

# The influence of the highway on the protected springs of Gacka River

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**Abstract:** The highway Zagreb-Split-Dubrovnik passes along the west boundary part of the protected area of the springs zone of the Gacka River. Despite the protection measures that were carried out, the possible highway influence on the springs immediate to road (catchment area B) and main springs (catchment area A), is being considered. Besides the hydrogeological relations and groundwater flow tracing, geochemical properties of the spring waters are used for the defining the catchment areas. Through the monitoring of the characteristic springs, the highway influence on the springs and on the Gacka River will be evaluated.

**Key words:** highway, protected area, hydrogeological relations, geochemical properties of the water.

## INTRODUCTION

The spring area of the River Gacka with the highway Zagreb-Split-Dubrovnik - in construction phase - passing through its protection area, is the investigated region. Protection area is the whole catchment area of the springs zone of about 490 km<sup>2</sup>, which belongs to the wider region of Dinarides. Springs zone of the River Gacka consists of number of strong karst springs, which present the strategic reserves of the drinking water by their water quality and quantity. The water supply of the middle part of Lika region, the city of Gospić and surrounding settlements as well as the coastal foothill of Velebit Mt. and neighbouring islands, is planned based on the water reserves from springs zone of the River Gacka. Today's poor inhabitation and small industrial and agricultural occupancy of the catchment area, enables the right time planning of this region development rate in the sense of water protection.

## HYDROGEOLOGICAL PROPERTIES OF THE CATCHMENT AREA AND THE GROUNDWATER FLOW

The group of (initial) springs of the Gacka River are composed of several major karst springs situated along the edge of a polje, about 460 m above the sea level (Fig. 1). They drain water from a large recharge area consisting of a mountain part and several minor karst fields. The mean rate of flow of the river Gacka is 14 m<sup>3</sup>/s. The highest river flow is in April (mean rate is 19 m<sup>3</sup>/s) and the lowest in August (mean rate is 8.5 m<sup>3</sup>/s).

The boundaries of the springs zone of the Gacka River are, in major part, quite well defined. This is partially the consequence of the dolomites (area of Vrhovine) - in the function of hydrogeological barrier. In the permeable deposits the defining possibility is connected to tracing of the groundwater flow or to water level measuring in piezometric boreholes (boundary towards the Lika River). The catchment boundary, drawn on the map, is in its major part taken from the earlier papers.

The tectonics is the main factor for the defining of waterflow in this lithologically uniform terrain <sup>[1]</sup>. The most expressed isolation is one of the catchment area of the spring Pečina (5) - catchment area B, from the main spring of the River Gacka - Tonkovića spring (7) - catchment area A, which is reflected on the hydrogeological properties of these springs as well. The spring Pečina gets the water mostly from the western part of the catchment area, where the structures separated by parallel vertical faults prevail. The consequences are the high oscillations of discharge, from the dozen m<sup>3</sup>/s in the maximum to only 60 l/s in the

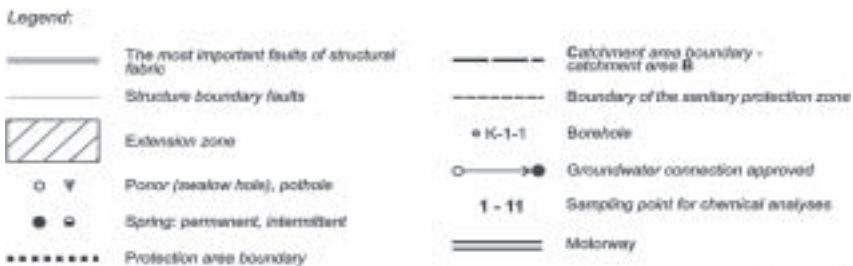
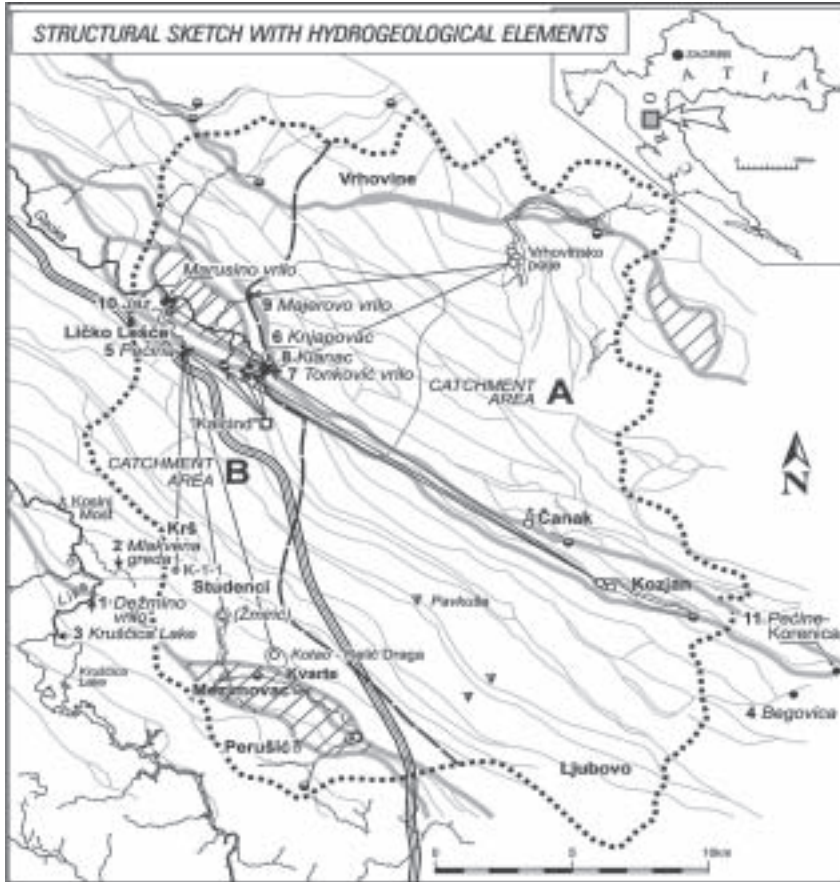


