ISOHYET AND EVAPOTRANSPIRATION ELEMENTS IN THE UNA REGIME

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Physicalgeographical characteristics of the river basin have a very important role in the study of water regime, especially in those where there are no continuous monitoring hydro-climatic parameters, in order to determine the water regime. The studying of the regime of the river Una is limited potamological factors, and runoff is just one of the most important. Starting from the water balance, which is the difference between runoff and evaporation, then it follows that the precipitations one of the key factors of the river regime.

Analysis of runoff with the Una River basin, which is derived from the total amount of rainfall, which is spatially distributed unevenly, actual evapotranspiration and infiltration of rainfall through the surface, is the object of this paper. Using concrete scientific methods, depending on physicalgeographic determinants of the Una, such as climate (precipitation and temperature), characteristics of soils and vegetation there is, to the conclusion of the total amount of effective rainfall or excess of rainfall that rains, and water quantity that is lost through actual evapotranspiration.

Key words: *The River Una basin, physicalgeographical characteristics, evapotranspiration, infiltration, runoff.*

INTRODUCTIONS

The river regime's indicators are often misinterpreted or wrong conclusions are brought if not taking into account physical-geographical characteristics when study the regime. However, without analyses, factors and indicators of the regime, the research on a river regime is almost impossible. A special overview has been put on inflow in the Una basin.

Starting from an universal definition of inflow, which represents the quantity of fallen waters that come to watercourse in a certain time period, a question is put upon the conditions under which it has been done, of which the most important are: precipitation, geological structure, the energy of relief and morphometrics characteristics of the river basin. Thus precipitation affects the watercourse power supply and change of its conditions, a soil transforms meteorological appearances and processes into hydrological, becoming a mediator between climatic and hydrologic regimes, a fall of the watercourse and the river basin influence on faster concentration of huge waters and production of drifts and so.

Potamological analyses of climatic parameters, above all temperature and precipitation, analyse of hydrogeologic conditions in a basin, pedologic and phitogeographic prospections will enable assessment and evaluation of balance of inflow from the basin into the Una river system. Basic scientific methods, as well, will be used in this paper, especially these: analyses and synthesis, morphografic and morphometric, cartographic, pluviometric and statistic methods. Beside these, there will be used also Thornthwait's methods on calculations of evapotranspiration (PET), Turc's method (ET), and modified Langbein's method (ET), as well as method for determination of effective rain SCS. Calculations and analyses by these methods are part of detailed scientific work, the author's doctoral dissertation, and thus it represents yet new and original data within a framework of potamology researches. For evaluation of the inflow regime into the Una basin, a monitoring with total of 21 water meters was treated for hydrologic period 1961-1990. Selection of this 30-years period is compatible with climatologic standard in the Una regime evaluation.

Potamology elements of the Una Basin

The Una basin, this work's domain of study, makes border northwest part of Bosnia and Herzegovina. Smaller part of the basin belongs to the neighbour Republic of Croatia and refers to morphostructures of Mala Kapela, Plješevica and Zrinjska gora. The Una river system drains waters from the basin which watershed encompasses the territory among the following basins: the Kupa and the Sava in the north, the Korana in the northwest, the Zrmanja and the Krka on the south and southwest, the Vrbas in the east and smaller Sava's tributaries in northeast.

