FIELD CAMPAIGNS: PUMPING TESTS AND TRACER TESTS

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ABSTRACT: The pumping tests and tracer tests campaigns were undertaken both in Hungary and in Romania. In Hungary, two sites in Szatmárcseke for the shallow aquifer and one site in Csenger for the deep aquifer were chosen. The fluorescein, used as tracer, was recovered in all cases from the pumping wells. The Hungarian team, based on isotopes measurements, put into evidence fresh and young water in Szatmárcseke, respectively several thousand-year-old water in Csenger site. The first phase of the field campaign in Romania consisted in pumping tests in four sites: two for the deep aquifer in Martinesti area and two for the shallow aquifer at Livada and Micula Noua. As a result, hydraulic conductivity, transmissivity and storage coefficient values were obtained. The tracer experiments were performed in two sites: one for the deep aquifer (Martinesti) and one for the shallow aquifer (Livada). Fluoresceine and rhodamine were injected. In the case of tracer tests the breakthrough curve was not complete for Livada, while in the case of Martinesti the tracer did not arrive in the pumping well.

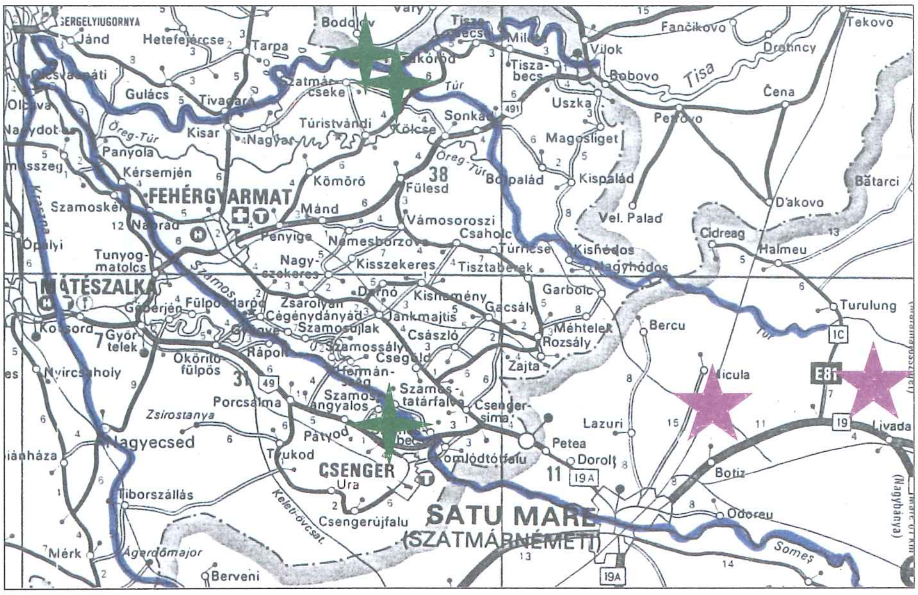
Key words: pumping tests, hydrogeological parameters, tracers, natural isotopes, groundwater age.

The different measuring sites, both in Hungary and in Romania can be seen on Figure 1.

1. Field campaign in Hungary

The Hungarian tracer test measurements and the pumping tests were carried out by the Geokomplex company at two sites in Szatmarcseke for the shallow aquifer and at one site in Csenger for the deep aquifer during the summer of 2003. The following tasks have been accomplished in the project work by the Hungarian team:

- The No.1 tracer and pumping test (Szatmárcseke, from 14.07. till 19.07.2003).
- The No.2 tracer and pumping test (Szatmárcseke, from 11.08. till 16.08.2003).
- The No.3 tracer and pumping test (Csenger, from 16.07. till 05.08.2003).
- Preliminary water samples analysis (July-August 2003, with Upper - Tisza Region Environmental Inspectorate = FETIKÖFE).
- Final water samples analysis for tracer material (2003-2004, with the help of the



Legend : Pumping and tracer tests on Romanian site

Pumping and tracer tests on Hungarian site

Fig. 1 Locations of measuring.

