Some approaches to groundwater flow regulation in karst terrains

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Abstract: By tapping adjusted to concrete hydrogeological conditions, it is possible to improve situation degraded by natural processes through geological time, contributing to more rational karst groundwater consumption. In the paper, this approach is discussed through case studies.

Key words: Groundwater, karst terrains, regime regulation solutions

Artificial measures in the areas of contact springs

Ideas referring to artificial interventions in karst terrains were predominantly related to overflowing springs, where, by constructing some barrier (groundwater reservoir), regime of water discharge could be significantly improved in easy and cost-effective way. In such cases, by necessary hydrotechnical measures, eroded part of hydrogeological barrier is successfully reclaimed. However, according to practice, such task has not been solved successfully, particularly if the question of karst process evolution for the study area is neglected. So, in the open karst of the coastal belt, thickness of karstification is determined by known changes of sea level (performed during Pleistocene), of 100 m - order. But, in the inner karst terrains, removing of dissolved or mechanically degraded limestone material under the level of the contact spring, that is - the lowest level of limestone-impermeable barrier contact, during the stage of recent and sub recent karst, was almost impossible, while paleokarst forms were predominantly filled with clayey material or terra rossa.

Anyway, idea on groundwater accumulation, analogue to regulation of river flow regime, by constructing a dam, appeared a long time ago. At the territory of the former Yugoslavia, about subsurface reservoirs as hydrotechnical structures, (Peric, 1962, 1963) published papers discussing the idea forty years ago, analyzing certain examples of overflowing springs Vrelo and Istok, at the northern edge of Metohijska kotlina (valley) (Serbia and Montenegro). Subsequently, M. Komatina (1966-1990) made experiments several times and developed other possible ways of artificial interventions, in dependence on hydrogeological structure of the study area. Unfortunately, it can be concluded that concept of artificial regulation of groundwater flow in karst terrains found sporadic application.

In karst terrains, opportunities of enlarging exploitation reserves through the aquifer overexploitation were used rarely, although for application of this procedure suitable conditions are present very often. For overexploitation, drilled well, but also shaft or combination of the shaft and short gallery developed within karst environment can be used (Fig. 1). For example, the shaft-gallery combination was applied by M. Komatina in 1980 in the near

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vicinity of the Bela voda spring near Pec (Serbia and Montenegro). Negative effects of overexploitation were eliminated just after the first rainfall period.

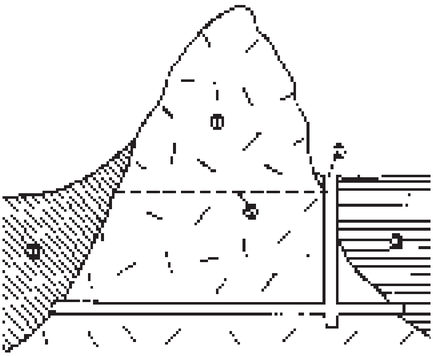

Figure 1. Schematic profile of a shaft and gallery in immediate hinterland of a spring Bela Voda (Pec): 1. limestone; 2. diabase-chert formation; 3. impermeable deposit; 4. shaft with gallery; 5. groundwater level under the natural conditions (KOMATINA, 1985)

OTHER TYPES OF ARTIFICIAL INTERVENTIONS

Karst is water-bearing medium offering possibilities for performing different ways of artificial intervention, not only in the area of the aquifer, but also in the zones of privileged collectors within the watershed area. Very good knowledge of hydrogeological conditions as well as creative approach in defining solutions is required.

By constructing drainage gallery at the lower level than of the groundwater (under natural regime), for example, water can be better capped - that is, enlarged exploitation reserves are available. In the area of the Crna Voda spring (near Pec), convenient position of very permeable alluvial deposit of the Pecka Bistrica river was used, and complex drainage system was performed - intake structure of the spring, the other galleries and drainage systems within the alluvial plain caused the doubled capacity of the aquifer (Fig. 2) (KOMATINA, 1980). The next step is to start with artificial recharge of the aquifer, where ideal conditions are existent, and positive effects of the dam at the exit of the gallery are distinguished.

Under conditions of inner karst, various types of artificial interventions are available, in dependence of specific (hydro) geologic relations. The following procedures are most interesting:

1. Enlarging of exploitation reserves by controlled recharge through conveniently located ponors, linked with interesting karst spring. In that way, the spring regime is regulated by regulating water inflow to the ponor by constructing small dam (Fig. 3).
2. Incomplete flow regulation through privileged collector in the areas of morphologically less developed karst. Such approach can give results particularly in the far rear of contact or other springs. Goal of the intervention is to make water circulation in the zone of the main part of a certain hydrogeological unit (watershed) impossible. Because of morphological conditions, and in order to discover and inject leading collectors, the most often type of solution is constructing shaft and gallery.

