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LAND CONSOLIDATION AND IRRIGATION, CASE STUDY, MUNICIPALITY OF VELIKA PLANA

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ABSTRACT

The Municipality of Velika Plana has been taking serious steps when it comes to initiating land consolidation projects which help realize the land reclamation projects in the simplest way. Whit the aim of obtaining the base for carrying out land reclamation projects, this work deals with and presents the survey of the hydrographic features of Municipality of Velika Plana, as well as, water regime and the river basin of the Velika Morava River. Based on measuring data obtained at Ljubicevski most, water gauge survey station we have performed and presented the analysis of the distinctive annual flow over a longer period of time as well as the analysis related to the changes in parameters which occur on an annual basis. On the basis of performed analysis we have been able to determine the amounts of water for irrigation available in the Velika Morava River basin at the territory of Velika Plana, which was the main focus and objective of this research.

Keywords: *land consolidation, irrigation, flow of, runoff*

INTRODUCTION

One of the significant limiting factors in the food production is the lack of moisture in the arable land, which occurs in the growing season, particularly during the dry years. This problem is solved by the irrigation. According to [1], the experience worldwide has shown that the irrigation system development played the crucial role when it comes to the increase in agricultural production and satisfying food needs on the global level, which have been sharply increasing during 20th century. At the same time the irrigation systems experienced the significant development, as the areas covered by irrigation systems have increased from 50 million hectares to 250 million hectares during 20th century. One of the main factors required for meeting land consolidation objectives, apart from the other necessary factors, is functional canal network. Improving the basic economic effects is closely related to proper land consolidation and planning of parcels which have to be secured by proper planning of the cannel and road networks. The absence of the functional canal network makes the agricultural production hindered, simply because the drainage of the surplus water from the arable land and the irrigation of the same land, in the periods when it is necessary, is impossible.

The Municipality of Velika Plana has taken serious steps when it comes to the initiation and realization of the land consolidation projects. Namely, at the end of 2015 the municipal administration designed land consolidation programs for four cadastral municipalities and the case study of the irrigation possibilities. It is a common knowledge that the land consolidation programs are the necessary base for the initiation and realization of the land consolidation projects.

Land consolidation of agricultural land is a very complex and demanding project, which consists of a great number of activities and subprojects. Among other projects which have to be carried out and realized in the process of land consolidation, these projects also include the projects of water regime regulation.

Given that the projects related to the water regime regulation are the easiest and simplest to realize through the process of land consolidation, the need for launching irrigation systems projects arose. Those projects would be also realized in the process of land consolidation.

Therefore the focus of this work are the hydrographic features of the municipality of Velika Plana as well as the water regime of the Velika Morava River basin, which covers more than three quarters of the municipality, and the work is written for the purpose of realizing land consolidation projects.

The main and the principal objective of the scientific research is to create the solid base for the development of land reclamation projects, through the analysis and determination of the amount of water used for irrigation available in the Velika Morava River basin at the territory of Velika Plana Municipality.

LAND RECLAMATION PROJECTS IN THE PROCESS OF LAND CONSOLIDATION

According to [2], reaching the main objective of the land consolidation process, which is the increase of the agricultural production, would not be efficient if it was based purely on merging the fragmented land properties. This process has to be coordinated and accompanied by a number of measures, whereof the soil preservation is the most important one. According to [3], the soil preservation, among other things, includes the regulation of water regime, that is, carrying out projects related to the drainage and irrigation systems.

One of the biggest challenges related to designing and carrying out those projects is to provide land for construction. As it is already known, when it comes to the land consolidation projects, land for the common needs is provided by the proportional participation of all participants, who are part of the land consolidation project, which reduces this significant problem to minimum.

In his work [2] the author claims that the most rational and useful method of building irrigation systems is to realize them through the process of land consolidation. He also states that the previous practice has shown that the highest quality solutions to those systems were achieved in the areas where they were realized through the land consolidation projects.

HYDROGRAPHIC FEATURES OF THE TERRITORY

The teritorry of Velika Plana in terms of hidrography, according to [4], belongs to the Velika Morava river basin (262 km^2) and the Jezava (83 km^2) river basin. Watershed of the two basins is possible to be determined in mountainous terrain while in lowland it is not defined. The area of the municipality is mainly oriented to the left bank of the Velika Morava River, with the lower course of the river and the confluence of the Jasenica and the Raca rivers. The total length of the Velika Morava bank at the territory of Velika Plana is approximately 38 km (left bank) and approximately 8 km (right bank) [4].

