THE ROLE OF THE LITHOLOGICAL FORMATIONS FROM DANUBE FLOOD PLAIN BETWEEN GIURGIU AND CALARASI ON THE PHREATIC AQUIFER LEVEL IN 1967-1975 PERIOD

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Abstract: Based on the geological and hydrogeological interpretation performed in Danube's flood plain between Giurgiu and Calarasi, the phreatic aquifer level evolution correlated with Danube's level was studied for 1967-1975 period. From lithological point of view, the sedimentary formations crossed by the monitoring wells, represent important elements for making evident hydraulic connections between Danube and its flood plain phreatic aquifer. Groundwater and Danube chemical variation and their spatial connections were also performed. The results of this study are represented on GIS format maps and charts.
Key words: Danube, lithological formations, phreatic aquifer level, gauging stations, GIS.

DIE ROLLE DER LITHOLOGISCHE FORMATIONEN AUS DER DONAUFLUSSNIEDERUNG ZWISCHEN GIURGIU UND CALARASI ÜBER DIE PIEZOMETRISCHE DRUCKFLÄCHE IM ZEITRAUM 1967-1975

Zusamenfassung: Auf Grund der geologischen und hydrogeologischen Interpretationen, die man in die Donauflussniederung zwischen Giurgiu und Calarasi gemacht waren, wurde die Entwicklung zwischen dem Wasserpregel der Donau und der piezometrischen Druckfläche den freier Grundwasserleiter für den Zeitraum 1967-1975 studiert. Lithologisch gesehen stellen die Sedimentärformationen, die von den Kontrollbrunen durchgequert sind, wichtige Elemente für die Hervorhebung der hydrauliken Beziehung zwischen der Donau und der piezometrische Druckfläche seiner Flussniederung dar. Die hydrochemische Abwechselung der Donau und der Grundwasser und ihre räumlichen Beziehungen wurden auch beobachtet. Die Ergebnisse dieses Studiums wurden in GIS-Karten und Diagramme vorgestellen.
Schlüsselworte: lithologische Formationen, piezometrische Druckfläche, hydrometrische Station, GIS.

1. Introduction

With a length of 2857 km, ***the Danube*** separates 10 montain chains, goes through 4 gorges and drains 3 great plains. Along its hydrographic basin, 3 sectors are distinguishable: the upper sector from the sources to Bratislava, the middle sector from Bratislava to Bazias and the lower sector from Bazias to the Black Sea.

The Danube is as old as the last era, the Quaternary; it has formed its course, with its 8 terraces of the lower sector in the first quaternary period - the Pleistocene, and the Delta and the Flood plain in the present period - the Holocene, which is much shorter.

The lower sector, of 1 075 km, represents 37.6% of the total river length, while its catchment bassin 28.4 % of the total. According to the landformes and hydrography, this sector includes 3 zones: the Defile of the Iron Gates, the Floodplain between Drobeta-Turnu Severin and Ceatal Izmail and the Delta.

Out of the total of the Lower Danube Flood plain, 92% is the Romanian territory, measuring 513 876 ha; in natural regime, over 400 000 ha were higher grounds, used as pasture, wood and cultivated land, the rest being lakes and ponds with reedmassifs.

2. Study area geographical position

The study area (the Danube flood plain between Giurgiu and Calarasi towns) is situated in the lower sector, in the flood plain between Drobeta -Turnu Severin and Ceatal Izmail, in the very neighbourhood of Romanian Plain (fig. 1); because of the Danube, the Romanian Plain is also named the Danube Plain.