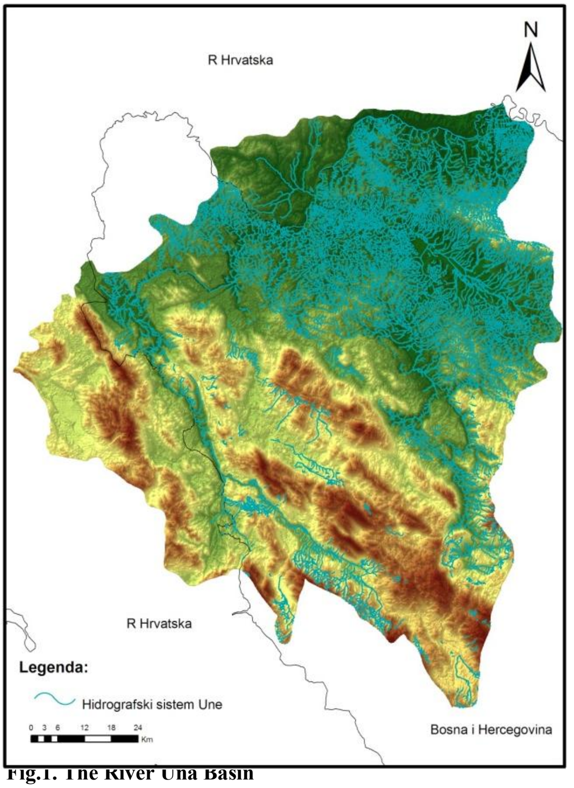

Fig.1. The River Una Basin

The Una rises from a strong karst vauclusian spring near Donja Suvaja (375,85 m) in east slopes of the Čemernica Mountain, and mouths in the Sava River near Jasenovac (94 m). Both on surface and underground, from upper and middle basins the Una drains higher zone of high karst, and in lower part first of all, zone of Mesozoic lime-stones and dolomites, then, central Palaeozoic and ophiolite zone, while at the mouth into the Sava, her basin is situated inside the flysch zone.

Such morphostructural plan of the river basin predisposed very complex geological composition. Upper and middle river basins are built by karstificated carbonates with limited surface and more expressed underground inflow. The middle part of the catchment area belongs to the sedimentmetamorphic complex with mainly surface inflow, while its outmost north parts come into composition of molasse complex with limited capacity of the underground inflow. The Una basin with its great part belongs to the Una – Korana plateau, which is bound to orographic slopes of Grmeč and Plješevica. Una-Korana plateau originated on Cretaceous and Triassic carbonates by action of intensive corrosive-erosive processes, during peaceful and very humid Pliocene. Its own evolutionary development it preserved very well in the middle flow, which morphostructure expressions are Bihać-Krupa ravine and Grabež-Ostrožac plateau. Those morphostructures are recipients to precipitation waters which take part in component of stable flow (M. Spahic, 1991).

In scientific and expert hydrologic papers are met various data on the Una catchment area. Data start from 9640 km^2 [1] and refer to the whole Una basin, to 9368 km^2 on the area of Bosnia and Herzegovina, of which 5020 km^2 [2,3] refers to territory of The Federation of Bosnia and Herzegovina. Majority of data is linked to orographic watershed which, due to prevailed terrains with aquifers crack-cavernous porosity, do not make real watershed between neighbour basins and the Una basin, so it has to be taken with reserve. Concrete and accurate watershed, so as the catchment area is hard to determine without direct hydrogeologic researches in the whole river basin. In recent time these researches are led in the west and southwest part of watershed. As a basis for this work, it has been used hydrogeological map (in further text HGM) of the former Yugoslavia region, papers Zagreb, Sarajevo and Dubrovnik, scale 1:500 000, with certain changes conditioned by recent investigations[4].

Hydrogeological maps with larger scale for the Una basin have never been done. The basic and amended cartographic data allowed morphometryzation of the Una basin in program ArcGIS 9 (ArcMap) with which is determined area of 9979,5 km^2, of which to Bosnia and Herzegovina belongs 8014,8 km^2, and to Republic of Croatia 1964,7 km^2.

Concerning the area it encompasses (9979,5 km^2), hydrographically, the catchment area can be divided into three big units, of which each of them has its own specific potamologic characteristics. The lowest, but the largest by size, is direct Una basin, which includes mainly left side of the basin, then the source and part of the basin near the mouth. This morphologically lowest part of the basin with average altitude of 546,03 m encompasses the area of 4719,4 km^2 what is 47,3 % of the basin. Other two units, important by size, of the Una basin are basins of the Sana and Unac. The Sana basin on the average hypsometric level of 587,1 m takes the area of 4356,3 km^2, and is more plentiful with water than the Unac basin which amounts 903,8 km^2 of the area on the average altitude of 933,5 m. Beside surface flows, especially in direction from the mouth Unac to Bihać, the Una is made rich with water by numerous karst sources which appear on the bottom of the river bed.