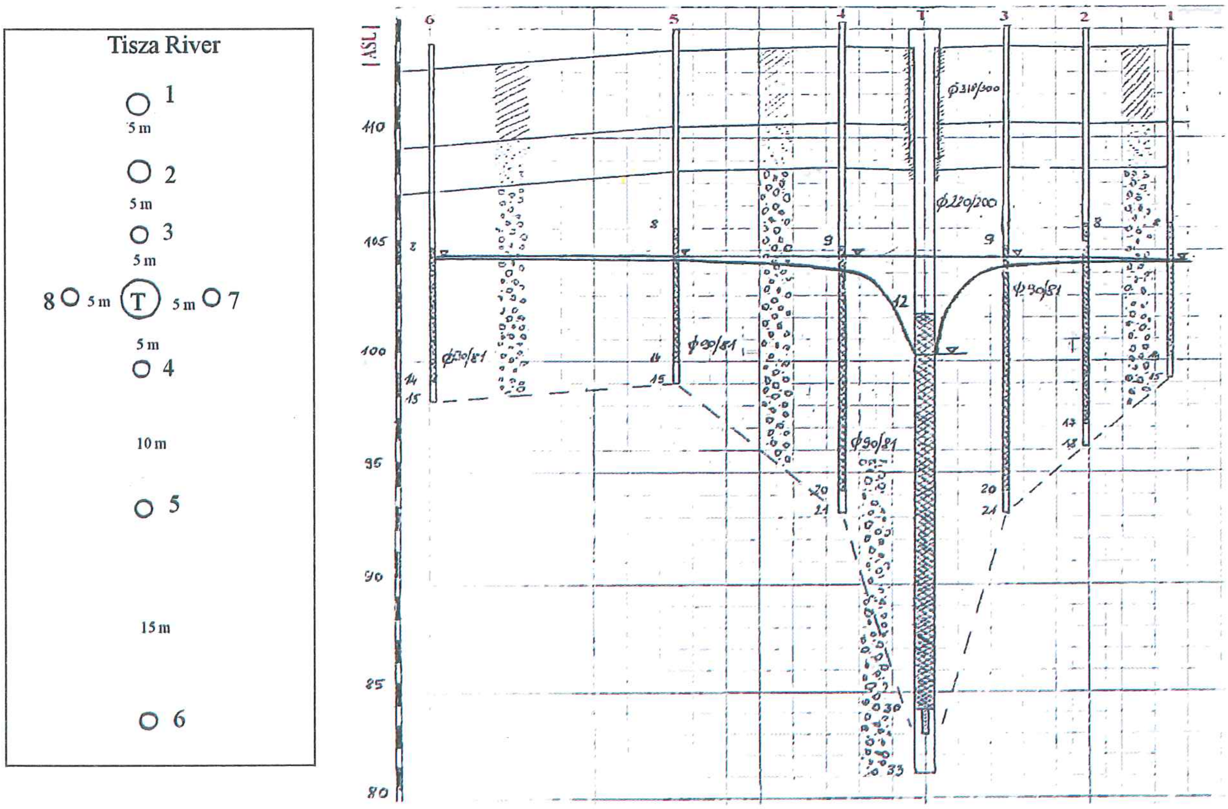


Fig. 2 The position of the wells and the hydrostratigraphic cross-section (Szatmárcseke No.1).
Legend: T - Pumping well; 5 - Observation Tracer well; T,1,2,3,4,6,7,8 - monitoring well
The distance between the wells: 1-2: 5 m; 2-3: 5 m; 3-T: 5 m; T-4: 5 m; 4-5: 10 m; 5-6: 15 m.

Research Center of Eszterházy Károly College, Eger).

• 16 water samples analysis for tritium, ^{18}O and ^{2}H contents (2003-2004, with the help of the Institute of Nuclear Research of the Hungarian Academy of Sciences = ATOMKI, Debrecen).

a) First Hungarian tracer and pumping test, Szatmárcseke, No.1

Water prospecting activity was made between Szatmárcseke and Tiszakóród (Figure 1).

As a result, a monitoring site with 9 wells has been created. Long pumping activity was performed in the centre position well with a diving pump. Water level measurements were done in the surrounding wells. The geology and well positions are given in the figure 2. The fluorescein tracer was injected into the Well No.5. The main properties about the measurement are given in Table 1.

Due to the continuous pumping (Q=1500 *l*/min = 2.160 m^3/day), the groundwater levels stabilized rapidly by Eijkelkamp DIVER measuring instruments. Some changes were induced however by the Tisza river's flood. The water temperature was nearly con-

Table 1 *Summary data of the pumping tests and the tracer measurements (Szatmárcseke No.1).*

T = Pumping well

Pumping: 14.07., 18^{00} – 19.07., 6^{00}, Q=1500 *l*/min = 2160 m^3/day = 0,025 m^3/s

5 = Observation tracer well

16.07., 7^{25}, 300 g fluorescein (5 *l* NH_4OH + 5 *l* water)+ topping up: 80 *l* water

17.07., 7^{30}–8^{32}, air to observation tracer well

17.07., 14^{10}–15^{50}, water to observation tracer well, Q=4,5 *l*/min = 6,48 m^3/day

17.07., 15^{50} – 18.07., 12^{42}, water to observation tracer well, Q=11 *l*/min = 15,84 m^3/day

Samples from monitoring wells (1, 2, 3, 4, 5, 6, 7, 8: 07.16–09.03; T: 07.16–09.03.:

1:well	7 pieces
2:well	7 pieces
3:well	7 pieces
4:well	85 pieces
5:well	27 pieces
6:well	9 pieces
7:well	8 pieces
8:well	9 pieces
T:well	85 pieces