The Velika Morava river basin has a developed basic hydrographic network and according to [5], it covers the central zone of the fissure mountains and basins partly covering the Carphatian –Balkan mountain range in the East and Dinara mountain range in the West. The riverbed of the Velika Morava with a width varying at the inflections from 110 m to 250 m, at the sharpest curvature is cut 5-6 m into the gravelly-gritty alluvium which is not more than 10 m thick. One of the prominent features of the river flow is meandering. The river cuts the old meanders creating backwaters and flows in the new riverbed by creating new meanders and the process is constantly repeated. The constant changes in the riverbed of Velika Morava River are the result of the interplay of the sediment movement movement and lateral forces effects

The Velika Morava river basin includes the following: the Jasenica River, The Raca River and the Grabovacki stream. A number of smaller watercourses flows into pheripherial canals which further flow into the Jasenica. The Velika Morava river basin is characterizd by an extremely adverse water regime which is conditioned by specific climate conditions, topography, geological structure, the condition of the vegetative cover etc. Water runoff, according to [5], in this river basin is characteristic for two periods which are:

- The great waters period during which 60-70% of the total amount of the annual waters flows off, destroying and flooding agricultural land, endangering villages, industry and roads;
- The low waters period during which the remaining amounts of water flow off. This period coincides with the vegatation period, when the water is the most necessary for agriculture.

The ratio of great and low waters in the Velika Morava River basin is very big – 1: 128.
The level of underground waters in the river alluviums is considerably high. The gravel collector from Lozovik to Trnovce is approximately 8.0 m thick. The optimal capacity of the wells used for a survey varies from 15 to 40 L/s. At the higher points the level of underground waters is 8-15 m above the surface.

WATER REGIME OF THE VELIKA MORAVA RIVER BASIN

Water regime of the Velika Morava River basin is interesting from the perspective of using water for irrigation, whether the water is taken from the open flow or the reservoirs are built for the purpose of irrigation, which enable creating water consolidation over the period of time and provide irrigation during the periods when the natural water flows are low.

For the subject hydrological analysis we have used the daily flows at the representative water gauge station Ljubicevski most. The water gauge station is located north of municipality of Velika Plana, and being the representative one, it has been chosen. It has also been chosen due to the availability of the data necessary for the hydrological analysis. Available time series at the analyzed water gauge station cover the period of 60 years, which is satisfying criteria for performing the necessary analysis.
Table 1 shows the data about the analyzed hydrological profile [4], and table 2 represents the average monthly flow at the water gauge station Ljubicevski Most [6].

Table 1. Basic data about the the analysed hydrographical profile

River	Station	Altitude [mnm]	Distance from the confluence [km]	Basin area [km^2]	Time period
Velika Morava	Ljubicevski Most	73,42	21,8	37.320	1948.-2005.

Daily flows have been taken from the database of the Republic Hydrometeorological Institute of the Republic of Serbia. Before performing the analysis we have done the basic sistematization and the processing of the all daily flows by months, so that we can generally conclude that the flow variability is considerably big both on annual basis and during the period of more years.

The average monthly flow values by years and months are calulated according to the following formula [7]:

$$Q_m(i,j) = \frac{1}{n(j)} \sum_{k=1}^{n(j)} Q_d(i,j,k) \tag{1}$$

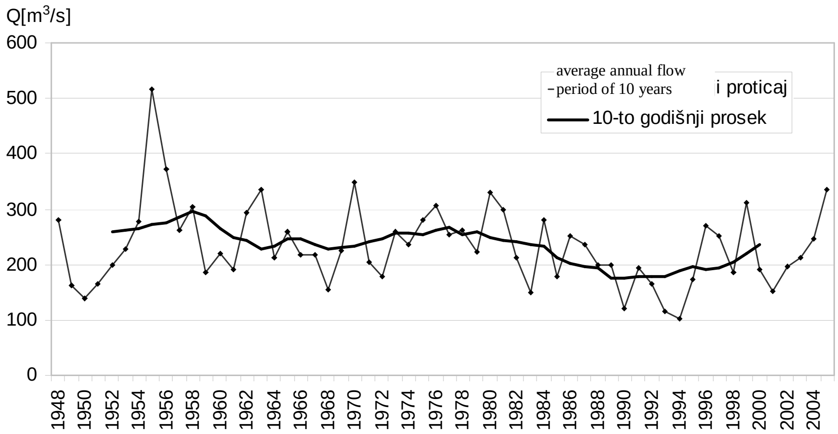
Table 2. Average monthly flow at water gauge station Ljubicevski Most

