The contribution of geological-mining engineering to groundwater tapping in karst aquifer systems. Case studies

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Abstract: Many case studies existing in karstic countries prove that in hydrogeological investigation of karstic terrains, the methodological concept of geological-mining engineering works appears as irreplaceable method for groundwater tapping in karst aquifer systems.

Key words: karst, aquifer systems, geological-mining engineering work.

Introduction

Although direct observations in limestone areas prove the heterogeneous of permeability and well-expressed anisotropy caused by significant development of karstic forms, from surface to a depth, another adaptation to the aquifer scheme system for studding groundwater flow appears to bi possible. Faced with those particularities we ought to pint that in carbonate rocks the aquifer systems are situated in a media which reflects different kinds of groundwater flows: the first, represented with the channel-networks of great transmissivity and the second, consisted of voluminous media with poor permeability in block-matrixes. Consequently , in the saturation zone of karst aquifer system, the channel-networks drains the block-matrixes during the dry period, but in the recharge period feed them (Fig.1). This is the very known phenomenon, named «inversion of hydraulic gradient»[1]. It is very important to emphasize, that this phenomenon implicate the notion of «basic level of groundwater flow», which is most important parameter to define the boundary conditions for reliable design of geological-mining engineering works.

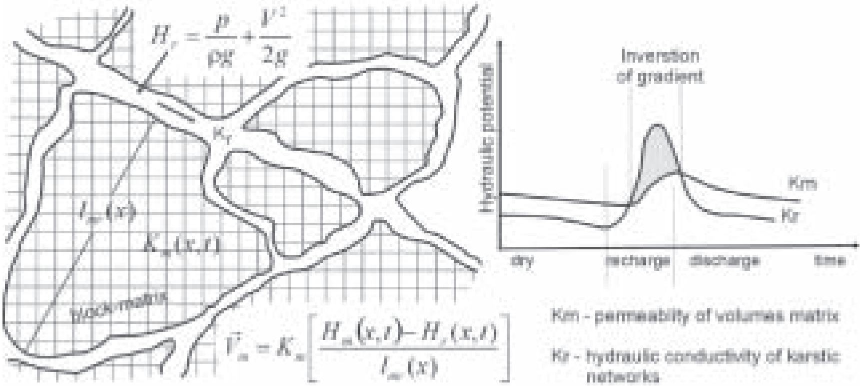

Figure 1. Hydrodynamic behavior of karstic system

So, it is clear that in karst aquifer system only channel-networks are responsible for the groundwater flows. This fact continually forced us to face the question if, and in what

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manner, we can use technical control measures to regulate groundwater flows for more efficient exploitation. Several case studies representing the typical examples of geological-mining engineering work for artificial improvements of groundwater tapping. The method for increasing the volume of stored water and for controlling discharge, with better yield, involves such measures, as underground dams, the grout curtains and particularly the drainage galleries. It is emphasized that geological and hydrogeological research is essential and irreplaceable approach to the success of planned (projected) artificial improvements.

RESULTS AND DISCUSSION

On groundwater tapping in karst aquifer systems by geological-mining works, the phenomenon, named inversion of hydraulic gradient has, them, as a consequence the problem of reliable determination of optimal level of drainage gallery in connection with the «basic level of groundwater flow». This complex problem is tested during excavating works in on drainage gallery in mountain karstic area in Montenegro. This example gives the some important remarks, concerning the hydraulic potentials measures simultaneously in the block-matrixes and in the channel-networks, during several years: /1/ The potentials measures in observation well Mo_1, during recharge period, are below basic level of groundwater flow in channels-network (observation well Mo_3), because drainage gallery yields more than 1m^3/s; /2/ In dry period the yield of the gallery is decreasing to only 20-30 l/s, because measured potential of groundwater flow in Mo_3 is below the water level in Mo_1 and also below level of drainage gallery.

