3. INVESTIGATIONS OF THE WATER BALANCE (1993-1995)

3.1. HYDROLOGICAL INVESTIGATIONS IN THE AREA OF THE TRNOVSKO-BANJŠKA PLANOTA PLATEAU BETWEEN 1993 AND 1995 (N. TRIŠIČ)

The equipment at the gauging profiles that existed before 1993 in the area under investigation was not satisfactory for the forthcoming investigations. The gauging profiles were only equipped, except for the profiles on the Lijak and the Idrijca, with gauging staffs where water levels were usually read only once a day. For a more detailed registration of water waves and the establishing of water regime, we installed in summer 1993, even before the first tracing experiments were performed, water level recorders (LP) at the most important gauging profiles (Tab. 3.1). The positions of individual hydrological stations are presented in chapter 2.2, Figure 2.9.

Tab. 3.1: Gauging profiles, installed in the framework of the ATH investigations.

Gauging profile	water level recorder operating since
8630 The Hubelj-Ajdovščina	April 01, 1993
8560 The Vipava-Vipava	June 17, 1993
8350 The Idrijca-Podroteja	June 24, 1992
8345 The Idrijca-Fežnar	May 4, 1994

Since a part of investigations was focused on the catchment area of the Vipava springs, an additional observation and gauging network was established in this area, which operated from July 1993 until the end of 1995; only the operation at the Bela-Sanabor profile began later due to the troubled water level recorder (Tab. 3.2).

Tab. 3.2: Additional gauging profile with LP - water level recorder; VP - staff gauge.

Gauging profile	Station operating since
8546 The Belščica-LP Bukovje	July 27, 1993
8547 The Lokva-VP Predjama	August 25, 1993
8549 The Vipava-VP Pod Farovžem	September 14, 1993
8602 The Bela-LP Sanabor	January 1, 1994
8603 The Bela-VP Vipava	July 27, 1993

With the existing network of hydrological stations it was not possible to register discharges of the Divje Jezero and the Podroteja springs, which both join the Idrijca above the Idrijca-LP Podroteja gauging profile. Therefore, we also installed an additional station with water level recorder in 1994, on the profile 8345 the Idrijca-Fežnar. Since the distance between the profiles the Idrijca-Podroteja and the Idrijca-Fežnar is rather short (4.3 km), the difference in discharges between the both profiles can be taken as the discharge quantity from the both karstic springs. Yet, due to the torrential hydrological regime of the upper Idrijca and the Bela, and the short string of observations, we did not succeed to register so high discharges to be high enough to establish the upper part of discharge curve.

For the four representative hydrological stations (Compare Chapter 2.2.) which register the most important outflows from the karstic massif, the data were processed for the investigation period from August 1, 1993 to December 31, 1995, and comparatively, also for the period of two hydrological years, from November 1, 1993 to October 31, 1995.

The Hubelj - LP Ajdovščina

Presented are the data on daily heights of precipitation at the precipitation station Otlica (835 m above sea level), and the mean hourly discharges of the Hubelj at the gauging profile (Fig. 3.1). The maximum daily precipitation (143 mm) fell on December 27, 1995, and the second maximum of daily precipitation (134 mm) occurred on November 17, 1995. The majority of precipitation at the station Otlica fall, on the average, as to the 1961-90 period, in the autumn months (704 mm), while the shares of precipitation in the other seasons of a year are practically equal (562 mm; 587 mm; 559 mm).

The discharges of the Hubelj in both the discussed periods do not stand out from the frame of statistical values for the 1961-90 period. Both value of the mean discharges is only by approx. 10 % above the mean discharge of the

