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SOME CHARACTERISTICS OF GROUNDWATER IN SOUTHEAST SREM

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Abstract: The area of Southeast Srem is rich in groundwater. Water regime of the first aquifer has a great significance from the standpoint of agricultural production. 32 piezometers were singled out and groundwater depth was measured aiming at the analysis of some groundwater characteristics. In the area of Southeast Srem, groundwater level fluctuates very widely, depending on the distance from water courses. Mean value of groundwater fluctuation in Southeast Srem amounts to 3.49m.

In this area, groundwater moves in Southeast direction, i.e. in the direction of the main receiving streams of the region, the Sava and the Danube. The greatest risk of groundwater overflowing in Southeast Srem occurs in the central parts of the loess terrace and in low parts of the alluvial plain along the Sava, where groundwater level is at the depth of less than 1m.

Key words: Southeast Srem, groundwater, fluctuation, movement.

Introduction

Southeast Srem is a part of the Pannonian Plain, and it consists of three clearly distinctive entities: the loess plateau, extending from the slopes of Fruška Gora to the Danube upstream of Zemun, average altitude about 100 m, the Srem loess terrace, average altitude 75-78 m, and the river Sava

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alluvial plain. The study area extends between 44° 40' and 45° North latitude and 19° 50' and 20° 25' East longitude. It is bordered by two rivers: the South boundary of the area is the river Sava, and the East boundary is the Danube.

Southeast Srem is rich in groundwater. Water regime of the first aquifer has a great significance from the aspect of agricultural production. Favourable groundwater regime has a positive effect on crop yield, whereas unfavourable regime has a detrimental impact on plant production by reducing the yield and in some cases by complete obstruction. “It is difficult to determine which depth of the first aquifer is optimal. It would be best if, in arid years, the level was sufficiently high to be available to normally developed plant root systems (for the crop size below 2 m). In rainy years, it is best that the plants get their moisture from precipitation, and groundwater level should be as deep as possible" (Škorić, 1994).

In addition, during the growth season, especially during high temperatures, the high level of the first aquifer with unfavourable chemical composition of water can lead to the secondary salinisation of the soil.

The two parameters of the first aquifer which are of high significance to intensive agricultural production are: groundwater depth and the directions of its movement. Deep groundwaters initiate the need of irrigation and vice versa, shallow groundwaters require drainage as reclamation measures. Groundwater which flows to the surface remains in the lowest parts – depressions, while the higher parts of the region - ridges are outside the effect of excessive groundwater. In such cases, groundwater can be collected in open canals and flown to the receiving stream, where it does not endanger the reclaimed area.

The objective of this paper was, based on the data analysis in the study area, to show the main characteristics of groundwater, its occurrence and direction of movement, from the aspect of significance for agricultural production.

Materials and Methods

The study area covers altogether 86,303 ha (VP Galovica), which accounts for 24.8% of Srem area (area of Srem District 348,600 ha), i.e. 4.0% of the area of Vojvodina (2,150,600 ha) (Statistical Yearbook of the Republic of Serbia, 2003).

In Srem, the monitoring of groundwater level by twenty-one dug wells, dates back to 1948. The first monitoring network was formed in 1953. This network included the existing dug wells, selected so as to cover uniformly the lowland parts of Srem. Over time, some wells were abandoned, and some were replaced by tube wells, piezometers.

The number of wells is relatively high, however their spatial distribution is highly nonuniform. The greatest number of piezometers was installed in towns, e.g. in New Belgrade and Zemun. Also, a great number of wells with the main function of monitoring the effect of the Sava backwater on groundwater level, created by the hydroelectric power station Đerdap, are in the alluvial area. The number of piezometers in the central part, on the loess terrace, is fewer. The difficulty is also the fact that the measurement periods on different piezometers were different. The measurement data presented in this paper refer to the period 1980 – 2004, although there were some interruptions in measurements.

To analyse the groundwater characteristics in the study area, 32 piezometers and 3 batteries of piezometers were singled out and subjected to in-depth analyses (Figure 1).

