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HYDROGEOLOGICAL INVESTIGATIONS OF THE LOCALITY "MITEV MOST" FOR WATER SUPPLY TO KUMANOVO WITH GROUND WATER

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A b s t r a c t: This paper shows the results from detailed hydrogeological investigations on locality Mitev Most for water supply to Kumanovo with ground water. In the first stage of investigations were conducted detailed hydrogeological and geophysical explorations and were made six exploration boreholes. In the second phase, in the alluvial Quaternary sediments and in the Paleozoic marbles were made three exploration – exploitation wells EB-MM–1 with depth of 42 m, EB-MM–2 with depth 33 m and EB-MM–3 with depth of 46 m. Based on the individual and grouped testing of the wells and conducted graphical analysis on the results from pumping, exploitation yielding of each well was determined and they amount to 20 l/s for EB-MM–1, 12 l/s for EB-MM–2 and 18 l/s for EB-MM–3.

Key words: ground water; Paleozoik marble; alluvial sediments; exploitation wells; Kumanovo

INTRODUCTION

Ground waters in the Republic of Macedonia very often are used for water supplying of the cities with quality drinking water or technical water (Gjuzelkovski, 1997). For the provision of ground water for water supply in Kumanovo, on site "Mitev Most" is performed detailed hydrogeological investigations. In the first phase of investigation is conducted hydrogeological mapping, geophysical electrical sounding and were made six investigation hydrogeological boreholes (Peševska, 2003). Based on the data from the first phase, in the second phase were carried out three test exploitation wells (Peševska, 2004).

Exploration area is located in southeast suburban parts of the town of Kumanovo near the village of Proevce (Fig. 1), or it is located between the Kumanovska River and the road to the village of Proevce.

GEOLOGY OF THE RESEARCH AREA

According the tectonic regionalization of Macedonia, exploration area "Mitev Most" belongs to Vardar zone (Arsovski, 1997).

Geological composition of the wider vicinity of the exploration area is presented on Figure 2. It is composed of Quaternary and Neogene sediments, Cretaceous granodiorites, Jurassic sediments and Paleozoic marbles (Karajovanović et al., 1972).

The youngest rocks on the research area are Quaternary alluvial sediments present along the riverbed of Kumanovska River and represent with sands and gravels.

Neogene sediments are represented with Pliocene sands and clay and Miocene sandstones which are widespread on the west of the locality "Mitev Most".

On the south of the investigation area is present small protrusion of granodiorites of Cretaceous age, and south of it ocurs larger mass composed of Jurassic limestones and Jurassic flysch sediments.

The oldest rocks on this terrain are Paleozoic marbles present north of the village of Proevce and on the left side of Kumanovska River, around the place Golem Rid, and serpentinites of Biljanovce which are of Paleozoic age, too.

Fig. 1. Location of the research area

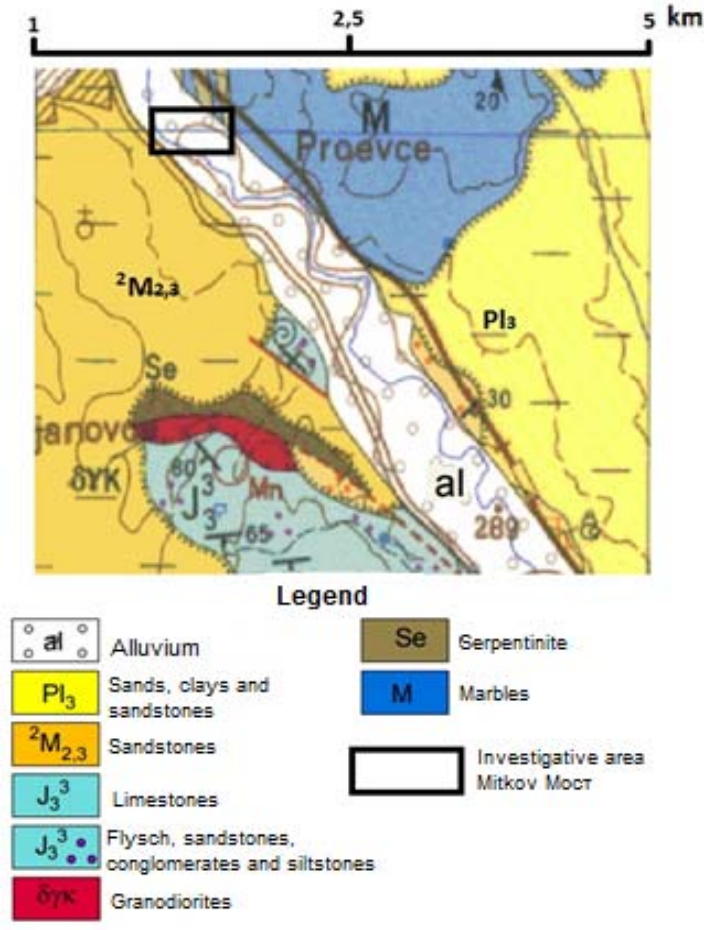

Fig. 2. Geological composition of the wider vicinity of the exploration area

HYDROGEOLOGICAL CHARACTERISTICS

Based on the conducted exploration hydrogeological boreholes is determined that the locality Mitev Most is composed of:

1. Water permeable rocks represented by:
   – water permeable loose rocks
   – water permeable solid rocks
2. Waterproof rocks
   – waterproof semi-bound rocks.