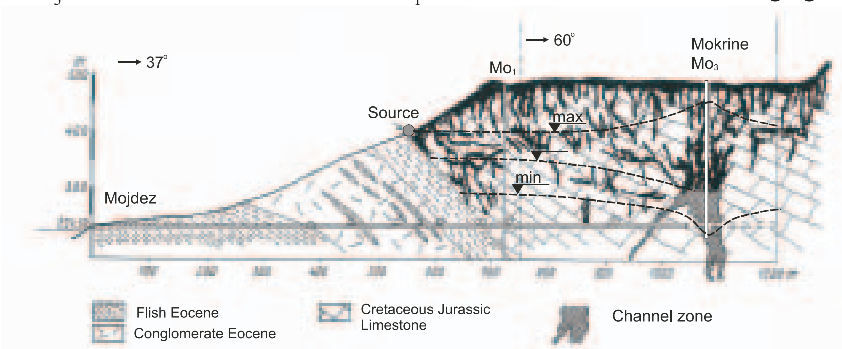

Figure 2. Hydrogeologic cross-section at the Modez-Mokrine site

The main purpose of the groundwater tapping project in the locality Sidi Mansur, near Benghazi (11 km from coast) consisted of geological-mining excavating the vertical shaft (deep 82 m) and horizontal drainage gallery (length 500 m) perpendicular to groundwater flow, which is tectonically predisposed on direction from Sidi Mansur to coastal spring Ain-Zeina (Lagoon Blue). On the base of complex hydrogeological research two important data were found out: /1/ The minimum level of groundwater in the site of captage is at + 3.5 m and because of the bottom of the gallery is seated at + 1.90 m; /2/ The width of groundwater brackish zone from the costal spring Ain-Zeina (whose minimum yield reaches more than 1.0 m^3/s is measured to more than 1 km (by observation wells network), what caused that the gallery length must have been 500 m [3]. The total capacity of pumping is 400 l/s with average salinity of 300-350 ppm. Unfortunately, monitoring system for saltwater encroachment control has never been established; This situation resulted with serious deterioration of freshwater quality, (1500 ppm Cl), after 15 years of permanent water supply by Sidi Mansur captage.

Figure 3. Spring Ain-Zeina (Lagoon Blue)

The "Roman Well" tapping structure 2 km far from the brackish spring at the sea coast was constructed for water supply of the town of Trogir (Croatia). The tapping structure consist of a vertical access shaft, 82 m deep (the shaft bottom is at sea level), and two branches of a horizontal water-collecting gallery in total length of 270 m[2]. Gallery bottom elevations are 1.5 m and 2.5 m a.s.l. The galleries intersects five tectonized and karstified zones containing concentrated underground flows. The pumping rate from gallery, in dry period, amounts to 120 l/s. To control the eventual salt-water intrusion and observation well was installed. It reaches the depth of 30 m below seal level[4].

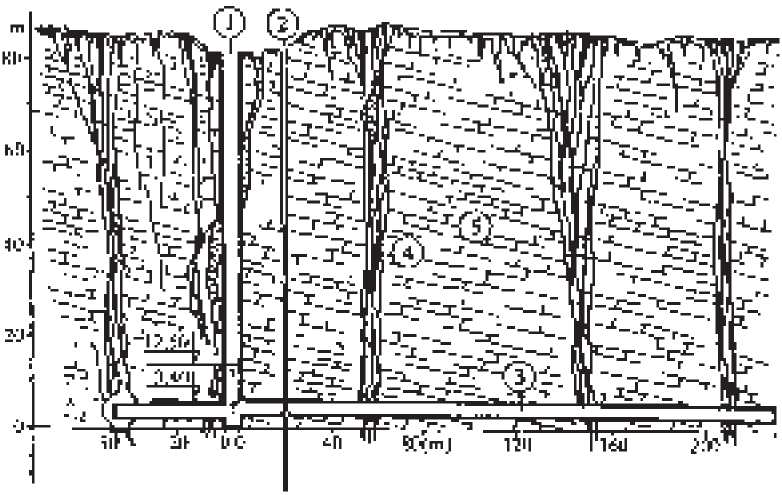

Figure 4. Cross-section of "Roman Well" gallery

1. Vertical shaft; 2. Piezometric borehole; 3. Horizontal gallery; 4. Tectonized zone; 5. Limestone;

The tapping of freshwater in costal karst aquifers with cavities of large size and preferred directions of drainage, involves many risks concerning both capacity and water quality if the tapping is based on a system of wells. It is evidently that the tapping facilities of the horizontal gallery type have proven to be reasonably efficient under such conditions. They obtain maximum capacity through cavities with preferred level of groundwater flows, they reduce salt-water encroachment during withdrawal of freshwater. The balance can be obtained by regulation of pumping or by radical intervention in the channels themselves (building and artificial barrier, like grout curtains, across direction of water circulation).
Horizontal drainage galleries have played positive roles at several locations in coastal karst regions. Table below gives some basic information concerning the tapping facilities on the Dalmatian coast and the one near Benghazi on the Libyan coast.

Locality	Distance from the sea (km)	Technical Characteristics		Min capacity (l/s)	Cl^- content ppm (mg/l)
		Depth of shaft (m)	Length of gallery (m)		
Dubrava 1	3.0	28.0	110.0	35.0	35
Dubrava 2	3.7	40.0	150.0	15.0	50
Kovèa	4.0	70.0	50.0	25.0	30
Roman well	2.0	82.0	270.0	100.0	150-300
K_1-Braè	0.8	18.0	20.0	1.0	400-500
K_2-Braè	1.8	520	400.0	5.0	300-400
Žuljana	1.0	18.0	30.0	10.0	300-400
Marina	3.0	33.0	400.0	45.0	200-250
Sidi Mansour Lybia	11.0	80.0	500.0	400.0	250-300

CONCLUSIONS

Groundwater potential of karst aquifer systems as natural reservoirs brings out the necessity of their rational exploitation by geological-mining engineering works, to aim the artificial improvements of groundwater tapping and technical systems of control.

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