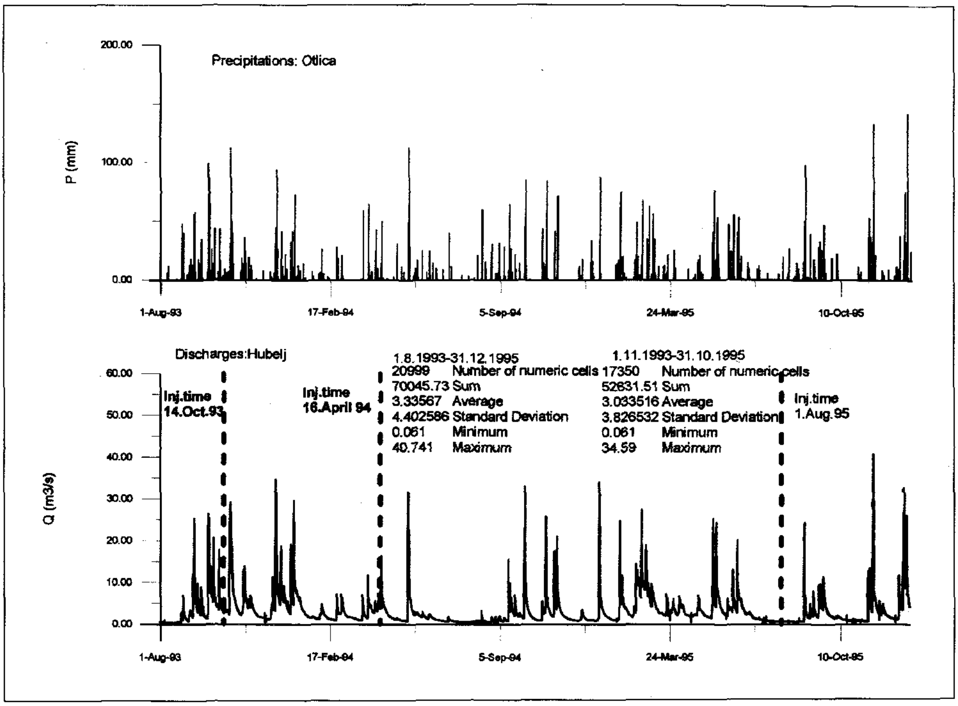

Fig. 3.1: Mean hourly discharges of the Hubelj spring at the gauging profile Hubelj-LP Ajdovščina and daily heights of the precipitations at the precipitation station Otlica.

period. The maximum discharge in the shorter period of two hydrological years also coincides with the mean maximum discharge of the 1961-90 period (34.59 m^3/sec; 33.4 m^3/sec). When dealing with minimum discharges it should be emphasised that these data refer to discharges at the gauging station, and not to discharges at the Hubelj spring. There, a certain quantity of its water is tapped for the water supply of Ajdovščina and its surroundings, and also for the operation of the Hubelj hydropower plant. Evident in the hydrograph at lower discharges are the abnormal extremes in time distribution of discharges which are due to the hydropower plant operation. This influence on the discharges of the Hubelj had not been registered in the profile of the gauging station before the installation of a water level recorder. The lowest discharge of 0.061 m^3/sec was registered on August 5, 1994, when the regular maintenance works were performed on the sluice gate at the dam below the Hubelj spring. The exact data on the water quantity taken for water supply do not exist; but by approximate assessment, between 50 and 100 l/sec are taken on average, during the summer droughts, even up to 150 l/sec.

