába	14,702	61
Váh	9,714	128
Nitra	5,415	27
Hron	5,251	48
Ipel/Ipoly	5,494	20
Sió	15,129	39
Drau/Drava/Dráva	41,810	577
Tysa/Tisza	158,182	888
Sava	94,778	1545
Velika Morava	38,233	262
Jiu	10,731	95
Iskar	7,811	57
Olt	24,810	184
Lom	3,380	7
Arges	11,814	71
Ialomita	10,305	48
Siret	45,420	226
Prut	28,954	88
Danube (at the mouth to the Black Sea)	817,000	6,857

extends from the western regions of the Upper Danube with high Atlantic influence, to the eastern territories affected by a continental climate. In the Upper and Central Danube Region, especially in the Drau/Drava/Dráva and Sava basins, the climate is influenced by the Mediterranean. This basic character of the climate is varied and modified into natural regions by the great mountain systems, influenced by the height above sea level and the relief features (exposure, leeward and windward position) too (Stančík and Jovanović 1988).

The summarized effects of the climatic components show great differences over the sub-basins of the Danube Catchment. In the case of this investigation, the exact climate types of the sub-basins are not really important, only the tone of the colours in every patch is interesting on the map. This is the reason for presenting the map without a legend, while the original printed version – with its legend – can be found near the publication of the climate types (RZD 1986). On the climate map, the colours change from dark (blue) to bright (yellow), as the measure of the precipitation in that climate type decreases.

5.3.2.1 Air Temperature

The pronounced air temperature differences are also determined by the extensive area and elongated character of the Danube Basin from west to east. Average annual air temperature within the basin ranges from –6.2°C to +12°C. The lowest value originates from Sonnblick, the highest mean annual temperature was observed in the northern part of the Hungarian Lowland and at the Black Sea coast. In the entire Danube Basin July is the warmest month, January being the coldest one (Stančík and Jovanović 1988).

In the upper reach of the Danube Basin the Winter period usually lasts from December to February. The average January temperature in the plains being –0.8 to –3°C, and in the mountains –6 to –13°C. Summers are warm and last here from June to August. Mean July temperatures are 17–20°C, the mean July isotherm in the high mountains being 0°C at heights of about 3,500 m.

In the Central Danube Region Winter only lasts for 1.5–2 months, the mean January temperatures in the lowlands being –0.3 to –2°C and on the highest points about –10°C, but in some places even lower. In July in the middle reach of the Danube basin the average air temperatures in the valleys rise to 20–23°C, but in the higher mountain regions it is only 4–5°C.

The Winter period of the Lower Danube Region usually begins 2 weeks later than the westernmost parts of the Danube Catchment and lasts from the second half of December to the end of February. Mean January temperatures fluctuate within the range –1.2 to –3°C and in the mountains –8 to –9°C. Summer starts in late May and ends in September with maximum monthly temperatures of 22–24°C in July (Stančík and Jovanović 1988).

5.3.2.2 Precipitation

Average annual precipitation fluctuates within the range of 2,300 mm in the high mountains to 400 mm in the delta region. The regional variation of the annual precipitation in the Danube Catchment is shown in Annex 1, where the mean annual values are interpreted for the time period 1961–1990 (Holko et al. 2005).

The Upper Danube Basin shows an astonishingly variable character for precipitation. In the high Alpine regions values of 2,000 mm are sometimes exceeded, the mountain marginal belts being extraordinarily rich in precipitation. The increment of mean annual precipitation values amounts to about 50 mm per 100 m height in the northern Alpine promontories and in the Alps. A further contribution is the distant influence of the mountains, affecting precipitation on windward slopes and increasing precipitation on approach to the mountains. Thus, the lines of uniform precipitation follow the contours of the mountains. In the northern Alpine Foothills the amount of precipitation decreases in this way from about 1,500 mm per year on the periphery of the mountains to 700 mm per year in the Danube valley. About 1,500 mm precipitation per year also falls in the Danube source area, in the Schwarzwald Massif and in the higher regions of the Bavarian and Bohemian

Forests. Other territories show average precipitation values 600–1,000 mm, the valleys and basins being relatively dry with about 700 mm. The intermountain valleys are also relatively dry (Stančík and Jovanović 1988).

In the Central Danube Region the highest values of mean annual precipitation occur on the outskirts of mountains surrounding the lowlands. The highest precipitation values above 2,000 mm occur on the southern-oriented mountain chains of the Julian Alps and the Dinaric system, which are exposed to the effect of humid-warm air masses coming from the Mediterranean. In the Carpathians the mean precipitation values vary between 1,000 and 1,500 mm. In the shelter of those mountains in the east Bohemian-Moravian Uplands, as well as in the Carpathian Foothills, the average precipitation amounts to 600 to 1,000 mm. In the southern part of the Central Danube Lowland the annual precipitation falls to 600–800 mm, in Alföld to 550 mm and in the region of the middle Tysa/Tisza to 500 mm.

This dry climate regime increases in the middle Danube Lowland in the northerly and easterly direction. In the plains of the Lower Danube Basin, the precipitation is only 500–600 mm, though the lowest precipitation values of less than 400 mm are recorded within the Danube estuary. In some years there is no precipitation over the Summer period. Because of the low precipitation and high Summer temperatures, the region of the Danube estuary may be considered as a region with a steppe climate.

When the annual distribution of the precipitation is studied, it can be seen that the maximum occurs regularly in the Summer months. This is especially true in low-lying parts of the Danube Basin, where convective precipitation constitutes a considerable contribution to the total precipitation (Stančík and Jovanović 1988).

In those regions the maximum is shifted with increasing continentality from July to June or May, since in mid-Summer the low air humidity is not sufficient for the development of the showers. The minimum precipitation occurs there in February and sometimes in January in mid-Winter when the Asiatic region of high pressure blocks the transfer of Atlantic air masses to the east.

The conditions in mid-mountain and high mountain ranges under the influence of a maritime climate are different. They usually have their maximum in Summer but due to their orography enabling gliding precipitation in the Winter months of December and January, they frequently show a secondary maximum, in some places even an absolute maximum of the precipitation activity, as for instance in the Bavarian and Bohemian Forest.

A deviation from this basic pattern is shown by regions influenced by the Mediterranean, where the months of October–December show maximum precipitation and the Summer is relatively dry.

The number of days with snow cover, duration and thickness increase with altitude. The shortest duration of snow cover (9–12 days) is on the Black Sea coast. The snow cover lasts for only 20–30 days in the Central Danube Region, 40–60 days in the Upper Danube Basin and the mean proportion of the total annual precipitation is about 10–15% (Stančík and Jovanović 1988).

5.4 Data Collection for the Investigation

For characterization and regionalization of the runoff regime and its stability, we used the data series of 206 discharge gauging stations from the countries of the Danube catchment. Investigating the number of data series sent from the Danube Countries (see Table 5.3), three casts of countries can be separated by using the index of the station density in this investigation. The average over the whole basin is 0.25 stations per 1,000 km^2; around this value are five countries out of the 13, Germany, the Czech Republic, Slovakia, Serbia and Montenegro and Moldova. There are another five countries with values between 0.13 and 0.17 which includes Slovenia, Croatia, Bosnia and Herzegovina, Romania and Bulgaria. The highest values for station density are above 0.40 in three countries of the Danube Basin: Austria, Hungary and Ukraine.

We planned to use rather extended catchments (>500 km^2), which limits the resolution of the investigation. We used 206 stations for the project, and there were five data series with a watershed size under this limit. We used them for the investigation, because they are located in mountainous regions; all of them are above 450 m a.s.l. They have a determinative function for the set of the runoff regime of their receiver.

The limitation at 500 km^2 means that some features of smaller catchments are merged into the value of the bigger area. But there are some great basins, which contain some smaller areas: for example the basin of Sajó at Felsőzsolca includes

Table 5.3 The number of stations for the Danube Countries

Country	Number of stations	Territory in the Danube Catchment (1,000 km^2)	Station density of the investigation (station/1,000 km^2)
Germany	16	59.6	0.27
Austria	34	80.7	0.42
Czech Republic	6	24.5	0.24
Slovakia	12	48.5	0.25
Hungary	38	93.0	0.41
Slovenia	3	18.0	0.17
Croatia	5	35.4	0.14
Bosnia and Herzegovina	5	38.3	0.13
Serbia and Montenegro	26	91.4	0.28
Romania	37	232.2	0.16
Bulgaria	8	48.2	0.17
Moldova	3	12.0	0.25
Ukraine	13	32.5	0.40
Total	206	814.3[a]	0.25

[a]The total area of the Danube Catchment is 817,000 km^2, this number is the territory of the countries with a major areal share in the Danube Catchment. The other 2,700 km^2 is divided between five countries, Switzerland, Poland, Italy, Albania and Macedonia, which each have a minor share in the Danube Basin (under 2,000 km^2/country).

the area of Slana/Lenartovce and Bodva/Turna. Of course the downstream stations contain all the investigated areas above them.

The time period of the investigation is 1950–2000. The length of most of the data series matches this – 131 stations from the total, which is almost 64% (51 years). The other 75 are shorter. As the length of the data series influences the results of the computation we had to make a compromise and we decided to apply an allowance of an 8-year-long time section to the data to increase the number of usable data series. This means, that if the data series is at least 42 years long, no limitation is applied in its utilization. After this, 196 stations were available, which is more than 95% of the total number.

The lengths of the remaining ten data series are between 11 and 41 years. These significantly shorter data series had to be included in the investigations as their exclusion would have resulted in extended empty spaces in the map of gauging stations within the Danube Catchment, thus enabling the investigation of only a part of that Catchment. In these cases we did not use any extending statistical operation, so the collation of the results of individual rivers is restricted, while the separation of the discriminant period – the basis of the calculation – is hardly ever influenced by them. In terms of geography for the stations with much shorter data series, seven out of the ten are on the territory of the former Yugoslavia. Reasons for data shortcomings in these cases should be looked for in the historical and political circumstances of the country involved. Mostly the missing data are at the end of the time period of the investigation, usually starting around 1990.

