Project No. 037005

CECILIA

Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

Specific targeted research project

1.1.6.3.I.3.2: Climate change impacts in central-eastern Europe

D 5.3: Analysis of natural conditions, climate, hydrology, development of land use, surface water quality, and water management during the period from 1960 to the present

Due date of deliverable: 1st June 2007

Actual submission date: 1st June 2007

Start date of project: 1st June 2006 Duration: 36 months

Lead contractor for this deliverable: **National Forest Centre – Forest Research Institute Zvolen (FRI)**

Project co-funded by the European Commission within the Sixth Framework Programme (2006-2009)		
Dissemination Level		
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)	

SUMMARY

THE HRON RIVER BASIN (SLOVAKIA)

(JÁN SZOLGAY, KAMILA HLAVČOVÁ)

Description of natural conditions

The Hron River is a left-side tributary of the Danube River; its basin is located in Central Slovakia. The catchment is feather-shaped, located along the long main river with numerous shorter tributaries. It covers an area of 5465 km^2; its upper and middle parts are situated in the area of Inner Carpathian Mountains, while the lower part of the basin belongs to the Danubian Lowlands. The location of the catchment within the territory of Slovakia is shown in Figure 1.

The spring of the Hron River is at an altitude of 934 m a.s.l. near the village of Telgart and it flows into the Danube near Sturovo at an altitude of at 103 m a.s.l. The total length of the Hron River is 284 km. The mean slope of the river varies from about 7.6 ‰ in the upper part to 0.9 ‰ in the lowlands. The Hron River drains 11.2% of Slovakia. After the Váh and Bodrog catchments, the Hron is the third largest river in Slovakia. The most important tributaries in the upper part of the basin are Hronec, Cierny Hron and Rohozna from the left, Bystra, Vajskovsky and Jasensky potok from the right side. In the middle part of the basin the Slatina is the largest tributary; other important tributaries are Bystrica, Kremnicky and Zarnovicky potok.

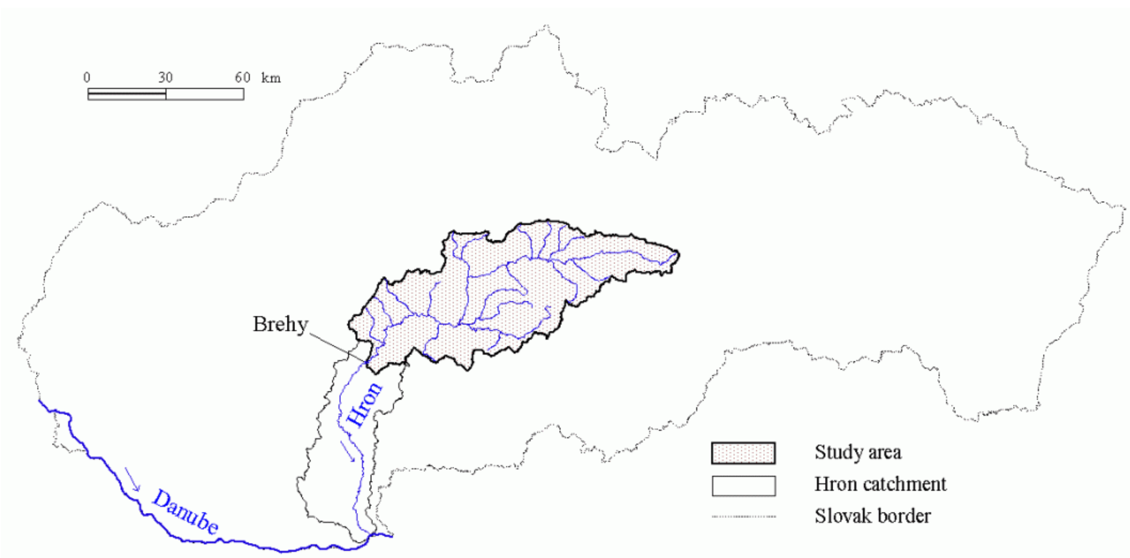

Figure 1. Location of the Hron River basin in Slovakia

With regards to the availability of hydro-meteorological data and also according to the character of the hydrologic processes in the catchment the alluvial part of the river has not sufficient data suitable for modeling (short series and less a dense network), but due to its lowland character and very low specific discharge (mostly less then 1.5 l/skm2), modeling approaches have to be applied, which better account for the physically based description of processes in the unsaturated zone than the WATBAL model and other conceptual monthly water balance models. Therefore the discharge gauging station Brehy was selected as the closing cross section for the CECILIA project (the term “Hron River basin” refers mainly to the Hron catchment to Brehy hereafter). This subcatchment has an area of 3 821 km2 (8% of the Slovak territory). Its relief is represented by digital elevation model in *Figure 2.*

With respect to geology, the eastern part of the catchment consists of abyssal magmatic and metamorphic rocks (*Figure 3*). The western and southern sides of the region are formed of neovulcanites of latter Tertiary era. Sedimentary Mesozoic stones occur in the north-western part

(Krížna sheet), while Tertiary solid sedimentary stones form the central part of the region. Cenozoic untoughened or disintegrated sediments can be found particularly on alluvial plains.

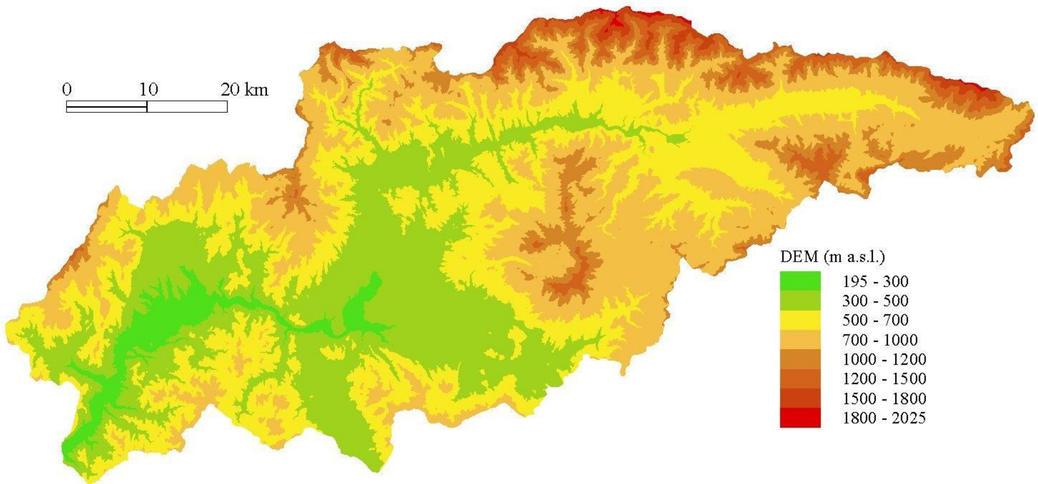

Figure 2. Digital elevation model (DEM) of the Hron River basin (50x50 m resolution)

From the hydrogeological point of view the Hron River catchment can be divided into three sections similar to the general geological division: the Central Western Carpathians at the north eastern part of the area of Central Slovakia, the Volcanic Field in the center of the catchment area, and the upper part of the Danube basin in the southern part of the area.

Eleven categories of the the USDA soil classification can be found in the Hron River basin. Silt, sandy loam and silt loam soil types prevail (*Figure 4*).

The landuse map, which is shown in *Figure 5*, is based on Landsat images from the year 2000 with the resolution 30 x 30 m. Fifteen landuse categories occur in the region. Fifty six percent of the area is covered by forests, 26% by arable land, 14% by meadows, pastures and shrubs and 4% by urban areas.

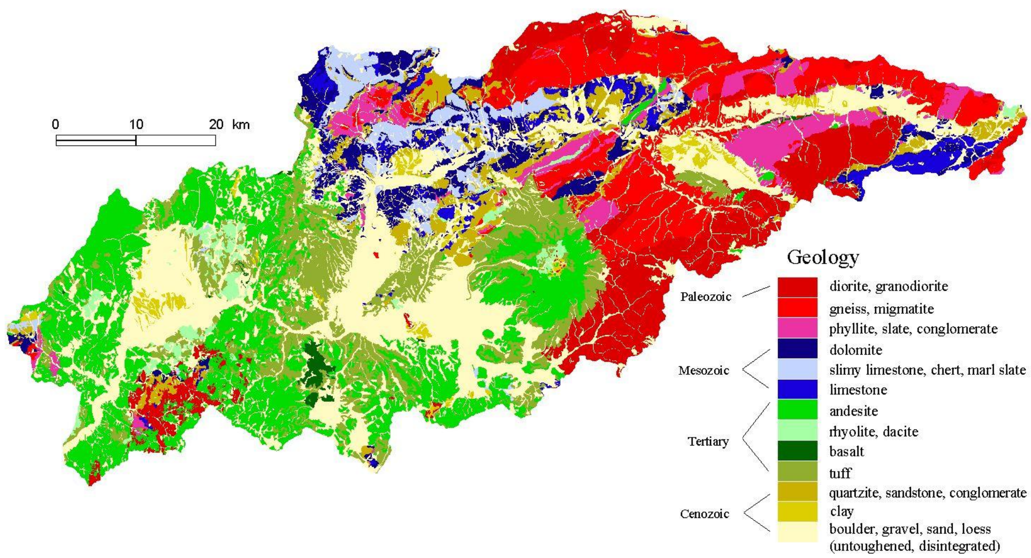

Figure 3. Geological map of the Hron catchment produced by the State Geological Institute of Dionýz Štúr.

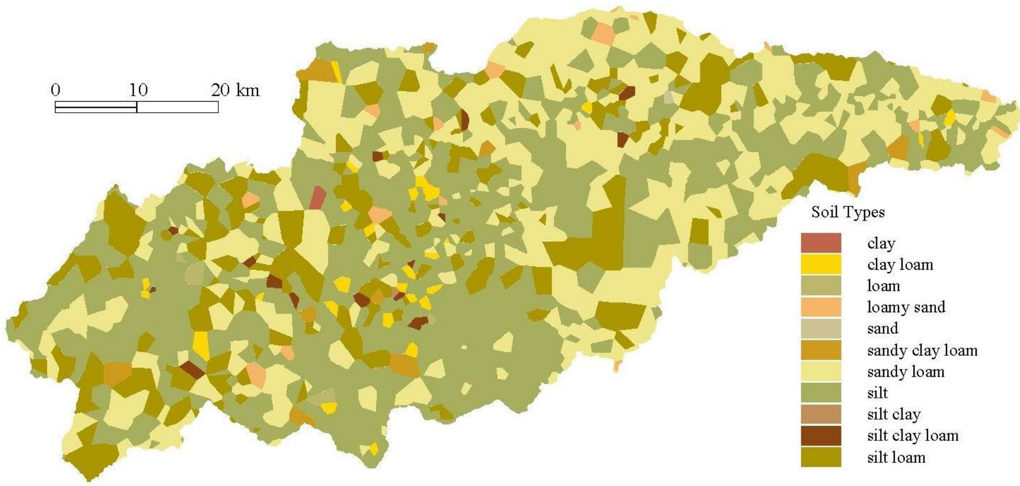

Figure 4. Map of the soil types of the Hron River catchment

The climatic conditions of the Hron River basin correspond to the European-continental climatic region of the mild zone, with oceanic air masses transforming into continental ones. The annual precipitation in the basin varies from 570 to 700 mm/year in the lowlands to about 700-1400 mm/year in the valleys and upper mountainous areas. The overall average is approximately 800 mm/year. Evaporation amounts to approximately 300 to 600 mm/year.

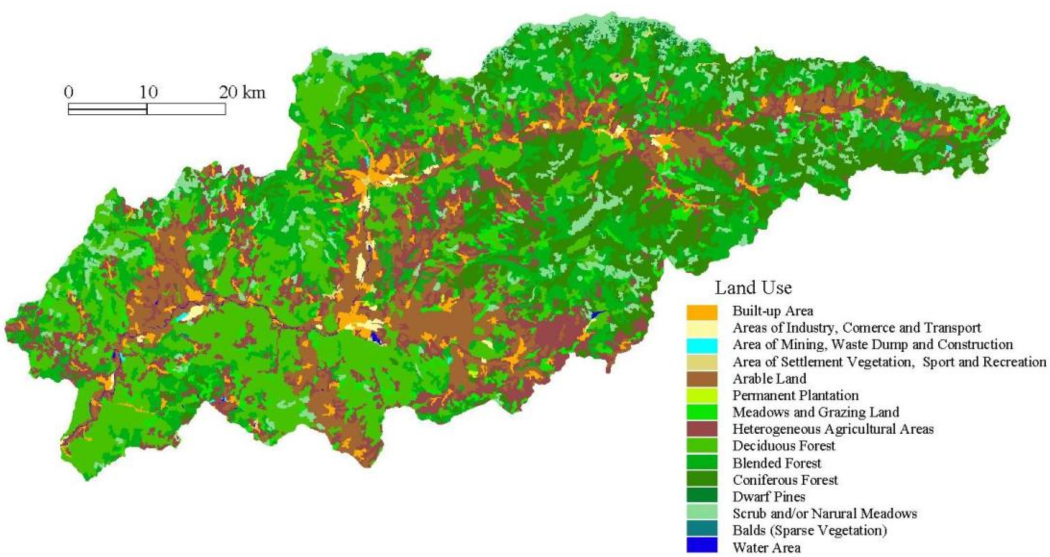

Figure 5 Landuse of the study region based on Landsat images from 2000

Three regional subdivisions of the catchment can be made according to relief and elevation: the warm region (lowlands), which is spreading out in the Danube lowland, the Ziar and Zvolen Valleys, the mild-warm region (valleys), which covers the mountain slopes up to 800 m a.s.l., and the whole Upper Hron Valley. The third, the cold region (mountainous slopes), is located above 800 m a.s.l. in all mountains surrounding the upper part of the basin. The basic climatic characteristics of these sub-regions are given in *Table 1*.

