

4 BOSNIA AND HERZEGOVINA: VRELO BUNE SPRINGS

4.1 Overview

The spring of Buna is located in the south of Bosnia and Herzegovina, not far from Mostar. The source is located in the area of the Dinaric karst, which runs SW-SE from Slovenia, through Croatia and Bosnia and Herzegovina to Montenegro and Albania. The area is characteristic by pronounced karst morphology, absence of surface water on elevated plateaus and mountains, and occurrences of large karstic springs at their foothills. „Vrelo Buna“ is one of the most famous and largest springs in the Dinarides. It is formed at the contact of Cretaceous limestone and Eocene flysch, at an altitude of 64 m. The basin area is estimated at more than 1100 km².

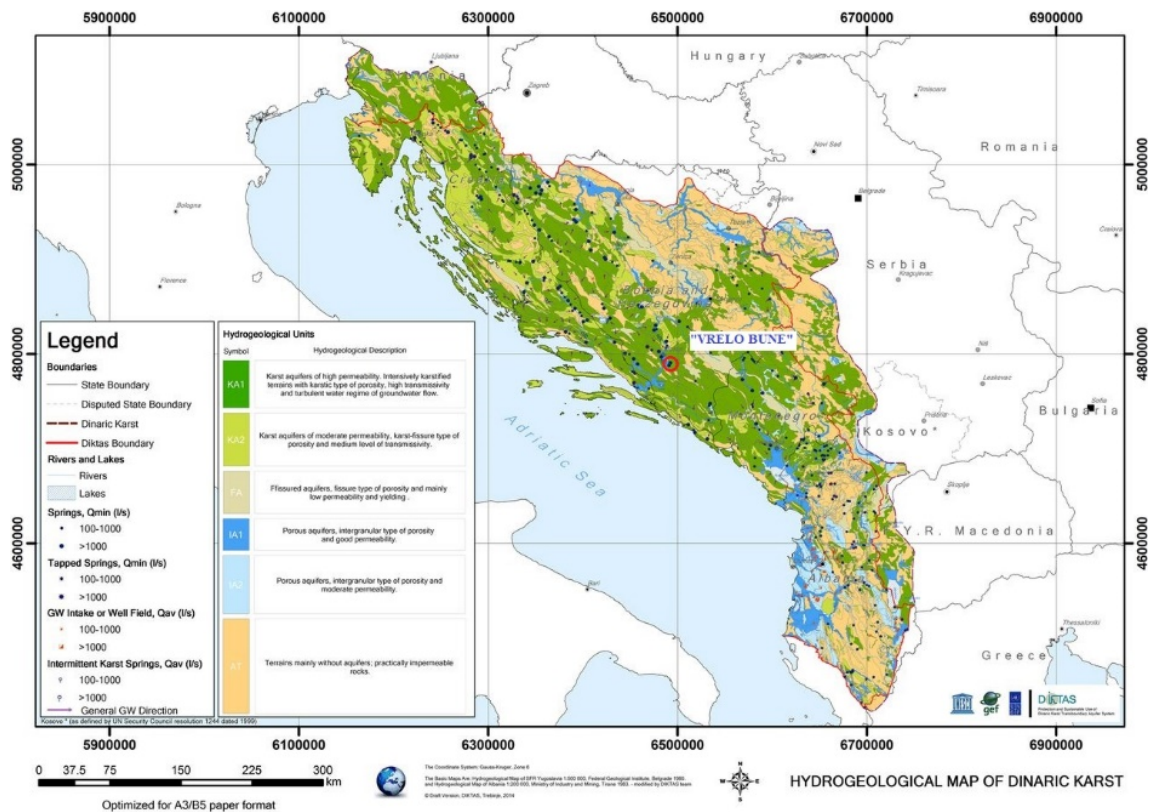


Figure 7: The position of the “Vrelo Buna” in the Dinaric karst



4.2 Geology

The catchment area of the “Vrelo Buna” basin is built mainly by the carbonate cretaceous of the through which there are discordantly deposited clastic deposits of Eocene. Only the bottom of the Nevesinje field are deposits of alluvial deposits found.

