SUPPLY OF WATER TO CITIES IN EMERGENCY SITUATIONS

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METHODS AND TECHNICAL DEVICES FOR SOLVING PROBLEMS IN RISKY HYDRO-GEOLOGICAL AREAS

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Abstract

The Republic of Macedonia is located in a seismicly active region. The water supply to the city of Skopje is trought the regional water supply system “Rasce”. Changes in the flow of waters in the geological structures depend on the geological cracking formed during seismic activity.

In same cases, earthquakes can disrupted the geological structure and with them, those containing underground waters.

Up to now in the Republic of Macedonia, no noticable differences have been observed in the flow of drinkable underground waters. There have, however, been changes in capacity and temperature of thermal waters. Also, some minor changes have been observed in small above-ground flowing waters. These phenomena may (or may not) occur especially in epicentral locations.

It is well known that during seismic activity, further to the effects on the flow of underground waters and other geo-anomalies, there is the appearance of a reinforced geomagnetic field. Scientific studies of the damaging effects and protection thereof have been made by “Soncev Zrak”-Skopje.

Research of the flow of underground waters is carried out using modern methods such as:

- Satellite data;
- Above ground methods.

Combinations of these methods enable obtaining greater precision, as well as rapid and economical results.
Introduction

The Republic of Macedonia has fresh water in abundance. It has three natural reservoirs (lakes) as well as many artificial reservoirs serving as hydro power plants, irrigation systems and for other purposes. It also has many rivers and hot springs which are water abundant all year round, as well as ground aquifers (artesian, sub-artesian and phreatic water). All this water may be used for various needs.

But despite this plenty of fresh water at certain locations and regions, it has not been sufficiently present or sufficiently used. This is the case with the Prilep valley which has fresh water in abundance, which has not been sufficiently used, although the town of Prilep has water shortages.

The “Soncev zrak” (Sunray) Research Center from Skopje has been professionally working on human environment protection from the electro-magnetic radiation and it produces apparatus against it. Within this field of work, it has studiously involved itself into solving problems with water supply and discovering water in hydro-geological water scarce areas. To find a solution to this problem we use most advanced combined hydro-geological methods and techniques including satellite methods. These methods achieve quite precise results and success when discovering locations of ground fresh water flows.

One of such projects is the Project for solving the water supply problem to the towns of Prilep and Krusevo in Macedonia. This project also guarantees solution to the fresh water supply problem over a longer period.

Materials and methods

The “Soncev zrak” (Sunray) Research Center uses several methods and techniques for discovering ground fresh water. It is especially interesting to point out that it has specialized in discovering ground water flows.

This problem may be solved also in regions with low hydro-geological potential. In case there is a ground water flow, it keeps flowing aimlessly within the geological structure or flowing out into larger water basins. This may especially happen in deserted places or other areas that are poor in fresh water.

The methodology that is being used for discovering ground flowing water is developing in the following way:
- determination of necessary search location with the help of certain magnetometry obtained from appropriate satellite pictures (fig. 1);
- the magnetometry of the selected search location;
- electric sounding;
- hydro-geological test drilling;
- construction of wells, their pumping and putting them in use.

The searching methodology is very specific, so there is a need of well-trained expert team who can successfully apply these combined methods and techniques. Our previous experience has confirmed that these methods save time and money while yielding positive results.
The town of Prilep is being water supplied through the regional water supply system “Studencica”. The water system “Studencica” has been intended for capturing the water from the spring “Studencica” and its distribution to the finite beneficiaries, Kicevo, Prilep, Makedonski Brod and Krusevo, as well as raw water for the Mining Energetic Plant “Oslomej” (fig. 2).
The regional water supply system “Studencica” was put into use in 1981 and its designed exploitation capacity was 30 years. In 1998, the system was used for the water supply to 135,000 inhabitants, for which, along with the industrial and other water consumption about 700-800 l/sec are necessary. The maximal transporting capacity of the system is 1,5 m³/sec. At the end of the planned period – 2010, water supply to 192,000 inhabitants has been foreseen. Regarding the technical aspect, “Studencica” has been functioning without any serious problems from its launching into work in 1981 till the present. But it is important to note that since the moment of starting the system “Studencica” there have been periods when the discharge has lowered to 500 l/sec which caused serious problems with the water supply to the population.

