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# Hydro-geological problems of Vranjaš accumulation (Vojvodina, Serbia)

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## *Abstract*

Srem, as traditional farming, orchard and wine-growing region, faces the problem of shortage of water needed for agriculture. In order to solve this problem brook valleys in the southern part of Fruška Gora loess plateau were intended to be dammed during the seventies of the last century. Thus, artificial lakes would have been formed. It took long period of time to put these projects into practice and numerous projects have not started yet. After the dams had been built and lakes filled with water numerous hydro-geological problems occurred at many locations. Nevertheless, these accumulations fulfill their primary functions, e.i. they ensure water for irrigation and protect agricultural land from floods. Accumulation Vranjaš is situated near Mandjelos village in Srem. Problems that occurred at this accumulation from the very beginning are the loss of water and inability to achieve maximum volume. Eventually this accumulation got new functions which can be noticed in fish rising and sport fishing development.

**Key words:** Srem, hydrology, artificial lakes, Vranjaš.

## Introduction

During the fifties of the last century, there was an idea to dam Fruška Gora brook valleys and build numerous accumulations. These projects were not quickly put into practice. The first projects were completed at the end of the sixties and at the beginning of the seventies of the last century. The first dam was built at Borkovački potok in 1972, north of Ruma and soon after that Borkovac lake was formed.

The brooks of Fruška Gora at lower loess terrain lose a lot of water because of infiltration. This water raises the level of groundwater in the lower parts of Srem in the spring. Thus, plowed land is endangered. Because of heavy rain during the spring and summer these brooks often flood land under cultivation. These floods also cause erosion of the land, and roads and some parts of the settlements are flooded, too. Water is necessary to this region, especially during the summer, primarily because of irrigation. All these factors contributed to the building of accumulations in Fruška Gora brook valleys. The first dams were built during the seventies of the last century. Thus, the first lake basins were formed. Unfortunately, there was no continuity in the realization of these projects, and the last lakes were formed during the nineties of the last century. Numerous accumulations were not built because of insufficient financial support, and some accumulations cannot completely fulfill their functions. 39 accumulations were planned to be built at Fruška Gora and its slopes, but only 13 accumulations were built until 1998 (12 accumulations were built at southern slope and 1 accumulation was built at northern slope) (Lazic, 1999).

Numerous problems that occurred at these accumulations were mostly caused by neglecting of lake basins. Intense eutrophication (Simeunović et al., 2005) and filling the lake basins with loess material caused these problems in most cases (Svirčev et al., 2006). Eventually activities such as fish growing, fish sporting, and tourism took advantage of some properties of these accumulations and gave them new significance (Dolinaj et al., 2007).

## Geographical situation of the lake

Accumulation Vranjaš is situated at the southwest part of Vojvodina, 2 km southeast of village of Manđelos in Srem. The lake can be approached from different directions. The easiest way to reach the lake from Sremska Mitrovica is by regional road Sremska Mitrovica- Ležimir. After you turn right to Manđelos there is a field road that leads to the east. Only 1 km later you will reach the west bank of Vranjaš accumulation. In the north-east there is an asphalt road that goes from Manđelos to Grgurevci. 1 km after the centre of Manđelos you can turn right to the field road and 1,5 km later you will come to the east bank of the lake. You can also reach the lake from the east by regional road Sremska