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Value
Q [m^3/s]	249	337	399	429	339	243	151	97	87	110	149	210	233

Average annual flow values for each year are calulate according to the following formula [7]:

$$Q_g(i) = \frac{1}{12}\sum_{j=1}^{12} Q_m(i, j) \quad (2)$$

The results of those calculations for water gauge station Ljubicevski Most are graphically presented in the picture 1.



Picture 1. Average annual flow of the Velika Morava, Ljubicevski Most water gauge station

Based on the data obtained at Ljubicavski Most water gauge station, two groups of analysis have been performed [8]:

- Analysis of the characteristic annual flows over a longer period of time, that is over a period of time when the data was available;
- Analysis of the changes in the characteristic parameters which occur within the year

ANLAYSIS OF THE CHARACTERISTIC ANNUAL FLOWS

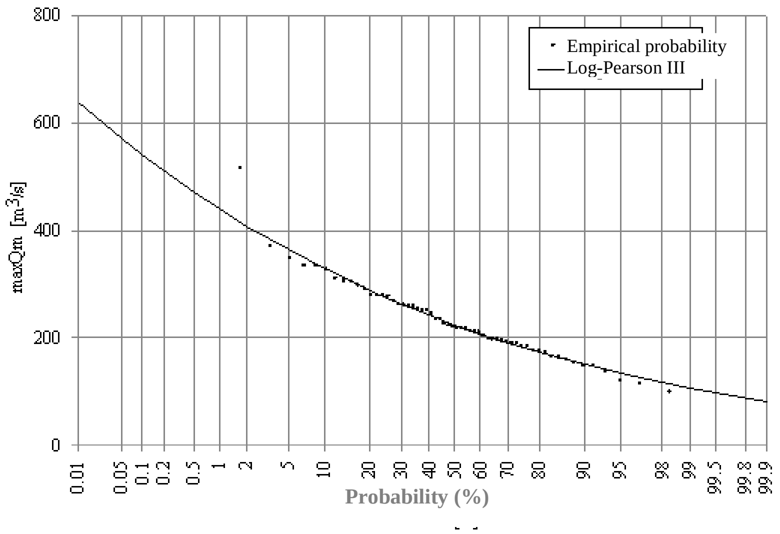
Analysis of the characteristic annual flows that is their function per years, can be best estimated according to the data given in table 3.

Table 3. Characteristic flow at the examined watercourse

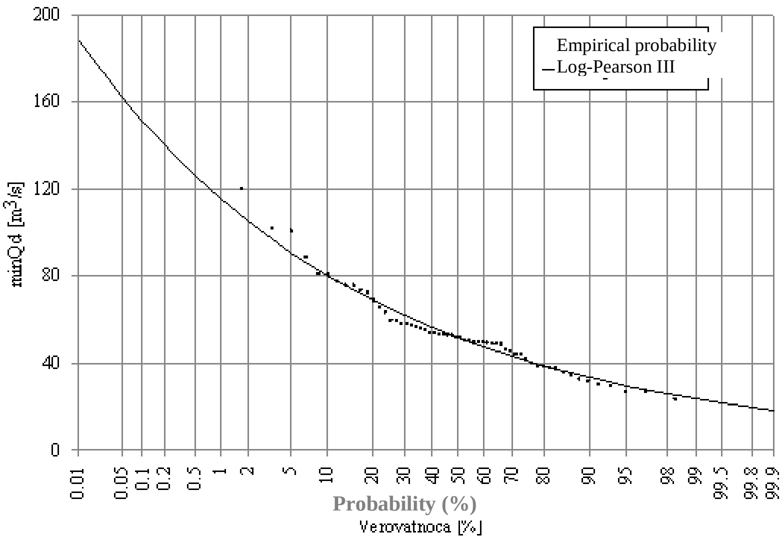
Watercourse	Station	Basin Area [km^2]	$\overline{Q_g}$ [m^3/s]	S_g [m^3/s]	$C_{v,g}$	$C_{s,g}$	maxQ_d [m^3/s]	minQ_d [m^3/s]
Velika Morava	Ljubicevski Most	37.320	233,4	72,1	0,31	1,08	2.333	23,7

In order to estimate the changes in annual characteristic values, in a better way, statistical analysis of the data was carried out, and the obtained results are presented in picture 2.