Of the other three stations, two are in the Republic of Moldova, in which there were also remarkable political changes at the beginning of the last decade of the twentieth century. The gauging station of the last short data series is located on the River Hornád/Hernád in Slovakia close to the Hungarian border. It is possible that the beginning of the data series is the starting point of the data collection in this location. It was possible here to check the geographical correctness of this investigation, because there is a gauging station on the Hungarian side – Hidasnémeti, not far down from the Slovak station, with a reliably long data series. After comparing the outcomes of the computations for these two stations, it became apparent there were no differences between the results for runoff regime types or stability.

As the number of stations with shorter then the 42-year-long data series was low and because their runoff patterns did not differ sharply from that of nearby stations, artificial extension of the short data series was not necessary.

5.5 Methodology for Determination of Runoff Regime Types, Stability Index and Stability Categories

The method of identifying the runoff regime type is based on the investigation of so-called discriminant periods within the years, for six selected hydrological events which represent the first, second and third highest as well as the first, second and third lowest monthly (mean) discharges (symbolized: MAX1, MAX2, MAX3 and min1, min2, min3). The discriminant period is defined as that partial period of pre-fixed length of the year, in which at a given gauging station, one particular (hydrological) event – for example the first highest monthly mean discharge or the second lowest monthly mean discharge – has occurred in most years (i.e., with the highest frequency) during the observation period. In this investigation the discriminant period was chosen as 3 months.

Using the time series of monthly flow the discriminant periods were evaluated for all hydrological stations investigated. Two hydrological stations have the same runoff regime type if the discriminant periods related to all hydrological events are the same or differ with only some limitations. The runoff regime of two stations may be accepted as identical if the discriminant periods of one or two hydrological events, especially of MAX3 or min3, rarely MAX2 or min2, are different by not more than 1 month (Nováky et al. 2001).

After having determined the type of runoff regime for all hydrological stations, the runoff regime stabilities of the individual stations (or else of regional station groups) can be investigated.

Stability can be characterized by adopting the following index: the index H, measuring the entropy as defined by Shannon, is the sum $H = \Sigma H\,(E_j)$ of the index $H(E_j)$, characterizing the individual stabilities of the six hydrological events listed above, as defined by the following equation (Nováky et al. 2001):

$$H\left(E_j\right) = p_i \times \ln p_i + (1 - p_i) \times \ln (1 - p_i) \tag{5.1}$$

where p_i is the probability of occurrence of the given hydrological event within the selected discriminant period of the year and $(1 - p_i)$ is the probability of occurrence of the same event within the complementary period. The value of entropy $H(E_j)$ depends on the length of the observation period, namely the number of the investigated years, and the position of this period in absolute time. The entropy decreases with the growth of the investigated period if its length is at least 30 years or more.

Function (5.1) is symmetrical, that is $H\,(p_i) = H\,(1 - p_i)$. Thus, the stability index H can be used only in the case where $p_i > 0.5$. This limitation can be lifted by introducing a modified version as was proposed by Nováky and Szalay (2001):

$$N = -\sum p_i \times \ln p_i \tag{5.2}$$

where p_i is the probability of occurrence of a given hydrological event within the ith period, with i ranging from 1 to 4. This means that the whole year is divided into four equal periods, consisting of 3 months. One of the periods will become the discriminant period. Obviously, the equality

$$p_1 + p_2 + p_3 + p_4 = 1 \tag{5.3}$$

is valid.

On the basis of the index of the runoff regime stability, the stability can be qualified or categorized. The selection of the category limits needs to be made and may

Table 5.4 Empirical classes of runoff regime stability on the basis of the Nováky index

N(MAX1), . . ., N(min3)	N_{MAX}; N_{min}	N_R	Stability grade
<0.28	<0.84	<1.68	Very stable
0.28–0.92	0.84–2.76	1.68–5.52	Stable
0.92–1.24	2.76–3.72	5.52–7.44	Relatively stable
1.24–1.39	3.72–4.17	7.44–8.34	Relatively unstable
>1.39	>4.17	>8.34	Unstable

even be modified in the course of the investigation. Not only the yearly runoff regime (runoff regime as a whole) can be qualified, but also individual hydrological events or selected groups (e.g.: the group of maximum monthly flow) as well (Nováky et al. 2001). The stability of only the high flow regime can be characterized by the index

$$N_{MAX} = N(\text{MAX1}) + N(\text{MAX2}) + N(\text{MAX3}), \tag{5.4}$$

the stability of only the low flow regime by the index

$$N_{min} = N(\min 1) + N(\min 2) + N(\min 3) \tag{5.5}$$

and the stability of the yearly flow regime by the index

$$N_R = N_{MAX} + N_{min}. \tag{5.6}$$

On the basis of the N index the stability of a given hydrological event or the flow regime can be classified as by Nováky and Szalay (2001) as is shown in Table 5.4.

The stability index can be displayed on a map, on which (1) the isolines of the identical stability indices can be plotted and (2) the regions belonging to the same stability categories can be identified. It is proposed to compile isoline maps (1) for all the six events considered (N_R), (2) for the three flood events (N_{MAX}), (3) for the three low flow events (N_{min}), (4) for MAX1 and (5) for min1. Both for the identification of discriminant periods and for the computation of stability indices, software have been developed.

5.6 Runoff Regime Typization

The characterization of the runoff regime was executed by using the discriminant periods, selected as a basis for computing the Nováky index. The discriminant periods are in accordance with the statement, according to which the highest monthly runoff usually occurs during the period between the end of the Winter to the dawn of the Summer, and the lowest monthly runoff falls between the end of the Summer to the end of the Autumn.

The investigation was executed by using the so-called "closest neighbour" principle. This means that the catchments are graded by the discriminant periods to obtain an order, where the basins with identical discriminant period come close together by using a chosen power sequence of the six hydrological events. This settlement insures that the discriminant periods of the directly neighbouring catchments would be the closest together. Our chosen power sequence of the discriminant periods – as was used by Nováky et al. (2001) – is:

$$\text{MAX1} \rightarrow \min 1 \rightarrow \text{MAX2} \rightarrow \min 2 \rightarrow \text{MAX3} \rightarrow \min 3$$

In this case we try to grade the rivers by setting together the stations with similar discriminant periods of the MAX1 event. Within the group of similar discriminant periods of the MAX1 event the order is then defined by the identity of the discriminant periods of the min1 event. The principle of alignment hereafter is based on the similarity of the discriminant periods of events in the order: MAX2, min2, MAX3, min3.

The grouping of the catchments is executed by the changing of the discriminant period of a given group and event. The increase of the period is as big as the length of the time space between the earliest and latest discriminant periods of that event in a given group. So the new discriminant period covers all the individual periods of the catchments belonging to the group.

The number of stations with less accommodation to their groups is 29, which is 14% of the total number of data series. For the runoff regime types of these stations the length of the discriminant period of the min1 event is extended to 4 months, because of the 1 month variance of the given discriminant periods. There are some catchments in the contracted runoff regime types, which occur as outliers to their group. In these cases the obligate increase of the discriminant period at the designation to a given type is at least 2 months. Possible reasons for these discrepancies can be found in the smaller length of the given data series, and in some cases the anthropogenic modifying effects or the limits of the characterization methodology.

Considering the above-mentioned observations – more or less subjectively – the 206 stations of the Danube River Basin are classified by their runoff regimes. As seen in Table 5.5, eight main types were defined, and together with the subtypes in total 17 runoff regime types were identified within the whole Danube Catchment. After the investigation of the runoff regime types, it can be seen, that the high-water period is drifting from the beginning of the year to the Summer time section. The high values of discharge occurrences follow well the 3-month time sections of the discriminant periods of the MAX1 event in each runoff regime type. Most of the

Table 5.5 Runoff regime types in the Danube Catchment

Runoff regime type	MAX1	MAX2	MAX3	min3	min2	min1	Number of catchments
1	X–XII	X–VI	X–VI	VI–IX	VI–IX	VIII–X	4
2	XII–II	XII–IV	II–V	VI–XI	VII–XI	VII–XI	4
3/a	I–III	I–V	XII–V	VII–XI	VII–X	VII–X	4
3/b	I–III	II–IV	II–IV	VI–X	VIII–XI	IX–XI	4
4/a	II–IV	XII–VI	XI–VI	VI–XII	VII–XI	VII–X	48
4/b	II–IV	II–IV	I–VI	VIII–I	VIII–XI	IX–XI	5
4/c	II–IV	II–IV	III–V	VIII–XI	IX–I	XI–II	2
5/a	III–V	XI–VI	I–VII	VII–I	VII–XI	VII–X	27
5/b	III–V	II–VII	I–VII	VII–I	VIII–XII	IX–XII	15
5/c	III–V	III–VI	II–VII	VII–III	VIII–I	XII–II	5
6/a	IV–VI	II–VI	XI–VI	VI–XII	VII–XI	VIII–X	8
6/b	IV–VI	II–VIII	II–VII	VII–II	VIII–XII	IX–XI	13
6/c	IV–VI	III–VII	III–VIII	IX–III	VII–III	XII–II	28
7/a	V–VII	IV–VII	IV–VII	X–III	X–I	X–I	6
7/b	V–VII	IV–VII	IV–IX	X–IV	IX–III	XII–III	21
8/a	VI–VIII	III–VI	IV–VI	IX–I	IX–I	IX–XII	5
8/b	VI–VIII	III–VIII	IV–VIII	IX–III	IX–III	XII–III	7
Total number of catchments							206

runoff regime types have one peak in their runoff regime, with the exception of Type 1, where complex climatic effects cause a double peak.

It can be determined that the dates of the hydrological events change widely over the year. The occurrence of the two most important events, the first highest and first lowest monthly mean discharge, follows well the specifications of the defined global climate type of the whole Danube Basin: the high water period usually occurs in the first half of the year and the low water period is usually the second half of the year. This general idea is modified by many local effects, when the highest discharges occur from October to August, while the lower water period is from July to March in the catchments of the Danube and its tributaries.

The territorial delimitation of the runoff regime types is displayed in Annex 2. On the map, in the headwater regions of the rivers, the types represent the catchments, but downstream of the main rivers (Danube, Sava, Tysa/Tisza, Mures/Maros and Crisul/Körös) the runoff regime classes represent the river sections, because of the complexity of influencing factors. In these cases the letters and the colour of the line on the river section shows the regime type.

