Groundwater of alluvial aquifer as a significant resource for municipal water supply in Republic of Serbia

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Abstract: When solving the problem of municipal water supply for the towns in Republic of Serbia, groundwater from alluvial aquifers has been considered as a significant resource. Nowadays, in the Republic of Serbia all larger towns, including the capital Belgrade, utilize water from these aquifers, formed within alluvial deposits along the major river in Serbia. This paper presents hydrogeological properties of alluvial sediments of mentioned rivers including their location, width, lithological content, structural type, filtration and other hydraulic characteristics. A water-bearing horizon is a natural reservoir of unconfined groundwater that replenishes continuously during the year and is specifically described. The paper also describes the quality of groundwater and how it can be maintained.

Résumé: Pour remédier la problématique de l'alimentation en eau potable des villes en Serbie, les eaux souterraines des resources aluviales ont été concidérées comme un atout signifiquatif. Toutes les grandes villes, y compris la capitale Belgrade, utilisent aujourd'hui de l'eau provenant de ces aquifères qui se sont formés au sein des dépots aluviaux des cours d'eau majeurs de Serbie. Les caractéristiques hydrogéologiques des couches aluviales, y compris leur situation, épaisseur, composition lithologique, type structurel, capacité filtrante et autres caractéristiques hydrauliques, sont presentées dans cet ouvrage. Bassin aquifère constitue le réservoir naturel des eaux souterraines, qui se remplie durant toute l'année, ce qui est particulièrement détaillé dans l'ouvrage. L'ouvrage en question offre également la description de la qualité des eaux souterraines, ainsi que les moyens à mettre en oeuvre pour la préserver.

Keywords: alluvium, aquifers, groundwater contamination, hydrogeology.

INTRODUCTION

With regard to geological formations and hydrogeological properties of the terrain, alluvial aquifers are recognised as important sources of groundwater. They are developed along the largest rivers in Serbia including the Danube, Sava, Morava and Drina (Figure 1) (Energoprojekt 1985).

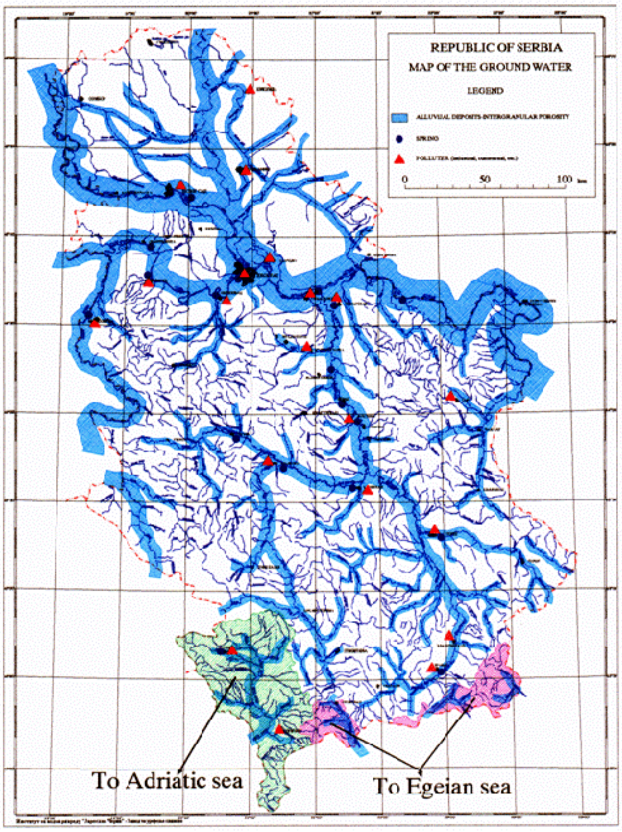

Figure 1. Map of alluvial aquifers

Most of the groundwater resources occur within river floods with e direct hydraulic connection between the surface (river) and the groundwater flows. In that way the river recharges the aquifer and increases the total exploitable capacity of the aquifer.

This mode of aquifer replenishment (recharge) implies that if there is a deterioration of river flow quality this will lead to a change in the quality of the groundwater from the aquifer. Therefore, preservation of the quality of the river flow must be of the highest concern of all users in the river basin. Almost all the main towns of Serbia that are located in basins of the Danube, Sava, Morava and Drina utilize water from the alluvial aquifers, which is subjected to chemical treatment before it is distributed to consumers. Nowadays groundwater is used both by population groups and by industries.