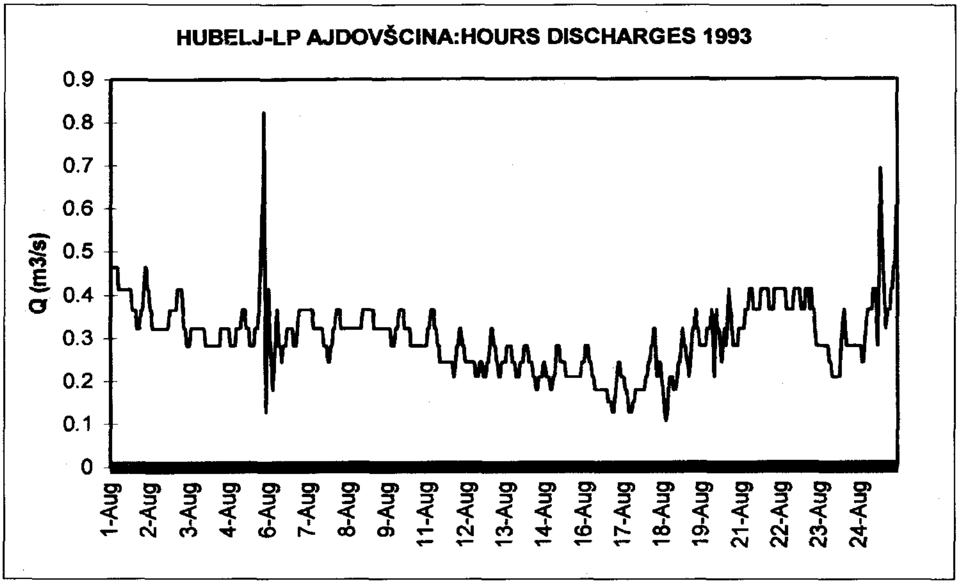

Fig. 3.2: Hydrograph of the Hubelj discharges during low water conditions in August 1993 exhibiting an explicit daily variation caused by water abstractions for both the hydropower plant and for water supply.

On the hydrograph of the Hubelj discharges, an explicit daily oscillation of discharges is evident at low water situation in August 1993, which is due to the tapping for water supply, while the oscillation on August 5 and 6 is due to the Hubelj hydropower plant operation (Fig. 3.2). Such oscillations are frequent because they occur at each disengagement or omission of turbine operation. On the basis of the registered minimum discharges and the known influences, the minimum discharge of the Hubelj spring can be assessed to amount to 0.250 m^3/sec.

The Vipava - LP Vipava

For the presentation of discharges at the Vipava springs and precipitation in the catchment area, the data were processed, from the station with a water level recorder at Vipava, and the precipitation station Nanos-Ravnik at the altitude of 915 m (Fig. 3.3). The height of precipitation here is lower (the average of 1834 mm) than at the station Otlica. The largest daily quantity of precipitation fell on October 29, 1994 (99.8 mm), and the second maximum of the discussed period occurred on August 29, 1995, with 91.6 mm of daily precipitation. In this area, too, the majority of precipitation fall in the autumn months, 524 mm on average, and in the remaining seasons, the heights are essentially lower (399 mm; 447 mm; 468 mm).

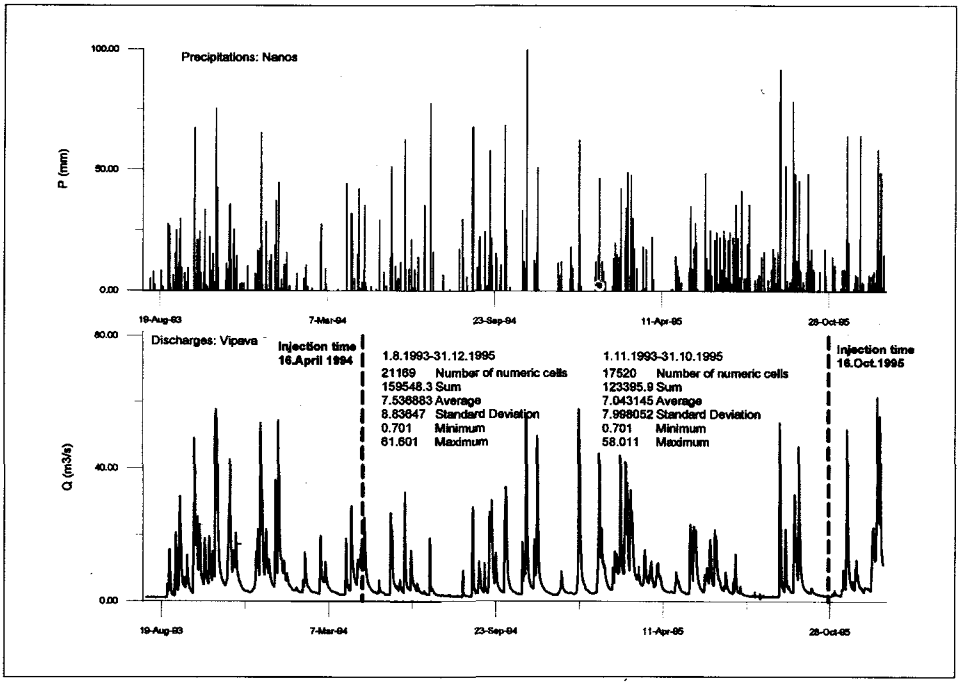

Fig. 3.3: Mean hourly discharges of the Vipava spring at the gauging profile Vipava-LP Vipava and daily heights of the precipitations at the precipitation station Nanos-Ravnik.