There are some white patches on the map of Annex 2. Basically this means that we did not have any runoff regime information concerning those sections of the rivers (e.g. in the case of the downstream sections of the tributaries). On the other hand, at the gauging stations of the downstream sections of the main rivers, where the regime types are assigned by letters, the catcments could not be pictured on the map, so these territories must be uncoloured too.

5.6.1 Runoff Regime Types Defined by River Catchments

In runoff regime Type 1, there are the four headwater catchments of the River Sava, in the territory of Slovenia and the western part of Croatia. Here the first maximum of the monthly mean discharge is the earliest for the whole Danube Basin; it usually arrives between October and December. The other two maxima show significant discrepancies in these four subcatchments: there is a 6-month difference in the occurrence of the second or third maximum between the different territories. The MAX2 and MAX3 events usually occur from March or April to June, but in some cases they occur in the Autumn, as for the MAX1 event. In this runoff regime type the first lowest monthly mean discharge occurs between August and October, and the two other minima are also in the Summer period (from June to September). The runoff regime of this type is two-faced, as it lies at the border of two climatic areas. The Mediterranean effects mostly define the high flow characteristic – the water surplus in Winter – but sometimes the springtime maximum of the continental climate prevails. The continental climate determines the low flow conditions – the water deficit in late Summer or in Autumn – but in some places low flow occurs in mid-Summer, just as in the real Mediterranean territories.

Runoff regime Type 2 is a specific group, because four individual catchments belong to it. Three of them are in the marginal area of the Carpathian Basin and the fourth is the spring area of the River Danube, in the Black Forest region. They are not located that close to each other. Here the first maximum usually occurs in Winter, between December and February, and the other two maxima occur in early springtime or in Winter too. All the low flow events are mostly in Autumn, sometimes in late Summer. This phenomenon is possibly caused by local effects.

Runoff regime Type 3 has two subtypes. It can be seen – just like the catchments of runoff regime Type 2 – that the basins belonging to this type are scattered throughout the Danube Basin. In this group the first highest monthly mean discharge is usually detected between January and March.

In runoff regime subtype 3/a, the date of the second and third maxima is highly variable; these periods can be 6 months long. The three minima are usually in the same time period, between June–July and October. Four catchments belong to this subtype: three from the marginal area of the Bavarian Basin and one from the Carpathian Basin.

Runoff regime subtype 3/b contains four catchments again, from three "edges" of the Danube Basin: the Naab catchment from Bavaria, the two subcatchments of Crisul Negru/Fekete-Körös from the Carpathian Basin and the Kolubara from the Dinarides. In this group, the occurrence of the hydrological events is more uniform than it was in the previous types. The MAX1 event is between January and March; the other two maxima occur in the same period, between February and April. The lowest monthly mean discharge is usually detected from September to November, and the other two minima occur in late Summer or in Autumn.

The geographical distance of the subcatchments belonging to runoff regime Type 3 is possibly caused by local effects, because there are no basin-wide reasons for it on the thematic maps of the Danube Catchment.

Runoff regime Type 4 is the most populous group in this investigation; it contains 55 subcatchments in its three subtypes. A general feature of this group is that the first maximum flow occurs between February and April and most of the subcatchments are creating bigger continuous territories in the Danube Basin.

Runoff regime subtype 4/a contains the most elements among the runoff regime types, it has 48 subcatchments. This subtype has the earliest occurrence of the hydrological events in this main group, where MAX1 occurs between February and April. The time period of the other two maxima has more than a 6-month long section from November to June. The low flow events occur naturally in the other part of the year, from June to December, while min1 is usually between July and October in this group. Geographically the catchments belonging to this subtype – besides some individual basins – creating some cohesive zones in the Danube catchment: all the Moravian basins, most of the catchments of the Little Hungarian Plain, some rivers of the Northern Carpathians (Nitra, Ipel/Ipoly, Slaná/Sajó and Bodrog), the western part of Transylvania and the eastern region of the Dinarides, the Serbian catchments.

In runoff regime subtype 4/b, there are five basins: Regen, Somes/Szamos, Crasna/Kraszna, Ondava and Kysuca. Here the MAX2 event occurs in the same time period as MAX1, between February and April, while MAX3 – similar to the previous subtype – has a 6-month long section. The first lowest monthly mean discharges are usually detected between September and November, 1 or 2 months later than for subtype 4/a. The other two minima usually occur after August, and their period is 4–6 months long.

The smallest group in the investigation is runoff regime subtype 4/c, which contains only two elements: Rika and Jijia catchments. For these two basins all the high flow events arrive at the same time, the first two maxima occur between February and April, MAX3 occurs 1 month later. The three minima are in Autumn or in Winter, the earliest is min3 from August, the latest is min1 from November to February. Possibly local effects cause this significant variance from surrounding territories.

Runoff regime Type 5 is a more or less mountainous group. The highest ridges of the Northern Carpathians, the eastern part of Transylvania, most of the Dinarides and the catchments of the Balkan Mountains are represented under the three subtypes. The common features of these areas are the time period of the first maximum discharge, from March to May, and the occurrence of the second and third events, which last over a long period.

Twenty-seven subcatchments create the runoff regime subtype 5/a. The first maximum of this group is 3 months long (from March to May); the first minimum lasts from July to October. The time period of the other hydrological events (the second and third maxima and minima) lasts for a longer time, usually 5–8 months. In this subtype there are the southern mountainous territories, the western ridges of the Dinarides and the Balkan Mountains, while there are some marginal parts of plains, for example at the Austro-Hungarian border (Leitha/Lajta or Raab/Rába) and Tysa/Tisza upstream in the northern part of the Great Hungarian Plain.

In runoff regime subtype 5/b, there are 15 catchments. Here the first maximum is between March and May, of course, while the first minimum is detected from September to December. Here the second and third events have a longer period again, 5–7 months. The catchments of the High Tatras, the upstream area of the River Mures/Maros and some smaller direct tributaries of the Danube in its Austrian section belong to this subtype.

Runoff regime subtype 5/c is a group with individual catchments again. There are five basins in it, the upstream area of the River Olt, and four upstream river sections from the Alps. In the latter cases climatic reasons may include that the intermountain valleys of these rivers are relatively dry (see Annex 1). Here the second and third events have a long period again – 4–9 months, while the length of the time section of the first events is only 3 months. MAX1 is from March to May, min1 is observed between December and February.

The subcatchments of runoff regime Type 6 are mainly in the eastern part of the Danube Basin, especially around the Eastern and Southern Carpathian Mountains. The first monthly mean discharge is between April and June in the three subtypes of this group.

In runoff regime subtype 6/a, the first lowest monthly mean discharges were detected in the three-month period of August–October. The second events have a 2-month longer time section (MAX2 from February to June, min2 from July to November), while the third events have a 6–8-month long period. Three catchments of this subtype are in the Dinarides, another three are on the southern slopes of the Southern Carpathians, and one is in the Balkan Mountains.

In runoff regime subtype 6/b, the min1 events usually occur between September and November. For this group the other four events (MAX2, MAX, min2, min3) have a much longer, 5–8-month long time period. The subcatchments belonging to this group are on the inner side, on the slopes looking towards the Great Hungarian Plain, of the Eastern Carpathian Mountains. These include the Timis watershed, the upstream area of River Tysa/Tisza and the whole catchment of the Crisul Repede/Sebes-Körös, which collects the waters of the northern slopes of the Apuseni Mountains. There is a specific watershed belonging to this group in the Northern Carpathians, the Hnilec basin. It is completely east-facing and more or less closed in by mountain ridges. Possibly this is the reason for the slight difference from the regime type of its surrounding territories.

The most populous subgroup of Type 6 is runoff regime subtype 6/c. It has the second highest number of elements of the 17 regime types. The low flow is usually detected in wintertime, between December and February in its subbasins, while the other events have 5–9-month long intervals. This group is the easternmost type of the Danube Basin; most of its catchments are located on the eastern or south-eastern slopes of the Carpathian Mountains. The upstream sections of the Rivers Siret and Prut and its tributaries belong to this subtype. Moreover, there are four northeast-facing smaller basins in the Alpine region pertaining to this group too.

Runoff regime Type 7 is the group of the Alpine region. Here the high flow events always occur after April and are usually finalized by mid-Summer. The low flow events generally begin in October and the rivers reach their lowest discharges in the Winter months.

The first group in this type is runoff regime subtype 7/a with three basins of the Iller and Lech rivers, where the flood events are always between April and July and the low flow events usually cover an approximately 4–6-month long time period.

The other subtype is runoff regime subtype 7/b, which forms the main body of the Alpine region with its more than 20 elements. The catchments in this group are under the climatic and geomorphological influence of the Alps. Here the high flow events are usually finalized by July – as in the previous subtype, but they can sometimes extend to September. The time section of the low flow events fluctuates between September and March.

The watersheds of runoff regime Type 8 are in the Alps again. It has two subtypes, in which the first maximum monthly mean discharge usually occurs in Summer. It is highly controlled by snow-melt, as a climatic effect of the highest regions of the Alpine Mountains.

Runoff regime subtype 8/a contains only one catchment, the Isar Basin. Here the MAX1 event is possibly defined by the melting of snow of the spring area (between June and August), while the other two flood events are modified by the effects of the lower plains of the downstream section (beginning in March or April). The low flow events generally arrive in September and usually finish before January.

The real high mountainous regime type is runoff regime subtype 8/b in the Danube Basin. In those catchments belonging to this subtype, the first maximum is detected between June and August and the first minimum is observed from December to March. Flood events can occur from March, but not later than August, while the earliest time for low flow events is September and the high water always arrives by the beginning of April. This is a specific snow-melt regulated runoff regime, which can be seen on rivers like the upstream section of the Rivers Inn, Salzach or some smaller watercourses. Moreover it can be seen in Annex 1, that the upper Inn valley, extending in a west-east direction is a characteristic interalpine dry valley with a precipitation of only 600–700 mm.