The lower cretaceous ($K_{1,2}$) is predominantly dolomite and limestone with, a total thickness of about 700 m. The upper cretaceous (K_2) is built mostly of limestone and subordinate dolomite and dolomite limestone. The total thickness of the upper chalk is about 1000 m. Chalk deposits of over 1500 m thick have the most important hydrogeological role because they are very cracked and karstified, and represent an aquifer that drains on the “Vrelo Buna”.

The Eocene deposits are discordant through Cretaceous deposits; alveolin-numulative limestones of the lower-middle eocene ($E_{1,2}$); deposits of middle-upper eocene ($E_{2,3}$) built of sand, marl, conglomerate and clay, and conglomerates of oligomiocene (E, Ol). These Eocene deposits have an important hydrogeological function of hydrogeological barriers, especially in the case of cretaceous deposits. The total thickness of eocene sediments is about 500 m.

Quaternary sediments are represented mainly by the glowing alluvial layers of gravel, sand (al) in the Nevesinje field. Their thickness is less than 10 m.

4.3 Geomorphology

In the geomorphological view, the “Vrelo Buna” catchment area is located in the area which, belongs to the area of the Dinaric mountain system. The Dinaric mountain system is orientated in the northwest-southeast direction, characterized by the greater part of the southern branch of the Alpine Mountain Wreath. The Dinaric mountain system is characterized by deep river valleys and canyons, large karst fields and mountain ranges with heights from about 1,000 to over 2,000 m. The larger mountains in the Vrela Buna Basin are Velež, Crvanj, Bjelašnica-hercegovacka, Baba, and others.

The special geomorphologic features of the terrain in the Vrela Buna basin are large karst fields among which the Nevesinje field stands out.

One of the special features of the terrain in the “Vrela Buna” basin, which is of decisive importance for the overall hydrogeological relations of this area, is a large area of karst terrains. In limestone, which are mostly built by mountains, fields and plains in the catchment area of Vrelo Buna, various surface and underground karst forms have been formed. From the karst forms, there are many kindergartens, bays, squares, fields, dry valleys, occasional floating fields, and other forms, and from underground sinks, caves, and karst springs. In addition to the occurrence of many karstic forms, one of the important characteristics of the mountains in these terrains is the absence of river flows on the surface, and the water-mobility of karst aquifers in the interior of carbonate masses that empties over strong karst springs at the foot of the mountains. In the area of the Nevesinje field, the built-in flysch sediments of Eocene, the river Zalotka appears, and other smaller occasional watercourses that, after a short flow, are lowered into karst terrains.

4.4 Climate

The catchment area of the “Vrelo Buna” has a sharp mountain climate with long cold winters and short warm summers. There is a very pronounced influence of the Mediterranean climate where due to the geomorphologic features of the Dinaric Mountain System collide warm and cold air masses that bring great precipitation in the catchment area. The mean annual air

temperature is 12.3 - 15.3 ° C. Precipitation is unevenly distributed; from 1,135 mm in the lower Neretva stream to 3,124 mm on karst plateaus of high mountains and Nevesinje polje. Climatic conditions, in addition to hydrogeological relations, are of crucial importance for the formation of enormous water wealth, as well as the water regime that is emptied on the “Vrelo Buna”. Maximum precipitation is from April to May, and from September to November, and minimum from July to September.

4.5 Hydrogeology

Hydrogeological relations

The catchment area of the “Vrelo Buna” is largely composed of the permeable rocks of the cavernous-cracking porosity of the Cretaceous, and the predominantly impermeable complexes of the Eocene. The permeable rocks with cavernous-cracking porosity are limestone. The Limestone is fractured and very karstified; good water conductivity and porosity. These rocks have hydrogeological functions of an aquifer. The aquifer is characterized by the flow of groundwater to favoured directions and karst channels. It is distinguished by its high-water conductivity and the flow rate of groundwater.