3. In the near future, it is expected to involve regulation of concentrated water discharge of estavelles, that is - «sinkhole» (siphon) exsurgences. After constructing concrete seal or carpet, which have to make groundwater discharge impossible, controlled water capping from siphon is carried out, by some of relatively simple known types of intake structures (well, shaft, shaft and short gallery). Procedure of higher or lower overexploitation of reserves is used.

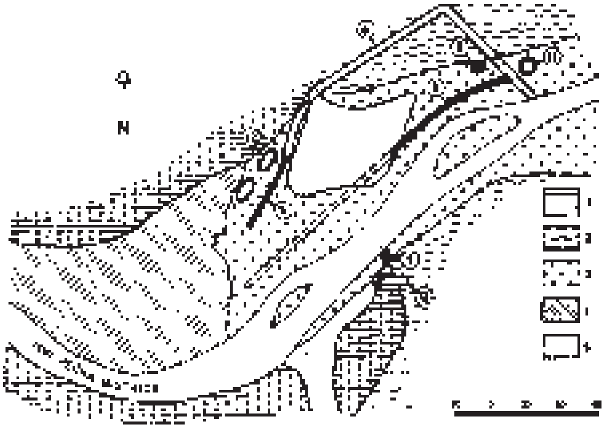

Figure 2. Hydrogeologic map in the area of the springs Crna and Bela Voda near Pec. 1. limestone - permeable; 2. diabas - chert formation - impermeable; 3. alluvial deposit - very permeable; 4. river terrace - low permeable; 5. torrential fan - impermeable; 6. old intake structure Crna Voda; 7. old intake structure Bela Voda; 8. gallery Crna Voda; 9. horizontal drainage within alluvial plain (dashed - projected part); 10. shaft and gallery Bela Voda; 11. water-collecting reservoir (Komatina, 1990)

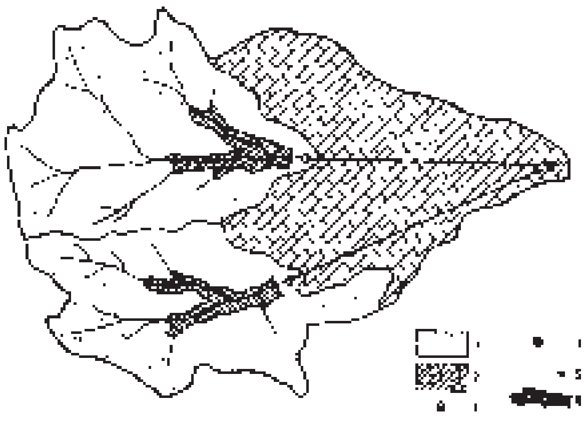

Figure 3. Feasible storage reservoir in the basin for a controlled karst spring discharge. 1. impermeable rocks; 2. limestones; 3. ponor; 4. spring; 5. proved communication between ponor and spring; 6. possible surface storage (Komatina, 1985)

Under conditions of coastal karst, the principal question is how to level groundwater amount during the budget year. But, it seems that it is of the less importance in comparison to problem of confining fresh water from hydrochemical influence of the sea. Although this problem is more difficult for solving, within coastal karst, there are localities where successful regulation solution can be prognosed. That is the case with areas rich in contact springs, where, by damming (injecting) of limited number of privileged collectors, water level is possible to be lifted, and by suitable backwater, to eliminate (or significantly reduce) hydrochemical influence of the sea. The most important procedure is to «heal» the eroded part of the barrier by a suitable way (grout curtain, for example). Such intervention, with previous experiments, was performed in the area of Orebic (Peljesac peninsula, Croatia) (KOMATINA, 1971, 1976). Obtained results served to justify correctness of the applied concept in solving the problem (Fig. 4).

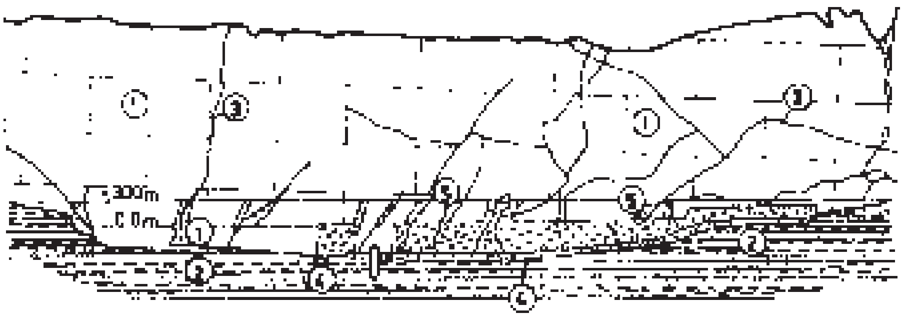

Figure 4. Geologic cross-section along the area of the exsurgence Veliki Vodovar near Orebic. 1. limestones - permeable; 2. flysch - impermeable; 3. open fracture; 4. concrete wall; 5. fracture filled with cement (KOMATINA, 1990)

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