5.6.2 The Runoff Regime Types of the Main River Sections

At 18 measuring stations and data series, the runoff regime types do not belong to catchments, but only to the river sections, because of the complex influence of the tributaries. These rivers are the Danube – except for some subcatchments around the spring area, the downstream part of the River Sava, and River Tysa/Tisza together with its main tributaries, downstream of Crisul/Körös and Mures/Maros. On the one hand, here the runoff regime types are noted by letters, located to that section of the river, where the investigated data series were observed. Secondly, the type of runoff regime is also assigned a colour. The lines of the river sections are toned according to the colour assigned to a particular type. The lengths of river sections, belonging to one type, are defined by the availability of information: (1) one type section lasts until the next upstream gauging station – from which we have the data series – above the investigated one; (2) the type section lasts until the mouth of the closest considerable tributary, which is delineated on the map of Annex

2, where the different runoff regime presumably changes the regime type of the main stream.

Runoff regime types continuously change down the rivers. If we investigate longitudinally the main stream, the Danube River, a linear change can be observed above the mouth area of the two greatest tributaries, the Sava and Tysa/Tisza. While in the spring area the regime type is Type 2 or 3, down the river – from the station Hofkirchen – the regime types change permanently from Type 6/a to 7/a and 8/a. After receiving the two main tributaries, the regime type of the Danube is altered to Type 5/a. Under the river section of the Iron Gate, on the territory of the Romanian Lowland, the regime type is 6/b, and at the bottommost station (from which we have data series), at Giurgiu, Type 5/b is observed.

The regime type of the downstream part of the River Sava is 5/a, which is possibly defined by the runoff regime of its tributaries coming from the Dinarides. At the River Tysa/Tisza, the matter is a little bit more complicated. The system is confused by the effects of its significant number of great tributaries. While the type of the main stream individually is 5/a, the Type 6/b runoff regime of the downstream sections of Rivers Crisul/Körös and Mures/Maros change the regime type of Tysa/Tisza at Szeged to 6/b. The category of the bottommost station of the Tysa/Tisza (of our investigation) becomes regime Type 5 again.

Where the regime type belongs to the river sections, it is interesting to observe, that different subtype categories are able to connect to longer watercourses. Above the Iron Gate, the main stream, the Danube, has all the subtypes assigned to a, which means, that the hydrological events usually occur at the first section of the time period of their runoff regime main type. On the Romanian Lowland, under the Iron Gate, there are only subtypes assigned to b, where the occurrence of the investigated events is in the latter part of the time period belonging to the main regime type. Moreover the most important tributary, the River Tysa/Tisza has only subtypes assigned to b. Probably this phenomenon is justifiable because of the subjectivity of the categorization, but there can be some other – later researchable – reasons too.

5.7 Characterization of the Runoff Regime Stability

The stability of the runoff regime was computed for 206 catchments of the Danube River Basin by using the Nováky stability index of Eq. (5.2). The runoff regime stability was calculated finally for nine hydrological events:

- the first (1), second (2) and third (3) highest (MAX1, MAX2, MAX3)
- and the first (4), second (5) and third (6) lowest monthly mean discharges (min1, min2, min3), which are the six basic events of the investigation;
- and for three cumulative events [as is defined by Eqs. (5.4), (5.5) and (5.6)];
- the stability of the high flow regime (N_{MAX}), which is the sum of the stabilities of the three flood events (7),
- the stability of the low flow regime (N_{min}), which is the sum of the stabilities of the three low flow events (8)

- and the stability of the annual flow regime (N_R), which is the sum of the stabilities of all the six basic hydrological events (9).

The results are presented in the table of Annex 3, the graphical presentation of the three most important indices [N_R, N(MAX1), N(min1)] are in Annexes 4–6.

By the annual runoff regime stability (N_R), most of the rivers belong to the relatively stable category. From the 206 stations, about 130 are in this rate, which is more than 60% of the investigated places. A little bit more than one third of the Danube Catchment is rated to the stable section and eight measuring stages were placed in the relatively unstable group.

The geographical spread of these categories in relation to the stability of the annual flow regime can be seen in Annex 4. As is shown on the figure, the stable parts of the Danube Catchment are all in the mountainous regions, the Alps, the Eastern Carpathian Mountains and the Dinarides, because of their less variable climate. From the three territories, the most stable is the westernmost Alpine area, possibly because the regular oceanic climatic effect determines the runoff regime of its rivers. The stability rate of the other two mountainous regions is almost the same.

The most unstable part of the Danube Catchment – from the point of view of N_R – is the western side of the Carpathian Basin, consisting of subcatchments of the river systems Raab/Rába and Mur/Mura. A possible reason for this phenomenon is climatic again, because the normally continental climate of this area is often influenced by Mediterranean or sometimes oceanic climatic impacts. These effects are reflected in the runoff regime of the rivers (e.g. the two peaks of the runoff regime curve).

At the maximum events (N_{MAX}), only one station – Inn-Magerbach – is in the very stable category. About a quarter of the stages are stable, but generally the observed measuring places – more than 140 stations – are in the relatively stable group. There are 11 relatively unstable stations in the Danube Catchment based on the flood events.

Geographically the more stable regions are located in the mountains again. In the Alps it is the same territory as for the stability of the annual flow regime. In the Carpathians the size of the stable area is increased, but in the Dinarides it is decreased according to the previous index. The relatively unstable sector is the same as for the annual flow regime, complemented with some smaller territories from the Alpine region.

Investigating the stability of the MAX1 event, we can establish that almost half of the Danube Basin is in the stable category (Annex 5). For the western side of the Danube Catchment, the Alps and its wider countryside frame is a stable area, while in the eastern south-eastern part, the Carpathians together with the Dinarides create a far-flung continuous stable territory. About 5% of the stations have a very stable runoff regime, and these are located mainly in the Upper Inn catchment, in addition to some stages from the north-eastern Carpathians, around the spring area of the Rivers Tysa/Tisza and Prut. The inner parts of the Carpathian Basin and the Western Dinarides form the relatively stable category for the stability of the first highest monthly mean discharge. In the relatively unstable group, there are almost the same rivers as for the previous indices. The only new element in this category is station Hegyeshalom on the River Leitha/Lajta, where the runoff regime is substantially influenced by anthropogenic activities.

At the minimum events (N_{min}), only the Ötztaler Ache-Tumpen station is in the very stable grade. Forty percent of the Danube Basin is stable, seven stages are relatively unstable, while relatively stable results were calculated in almost 120 cases. The mountainous regions are the most stable parts again: the stable area sensibly increased in the Dinarides and in the Alps, while it is decreased in the Carpathians according to its range in terms of stability of the flood events. It can be seen that there are some new stable locations in the middle of the Carpathian Basin and between the ridges of the Balkan Mountains too. It is remarkable that the two longer sections of the Danube River – between Achleiten and Bratislava and from Giurgiu to the mouth – belong to the stable category. The territory of the relatively unstable group – which is in the same area as it was before – decreased slightly, creating a homogene patch in the middle section of the Raab/Rába catchment.

At the min1 event (Annex 6), more than 65% of the Danube Catchment is at least stable, together with the very stable values of some stations in the Alps. In the western part of the Danube Basin, there are only three greater districts with a relatively stable rate: the northern part of the Bavarian Basin, Moravia and in a lane that extends from the Western Dinarides to the North. In the eastern part there are more smaller patches with relatively stable values: for example around the ridges of the High Tatras, in the northeastern Carpathians in Ukraine, around the mouth section of Crisul/Körös and Mures/Maros, or the area between the Rivers Siret and Prut. There are three stages with relatively unstable runoff regime, again from the watershed of the River Raab/Rába, with a significantly reduced, small and fettered area.

5.8 Conclusions

It can be declared that the runoff regime types – basically defined by using the first maximum and minimum values of the monthly mean discharges (MAX1 and min1) – follow well territorial climatic changes connected with elevation, and this system in some places may be modified by significant aerial impacts, mainly the delayed effects of underground storage basins or anthropogenic interferences.

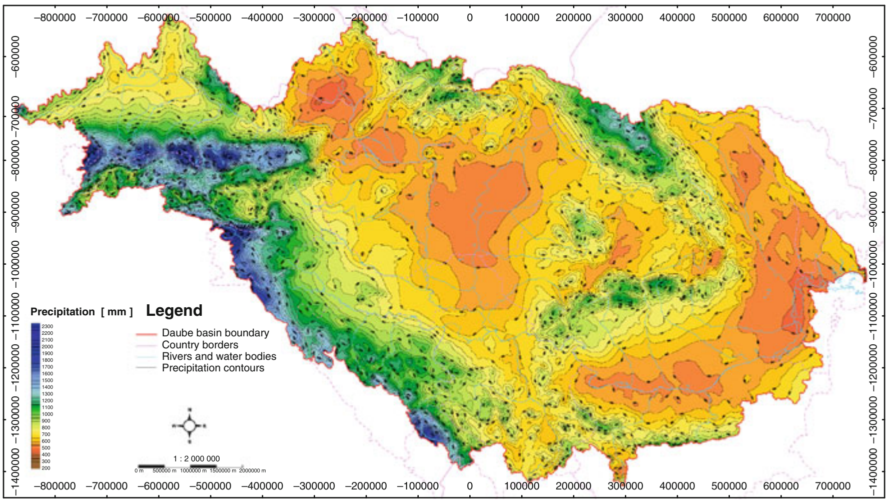
As is seen in Annex 2, eight main runoff regime types were defined, and together with the subtypes in total 17 runoff regime types were identified within the whole Danube Catchment. In the headwater regions of the rivers, the regime types are associated with the catchments, but downstream of the main rivers the runoff regime classes are associated with the river sections. On some rivers longitudinal changes in runoff regime type can also be investigated. The regime type of the main stream may be modified by its incoming tributaries, like at the Tysa/Tisza or at the Danube River.

It should be noted, that the runoff regime stability of the minimum events is larger than that of the maximum events. This is especially true at the first maximum (MAX1) and minimum (min1) events, where the difference is the most spectacular (see Annexes 5 and 6). The same phenomenon can be identified in the case of the cumulative values of the flood and low flow events too. The maps show that the regime stability of the flood events is more influenced by geographical conditions than at the minima. At the flood events, the stability is slightly larger in the mountainous areas, while at the low flow events this effect does not appear. The regional variation of the stability of the annual flow regime is mostly affected by the same geomorphologic criteria as the flood events, so on the map of Annex 4, the three mountainous regions of the Danube Basin (the Alps, the Dinarides and the Carpathians) belong to the stable category.