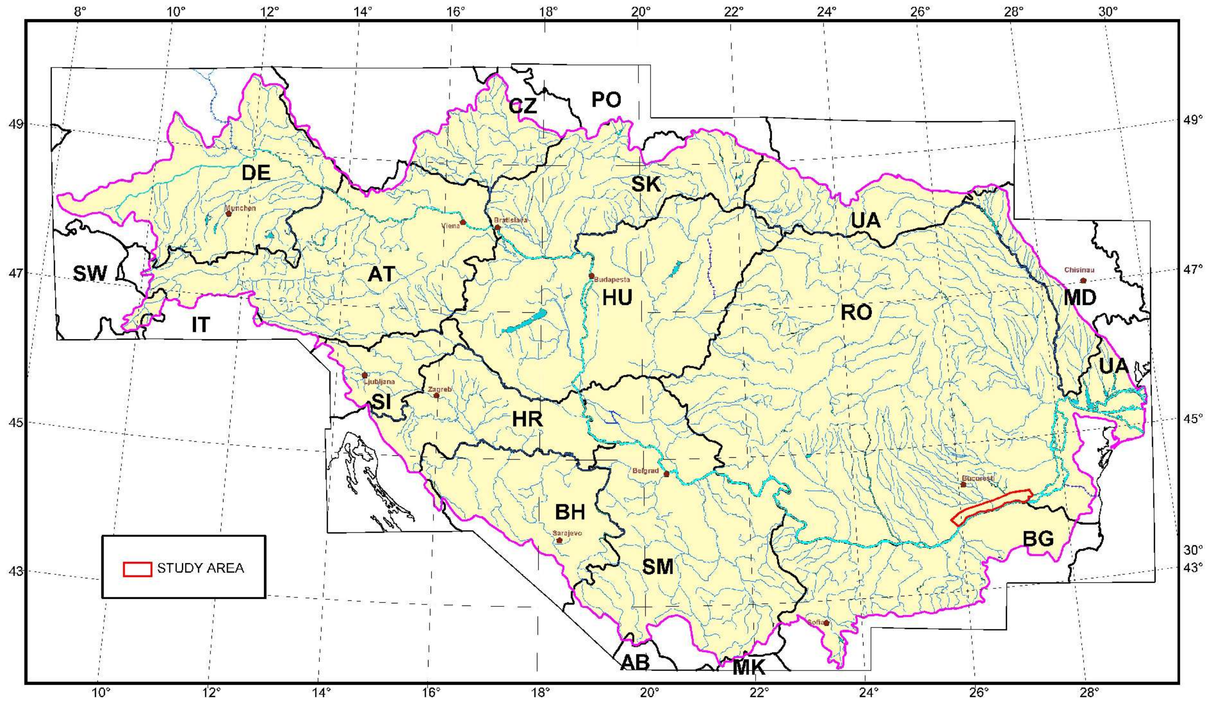

Figure 1. The Danube Basin and the studied area

In this sector, the flood plain has a large extend (10 km its width) and it is extended only on the left bank of the river; it isn't extended on right bank because of the Prebalcanic Plateau, which presents a higher relief caused by harder geological formations.

Between 1946 and 1970, the Danube's flood plain from this lower sector supported some complex arrangements of embankment for high water protection, but also some irrigation and draining arrangements.

This paper, based on level data measured on 3 gauging stations and 8 hydrogeologic stations by first order, make evident correlation Danube level - phreatic level in conditions of anthropic influence regim.

The Danube mean annual discharge measured at Oltenita gauging station (1931-1999) revealed that the study period (1967-1975) presents the highest discharge in 1970 - 8650 m^3/s (fig. 2); this is the reason why this period was selected.

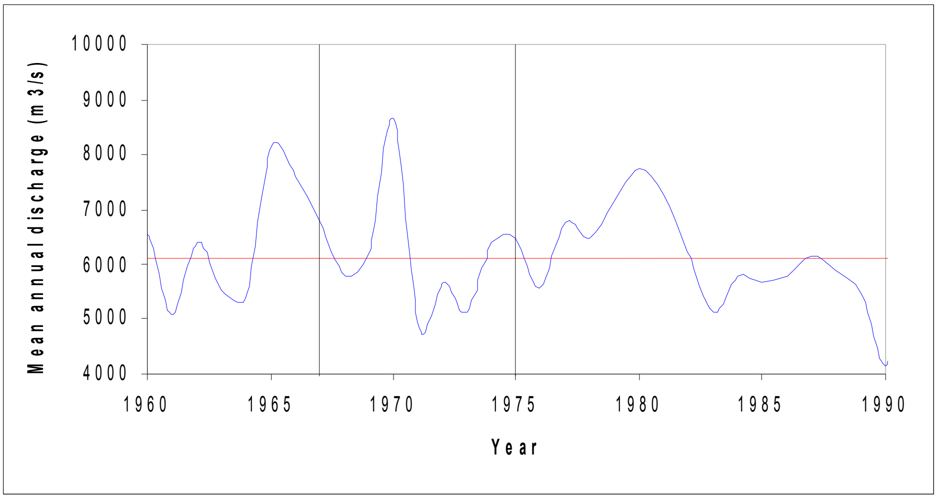

Figure 2. Mean annual discharge at Oltenita gauging station

3. Hydrological characteristic of Danube

The Danube flood plain is the Holocene terrace in forming process through alluviation. The thickness of alluvial deposits increase downstream the river. In a cross section, from minor-river bed toward terrace, 3 zones are to be distinguished: the sandbanks zone, the intermediate zone and that of near the terrace with ponds. The thalweg of the Danube presents a shifting tendency towards the left Romanian bank.

From the hydrological point of view, Danube presents the best known regim from all the Romanian rivers. The first gauging station and first observations were performed at Orsova (1838), and at the end of the XIXth century all the important gauging stations were inaugurated (23 from the actual 30 stations); Giurgiu, Oltenita and Calarasi gauging station were founded in 1879.

In a generical manner, the Danube's hydrological regime can be divided in a high spring-summer water period and a low autumn-winter water period. There must be emphasized that 80% from Danube's discharge is formed in the upper and middle sector, the Romanian and Bulgarian tributary contribution being of about 20%.