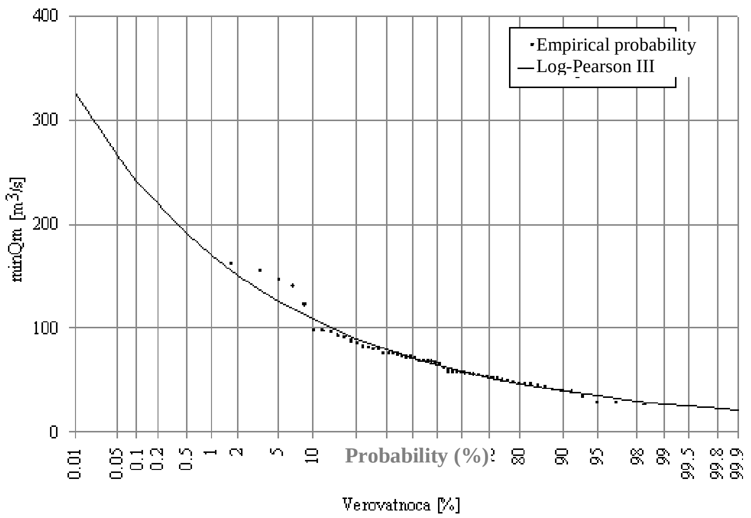
Based on the diagrams which are shown in pictures 3 and 4 we can conclude that there is a significant deviation of the extreme values comapred to the average values.This fact indicates the high variation of the flow during the year.



Picture 2. Probability lines of the average annual flows at water gauge station Ljubicevski Most

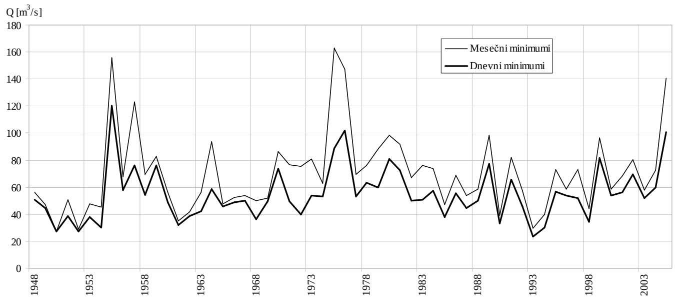


Picture 3. Probability lines of the minimal daily flows at the water gauge station LJubicevski Most



Picture 4. Probability lines of the minimal monthly flows at the water gauge station Ljubicevski Most

Picture 5 shows the minimal monthly and the minimal daily flows and we can conclude that the presented values are remarkably similar. This fact brings us to the conclusion that the low flow periods are relatively long that and during those periods the flows are quite simmilar. The detailed discussion of these phenomena is given below.