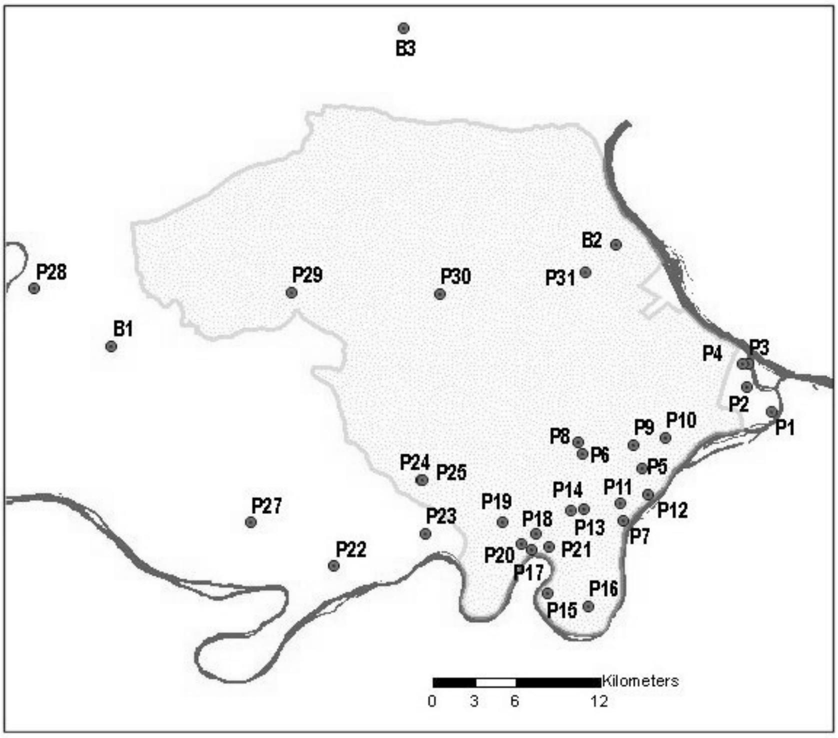

Fig. 1. – The situation with the positions of the analysed piezometers

– The absolute elevations of groundwater level were calculated for each piezometer, based on the data of the measured groundwater depth in piezometers and benchmark elevations (elevations of piezometer zero).

– Groundwater level curves were used to plot the lines of level duration, separately for each observed well (piezometer), (Gregorić, 2008). Based on these diagrams, we computed the ranges of groundwater level fluctuation, maximum and minimum levels, and groundwater duration, at less than 1 m from the surface. The results are presented in the Tables.

– The situation showing the movement of groundwater level for the entire area of Southeast Srem was obtained by processing the piezometer values of the average groundwater levels during the study period, by applying GIS technology. The maps of groundwater isolines were constructed for all characteristic levels interesting to the issues of melioration of agricultural soil (minimum, maximum).

Results and Discussion

GENERAL GEOMORPHOLOGICAL FEATURES OF SOUTHEAST SREM

From the aspect of geomorphology, Vojvodina, and also Southeast Srem as its part, belongs to the South part of the vast Pannonian Plain, formed during the Middle Eocene by the lowering of large blocks by regional ruptures, which was, by much smaller scope and intensity, continued also during the Quaternary (Radojčić et al., 1969). The lowland part of Srem represents the part of the Sava intramontane depression lowered between the horst mountains Fruška Gora, Cer and Avala.

The present micro-forms of Srem relief are genetically related to the creation of the Neogene and, especially, of the younger Quaternary formations. The lowland part of Srem belongs to a unique Pannonian sedimentation basin, in which semi-cemented and cohesionless rock masses were deposited. After the Levantinian - Paludinian age, the lacustrine basin was shallowed and disintegrated into a greater number of shallow basins – marshes. The final forms of the relief were created in four phases: lacustrine, marsh, terrestrial and the phase of ingression of water masses from the North (Josipović, 1985).

During the second half of the Pleistocene, the channel of the river Danube was formed, large lakes were dried, followed by the accumulation of aeolian material. Climate change in the glacial and interglacial periods resulted in the alternation of the aeolian accumulation and fluvial erosion.