Mean annual discharge, of 5 500 m^3/s at entrance in Romania increases to 6100 m^3/s at Oltenita and to 6500 m^3/s at Ceatal Izmail gauging stations. The minimum discharge (year 1947) was 1340 m^3/s at the entrance in Romania and 1780 m^3/s at Ceatal Izmail. As for average concentration of suspended alluvium, dividing those measured at Ceatal Izmail (67.5 mil. t/an) at the catchment basin surface results a mean specific index of 0.87 t/ha. Measures performed at Orsova and Ceatal Izmail reveale that nearly half of these come from the Romanian territory, as the Romanian liquid discharge contribution is only of about 15%.

4. Geological and hydrogeological features of the study area

The geological information arrives from the National Hydrogeological Network, composed by monitoring wells, which investigate the phreatic aquifer up to maximum 50 meters depth.

As it can be seen on the geological map (fig. 3), there are 8 hydrogeologic stations ordered from weast to east as follows: Giurgiu - 3, Baneasa-Gostinu - 5, Prundu - 5, Chirnogi - 7, Spantov - 6, Ciocanesti - 7, Modelu - 6 and Ostrov - 2 wells. Generally, the first 3-4 wells are situated in the Danube flood plain and the last 1 or 2 are situated on the terraces.

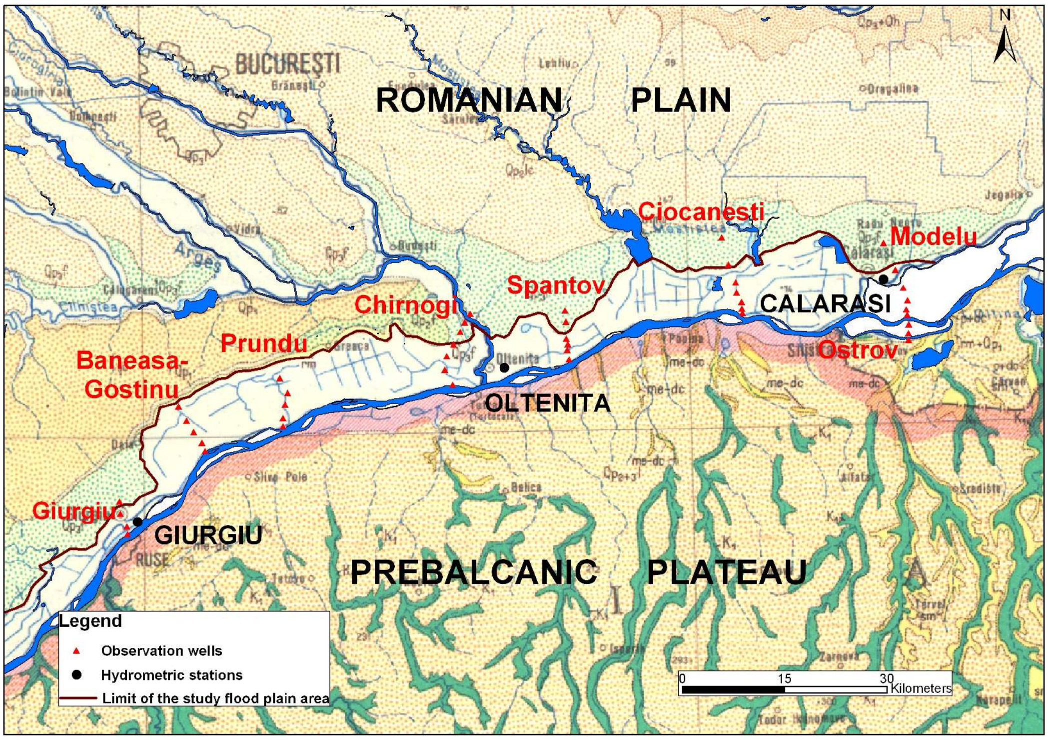

Figure 3. Geological map of the studied area

From the lithological point of view, the sector of the Danubian flood plain Giurgiu-Calarasi is formed by Quaternary, Dacian and Kretaceous sedimentary formations, vertically disposedas follows (fig. 4, 5 and 6):

a) cover formations: loess, fine claily silts, rarelly silty sands and alluvial soils in different stages of evolution and gleying;
b) the aquifer formations: fine claily sands lying on coarse sand mixed with gravel and boulders. The thickness of this base stratum increases from south to north. The age was established as Lower Holocen and Upper Pleistocene, which have a large extension in the Dacian Basin and they are known as the Fratesti Formation;
c) all this movable sediments are staying on a basement formation constituted by Dacian marls and Kretaceous limestones.