HYDROGEOLOGICAL PROPERTIES OF THE ALLUVIAL AQUIFER LAYER

Alluvial sediments, deposited along wide and spacious river valleys, are composed of layers of sand and gravel. The water-bearing sands and gravel layer is overlain by a surface layer that is composed of aleurite (silt) while the underlying strata are mostly made of impermeable Neogene clays (Figure 2). Considering the grain-size composition of samples from boreholes, we conclude that gravels form about 65% of the sediments with medium-grained sands forming the rest. These unconsolidated sediments have an intergranular porosity that averages 25 – 35 %.

The total depth to the base of these alluvial sediments is variable. The thickness of the sediment layers varies from 10 to 30m along the Danube (Table 1), from 10 – 20m along the Sava, from 3 to 14m along the Great Morava, (Table 2), while the average depth of this water-bearing gravelly layer along the Drina amounts to 15m, tending to increase toward the river mouth. The permeability of the water-bearing sediments layer varies from 1×10^{-2} to 1×10^{-5} m/s indicative of good groundwater storage (Table 1 and Table 2). These good water permeabilities relate to transmissivity coefficients of 1×10^{-2} to 1×10^{-3} m^2/s. Thus an abundant groundwater reservoir has been recognised within the sandy-gravel fluvial sediments (Anon. 1995).

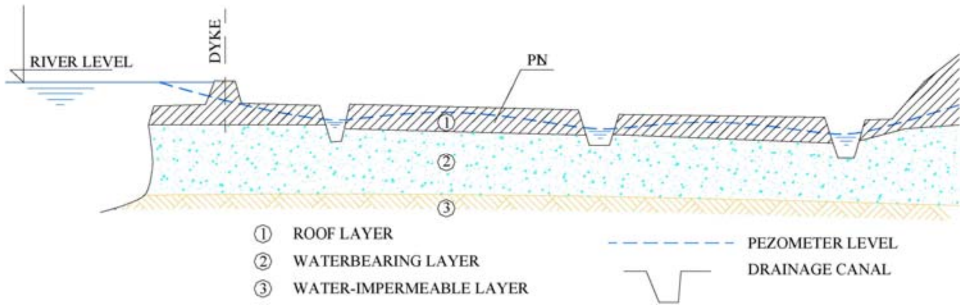

Figure 2. Hydrogeological section in the aquifer-river communication area

Table 1. Average depth (thickness) and permeability coefficient of the waterbearing layer of Danubian aquifer

Profile	Depth (m)	Permeability coefficient (m/s)
Pancevacki rit	20-25	1-4 x 10-4
Godomin	25-30	1-2 x 10-3
Kostolac	14-28	1-5 x 10-3
V.Gradiste	15-20	1-5 x 10-4
Golubac	10	1-2 x 10-4 - 10-5
Kladovo	10-15	1-8 x 10-3 -10-5

Table 2. Average depth (thickness) and permeability coefficient of the waterbearing layer of Great Morava`s aquifer

Profile	Depth (m)	Permeability coefficient (m/s)
Paracin	3.5-6.0	2.7 x 10-3 – 2.1 x 10-5
Cuprija	4.0-7.0	1.0 x 10-3 – 3.0 x 10-5
Bagrdan	6.0-10.0	1.0 x 10-4
Svilajnac	2.0-5.0	3.0 x 10-3 – 1.7 x 10-5
V.Plana	4.5-8.5	1.0 x 10-2 – 1.0 x 10-4
Vlaski Do	5.0-7.0	2.0 x 10-2 – 1,0 x 10-3
LJubicevo	10.0-14.0	7,2 x 10-2 – 5,0 x 10-3

Recharge of this aquifer is carried out by rainfall as well as by infiltration from river flow. Recharge by rainfall occurs over the whole surface of the aquifer while recharge from river flow occurs where the river channel cuts through the water-bearing gravel-sandy layer, establishing direct hydraulic connection between groundwater and surface flow.

The river flow affects groundwater mainly within the floodplain area, where the aquifer is directly influenced by the river, as confirmed by observations of piezometric levels. The results of such observations can be expressed by exponential graph (Figure 3). The amplitudes of the wave front are reduced with increased distance from the river.