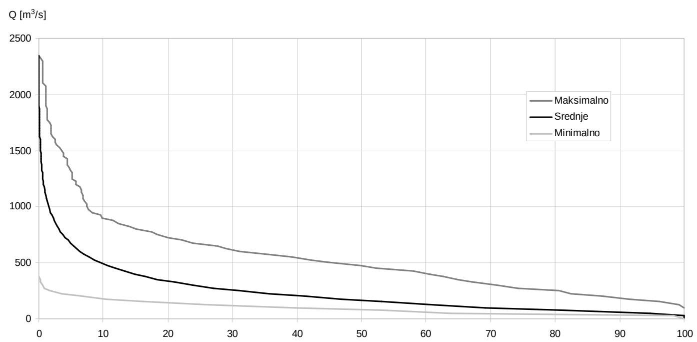


Picture 5. Minimal daily and minimal monhly flows

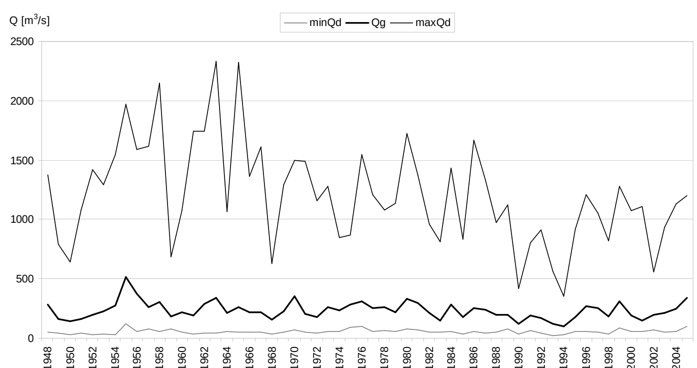
FLOW VALUES WITHIN THE PERIOD OF ONE YEAR

The flow regime is presented using the characteristic features within the period of a year those are minimal, average and maximal flows. Comprehensive analysis has been performed in order to study the flow features within the period of one year. The first step of a number of activities, mainly based on daily flows in the analysed series of data, is to form the line of the average minimal and maximal durations (Picture 6). These diagrams indicate that the fluctuations in flow are big.

For the better estimation of flow variations the average valuse of the annual flows are graphically presented (by years), then in picture 7 there are minimal values .Those diagrams and the line of duration show that the flows may vary througout the year.



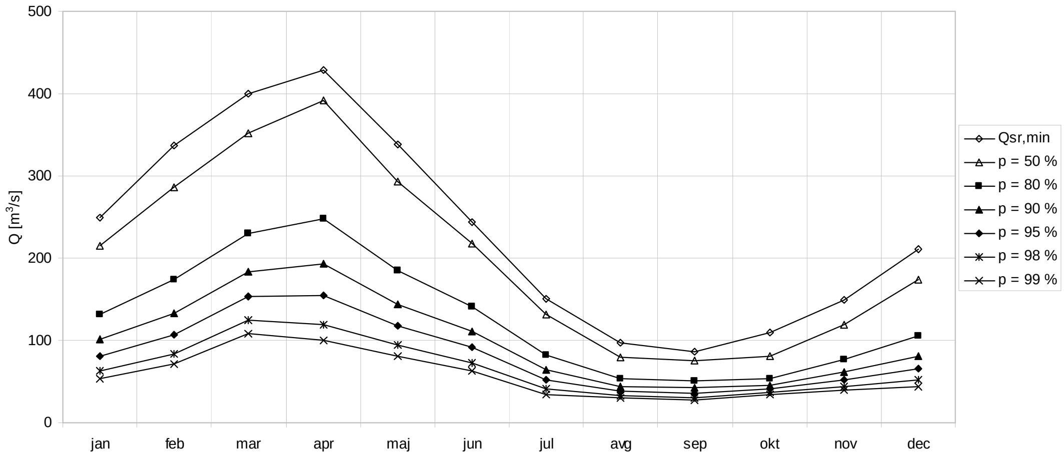
Picture 6. Line of the flow duration



Picture 7. Duration curve of the flow average values of the annual flows, minimal and maximal daily values that were observed

For the purpose of understanding the flow variations within the year, analysis of the monthly flow regime was carried out. For this analysis we have used monthly flow values by years, $Q_m(i,j)$, with their statistical parameters which define the distribution of those series for each month. Statistical parameters and monthly flow extremes are determined according to the equations which have already been mentioned [6].

A synthesized image for the water gauge station Ljubicevski Most (picture 8) apart from the average monthly flows, includes the flows $Q_m(p)$ for a couple of characteristic probabilities, p=50%, p=80%, ... , p=99%.