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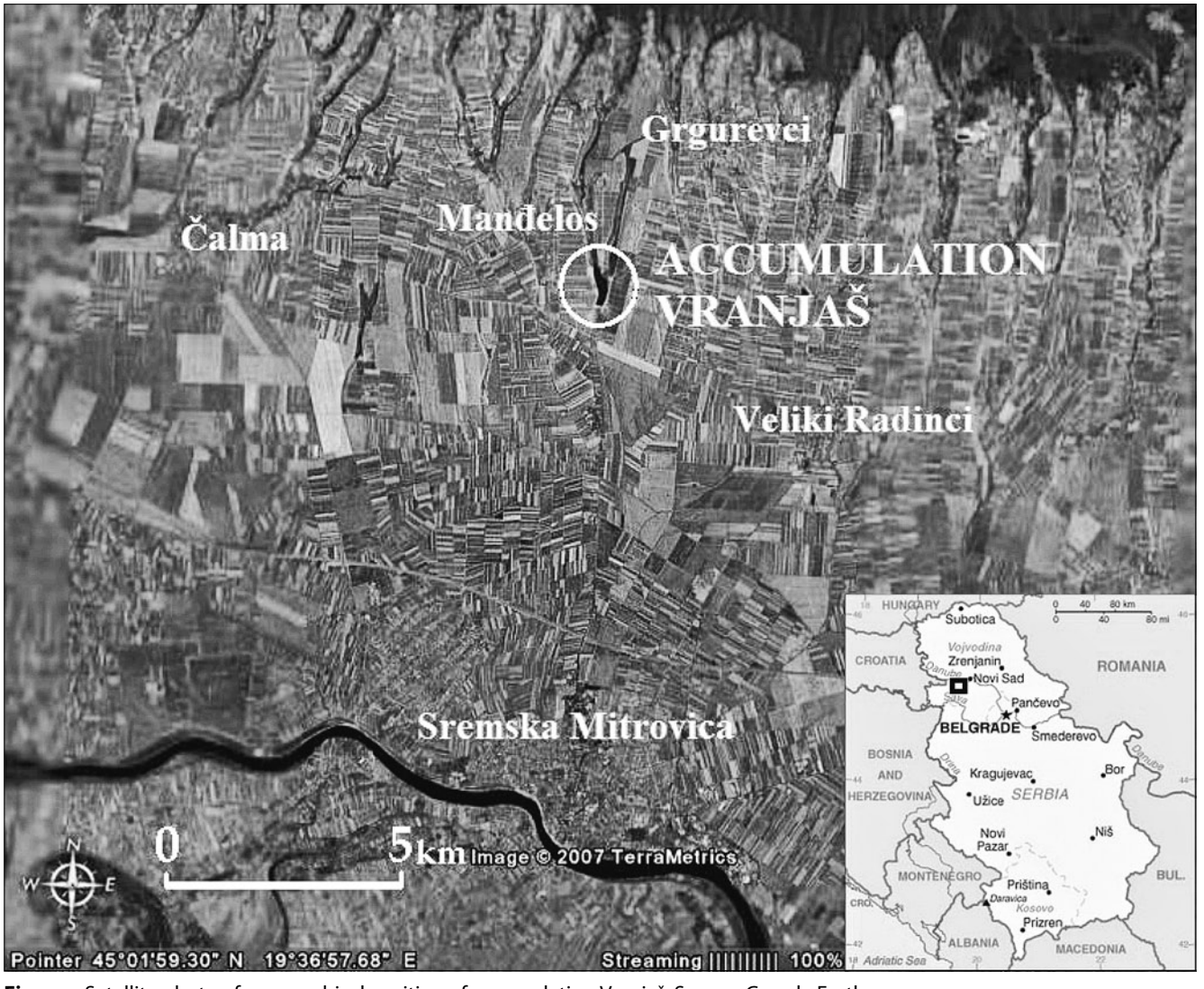



**Figure 1** Satellite photo of geographical position of accumulation Vranjaš; Source: Google Earth

Mitrovica – Radinci. Before you reach the village, there is a field road that leads to the west and directly to Vranjaš. This road is 10 miters wide, and by this road you can come to Čalmanska jezera, too. This road connects villages of Veliki Radinci and Čalma. The lake stretches on the south-north axis, and because of the field road that goes along its east and west banks it is not difficult to reach the lake at all. West and east bank of the lake are connected with the dam, and the field road that goes across it.

## Physical and geographical factors for lake basin

Geological structure of Fruška Gora as well as its tectonic structure have a great significance for solving problems that occur at most accumulations of Fruška Gora brooks.