Non-permeable rocks in the catchment area of the “Vrelo Buna” are predominantly impermeable complexes of Eocene. Non-permeable rocks have functions of lateral, and partly roof hydrogeological barriers. The Upper Cretaceous are locally entrenched on the deposits of the Eocene, which together with the dolomites of the Upper Cretaceous, most likely caused the appearance of the "Buna" spring.

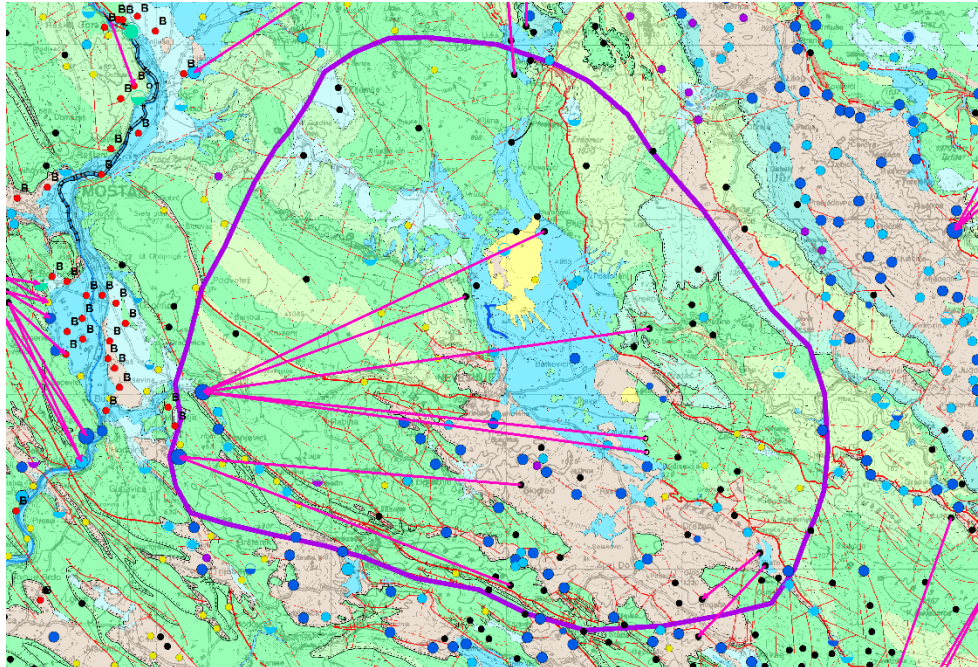


Figure 8: Hydrogeological map of the catchment area of the “Vrelo Buna” spring

The catchment area, sources and accumulations of groundwater

The “Vrelo Buna” spring watershed area is defined by hydrogeological research and tracer testing. The “vrelo Buna” spring is mostly concentrated through the sinkholes in Nevesinjsko polje, and diffused from karst massifs of Velež, Crvanj and Hercegovačka Bjelašnica. The catchment area of the “Vrelo Buna” Buna spring is about 1100 km².

Directions and speeds of the flow of underground waters were determined by tracer studies, from sinks in the Nevesinjsko polje, Trusina and Hansko polje.

According to the Vrelo Buna spring, the waters that sink in the Zalomka basin flow, from the Kifino selo to the estavela Ždrebanik, then the waters that sink in the Zovidolka cove, before flowing in Zalomak (estavela Četanuša). The part of the catchment area of Vrelo Buna which includes the sails of the northwest part of the Nevesinje field with the most significant sinks Ždrijelo, Baba and Zlatac has an area of 98 km². And the connection of these sinks with the “Vrelo Buna” has been repeatedly confirmed. The catchment area “Vrelo Buna” also belongs to the mountainous area between the Nevesinje field and the spring (Podveležje massif and parts of Velež).