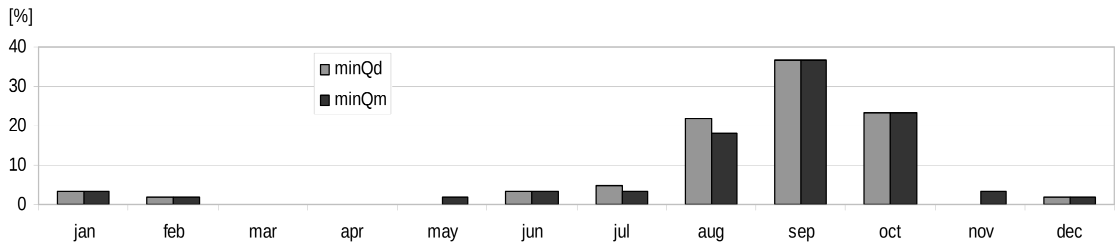
Picture 8. Probability of the average monthly flows incidence

It is obvious that the low flow months at the Velika Morava River are between August and October. Minimal flows are relatively high in March, April and May and dry months are July, August, September, October and November. For the watercourses of Central Serbia low flow months are a characteristic feature even during summer.

Taking into account the objectives of this study, the incidence of dry months deserves special attention. In the examined series we have analyzed the number of the minimal monthly flows (*min*Q_m), and minimal daily flows (*min*Q_d). Picture 9 and table 4 show the number of the minimal flows in percent. Those results also confirm the finding that the minimal flows at the Velika Morava River are relatively high in the period between February and May and that the dry months are August, September and October.

Table 4. Incidence of minimal average monthly flows (%)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
3	2	0	0	2	3	3	19	38	24	3	2



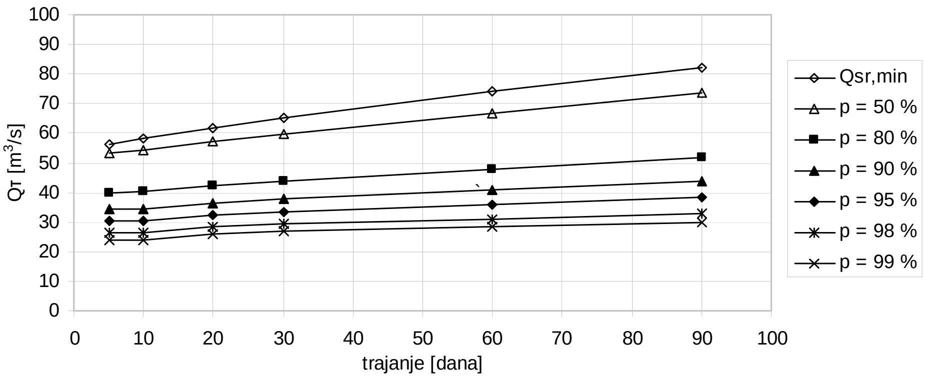
Picture 9. Minimal average monthly flows expressed in percent

Based on the presented facts we can conclude that this feature is unfavorable when it comes to irrigation since the hydrological droughts occur in the period when the irrigation water is the most necessary particularly for the irrigation of the crops during the second seedtime.

Continuance of the low flow or dry periods has been analyzed in the following manner. Except for the characteristic monthly values, we have analyzed flows during the low flow periods for 6 different durations (τ):

$$\tau = 5, 10, 20, 30, 60, 90 \text{ days}$$

Within these analyses it was possible to determine the lowest average flows for the predetermined durations for each year, Q(τ,i). In that manner we were able to form 6 data series for the analyzed water gauge station. For each data series we have calculated statistical parameters which were subjected to the statistical analysis (table 5). Based on the data obtained we were able to form the diagram $Q_{\tau,p}()$, which is shown in picture 10. The presented results show that the flows related to a number of probabilities of the features important for the irrigation, do not significantly increase by the increased of duration τ. This fact bring us to the conclusion that the low flow periods are relatively long at the examined profile of the Velika Morava River.



Picture 10. Average flows during the dry periods of different duration

Table 5. Average flows during the dry periods of different duration

	5	10	20	30	60	90
Qτ [m³/s]	56.4	58.2	61.7	65.1	74.0	82.3
Sr. datum	16. sept	14. sept	11. sept	2. sept	23. avg	8. avg
σ	20.3	21.9	23.7	26.7	33.2	39.3
Cv	0.359	0.377	0.385	0.409	0.449	0.478
Cs	1.120	1.272	1.314	1.486	1.577	1.698

AVAILABLE IRRIGATION WATER AMOUNTS

Taking into account the presented conclusions and findings in terms of intensity, duration and the incidence of dry periods, it is obvious that the irrigation possibilities during the vegetation season have to be examined more precisely. Therefore, we have examined the indicators which define the low water regime of the probability incidence of 80 and 95%. We have analyzed the basic hydrological features necessary for studying the total amount of the available waters, their space and time disposition and we have defined the amounts of the extreme flows from the perspective of satisfying the needs of different users.