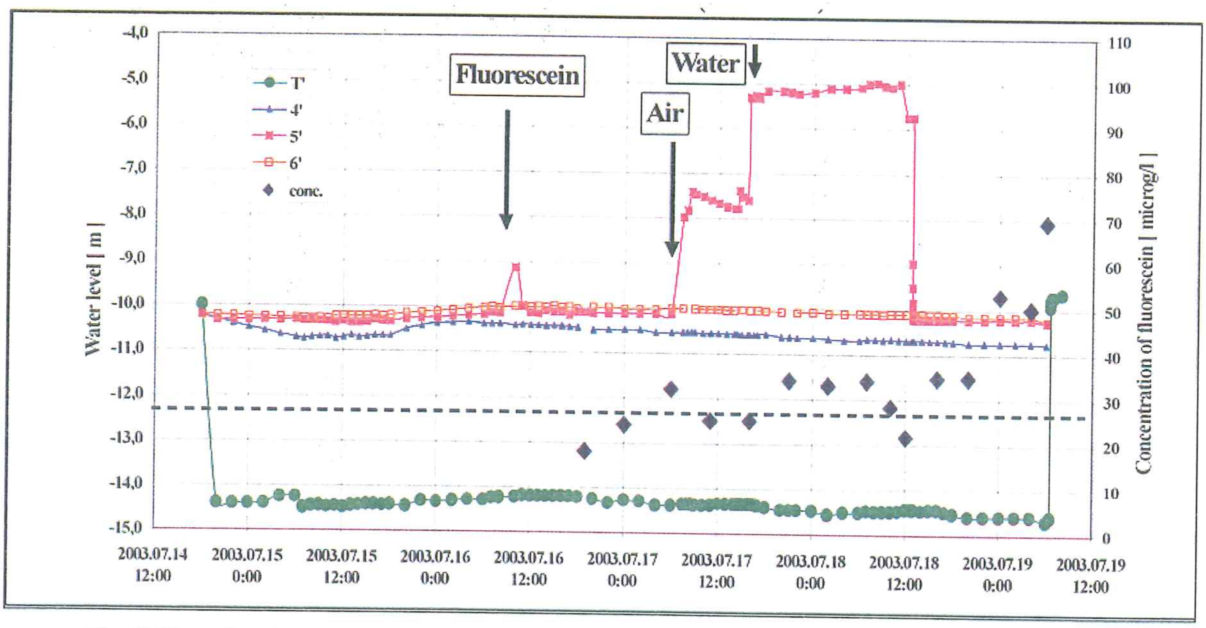


Fig. 3 *Water level, manual measurement (T, 4, 5, 6) and concentration of fluorescein in pumping (T)-well (Szatmárcseke No.1; 14.07-19.07.2003).*

Fig. 4 Tracer test, Szatmárcseke No.1, fluorescein in No.5 (tracer)-well. Fluorescein analysis: Laboratory in Eger.

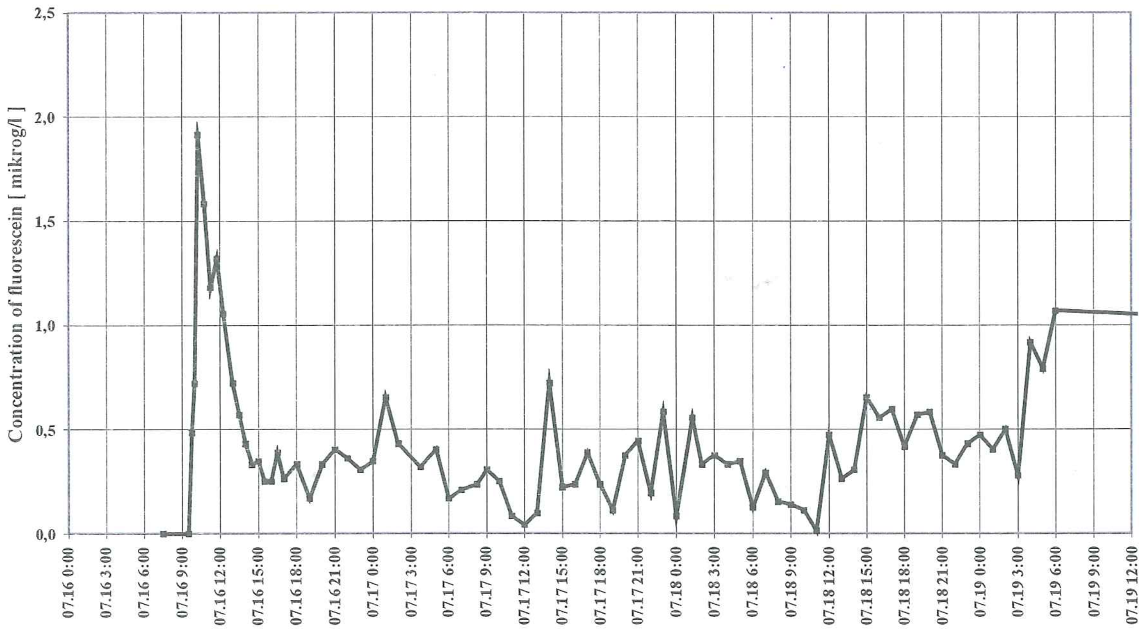


Fig. 5 Tracer test, Szatmárcseke No.1, fluorescein in No.4 (monitoring) well. Fluorescein analysis: Laboratory in Eger.

stant during the measurement. The Tisza flooding did not change the temperature in the investigated aquifer.