The Hron River has a snow-rain combined runoff regime type. The precipitation in the upper part of the Hron basin reaches 1600 mm, while in lower flat areas it is only 600 mm. The runoff represents in the upper part up to 60 % of the precipitation, while in the flatlands only 10 %, the mean value for the whole basin being 37 %. The long-term mean annual discharge for the Hron in Brezno is 8.12 $m^3.s^{-1}$, in Banska Bystrica 28.0 m^3s^{-1}, and at the confluence with the Danube it increases to 55.2 $m^3.s^{-1}$ (*Table 2*).

The specific runoff in the Hron River basin varies between 1.6 in the lowlands to 28 ls^{-1} in the mountains. The richest tributaries are Bystrianka, Jaseniansky potok, Vajskovsky potok and Bystrica, where these values reach 22 - 25 $ls^{-1}km^{-2}$. In the flatland areas the specific yield is only 1.5 $ls^{-1}km^{-2}$. The mean values for the whole basin is 10.1 $ls^{-1}km^{-2}$, which is 20 % more than that for the whole territory of Slovakia.

The flood generation problem in the basin is complex. In the alpine high mountain regions floods from snowmelt, mixed events and flash floods represent a threat to local villages build in narrow valleys all over the year. Due to runoff concentration snowmelt floods and floods of cyclonic origin represent danger to major cities and industrial areas with heavy and chemical industry, electric and atomic power plants in the middle of the catchments.

Table 1. Climatic characteristics of the Hron Basin

Climatic characteristics	**Lowlands**	**Valleys**	**Mountainous slopes**
Mean temperature in January (°C)	-1.5 to -2.5	-2.5 to -6.5	-2.5 to-8.0
Mean temperature in July (°C)	20.3 to 19.5	19.5 to 14.5	19.5 to 9.5
Days with temperature above 0 °C	320 - 300	300 - 245	300 – 195
No of summer days	75-60	60-20	60-0
No of ice days	25-35	35-50	35-75
Days with precipitation above 1 mm	85-100	100- 120	100-150
Annual precipitation (mm)	580 - 700	700 - 900	700 - 1400
Precipitation in the warm season (mm)	330 - 400	400 - 500	400 - 750
Precipitation in the cold season (mm)	250 - 300	300 - 400	300 - 650
Number of days with snow cover	35-50	50-100	50 - 220
Evapotranspiration (mm)	600 - 500	500 - 400	500 - 300

Table 2. Discharge characteristics in selected profiles in the Hron basin

River Profile	**Basin area**	**Mean discharges**	**Mean annual runoff**	**Mean monthly discharges for period 1931-1980 ($m^3.s^{-1}$)**					
	(km^2)	($m^3.s^{-1}$)	(10^6 m^3.y-^{1})	11	12	1	2	3	4
				5	6	7	8	9	10
Hron				26.690	24.440	17.490	20.020	37.050	57.230
Banska Bystrica	1766.48	27.990	883.3	42.850	31.080	23.850	18.960	16.450	19.760
Hron				48.490	47.980	34.760	47.270	82.540	99.310
Brehy	382138	49.970	1576.9	66.860	49.570	36.620	28.750	25.620	32.390

Table 3. Water balance characteristics of Hron and its tributaries in the period of 1931-1980

	Hron River mouth	**Bystrianka**	**Vajskovsky potok**	**Jaseniansky potok**	**Bystrica**
Precipitation in basin (mm)	869	1414	1466	1407	1194
Runoff (mm)	319	755	820	704	722
Losses (mm)	550	659	646	703	472
Runoff coefficient	0.37	0.53	0.56	0.50	0.60
Specific runoff ($l/s.km^2$)	10.10	23.92	25.98	22.31	22.89

Development of climate, land use, surface water quality, and water management

Extensive studies have shown that hydrological time series from the periods 1931 to 1960 and from 1931 to 1980 can be considered stationary. These periods have been therefore chosen as "representative periods" for hydrological design purposes and water resources planning in Slovakia. In previous climate change impact studies both were considered as baseline scenarios. Here, where appropriate, development of climate, runoff and water management during the period from the 1960s to the present will be compared with data from these periods.

When comparing statistical data from the period 1961 -2000 with the long term behavior of the catchments as described by data from the period 1931 – 1980, usually a decrease in runoff can be shown. The decrease in runoff is approximately the same for the Hron as for the whole country (about 10 %), precipitation decrease is less significant (about 1 to 4 %). In consequence there was a slight increase in the evapotranspiration from the water balance.

As for long-term mean monthly discharges for the same two periods, both increase an decrease can be detected in the Hron basin, the generally observable tendencies are illustrated in *Figure 6*. It can be seen, that the mean monthly discharges do not necessarily decrease in all months' in all catchments. An increasing tendency can be detected in some catchments in the spring and early winter.

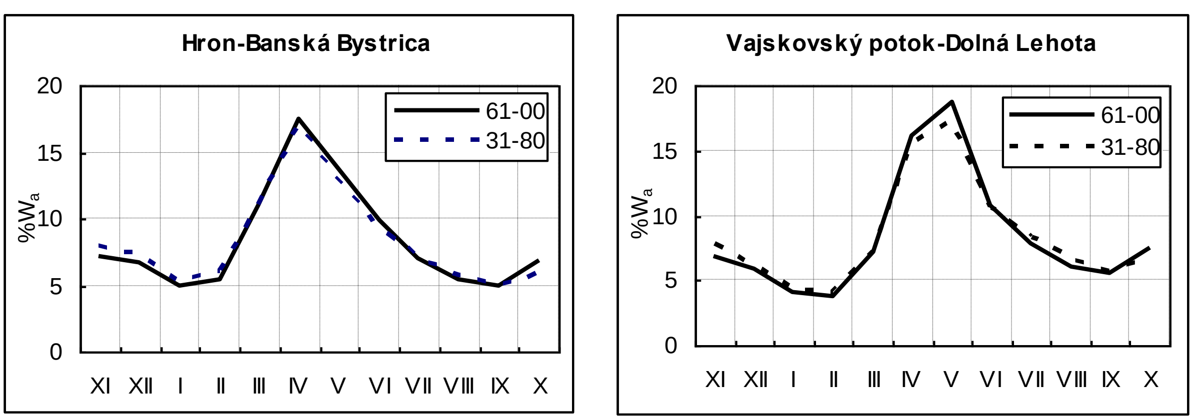

Figure 6. Comparison of mean monthly runoff for the periods 1931-80 and 1961-2000 for two selected subcatchments of the Hron catchment (Pekarova and Szolgay, 2005).

These results have to be interpreted with care and should always be evaluated in a broader perspective of the selection of the analyzed period. Long-term data (1881-1998) indicate a decreasing linear tendency of precipitation and increase in air temperature. In consequence mean annual average discharges of the Hron River can also show decreasing tendency. Due to the shorter discharge series, serious documentation of the phenomenon of a generally decreasing trend is more difficult. Moreover these relatively short series can be more pronouncedly influenced by the warm period in the last decade of the last century. This period could so introduce a bias toward a more significant decrease, that it would be indicated by data from longer series.

The occurrences of floods seem to be more frequent in the near past and damages are growing. A joint thorough analysis of the climatic driving factors and development of new modelling approaches is needed in order to cope with the problem. However the annual maximum flood series do not exhibit a clear trend.

Low flows occur in the catchment in two periods, the summer-autumn and the winter period. These two are separated by the secondary maximum of the mean monthly precipitation in November. The minimum flow usually occurs in September and in January. Analysis of flow duration curves from the period 1961-2000 and 1931-1980 shows, that as in the case of monthly discharges, only in few cases an increase of the M-day flows can be seen, the overall tendency is generally decreasing. From the time series of annual maximum minimum flows can be seen, that the last warm period has led to the occurrence of a series of very low values in the last years; however these do not represent extraordinary extremes when compared with the previous records.

As for landuse, due to past and ongoing changes in the administrative organization of governance and the difference statistical methodologies, it is rather complicated to conduct a comparative quantitative analysis in various economic and social sectors and their obviously existing relation to landuse and its change. The major industrial factories were mainly and traditionally located in the large towns along the main flow of the Hron and its tributaries. This urbanization and industrialization pattern prevails till present and together with the rather narrow river valleys and the mountainous character of the whole region under study it prevented larger scale landuse changes during the last decades especially in the upper and middle part of the catchment.

Population growth, as an indicator for pressure on land use and landuse change in the area, showed, that only two urban areas, namely the cities of Banska Bystrica and Zvolen were significantly growing during the last hundred years. The other cities exhibiting growth, like Banska Stavnica, Detva, Hrinova are outside of the main river valley in the project area. It can be concluded, that pressure from industrialization and urbanization was localized to a few hotspots with locally expanding industrial production. Therefore there were no significant large scale land-use changes in the catchments under study in the second half of the past century except of urbanization of the surroundings of larger urban settlements. Local changes have taken place in course of the collectivization of the farming, industrialization of rural areas and development of transport infrastructure since the fifties of the last century. During the socialist industrialization a few new major projects were built. The most important industries contributing the economy of the region located in the main cities were as follows: metallurgical and mining industry (Brezno, Ziar nad Hronom, Zarnovica), engineering industry (Brezno, Banska Bystrica, Zvolen. Detva), food industry (Zvolen, Banska Bystrica), textile industry (Banska Bystrica, Banska Stiavmca), wood processing industry (Banska Bystrica, Zvolen, Zarnovica), chemical and pharmaceutical industry (Brezno, Banska Bystrica).

The agricultural production in the region is at the average in Slovakia, in general. The livestock production focuses at the production of cow and sheep milk, eggs and sheep wool. There are approx. 63 companies with more than 20 employees that employed 6 574 persons. A larger part of the agricultural area is utilized for permanent grass, while the area of arable land is not large except around Revuca and Zvolen. The region is located in the central part of the country and has a good accessibility from major population centers and for international tourist from Krakow and Budapest. Various natural and cultural resources, such as National Parks, historical towns, ski resort areas, etc. are used for tourism. In the southern part of region water tourism, thermal spas, water sports, cycle-tourism and village tourism exists. These activities were underdeveloped in the past and represent a certain potential of pressure on land use in protected areas and possible larger scale change in existing land-use in agricultural areas for the near future.

Since the potential to more pronounced changes started to grow after the economic transition in 1990, the quantitative analysis of the change in land use was restricted here to this period. The area that have been changed from one to other types of land cover between 1990 and 1998 is around 3 000 ha. Within the areas of changed land cover, larger areas of subtypes of forest and agricultural lands have changed. The factors for these changes could be explained by:

- Abandonment of large-scale agricultural and pasturelands including state farms.
- Abandonment of arable lands, vineyards and fruits gardens due to economic change.
- Forestation on agricultural land.

It has to be noted that although the area with change is not large, the urban and industrial use of land has a tendency to grow, mostly due to urban expansion, extraction of construction materials, building industrial sites.

With regard to water quality one can conclude, that after a longer phase of gradually increasing pollution of surface waters in Slovakia in the second half of the last century, a general improvement in water quality was observed since 1990. The variation of water quality has undergone since 1960 the same cycle as water consumption, and the reason for the observed trends ape in principle also the same. Despite this and the fact that the Hron River has a considerable capacity for self-purification, its water quality, in general, can be still assessed as polluted. This assessment is primarily based on high values of microbiological pollution indicators, such as coliform bacteria, and to a lesser extent based on other organic and chemical/physical parameters, including heavy metals. Based on water quality data and the Slovak Classification of Surface Water Quality (STN 75 7221), the river water is therefore considered suitable for limited number of types of use.

When looking at the sources of pollution, municipal wastewater effluents accounts for 70.1% of the recorded BOD load discharged. The slowly diminishing deficiency of wastewater treatment plants and inadequate treatment of domestic and industrial wastewaters in existing plants are considered to be the major causes of the pollution of the Hron River. Untreated domestic sewage discharges from areas that are not currently monitored are an additional source of surface water pollution. Among the municipal wastewater effluents, the BOD load of Banska Bystrica is the largest, at about 38.1% of the total. Industrial wastewater effluents account for 28% of the total BOD load discharged. These sources are mostly located between the Banska Bystrica area and the Zvolen area, therefore BOD5, shows higher values between the Banska Bystrica area and the Zvolen area, due to industrial and urban sources of pollution.

Heavy metal concentrations are, in general, at acceptable levels in the Hron River Basin, except around the Zarnovica area, where the concentration of zinc is relatively high. The organic pollutant loads are comparatively high between the Banska Bystrica area and the Zvolen area where many of the major sources of pollution are concentrated.

Groundwater quality is generally good, through some of the drinking water quality standards are exceeded before treatment. Groundwater sources along the Hron River are susceptible to pollution from discharges of inadequately treated domestic, industrial and agricultural wastes, as well as the application of fertilizers and pesticides in areas of intensive agriculture.

With respect to groundwater, the lower region of the catchment is more contaminated. The main contaminants are N03, Ca and Total Dissolved Solids (TDS). Furthermore, areas heavily contaminated with these contaminants and with Cl and Mn can be found along the Hron Alluvial valley. This contamination in the lower region is attributed to agricultural activities, especially fertiliser use and possibly from old environmental loads at some locations.