The mean discharge of the Vipava in the discussed 1993-95 period is by gross 20-30 % higher than the mean discharge of the 1961-90 period (6.78). The maximum discharge in the two-year period (61.6 m^3/sec) did not reach the highest registered discharge in the entire observation series. Yet, the extremes of high-water waves exceeded nine times the discharge of 50 m^3/sec. However, in the 1993-95 period, the lowest discharge was registered in the entire observation period (0.701 m^3/sec), but not even in this case it was the natural lowest discharge of the Vipava springs but an artificial result due to the opening and closing of sluice gates that dam up both groups of the Vipava springs. These effects were also registered several times by the data logger at the spring Pod Farovžem (VIP-7), as well as by the water level recorder at the gauging station Vipava. The natural lowest discharge at the profile of the gauging station amounted to 1.032 m^3/sec in July 1993. Also one of the Vipava springs, the spring Pod Lipo (VIP-2) serves for water supply of the surroundings, yet the tapped quantities here are smaller than those at the Hubelj spring, and due to higher discharges of the Vipava, the share of the pumped water is negligible. For a clear determination of the Vipava discharges an additional network of hydrological stations in the catchment area of the Vipava was used. On the streams Belščica, Lokva and Bela, their quantitative shares in the discharges of the Vipava were determined for the 1994-1995 period.

Tab. 3.3: Characteristic discharges (m^3/sec) measured in the gauging profiles in the catchment area of the Vipava for 1994-1995.

	Q_{max}	Q_{mean}	Q_{min}
The Belščica-Bukovje	2.77	0.132	0.021
The Lokva-Predjama	10.8	0.215	0.019
The Bela-Sanabor	4.51	0.313	0.003
The Vipava-Vipava	61.6	7.04	1.032

The share of mean discharges at the gauged profiles in the catchment area does not reach 10 % of the mean discharges of the Vipava, and the shares of low and high discharges are even lower (Tab. 3.4). There are also some ponor streams in the catchment area of the Vipava springs, yet the share of their discharges is small and cannot change the ratio.

Tab. 3.4: Comparison of the discharges of the gauged profiles in the catchment area (Belščica, Lokva, Bela) to discharges of the Vipava (m^3/sec).

	Q_{max}	Q_{mean}	Q_{min}
The catchment area	18.08	0.66	0.043
The Vipava	61.60	7.04	1.032

The springs Pod Farovžem - Vipava (VIP-7)

The water levels in the area of the western group of the Vipava springs, called the Izviri pod Farovžem, were registered by a data logger. Due to the operation interruption of the data logger, the string of data is not continuous; therefore, the characteristic values for the two-year period under observation cannot be presented. For the time of the second tracing experiment, i.e. October 1995, a hydrograph of discharges was made on the basis of which were determined the discharges of the eastern group of the Vipava springs (from VIP 1 to VIP 5) using the difference between the discharges at the LP Vipava station and the discharges of the springs Pod Farovžem. At low water levels, the ratio of discharges between both groups of the springs is almost even (Pod Farovžem : Pod Skalco = 1:1.2), but at high water levels, the discharges of the eastern group of the springs are even more than by 5-times higher than those of the springs Pod Farovžem. The maximised quantity of the springs Pod Farovžem (about 10 m^3/sec) is compensated by the springs between Vrhpolje and Vipava which are activated at higher water levels and contribute their discharges to the Bela. Therefore, for the study of discharge conditions in the catchment area of the Vipava springs, and in the Nanos massif, it would be necessary that a water level recorder register the Bela discharges at Vipava (town), since a part of the Bela waters sink below the village Sanabor and are linked with the Vipava springs, while at high waters, also the springs below the settlement Vrhpolje are active, and contribute their waters to the lower section of the Bela (Tab. 3.5).

Tab. 3.5: Comparison of the discharges of the Vipava and the Bela in September 27, 1993.