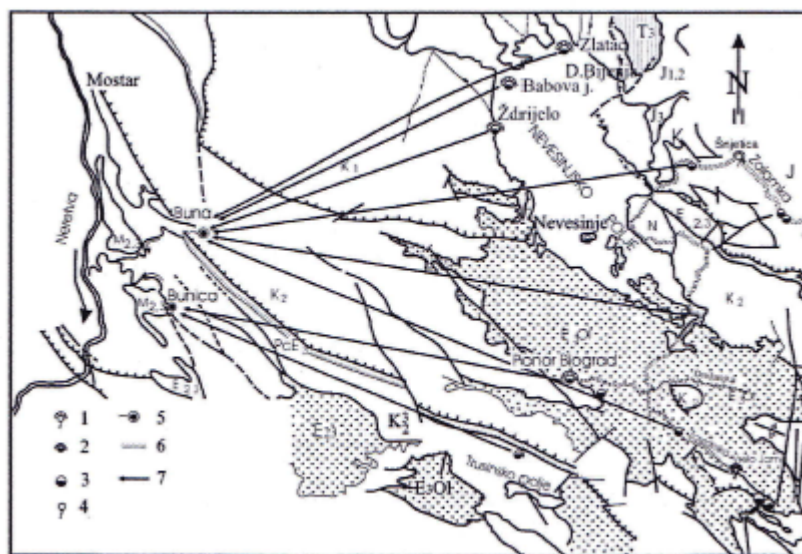


Figure 9: Directions of the flow of groundwater in the catchment area “Vrelo Buna”

The very strong underground connection with the “Vrelo Buna” has been demonstrated by the sinking of the Zlatac, Zdrile, Zalomke sands, the Žljebovi and Ždrebanik boreholes. The fictitious circulation velocities of the boiling water are of the order of $v = 4 \text{ cm / sec}$ (approx. 3400 m / day).

The spring of the “Vrelo Buna” (Figure 10) is certainly one of the most famous and most attractive springs in the Dinaric karst. The spring has a concentrated outlet from the cave, and according to the latest research, the upward spinning mechanism (deep siphon boiling). According to a study by C. Touloumdjian (2001), 470 m of the Buna sifon channel was explored. The depth of the excavated part of the siphon is -78 m (in relation to the place of the dive).

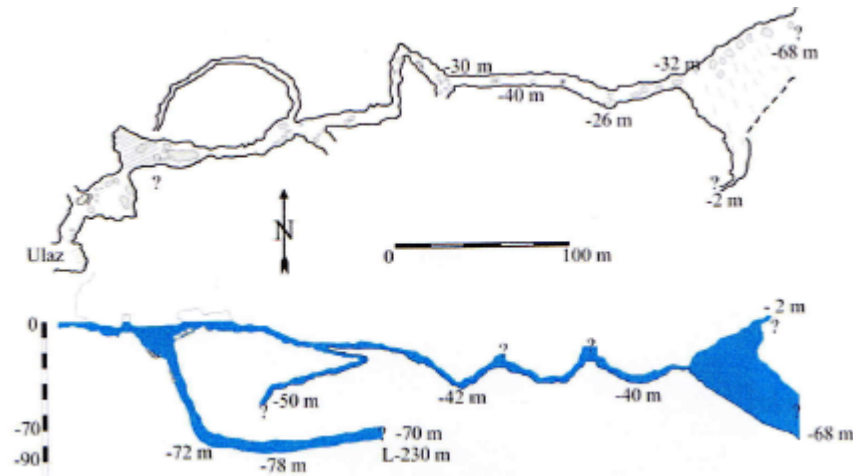


Figure 10: Speleological sketch of the cave channel "Vrelo Buna"

4 km south from "Vrelo Buna" (Figure 11) is the source of "Bunica". The source "Bunice" is located at the elevation 63 m.n.m. The springs are descending-overflow type, and it rises at the contact of permeable cretaceous limestone and impermeable sediments of the Eocene flych.