Hydrogeological characteristics of the locality Mitev Most, hydrogeological profile and location of conducted test and exploitation boreholes are shown on Figs. 3 and 4.

Water permeable loose rocks

In the group of loose rocks belong Quaternary alluvial sediments along the riverbed of Kumanovska River. These sediments are represented by gravels and sands which on some places are clayed. With the exploration boreholes they are determined on depth of 0.0–10.2 m.These sediments are with intergranular porosity and in them is formed boundary spring with free level. The level of ground water is shallow under the terrain surface in the interval 2.0–2.46 m and is in hydraulic connection with Kumanovska River. Feeding of the spring is with water from Kumanovska River and atmospheric falls.

Water permeable solid rocks

Water permeable solid rocks are the most present on the exploration area and are represent with Paleozoic marbles. With the exploration drilling were confirmed on depth of 7 – 50 m. Above the marbles are alluvial sediments. They are captured with the process of karstification and in them is developed cavernous – fissure type of porosity. There is karst – fissure type of aquifer with free level. The level of ground water depends on morphology of the terrain and local hydrogeological structure. Feeding of the aquifer is with atmospheric falls, as well as feeding from ground water from other aquifers.

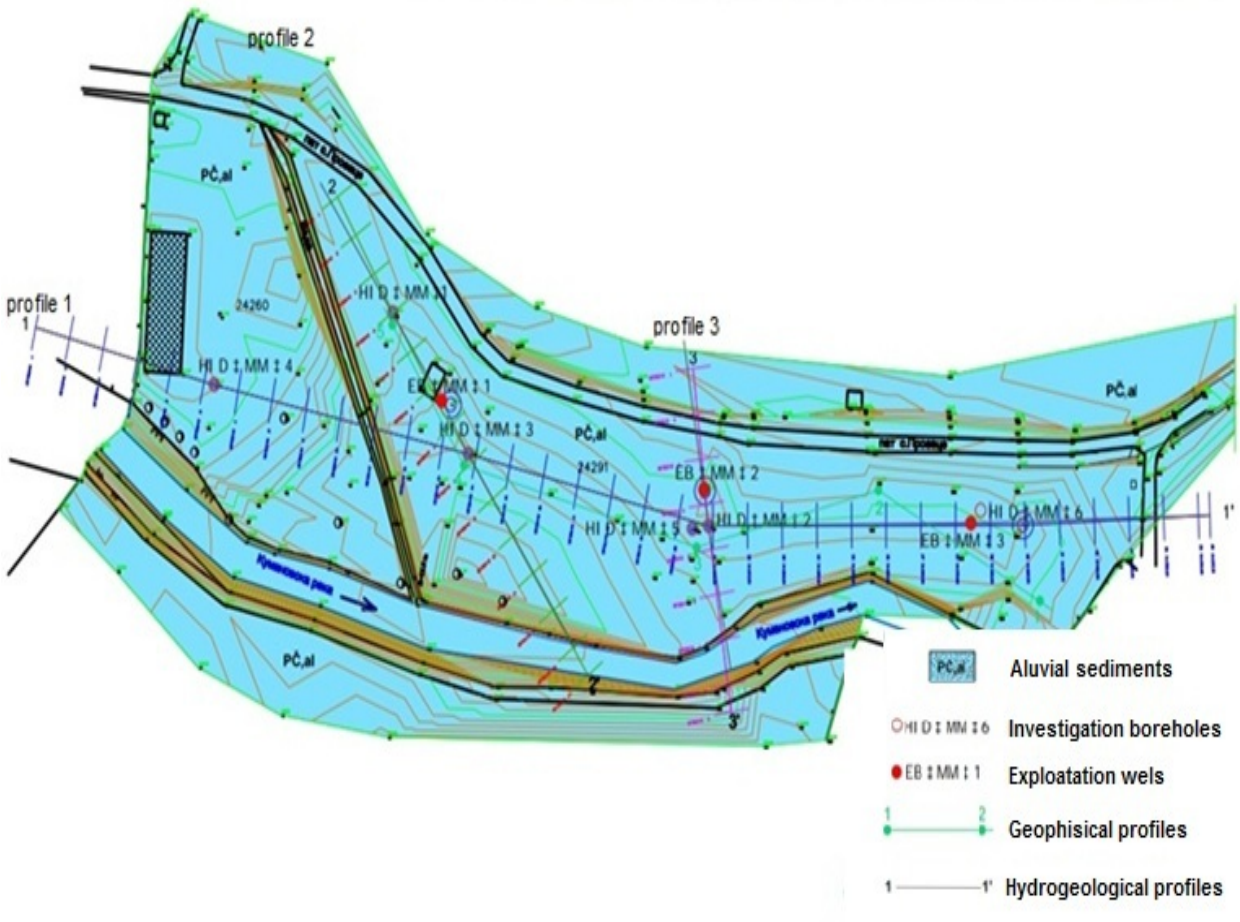

Fig. 3. Hydrogeological map with presented boreholes and wells at a locality “Mitev Most”

