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Mathematical modeling to define catchment size and real evapotranspiration (case study: Andrića karst spring, Western Serbia)

Математично моделиране за определяне на размера на водосбора и действителната евапотранспирация на примера на карстовия извор Андрича (Западна Сърбия)

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Water resources in karst are extremely important sources of drinking water supply. The quality of groundwater formed in karst aquifers is generally high and in most cases only chlorination is required. However, from a hydrogeological perspective, these water resources are the least studied. Often only basic information is available on catchment size, groundwater reserves (dynamic and static, if any) and groundwater balance. Detailed hydrogeological investigations and long-term monitoring of karst spring discharges are needed to acquire such information. In Serbia, only one spring (the source of the Mlava River) is being continuously monitored. Other karst springs are either not monitored at all or observed for short periods of time, usually to address a specific problem. In 1995, the National Hydrometeorological Service of Serbia established gauging stations at another 5 karst springs, including Andrića Vrelo (Andrića Spring) in Western Serbia, Zlatibor District. Monitoring of the 5 springs was discontinued between 2004 and 2006.

During the period of monitoring (1995–2004), the mean annual discharge of Andrića Vrelo was Q_{av} = 1.157 m^3/s. The absolute maximum was Q_{max} = 3.417 m^3/s, recorded in April 1996, and the absolute minimum Q_{min} = 0.287 m^3/s recorded in August 1998. The catchment area is known to be built up of Carboniferous psammitic-pelitic sediments, Triassic carbonate formations, Jurassic diabase-chert deposits, and Quaternary sediments. The karst aquifer drained by the spring is formed in banked and massive Triassic limestones. It is recharged by direct infiltration of precipitation through an exposed part of the aquifer. Drainage occurs on the right bank of the Prištavica River, via Andrića Vrelo, which is an ascending type of spring. No detailed hydrogeological exploration has been undertaken, so the position of the hydrogeological water divide and consequently the catchment size are unknown. The latter parameter is extremely important for estimating groundwater reserves and assessing the water balance components of the spring. However, conclusions about potential abstraction can only be drawn by defining the multiyear groundwater balance and reserves in the catchments of karst springs.

For such cases, the University of Belgrade/Faculty of Mining and Geology has developed a mathematical model for calculating catchment size and real evapotranspiration, as well as for simulating daily discharges (Ristić, 2007). The model has been calibrated for more than ten springs, with good results (Ristić Vakanjac et al., 2013a, b; Čokorilo Ilić et al., 2014) It comprises several modules/steps. In the first step, mean daily discharges of the karst spring are calculated for a multiyear period (e.g. 1960–2010), based on available meteorological data: precipitation and air temperature in the karst spring catchment and runoff from the catchment recharged by the spring. In the present case study, data from a weather station at Zlatibor were used. The station is located in the immediate vicinity of the Andrića Vrelo catchment. The outputs of the next two steps of the model are catchment size and real evapotranspiration. In the specific case, the modeled catchment size of Andrića Vrelo was 60.4 km^2. The other parameters, such as the estimated real evapotranspiration E (mm), derived catchment size F (km^2), multiyear average yield/discharge Q (m^3/s), outflow volume W (10^6 m^3), multiyear average runoff modulus q ($l/s/km^2$), runoff depth h (mm), average annual precipitation P (mm), and average annual runoff coefficient φ, are shown in Table 1.

It follows from Table 1 that the annual discharge from the karst aquifer at Andrića Vrelo is Q_{av} = 1.106 (m^3/s)

Table 1. Summary of estimated multiyear groundwater balance of the karst aquifer at Andrića Vrelo, 1960–2010

Spring	F	P	E	h	Q_{av}	q	W	φ
	km^2	mm	mm	mm	m^3/s	$l/s/km^2$	$10^6\ m^3$	
Andrića Vrelo	60.4	987.4	408.1	577.2	1.106	18.3	34.87	0.585

and that the specific yield of the Andrića Spring catchment is 18.3 $l/s/km^2$. Based on the calculated runoff coefficient, the conclusion is that 58.5% of the precipitation that reaches the ground is infiltrated and later discharged via Andrića Vrelo. A stable discharge regime and good groundwater quality parameters of Andrića Vrelo make it highly prospective for water supply. In closing, it should be noted that detailed hydrogeological investigations are needed to define the real catchment size for comparison with the results of modeling.

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