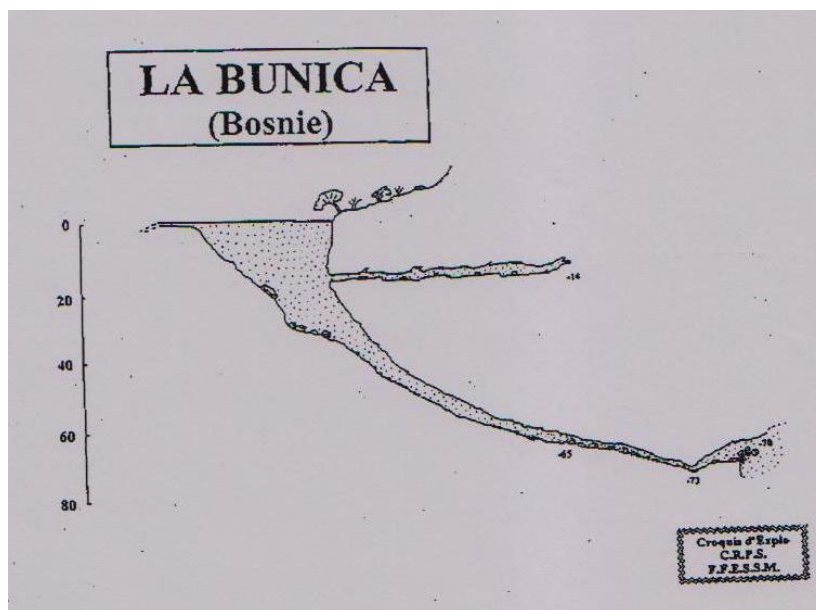


Figure 11: Speleological sketch of the cave channel "Bunica"

The flow rates of groundwater in the "Bunice" aquifer were determined by tracer testing, by the diving of the "Biograd" sink in the southwestern edge of Nevesinjsko polje. The subterranean link of "Biograd" with the spring "Bunica" represents one of the most direct underground links in the Dinaric karst with the underground flow rate of 33.67 cm / s.

The delineation of the catchment areas of the "Vrelo Buna" and the source "Bunica" is very complicated. The hydrogeological investigations so far have shown that there is no mutual hydrographic connection between the "Vrelo Buna" and the "Bunica" source. However, the geomorphologic characteristics, geological and hydrogeological characteristics of the terrain, the type of aquifers, the conditions of feeding and drainage, the water chemistry, the type of



source and their quantitative and qualitative regime indicate that the ***springs of "Vrelo Buna" and "Bunica" have a very similar genesis***. The results of tracer groundwater testing that do not show their interconnection can be caused by complex hydraulic and filtration conditions and pressures of groundwater in the aquifer. The issue of the demarcation of the "Vrelo Buna" and "Bunica" catchment is of great importance and it is possible to separate out the isotopic signal of the precipitation in the catchment area and water these sources.

4.6 Hydrodynamic characteristics of the springs

The "Vrelo Buna" spring is characterized by large oscillations of flow and extremely high maximum yield. The basic characteristics of the hydrological regime of "Vrelo Buna" at the watermeter Blagaj station are:

- Average flow, $Q_{sr} = 23.70 \text{ m}^3/\text{s}$
- Minimum flow, $Q_{min} = 2,95 \text{ m}^3/\text{s}$
- Maximum flow, $Q_{max} = 380 \text{ m}^3/\text{s}$

The line of inclination of the tarisman curve with regression conditions is extremely steep, which results from the nature of feeding through concentrated flows (sinks), and depending on the precipitation regime.

Based on the discharge curve, the "Vrelo Buna" emission coefficient has a value $\alpha = 0.01056$ of the tarisman equation has the form

$$Q_t = 20 \times e^{-0,01056 t}$$

The volume of accumulated water in the recession period is $V_o = 163.64 \times 10^6 \text{ m}^3$ while the residual reserves are $V_t = 85.91 \times 10^6 \text{ m}^3$ (I. Slišković, 1983, p. 315).

The retardation capabilities of the aquifers that emptied on the "Vrelo Buna" are very good.