The most stable part of the Danube Catchment is the territory of the highest ridges of the Eastern Alps – in the area of runoff regime subtypes 7/b and 8/b (see Annexes 2 and 4). Here are almost all of the very stable parts of the whole basin for all the flood and low flow events, and this area is within the stable category for the annual values too. The possible reason – together with the high elevation – is climatic; this is one of the most stable wet areas of the catchment (defined by precipitation and snow melt). The most unstable territory of the Danube Catchment – which belonging to the relatively unstable category, is in the Raab/Rába area and – in some cases – in the Mur/Mura Basin. The most likely reason is climatic, because this area is the crossing point of three determining climate types, i.e. Atlantic, continental and Mediterranean effects.

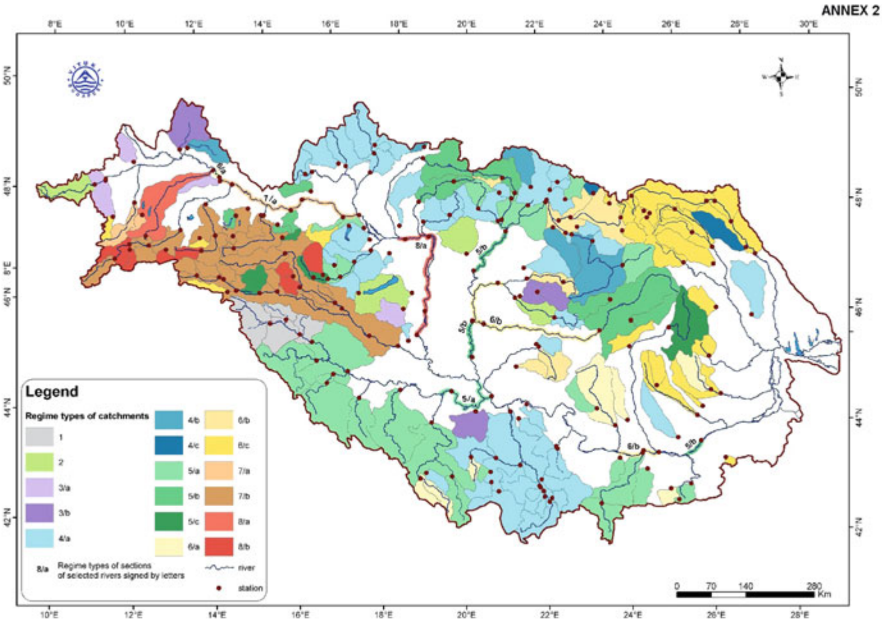
The results of this investigation are fitting in well with the outcomes of the preliminary research (Stanescu and Ungureanu 1997, Nováky et al. 2001). The purpose of the present work was to investigate the whole Danube Catchment and to increase our knowledge of this international river.

Annex 1



Mean annual precipitation in the Danube Basin (1961–1990)

Annex 2



Runoff regime types in the Danube catchment

Annex 3

Country code	No.	River	Station	N(MAX1)	N(MAX2)	N(MAX3)	N(min3)	N(min2)	N(min1)	N_{MAX}	N_{min}	N_R
				computed by								
				Eq. (2)						Eq. (4)	Eq. (5)	Eq. (6)
D	1.	Donau	Berg	0,998	**0,872**	1,205	1,197	**0,900**	**0,613**	3,075	**2,710**	5,785
	2.	Iller mit Kanal	Wiblingen	1,002	0,954	**0,891**	1,077	1,069	**0,649**	2,847	2,795	5,642
	3.	Iller	Kempten	**0,848**	**0,882**	**0,916**	1,030	1,018	**0,783**	2,646	2,831	5,477
	4.	Donau	Neu Ulm-Bad Held	1,188	1,044	1,234	1,226	**0,919**	**0,836**	3,466	2,981	6,447
	5.	Lech	Landsberg	**0,513**	**0,673**	**0,693**	1,094	**0,780**	**0,679**	**1,879**	**2,553**	**4,432**
	6.	Naab	Heitzenhofen	**0,817**	0,935	**0,900**	1,152	**0,905**	0,967	**2,652**	3,024	5,676
	7.	Wörmitz	Harburg	**0,794**	1,040	1,183	1,109	**0,888**	**0,595**	3,017	**2,592**	5,609
	8.	Regen	Regenstauf	1,091	1,082	1,202	1,038	1,032	1,014	3,375	3,084	6,459
	9.	Ammer	Weilheim	1,074	1,007	*1,247*	1,109	**0,913**	0,987	3,328	3,009	6,337
	10.	Isar	Mittenwald	**0,287**	**0,544**	**0,608**	**0,671**	**0,287**	**0,334**	**1,439**	**1,292**	**2,731**
	11.	Isar	Plattling	1,050	1,005	1,204	0,998	1,153	0,998	3,259	3,149	6,408
	12.	Vils	Grafenmühle	1,062	*1,275*	*1,283*	*1,242*	**0,857**	0,952	3,620	3,051	6,671
	13.	Inn	Oberaudorf	**0,196**	**0,227**	**0,611**	**0,761**	**0,636**	**0,377**	**1,034**	**1,774**	**2,808**
	14.	Salzach	Burghausen	**0,475**	**0,704**	**0,732**	**0,679**	**0,692**	**0,518**	**1,911**	**1,889**	**3,800**
	15.	Donau	Hofkirchen	1,173	1,189	1,165	1,168	1,105	0,977	3,527	3,250	6,777
	16.	Donau	Achleiten	**0,639**	1,027	1,023	1,034	**0,840**	**0,731**	**2,689**	**2,605**	**5,294**

Stability indices according to equations of the methodology chapter, characterizing the runoff regime at selected gauging stations of the Danube River Basin

Country code	No.	River	Station	N(MAX1)	N(MAX2)	N(MAX3)	N(min3)	N(min2)	N(min1)	N_{MAX}	N_{min}	N_R
				computed by								
				Eq. (2)						Eq. (4)	Eq. (5)	Eq. (6)
A	17.	Ötztaler Ache	Tumpen	**0,372**	**0,646**	**0,683**	**0,533**	**0,100**	**0,100**	**1,701**	**0,733**	**2,434**
	18.	Sill	Innsbruck-Reichenau	**0,171**	**0,100**	**0,632**	**0,650**	**0,230**	**0,171**	**0,903**	**1,051**	**1,954**
	19.	Ziller	Zell am Ziller-Zellbergeben	**0,171**	**0,427**	**0,450**	**0,789**	**0,771**	**0,636**	**1,048**	**2,196**	**3,244**
	20.	Salzach	Bruck-Salzach	**0,100**	**0,372**	**0,507**	**0,687**	**0,664**	**0,658**	**0,979**	**2,009**	**2,988**
	21.	Saalach	Weissbach	**0,603**	**0,643**	**0,827**	**0,846**	**0,790**	**0,517**	**2,073**	**2,153**	**4,226**
	22.	Traun	Steeg	**0,100**	**0,398**	**0,901**	**0,771**	**0,786**	**0,518**	**1,399**	**2,075**	**3,474**
	23.	Ager	Schachham	1,159	*1,302*	*1,273*	1,176	1,140	0,933	*3,734*	3,249	6,983
	24.	Steyr	Pergern	**0,774**	**0,713**	**0,894**	0,980	**0,783**	**0,791**	**2,381**	**2,554**	**4,935**
	25.	Ybbs	Opponitz-Mirenau	1,008	0,941	1,061	1,215	1,005	**0,920**	3,010	3,140	6,150
	26.	Erlauf	Niederndorf	0,987	0,982	1,059	1,154	1,021	1,023	3,028	3,198	6,226
	27.	Kamp	Stiefern	1,064	1,074	1,099	1,063	1,018	1,036	3,237	3,117	6,354
	28.	Fischa	Fischamend-Rohrbrücke	0,949	1,050	1,162	1,173	1,194	1,073	3,161	3,440	6,601
	29.	Thaya	Raabs an der Thaya	0,982	1,075	1,164	1,116	1,031	1,022	3,221	3,169	6,390
	30.	Lafnitz	Dobersdorf	*1,340*	1,195	*1,347*	*1,280*	*1,301*	*1,259*	*3,882*	*3,840*	*7,722*
	31.	Enns	Schladming	**0,450**	**0,437**	**0,658**	**0,736**	**0,598**	**0,280**	**1,545**	**1,614**	**3,159**
	32.	Salza	Wildalpen	**0,533**	**0,786**	0,956	**0,823**	**0,881**	**0,644**	**2,275**	**2,348**	**4,623**
	33.	Raab	Feldbach	*1,319*	*1,323*	*1,291*	*1,343*	*1,351*	*1,269*	*3,933*	*3,963*	*7,896*
	34.	Kainach	Leiboch	1,223	*1,303*	1,175	*1,356*	*1,351*	1,202	3,701	*3,909*	*7,610*
	35.	Sulm	Leibnitz	*1,305*	*1,241*	*1,326*	*1,323*	*1,286*	1,233	*3,872*	*3,842*	*7,714*
	36.	Isel	Lienz	**1,100**	**0,372**	**0,450**	**0,445**	**0,283**	**0,230**	**1,922**	**0,958**	**2,880**
	37.	Möll	Möllbrücke	**0,664**	**0,840**	1,210	1,228	1,154	1,183	**2,714**	3,565	6,279
	38.	Lieser	Spittal-Fasan	**0,507**	**0,507**	**0,891**	**0,703**	**0,572**	**0,280**	**1,905**	**1,555**	**3,460**
	39.	Gail	Nötsch	**0,715**	0,932	1,128	1,038	**0,782**	**0,576**	2,775	**2,396**	**5,171**
	40.	Gurk	Gumisch	*1,246*	*1,259*	*1,305*	*1,242*	1,102	**0,819**	*3,810*	3,163	6,973
A	41.	Lavant	Krottendorf	**0,876**	0,951	1,228	1,093	**0,853**	**0,829**	3,055	2,775	5,830
	42.	Drau	Villach	**0,287**	**0,386**	**0,685**	**0,634**	**0,513**	**0,334**	**1,358**	**1,481**	**2,839**
	43.	Inn	Kajetansbrücke	**0,101**	**0,334**	**0,662**	**0,725**	**0,703**	**0,609**	**1,097**	**2,037**	**3,134**
	44.	Inn	Magerbach	**0,101**	**0,101**	**0,548**	**0,582**	**0,512**	**0,599**	**0,750**	**1,693**	**2,443**
	45.	Leitha	Deutsch Brodersdorf	1,074	1,227	1,119	*1,245*	*1,269*	1,144	3,420	3,658	7,078
	46.	Mur	Leoben	**0,433**	**0,513**	0,983	**0,804**	**0,548**	**0,135**	**1,929**	**1,487**	**3,416**
	47.	Salzach	Golling	**0,287**	**0,386**	**0,634**	**0,685**	**0,662**	**0,512**	**1,307**	**1,859**	**3,166**
	48.	Enns	Steyr	**0,602**	**0,712**	**0,608**	1,011	**0,780**	**0,772**	**1,922**	**2,563**	**4,485**
	49.	Traun	Wels	**0,858**	**0,849**	1,062	1,024	**0,869**	**0,795**	2,769	**2,688**	**5,457**
	50.	Donau	Kienstock	**0,764**	1,032	1,007	1,007	**0,775**	**0,767**	2,803	**2,549**	**5,352**
CZ	51.	Morava	Komeríz	0,993	0,977	1,185	1,197	**0,876**	0,948	3,155	3,021	6,176
	52.	Morava	Straznice	0,954	1,074	1,176	*1,244*	**0,846**	0,922	3,204	3,012	6,216
	53.	Dyje	Podhradí	**0,797**	1,105	1,165	1,140	1,049	0,945	3,067	3,134	6,201
	54.	Svratka	Zidlochovice	**0,874**	0,990	1,093	1,103	1,022	1,017	2,957	3,142	6,099
	55.	Jihlava	Ivancice	**0,810**	**0,769**	*1,273*	1,156	1,094	1,018	2,852	3,268	6,120
	56.	Becva	Dluhonice	1,042	1,171	1,104	1,116	1,066	1,081	3,317	3,263	6,580
SK	57.	Dunaj	Bratislava	**0,883**	0,955	1,059	1,039	**0,830**	**0,767**	2,897	**2,636**	5,533
	58.	Vah	Zilina	1,160	1,092	1,178	1,133	1,010	**0,873**	3,430	3,016	6,446
	59.	Kysuca	Cadca	0,936	1,206	1,230	*1,259*	1,203	1,116	3,372	3,578	6,950
	60.	Nitra	Nové Zámky	**0,827**	0,960	0,965	0,939	**0,908**	**0,777**	**2,752**	**2,624**	**5,376**
	61.	Hron	Brezno	1,049	**0,864**	1,048	1,034	1,009	0,994	2,961	3,037	5,998
	62.	Hron	Brehy	1,081	**0,814**	0,994	1,073	0,998	**0,849**	2,889	2,920	5,809
	63.	Ipel	Ipelsky Sokolec	0,924	0,970	0,936	1,100	**0,729**	**0,714**	2,830	**2,543**	**5,373**
	64.	Slana	Lenartovce	1,166	1,132	0,985	1,153	1,046	0,955	3,283	3,154	6,437
	65.	Bodva	Turna nad Bodvou	1,004	1,115	1,098	1,220	1,028	1,019	3,217	3,267	6,484
	66.	Hnilec	Jaklovce	**0,916**	1,129	1,151	1,206	0,976	0,959	3,196	3,141	6,337
	67.	Hornad	Zdana	1,055	**0,810**	1,138	1,073	0,979	0,930	3,003	2,982	5,985
	68.	Ondava	Horovce	**0,814**	1,192	1,168	1,226	1,069	**0,775**	3,174	3,070	6,244