Figure 3 shows the results of the control water level measurements, the time of the pumping, the injection of the tracer material, the flushing of the tracer material from the well and the detection of the tracer material.

The results of the tracer tests are presented in the Figures 4 and 5.

The tracer disappeared completely from the injection well after 22 hours.

In the nearest detection well, the tracer appeared with a sharp peak after two hours, and then the tracer was present with fluctuations. After July 19, the pumping to abstract water stopped because there were not higher indica-

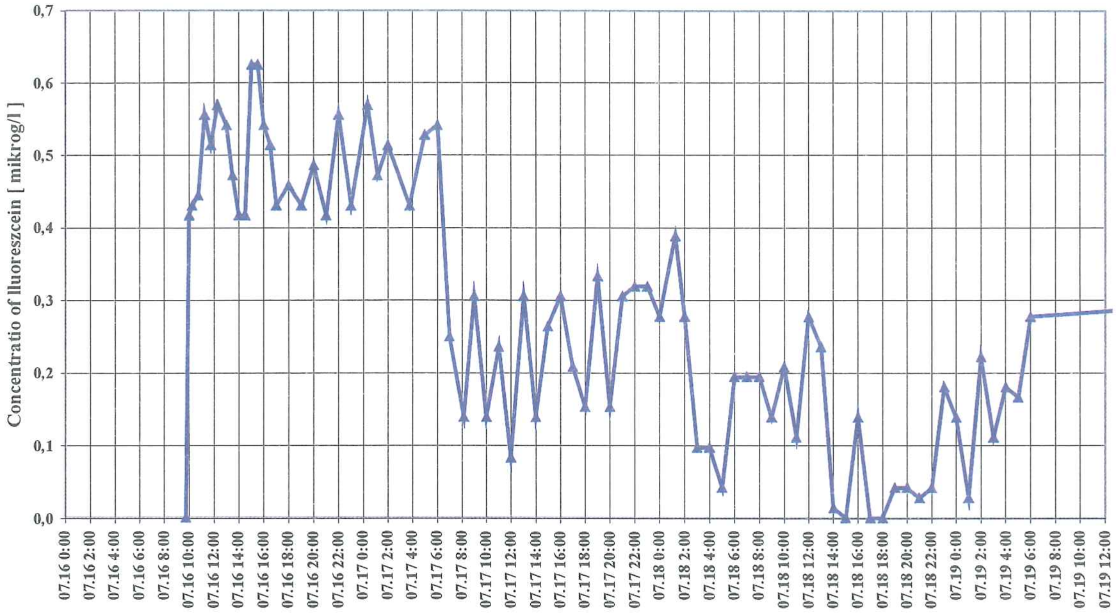


Fig. 6 *Tracer test, Szatmárcseke No.1, fluorescein in T (pumping) well.*
Fluorescein analysis: Laboratory in Eger.

tions. The analysis was made by the Research Center of Eszterházy Károly College in Eger with Varian Cary 3E spectrophotometer on 490 nm wave length. Checking tests were also made on 512 nm wave length with additional spectro-fluorimeter (Figure 6).

The fluorescein appeared after two and half hours with a sharp peak in the pumped well. Finally, $5{,}6 \cdot 10^{-3}$ m/s maximum flow speed was determined. This corresponds to $5 \cdot 10^{-3}$ m/s maximum hydraulic conductivity (Darcy-law). This hydraulic conductivity value agrees well with the one of the calibrated flow model (the hydraulic data can be seen in Figure 2).