In the middle region, two significant areas of contamination can be found. One is along the Hron Alluvial valley, where Fe, Al, As and Ca are the main contaminants. The concentration of factories and the accumulation of metal-rich sediments are the main causes of this contamination. The other contamination area consists of the surroundings of the old mining sites; Ma, Al, Ca, As and Cd are the main contaminants in this area. Mining activities are the main cause of this contamination.

Groundwater contamination in the upper region is relatively light compared with the other regions but Zn and Al contamination can be found in the mountain area. Old mining activities or natural geochemical anomalies are the causes of this contamination. N03 and NH4 contamination can be found in the Hron Alluvial valley. Agricultural activity and sewage effluent is the cause of this contamination.

With respect to water management, the Hron River Authority, a subsidiary of the Slovak River Authority, manages the waters in the basin. It is a state owned company responsible for the management of water (including flood protection), except the direct drinking water supply. There are many stakeholders in the area, these use the water distributed by the river authority for hydroenergy, thermal and atomic power plants, drinking water supply from reservoirs, for agriculture – water for irrigation.

The Hron river system has few medium sized reservoirs. Only one is on the Hron River, at Velke Kozmalovce, two, the Hrinova and Motova reservoirs, are on the left tributary of the Hron, the Slatina River and the fourth is at Batovce on the Jablonovka River.

Table 4. Basic characteristics of the larger reservoirs in the Hron River basin
(Source: Lukac and Abaffy, 1995)

Reservoir	**Dam Height**	**Catchment Area**	**Capacity**	**Main purpose**
	(m)	(km^2)	(m^3x10^6)	
Velke Kozmalovce	8.0	4016	3.23	Water for industrial use, hydropower, domestic supply, irrigation, fish pond supply
Hrinova	51.0	71	7.28	Domestic water supply
Motova	16.2	411	2.93	Industry, hydropower, recreation, flood control
Batovce	13.4	-	1.04	Irrigation, flow augmentation, recreation, aquaculture

These reservoirs are all of small to medium size and none has a significant accumulation capacity. Therefore they do not significantly influence the hydrological regime and its characteristics of the Hron River itself, since the reservoirs on the tributaries exhibit some influences downstream on these, but these are negligible with respect to the discharge of the Hron. The barrage and reservoir at Velke Kozmalovce reduces flows immediately downstream for a few kilometers.

In addition to these reservoirs there is a number of small reservoirs and barrages on the Hron river and its tributaries. These have been constructed for local irrigation and industrial water supply, hydropower and fish breeding purposes. The number of reservoirs with volume less than 1 million

m^3 is 73. Beside the water transfers remaining within the basin, there is a historical water transfer scheme, which was put in operation during the 14th century, when a 22 km canal was constructed to carry a discharge of 0.6 m^3/s from the Turiec River, a tributary of Vah River, to the Hron River basin to supply water to the Kremnica mining region. Later in 1930 this system, which is still in operation, was redesigned as a multipurpose water transfer scheme with hydropower stations and small reservoirs. The present water transfer is of the order of 0.38B m^3/year.

The total hydropower potential of the whole Hron River basin is estimated at 140 MW, the installed capacity at 98 locations has a total annual output of 340 GWh. The Hron River itself is not a major source of hydropower. The total technically useable hydropower potential of the main river is an estimated 46.9 MW with an annual production of 247.8 GWh. The proposed Slatinka dam on the Slatina River has the potential of 36.6 MW.

The total annual power production in the Hron basin is about 25.1 GWh. The presently installed capacity is 8.1 MW, the larges proportion of this is at the Velke Kozmalovce barrage (5.1 MW). Smaller hydropower stations are at Motova on the Slatina River (1.0 MW) and on the Turcek water transfer from the Turiec River. Additionally there are numerous historical and new small hydropower stations.

With respect to damming for flood protection, engineering works have been undertaken on about 80 km (27%) of the Hron River especially on the lower Hron and designed to prevent the flooding and erosion of agriculture lands as well as urban areas. River canalization has been undertaken mainly at Banska Bystrica and Zvolen. Below Levice the Hron has been shortened by about 11 km by elimination of meanders. Despite these measures, some flood risks remain, particularly at Banska Bystrica and in sections of the lower Hron.

A particular problem of evaluating the water consumption and water uses is, that the administrative districts were changed in Slovakia after the economic change, so several statistics are difficult to compare or depict for the whole period from1960. Moreover from point of view of hydrological modeling and climate data on consumption from the period before 1990 are only of interest, when questioning stationarity or homogenizing data. The data used here was checked and homogenized before entering the database of the SHMI.

The development of water consumption and water discharge into rivers (including wastewater) has shown strong variations since 1960. In general there was an increasing tendency in consumption and withdrawals till 1990. The rate of increase was regionally different. In Figure 7 it can be seen, that after 1990 there was a sharp break in the time series followed by a decrease, which more or less continued till recent. The reasons for this were the lower industrial and agricultural production after 1990, decrease of subsidies for irrigation, new technologies and increased recycling of industrial water, and increase in water tariffs (from Crowns (SK) 1.74/m^3 in 1990 to e.g. SK 8/m^3 in 1998). The same general tendency can be detected in the use of surface water for various purposes. Surface waters supplied less than half (43.3%) of total water consumption in the Hron basin in 1998. In the By 2000 the amount of water used for agricultural purposes declined by more than 90% from a total utilised volume of 26 645 Mm^3 in 1990. The decline in agricultural consumption was caused by the falling agricultural production and by the decrease of subsidies for using water for irrigation.

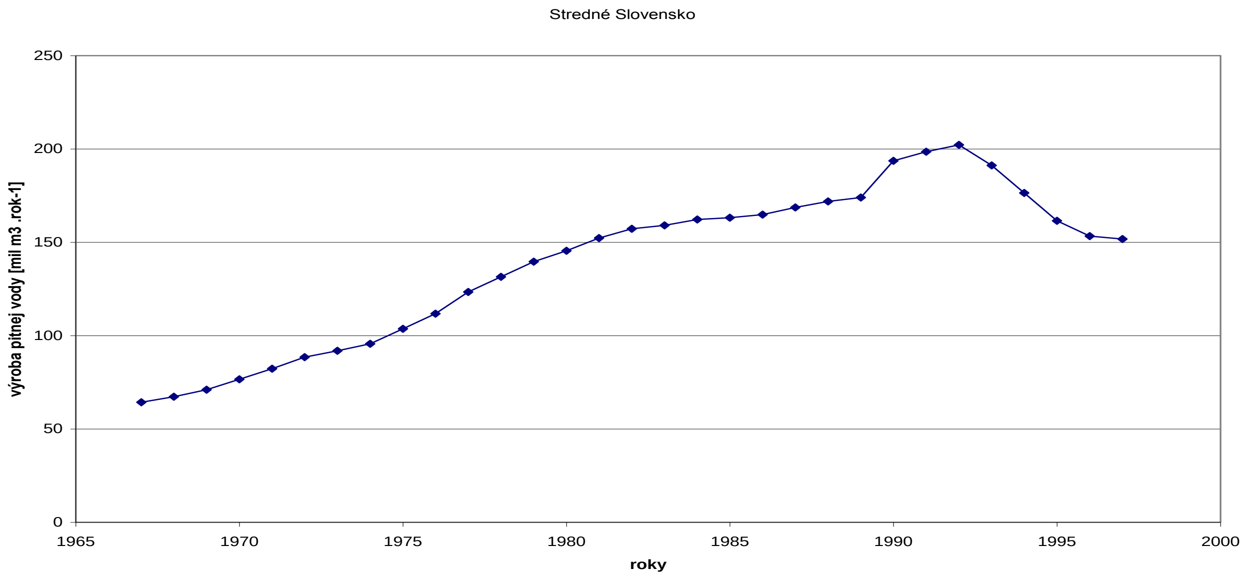

Figure 7. Water produced for drinking water supply in the administrative district Middle Slovakia, which includes the Hron basin, between 1967 and 1997.

The annual volumes of water used for industrial purposes also declined. The largest source of industrial water was surface water (90.8%), and this was drawn mainly from the Hron River and its main tributaries (e.g. Hnusno, Lupcica, Bystrica, Driekyna and Tajovsky potok) and from the reservoirs Motova and Vel'ke Kozmalovce. The observed decline in industrial consumption was caused by the decreasing industrial activities, improved technologies and introduction of water recycling in the major industries. There was a decline of the annual volumes of water used for domestic and municipal supply, e.g. the supply in 1998 was 59.0% of that in 1989. This significant decline was probably due to the sharp increase in domestic water tariffs in the 1990s.

References

Lukáč, M. and Abaffy, D.: Dams in Slovakia, 1995

Slovak Environmental Agency & Japan International Cooperation Agency: The study on the regional environmental management plan for the Hron River Basin in The Slovak Repubic. Final Report. 2000, Tokyo

Pekárová, P., Szolgay, J., eds.: Assessment of Climate Change Impact on Selected Components of the Hydrosphere and Biosphere in the Hron and Váh River Basins. VEDA, Bratislava 2005, 492 p., ISBN 80-224-0884-0 (in Slovak)

www.shmu.sk
www.sazp.sk
www.vuvh.sk

THE VLTAVA RIVER BASIN (CZECHIA)

Description of natural conditions

The Vltava River basin is situated in the southern part of the Elbe River basin (Kredba 1969). The area of the studied part of the basin with the closing profile at Vrane n/V. is 17,793 km^2. The altitude of this part of the basin ranges from 190 to 1378 m a.s.l. Geography includes different climate, geological, hydrological, and land-use conditions in a spectum of locations ranging from river valleys and upland plains that are largely used for agriculture and urbanisation to forested, almost uninhabited mountainous parts. The river network includes four major rivers: the Vltava River with its two right-side tributaries – the Luznice and Sazava Rivers, and one left-side tributary – the Otava River *(Figure 1*).

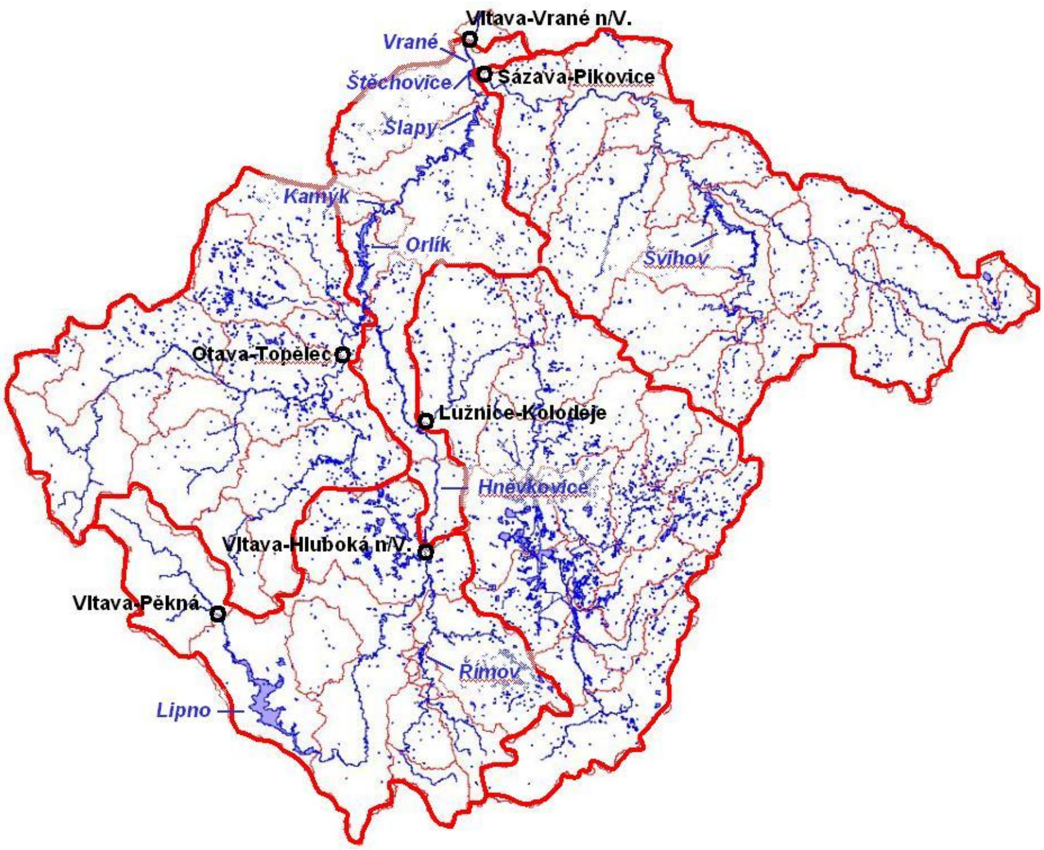

Figure 1. The upper Vltava River basin with major rivers and reservoirs. Circles – selected hydrology and water quality monitoring stations; thick red line – the main catchments described in text; little red line – the subcatchments used in HSPF modelling.

A large part of the Vltava River valley of is impounded with a cascade of reservoirs (Lipno, Hnevkovice, Orlik, Kamyk, Slapy, Stechovice, and Vrane), called the Vltava River Resevoir Cascade (VRRC) that have been built for a main purpose of hydropower production. In addition, two important drinking water reservoirs are situated on side tributaries, i.e. Svihov Reservoir on the Zelivka River and Rimov Reservoir on the Malse River. Main characteristics of the principal reservoirs are in *Table 1*.