Annex 3 (continued)

Country code	No.	River	Station	N(MAX1)	N(MAX2)	N(MAX3)	N(min3)	N(min2)	N(min1)	N_{MAX}	N_{min}	N_R
				computed by								
				Eq. (2)						Eq. (4)	Eq. (5)	Eq. (6)
H	69.	Lajta	Hegyeshalom	*1,247*	1,157	1,129	1,239	1,170	1,196	3,533	3,605	7,138
	70.	Rábca	Lébény	1,226	1,151	1,046	1,072	1,069	0,990	3,423	3,131	6,554
	71.	Rába	Körmend	*1,314*	*1,320*	*1,345*	*1,244*	*1,264*	1,237	*3,979*	*3,745*	*7,724*
	72.	Rába	Sárvár	*1,318*	*1,249*	*1,360*	*1,327*	1,227	*1,247*	*3,927*	*3,801*	*7,728*
	73.	Rába	Árpás	*1,280*	*1,312*	*1,273*	*1,299*	1,224	1,038	*3,865*	3,561	7,426
	74.	Rába	Szentgotthárd	*1,342*	*1,323*	*1,307*	*1,301*	*1,269*	1,141	*3,972*	3,711	*7,683*
	75.	Pinka	Felsőcsatár	*1,315*	1,225	*1,276*	*1,280*	*1,302*	1,148	*3,816*	*3,730*	*7,546*
	76.	Marcal	Mórichida	1,008	1,046	1,200	1,011	1,016	**0,830**	3,254	2,857	6,111
	77.	Zala	Zalaapáti	1,157	1,166	1,122	0,984	0,935	**0,503**	3,445	**2,422**	5,867
	78.	Kapos	Kurd	1,231	1,196	1,119	1,154	**0,826**	**0,584**	3,546	**2,564**	6,110
	79.	Sió	Simontornya	1,040	1,041	*1,291*	1,213	1,045	**0,857**	3,372	3,115	6,487
	80.	Mura	Letenye	0,942	**0,799**	1,129	0,992	0,990	**0,835**	2,870	2,817	5,687
	81.	Dráva	Barcs	**0,685**	1,003	1,052	1,056	0,998	**0,695**	**2,740**	**2,749**	**5,489**
	82.	Duna	Dunaalmás	1,008	**0,902**	1,046	1,089	1,011	**0,778**	2,956	2,878	5,834
	83.	Duna	Nagymaros	0,961	**0,889**	1,077	0,980	1,038	**0,771**	2,927	2,789	5,716
	84.	Duna	Dombori	**0,900**	**0,840**	1,157	1,006	1,019	**0,752**	2,897	2,777	5,674
H	85.	Duna	Mohács	**0,893**	**0,901**	1,081	0,949	1,091	**0,873**	2,875	2,913	5,788
	86.	Karasica	Villány	1,198	1,176	1,128	1,100	0,936	**0,501**	3,502	**2,537**	6,039
	87.	Cuhai Bakony ér	Bakonybánk	1,116	*1,276*	1,065	1,222	**0,823**	**0,648**	3,457	**2,693**	6,150
	88.	Ipoly	Nógrádszakál	0,935	1,116	1,088	1,134	**0,814**	**0,686**	3,139	**2,634**	5,773
	89.	Tisza	Tivadar	1,046	1,160	1,181	1,172	1,092	**0,916**	3,387	3,180	6,567
	90.	Tisza	Záhony	0,981	1,075	1,053	1,135	1,021	**0,796**	3,109	2,952	6,061
	91.	Tisza	Tiszapalkonya	0,978	1,084	**0,903**	1,105	1,059	**0,829**	2,965	2,993	5,958
	92.	Tisza	Szolnok	0,972	0,977	1,091	1,124	1,029	1,001	3,040	3,154	6,194
	93.	Tisza	Szeged	0,989	**0,877**	1,035	1,066	1,071	**0,883**	2,901	3,020	5,921
	94.	Szamos	Csenger	0,960	1,070	0,959	1,083	1,013	**0,875**	2,989	2,971	5,960
	95.	Kraszna	Ágerdőmajor	**0,894**	1,202	1,196	0,995	1,042	0,993	3,292	3,030	6,322
	96.	Bodrog	Felsőberecki	**0,916**	1,020	0,921	1,102	1,105	0,960	2,857	3,167	6,024
	97.	Hernád	Hidasnémeti	1,109	**0,759**	1,164	1,060	0,987	0,931	3,032	2,978	6,010
	98.	Hernád	Gesztely	1,141	1,001	1,188	1,110	**0,908**	0,966	3,330	2,984	6,314
	99.	Sajó	Felsőzsolca	1,192	1,120	1,133	1,114	1,028	1,074	3,445	3,216	6,661
	100.	Zagyva	Jásztelek	1,109	1,184	1,180	1,038	**0,801**	**0,375**	3,473	**2,214**	5,687
	101.	Berettyó	Berettyóújfalu	1,025	1,065	1,128	1,043	**0,849**	**0,718**	3,218	**2,610**	5,828
	102.	Sebes-Körös	Körösszakál	1,157	1,128	1,098	1,143	1,062	**0,796**	3,383	3,001	6,384
	103.	Fekete-Körös	Sarkad	1,123	1,117	1,142	1,142	1,027	**0,830**	3,382	2,999	6,381
	104.	Fehér-Körös	Gyula	1,082	1,085	1,218	1,069	1,003	**0,779**	3,385	2,851	6,236
	105.	Hármas-Körös	Gyoma	1,045	1,102	1,189	1,094	1,226	1,078	3,336	3,398	6,734
	106.	Maros	Makó	**0,694**	**0,883**	1,126	1,048	0,998	0,938	**2,703**	2,984	5,687
SLO	107.	Sava	Litija	1,130	1,122	1,178	1,130	1,085	1,171	3,430	3,386	6,816
	108.	Sava	Catez	1,141	*1,264*	1,177	1,204	1,018	1,101	3,582	3,323	6,905
	109.	Savinja	Lasko	*1,256*	*1,258*	1,219	1,134	*1,273*	1,159	*3,733*	3,566	7,299
HR	110.	Drava	Donji Miholjac	**0,816**	**0,877**	1,045	1,077	1,045	**0,885**	**2,738**	3,007	5,745
	111.	Mura	Mursko Sredisce	0,938	0,971	0,948	1,169	0,943	**0,795**	2,857	2,907	5,764
	112.	Sava	Zagreb	1,190	1,274	1,071	0,973	1,094	1,129	3,535	3,196	6,731
	113.	Sava	Jasenovac	**0,829**	1,083	1,153	1,041	**0,653**	0,943	3,065	**2,637**	5,702
	114.	Kupa	Sisinec	0,996	0,967	1,149	1,219	**0,848**	**0,819**	3,112	2,886	5,998