Bela-Sanabor gauging at 12:00	**Bela-Vipava** gauging at 11:00	**Pod Farovžem** gauging at 09:45	**Pod Skalco** difference (48.7-9.74)	**Vipava - LP Vipava** reading at 10:00
1.81 m^3/sec	3.89 m^3/sec	9.74 m^3/sec	38.96 m^3/sec	48.7 m^3/sec

The Lijak - LP Šmihel

In the central part of the Trnovski Gozd, in the area of Lokve (965 m above sea level), 2381 mm of precipitation fall on average. They are most abundant in the autumn months (703 mm), and evenly distributed in the remaining seasons (from 541 to 586 mm) (Fig. 3.4). The distribution and the quantity of precipitation at the station Lokve is entirely comparable to the area of Otlica (Fig. 3.1).

The station with a water level recorder which registers the discharges of the Lijak spring is located approx. 500 m downstream of the spring. Although the surface part of the catchment area between the spring and the hydrological station contributes a part of discharges to the gauging profile, it is negligible. The discharges of approx. 60 l/sec are a share of this surface part of the catchment area. The spring Lijak is only active at waves the course of which is clearly visible on the hydrograph (Fig. 3.4). The maximum discharge in the discussed period was 17.2 m^3/sec. It occurred after the heavy precipitation of November 17, 1995, when as much as 216 mm of rain was registered at the precipitation station Lokve. The spring Lijak was not under the continuous observation between 1961 and 1990, so that the exact comparison of the characteristic data, above all of the data on mean discharges, is not possible. In the years of observations, 1964-73 and 1989-90, the calculated mean

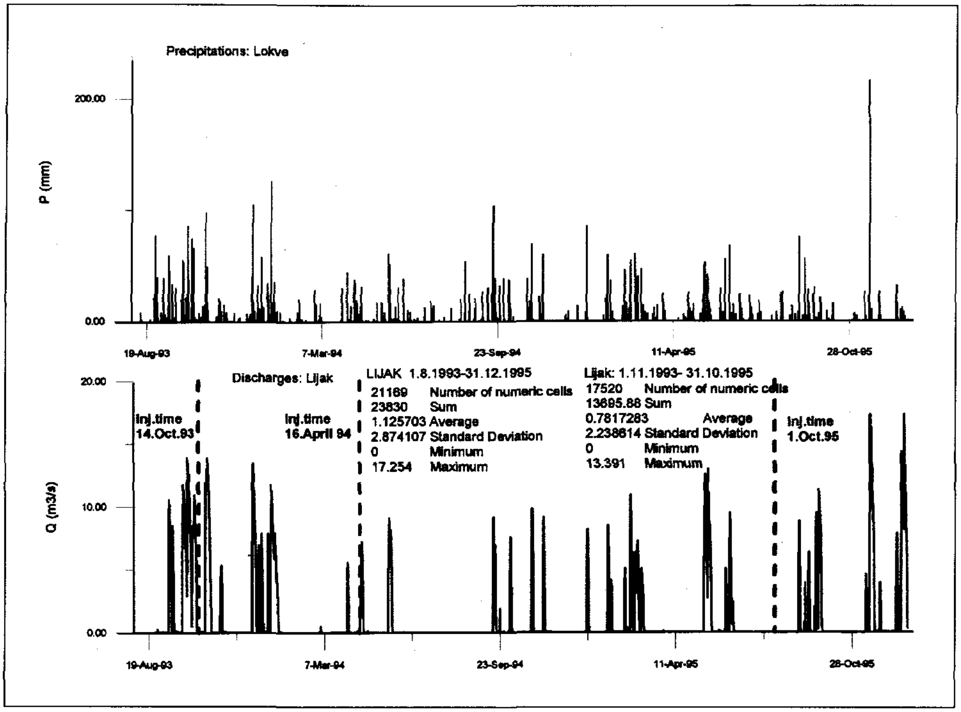

Fig. 3.4: Discharges of the periodical Lijak spring at the gauging profile Lijak-LP Šmihel and daily heights of the precipitations at the precipitation station Lokve.

discharge of 0.6 m³/sec is lower than the mean discharge in the time of investigations, 1993-95 (1.12 m³/sec and 1.00 m³/sec).