Table 1. Selected characteristics of reservoirs and their catchments with periods of available limnological data

Parameter	Rimov	Lipno	Svihov	Orlik	Slapy	Vrane
Catchment:						
area, km^2	489	952	1,178	12,110	12,980	17,793
population, inh./km^2	35	15	45	50	49	55
farmland/forest, %	40/50	3/77	62/29	52/45	52/45	55/42
min./max. altitude, m a.s.l.	430/1111	710/1378	325/765	280/1378	213/1378	190/1378
Reservoir:						
Built	1979	1960	1972	1961	1957	1935
volume, mil. m^3	33	310	267	704	270	11
Surface area, km^2	2	49	14	26	14	2.5
max. depth, m	43	22	52	71	58	10
hydraulic retention time, d	90	270	430	100	39	2
Available data periods	1979-2004	1967-1968 1991-2004	1980-2004	1991-1993, 2000	1961-2004	1963-2004

Geology and soils

The area is dominated by a crystalline of the Vltava-Danube area known as moldanubicum. The geology is varied with several units ranging from Proterozoic to Tertiary (Quaternary) age. The basin background is composed of deep igneous and metamorphosed sedimentary rocks, e.g. granites, gneisses, and pegmatites. Typical soil types include cambisols at moderate elevations, podzols in the mountainous parts of the basin, and gleysols in river valleys. Peat accumulations and active peatbogs are situated in the uppermost part of the Vltava River valley upstream from Lipno Reservoir and in the upper parts of the Luznice subcatchment.

Climate and hydrology

The upper Vltava River basin belongs to the temperate, mildly cold climatic region. It is situated in a transient region between a wet oceanic climate of the west Europe and a dry continental climate of the east Europe. A long-term annual mean precipitation amount is about 680 mm. The distribution of precipitation amounts across the basin is uneven with more than 1,000 mm at the southern mountainous part (e.g., the station of Churanov, 1019 mm) and about 600 mm in the central and northern parts of the basin (e.g., the stations of Ceske Budejovice and Tabor). The annual mean temperature is about 9°C at the lowest parts of the basin and <5°C at altitude above 1,000 m a.s.l.. A highly significant increasing trend of temperature was detected at most climate monitoring stations in the basin during the period from 1961 to 2004 with an annual increase by 0.02 to 0.03°C. Main characteristics of climatic and conditions in the basin are given in *Table 2*.

Table 2. Main characteristics of subcatchments and the whole Vltava basin with the closing profile at Vrane n/V.

Characteristic	Vltava- Hluboka n/V.	Luznice	Otava	Sazava	Vltava- Vrane n/V.
Catchment area, km^2	3395	4233	3840	4349	17793
Elevation-mean, m a.s.l.	678.0	521.0	609	493	553
Elevation-min., m a.s.l.	365.0	349.0	311	200	188
Elevation-max., m a.s.l.	1372.0	1057.0	1372	807	1372
Slope, °	5.6	2.9	5.4	4.8	4.7
Temperature (mean 1961-2004), °C	7.0	7.8	7.4	8.0	7.6
Precipitation (mean 1961-2004), mm	706	641	705	667	669
Runoff (mean 1961-2004), mm	270	173	229	180	208
Runoff/Precipitation	0.38	0.27	0.32	0.27	0.31
Land cover (2002):					
forest, %	46.9	37.5	37.6	30.4	37.7
farmland, %	47.2	55.1	57.2	63.3	55.9
urban, %	3.0	4.6	3.8	5.4	4.3
water, %	2.9	2.8	1.4	0.9	2.1
Population (2001), thousands	229	256	210	300	1086
Population density (2001), inh./km^2	68	60	55	69	61
Access to public water supply (2002)	89%	85%	79%	78%	81%
Attachment to sewers (2002)	81%	81%	72%	57%	71%

The long-term (1961-2004) runoff from the upper Vltava River basin at the closing profile of Vrane n/V is 117 m3 s-1, which equals 6.6 l s^{-1} km^{-2} or the runoff depth of 208 mm. At the mean precipitation amount of 669 mm it means that the evaporation in the basin is 461 mm (69% of precipitation). The runoff depth differs between the southern, mountainous part of the basin, where mean values >500 mm are common, and the northern part with mean values of about 150 mm. The coefficient of variation of annual mean discharge is relatively high; it varied between 27 and 40% at 14 selected stations in the basin during the period 1961-2004. More that 60% of the annual runoff volume from the basin occurs during the winter hydrologic period (November-April).

Development of land use, water quality, and water management

Major features of changes that occurred in the upper Vltava basin during the studied period 1961-2004 are documented in *Table 3*.

Table 3. Development of main characteristics in the Vltava basin (profile Vltava-Vrané) during 1961-2001 (CSU 2003)

Characteristic	Year				
	1961	1971	1981	1991	2001
Inhabitants, thousands	1009	1017	1073	1085	1086
Access to public water supply, %	49	49	50	74	81
Attachment to sewers, %	30	41	58	69	71
Spec. production of P in sewage, g/inh./d	2.1	2.6	2.5	3.0	2.5
Land use, %					
forest	33.3	34.5	37.1	37.6	37.7
farmland	60.6	58.4	57.3	56.2	55.9
arable land, % of farmland	65.8	67.6	70.7	71.4	66.5
grassland, % of farmland	34.2	32.4	29.3	28.6	33.5
water	1.9	1.9	2.0	2.1	2.1
Tile drainage, % of farmland	4.6	13.9	32.2	43.0	43.1
Livestock, LU*/ha of farmland	1.2	1.1	1.4	1.2	0.8
Livestock composition, % of LU					
cattle	81	79	77	74	66
pigs	17	19	20	23	29
poultry	2	3	3	3	5
Fertilisation - P, kg/ha of farmland					
manure	20	20	25	23	17
fertilisers	10	22	31	12	8
total	30	42	56	35	25
Fertilisation - N, kg/ha of farmland					
manure	85	85	104	94	67
fertilisers	19	58	98	71	83
total	104	143	202	165	150

* LU, livestock unit – 1 LU is equivalent to 500 kg of alive weight of animals.

Population

The population of the basin increased by 8% during 1961-2004 (*Table 3*). A major increase occurred in the 1970s, reflecting the fact that a strong age classes that were born in the first decade after the World War II reached the reproduction age. The standard of living improved significantly during 1961-2004 and the economic structure changed. The sector of agriculture employed less people, which induced moving of people from small countryside settlements and villages into larger centers and cities.

The improvement in sanitation (higher consumption of water for bathing and washing and for water closets) was an important change resulting in the pollution or streams with wastewater. Whereas in the beginning of the 1960s only about a half of basin population used tap water from public water supply systems and less then one third were connected to sewers, these shares increased to 81 and 71%, respectively, in the 2000s. Specific production of phosphorus (P_{spec}) into sewage by population increased from 2.1 g per inhabitant and day (g/inh./d) in 1961 to 3 g/inh./d in the early 1990s, mostly due to the increase of P in detergents and their increasing consumption. In the middle of the 1990s this value moderately decreased due to a partial restriction of P concentration in detergents produced in the Czech Republic and remained steady until the end of study period.

Land use

A gradual increase in the proportion of forested area (by 4%) was paralleled with a decrease of farmland area. This change has been a part of long-term process with the beginning at least in the 19th century, when less productive and net readily accessible areas, e.g., waterlogged or situated on of high slopes, are abandoned and change into natural types of land cover, i.e. mostly forest.

The structure of farmland plots has changed little since the 1960s till the present, but the major change of unifying small plots of private farmers into large blocks occurred earlier, in the 1950s during the forced collectivisation. A large-scale, state subsidized construction of subsurface drainage systems, mostly at arable land (but partly also at grassland in waterlogged areas at hill slopes and valley inundations), occurred until the end of 1980s.

The development of density and structure of livestock together with the changes in fertilisation rates (*Table 3*) reflects the rise in the intensity of farming practices until the end of 1980s. Then, in the early 1990s, an abrupt decrease occurred in both indicators due to the change of political/economical conditions.

Water quality

The development of major indicators of water quality (organic pollution and nutrients) within the Vltava River basin is shown in *Figure 2*.

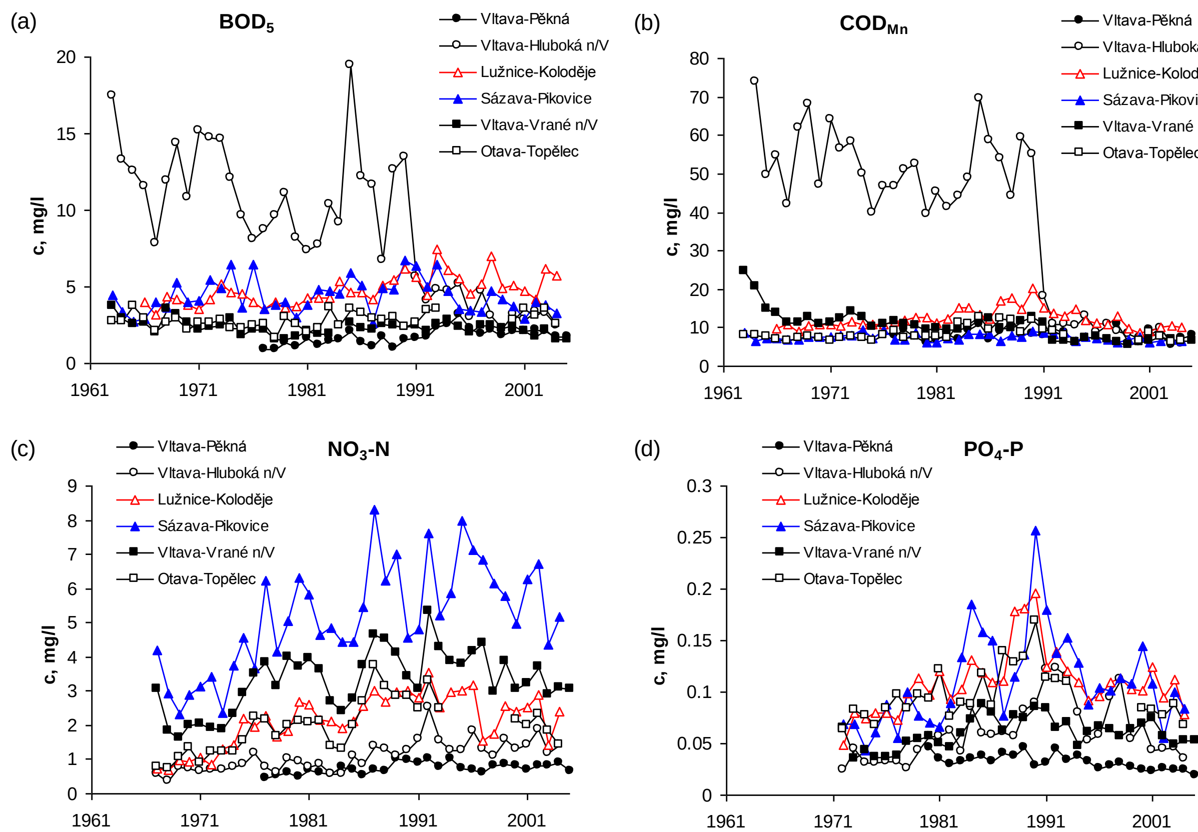

Figure 2. The time series of annual mean concentrations of (a) BOD_5, (b) COD_{Mn}, (c) NO_3-N, and (d) PO_4-P in selected monitoring stations in the upper Vltava River basin (see Figure 1 for their location) during available data periods

Natural background concentrations can be inferred from the profile Vltava-Pekna that is situated in the predominantly forested catchment (72%) with low farming intensities (meat cattle production on pastures) and density of population. The Vltava River experienced a period of heavy organic pollution from a paper mill situated at Vetrni (cca 30 km downstream from Lipno Reservoir) until 1990. The pollution with nitrate and phosphorus peaked during the early 1990s.

Water management

The largest amount of water in the Vltava River basin is used for hydropower production; actually the total river flow in the catchment is used for this purpose in the Vltava River Reservoir Cascade. The hydropower use does not change the total amount of runoff, however, it modifies its temporal distribution. The effect of storing and releasing of water in reservoirs is most marked at the outlet from the VRRC at the daily and monthly time scales. Monthly average inflow and outflow differ in dry periods of year when the outflow may be augmented up to 20 m3/s (= ca 25% of the mean flow value) and in the following periods of increased runoff the outflow is less by the same amount of flow until the storage volume in the VRRC is replenished. This effect is not observed at annual time scales.

The most important withdrawals within the Vltava River basin are due to the use of water in drinking water production, cooling systems of power plants, heating plants, and industrial production. The largest withdrawal is in the Sazava subcatchment from Svihov Reservoir (98 to 160 mil. m3 per year or 3 to 5 m3/s). This amount water is transferred out of the basin via a water conduit to the city of Prague, which, therefore, decreases flow in the Sazava River and in the closing profile of the basin. The second largest withdrawal is in the upper Vltava subcatchment from Rimov Reservoir (21 mil. m3 per year or 0.7 m3/s). This water remains in the basin as it is discharged again as municipal wastewater mostly within a nearby city of Ceske Budejovice and its surroundings. The loss of runoff is caused by the third largest withdrawal for the cooling system of the Temelin Nuclear Power Station that is situated in Hnevkovice Reservoir (18 mil. m3 or 0.6 m3/s). Most of this water amount (ca 90%) is lost to the atmosphere by evaporation. There was filed additional ca one hundred smaller withdrawals in the basin with a total amount of withdrawn water 35 mil. m3 (1.1 m3/s) by River Authorities in 2004. Approximately the same amount of wastewater was discharged close to the point of withdrawal.