The area can be divided into three geomorphological units: loess plateau, loess terrace and alluvial plain.From the geological aspect, the territory of Southeast Srem is the extreme Southeast part of the Pannonian Neogene basin. It consists of different formations, starting from the oldest Palaeozoic formations, Mesozoic complexes, to Neogene and Quaternary sediments, as the latest. (Energoprojekt, 1985, Institute Jaroslav Černi, 1996, Laskarev, 1938, Luković, 1958, etc.).

CLIMATE CHARACTERISTICS

The geographic position of Southeast Srem is in the belt of temperate continental climate. As a part of the Pannonian Plain, it is for the most part surrounded by mountain massifs. As the region is more open to the North and West, the influence of air currents and weather changes from these directions is stronger. As the consequence of such influences, the study area is characterised by more expressed characteristics of continental climate (Katić, 1979).

ANALYSIS OF GROUNDWATER FLUCTUATION IN THE AREA OF SOUTHEAST SREM

For each of the singled out piezometers (Figure 1), the absolute elevations of groundwater level were calculated based on the data on measured groundwater depth in piezometers and benchmark elevations (piezometer zero elevations) (Table 1). The results are presented by water level curves. An example of a water level curve is given in Figure 2 (Piezometer P17 in Boljevci).

The plotted groundwater level curves were used to construct the lines of groundwater level duration, separately for each piezometer, i.e. for the monitored wells. Figure 3 presents groundwater level duration line of a piezometer in Krnješevci. Based on these diagrams, the following parameters were determined in the subsequent phase of groundwater analysis: range of level fluctuation, mean, maximal, and minimal levels (Table 2). As high groundwater levels are especially important from the aspect of the excessive soil moisture, their duration in the zone from the surface to the depth of 1 m was calculated for each piezometer. Table 2 shows that water fluctuation in the area of South East Srem varied in a very wide interval. So, for example, the fluctuation in groundwater level amounted to only 1.63 m in piezometer (P11) in Surčinsko Donje Polje. This piezometer is about 1 km distant from the Ranney well, and it is under its continuous influence. The greatest groundwater fluctuation was recorded by piezometer in Inđija (B3), amounting to as much as 8.22 m. The piezometer (B3) is on the loess plateau. Mean value of groundwater fluctuation in Southeast Srem was 3.49 m. The greatest depth of groundwater during the study period was measured by piezometer 12, located in Surčinsko Donje Polje in the vicinity of a Ranney well, resulting from the high impact of the Ranney well on the lowering of water level in the well.

Interestingly, only a few piezometers are characterised by a high percentage of duration of high groundwater level. Such examples are piezometers P9, P30 and P31, with the duration of high groundwater level accounting for 43, 43.1 and 20%, respectively. Piezometer P9 is in Surčinsko Donje Polje at the low elevation of 70.82 m, piezometer P30 is in Krnješevci, and P31 is in Batajnica.

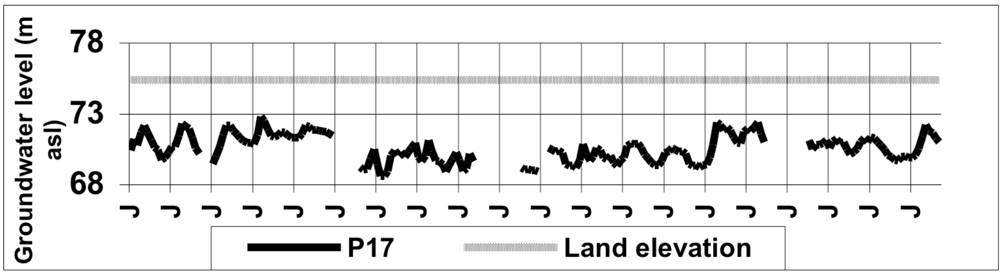

Fig. 2. – Groundwater level curve on piezometer P17

Tab. 1. – Data on the analysed piezometers

Sign	Location	Absol. elevation "0"	Land elevation	h tube	Study period
		(m asl)	(m asl)	(m)	
VP Galovica					
P1	Novi Beograd	74,82	74,34		jan.1985 – dec. 2000.
P2	Zemun	74,68	74,39		jan.1985 – dec. 2004.
P3	Zemun	75,76	75,83		jan.1985 – dec. 2004.
P4	Zemun	74,66	74,78	21,62	jan.1985 – dec. 2004.
P5	Donje Polje	72,88	72,49		jan.1985 – apr. 1991.
P6	Donje Polje	74,08	73,67		jan.1985 – apr. 1991.