Sedimentary rocks from the period of Cenozoic that cover older structures from Mesozoic and Paleozoic are of the greatest importance for the occurrence of subterranean and surface water of all petrographic formations (Miljković, 1998).

Crystal slates are of Paleozoic origin and they include green slates, amphibolites slates, dioritic green slates, sericit slates and argillaceous quartzite's (Milić, 1973). They can be noticed north of Ležimir, at higher course of Vranjaš and Manđeloski potok and they are quite metamorphosed, tectonically changed, curved with numerous cracks. That was the main reason of formation of crack system and groundwater springs.

Mesozoic rocks can be seen in Fruška Gora, too. They include slates, sandy terrains and deep and massive layers of limestone. Accumulation basin of Vranjaš lake was formed at Neogene's sediments which cover limestone. Limestone hydro geological features are the main cause why accumulation loses water. They are tectonically changed, crumbled, breeched at some parts and have numerous cracks in its structure. Some of the cracks are widened and dugouts were formed in them. Karst groundwater is formed in these limestone's.

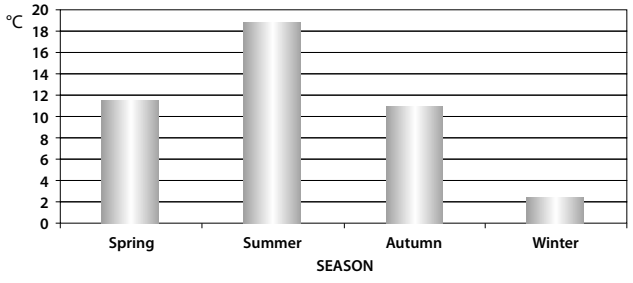
At the slopes of Fruška Gora there are numerous Neogene's sediments. They include Miocene and Pliocene series of sediments that transgressively and discordantly cover older geological formations.

Quarter products cover Neogene's sediments. They include sand (of different color and granulation), clay and loess in which the artificial lake is formed. Loess layers are very interesting from hydro-geological point of view, since their porosity varies from 35% to 45%. Filtration coefficient varies from $K=1x10^{-3}$ to $1x10^{-4}$ cm/s, and in deeper parts where loess had been degraded, coefficient varies from $1x10^{-}$

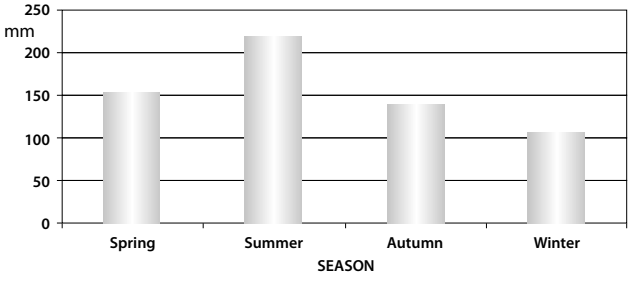
**Table 1** *Monthly and annual mean air temperature and monthly and annual mean precipitation recorded at Sremska Mitrovica meteorological station (1981-2000)*

| month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | amp. | Annual mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| temp. (°C) | -0,9 | 1,5 | 6,5 | 11,1 | 16,6 | 19 | 20,7 | 20,1 | 16,3 | 11 | 5 | 1,7 | 21,6 | 10,8 |
| rainfall (mm) | 38 | 32 | 40 | 55 | 57 | 88 | 65 | 65 | 44 | 46 | 49 | 36 | | 615 |

*Source: Meteorological annual 1981-2000.*




**Graph 1** Season temperatures in Sremska Mitrovica for the period 1981 – 2000. period 1981 – 2000




**Graph 2** Season precipitation in Sremska Mitrovica for the period 1981 – 2000. period 1981 – 2000

$^{4}$ to 1x10$^{-6}$ cm/s. These figures greatly influence filtering, i.e. losing of water that reaches lower and older geological series where limestone formations dominate and where karst or crack groundwater springs had already been formed. Thus, water from accumulation comes to these springs, and this represents important geological problem of this accumulation that has great impact to hydrological characteristics of the lake.