In such periods, the town of Prilep, instead of the necessary 350-400 l/sec, was getting 100-130 l/sec of water, quantity that didn’t satisfy the town’s needs for drinking water, since it has about 75,000 inhabitants. If we take into consideration the necessary water quantities for the industry, the raw water for communal and other purposes, unavoidable losses etc., the town of Prilep, at the moment needs 400-450 l/sec of water. The estimated necessary water quantities for the town of Prilep by 2025 will exceed 500 l/sec.

All these facts prompt to urgent action for discovering new springs for water supply to the town of Prilep, which is exactly what this project offers.

**Tectonic characteristics of the Prilep region**

According to G. Kotevski and M. Arsovski, the Prilep Neogene basin with its greater part belongs to the horst anticlinorium, and a very little part belongs to the West Macedonian Zone (south-western part of the basin). The Prilep Neogene basin is a constituent part of the Pelagonian basin and the tectonic characteristics should be considered within the Pelagonian basin. It is known that the Pelagonian basin is a Neotectonic crag structure whose formation, according to N. Dumurdjanov et al., started at the end of the middle Miocene. The Prilep Neogene basin is situated between the Ljuben block in the west, the Jakupica block in the north, the Babuna block in the east and north-east, the Selecka block
in the south-east and the Topolcani beam (faultless structure) in the south which separates this basin from Bitola's share of the Pelagonian basin. These structures are located mainly along old pre-Neogene ones, reactivated during Neogene fault structures.

Within the Prilep region, the ground water accumulated is of these three types:

- Free level aquifers;
- Pressure level aquifers;
- Karst-fractured aquifers.

**Results and discussion**

**Ground water reserves**

One of the basic tasks of the hydro-geological exploratory works is to determine the ground water reserves, which is necessary for their rational use. On the basis of the reached degree of exploration of the Prilep Neogene basin, quantitative estimation of the ground water reserves and their categorization has been done. The ground water reserves of the Prilep basin have been formed in the Quaternary and Pliocene sediments. The alluvion of the river Crna Reka (Black River), in the south-western part of the explored area is a special hydro-geological region with a little stretching.

The ground water reserves of the Quaternary alluvial sediments of the Prilep Neogene basin are known and estimated according to the regional and detailed explorations, samples and exploratory-exploitation drawing from a great number of boreholes, dug and drilled wells, whereas the degree of exploration of the Pliocene sediments is significantly less and they have been categorized as potential reserves. The alluvial sediments of the Crna Reka (Black River) have been very little explored. The exploratory works went to shallow depth and dug wells and stamped pipes down to a depth of 6 m have been mostly done.

According to these data, the ground water reserves of this hydro-geological region may be categorized as potential reserves.

**Static reserves**

The static reserves are water quantity which has been formed and exists within the ground aquifer below the minimal level of ground water. These reserves depend on the aquifer volume and the effective porosity coefficient.

\[ Q_{st.} = F \times H \times n \]

\(F\) – aquifer surface;
The total static ground water reserves of the Prilep Neogene basin amount:

\[ Q_{\text{st. total}} = Q_{\text{st.1}} + Q_{\text{st.2}} + Q_{\text{st.3}} = 6980 \times 10^6 \text{ m}^3 \]

**Dynamic reserves**

Ground water flow directions in the Prilep Neogene basin can be seen on the hydrogeological map, M = 1:100,000. These directions have been known as dynamic reserves whose capacity amounts:

\[ Q_{\text{din.}} = 50 \times 800 \times 50 \times 0.001 = 2,000 \text{ m}^3/\text{day.} = 0.023 \text{ m}^3/\text{sec.} \]