		Absol. elevation "0"	Land elevation	h tube	
P7	Donje Polje	73,01	72,72		jan.1985 – okt. 1990.
P8	Surčin	78,98	78,54		jan.1985 – dec. 1989.
P9	Donje Polje	71,81	70,82		jan.1985 – dec. 1989.
P10	Donje Polje	71,83	70,56		jan.1985 – dec. 1989.
P11	Donje Polje	72,86	71,92		jan.1985 – dec. 1989.
P12	Donje Polje	71,86	71,18		jul.1990 – maj. 2003.
P13	Jakovo	75,97	75,26		jan.1985 – dec. 2004.
P14	Jakovo	76,48	76,03		jan.1985 – dec. 1998.
P15	Zidine	73,47	72,94		jul.1990 – feb. 2000.
P16	Zidine	72,60	72,12		jul.1990 – feb. 1997.
P17	Boljevci	75,87	75,37		jan.1985 – dec. 2004.
P18	Boljevci-Progar	73,10	72,70		jan.1985 – jun. 1993.
P19	Boljevci	78,42	77,67		jan.1985 – dec. 2004.
P20	Boljevci	74,41	73,86	9,95	jul.1990 – dec. 2004.
P21	Boljevci	73,98	73,35	10,35	jul.1990 – dec. 2004.
P22	Kupinovo	77,25	76,80		jan.1985 – dec. 2004.
P23	Progar	77,00	76,24		jan.1985 – dec. 2000.
P24	Progar-Petrovčić	79,9	79,09		jan.1985 – avg. 1999.
P25	Progar-Petrovčić	79,84	79,05		jan.1985 – avg. 1999.
		RHMZ:			
P27	Obrež (137)	78,99	78,44	6,80	jan.1978 – dec. 2004.
P28	Hrtkovci (142)	80,78	79,91		jan.1978 – dec. 2004.
P29	Prhovo (145)	77,67	77,27	6,00	jan.1978 – dec. 2004.
P30	Krnješevci (146)	76,10	75,50	6,00	jan.1979 – dec. 2004.
P31	Batajnica (64)	77,78	77,61	4,50	jan.1993 – dec. 2003.
P32	Sremska Mitrovica (67)	85,74	85,60		feb.1979 – dec. 2004.
P33	Sremska Mitrovica (85)	81,57	81,14		jan.1993 – dec 2004.
B1	Baterija Nikinci:				
	Nikinci (NI-1/2)	80,49	80,32	5,20	jan.1992 – mart. 2003.
	Nikinci (NI-1/1)	80,47	80,31	8,70	jan.1992 – mart. 2003.
	Nikinci-Ekonomija (NI-1)	80,45	80,29	16,40	jan.1992 – dec. 2003.
B2	Baterija Nova Pazova:				
	Nova Pazova (NP-1/1)	79,03	78,84	6,00	jan.1992 – jul. 2001.
	Nova Pazova (NP-1)	79,00	78,83	11,00	jan.1992 – jul. 2001.
	Nova Pazova (NP-1/D)	79,02	78,83	30,60	jan.1992 – jul. 2001.
B3	Baterija Inđija:				
	Inđija (IN-1/1)	112,13	111,90	10,20	jan.1992 – maj. 2003
	Inđija (IN-1/D)	112,14	111,92	22,20	jan.1992 – dec. 2003.

Tab. 2. – Fluctuation, mean, maximal and minimal groundwater levels in piezometers and percentages of duration of high groundwater level