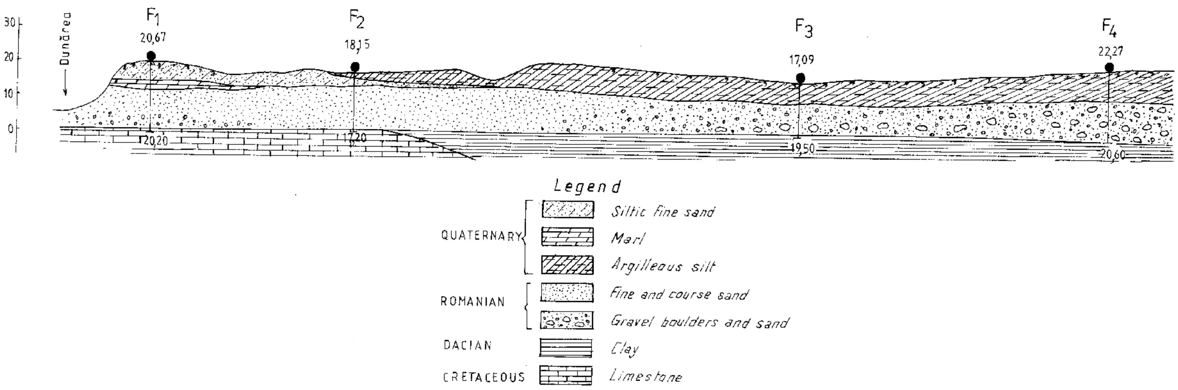

Figure 4. Geological cross section through Giurgiu hydrogeologic station

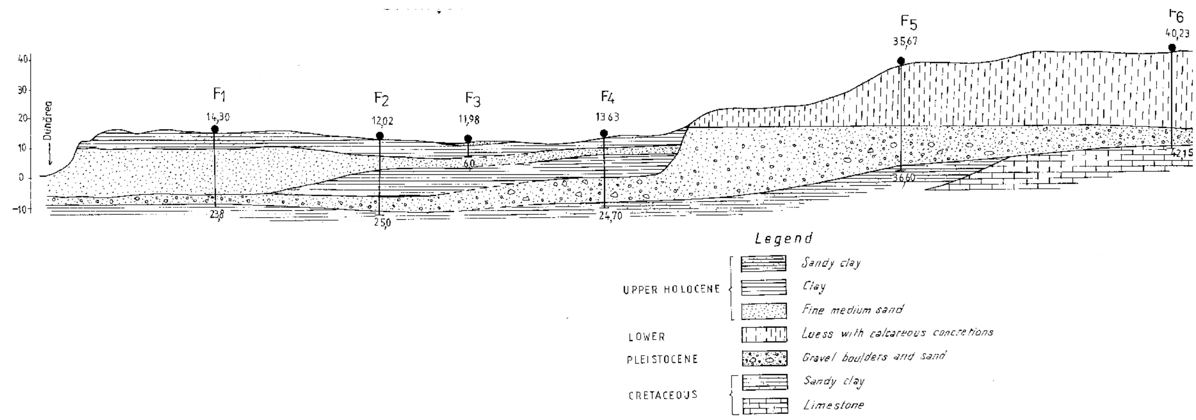

Figure 5. Geological cross section through Spantov hydrogeologic station

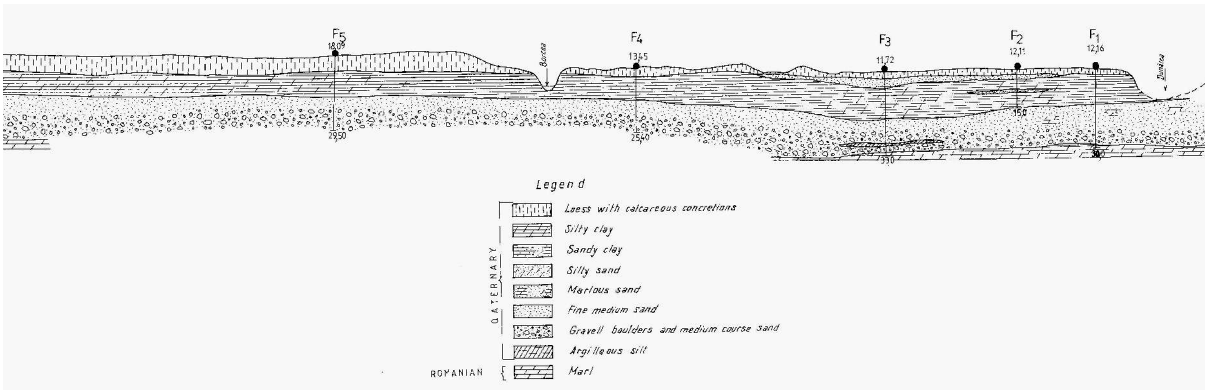

Figure 6. Geological cross section through Modelu hydrogeologic station

The phreatic water, slightly rising under the pressure because the connections with the minor-river bed and with terraces aquifer, lays on porous-permeable formations by different granulometry.