References

CSU (2003): Statistical Environmental Yearbook of the Czech Republic. The Ministry of the Environment of the Czech Republic, Prague.

Kredba M., Ed. (1969): Vltavska kaskada. Ministerstvo lesniho a vodniho hospodarstvi, Prague. In Czech

THE DYJE RIVER BASIN (CZECHIA)

Description of natural conditions

Relief

The Dyje catchment is located in the south-eastern part of the Czech Republic. The catchment area of the river Dyje as far as the gauge station Ladná is 12.280 km^2 (Figure 3) and the long-term average discharge (Qa) is 41.7 m^3/s. The elevation above sea-level of water gauge's zero of the station Ladná is 157.38 m a.s.l. and so it represents the lowest point of the reference basin. The highest point of the Dyje basin is the hill Javořice (837 m a.s.l.) situated about 13 km west from the municipality Třešť.

The Dyje River is made up initially by two individual streams: The Moravian Dyje, originating in the Brtnická Highlands at an altitude of 635 m a.s.l., and the German Dyje, which originates near Schweiggers, in Lower Austria. Both Dyje rivers join together in Raabs in Lower Austria, and make up one, united Dyje river, which continues to flow from the west to the east through the Dyje-Svratka Valley and the Lower – Moravian Valley. Other important streams in the Dyje River Basin are the Svratka and Jihlava rivers, which drain the Czech-Moravian Highlands, together with the Brno Highlands, and the northern part of the Dyje-Svratka Valley, respectively.

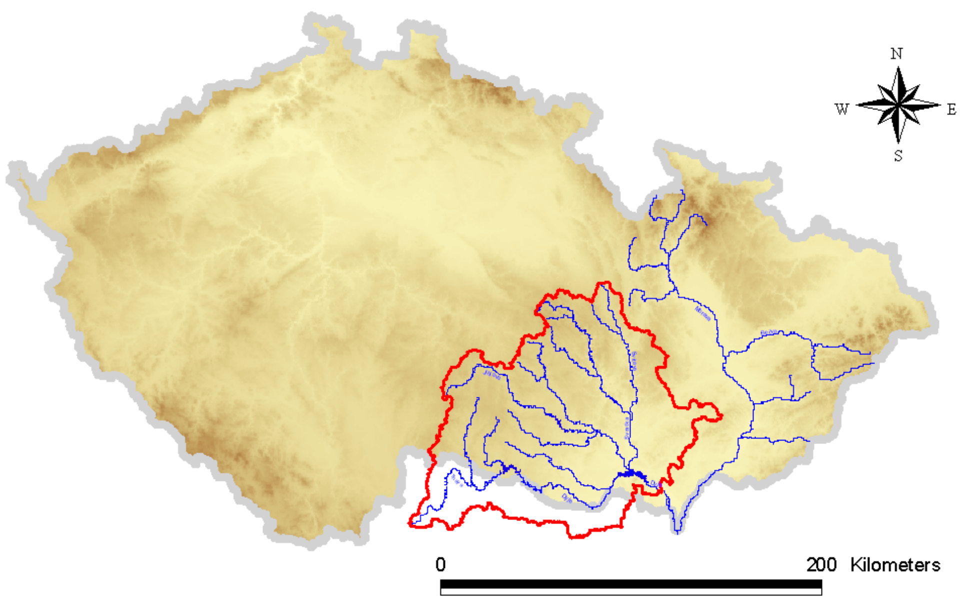

Figure 1. The Dyje catchment is located in the southern part of the Czech Republic.

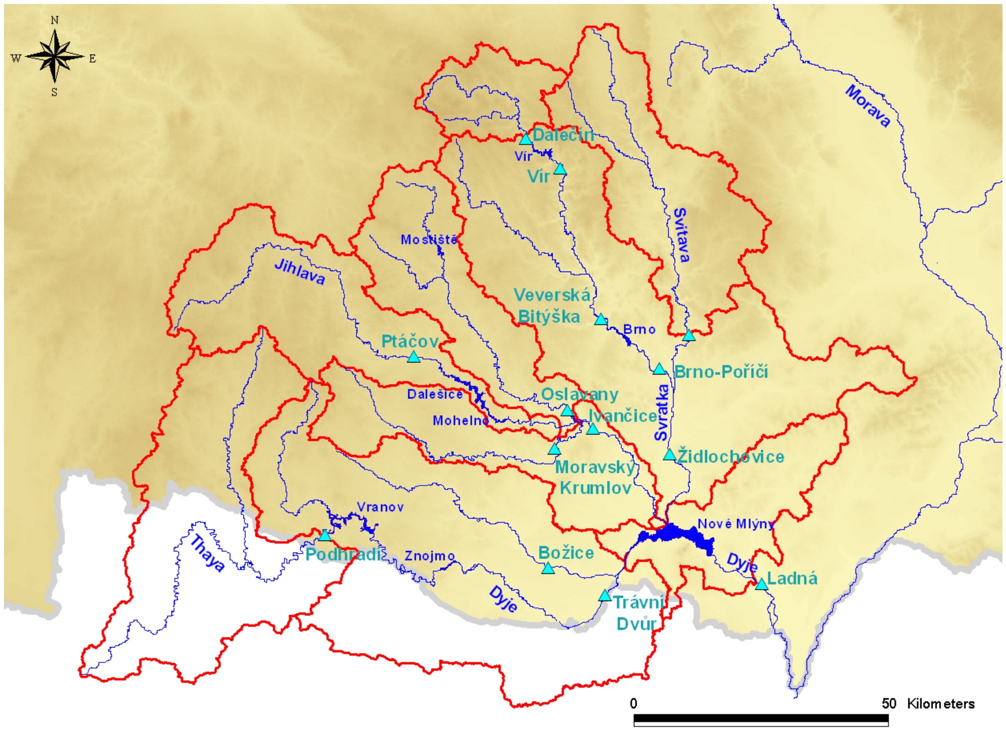

Figure 2. The figure depicts the important river profiles and reservoirs in the Dyje catchment.

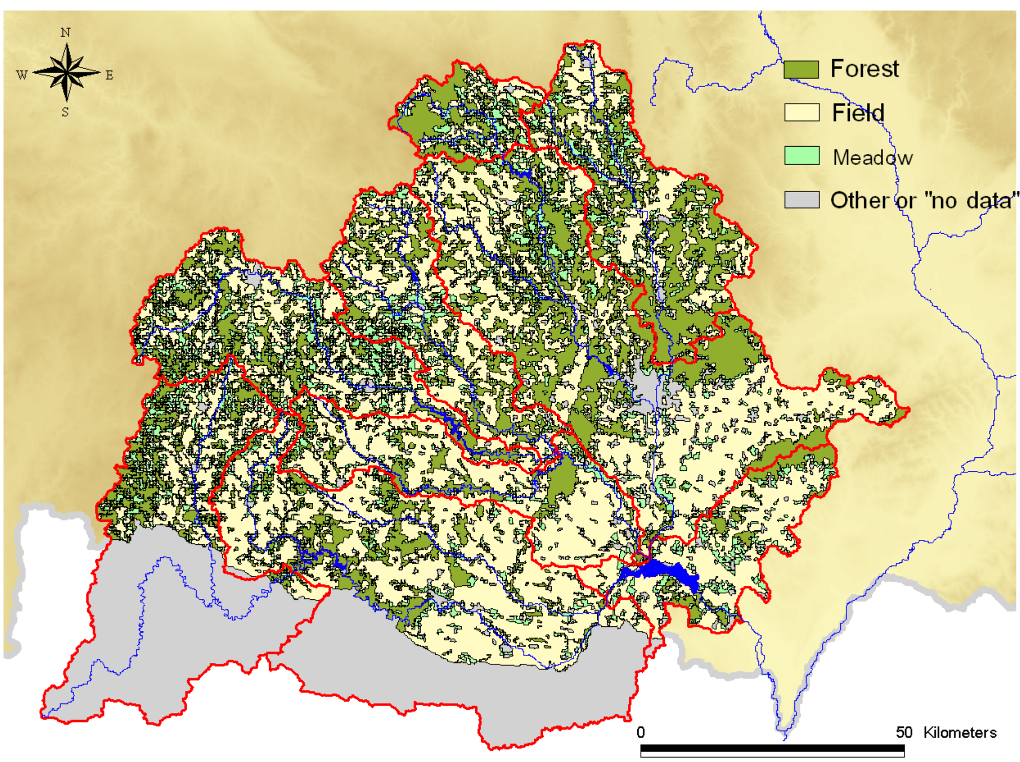

Figure 3. The landuse of the Dyje catchment.
(the data for the Austrian part of the Dyje catchment are not available.)

Landuse

The landuse of the Dyje catchment is depicted on *Figure 3*. Fields and forests are the prevailing form.

Hydrology

In the Czech Republic almost all the water is drained off to the other countries. So the water resousces are depended prevailingly on precipitation. The most floods are caused by snow melting in February and March (*Figures 9 and 13*). The map of the important river profiles and resevoirs of the Dyje catchment is given on *Figure 3* and 4. The hydrological situations are depicted by *Figures 4-13.*

Dyje catchment (profiles Podhradí and Vranov)

The time series on *Figures 5 to 8* show the average annual and monthly discharges in Vranov profile and annual and monthly peak discharges in Podhradí profile (the same catchment, Vranov profile is about 20 km downstream from Podhradí). From the figures it is obvious that the average annual and monthly discharges do not show any significantly changed behaviour. From the point of view of hydrological extremes – the annual and monthly peak discharges - it is quite well known that the period till 60ties was more balanced than the period 1970-2006, which shows the periods of low and very high discharges.

From the historical point of view we can say that extreme floods are not new phenomena in the Dyje catchment, as it is obvious from the *Figure 4* – the annual peak discharges in Vranov profile (some historical floods were evaluated for this river profile). Nevertheless, in the last five years three huge floods occurred in this catchment – after more than 50 years of, from the point of view of hydrological extremes, a relatively balanced period.

Jihlava catchment (profile Ptáčov)

A little bit different situation is in Ptáčov profile. The *Figures 10* and *11* depict the time series of average annual and monthly discharges - the last 30 years were drier than the period 1930-1960. In 1990-2000 there was a more significant dry period (the same it is obvious in Prodhradi and Vranov profiles).

From the point of view of hydrological extremes, since 1960 the peak discharges seems to be lower, the exceptions are two significant floods which occurred in 1985 and 2006 (see *Figure 12*).

The return time period of the peak discharges for the selected profiles is given in *Table 1.*

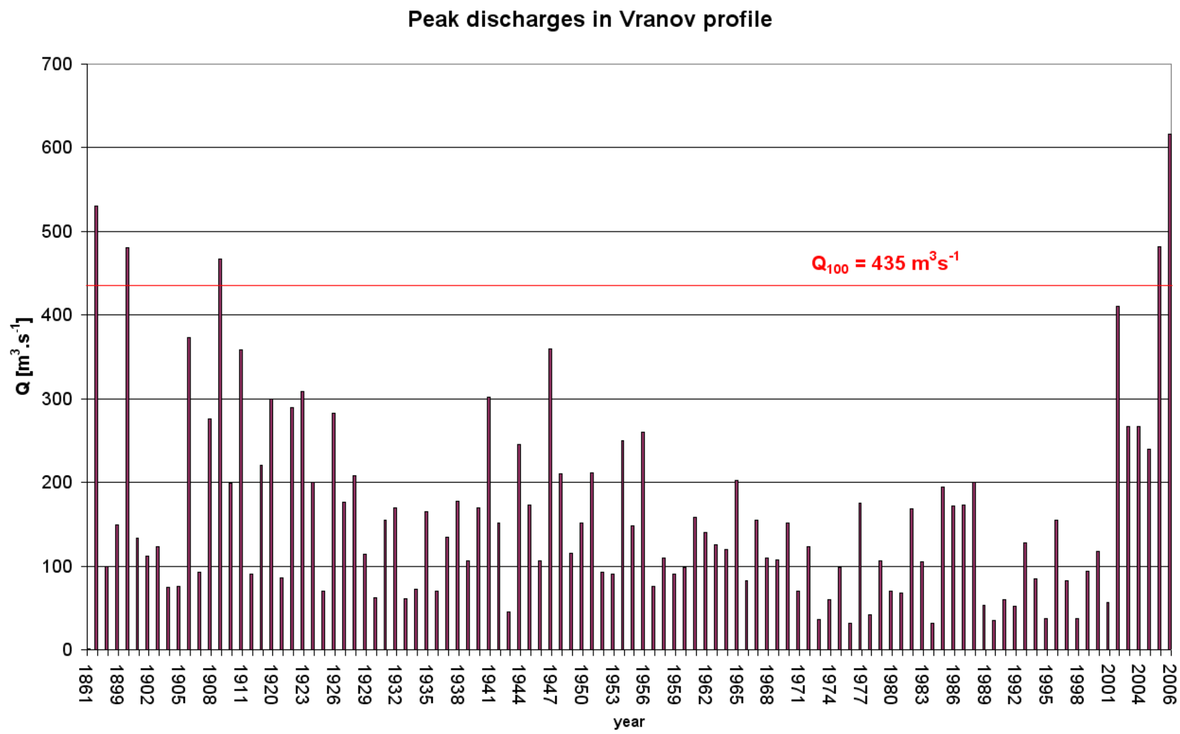

Figure 4. The graph of annual maxima discharges in Vranov profile (the dam of Vranov reservoir, 20 km downstream from the Podhradí station). In the last 5 years three huge floods occurred, while the record culmination was reached in July 2006.