Basic characteristics of hydrological regime of "Bunica" on the water station Malo polje:

- Average flow, $Q_{sr} = 20.25 \text{ m}^3/\text{s}$
- Minimum flow, $Q_{min} = 0,72 \text{ m}^3/\text{s}$
- Maximum flow, $Q_{max} = 207 \text{ m}^3/\text{s}$

The general equilibrium equation for "Vrelo Buna" and "Bunica" has the form:

$$P = Q + R + E$$

$$1937,10 \times 10^6 = (1027 + 2341,10 + 569) \times 10^6$$

$$100 \% = 53 \% + 17 \% + 30 \%$$

4.7 Data available for the project

1. Vrelo Buna spring			
Data type	Time step	Monitoring period	Time period
Discharge	1 day	5 year	01/2015-12/2019
Electrical conductivity	4 times a year	5 year	01/2015-12/2019
Temperature	4 times a year	5 year	01/2015-12/2019
pH		5 year	01/2015-12/2019
Dissolved oxygen O ₂	4 times a year	5 year	01/2015-12/2019
Suspended matter	4 times a year	5 year	01/2015-12/2019

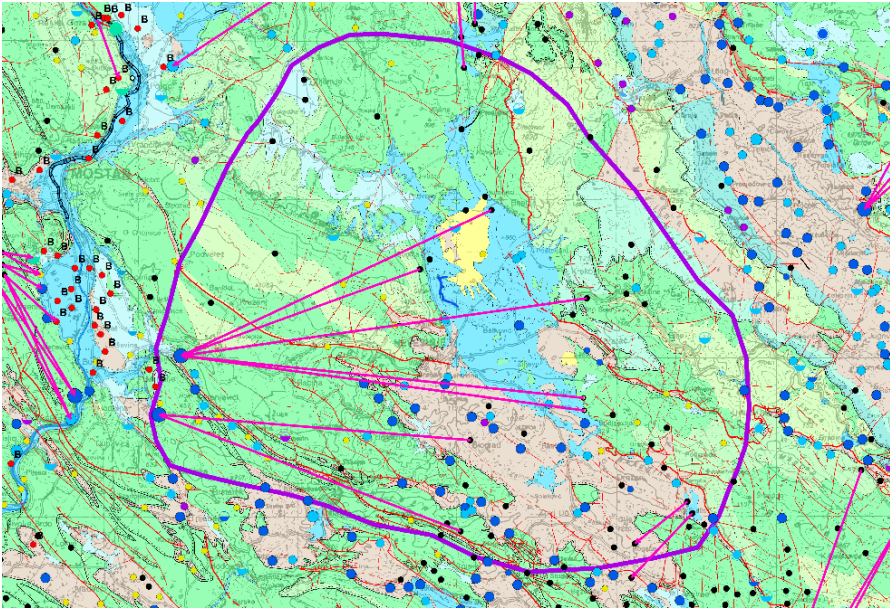


Major anions/cations	4 times a year	5 year	01/2015-12/2019
NH ₄	4 times a year	5 year	01/2015-12/2019

2. Bunica spring			
Data type	Time step	Monitoring period	Time period
Discharge	1 day	5 year	01/2015-12/2019
Electrical conductivity	4 times a year	5 year	01/2015-12/2019
Temperature	4 times a year	5 year	01/2015-12/2019
pH		5 year	01/2015-12/2019
Dissolved oxygen O ₂	4 times a year	5 year	01/2015-12/2019
Suspended matter	4 times a year	5 year	01/2015-12/2019
Major anions/cations	4 times a year	5 year	01/2015-12/2019
NH ₄	4 times a year	5 year	01/2015-12/2019



4.8 Summary

Pilot name	VRELO BUNE		
Country	Bosnia and Herzegovina	EU-region	Mountain areas
Area (km ²)	1100	Lithology	Limestone & dolomite
Short description:	„Vrelo Buna“ is one of the most famous and largest springs in the Dinarides. It is formed at the contact of Cretaceous limestone and eocene flysch, at an altitude of 64 m. The basin area is estimated at more than 1100 km². The spring has concentrated outflow from the cavity channel, and according to the latest research, the ascending mechanism 		
Monitored objects	Springs		
Monitored data	Discharge, temperature, EC, chemistry, major anions/cations		
Contact person	Ferid Skopljak (ferid.skopljak@fzzg.gov.ba)		

4.9 References

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