Geological problems of Vranjaš accumulation are connected to the genesis of the brook valley of the eastern part of Manđelos brook, where the lake basin is situated.

The lake was formed by damming of wide valley of Manđelos brook. Loess sides of the brook valley go gently down to the lake basin. The basin itself is situated at the contact of loess and clay layers, whereas the bottom of the basin is at firm clay layers. The base of the north part of the basin is formed of loess and clay materials.

Similar geological problems are expected to occur at other accumulations in the vicinity of Vranjaš and Manđelos brook, because of the same or similar geological formations.

South area of Pannonian plane and Sremska Mitrovica is characterized by continental climate with some elements of continental steppe climate (Lazić et al., 2006). Mean annual temperature in Sremska Mitrovica is 10,8°C, the coldest month is January with mean temperature of -0,9°C, and the warmest month is July with mean temperature of 20,7°C (table 1). The warmest season is summer with mean temperature of 20 °C, and winter mean temperature is 0,9°C. Mean temperatures for spring and autumn months slightly differ. Mean temperature for spring season is 11,4°C, whereas mean temperature for the autumn it is 10,8°C. Data for highest and lowest temeperatures confirm the fact that continental climate dominates this area. The highest temperature ever recorded is 39,8°C, and the lowest -29,5°C.

Annual mean precipitation total in Sremska Mitrovica is 615 mm (table 1). It is the highest in the summer, 218 mm, and the lowest during the winter, 106 mm (figure 3). Mean air humidity is 76 %. All these data refer to the period from 1981 to 2000, and they are recorded at Sremska Mitrovica meteorological station.

## Origin and morphometry of the lake

Vranjaš accumulation building project was done at the beginning of the seventies of the last century. According to this project, big accumulation lake was intended to be built in the valley of east branch of Manđelos brook. Field research of sonde type was done during the first phase of the project in order to set the base of planned accumulation. Limestone was noticed at some parts of future lake basin, but it was thought that thick clay layers will prevent draining of water. After the bottom and the sides of the valley had been studied for months, it was decided that there were geological conditions for building the lake. The building of the lake started during the seventies of the last century. Private land was bought and the bottom of planned accumulation started to be built there. Orchards in the vicinity of the dam were cut, whereas the forest at the northern part of the lake was not entirely cut. At the same time, building of the dam started. As soon as 1975 the dam was finished, and formation of the lake began.

The lake has irregular shape and it stretches on the south-north axis. Lake basin is the widest in its central part (figure 5), it narrows at north (figure 4), whereas it slightly narrows in the south until it reaches the dimensions of the dam. Both east and west valley slopes slide gently into the lake basin. Only in its north part (north of wide bay) east bank is above the lake level, only 1.5-2 m above it (figure 4). At all other parts of the lake it is quite low and goes gently to the lake basin. Slopes are more noticeable at the east bank, very close to the dam. These banks are covered with grass, as well as the central parts of east and west coast, and reed can be noticed at some parts (figure 3, 5). At the north part of the east coast there are some trees and reed, whereas trees prevail at the north part of the east coast and reed can be noticed at the very banks of the lake (figure 3, 4).

The lake is 1100m long, from the confluence of Manđelos brook to the east point of the dam. This direction slightly deviates from south-north axis. The lake is widest at its middle zone where its width is 280 m. Mean width of the lake is 174 m. East bank is a bit more jagged and its length is 1260 m in comparison to the west, 1060 m, whereas shoreline is 2510m long in general. Shoreline length changes over