**Exploitation reserves**

If we already know the dynamic and static reserves of ground water, the conditions of their formation, recharging and renewing ability it is easy to calculate the exploitation reserves. Hydro-geological practice offers several methods for calculation of these reserves: hydrodynamic, hydraulic and balance method. According to these methods, the exploitation reserves of ground water in the Prilep Neogene basin are as follows:

\[ Q_{\text{explo}} = \frac{6755 \cdot 10^6}{35 \text{ years}} \cdot 0.20 = 1.22 \text{ m}^3/\text{sec.} \]

A part of the renewing ability of these reserves is being obtained by infiltration of 8% of the total volume of water deposition of the whole confluence area of the Prilep Neogene basin. The renewing ability of the exploitation reserves has been provided by the infiltration of atmospheric deposits on the immediate surface of the Quaternary-Alluvial Proluvial sediments and by infiltration of water, which comes through surface flowing from the surrounding river basin and flows like occasional or lasting water course through the Prilep Neogene basin.

The area of the alluvial-proluvial sediments is 580 km\(^2\).
The mean quantity of water deposit is 570 mm.
The average infiltration is 10%.

With these input parameters, water quantity of 1 m\(^3\)/s. is being provided. The remaining 0.32 m\(^3\)/s are being provided with the water that comes from surface flowing from the surrounding confluence area. The renewing ability of the exploitation reserves within the alluvion of the Crna Reka (Black River) would be mostly done through infiltration of river water.

**Alluvial deposits of the river Crna Reka (Black River) (locality “A”)**

As mentioned in the previous chapter, the alluvial sediments of the river Crna Reka (Black River) in the whole Prilep region are lithological formations with most favorable filtration
characteristics and the best water bearing capacity. This locality is the most potential one from the aspect of supplying greater water quantities to the town of Prilep, which according to the previous findings are of good quality. Concerning the expected discharge from 30 to 50 l/sec. per well and possibly more, this locality, from this aspect, is far more perspective in relation to the other localities analyzed below in the text of this project. With the designed exploratory works all the hydraulic parameters of the aquifer and the total exploitation reserves will be precisely defined, as well as the possibilities and way of their capturing.

The area of 4-5 km in length and 1 km in width i.e. 4-5 km², will be included within the hydro-geological explorations, along the Crna Reka flow (Black River). The locality's distance from the town of Prilep is 20 km.

**Quaternary – alluvial sediments (phreatic aquifer) in the Prilep Neogene basin (localities ”B” and “C”)**

As mentioned in the previous chapter, the greater part of the water permeable rocks which are very interesting as springs from the aspect of the water supply to the town of Prilep, belong to this group of sediments. Within Prilep field, they occupy an area of about 375 km² in depth of 30-80 m. Within the Prilep region these rocks have been explored at the most.

A confined type of aquifer has been formed within these sediments, with free ground water level (phreatic aquifer), local and sub-artesian level.

The total exploitation reserves formed within these sediments in the Prilep Neogene basin, calculated at level C₁ and category B amount 0.68 m³/sec. From the previous findings about the existing exploitation wells in such sediments, the expected discharge of a constructed drilled well, 50 m in depth, ranges from 10 to 15 l/sec, and rarely, at certain locations, up to a greater discharge of 20 l/sec. Several populated areas are being water supplied from the wells constructed within these sediments in the Prilep region at the moment. Two localities have been foreseen for detailed hydro-geological exploration works concerning this hydro-geological region: the locality ”B” and locality “C” shown on the topographical map 1:25.000 (Fig. 3).