Table 1. The return time period of peak discharges [$m^3.s^{-1}$] for chosen river profiles in the Dyje catchment.

Profile	***1***	***5***	***10***	***50***	***100***
Podhradí	*97.8*	*157*	*196*	*320*	*390*
Trávní Dvůr	*72*	*136*	*167*	*244*	*280*
Ptáčov	*45*	*103*	*132*	*217*	*260*
Ivančice	*104*	*192*	*234*	*341*	*390*
Dalečín	*36.3*	*69.4*	*85.3*	*126*	*145*
Veverská Bítýška	*64*	*128*	*160*	*241*	*280*
Židlochovice	*117*	*208*	*250*	*353*	*400*
Ladná	*283*	*516*	*624*	*890*	*1012*

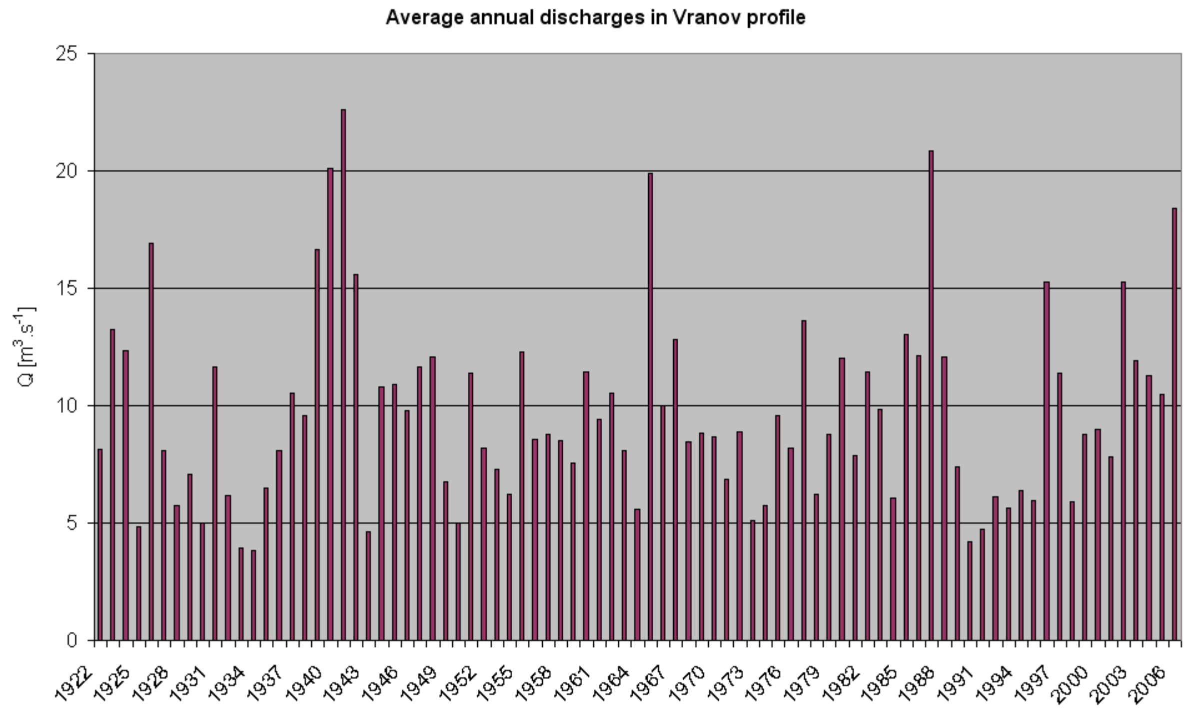

Figure 5. The average year discharges in Vranov profile (catchment area 2 220 km²).

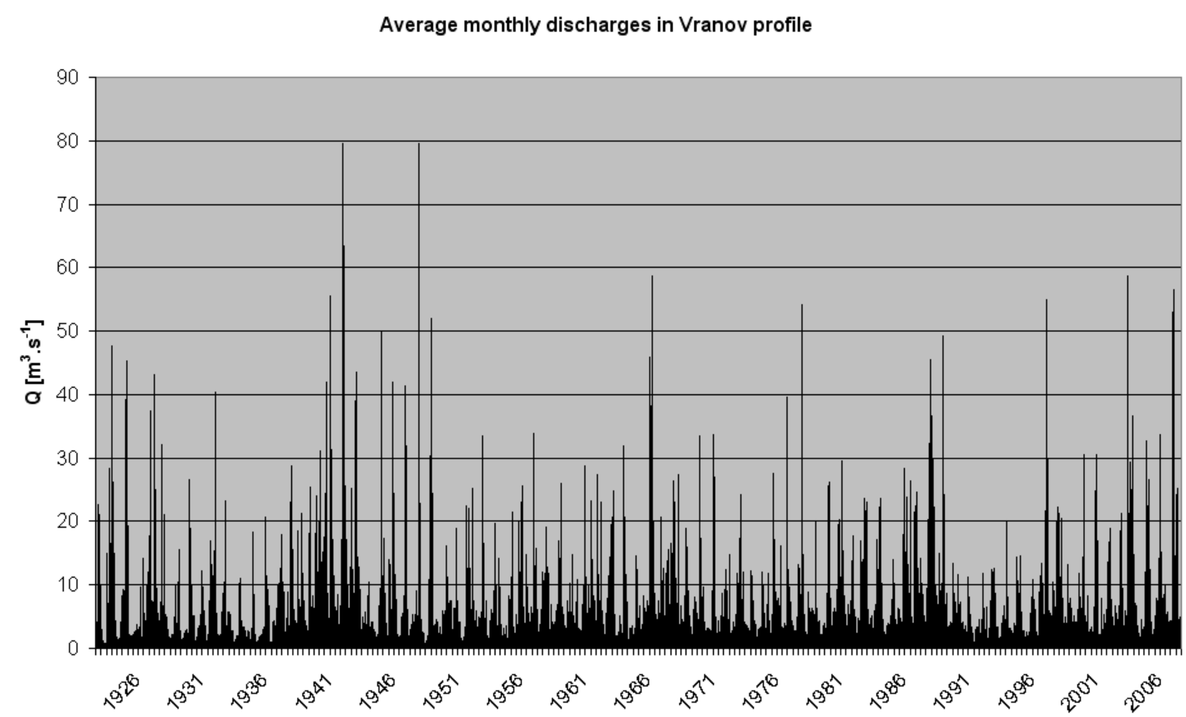

Figure 6. The average monthly discharges in Vranov profile (catchment area 2220 km²).

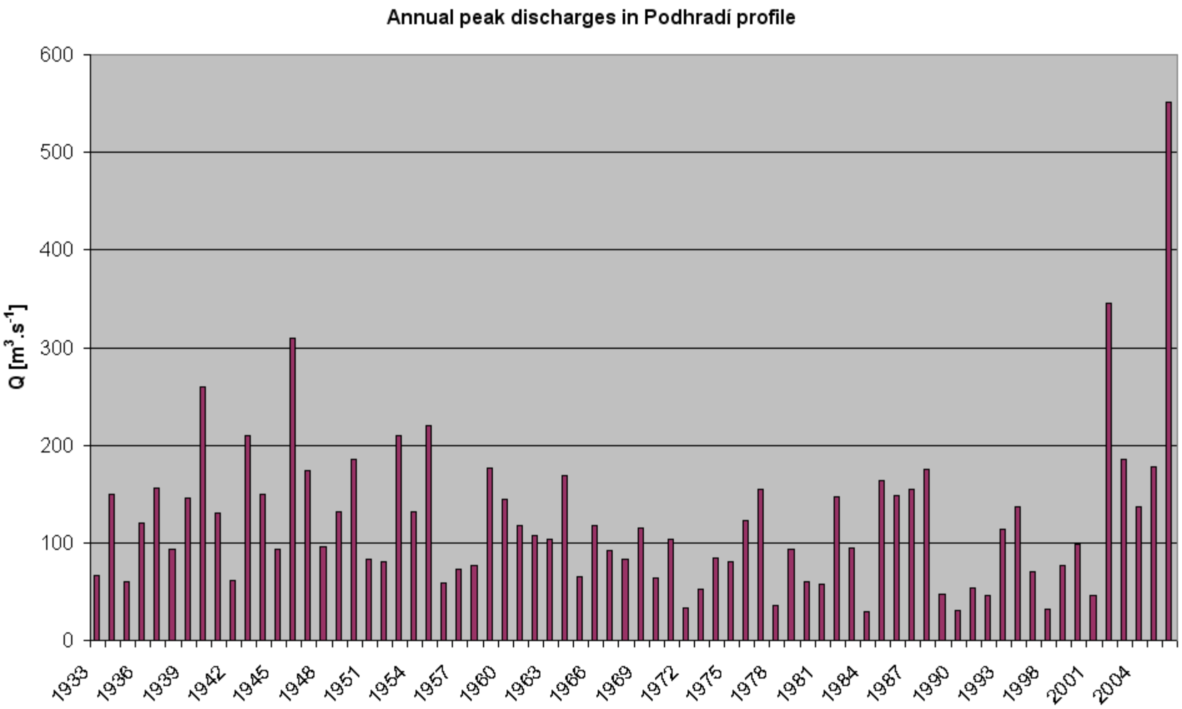

Figure 7. The annual peak discharges in Podhradí profile (catchment area 1760 km^2).

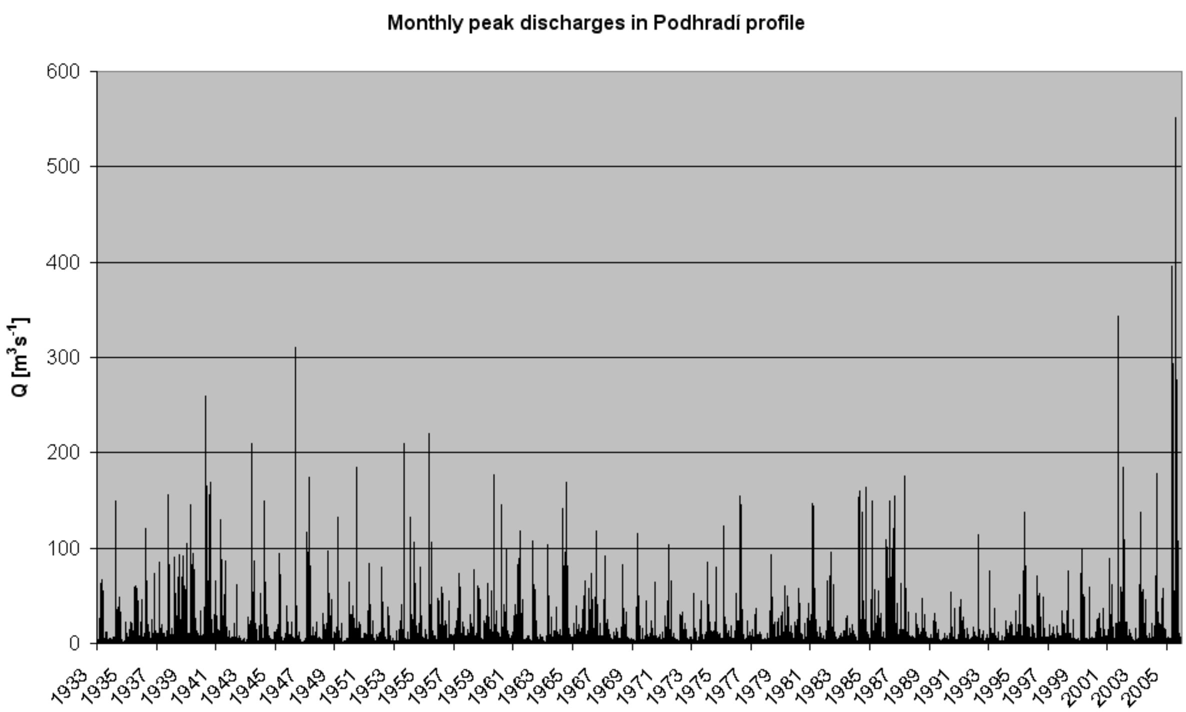

Figure 8. The monthly peak discharges in Podhradí profile (catchment area 1760 km^2).