Some of the samples were also checked in Bucharest; the control measurements showed good agreement with the Hungarian values (Figure 7).

b) Second Hungarian tracer test, Szatmárcseke No.2

The Geokomplex Company was interested in the water prospecting activity between Szatmárcseke and Tiszakóród. This is the reason why the Geokomplex company made a different series of measurement using a moni-

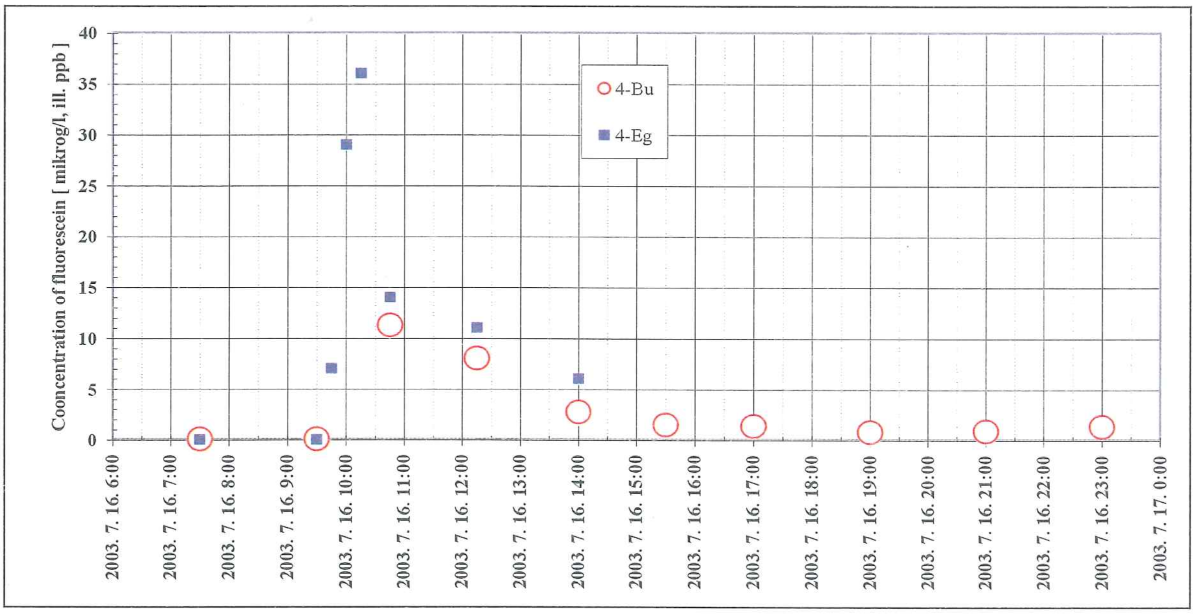


Fig. 7 *Tracer test, Szatmárcseke No.1, fluorescein in No.4 (monitoring) well.*
Fluorescein analysis: Laboratory in Bucharest and Eger.

toring well 1 km away from the previous site. To provide the suitable conditions for the tracer test a new well was drilled (Figure 8). This site was very close to the Túr river. The fluorescein tracer was injected in the S-6/3a well. The main data of the measurements are given in the (Table 2).

It was not economically to continue the measurements for extremely long time. To optimise the measurement process, the laboratory of the FETIKÖFE end-user provided some additional measurements. The trends are correlating well with the measurements of the Eger laboratory. On the other hand, there are differences between the values. The later measurements carried out in Eger revealed the problem of the tracer decay. This process made the interpretation extremely difficult.

The tracer appeared after one and half hour (Figure 9). This mean $2,6 \cdot 10^{-3}$ m/s flow velocity, and the derived hydraulic conductivity is $1,16 \cdot 10^{-2}$ m/s (Darcy-law). The hydraulic conductivity was higher than at the Tisza river; probably, this very high hydraulic conductivity represents a local anomaly comparing to the

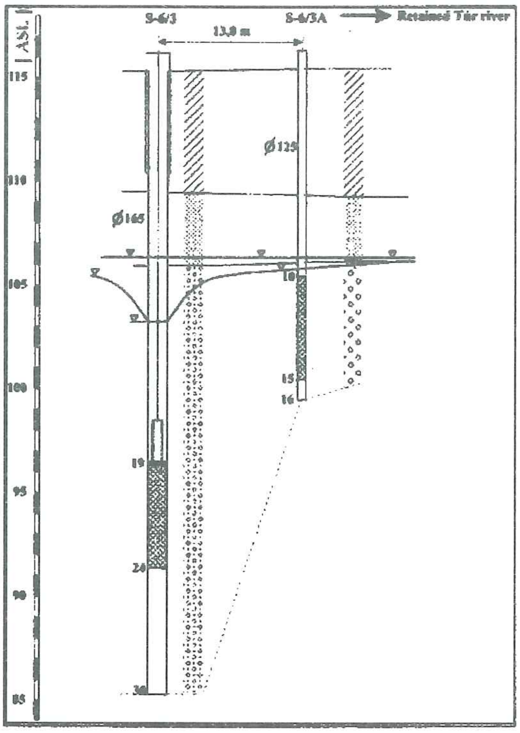


Fig. 8 Hydrostratigraphic cross-section (Szatmárcseke No.2). The pump can be found above the screen in No.S-6/3 well.

Table 2 Summary data of the pumping tests and the tracer measurements (Szatmárcseke No.2).