Low waters are features of the water regime which indicates the limitations when it comes to the usage of the watrecourse, particularly if we take into account the necessity of protecting the quality of river flow. The limitations related to the usage of available waters in the Velika Morava River according to [8], can be divided in two groups:

- Minimal maintenance flow as a limiting condition –the flow which has to be provided in the downstream part of the river flow

- Water supply as a limiting condition -population represents the priority group of users, taking water from the surface waterflow can have some effects on the level and amount of underground waters, and most of the water supply systems are actually based on using those underground waters

Law on Waters (″Official Gazette of RS″ No 30/10) [9], defines the minimal sustainable flow as ″the flow which has to be provided in the downstream of the water intake in order to secure the existence and development of the downstream biocenosis and to satisfy the needs of the downstream users″. Although the failure to provide the minimal sustainable flow Q_{mo} belongs to the economic offence, Law on Waters does not provide the method of determining the minimal sustainable flow, nor it relegates to the Book of Rules, Regulation or the methodology which can be used for defining this value. There is no a comprehensive Registry (at the republican level) which would provide an insight in the location of the existing users and their needs in this watercourse.

The amount of water in the watercourse is closely related to a number of physical parameters. The important parameters which are directly influenced by the water flow value are water temperature, flow rate, water level, wetted perimeter of the river bed, the potential of self-purification, sedimentation of the nutritive masteries, level of the underground waters etc.

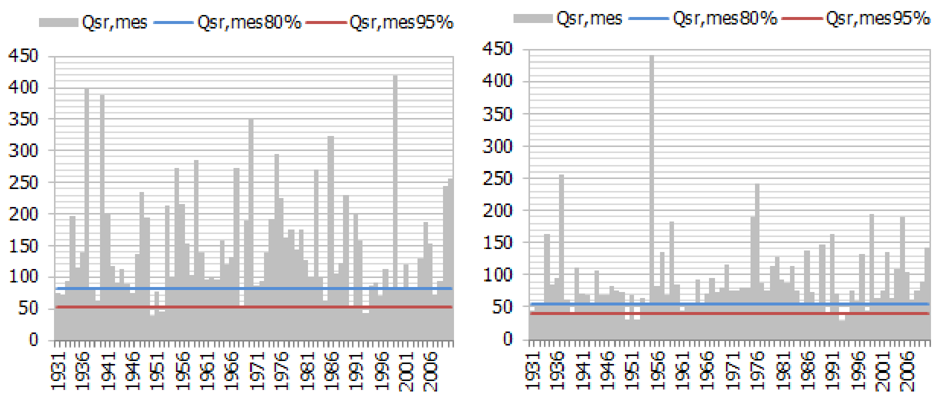
As it can be concluded these parameters determine whether a certain habitat is suitable for life (temporary or permanent habitat), nutrition, reproduction as well as the growth of the plant and animal species in the aquatic environment and its immediate proximity. Wet land areas are particularly sensitive to the decrease in water inflow. The objective of this analysis shown is to determine the minimal sustainable flow Q_{mo} which would ensure that the human activities related to using water would not destroy the established balance.

In order to determine the flow Q_{mo} we used the average monthly flows which are exceeded in 95% of cases ($Q_{sr,i}^{95\%}$ where index *i* indicates the number of month in the vegetative season) and based on the Log-Pearson III probability distrubution (table 6). This distribution has shown a satisfying match between empirical and theoretical function at the examined water gauge station. The calculation has been done for each month during the vegetative season individually due to the specific needs of the biosphere for water, at the series of the examined data of the maximal available lengths.

Table 6. Characteristic values of the probability of incidence p=95%

	IV	V	VI	VII	VIII	IX
[m^3/s]	151,9	116,5	92,3	53,8	39,7	37,3

Then the flows $Q_{sr,i}^{80\%}$ for each month of the vegetative season were determined, and they occur with the probability p=80% (on average once in five years). The average monthly values of the examined and statistically filtered flows for the characteristic months July and August are presented in Picture 11.