**The locality ”B”** This proposed locality is actually the most favorable one, from the aspect of its shortest distance from Prilep. This locality was also selected for detailed hydro-geological explorations because of the several wells drilled at this location with a capacity of 10-15 l/sec. which indicate favorable and perspective hydro-geological conditions. An area, 10 km in length and 1,5 km in width, i.e. an area of about 15 km² stretching on the left side of the road, at the exit from the town Prilep to the village Slavej, has been foreseen for detailed exploratory works. This greater area for detailed hydro-geological works has been selected due to the fact that the expected discharge of the wells is 15 l/sec. So, for supplying greater water quantities it is necessary to construct a greater number of wells, which in their turn will necessitate, within the exploratory works, and later on, within the well construction, encompassing of greater exploitation area. The wells constructed at this locality, in the vicinity of the town of Prilep, possibly in the area of the
old well field “Kosharka” could be included within the water supply system since this is the fastest and the most economic way to obtain additional water supply quantities for Prilep.

The locality “C”. This locality has been foreseen for detailed hydro-geologic exploratory works. It is located on the left of the road from Prilep to Makedonski Brod, and then from the dryery "Mazuciste" to the road to the village of Novoselani, 4 km in length and 1,5 km in width, an area of 6-7 km². This locality was selected because it is not so far from the town, as well as because of the three wells already drilled at this locality with a capacity greater than 10 l/sec. which indicates favorable hydro-geological conditions of this locality. The hydro-geological characteristics of this locality are very similar to those of the locality B. Here, for providing greater water quantities, it will also be necessary to construct greater number of wells and comprise a greater exploitation area.

Karst massif Debreshte (locality “D”)

This locality is situated in the north-westernmost part of the Prilep Neogene basin, in the north and north-west of the Debreshte village. An area of about 5-6 km² has been foreseen for exploring. The existence of the Debreste village at this locality is an indicator of the existence of a karst aquifer of greater ranges. The spring “Debreshte”, according to the data from the observations made in the period from 1992 – 1995 has a mean discharge of 51 l/sec and a maximal discharge measured in this period of 238 l/sec. This spring is not captured and is of a temporary character, which means there is a period when it gets dry.

This project foresees a minimal scope of exploratory works. Only if they give positive results will they be developed in the next phases.

The results obtained from the satellite explorations of the Seljacka Mountain slope are very interesting because of the indications of existence of ground water flow with a good discharge. In this case, there is a need of additional explorations with the application of geophysical hydro-geological methods.

After positive results have been achieved, de-leveling may be used, and then, in a natural way, by carrying out slope excavations, the same water may be taken out above the earth. After the project has been completed, the water flowing from the de-leveling, its speed and volume may be used for movement of small electric turbines, which will be installed on the pipe line. In this way, electric power will be achieved to meet some of the town's wants.

Most importantly, pure, drinking water with a constant temperature will be obtained. Finally, the water may be distributed to the beneficiaries in a natural way, without the use of additional pumping water and taking it into reservoirs.
CONCLUSION

From the above elaborated project, it may be concluded that the methodology for discovering ground water flow which the Sunray Research Centre from Skopje applies is fast, practical and very successful. It also gives a guarantee that the solution to the water supply problem to the town of Prilep is safe and permanent. These methods and techniques may be used for solving water supply problems to some natural reservoirs (basins) with reducing water abundance.

This was the case with Dojran Lake in Macedonia which was in danger of drying up. In the lake’s area ground water flow was discovered and wells were drilled to supply the lake with water. Two years later the condition is much more improved and a natural disaster is
avoided. Serious disasters threaten several lakes in the world as, according to some understandings, is the case with Galileo Lake. By implementing the same project as in Dojran Lake's case its disastrous end can be avoided. Five years ago, following a request of an Israeli firm, we prepared a project for discovering ground water flows in Israel. According to preliminary findings, there are indications of existence of ground fresh water flows in Israel, some of them in Galileo Lake's vicinity. If a project like this one is implemented there are good chances of finding ground water flows and their utilization for enriching and improving Galileo Lake's water-level and avoiding its disastrous end.

References