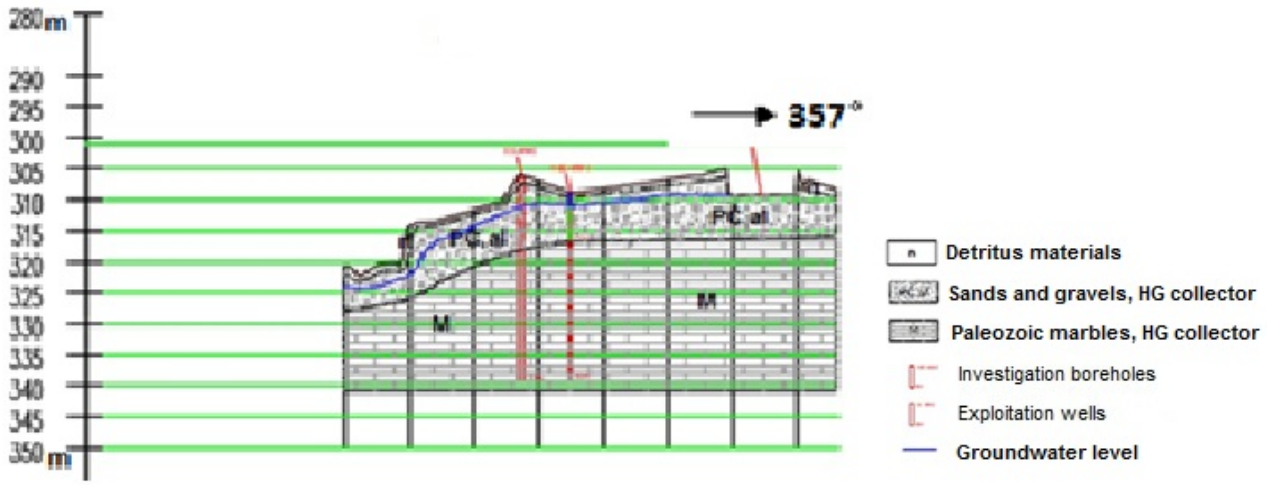

Fig. 4. Hydrogeological profile 3–3`

Waterproof rocks

Waterproof semi-bounded sediments are composed of sandstones, slates and marls. Miocene sediments on the surface of the exploration area are present southwest of Proevce and southeast of locality Mitev Most, on the right side of Kumanovska River. They are poor water permeable and water bearing to waterproof and locally in them can be formed aquifer, but mainly they have function of hydrogeological isolator and are not interesting of aspect of performed hydrogeological investigations.

DETAILED HYDROGEOLOGICAL INVESTIGATIONS

In the first phase of hydrogeological investigations on locality Mitev Most are performed six exploration boreholes, and obtained results are present in Table 1.

Data obtained with exploration drilling on locality Mitev Most show existence of two aquifers – one in the alluvial sediments of type boundary spring with free level and the second is formed in Paleozoic marbles which is of karst-fissure type.

T a b l e 1

Overview of performed exploration boreholes on locality Mitev Most

Locality	Investigation boreholes	Depth (m)	GWL (m)	Quantity of water (l/s)	Lowering (m)	Geological environment
Mitev Most	HID-MM–1	10	2.32	6.6	0.71	Alluvial sediments and marbles
	HID-MM–2	30	2.00	6.6	1.3	Alluvial sediments and marbles
	HID-MM–3	10	2.40	6.0	1.18	Alluvial sediments and marbles
	HID-MM–4	10	2.46	7.0	1.71	Alluvial sediments and flysch
	HID-MM–5	50	2.31	5.5	2.61	Alluvial sediments and marbles
	HID-MM–6	9	2.0			Alluvial sediments and marbles

Based on the performed chemical analyses of ground waters from the boreholes is determined that ground water from the aquifer formed in alluvial sediments, according the quality is not appropriate with the standards of MDK (maximum allowed concentration) of certain elements for drinking water such as increased presence of manganese, nitrates and nitrites. The result of test pumping of the borehole HID-MM–5, which is with depth of 50 m and enters in Paleozoic marbles, shows relative small depressions of ground water with significant capacities of pumping, testifies to the existence of a karst fissure aquifer with free level in the Paleozoic marbles. Chemical analyses of water from this aquifer showed better quality (lower concentration of manganese, nitrates and nitrites) so it was decided, the catchment of the ground water to be from karst – fissure aquifer formed in Paleozoic marbles which are under alluvial sediments.