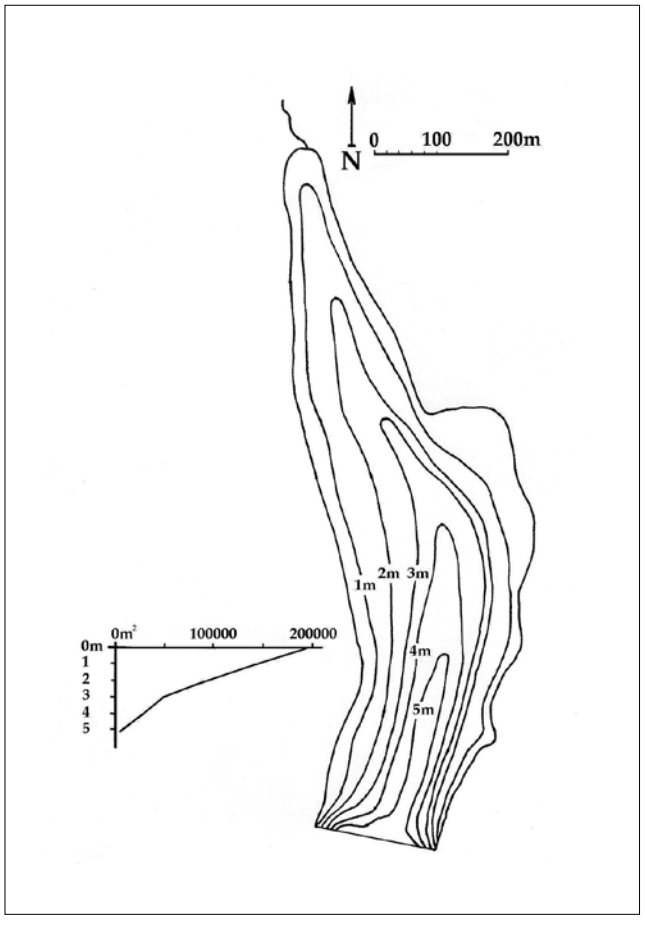



**Figure 2** Isobathic map of accumulation Vranjaš with bathigraphic curves


**Figure 3** Satellite photo of accumulation Vranjaš; Source: Google Earth

the year and it is influenced by the lake water level. If it is high, lower parts of the banks are flooded, the volume of the lake becomes bigger, and shoreline gets 15-20% in its length. The depth of the lake basin differs at different parts. North part of the lake is the shallowest. North zone of the lake basin goes to the isobate of 2 m, and its furthest part is the shallowest and the depth of the lake varies from 0.5 to 1 m at this part (figure 2). Apart from this part, wide bay at the east coast is also very shallow. The depth of the lake goes to 1 m here. The depth of the lake becomes bigger in south direction. If you follow south parts of both banks to the central part of the lake, you can notice that water is deeper, whereas the slope of the east coast is more noticeable (figure 2). The lake has its biggest depth at the central part of the dam and it is 5.8 m. Direction of the biggest depths of the lake coincide with the direction of former riverbed of Manđelos brook. Mean depth of Vranjaš is 2.1 m. The area of the lake is 191300 m², and it changes 10% maximally over the year, which is influenced by water level regime. The capacity of the lake basin is around 401000 m³.

## Lake water level regime

While the lake was being formed, the dam was built at the south part of the basin. It is 210m long and it is built on east-west axis. Its length is 188m above the water surface, and it is 7,7 m high. The dam is actually field embankment that is covered with concrete plates at its sides. At its central part there is a vertical concrete structure that supports the embankment. At the west part of the dam there is a canal that is 5 m wide and if water level is very high the canal regulates water level of the lake, because excess water overflows into it. At the base of the dam there is a drainage pipe that regulates water level of Vranjaš lake.

East branch of Manđelos brook supplies lake with water. The main spring of this brook is called Vranjaš, and the lake was given the same name. It is situated 1,5 km west of the accumulation and 1 km north of the central part of Manđelos village. This spring has three courses and the amount of water it gives is around 40-45 l/min. The brook flows south and 900 m later its only tributary Ležimir brook empties into it. Ležimir brook brings around 30-40 l/min to Mandjelos brook. 1.5 km later east branch of Manjđelos brook empties into Vranjaš lake.