Phreatic aquifer supply is achieved by three ways: the afflux from Danube, precipitation, irrigations losses and the terrace afflux; thus, from the terraces situated in the very neighbourhood of the Burnas Plain appear frequent springs from Aquifer "Fratesti" Formation.

In natural regim, the flooding of the flood plain represented the most important source for phreatic aquifer supply which was confirmed by the general diminution of the phreatic level after the embankment. A correlation was established between the phreatic level regim and the Danube level regim after the embankment, for the most part of the study zone.

5. The phreatic level regim correlated with the Danube level regim

Generally, rivers represent ways of drainage for phreatic groundwater. This rule is also available for the Danube river.

The correlation Danubes level-phreatics level is obviously for the flood plain area. On the general background of phreatic groundwater drainage by the Danube there are also situations, during the floods, when the river supplies the phreatic aquifer; in the increasing periods of Danube level the river supplies the phreatic aquifer, and in the period of low Danube level, the phreatic aquifer supplies the river. These are suggestivelly represented in charts, which allow the comparison between the Danube's mean annual level variations at 3 gauging stations in the 1967-1975 period and the phreatic mean annual level variations measured in the same period at 43 monitoring wells.

In order to emphasize the correlation Danube level-phreatic level we studied the correlations between these 8 hydrogeologic stations and the 3 gauging stations by the rule of proximity: Giurgiu, Baneasa-Gostinu and Prundu hydrogeologic stations with Giurgiu gauging station; Chirnogi and Spantov hydrogeologic stations with Oltenita gauging station; Ciocanesti, Modelu and Ostrov hydrogeologic stations with Calarasi gauging station.

They can remark on the wells from the flood plain a similarity of phreatic variation level with Danube level variation, more obviously for those situated in the very close of the river; thus, we can notice rises of phreatic level in these wells for 1970, when the Danube level also registered a general increase which explains this situation (fig.7, 8, and 9). Also, the wells situated on terraces aren't influenced by Danube's regim, the phreatic levels in this cases being influenced by other factors (precipitation).

As concern the mean monthly interannual phreatic level, we can notice a rise of it in autumn months-later than the rise of Danube level which happen in spring-begining of summer; this delay is due to slowly infiltration and water transfer between them. The response of phreatic level to the rise of the Danube level is more diminished or even absent for the wells situated on the terraces.

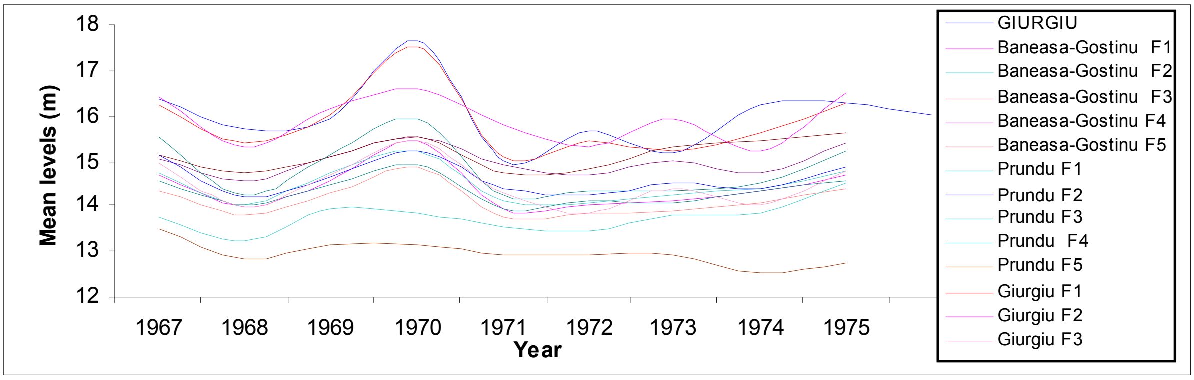

Figure 7. Mean annual levels at Giurgiu gauging station and the nearest observation wells

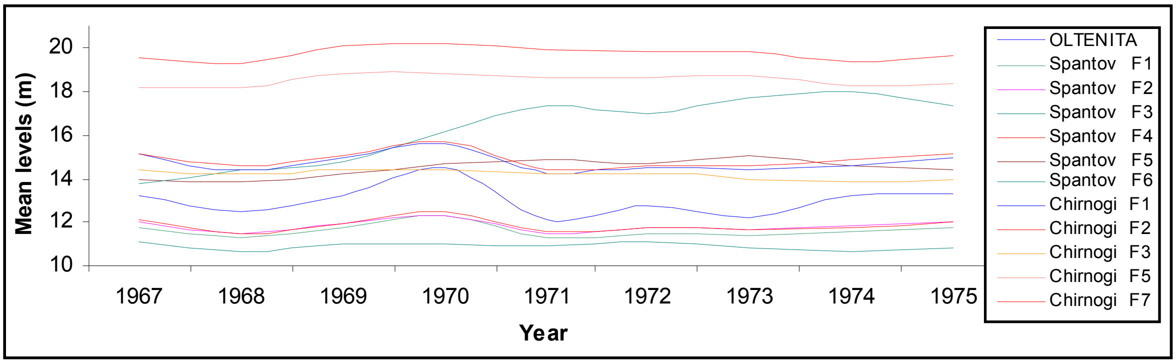

Figure 8. Mean annual levels at Oltenita gauging station and the nearest observation wells