Test pumping of boreholes

In order to define the filtration characteristics of the environment and the yielding of the boreholes it was performed test pumping of all (six) boreholes. The testing is performed on several dynamic levels, with duration of 24 – 36 hours, continuous, with systematic monitoring of the lowering of the ground water level depending on the yielding and time, during the pumping and during recovering of the level, or continuous monitoring of the functional dependance $S = f(t)$; $Q = f(t)$; $S = f(\log t)$ and $S = f(Q)$ (Jacob, C. E., 1944).

Calculation of filtration features of the environment

Filtration features of the environment are calculated for conditions of unsteady flow in the aquifer with free level of ground water after the Jacob's method and in the form of Dipi (Cooper, H.H. and C.E. Jacob, 1946).

– Water permeability T (m^2/s)

Water permeability is calculated based on the results of testing of the boreholes for the third lowering, from diagram $S = f(\log t)$.

$$T = 1\times10^{-2} \text{ m}^2/\text{s}.$$

– Coefficient of filtration K (m/s)

$$K = T/m \text{ (m/s)}$$

T – water permeability (m^2/s);

$$m = H = 4 \text{ (m)}$$

thickness of water bearing layer (adopted).

$$K = 2.5\times10^{-3} \text{ m/s}.$$

– Coefficient of filtration K (m/s) after Dipi.

Coefficient of filtration is calculated after the form of Dipi for the third lowering, for each well that drain aquifer with free level of ground water.

$$K = 2.45\times10^{-3} \text{ m/s}.$$

TECHNOLOGY OF PERFORMING AND TECHNICAL PARAMETERS OF EXPLOITATIONAL WELLS

For capturing of ground water from the locality Mitev Most karst-fissure aquifer in the Paleozoic marbles were drilled three exploitation boreholes EB-MM–1, EB-MM–2 and EB MM–3. Drilling was done with rotary roll chisels φ 650, 450 and 400 mm using bentonite drilling fluid through alluvial sediments and with clean water through marbles, with drilling set Fraste (FS-300). The technical characteristics of the exploitation wells are shown in Figure 5.

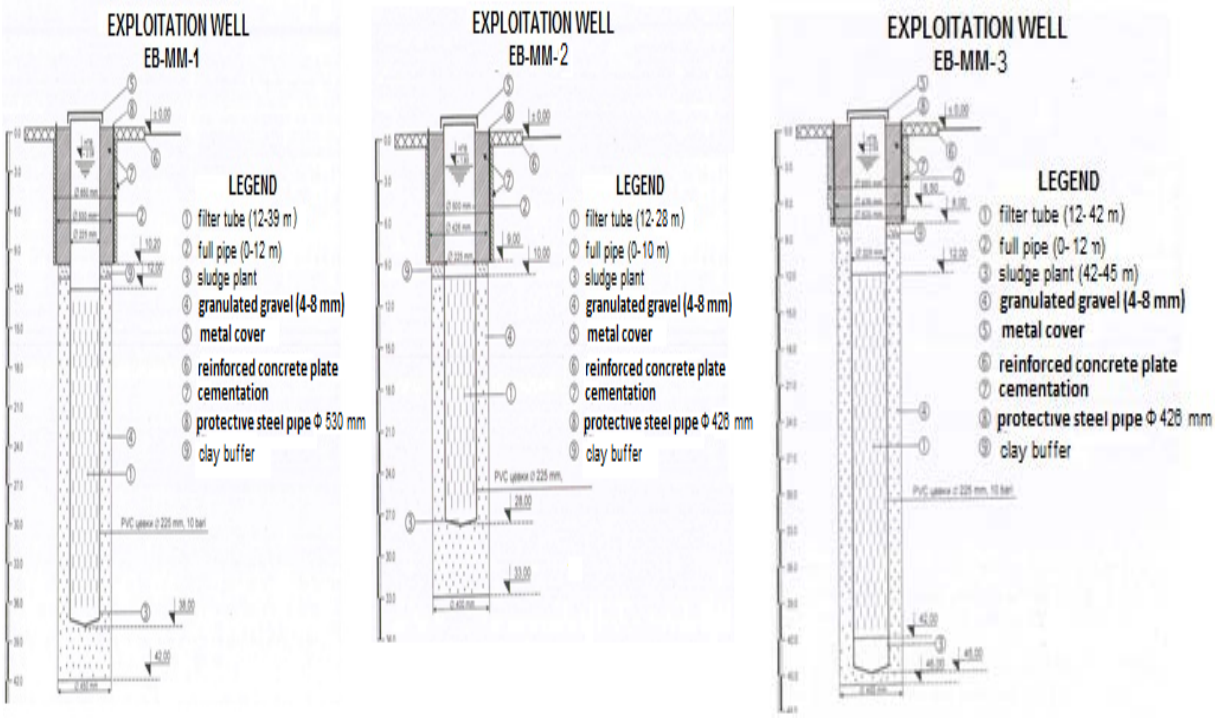

Fig. 5. Technical characteristics of exploitation wells

TEST PUMPING OF WELLS

In order to define exploitation yielding of the wells, performed is individual test pumping of all wells, as well as group pumping of the wells on locality "Mitev Most".