There are numerous canals that go to the lake basin and supply the lake with large quantities of water at the end of the spring and at the beginning of the summer, when they drain water from plowed land around the lake. Northeast canal is the biggest one, and it empties into the lake at the wide zone of east bay.

Rainfalls supply the lake with certain amount of water, either directly into the lake, or at its banks. The highest rate of rainfall is during the second half of the autumn, at the end of the spring and at the beginning of the summer.

While the lake basin was being built at the contact of loess and clay layers there was shallow zone of groundwater springs. These springs supply the lake with small amount of water. Thus, it is very difficult to say something more about their influence on Vranjaš water level regime.

The lake loses the water by drainage pipe at the base of the dam. The amount of water that goes through this pipe is controlled during the year, and it depends on season and amount of water that comes to the lake basin. When water level is very high, canal that is built near the dam helps this water to leak over.

It was noticed at the very beginning that the lake loses water at some parts, because even after a couple of years maximal volume could not be achieved during the summer months. After numerous analyses had been done, it was concluded that the lake loses water through limestone layers at the shallow parts of the lake basin. Water loss is not constant, but it is more noticeable over the period in which the lake reaches its maximal volume. It is assumed that higher water pressure leads to the infiltration of water through loess-clay layers that cover limestone cracks that are responsible for losing particular amount of water because of karst subterranean circulation. When the level of the lake is lower, water pressure becomes smaller, and the infiltration stops. At that moment the lakes does not lose water anymore and it can maintain its volume. It is assumed that due to this problem 55 % of the lake volume cannot be properly used. There was an attempt to close limestone cracks with cement milk, but it was not successful. Due to the loss of water the volume of the lake is only 401000 $m^3$ instead of 900000 $m^3$, which was its planned capacity.

The level of the lake varies over the year. Its annual amplitude is 90-120 cm, but it also varies over the period of time. The lake has its lowest level in September and October, and its maximal depth is 5,8 m during that period. At the second half of November first half of December and during March and April lake is rich in water, and its maximal depth over that period of time is up to 6,5 m.

## Water characteristics and flora and fauna of the lake

During the years 2003, 2004, 2005 and 2006 temperature of water was registered regularly in January, April, July and October. Temperatures were measured once a day, five times a month. Temperatures were occasionally registered during other months too.

The highest temperatures at the lake are in July and August, when mean daily temperature of water is higher than 29°C (table 2). In the autumn water is 1° warmer than during the spring months. The lowest temperature of water in the lake is in January and February and it varies from 0,8°C to 1°C. During winter months ice can be noticed on the lake surface. In 2003 the lake was covered with ice for 18 days, in 2004 it was covered with ice for 23 days, in 2006 for 31 days, and in 2006 for 20 days.

Transparency of water changes over the year. It is lowest in the spring when it is 60 cm, and during the summer it goes to 1 m.

**Table 2** *Mean water temperature (°C) at Vranjaš accumulation in January, April, July and October for period 2003-2006*

| January | April | July | October | Annual mean |
|---|---|---|---|---|
| 0,9 | 10,3 | 29 | 12 | 13,5 |

**Table 3** *Results of water analyses at lake Vranjaš*

| Ordinal number | Parametre | Unit of measure | Established values |
|---|---|---|---|
| 1 | Water temperature | °C | 28 |
| 2 | Color | | no |
| 3 | Smell | | no |
| 4 | Waste deposits | | no |
| 5 | PH value | | 7 |
| 6 | Turbidity | NTU | 6,5 |
| 7 | Electro conductivity | Micro S/cm | 372 |
| 8 | Dried residues of.filt. water | mg/l | 180 |
| 9 | Suspended mat. | mg/l | 58 |
| 10 | Dissolved oxygen | mg/l | 6.4 |
| 11 | Saturation | % | 42.6 |
| 12 | $BPK_5$ | $mgO_2/l$ | 3.2 |
| 13 | Use of $KmnO_4$ | mg/l | 5.3 |
| 14 | HPK | $mgO_2/l$ | 6 |
| 15 | TOC | mg/l | 1.1 |
| 16 | Ammonium ($NH_3$) | mg/l | 0.0 |
| 17 | Nitrites ( as N) | mg/l | 0.0 |
| 18 | Nitrates (as N) | mg/l | 0.0 |
| 19 | Alkylbenzensulphon. | mg/l | 0.0 |
| 20 | Iron | mg/l | 0.0 |
| 21 | Manganese | mg/l | 0.0 |