Picture 11. Analysis of the available waters in the Velika Morava (u m^3/s) – July (left) and August (right)

Flow range between the values of the mentioned probabilities of incidence is determined as the amount of water available for the satisfying different needs, presented to the different groups of water users: water supply, irrigation and other needs (industry and other econimies).The following has been adopted:

- Taking water in order to satisfy the needs of the residentrs and industry has already been examined through the examined flows therefore it does not require the additional examination;
- Population decline is evident –the great number of the existing systems for the watre supply at this moment can be seen as overszed and of sufficient capacity for the following period;
- The condition of the water network in not satisfying because the losses which occur in the process of water supply are 30-40% on average- solving this problem could leave additional amounts of water necessary for meeting other needs;
- Taking into account the descrease in industrial production, closing a great number of factories, and the need for rational usage of water recourses in the production (adopting cleaner technologies, which require smaller amounts of water), we can expect that the industry needs will not intensly grow in the folllowing period.

However, due to the uncertainty which is reflected in the unknown current need for water and the unknown need for water in future it is assumed that the amounts intended for irrigation Q_n may reach the half of the available amounts of water:

$$Q_{n,i} = \frac{Q_{sr,i}^{80\%} - Q_{sr,i}^{95\%}}{2} \tag{3}$$

If the half of the available waters is taken it still leaves the sufficient amount of water in reserve in the watercourse, and those waters can later be activated in the need of natural-social circumstances which are significantly different from those examined in this work:

- significant deviation from the flows recorded during the previous period, caused by the climate changes,
- signigicant increase of the population which could result in the additioal need for water,
- intesnse development of industry etc.

Analysis of the current social and economic conditions makes the deviations of the shown scenario almost impossible.
Table 7 gives the overview of the available amounts of water during the vegetative period.

Table 7. The amounts of water used for irrigation available at the territory of Velika Plana

River	Water gauge station	$(Q_{80\%} - Q_{95\%})/2$ [m^3/s]					
		IV	V	VI	VII	VIII	IX
Vel. Morava	LJ. most	46,280	33,787	22,553	15,580	7,451	6,862
Jasenica	Sm. Palanka	0,259	0,184	0,153	0,074	0,051	0,052
Kubrsnica	Sm. Palanka	0,170	0,108	0,119	0,053	0,038	0,075
Vel. Morava	Bagrdan	42,776	28,403	22,349	13,076	6,314	6,188

CONCLUSION

In order to present the amounts of water available during the vegetation period (table 7) we used the approach from the confluence to the river spring- firstly we presented the maximal amounts of water which can be used for irrigation at the furthest downstream hydrological station. That amount of water can be used for the irrigation of the areas in the entire basin of the analyzed watercourse. If the differences in flows at the nearby water gauge stations are formed, it is possible to determine the amounts of water which are available at certain sections.

According to the used method in the basin of the Velika Morava River during the months which are considered to be critical i terms of the lack of soil moisture, the water needs can be satisfied at approximately 31.000 hectares in July, that is 14.900 hectares in August. If the same method is applied to to the territory whic is in the wider hhydrographic sense represented by marginal profiles Ljubicevski most and Bagrdan, then during the critical months, the following amounts of water are available:

- July Q = 15,580 - 13,076 = 2,504 m^3/s F = 5.000 ha
- August Q = 7,451 - 6,314 = 1,137 m^3/s F = 2.270 ha

In terms of the municipal boundaries, the available amounts of water should be proportionally distributed by the municipalities which are located at that area, above all the Municipality of Velika Plana (left bank) and Zabari (right bank). The data shown in the table 7 indicate that there is a pronounced variation of the available amounts of water in space and time. However, the general conclusion, when it comes to irrigation, is that the Velika Morava River with its tributaries is one of the least abundant in watercourses.

Based on the carried research we can conclude that the water used from the Velika Morava River basin does not meet the irrigation needs of the Municipality of Velika Plana. From that reason it is also necessary to examine the possibility of *direct usage of undergoround waters* and potential construction of *micro reservoirs* at the small inner watercourses. In addition to this it is necessary to take into consideration the potential construction of the pumping station, piping system and compensation reservoirs. In that manner the water taken from the pumping station and piping system could be distributed to compensation reservoirs located at the higher elevations.

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