RESULTS AND DISCUSSION

Isohyet elements of the Una regime

Precipitation as climate element has a special role in forming an admission regime into the Una and its tributaries. Under the term of water balance it is considered the difference between inflow and evaporation, so it results from definition that precipitations have not only special role but they are also the most important factor of the river regime. According to Spahić M. (2013.), schedule and structure of precipitations are very important assumptions of the river regime. At the same annual precipitation height there is more water in rivers

[1] Spahić, M. (1991): Rijeka Una – potamološka razmatranja, Zbornik referata i rezimea Naučnog skupa „Valorizacija prirodnih i društvenih vrijednosti sliva rijeke Une“, Bihać – Sarajevo
[2] Žigić, I., Skopljak, F., Hrvatović, H., Pašić – Škripić, D. (2010): Hidrogeološka rejonizacija terena u slivu rijeke Une na teritoriji Federacije Bosne i Hercegovine, Zbornik radova RGGF-a Univerziteta u Tuzli, Tuzla
[3] Strategija upravljanja vodama Federacije Bosne i Hercegovine 2010-2022, Sarajevo 2012
[4] Tijela podzemnih voda podsliva Une, knj. I, Zavod za vodoprivredu d.d. Sarajevo, Sarajevo 2009.

in the year in which more precipitations occur during the cold period, evaporation is less then, so the admission from the river basin is larger.

Great influence on dynamics of pluviometric regime has the intensity of action and frequentation of barometer conditions on high and low air pressure with big and middle sizes. Their actions directly affect characteristics of termical regime, relative humidity, cloudiness and windiness, and they all together directly influence on precipitations' quantity. The connection between precipitations and altitude can be determined by linear correlation. It was noticed by this procedure that annual precipitation quantity in the Una basin increases on every 100 meters for 47,7 mm, what is more comparing to average for Bosnia and Herzegovina, which counts 23,0 mm/100 m.

Table 1. The average annual flow of precipitation in area of the Una River basin 1961st-1990th year (mm)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
The Una River basin	83	79	84	98	102	105	90	93	89	95	120	109	1147

Source: HMI of FB&H, Sarajevo

Regardless the statements of previous researches done by various authors, saying that precipitations grow continuously with height, the recent researches make corrections on them remarking that these increasemnets are not equable and steady. The position of weather station has dominant influence on stated precipitation relations, as well as cyclone activity and level of continentality of the region where this climate element has been measured. Besides that, precipitation measuring on weather stations doesn't bring enough information on precipitations which are extracted in the catchment area, which in fact represents the main parameter in admission process.

Average annual precipitations' amounts start from 875 mm in the region of the Una mouth into the Sava, until over 1800 mm in the highest mountain tops. The largest part of the catchment area is situated inside isohyet of 1125 mm and it covers the region made of valleys, ravine and foothills in the Una basin, and its most important tributary Sana. Morphostructures with altitude over 500 m have greater quantity of precipitations, in average over 1300 mm, while areas with altitude above 1000 m receive over 1600 mm annually.

Evapotranspiration elements of the Una regime

Evaporation represents important part of the hydrologic cycles, and within a framework of hydrologic researches, it has very important role in determining of the run balance. The evaporation quantity, under the same meteorological-climatic parameters, depends on physical characteristics of areas from which evaporation is performed, of which the most important are: water areas, relief, evaporation bottom, vegetation and similar. Evaporation or physical vapour has been observed separately from transpiration or biologic vapour, which together make total vaporization or evapotranspiration.

In nature, it is impossible to vapour larger quantity of water that the one it is on disposal. In that context, capability of vapour differs and is called the potential evapotranspiration, in opposite to the real vapour. There are many methods and approaches for determination of evapotranspiration or its several components, but none of them are acceptable under all conditions. For the purpose of this paper, it has been analysed evapotranspiration from the Una cahment area by three methods: Thornthwait's (PET), Turc's (ET) and modificated Langbein's (ET) method.