Individual testing

EB-MM-1

Testing was performed with three dynamic levels with duration of 72 hours, with systematic monitoring of the lowering of the ground water level depending on yielding and time, during the pumping and during recovering of the level, or continuous monitoring of the functional dependence

$$S = f(t); \quad Q = f(t) \quad S = f(Q).$$

Obtained results from test pumping are presented in Table 2.

T a b l e 2

Presentation of the results from test pumping of EB-MM–1

GWL	Test pumping				
static (m)	Q (l/s)	НПВ (m)	S (m)	q (l/s/m)	t (h)
	10.1	4.09	1.75	5.8	20
2.08 – l.t. 2.34	17	4.48	2.14	7.94	24
	23	5.08	2.74	8.39	28

l.t. = level of the terrain

On Figure 6 is showed diagram of dependence of lowering and yielding from time S,

$$Q = f(t).$$

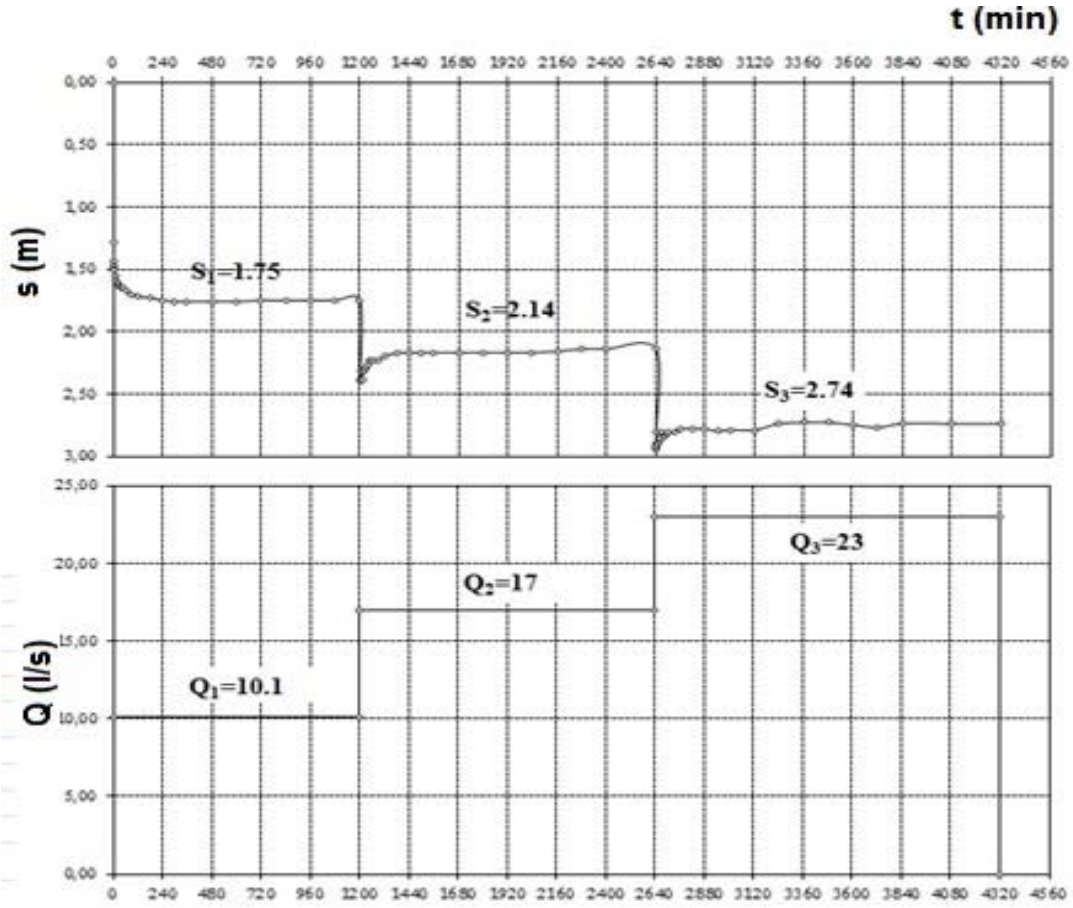

Fig. 6. Dependence of lowering and yielding from time S, $Q = f(t)$

EB-MM-2

The testing was performed in three stages with six hydrodynamic levels with duration of 90 hours. Obtained results are present in Table 3. In the Table 4 is shows the third stage of testing which is performed with 3 capacity and 3 hydrodynamic levels for a period of 46 hours.