The Idrijca - LP Podroteja

Due to the longer interruption of observations at the precipitation station Črni Vrh Nad Idrijo (683 m above sea level), the data on precipitation at the precipitation station Vojsko (1070 m above sea level) are comparatively presented for the station with a water level recorder the Idrijca-LP Podroteja (Fig. 3.5). On the average, the precipitation in the 1961-90 period were slightly higher at the station Črni Vrh (Črni Vrh - 2589 mm; Vojsko - 2450 mm), while in the individual precipitation situations, great differences can occur in the daily heights of precipitation. The maximum daily height of precipitation in the 1993-95 period amounted to 223 mm at the station Črni Vrh (on November 17, 1995), but only 102 mm at Vojsko. After the most abundant precipitation on November 17, 1995, only the height of 70 mm was registered

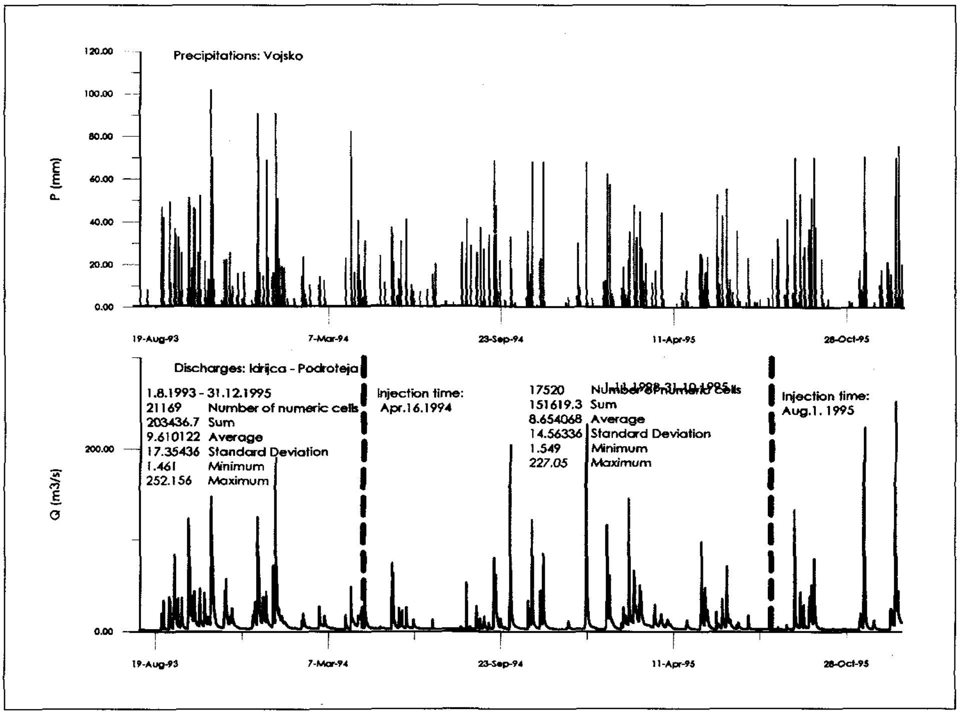

Fig. 3.5: Mean hourly discharges at the gauging profile Idrijca-LP Podroteja, which comprises the surface waters of the Belca and Idrijca as well as the discharges of the karst springs Podroteja and Divje Jezero and the daily heights of the precipitations at the precipitation station Vojsko.

at the station Vojsko, and the next day, further 30 mm, which is less than a half of the daily precipitation at the stations Lokve and Črni Vrh.

In the Idrijca-LP Podroteja gauging profile, the discharges are comprised, so from the surface part (the Belca, the Idrijca), as from the karstic part (the Divje Jezero-Jezernica, the Podroteja springs) of the catchment area. From the difference between the obtained discharges at the profiles the Idrijca-LP Fežnar and the Idrijca-LP Podroteja, the influx from the karstic part of the catchment area can be calculated; yet, these data are only representative of the situations when the gauging of discharges was performed (Tab. 3.6). Due to the time lag in reaction on precipitation of the karstic part of the catchment area, only the stable situations can be comparable, above all, at low water situations.