Thornthwait's method lies on exponential connection between average monthly temperature t_m and average monthly potential evapotranspiration PETm in form:

PETm = 16,2 Rf$\left(\frac{10\ tm}{tg}\right)^{a}$ (mm) (Hrelja, H. 2007). Data gained by this method are data of annual average potential evapotranspiration according to months for 17 analyzed weather stations in the Una basin. Average annual evapotranspiration in the Una catchment area on certain stations goes in diapason from 396,38 mm in Drinić to 484,93 mm in Saničani, where evaporation is the largest one. According to tabelar indicators (see table 2), average annual quantity of potential evapotranspiration amounts 450 litters of water on a square meter m^2.

Tab.2. The average potential evapotranspiration, PET, with the Una River Basin for period 1961st-1990th by the Thornthwait method

PET (mm)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	PET
The Una River basin	0,5	3,5	16,2	35,4	54,7	69,3	77,7	74,8	59,2	38,5	19,0	1,8	450,2

In opposition to previous method, Turc worked out own method on real evapotranspiration (ET) by bringing in correlation precipitations with air temperature from relation:

ET = $\frac{P}{\sqrt{0,9 + (P/CT)^2}}$ (mm/year) (Hrelja, H. 2007). Using Turc method, the value of real evapotranspiration, ET, is acquired for the Una catchment area.

Tab.3. The real evapotranspiration, ET, according to the Turc's method, on the Una River Basin, during the period 1961st to 1990th (mm/year)

Weather stations	T (°C)	C_T	P (mm)	ET (mm/year)	%
The Una River basin	9,7	443,1	1147	415,6	36,2

Real evapotranspiration is less than potential, on certain stations, so as in the whole Una catchment area. Of total precipitation quantity which extracts during the year on the catchment area, 415,6 mm evaporates through evapotranspiration, while the rest of water quantity runs into water flows and thus influence the Una river regime. The most used method for calculation of real evapotranspiration is modified Langbein's method, which consists of determining relation of average annual outlet (Q) and temperature factor (Ct) and relation between average annual precipitation (P) and temperature factor (Ct): Q/Ct = *f* (P/Ct) (Hrelja, H. 2007). This method represents simplified equation of the water balance for multiannual period, resulting with real evapotranspiration represents difference between precipitations and outlet height: ET = P–Y.

The outlet schedule in the Una catchment area, is conditioned by the quantity and schedule of precipitations as well as evaporation, which, due to high air temperatures is significant, so, beside small quantity of precipitations, the flows are higher in spring, comparing to greater quantity of precipitation, which are extracted during the first half of summer season. The largest flows are in April and Mart, while the secondary maximum is in

December. Several factors have influence on large quantity of water which runs by flows from this catchment area during the spring months, of which the most important ones are: increased quantity of precipitation, snow retention from higher hypsometric levels and great soil saturation with humid, which directly influence on increased coefficient of spring waters outlet. The smallest flows appear in August and September. When analysing middle flow water quantity from presented water meter, then observed differences can be brought in accordance of constant downstream increasement of the catchment area. Downstream increasement on average annual flows is evident on tributaries Unac and Sana, what is best illustrated by table 4.

Average annual outlet height for analyzed catchment area amounts 249 mm, and in this respect, the real evapotranspiration according to modified Langbein's method amounts 898 mm. Evaporation from surface is different in certain periods of year, especially during the vegetation period. Concerning that increased evaporation depends on vegetation covering, some authors use the potential evapotranspiration estimation for plant cultures during the vegetation period. In so doing, coefficient of evapotranspiration depends on a group of plants. Spahić, M. (2002), states that during the vegetation period from Middle European forests evaporates in average 370-450 mm, and from the mixed ones 300-400 mm of precipitations. However, during the full vegetation period from a soil planted with wheat evaporates about 201 mm of precipitations, and from barren lands only 121 mm. Such calculations have broad apply during analyse of water quantity necessary for irrigation. As this is not the case in this paper, when analyzing the contribution of precipitation waters in the river regime, we will stay on acquired results for real evapotranspiration and analyses of effective rain by SCS method.