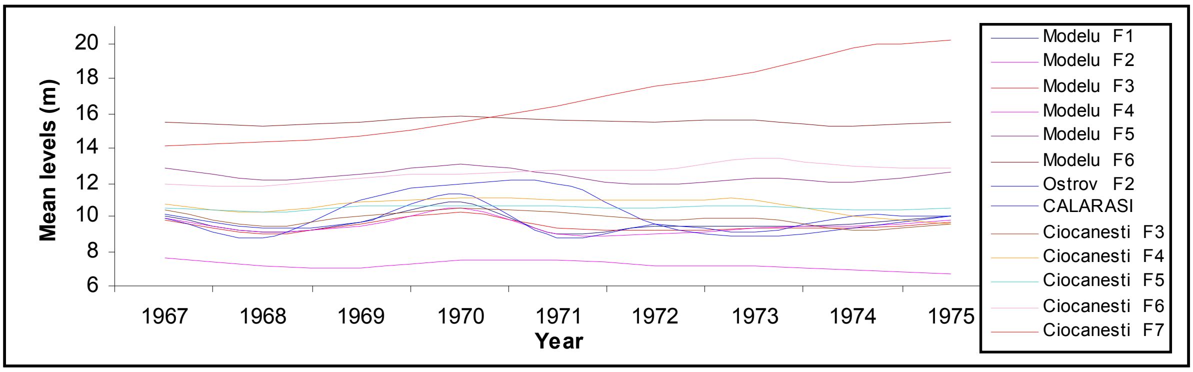

Figure 9. Mean annual levels at Calarasi gauging station and the nearest observation wells

These rules of correlation river level-phreatic level from the Danube flood plain and its terraces are also available in case of maximum and minimum mean monthly levels and also for 1967-1975 period (figs. 10, 11 and 12).

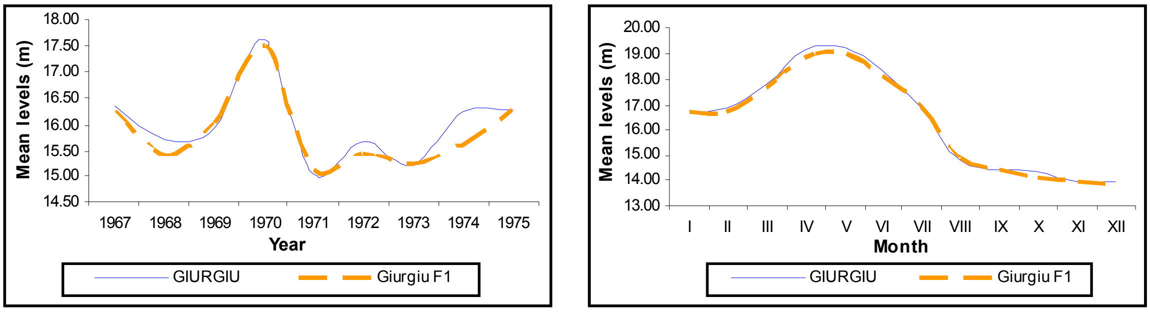

Figure 10. Mean annual and monthly level at Giurgiu F1 hydrogeologic station and Giurgiu gauging station

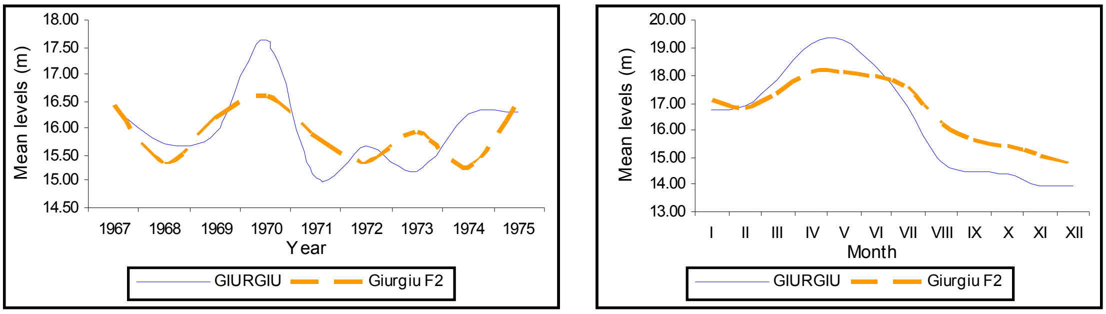

Figure 11. Mean annual and monthly level at Giurgiu F2 hydrogeologic station and Giurgiu gauging stations