*Source: Institute for Health Protection Sremska Mitrovica*

Institute for Health Protection in Sremska Mitrovica analyzed lake water in 2002 in order to test its quality, as well as its chemical characteristics (table 3).

Shallow north part of the lake is rich in aquatic vegetation, and the lake basin is rich in plants, trees and reed. The biggest problems of the lake are huge organic production at the north part of the lake (figure 4) and sludge deposits at its bottom, which are mostly of organic origin. At the north part of the lake, at its central part sludge layers are as thick as 90 and 130 cm. At the slopes of the basin these layers are around 70 cm.

Potential problem is caused by the fact that there is possibility of waste water pollution. Waste water contains bacteria of fecal origin from the settlement that is situated northwest of the lake. This problem could be solved if local settlement got sewage system and if septic tanks were emptied. Usage of chemical products at plowed field and land under cultivation can also represent potential problem. Besides watering, water from the lake is used for preparing chemical products that are used on land under cultivation. Thus, there is constant threat of excessive usage of chemicals and fertilizers that could easily get to the lake because of sloping terrain. There is also potential danger because the lake water is used for cistern cleaning.

The lake is rich in ichtio-fauna. It is home to a variety of species of fish, such as carp, tench and pike, and it is assumed that catfish can be seen in the lake. There is also white fish: golden carp, roach, perch and robin. Alochtonous species: crucian carp, grass carp and silver carp

**Figure 4** North part of the lake, winter 2006; Photo: D. Dolinaj

(grass carp and silver carp are regularly brought to the lake every year) can be seen, too. Beside these species, American catfish and pumpkinseed can be found in the lake.

## Conclusion

The idea to dam brook valleys at the southern slope of Fruska Gora and build numerous accumulation occurred during the seventies of the last century. One part of that project was Vranjaš accumulation formation. Its primary function was agricultural. Water was used for irrigation, and lake dam protected plowed field from floods at the eastern part of Manđelos brook that endangered planted fields and land under cultivation.

Planned hydro-technical work included taking diluvial sediments away from the lake basin. According to the building action plan the base of lake basin should have been clay layers from Neogene's period. When lake basin was filled with water it was noticed that the accumulation loses certain amounts of water because of the infiltration through clay sediments. Vranjaš has protected plowed field and land under cultivation from floods for years and ensured water for irrigation. However, over the period of time lake basin was filled with loess and clay- loess materials that formed layers at northern and eastern part of the accumulation. These parts of the lake are rich in flora because of shallow water. The process of eutrophication and filling the lake basin with fluvial and erosive materials made thick layer of organic-clay-loess sludge that makes the volume of the lake smaller, and presents potential problem to the flora and fauna of the lake. These problems have not been solved so far and they are opened to future scientific research. The authors assume that similar problems could occur at other accumulations at southern slope of Fruska Gora, as the consequence of similar geological structure.

National Park Fruška Gora and Fishing Association of Vojvodina gave new significance to this accumulation, since they have used its water for years, and realized that its maximal volume has not been used. The lake turned into fish pond where new commercial species (such as silver carp, grass carp and carp) are brought to every year. Due to favorable ichtio conditions, in the last ten years more money was invested into sport fishing at this lake. As the result of these activities it is thought that lake should be connected to Manđelos by new asphalt road.

## Acknowledgements

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**Figure 5** Central part of the lake, summer 2005; Photo: D. Dolinaj

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