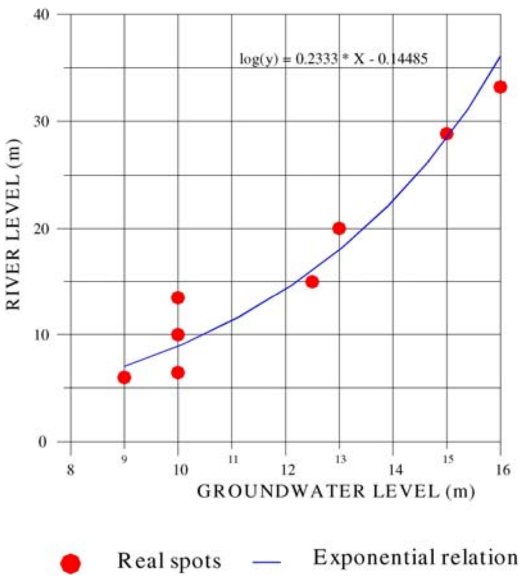

Figure 3. Relation graph between ground and river waters

POSSIBILITIES OF EXPLOITATION OF GROUNDWATERS FROM THE ALLUVIAL AQUIFER

For specific and regional provision of municipal water supply, the best aquifers are those in the alluviums of the Great Morava and Drina. The alluvium of the Great Morava is of strategic importance as its river course flows through the central park of Serbia. The groundwater reservoir formed in the alluvial sediments is continually replenished during the year. Its reserves are of dynamic character. For example, it is estimated that total dynamic capacity of the Great Morava for one hydrological year amounts to 1607 x 10^6 m^3 of water (Anon. 1995). The most abundant alluvial aquifer is Godominski rit, which, belongs to the alluvium of the Danube (Anon. 1980). It is possible to provide 1800 l/s from this aquifer (Babac & Kosti 1988). In the immediate vicinity of this aquifer is the locality "Salinac" that belongs to the alluvium of the Great Morava. It is utilized for water supply of the nearby town of Smederevo. Hydrological research of this aquifer confirmed the existence of a prominent water-bearing layer composed of gravel-sandy sediments of Pliocene-Quaternary age whose depth is over 50m. Such a good water-bearing layer provided conditions for the formation of an abundant aquifer that is in wide continuity with the Great Morava and the Danube whose waters replenish it. The rate of discharge from this wellfield is estimated at about 850 l/s (Komatina 1994).

The second best locality, is a region that stretches from the village of Trnavce to Lozovik. The depth of the alluvium on this part of the valley bottom is almost constant at 12-14m, while the depth of the collector layer amounts to 8m on the average, extending 7.5 km in the distance. It is estimated that this region could provide more than 1 m^3/s, while 600 l/s could be provided from the territory of the village Trnovce. The part of the valley from Osipaonica to Lubicevski Most has similar properties and it could provide 640 l/s, while the region Ljubicevski Most-Pozarevac could provide 900 l/s (Anon. 1985). With the potential for the possible utilization of regional groundwater springs, the development potential of the alluvium of the Drina is similar to the alluvium of the Great Morava. This is indicated by the significant depth of the alluvium, the good filtration characteristics of waterbearing layers of the aquifer, their potential specific capacity and very good hydraulic connection with the Drina river. The most abundant part of the aquifer is in the embankment area, along the river from Koviljaca to the mouth of the Drina with an estimated yield of 700 l/s including the spring at "Topolnik" within the Loznica`s aquifer. According to the Master Plan for Serbia the embankment area of the Drina could provide 4500 l/s of the high quality water (Stojadinovi 1992).

CONCLUSION

Considering the fact that groundwater represents a significant resource when solving the problem of municipal water supply and that it is the resource mostly used, we highlight its priority in utilization, especially in conditions where the alluvial aquifer provides the best solution. All the same, it is possible to execute long distance transfer of water from the regions with sufficient water to regions that lack water using regional distribution systems. The advantage of the utilization of this alluvial aquifer water illustrates the possible rapid development of a wellfield, and the possible of beneficial extension of a wellfield to meet increasing needs, as well as the application of cheaper technological facilities for water treatment.

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REFERENCES

ANON. 1980. *Elementary hydrogeological research on Determination of Capacity and Quality of the Groundwater in Godomin near Smederevo*, Geozavod, Belgrade

ANON. 1985. *Preliminary Report on Results of Research on Possible Water Supply of Smederevo from Salinac`s Lakes.* Institute "Jaroslav Cerni", Belgrade

ANON. 1995. *Water Master Plan of Serbia,* Institute "Jaroslav Cerni", Belgrade

BABAC, D. & KOSTIĆ, Z. 1988. *Hydrodynamic Investigations of Groundwater Sources,* Book 1.

ENERGOPROJEKT. 1985. Water Master Plan of Serbia, Book 1 and 2, "Energoprojekt", Belgrade

KOMATINA, M. 1994. *Hydrogeological Properties of the Territory of Serbia Proper and Possibilities of Groundwater Utilization for Water Supply of Towns and Industry,* Journal Geozavod, Book XII/XIII.

STOJADINOVI , D. 1992. *Hydrogeological properties of alluvial deposits and perimeter of the Great Morava with Regard to Utilization of the Aquifer,* Doctoral dissertation.