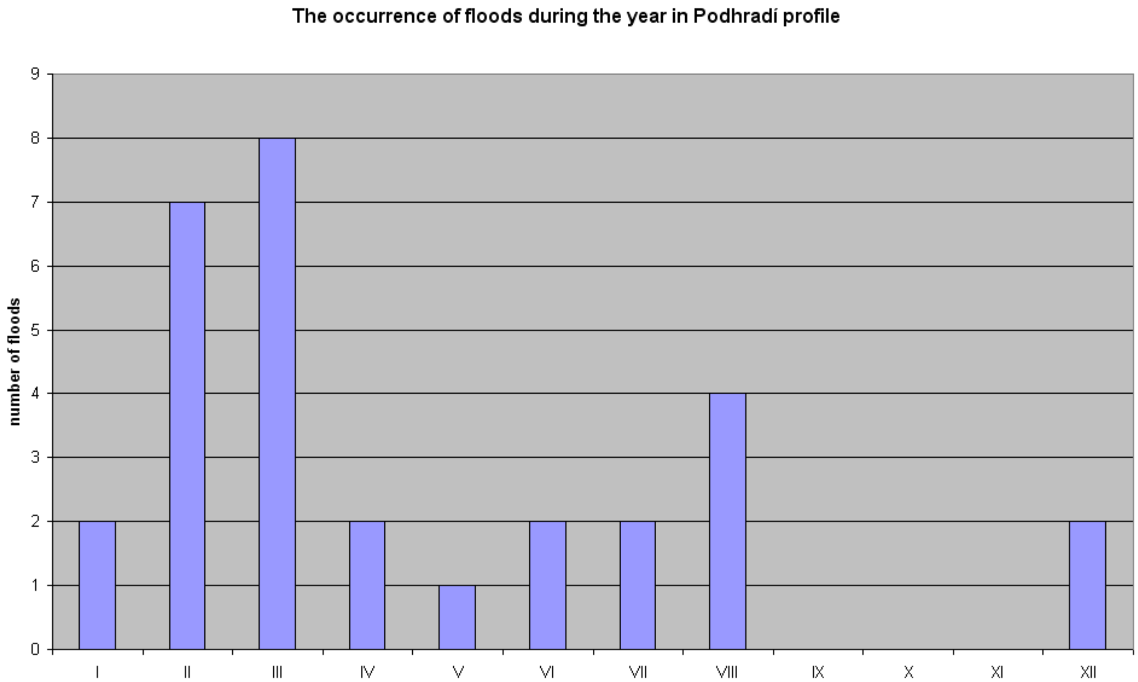

Figure 9.The occurrence of floods with peak discharge greater than 130 $m^3.s^{-1}$ in Podhradi profile. It is obvious that winter floods caused by snowmelting are the most common in this catchment, the summer floods occurred most frequently in August. The measurement in the Podhradi gaugestation started in 1934.

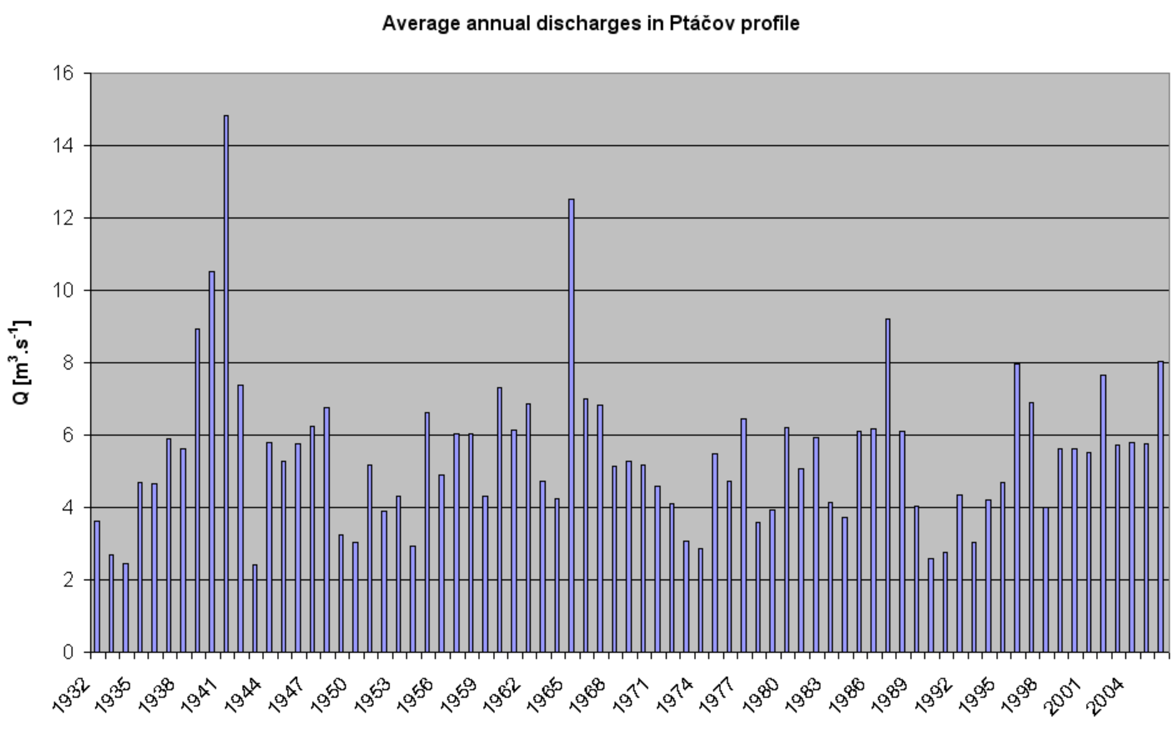

Figure 10. The average annual discharges in Ptáčov profile (catchment area 960 km^2).

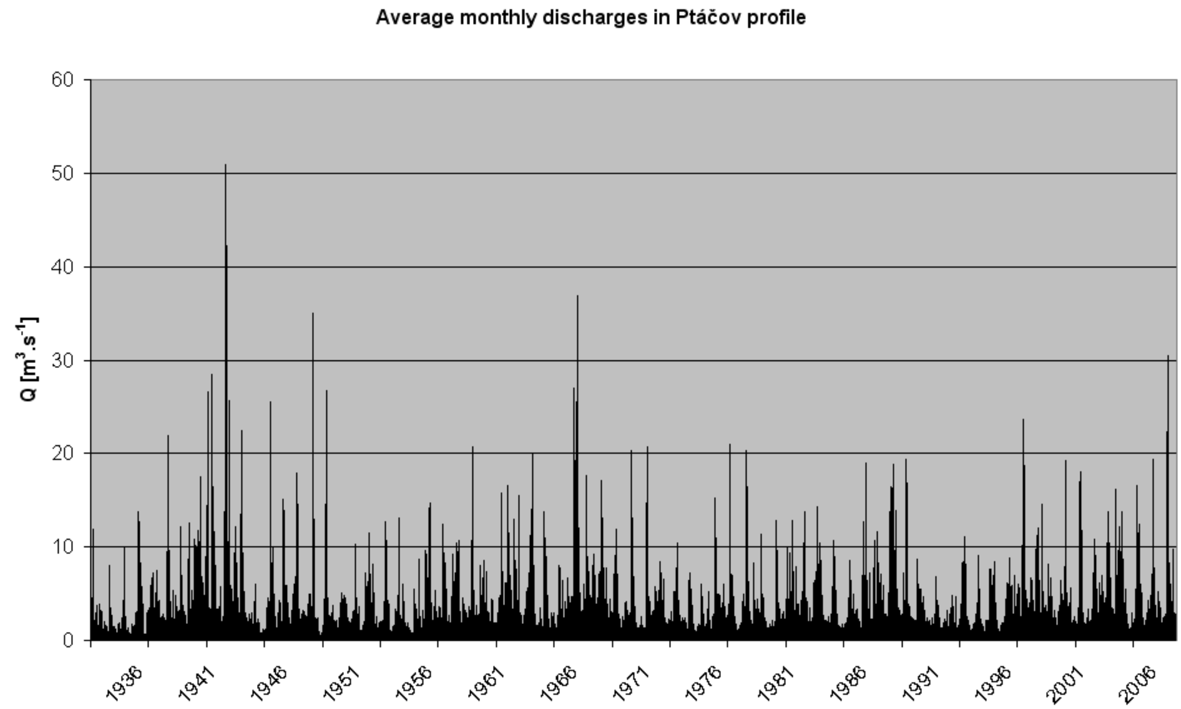

Figure 11. The average monthly discharges in Ptáčov profile (catchment area 960 km^2).

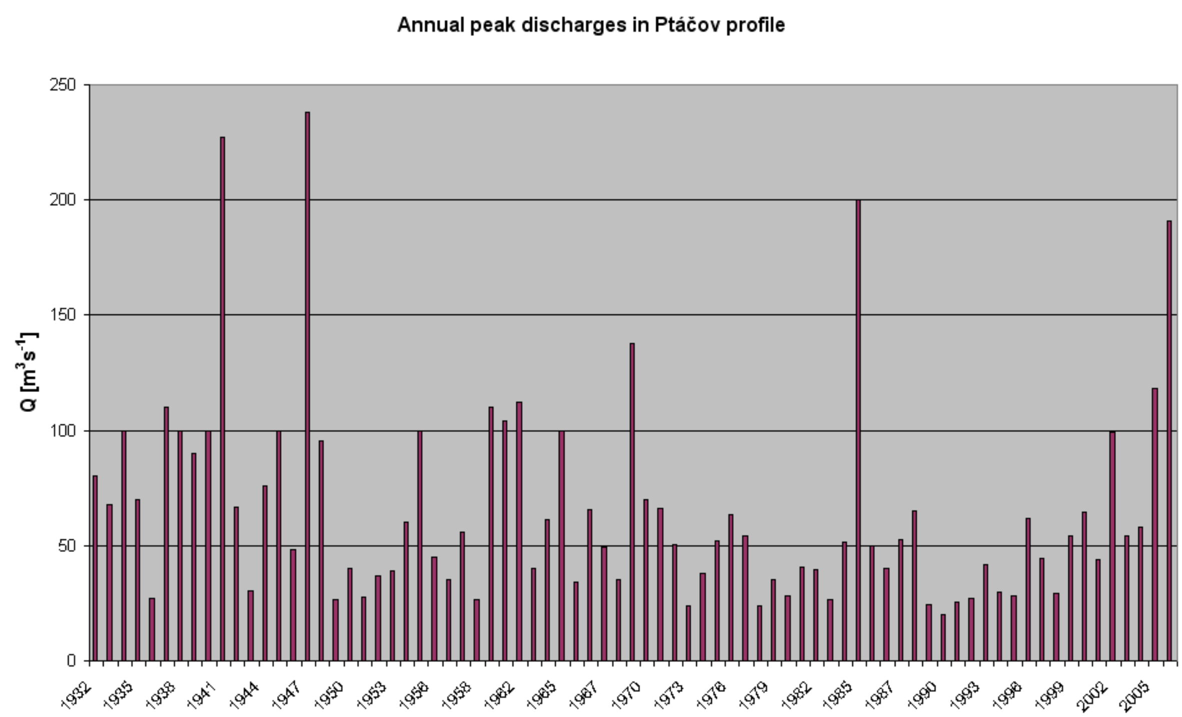

Figure 12. The annual peak discharges in Ptáčov profile (catchment area 960 km^2).

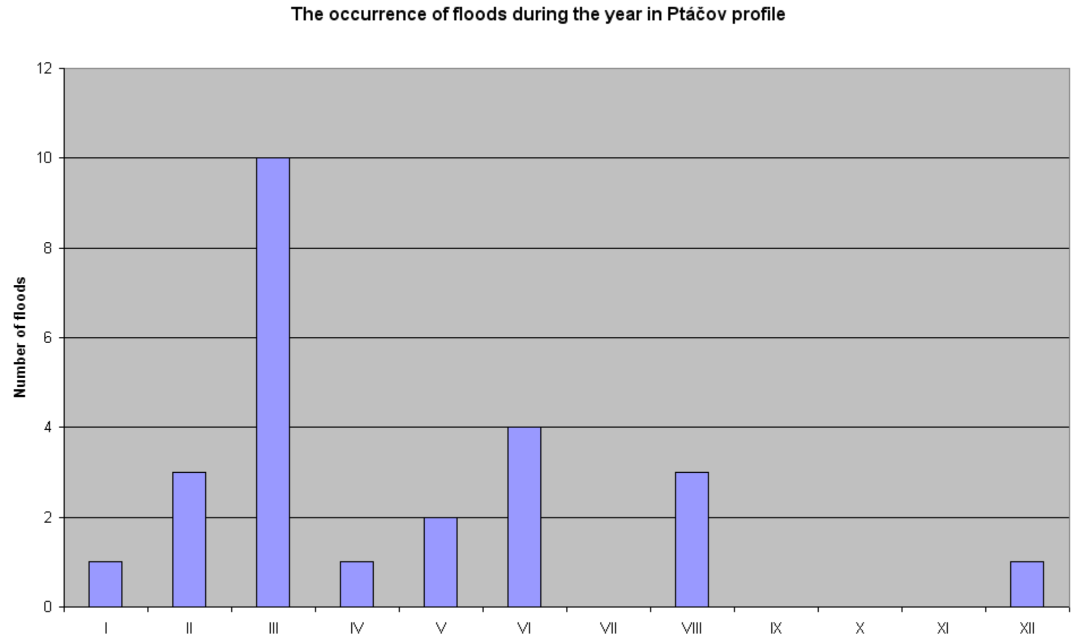

Figure 13. The occurrence of floods with peak discharge greater than 70 $m^3.s^{-1}$ in Ptáčov profile. Again, the winter floods caused by snowmelting are the most common. The measurement in the Ptáčov gaugestation started in 1932.

Water management

The water management in the Dyje catchment is influenced by 20 reservoirs, which were built in the period from 1896 to1990. Their total volume is 527 mil m^3. The largest is the system of three reservoirs called Nové Mlýny followed by Vranov and Dalešice. The most important reservoirs are mentioned in Table 2.

Table 2. The most important water resrvoirs in the Dyje catchment.