Figure 1

minimum (small retention area). The main springs of the River Gacka, Tonkovića vrelo (7) get the major part of the water from the structural unit in the immediate hinterland of the springs and in the middle part of the catchment area, the present pull-apart structure. This has the reflection on the hydrogeological properties of the spring: permanency and high discharge (mean rate of discharge, 3.43 m<sup>3</sup>/s, average minimum rate, 1.79 m<sup>3</sup>/s). Its minimal discharge in the period from 1982 to 1994 was 0.91 m<sup>3</sup>/s. It is connected to high retention area of the catchment area, about 400x10<sup>3</sup> m<sup>3</sup> in the catchment area of the Gacka River, which is proved with hydrogeological analyses (2).

## HYDROGEOCHEMICAL PROPERTIES OF WATER

Hydrogeochemical investigations in the protected region of the springs zone have been carried out for several hydrological seasons, so the hydrogeochemical facies of the groundwaters, mutual connections of individual drainage systems, area and the conditions of their recharge would be known prior to beginning of the highway usage. In that way the review on individual indicators of the initial state of groundwater quality along the future highway route can also be given prior to usage.

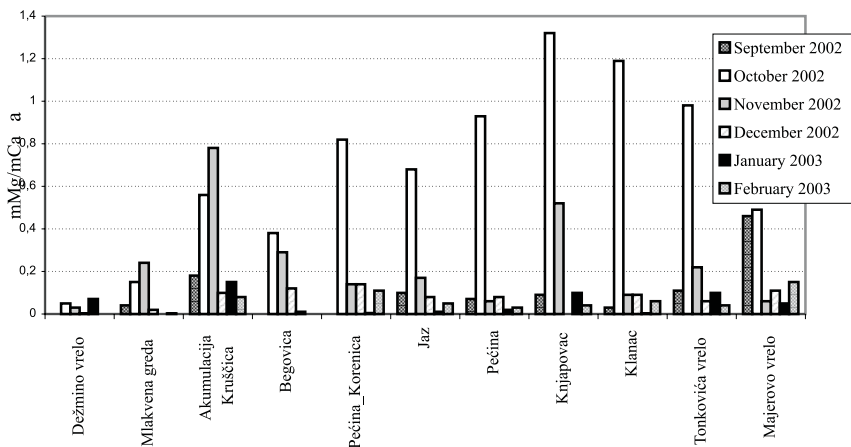


Figure 2. Molar mMg/mCa ratio of spring and surface waters

The molar ratio of magnesium and calcium shows the lowest values on Dežmino vrelo and Mlakvena greda, which points to limestone aquifer. In the recharging areas of the other springs, the presence of dolomites is higher in shallower aquifer parts and the presence of the limestones in deeper parts. First abundant autumn precipitations wash out the calcium, magnesium and hydrogencarbonate ions from the weathering zone located in the dolomite rocks, which reflects as the higher ratio values. In accordance with the mentioned, it could be concluded that the drainage systems are clearly different in the investigated area.

The recharge from the limestone terrain prevails in the catchment area B, and dolomite component is higher represented in the catchment area A. The indications of catchment size changes, considering the hydrological conditions, exist within the catchment area A. Dur-

ing the high waters the magnesium content increases, which points to water inflow from the shallower parts of the terrain (Vrhovinsko Polje) with higher dolomite content.

### INFLUENCE OF THE HIGHWAY ON THE SPRINGS ZONE AND THE RIVER GACKA

The highway Zagreb-Split-Dubrovnik passes through the west part of the protected area of the springs zone of the River Gacka, in its major part in the catchment area B (Fig 1). The water protection zone plan for the area along the route of the motorway and accompanying road facilities has been produced. The classification was performed due to existing data and in accordance with the Water Legislature acts of the Croatian Waters, as well as due to the water protection regime acts. The terrain in the wider region of the motor way route, and also in protection zone of the river Gacka springs, almost completely consists of carbonate rocks and. there is applied a strict protection regime, **a closed impermeable system** with drainage through pipes from the motorway and accompanying facilities, with a controlled outflow of purified water. Categorisation of protected areas of drinking water springs is primarily focused on the protected areas of drinking water spring, which are used for water supply. On the basis of Water Legislature criteria four main zones of water protection have been defined. In the shown area the highway in the whole passes through III protection zone (Zone of the restriction and control). In that zone water flows to the spring from 1 to 10 days.

### CONCLUSIONS

The performed hydrogeological and geochemical investigations and groundwater flow tracings enabled the division of the catchment area (catchment areas A and B) in that part of the protected region. The use of separators and lagoons was proposed for this especially sensitive region with strict protection regime. From the hydrogeochemical point of view, and for the estimation of consequences from direct input of the pollutant in the karst underground, it is necessary to know the geochemical properties of aquifer cover and hydrogeological properties of aquifer, among which the medium water sustain and hydrodynamic conditions in the aquifer are the most important, together with the knowledge on potential pollutant. Implementation of the monitoring the influence of highway on the springs immediate to highway, spring Pečina in the catchment area B (5) and spring Tonkovića vrilo in the catchment area A (7) is planned in the future.

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