Tab.4. The average annual runoff to water meters in the Una River Basin (m^3/s)

WM	Basin	Qav.an.	WM	Basin	Qav.an.	WM	Basin	Qav.an.
Martin Brod -up.	Una	20,4	Donja Pecka	Sana	9,26	Drvar	Unac	5,43
Martin Brod	Una	51,6	Ključ	Sana	33,2	Rmanj Manastir	Unac	30,5
Kulen Vakuf	Una	53,2	Vrhpolje	Sana	42,1			
Štrbački Buk	Una	65	Sanski Most	Sana	66,7			
Kralje (Bihać)	Una	97,6	Prijedor	Sana	81,4			
B.Krupa	Una	113	B.Novi	Sana	86,6			
B.Novi - up.	Una	133						
B.Novi - down	Una	218						
B.Dubica	Una	238						

Source: HMI of FB&H, Sarajevo

The effective rain or surplus of precipitations, Pe (netto rain), represents the part of the total precipitations P (gross rain) which outlets. Difference **P – Pe is called water's „loss“.** This water's loss is the most important because of infiltration in period of intensive, shower rains. Losses depend on, above all, basin characteristics such area: allocation of area, vegetation, pedologic and geologic characteristics, relief, then height and intensity of precipitations, level of underground waters and so.

One of the most known methods for determining effective rain is SCS method (Soil Conservation Service Hydrologic Method). At this method, the following elements are taking into account: previous soil humidity, soil types concerning capacity of infiltration, the way of soil usage, type of vegetation covering and the condition of area. According to this method, effective rain (Pe) is determined towards expression: Pe = $\frac{(P-0,2d)^2}{(P+0,8d)}$, (Petrović, J. 2001). Instead of soil capacity d, it is introduced so-called curve number CN as parameter in equation above. CN represents coefficient of outlet which considers action of infiltration, accumulation and duration of precipitations. The CN number is without dimension and his link with d arises from relation: $d = 25,4\left(\frac{1000}{CN} - 10\right)$.

CN numbers are determined according to the type and allocation of soil, according to classification which was given by SCS. If it is about a basin with large area and if in the catchment area are presented various outlet conditions, then is determined so-called complex CN. In order to get data on complex hydrologic CN numbers, it was necessary previously to analyze pedo-geographic and phyto-geographic characteristics of the catchment area.

Tab.5. Participation of individual hydrologic soil groups according to purpose of land use (%)

Kategorija	A	B	C	D
Road and rail network	0	30,97	69,03	0
Conifer forest vegetation	11,92	48,41	38,97	0,7
Barren rocks	0	100	0	0
Building sites	0	7,36	92,64	0
Cultivated parcel groups	4,91	56,7	15,47	22,48
Industrial and/or trade regions	55,9	15,7	17,4	11
Land marshes	13,35	31,43	27,52	27,7
Deciduous forest vegetation	8,64	66,42	20,42	4,51
Mineral exploitation sites	12,53	46,95	30,04	10,48
Mixed deciduous and conifer vegetation vegetacija	9,63	51,6	38,16	0,61
Non-irrigated acres	8,23	37,37	30,74	23,66
Unconnected city areas	4,86	49,54	12,8	32,8
Pastures	10,97	64,9	22,37	1,76
Regions with barren vegetation coverings	42,44	25,85	31,71	0
Agriculture areas with significant nature share	6,4	62,87	16,42	14,24
Natural grasslands	14,76	30,53	54,64	0,07
Forest vegetation succession	14,89	50,69	31,02	3,4
High mountain vegetation and heathland	76,83	0	23,17	0
Orchards and plantations of granular fruits	0	29,74	0	70,26

Soil humidity and physical characteristics of the catchment area are brought in connection in order to give four hydrological groups of soil. Soils are classified on the base of water absorption at the end of long term rain, seen after the certain previous soil humidity and possibility of its blistering. On the base of analysis of pedographic characteristics and allocation of catchment areas, CN numbers are gained, presented in table 5. In order to gain so-called complex CN number, it was approached to ponderation of individual CN's in proportion to individual participation of soil hydrological groups' areas according to allocation of soil usage on the catchment area. For watertight and water surfaces CN amounts 100, but for natural surfaces CN< 100. Complex hydrological number is acquired by usage of weighting coefficients, and for the Una basin it amounts 69.According to acquired data, calculated maximum soil capacity, concerning absorbing (*d*) or potentially maximum retention of precipitations in the Una catchment area amounts 114,1 mm. Putting these values in the expression which determines the quantity of the effective rain, it implicit that annually from the total precipitations' quantity of 1147 mm, in the catchment area drains water layer of 1020,6 mm.