T a b l e 3

Presentation of the results from test pumping of EB-MM–2 in the first and the second stage

GWL static (m)	Test pumping				
	Q (l/s)	GWL (m)	*S* (m)	*q* (l/s/m)	*t* (h)
1.93– l.t.2.20	6	3.16	0.96	6.25	6
	9	3.96	1.76	5.11	24
	12	4.41	2.21	5.42	12
	23.3	9.56	7.36	3.16	28
	20	9.42	7.22	2.77	8
	17.5	8.90	6.70	2.61	12

l.t. = level of the terrain

T a b l e 4

Presentation of the results from test pumping of EB-MM–2 in the third stage

GWL static (m)	Test pumping				
	Q (l/s)	GWL (m)	*S* (m)	*q* (l/s/m)	*t* (h)
1.95 – l.t. 2,22	12.5	10.36	8.14	1.54	12
1.93 – l.t. 2,20	8.8	6.75	4.55	1.93	6
	14.5	12.22	10.02	1.46	28

l.t. = level of the terrain

EB-MM-3

The test pumping was performed with four hydrodynamic levels with duration of 72 hours, and obtained results are presented in Table 5.

T a b l e 5

Presentation of the results from test pumping of EB-MM-3

GWL static (m)	Test pumping				
	Q (l/s)	GWL (m)	*S* (m)	*q* (l/s/m)	*t* (h)
2.04 – l.t. 2.37	9.3	3.46	1.09	8.34	16
	12	4.20	1.83	6.55	16
	18.1	9.29	6.92	1.95	24
	20	11.28	8.91	2.24	16

l,t. – level of the terrain

Group pumping

In order to obtain the total yielding of the three boreholes, it was performed group pumping with duration of 72 hours. Results from the group pumping are presented in Table 6.

On Figure 7 is shown diagram of dependence of lowering and yielding from time *S*,

$$Q = f(t)$$

from group pumping**.**

T a b l e 6

Presentation of the results of group pumping of the wells

Well	Group pumping					
	GWL static (m)	*Q* (l/s)	GWL dynamic (m)	*S* (m)	*q* (l/s/m)	*t* (h)
EB-MM–1	2.08 – l.t. (2.34)	17.2	4.51	2.17	7.92	24
		20	5.10	2.76	7.25	48
EB-MM–2	1.90 – l.t. (2.17)	9	5.94	3.77	2.38	72
		18	6.28	3.92	4.59	0.5
EB-MM–3	2.03 – l.t. (2.36)	16.5	5.31	2.95	5.59	5.5
		15.5	5.25	2.89	5.36	16
		18.0	6.93	4.57	3.94	50

(l.t. = level of the terrain)