Tab. 3.6: The gauged discharges at the stations Idrijca-LP Fežnar and Idrijca-LP Podroteja (m^3/sec). The difference between both profiles represents the approximately influx of the karst springs

Date	LP Fežnar	LP Podroteja	Difference
Jun/07/94	1.250	4.762	3.512
Jul/26/94	0.357	1.870	1.513
Aug/30/94	0.991	5.658	4.667
Sep/27/94	2.802	4.679	1.877
Nov/23/94	0.814	2.635	1.821
Jan/31/95	1.82	11.12	9.3
Feb/23/95	2.22	11.41	9.19
Apr/26/95	2.60	6.96	4.36
Jun/14/95	2.51	11.78	9.27
Aug/17/95	0.51	1.991	1.481
Oct/05/95	0.806	3.327	2.521
Nov/23/95	1.583	6.13	4.547
Mar/19/96	1.225	5.289	4.064
May/09/96	6.315	15.235	8.99
Jul/03/96	8.373	63.183	54.81

The contribution of the surface part of the catchment area between the profiles Fežnar and Podroteja is negligible at low water situations (approx. 50 l/sec), but within the low mean discharges it already amounts to 0.3 - 0.5 m^3/sec.

Nonparametric Spermann's correlation (Fig. 3.6) of the gauged discharges between both gauging profiles indicates the possibility of the occurrence of two populations and therefore, lower correlational dependence. The nonparametric Spermann's coefficient of correlation results in R = 0.83.

From the presented data, it is not possible to determine the lowest discharge from the karstic catchment area. The lowest discharges in the 1993-95 period were still within the range of the characteristic mean low discharges (1.461 - 1.66 m^3/sec). Also the calculated lowest discharge from the karstic catchment area of 1.481 m^3/sec ranks, together with the discharge of 1.991 m^3/sec of the Idrijca on the LP Podroteja profile, into the range of mean low

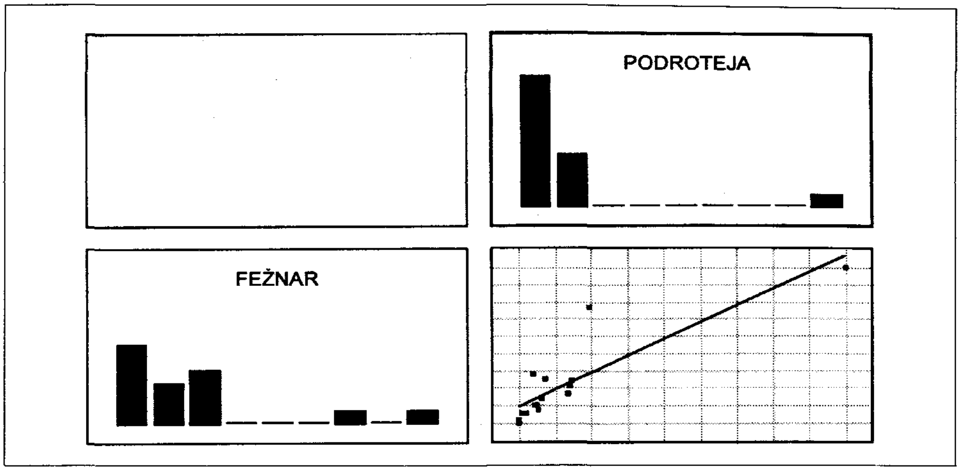

Fig. 3.6: Results of the nonparametric Spermann's correlation between the gauging profiles Idrijca-LP Fežnar and Idrijca-LP Podroteja showing the frequency distribution and the correlational dependence between both groups of data (N = 15).

discharges of the period. However, it was not possible to determine the share of discharges from the karstic catchment area, neither at the lowest (0.840 m^3/sec) nor at the highest (306 m^3/sec) discharges of the Idrijca on the LP Podroteja profile, in so short a period of observations (from May 1994).

For the assessment of contributing share of the remaining water springs in the investigated area, two series of gauging were completed, on the springs Hotešk, Avšček (below Bolterjev Zdenc) and Kajža, and on the ponor streams Slatna at Grgar and Čepovanski Potok (Tab. 3.7).