Annex 3 (continued)

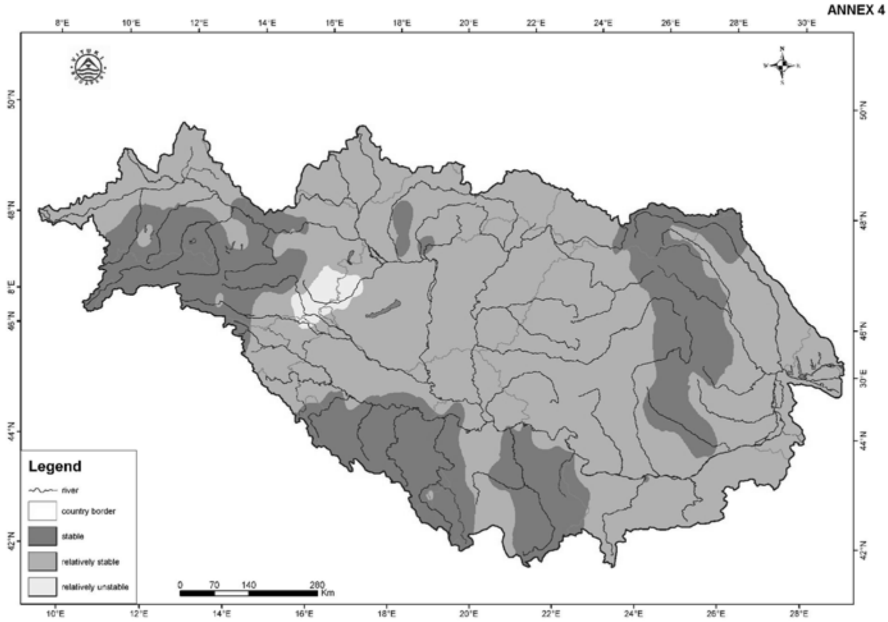
Country code	No.	River	Station	N(MAX1)	N(MAX2)	N(MAX3)	N(min3)	N(min2)	N(min1)	N_{MAX}	N_{min}	N_R
				computed by								
				Eq. (2)						Eq. (4)	Eq. (5)	Eq. (6)
	115.	Una	Kostajnica	1,064	**0,847**	1,064	**0,604**	**0,652**	**0,815**	2,975	**2,071**	**5,046**
	116.	Una	Bosanski Novi / Novi Grad	**0,880**	1,018	1,122	0,977	**0,697**	**0,719**	3,020	**2,393**	**5,413**
BIH	117.	Vrbas	Delibasino selo	**0,832**	1,103	1,126	1,018	**0,652**	**0,576**	3,061	**2,246**	**5,307**
	118.	Bosna	Modrica	1,022	**0,813**	0,949	**0,869**	**0,908**	**0,522**	2,784	**2,299**	**5,083**
	119.	Drina	Zvornik	**0,617**	1,010	**0,831**	**0,831**	**0,540**	**0,536**	2,458	**1,907**	**4,365**
	120.	Juzna Morava	Grdelica	0,939	**0,876**	1,040	**0,736**	**0,807**	**0,661**	2,855	**2,204**	**5,059**
	121.	Vlasina	Vlasotince	**0,844**	0,997	1,055	1,023	**0,706**	**0,829**	2,896	**2,558**	**5,454**
	122.	Nisava	Nis	**0,830**	1,027	**0,792**	**0,873**	**0,816**	**0,324**	**2,649**	**2,013**	**4,662**
	123.	Veternica	Leskovac	**0,905**	0,950	1,088	0,972	**0,600**	**0,567**	2,943	**2,139**	**5,082**
SCG	124.	Jablanica	Pecenjevce	**0,902**	**0,896**	1,079	**0,820**	**0,631**	**0,405**	2,877	**1,856**	**4,733**
	125.	Pusta	Pukovac	**0,849**	0,990	0,980	**0,861**	**0,712**	**0,628**	2,819	**2,201**	**5,020**
	126.	Toplica	Doljevac	**0,861**	0,926	0,997	1,021	**0,836**	**0,462**	2,784	**2,319**	**5,103**
	127.	Rasina	Bivolje	**0,876**	0,967	1,137	**0,902**	**0,891**	**0,656**	2,980	**2,449**	**5,429**
	128.	Ibar	Leposavic	**0,914**	1,059	1,024	1,105	0,966	**0,742**	2,997	2,813	5,810
	129.	Raska	Raska	**0,871**	0,927	1,046	1,050	1,045	**0,743**	2,844	2,838	5,682
	130.	Studenica	Usce	**0,733**	0,993	1,169	1,105	**0,905**	0,927	2,895	2,937	5,832
	131.	Moravica	Arilje	**0,861**	0,955	1,032	1,015	**0,810**	**0,902**	2,848	**2,727**	5,575
	132.	Zapadna Morava	Kraljevo	0,933	**0,784**	1,112	**0,843**	0,929	**0,749**	2,829	**2,521**	**5,350**
	133.	Beli Timok	Zajecar	**0,660**	1,062	**0,878**	0,978	**0,772**	**0,265**	**2,600**	**2,015**	**4,615**
	134.	Crni Timok	Zajecar	**0,564**	**0,756**	0,980	**0,500**	**0,764**	**0,334**	**2,300**	**1,598**	**3,898**
	135.	Mlava	Rasanac	0,959	0,999	1,118	0,968	**0,753**	**0,600**	3,076	**2,321**	**5,397**
	136.	Pek	Kusici	**0,768**	**0,851**	1,024	0,949	**0,666**	**0,623**	**2,643**	**2,238**	**4,881**
SCG	137.	Kolubara	Drazevac	0,991	0,990	1,156	1,039	1,035	0,977	3,137	3,051	6,188
	138.	Piva	Scepan Polje	**0,918**	0,958	1,074	1,043	**0,739**	**0,421**	2,950	**2,203**	**5,153**
	139.	Tara	Scepan Polje	**0,769**	**0,709**	1,079	1,081	**0,623**	**0,620**	**2,557**	**2,324**	**4,881**
	140.	Lim	Prijepolje	**0,766**	**0,718**	1,121	0,998	**0,613**	**0,516**	**2,605**	**2,127**	**4,732**
	141.	Cehotina	Vikoc	**0,846**	1,112	0,922	1,005	**0,843**	**0,872**	2,880	**2,720**	5,600
	142.	Dunav	Pancevo	**0,829**	1,124	1,192	1,139	1,042	**0,842**	3,145	3,023	6,168
	143.	Tisa	Novi Becej	1,011	**0,898**	1,077	1,139	1,102	**0,911**	2,986	3,152	6,138
	144.	Sava	Sremska Mitrovica	**0,877**	0,983	1,150	1,030	**0,714**	**0,546**	3,010	**2,290**	**5,300**
	145.	Velika Morava	Ljubicevski Most	**0,914**	**0,904**	1,010	1,029	**0,738**	**0,533**	2,828	**2,300**	**5,128**
	146.	Viseu	Bistra	**0,546**	**0,889**	1,217	1,203	**0,836**	0,968	**2,652**	3,007	5,659
	147.	Tur	Turulung	1,022	1,118	1,095	1,079	1,021	**0,888**	3,235	2,988	6,223
	148.	Somesul Mare	Beclean	0,973	1,062	1,009	1,018	0,940	**0,870**	3,044	2,828	5,872
	149.	Lapus	Lapusel	0,984	1,075	1,000	1,021	1,062	**0,864**	3,059	2,947	6,006
	150.	Somes	Satu Mare	0,952	1,058	**0,911**	1,006	0,999	**0,911**	2,921	2,916	5,837
	151.	Crisul Repede	Vadu Crisului	0,970	1,133	1,057	1,213	1,140	**0,851**	3,160	3,204	6,364
	152.	Crisul Negru	Tinca	1,083	1,142	1,109	1,144	**0,796**	**0,905**	3,334	2,845	6,179
	153.	Crisul Alb	Gurahont	0,948	1,112	0,945	1,142	0,948	**0,732**	3,005	2,822	5,827
	154.	Mures	Alba Iulia	**0,716**	1,016	1,157	1,054	**0,732**	**0,883**	2,889	**2,669**	5,558
	155.	Aries	Turda	**0,759**	0,992	1,031	0,999	0,951	0,952	2,782	2,902	5,684
	156.	Tarnava Mare	Medias	**0,752**	**0,876**	1,225	0,991	**0,907**	**0,868**	2,853	2,766	5,619
	157.	Bega	Balint	1,085	1,008	1,207	1,074	0,994	**0,803**	3,300	2,871	6,171
	158.	Timis	Lugoj	**0,749**	0,950	1,129	1,144	0,971	0,936	2,828	3,051	5,879
RO	159.	Barzava	Gataia	1,072	1,019	1,136	1,082	1,018	0,967	3,227	3,067	6,294
	160.	Jiu	Podari	0,929	0,922	1,196	1,083	**0,891**	**0,803**	3,047	2,777	5,824
	161.	Motru	Fata Motrului	0,926	1,077	0,962	1,051	1,084	**0,759**	2,965	2,894	5,859
	162.	Olt	Hoghiz	**0,594**	1,000	1,053	**0,854**	1,033	**0,815**	**2,647**	**2,702**	**5,349**
	163.	Cibin	Talmaciu	**0,690**	**0,914**	1,187	1,108	0,968	0,965	2,791	3,041	5,832
	164.	Oltet	Bals	1,105	1,088	1,031	1,078	**0,893**	**0,778**	3,224	**2,749**	5,973
	165.	Vedea	Alexandria	1,088	0,980	1,231	0,948	0,955	**0,794**	3,299	**2,697**	5,996
	166.	Arges	Malu Spart	**0,362**	**0,650**	0,998	1,095	0,961	**0,793**	**2,010**	2,849	**4,859**
	167.	Raul Targului	Piscani	**0,546**	**0,890**	1,106	0,927	1,013	**0,904**	**2,542**	2,844	**5,386**
	168.	Dambovita	Contesti-Lunguletu	**0,546**	**0,781**	1,056	1,039	0,958	0,975	**2,383**	2,972	**5,355**
	169.	Ialomita	Cosereni	0,977	0,979	1,109	0,927	1,025	1,008	3,065	2,960	6,025
	170.	Prahova	Adancata	0,936	0,955	1,184	0,961	0,984	1,022	3,075	2,967	6,042
	171.	Siret	Lespezi	**0,749**	0,973	1,130	1,157	1,073	**0,786**	2,852	3,016	5,868
	172.	Suceava	Itcani	**0,565**	0,918	**0,878**	0,977	1,020	**0,628**	**2,361**	**2,625**	**4,986**