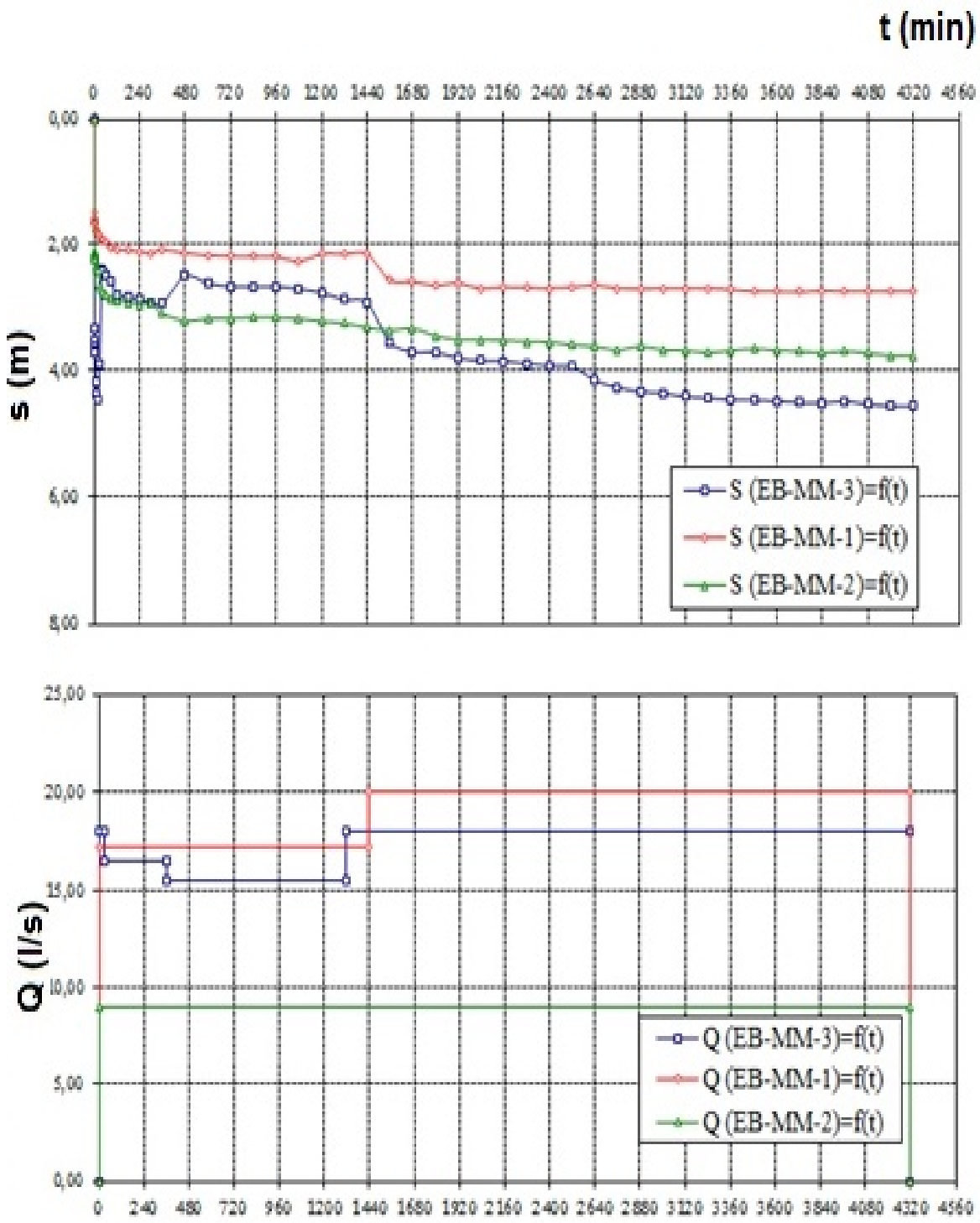

Fig. 7. Dependence of lowering and yielding from time *S*, $Q = f(t)$ from group pumping

EXPLOITATION YIELDING OF WELLS

According performed individual and group pumping of the wells EB-MM-1, EB-MM–2 и EB-MM–3 and graphical analysis of the results from pumping were determined exploitation yieldings of each well which are presented in Table 7.

For the well EB-MM–2 for exploitation capacity of 12 l/s which is not reached with the group pumping, the level of ground water or lowering is obtained graphically. Given the location of well system and analysis of the conditions of feeding,

the aquifers formed in the marbles that are subject to exploitation of performed wells do not expect major seasonal fluctuations of yielding of wells. In the dry period is expected up to 20% lowering of the ground water level in the wells (but not as a smaller capacity) which means that into a dry period for these facilities will occur lowering to 1–2 m. In the table with the presented results for the exploitation yielding of wells are taken into consideration such additional seasonal lowering of the ground water level, or larger lowering from that obtained with group testing.

T a b l e 7

Presentation of exploitation yielding of the wells

Well	Depth (m)	GWL dynamic (m)	*S* (m)	Exploitation yielding *Q* (l/s)
EB-MM–1	38	6.0	4.0	20.0
EB-MM–2	28	9.0	7.0	12.0
EB-MM–3	45	8.0	6.0	18.0

CHEMICAL COMPOSITION OF GROUND WATER

To define the chemical characteristics of ground water of the investigating area, from each well water samples been taken. The results are shown in Table 8. The contents of the analyzed components are compared with the maximum permissible concentration (MPC) provided in the Regulation on Water Safety (Official Gazette of R. Macedonia Nr. 46/08). From the completed comparison can be seen that in the well EB-MM–1 and EB-MM–2 have increased content of Fe and Mn, while the other components are with in the MPC. According to the classification of Alekin water belongs to the group of hydrocalcite waters (Alekin A. O., 1970). To be used for drinking water must be previously purified, i.e. to make demanganization and deferization.

Obtained values from hydro-chemical investigations presented in Table 8, graphically are presented in Figure 8.

T a b l e 8

Results of the analyzed hydro-chemical data (mg/l)

	EB-MM–1	**EB-MM–2**	**EB-MM–3**	MPC for drinking water standard of Macedonia
Fe	1.694	0.011	0.098	0,2
Mn	0.13	0.18	0.035	0.05
Ca	117.400	106.300	110.300	–
Mg	34.09	47.200	44.840	–
Cu	0.007	0.002	0.001	2
Zn	0.099	0.040	0.039	3
Ni	0.006	–	–	0.02
As (µg/l)	–	5.730	5.600	0.01
Sr	0.17	0.253	0.288	–
K	6.540	8.180	8.140	12
Na	68.500	36.400	34.090	200
HCO_3	445.300	420.900	420.900	<30
NO^2	0.008	0.011	0.006	0.10
NO^3	13.600	11.360	13.600	50
TDS	694	576	640	<1000
pH	7,24	7,09	7,19	6.5– 9.5