Name	***River***	***Volume [mil.m^3]***
Vranov	*Dyje*	*133*
Dalešice	*Jihlava*	*127*
Vír	*Svratka*	*56.2*
Brno	*Svratka*	*21*
Nové Mlýny I-III	*Dyje*	*134*

References

J. Matějíček, Hospodaření s vodou v povodí, Povodí Moravy, a.s., Brno 1996

ROMANIAN BLACK SEA COAST (ROMANIA)

Description of natural conditions

The Black Sea is a land-locked basin with an extended shelf continental platform situated in the northwestern part, while in the central southern one there is an abyssal zone (see *Figure 1*). The Black Sea gathers its water from a hydrological basin of 2405000 km^2 of which 82% lies on the European continent and 18% on the Asian. The main contributors of its rich watershed are Danube, Dnestr, Bug and Dnepr. The Black Sea link with Mediterranean Sea is the narrow Strait of Bosphorous (1 km), which imposes a strong control on the inflow of salty Eastern Mediterranean water and outflow of fresher Black Sea water. The restricted water exchange at Bosphorous and river runoff lead to a remarkable stability in stratification. A thin upper layer with low-salinity is superimposed on the Cold Intermediate Layer (CIL), while the greatest part of the water column is occupied by a deep-water mass. One of the effects of reduced mixing between surface layers and deeper waters is the prevailing anoxic conditions, which make the Black Sea the world's largest anoxic basin.

The Romanian coastline at the Black Sea has 240 km and its 3 sectors are geologically defined by faults. Morphologically the Romanian coast line has 2 sectors divided by the Cape Midia (see the white circle on *Figure 1*). The northern sector is located from the Chilia Arm to the Midia Cape and consists of sandy belts, sand banks, beaches. The southern one is situated from the Midia Cape to Vama Veche (Romanian-Bulgarian border) with high sea walls (40-60 m) interrupted by the lagoons and firths. Romanian shoreline is dynamically shaped by retreats of lands, seesawing and even land advances. Our air-sea interaction analysis has to take into account the distinct characteristics of the northern and southern sectors of the coastline.

The Black Sea ecosystem has experienced changes since the 1961 driven by several perturbations in the drainage basin of the rivers and the Black Sea itself. The man-made changes include land use, changes of hydrological regimes of out-flowing rivers, proliferation of exotic species, and selective or excessive fishing. The low salinity waters and associated sediments, nutrients and pollutants that originate from the Danube runoff have a significant impact in the hydrodynamic and biogeochemical processes of the western Black Sea. Our climatological analysis are aimed to identify changing points in the local climate variability and to make attribution either to natural phenomena or to local anthropogenic influences (such as the influences of Black Sea – Danube channel on local climate and air-sea interactions from 1984 onward).

We selected 19 climatological stations (yellow and white circles in *Figure 1*) to analyze variability and change of local climate. Daily data of mean, maximum, minimum temperature and daily precipitation are used to build extreme indices for the interval 1961-2005.

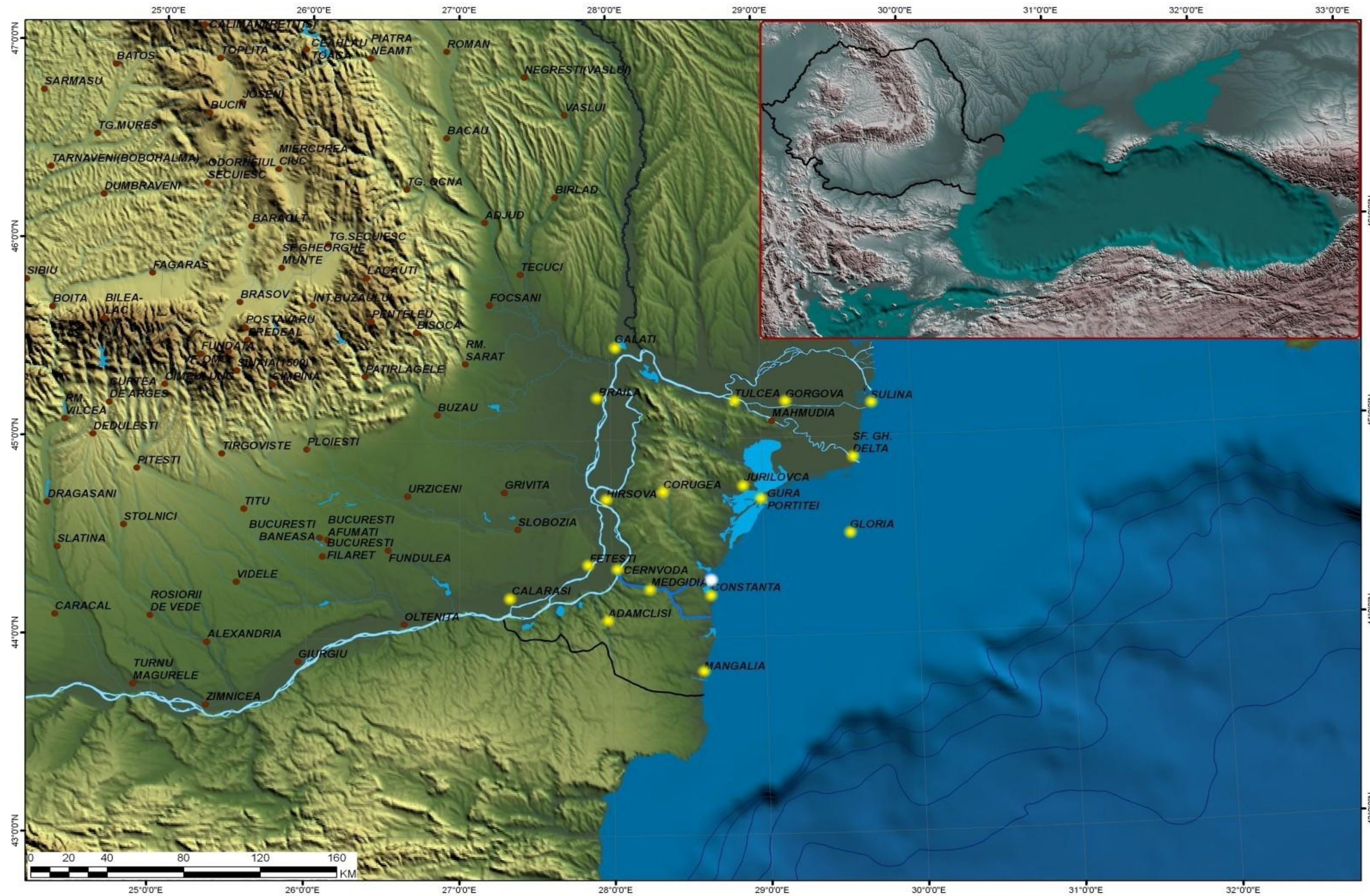

Figure 1. Location of Romania at the Black Sea coast and western coastline of Black Sea with the Romanian stations (yellow circles) selected for the climate analysis related to local air-sea-land interaction. White circle separates the northern and southern sectors of the shoreline.

Daily data of sea surface temperature (SST), salinity and wind from 7 stations situated at the Romanian shoreline (see *Figure 2*) and one located offshore (Gloria, see *Figure 1*) are selected to identify the coupled air-sea interaction patterns in the coastal zone (e.g. coastal upwelling variability). These data are available for the interval 1990 – 2001. Monthly means of sea level data from 2 stations (Sulina and Constanta) are available for the interval 1961-2005 (see *Figure 3*). In addition, we use SSTs from ERA-40 to identify SST patterns which could influence local climate fluctuartions (see *figure 4*).

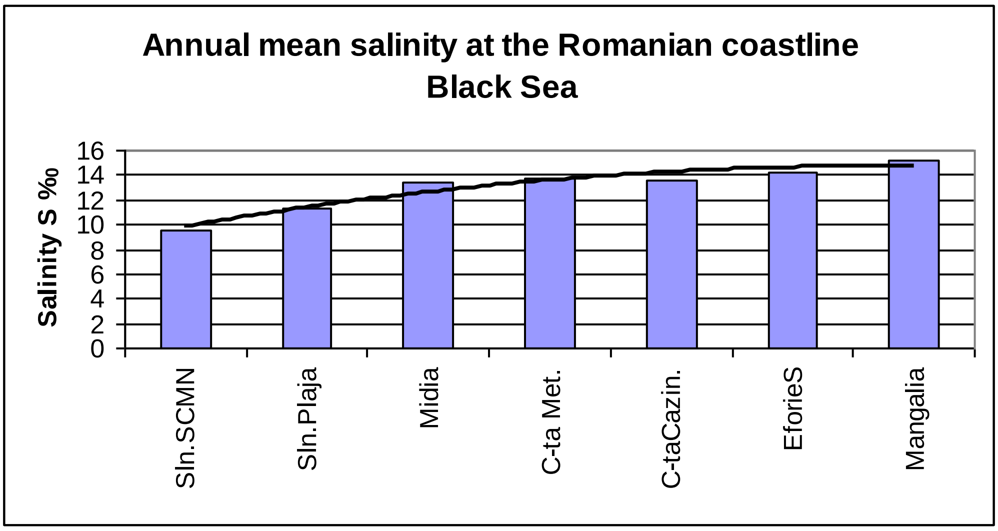

Figure 2. Annual mean salinity at 7 stations situated on the Romanian Black Sea coastline.

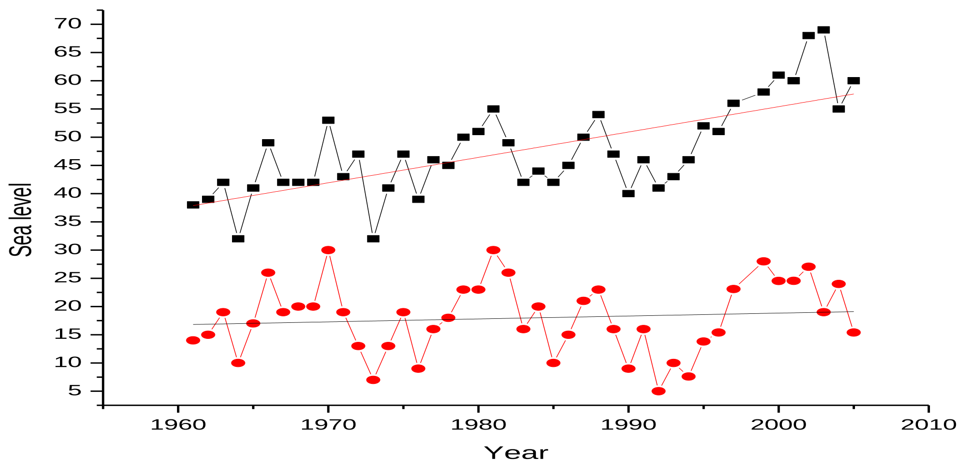

Figure 3. Sea level at Sulina (black squares) and Constanta (red circles) stations and their associated linear fit for the interval 1961-2005.

In the next stage, all the data presented above will be used, together with modeled data, to identify and attribute local changes in temperature, precipitation and associated extremes. Also, the variability and change of air-sea coupling parameters (e.g upwelling indices) will be analyzed.

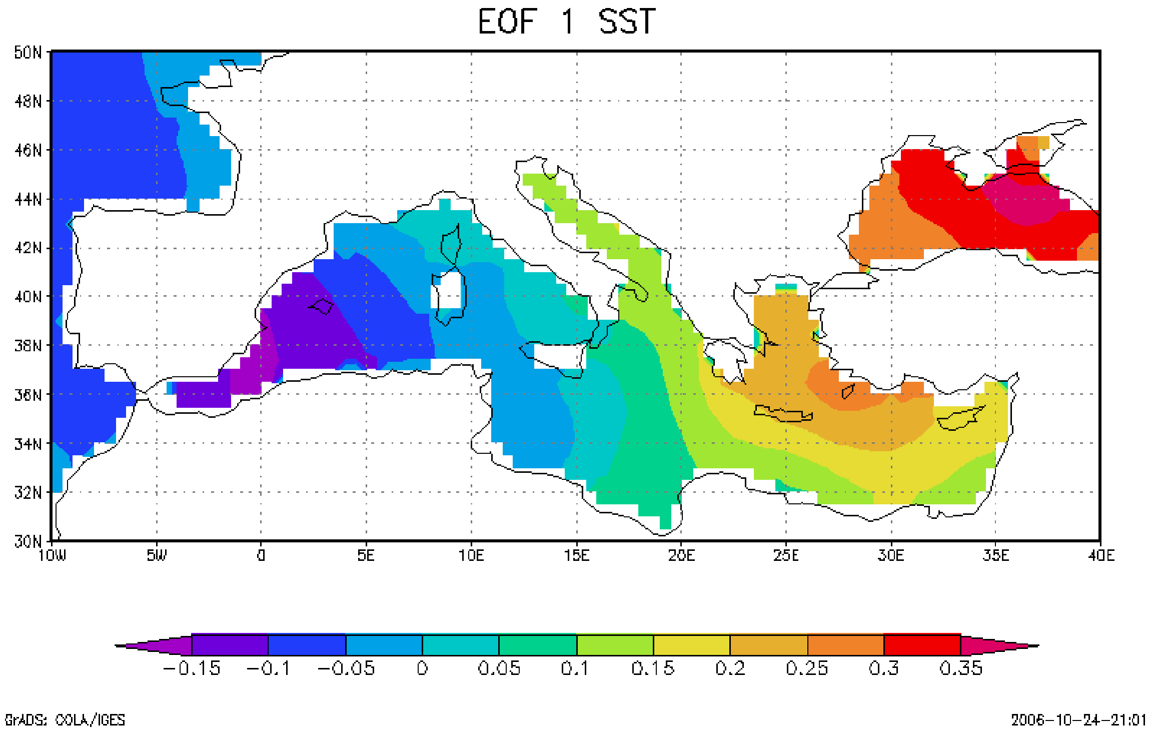

Figure 4. The spatial coefficients of 1st EOF of December-February SST (in ºC). SST data are taken from ERA 40 (1961-2000).