Sign	Elevation	Groundwater level fluctuation	Mean groundwater level	Mean depth to groundwater	Maximal groundwater level	Minimal depth to groundwater	Minimal groundwater level	Maximal depth to groundwater	Duration of high ground-water level
	m asl	**m**	**m asl**	**m**	**m asl**	**m**	**m asl**	**m**	**%**
P1	74,34	5,44	67,2	7,14	70,53	3,81	65,09	9,25	0
P2	74,39	2,6	71,03	3,36	72,35	2,04	69,75	4,64	0
P3	75,83	3,77	71,09	4,74	73,21	2,62	69,44	6,39	0
P4	74,78	3,35	71,86	2,92	72,87	1,91	69,52	5,26	0
P5	72,49	2,47	68,81	3,68	70,02	2,47	67,55	4,94	0
P6	73,67	1,95	70,42	3,25	71,62	2,05	69,67	4	0
P7	72,72	2,61	69,34	3,38	70,9	1,82	68,29	4,43	0
P8	78,54	1,89	74,13	4,41	75,27	3,27	73,38	5,16	0
P9	70,82	2,31	69,61	1,21	70,75	0,07	68,44	2,38	**43**
P10	70,56	1,68	67,7	2,86	68,79	1,77	67,11	3,45	0
P11	71,92	1,63	69,75	2,17	70,8	1,12	69,17	2,75	0
P12	71,18	8,39	65,86	5,32	70,09	1,09	61,7	9,48	0
P13	75,26	2,31	71,64	3,62	73,04	2,22	70,73	4,53	0
P14	76,03	3,7	71,27	4,76	73,28	2,75	69,58	6,45	0
P15	72,94	3,37	70,29	2,65	71,5	1,44	68,13	4,81	0
P16	71,12	2,3	70,43	2,69	71,42	1,7	69,12	4	0
P17	75,37	4,84	70,56	4,81	72,91	2,46	68,07	7,3	0
P18	72,7	2,82	70,56	2,14	72,08	0,62	69,26	3,44	**3**
P19	77,67	3,38	70,7	6,97	73,13	4,54	69,75	7,92	0
P20	73,86	3,66	70,67	3,19	73,05	0,81	69,39	4,47	**1**
P21	73,35	3,52	69,49	3,86	71,24	2,11	67,72	5,63	0
P22	76,8	3,54	73,18	3,62	75,35	1,45	71,81	4,99	0
P23	76,24	3,24	72,86	3,38	74,6	1,64	71,36	4,88	0
P24	79,09	4,36	74,26	4,83	77,18	1,91	72,82	6,27	0
P25	79,05	4,23	74,33	4,72	77,15	1,9	72,92	6,13	0
P27	78,44	4,35	75,09	3,35	77,97	0,47	73,62	4,82	**4**
P28	79,91	5,17	76	3,91	79,23	0,68	74,06	5,85	**1**
P29	77,27	3,4	75,16	2,11	77,15	0,12	73,75	3,52	**5,7**
P30	75,5	2,8	74,32	1,18	75,5	0	72,7	2,8	**43,1**
P31	77,61	2,25	76,37	1,24	77,41	0,2	75,16	2,45	**20**
P32	85,6	3,14	83,1	2,50	84,37	1,23	81,23	4,37	0
P33	81,14	3,09	78,69	2,45	80,15	0,99	77,06	4,08	0
B1	80,32	3,26	76,21	4,11	78,54	1,78	75,28	5,04	0
B2	78,84	3,35	76,18	2,66	77,75	1,09	74,1	4,74	0
B3	111,9	8,22	104,56	7,34	107,04	4,86	102,71	9,19	**8,6**
prosek	-	3,49	73,19	3,59	75,06	1,71	71,67	5,11	-