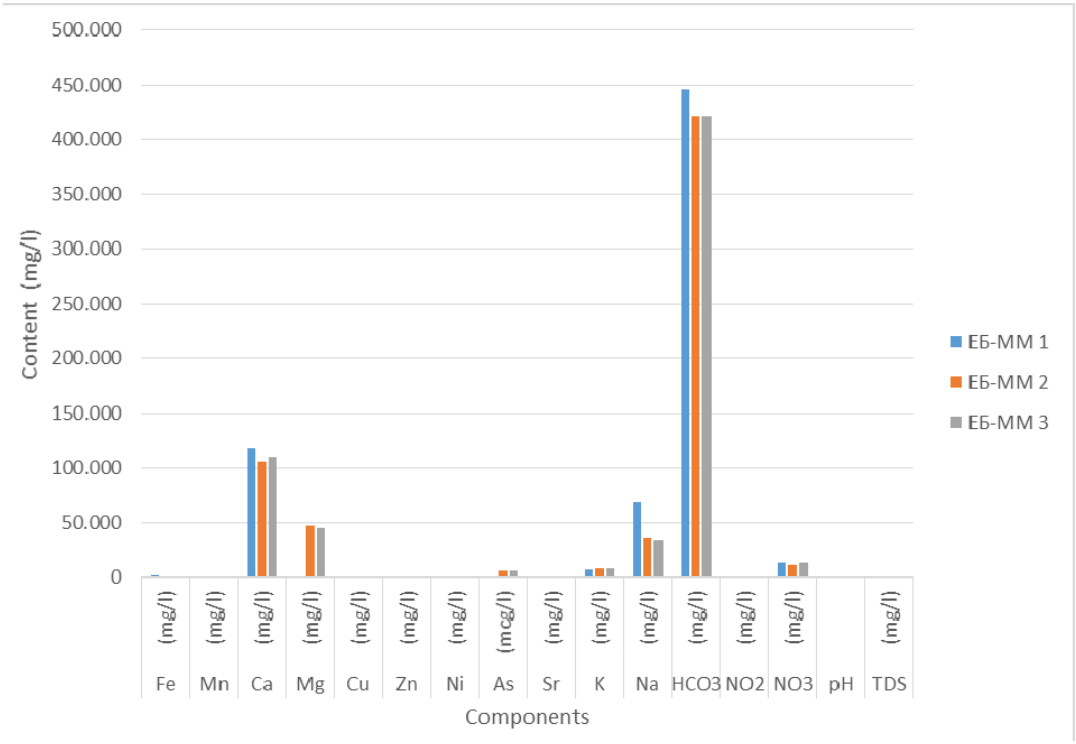

Fig. 8. Graphical presentation of analyzed hydro-chemical data

CONCLUSION

Performed detailed hydrogeological explorations showed that the most optimal solution for water supply of the city of Kumanovo are ground waters of karst fissure aquifer formed in karstified Paleozoic marbles on locality Mitev Most.

Based on the hydrodynamical characteristics of the level, the aquifer belongs to the group of aquifers with free level.

According the performed individual and group testing of the boreholes is determined that the total yielding of the wells amounts to 50 l/s.

Feeding of aquifer with water is with atmosphere falls and inflow from other springs.

Given the location of well system are not expect major seasonal fluctuations of well yielding.

Chemical analyses of water show increased concentration of nitrates, iron and manganese and it is necessary to carry out denitrification, demanganization and deferization of water to use it for drinking.

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Р е з и м е

ХИДРОГЕОЛОШКИ ИСТРАЖУВАЊА НА ЛОКАЛИТЕТОТ „МИТЕВ МОСТ“ ЗА ВОДОСНАБДУВАЊЕ НА КУМАНОВО СО ПОДЗЕМНА ВОДА

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Клучни зборови: подземна вода; палеозоиски мермери; алувијални седименти; експлоатациони бунари; Куманово

Во овој труд се прикажани резултатите од деталните хидрогеолошки истражувања на локалитетот Митев Мост заради водоснабдување на градот Куманово со подземна вода. Во првата фаза на истражување се спроведени детални хидрогеолошки и геофизички испитувања и се изведени шест истражни дупнатини. Во втората фаза во алувијалните квартерни седименти и во палеозојските мермери се направени три истражноексплоатациони бунари: ЕБ-ММ–1 со длабочина од 42 m, ЕБ-ММ–2 со длабочина од 33 m и ЕБ-ММ–3 со длабочина од 46 m. Врз основа на поединечното и групното пробно тестирање на бунарите и изведената графоаналитичка анализа на резултатите од црпењето, одреден е експлотациониот капацитет на секој бунар, кој изнесува за ЕБ-ММ–1 20 l/s, ЕБ-ММ–2 – 12 l/s и ЕБ-ММ–3 – 18 l/s.