Annex 3 (continued)

Country code	No.	River	Station	N(MAX1)	N(MAX2)	N(MAX3)	N(min3)	N(min2)	N(min1)	N_{MAX}	N_{min}	N_R
				computed by								
				Eq. (2)						Eq. (4)	Eq. (5)	Eq. (6)
RO	173.	Moldova	Tupilat	**0,551**	**0,854**	**0,889**	1,020	**0,915**	**0,570**	**2,294**	**2,505**	**4,799**
	174.	Bistrita	Frumosu	**0,516**	**0,620**	0,955	**0,909**	**0,636**	**0,616**	**2,091**	**2,161**	**4,252**
	175.	Trofus	Targu Ocna	**0,500**	**0,761**	0,955	**0,885**	**0,867**	**0,572**	**2,216**	**2,324**	**4,540**
	176.	Barlad	Barlad	1,045	1,028	*1,277*	*1,249*	0,998	1,042	3,350	3,289	6,639
	177.	Buzau	Nehoiu	**0,628**	**0,706**	*1,263*	1,094	0,925	**0,891**	**2,597**	2,910	**5,507**
	178.	Prut	Radauti	**0,565**	**0,872**	1,097	0,978	1,033	**0,753**	**2,534**	2,764	**5,298**
	179.	Jijia	Victoria	1,008	0,942	1,223	1,212	*1,271*	1,154	3,173	3,637	6,810
	180.	Dunarea	Corabia	**0,889**	1,050	1,016	1,081	**0,901**	**0,905**	2,955	2,887	5,842
	181.	Dunarea	Turnu Magurele	0,930	0,971	1,079	1,107	**0,814**	**0,883**	2,980	2,804	5,784
	182.	Dunarea	Giurgiu	0,973	0,955	0,932	0,988	**0,852**	**0,851**	2,860	**2,691**	5,551
BG	183.	Ogosta	Mizija	0,905	1,022	1,132	1,116	1,056	**0,879**	3,059	3,051	6,110
	194.	Iskar	Orjahovo	**0,750**	0,983	1,043	**0,863**	**0,811**	**0,651**	2,776	**2,325**	**5,101**
	185.	Iskar	Novi Iskar	1,042	0,997	1,033	1,142	**0,836**	**0,759**	3,072	**2,737**	5,809
	186.	Jantra	Tarnovo	**0,917**	1,107	1,141	1,077	**0,813**	**0,765**	3,165	**2,655**	5,820
	187.	Jantra	Gabrovo	0,987	1,037	1,152	1,061	**0,829**	**0,839**	3,176	**2,729**	5,905
	188.	Rositza	Sevlievo	0,957	**0,905**	1,141	1,038	**0,875**	**0,780**	3,003	**2,693**	5,696
	189.	Vit	Tarnjane	**0,893**	1,026	**0,903**	1,184	1,174	1,124	2,822	3,482	6,304
	190.	Rusenski Lom	Razgrad	0,972	1,161	1,186	1,197	1,155	1,017	3,319	3,369	6,688
MD	191.	Prut	Shireutsi	**0,325**	**0,500**	1,089	**0,898**	**0,500**	**0,572**	**1,914**	**1,970**	**3,884**
	192.	Prut	Costeshti	**0,655**	0,958	**0,855**	**0,668**	**0,888**	**0,854**	**2,468**	**2,410**	**4,878**
	193.	Prut	Ungheni	**0,783**	1,011	1,061	1,183	1,058	**0,773**	2,855	3,014	5,869
UA	194.	Tysa	Rahiv	**0,227**	0,973	1,100	1,137	**0,779**	**0,856**	**2,300**	2,772	**5,072**
	195.	Teresva	Ust Chorna	**0,450**	**0,843**	*1,290*	1,208	1,073	**0,901**	**2,583**	3,182	5,765
	196.	Rika	Mizhhirya	1,161	1,183	*1,281*	1,121	1,218	1,053	3,625	3,392	7,017
	197.	Latorycya	Mucachove	1,022	0,982	1,160	1,124	1,197	0,989	3,164	3,310	6,474
	198.	Latorycya	Chop	1,010	0,987	0,947	1,129	1,194	0,956	2,944	3,279	6,223
	199.	Uzh	Uzhhorod	0,994	**0,760**	*1,267*	1,119	1,146	1,052	3,021	3,317	6,338
	200.	Uzh	Zarichevo	**0,864**	**0,849**	1,203	1,074	1,200	0,925	2,916	3,199	6,115
	201.	Tysa	Vylok	**0,908**	0,971	1,207	1,055	1,028	1,024	3,086	3,107	6,193
	202.	Siret	Storozhinec	**0,856**	**0,919**	1,178	1,160	1,001	**0,758**	2,953	2,919	5,872
	203.	Prut	Jaremcha	**0,462**	**0,889**	0,999	**0,901**	0,948	**0,594**	**2,350**	**2,443**	**4,793**
	204.	Cheremosh	Usteriky	**0,253**	**0,569**	**0,858**	1,070	**0,660**	**0,649**	**1,680**	**2,379**	**4,059**
	205.	Chorny Cheremosh	Verkhovyna	**0,257**	**0,575**	**0,703**	0,939	**0,754**	**0,598**	**1,535**	**2,291**	**3,826**
	206.	Bily Cheremosh	Yablunyca	**0,519**	**0,732**	**0,765**	**0,909**	**0,777**	**0,583**	**2,016**	**2,269**	**4,285**

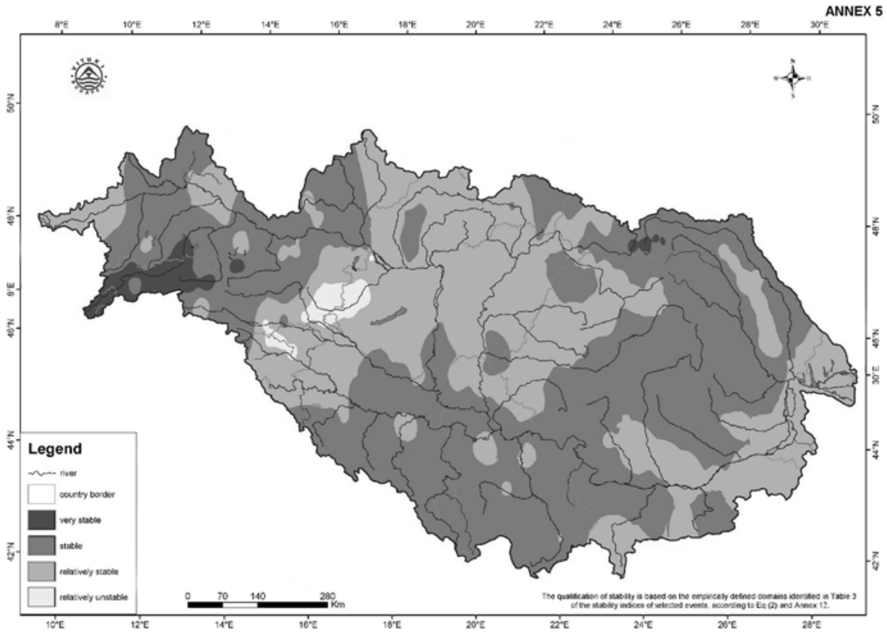
Annex 3 (continued)

Annex 4



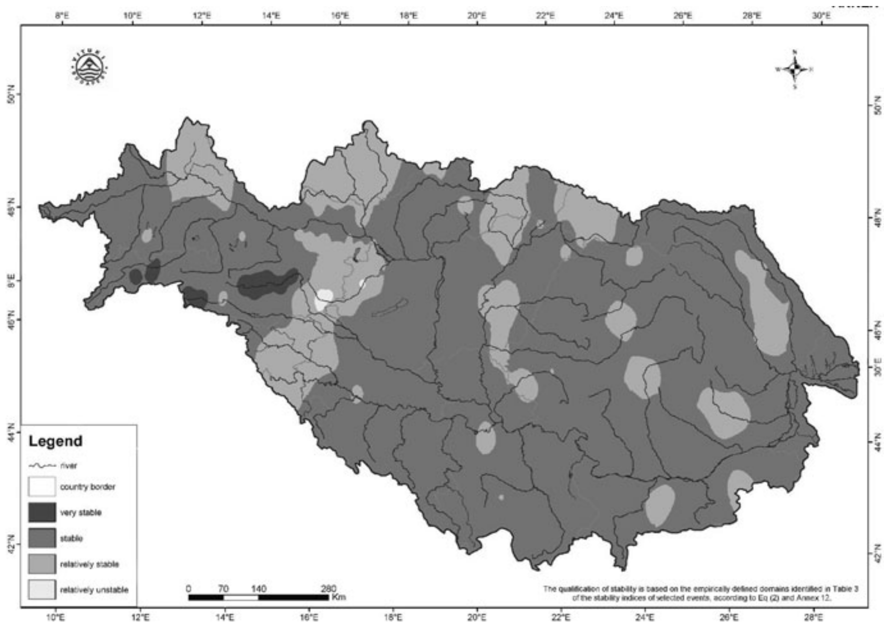
The regional variation of the stability of the annual flow regime N_R

Annex 5



The regional variation of the stability of the first highest monthly mean discharge N(MAX1)

Annex 6



The regional variation of the stability of the first lowest monthly mean discharge N(min 1)

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