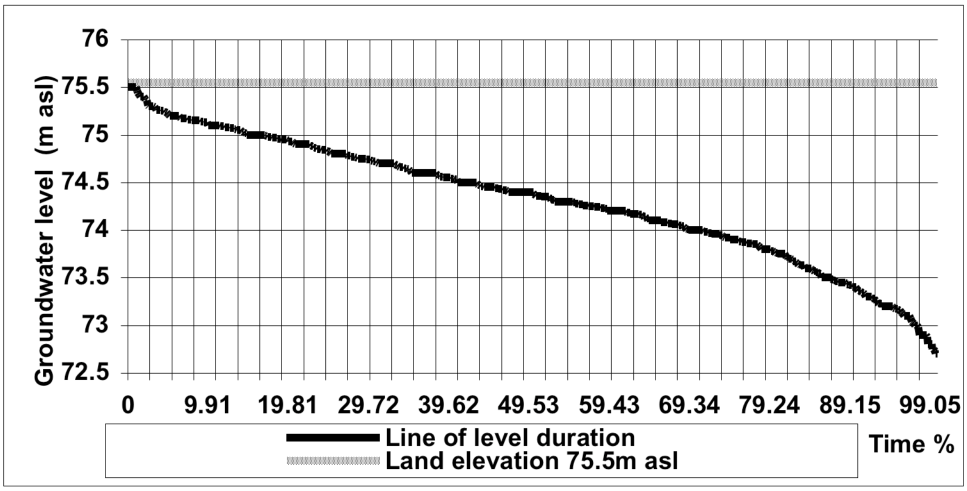

Fig. 3. - Example of the line of level duration - piezometer P30-Krnješevci

ANALYSIS OF GROUNDWATER MOVEMENT DIRECTIONS IN SOUTHEAST SREM

The Diagrams and Tables of groundwater fluctuation in Southeast Srem offer a general insight in the groundwater state, but it is not possible to get the direct data on the characteristic groundwater movement directions. To study the dominant directions of groundwater movement, it was necessary to construct the maps of hydroisohypses, i.e. the lines of equal groundwater levels.

The map of hydroisohypses of mean groundwater level for the entire area of Southeast Srem was obtained by processing the piezometer values of the average groundwater levels during the study period, by applying GIS technology. (Figure 4)

There is a clear tendency of groundwater movement in the direction of Southeast, i.e. in the direction of the main receiving streams, the Sava and the Danube. The hydraulic gradient in the extreme North part of the area was about 0.25% and in the central and South parts, it was lower than 0.05%.

The piezometer level, in the study area at mean values of groundwater level ranges from the elevation of 90 m to the elevation of 67.2 m. Hydroisohypse 90 is on the North boundary, and 68 along the lower course of the river Sava.

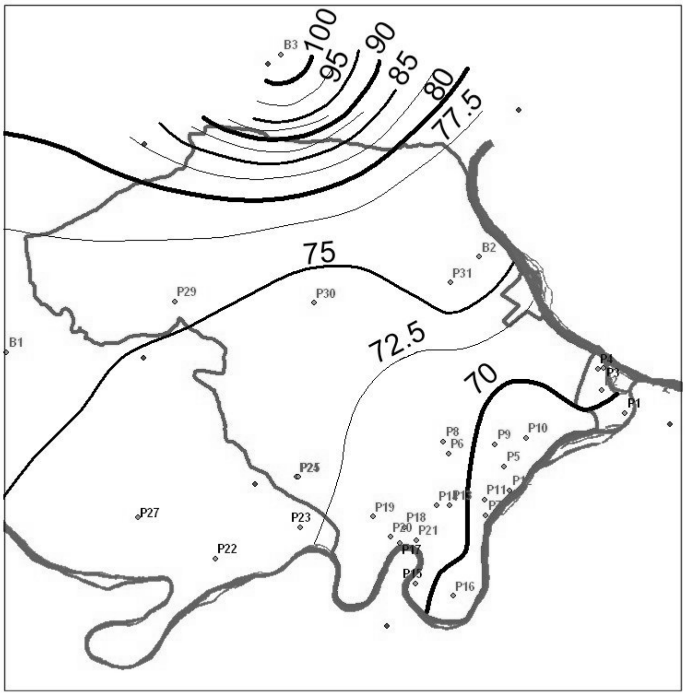

Fig. 4. – Map of hydroisohypses of mean groundwater level in the first aquifer in Southeast Srem

The direction of drainage in the canals of I and II orders, used also for drainage and irrigation within the melioration system, is mainly adapted to the direction of groundwater level movement.

As from the aspect of excessive soil moisture, the most important factors are high groundwater levels, it was necessary to construct first the approximate map of hydroisobaths for the maximal groundwater levels in the study period. The greatest danger of groundwater overflowing in Southeast Srem occurs in the central parts of the loess terrace and in low parts of the alluvial plain along the Sava, which are within the hydroisobath of 1 m. These lines mainly overlap with the hydroisohypses. This could have been expected, as it is primarily the lower parts of the area that are endangered by groundwater.