Difference P – Pe or the loss of water, layer of 126,4 mm, appears mostly because of infiltration. Gained data on water loss by infiltration, one should take with reserve, especially when it is about the larger basins. In fact, greater area takes more soil types and their allocation which influence, at the end, on complex CN number. Besides, complex CN number means constant rain intensity in the whole catchment area, what is not possible in a large basins, such is the Una. Regardless on a stated attitude, acquired data can help in consideration of general balance, especially water quantity distributed in the basin and the one that directly inflows into the Una.

Tab.6. Single and complex hydrological, CN, numbers, depending on the soil and purpose of land use

Category	CN	%	Complex number
Road and rail network	88	0,01	0,88
Conifer forest vegetation	57	2,51	143,07
Barren rocks	98	0,01	0,98
Building sites	90	0,01	0,9
Cultivated parcel groups	73	14,60	1065,8
Industrial and/or trade regions	92	0,04	3,68
Land marshes	100	0,03	3
Deciduous forest vegetation	67	36,55	2448,85
Mineral exploitation sites	85	0,28	23,8
Mixed deciduous and conifer vegetation vegetacija	62	11,05	685,1
Non-irrigated acres	83	1,13	93,79
Unconnected city areas	70	0,59	41,3
Pastures	80	10,86	868,8
Regions with barren vegetation coverings	58	0,07	4,06

Agriculture areas with significant nature share	70	12,44	870,8
Natural grasslands	59	3,96	233,64
Forest vegetation succession	68	5,36	364,48
High mountain vegetation and heathland	98	0,01	0,98
Orchards and plantations of granular fruits	83	0,02	1,66
Water bodies	100	0,16	16
Water streams	100	0,30	30
Total		**100**	**6901,57**

CONCLUSION

Detailed research isohyets and evapotranspiration elements correcting the previous indicators that were applied in the analysis of river regime and water balance in the basin of the River Una. The average annual height of precipitation that is excreted the basin of Una is 1147 mm. Potential evapotranspiration, which represents the maximum intensity of evapotranspiration, which would be achieved under the assumption that the available amount of water for evapotranspiration is not limited, in the same basin amunts to 450.22 mm. If we compare the potential evapotranspiration with monthly precipitation, then we noticed that during every month of the year is excreted sufficient amount of rainfall which is done maximum or potential evapotranspiration for each m^2 catchment areas. However, in order to take into consideration long term average rainfall, it may be that in certain periods fall and less amount of rainfall, which increases evaporation and reduces runoff water in the river system of Una. The real evapotranspiration is always less than or equal to the potential evapotranspiration. Of the total amount of rainfall that is excreted during the year in the area of the basin, evaporated 415.6 mm, or about 36%, while the remaining amount of water enters the waterflows which is a positive component of the regime Una River. By defining an effective amount of rain comes to the conclusion that from the annual of precipitation (1147 mm), which is excreted in the basin, surface drains in the Una River layer of water of 1020.6 mm. Loss of 126.4 mm, formed mainly by infiltration. If this amount of infiltrated water added layer of 415.6 mm, which is losing real evapotranspiration, to give the overall amount of water from 541.0 mm or 47.2% from the total amount of rainfall in the basin which does not participate in flow of Una. Larger losses of water in the basin, which amounts to 898 mm, are obtained by using the most common, a modified method of Langbein's, which represents the ratio of the amount of rainfall and runoff. The difference of almost 350 mm of water loss can be explained by anthropogenic impacts. Significant impacts of human are runoff of rainfall and water level originate from agricultural measures applied to large areas. Also, large amounts of water are used for water supply of population, agriculture and industry.

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