Pumping: from S-6/3 well (= Pumping) 11.08., 17^{00} – 16.08., 9^{00}
Pumping: $Q = 400$ l/min = 576 m^3/day = 0,0067 m^3/s
Tracer: to S-6/3a well 600 g fluorescein (2 l NH_4OH + 200 l water) at 12.08., 7^{28} – 7^{33} + taping up 15 l/min water 12.08., 7^{41} – 9^{28}

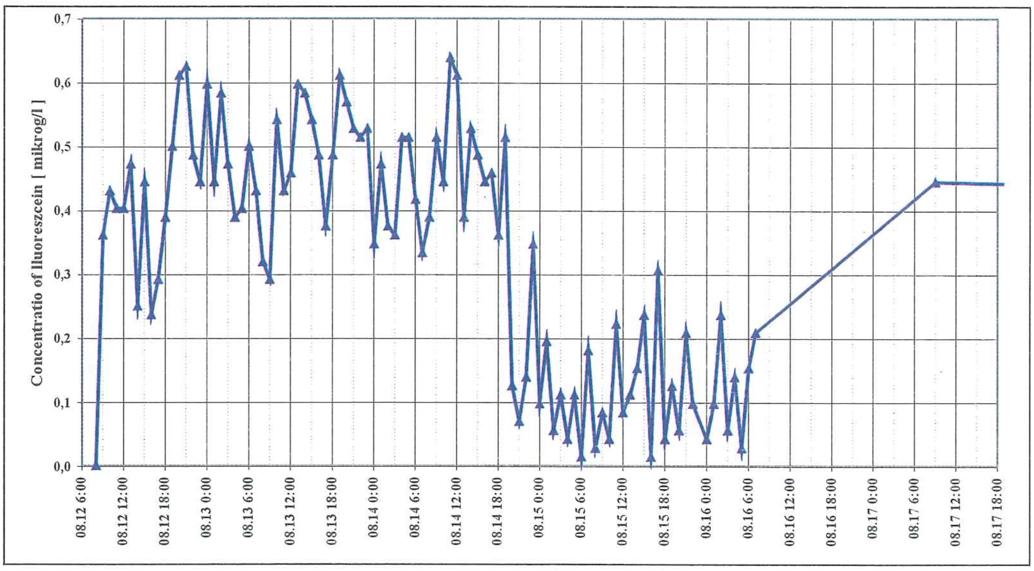


Fig. 9 Tracer test, Szatmárcseke No.2. Fluorescein in pumping well (S-6/3). Laboratory in Eger.

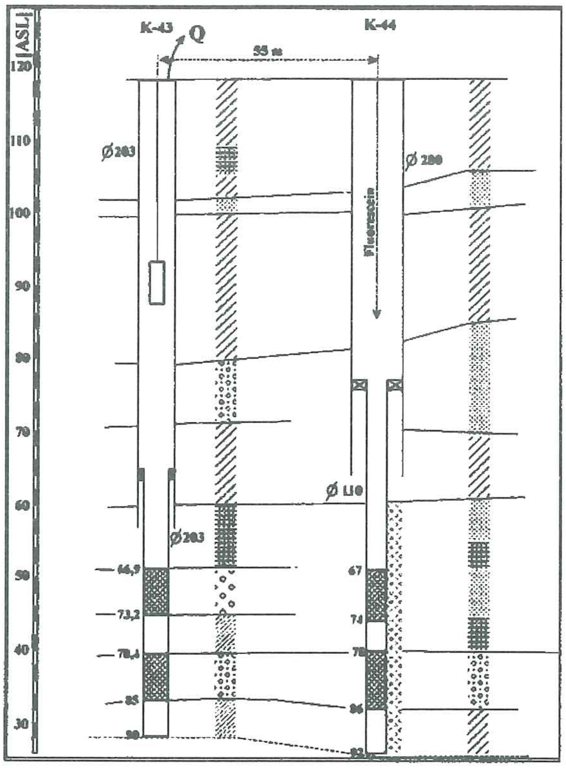


Fig. 10 The hydrostratigraphic cross-section of the investigated wells. The screens of No. K-44 well are connected by a gravel pack. (Due to some well problems, fluorescein tracer was injected above the packer during permanent water load - See Fig. 11).

value of the corresponding zone of the calibrated flow model.

During the pumping test, steady-state condition was not reached. The water levels were not stabilized even after a long pumping time. The water temperature increased. Probably, warm surface water represented replenishment for the investigated aquifer.

c) Third Hungarian tracer test, Csenger

Two wells out of operation distanced at 55 meters from each other were used for tracer tests. A few m^3 of drinking water were produced from the well K-43 earlier; there was no production from the well K-44. The fluorescein tracer was injected into the well K-44, and the pumping was started in the well K-43. Some problems to discharge the pumped water occured. The obtained results are presented in Figures 10 ÷12.

As the tracer did not reach the screen of the well first, some water was added into the well to achieve this state. This extra water load to the tracer material can be followed on the results.