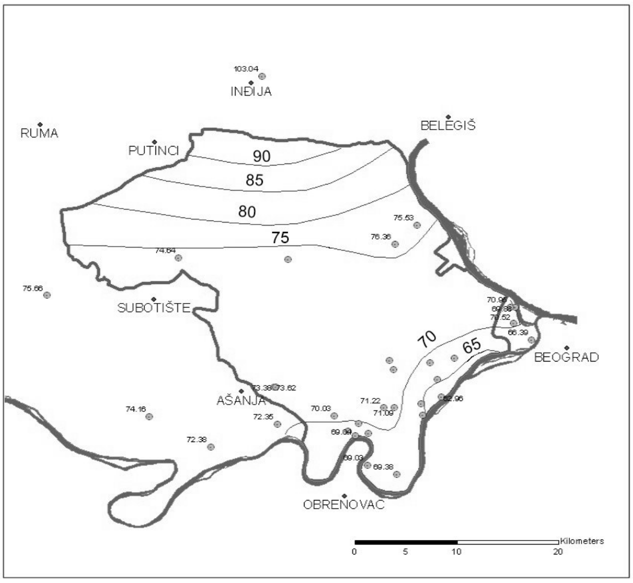

Fig. 5. – Map of hydroisohypses of minimal groundwater level based on the data for 1994

The third parameter significant for groundwater movement directions are the minimal groundwater levels in the study period. Figure 5 presents the map of isolines for the average groundwater level in 1994. The analysis of precipitation in a longer time period, under the condition that the sums of annual precipitation in three consecutive years were compared, shows that 1994 was one of the most arid years. So, the isolines in Figure 5 show the tendency of groundwater movement at a minimal level. The distribution of hydroisohypses for the minimal level is very similar to that for the averaged level. Based on the analysis of hydroisohypses constructed for the absolutely maximal depths to groundwater level, in the study period, it was concluded that groundwater in the central part of the area was not deeper than 3 m from the ground surface.

Conclusion

Groundwater level in Southeast Srem fluctuates very widely, depending on the distance from water courses. Mean value of groundwater fluctuation in Southeast Srem amounts to 3.49m.

Groundwaters in the region move in Southeast direction, i.e. towards the main receiving streams in the region, the Sava and the Danube. The hydraulic gradient, in the extreme North part accounts for about 0.25% and, in the central and South parts, it is below 0.05%.

The piezometer level, in the study area at mean values of groundwater level, ranges from the elevation of 90 m to the elevation of 67.2 m. The direction of drainage in the canals of I and II orders, used also for drainage and irrigation within the melioration system, is mainly adapted to the direction of movement of groundwater level.

The greatest risk of groundwater overflowing in Southeast Srem occurs in the central parts of the loess terrace and in low parts of the alluvial plain along the Sava, where groundwater level is at the depth of less than 1 m.

The distribution of hydroisohypses of the minimal level is very similar to the distribution of the averaged level. Based on the analysis of hydroisohypses constructed for the absolutely maximal depths to groundwater level, in the study period, it was concluded that groundwater in the central part of the area was not deeper than 3 m from the ground surface.

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NEKE KARAKTERISTIKE PODZEMNIH VODA U JUGOISTOČNOM SREMU

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R e z i m e

Područje jugoistočnog Srema obiluje podzemnim vodama. Režim voda prve izdani sa stanovišta poljoprivredne proizvodnje ima veliki značaj. U cilju analize nekih karaketristika podzemnih voda područja izdvojeno je 32 pijezometra na kojima su merene dubine podzemnih voda. Nivo podzemne vode na području jugoistočnog Srema osciluju u veoma širokom opsegu, u zavisnosti od udaljenosti od vodenih tokova. Srednja vrednost oscilacija podzemnih voda na području jugoistočnog Srema iznosi 3,49m. Podzemnih vode područja kreću se u pravcu jugoistoka, tj. u pravcu prema glavnim recipijentima ovog područja, Savi i Dunavu. Najveću opasnost od izlivanja podzemnih voda na području jugoistočnog Srema imaju centralni delovi lesne terase i niski delovi aluvijalne ravni uz Savu na kojima se podzemna voda nalazi na dubini manjoj od 1m .

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