Tab. 3.7: The gauged discharges of the karst springs Hotešk, Avšček and Kajža, of two ponor streams and of the Idrijca-LP Podroteja (m^3/sec).

Springs	**Apr/13/95**	**May/23/95**
Hotešk	0.093	0.264
Avšček	0.018	0.043
Kajža	0.023	0.112
Altogether	0.134	0.419

Ponor Streams	Apr/13/95	May/05/95
Slatna	0.013	0.048
Čepovanski Potok	0.012	0.020
Altogether	0.025	0.068
The Idrijca-LP Podroteja	2.91	5.01

It is assessed that the mean discharge of the gauged springs amounts to 0.8-1.0 m^3/sec. The most abundant is the Hotešk spring which is also the least investigated.

Calculations Of The Quantities Of Recovered Tracers

For the calculation of the quantities of recovered tracers the data were used, on the discharges at the hydrological gauging stations the Vipava-Pod Farovžem, the Hubelj-Ajdovščina, and the Lijak-Šmihel. The quantities of recovered tracers on the other springs of the Vipava, Pod Skalco and Pod Lipo, were calculated with the difference in discharges between the profiles the Vipava-LP Vipava and the Vipava-Pod Farovžem. In the analysis of tracers, the discharges at the sampling time were taken into account. The quantities were calculated by means of the following equations (1) and (2):

$$K_{ti} = \frac{t_{i+1} + t_{i-1}}{2} \times Q_{ti} \times C_{ti} \qquad (1)$$

K_{ti} - the quantity of tracer in the time between $t_i+l \Leftrightarrow t_i-l$
Q_{ti} - the discharge in the time t_i
C_{ti} - the concentration in the time t_i
or:

$$K = \sum_{i=1}^{n} \left(\frac{t_{i+1} + t_{i-1}}{2} \times Q_{ti} \times C_{ti} \right) \qquad (2)$$

K - the total recovered quantity

For the calculation of recovered tracers at the Mrzlek spring, the mean discharge was assessed on the basis of the mean ratio between the discharges at the profiles under observation (the Idrijca-Podroteja and the Hubelj-Ajdovščina) in the time of tracer occurrence in the Mrzlek, and the statistical value of discharge at both profiles in the 1961-90 period.

With the obtained coefficient the datum was calculated, from the balance of the mean discharge of the Mrzlek in the period (10.12 m^3/sec), of the mean discharge of the Mrzlek in the time of an individual tracing experiment (Tab. 3.8). More details are given in Chapter 6.

Tab. 3.8: The data base of the Mrzlek spring used for the estimation of the quantity of recovered tracer. Due to technical reason only in 1995 sampling from both the Mrzlek-spring in the Soča (i) and from the pumping station (v) was possible. In 1993 and 1994 only samples from the pumping station are available.

	1993	1994	1995
tracer presence: from - to	10/23 - 12/23	04/24 - 06/01	09/03 - 12/31
average concentration [mg/m^3]	0.022	0.125	0.041(i) 0.038 (v)
coefficients (k) used for the discharge estimation	1.7	0.9	1.2
average discharge $Q = 10.12 \cdot k$	17.20	9.11	12.14
average discharge $Q = 7.29 \cdot k$	12.39	6.56	8.75

3.2. THE WATER BALANCE OF THE TRNOVSKO-BANJŠKA PLANOTA

(J. POLAJNAR, J. PRISTOV, M. BAT, M. KOLBEZEN)

3.2.1. Introduction

By making water balance, the ratio was established between the average quantity of precipitation, evapotranspiration and water runoff into the border rivers in the area of the Trnovsko-Banjška Planota (TBP); the aim was to determine the shares of the underground drainage from the entire TBP, and of the still unknown drainage from the karstic massif into the area of the underwater spring Mrzlek.

The water balance of the TBP plateau was determined for three periods.

The thirty-year water balance (1961-1990)

Following the WMO recommendations, the 30-year period, from 1961 to 1990, was to be taken into account for the study of hydrological and meteorological data over several years.