The water levels are well correlated in the investigated two wells. On the other hand, water abstraction from other wells was reflected on

Table 3 *Summary data of the pumping tests and the tracer measurements (Csenger).*

Pumping from K-43 well (= Pumping) 16.07., 18^{00} – 05.08., 9^{00} (Pumping problems were detected during the beginning and the end of the measuring) $Q_{characteristic}$ = 750 l/min = 1080 m^3/day = 0,0125 m^3/s
Tracer: to K-44 well 900 g fluorescein (3 l NH_4OH + 200 l water) at 21.08., 19^{09} – 19^{18} - 41 m deep, overpacking box + topping up 10 l/min water 21.08., 19^{38} – 23.08., 11^{45} (See Figure 11)

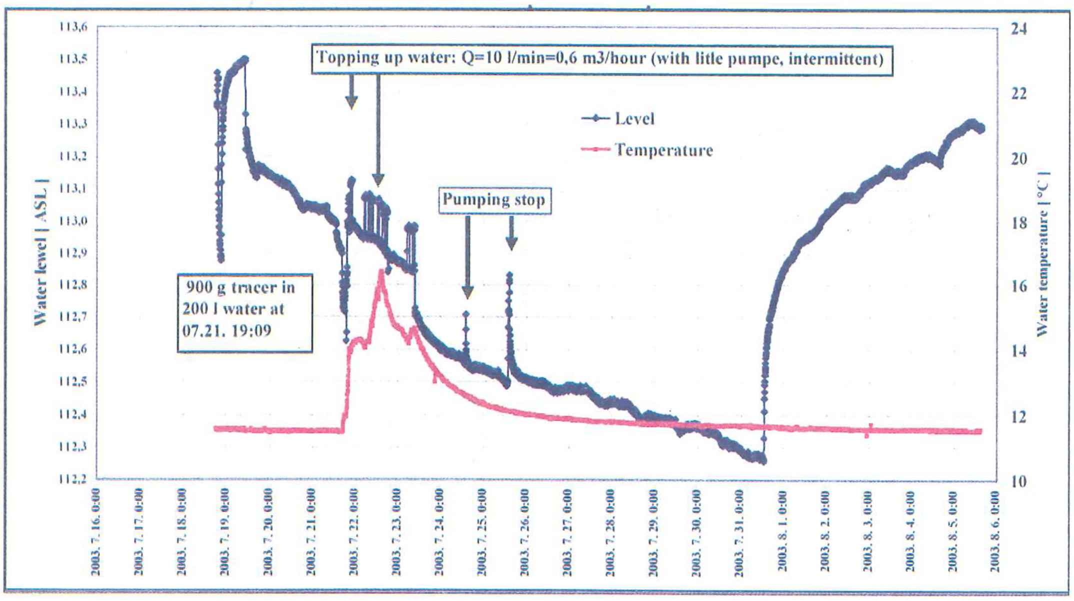


Fig. 11 Tracer test, Csenger, water level and water temperature in monitoring well (K-44) with Eijkelkamp measuring instruments.