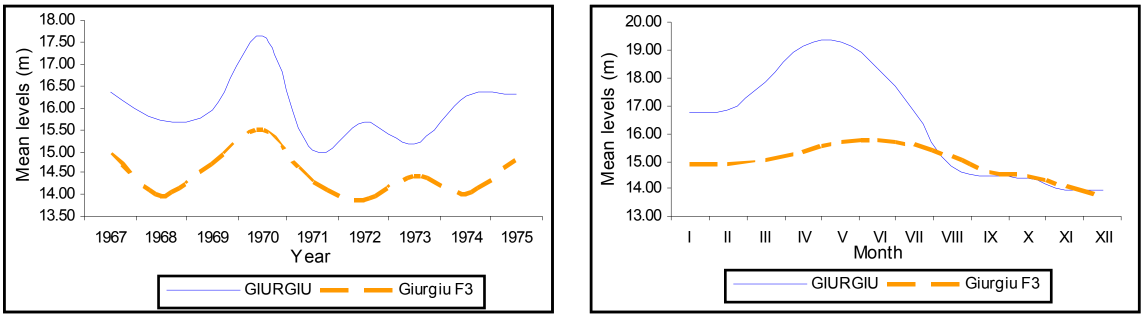

Figure 12. Mean annual and monthly level at Giurgiu F3 hydrogeologic station and Giurgiu gauging stations

The statistical correlation analysis were made for the monitoring wells and Danube levels, using the correlation coefficient defined as:

$$r = \frac{\operatorname{cov}(X,Y)}{\sqrt{D^2(X) \cdot D^2(Y)}} \qquad (1)$$

where X, Y = variables

D= dispersion.

They have calculated this coefficient for all monitoring wells and the results for Giurgiu hydrogeologic station are illustrated in table 1 and fig. 13.

Table 1. Correlation coefficients values at Giurgiu station

Wells	Mean year	Mean monthly	Max	Min
F1	0.95443	0.99881	0.63205	0.53981

F2	0.51833	0.96639	0.18135	0.49864
F3	0.71992	0.83454	0.59947	0.65496

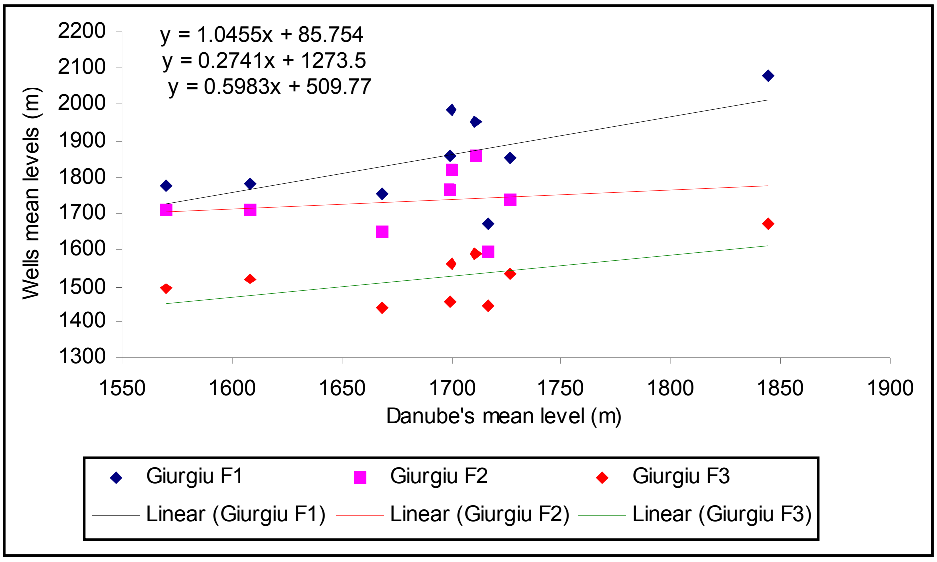

Figure 13. Trendlines at Giurgiu gauging and hydrogeologic stations

Selecting the wells with correlation coefficient higher than 0.6 it was obtained the breadth of Danube influence on its flood plain phreatic water, as shown in fig. 14:

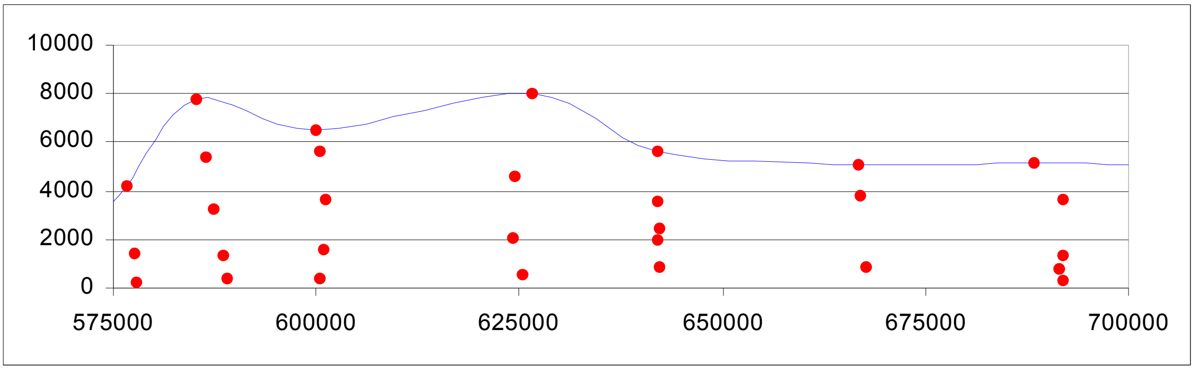

Figure 14. Variation of Danube breadth influence on its flood plain phreatic water

The Danube's level influence is obvious for phreatic level on the flood plain by 240 m (Giurgiu F1) and maximum 8 000 m distance from the river (Chirnogi F5).

An analysis was also made on the hydraulic conductivity, comparing the obtained values on pumping tests and those calculated by Zamarin formula - applicable without restriction for uniformity coefficient (d_{60}/d_{10}) :

$$K = 5572 \cdot \frac{n}{(1-n)^2} \cdot a^2 \cdot d_z^2 \qquad (2)$$

where $a = 1{,}275 - 1{,}5 \cdot n$

$\mathrm{n} = \mathrm{porosity}$

$$d_z = \frac{100}{\frac{3}{2} \cdot \frac{g_1}{d_1} + \sum_{2}^{N} \frac{g_i}{d_{i+1} - d_i} \cdot \ln \frac{d_{i+1}}{d_i}},$$

$N = \mathrm{number\ of\ fractions}$

d_1 = mean diameter of the fine fraction

d_{i+1}, d_i = the superior and inferior diameter of the "i" fraction,

g_1 = finest fraction

The results revealed a high difference vertically between the calculated values and those obtained on pumping test demonstrating that the last are mean values of hydraulic conductivity for strata crossed by the wells but does not reflect this parameter on each horizon. As for hydraulic conductivity calculated by Zamarin formula, the low values corresponding on clailly silty sand on supperficial depth become hundred times higher on 20-30 meters depths.

6. Hydrochemical characteristics

From the hydrochemical point of view, the samples chemical analysis couldn't clearly show the correlation between the Danube's water and its flood plain groundwater.

Thus, between 1972 - 1975, biannual campaigns of sampling and measuring of principal indicatories for drinking water (according to Romanian standard STAS 1342-91) were performed on Danube. In the Danubian study sector (Girgiu-Calarasi) two sampling sections were establish in the very neighbourhood of confluence with Arges river (one upstream and the other downstream of the confluence) because of the pollution potential role of this river for the Danube's water; the Arges's water is cosidered as degraded or very polluted because it collects Bucharest's unpurifying domestic water. And, indeed, after the confluence with Arges river, the values of indicatories for drinking water of the Danube's water show an increase.

On the whole Danubian study section it can be noticed exceedings of the values of indicatories for drinking water for phenol, pH, organic matter, iron and mercury (Hg^{2+}); these exceedings cause a second class degradation. Because of the hydraulic connection Danube's water- flood plain groundwater, it can also notice exceedings of the values of some indicatories for groundwater: organic matter, Fe and NH_4.

7. Conclusions

The statistical analysis for the existing values – 8 years and 43 observations wells - offered the possibility to appreciate the intensity of the relation between the phreatic aquifer and the Danube river. The alluvial formations, with a high degree of ununiformity, permit the water exchange from both sides. Even at lower permeability coefficients, depending on the granulosity, the phreatic level is coordinated by river fluctuations. The correlation analysis permit to reveal the following remarks:

- the limits of the domain by influence of surface water levels on phreatic levels variation are situated between 240 and 8 000 meters (corresponding to Giurgiu F1 and Chirnogi F5 wells);
- it was observed a high heterogeneous of all alluvial deposits, regarding the permeability and granulosity;
- the effects of the meteorological factors on the phreatic level variation are prevalent at observation points situated on greater distance from the Danube;
- the correlation cofficients were calculated for the mean annual, monthly, maximum and minimum phreatic level and the closest relationships are revealed for the monthly levels;
- the permeability coefficients, calculated by taking into account the porosity (by Zamarin), revealed the highest conductivity for the deeper sedimentary deposits (sandy gravels and boulders)and mostly for that situated at great distance from the Danube;
- the hydrochemical characteristics for the Danube indicates a degraded water because of exceedings for some indicators (phenol, ph, organic matter, iron and mercury), and for its flood plain groundwater exceedings for organic matter, iron and ammonium.

8. References

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