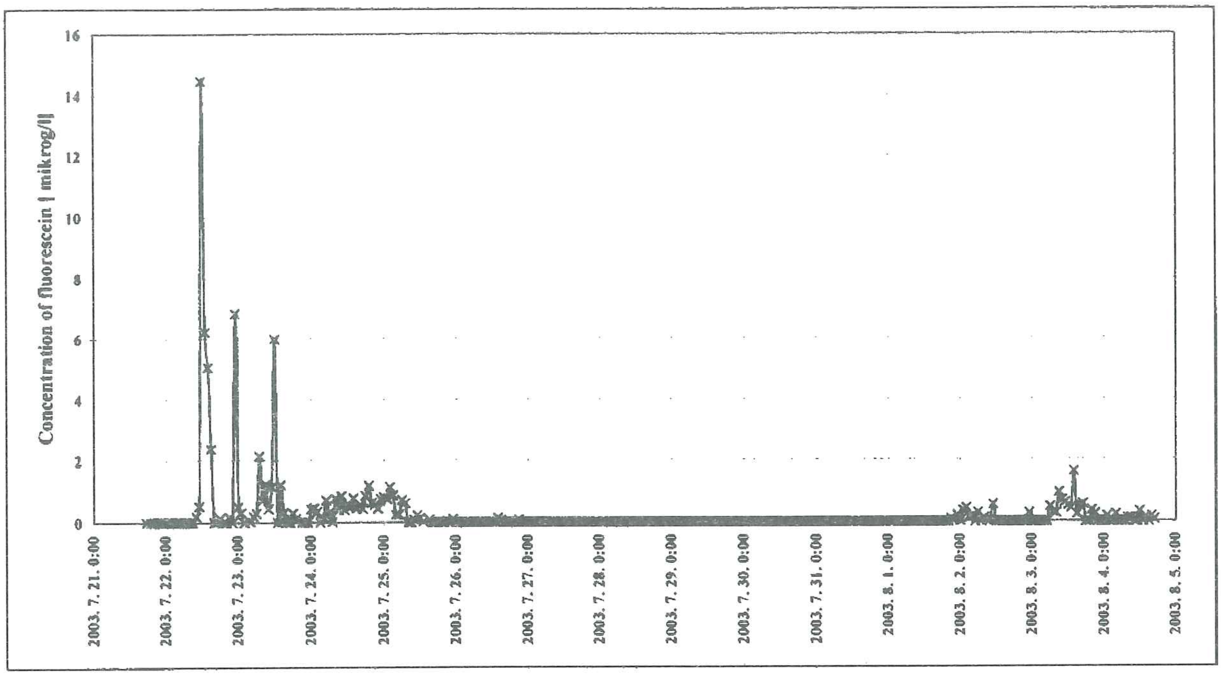


Fig. 12 Tracer test. Csenger, fluorescein in pumping well (K-43), in pumping time. Laboratory in Eger.

the water levels of well K-44. The first arrival of the tracer appeared in the well K-43 after 15 hours. It can be seen from the geological cross-section that three layers are screened together. In this case, it was not possible to determine which layer was actually conducting most of the tracer mass. In case of the best conductivity, the flow velocity could be around $1 \cdot 10^{-3}$ m/s. The derived hydraulic conductivity was $7{,}3 \cdot 10^{-3}$ m/s. (Darcy-law), showing a good agreement with the flow model parameters. Then, the measurement was stopped; a week later the production was started again. Green water was recognized even by eyes. Some new measurements were also made; the obtained tracer concentrations were quite constant.

d) Hungarian measurement of tritium, oxygen and hydrogen isotopes

The Laboratory of Environmental Studies Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI) in Debrecen performed some measurements in the frame of the project. The obtained results are summarized in the Figures 13÷16.

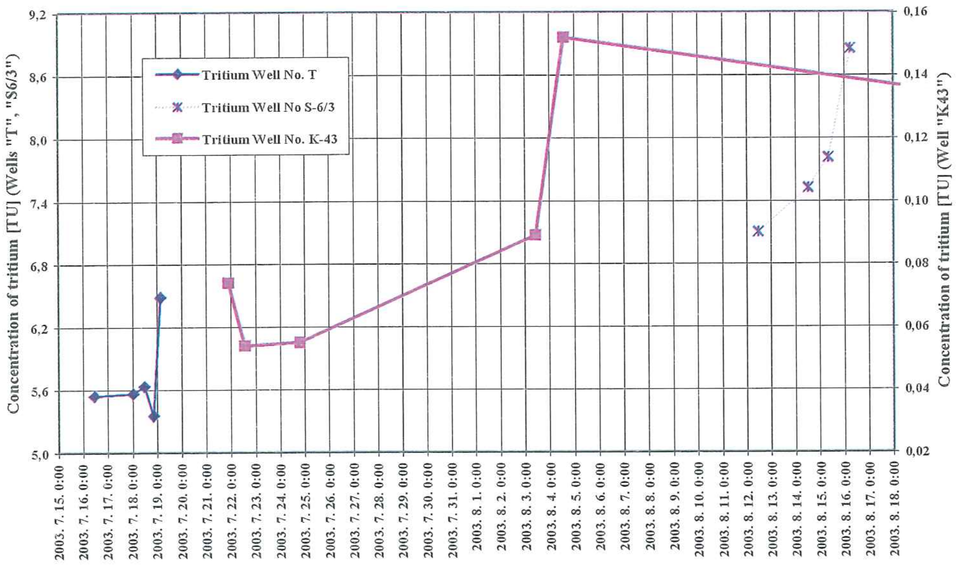


Fig. 13 Concentration of tritium (Szatmárcseke No.1 - Well No.T, Error: 2,9 %; Szatmárcseke No.2 - Well S-6/3, Error: 2,9 %; Csenger Well K-43, Error: 23,5 %).

The main conclusions are the following:

• The tritium content was higher with one magnitude on the Szatmárcseke sites than in Csenger (See Figure 13). Besides this, the values of Szatmárcseke No.1 were lower than the measured values on the Szatmárcseke No.2 site. It is possible that fresh phreatic water deriving from the Tisza river appeared in the well.

• In case of Csenger, older water was observed due to the intense pumping activity.

• In all the three cases, the tritium content increased with time, as more and more fresh water arrived to the pumping wells.

• The similarities of the Szatmárcseke measurements and the differences between the Szatmárcseke and Csenger data were confirmed by the differences between the hydrogen and oxygen isotopes (See Figures 14÷16). The tritium values show that fresh and young water were produced in Szatmárcseke. On the other hand, by means of the stable isotope ratio values of oxygen and hydrogen old, several thousand-year-old water was found close to the surface in Csenger.

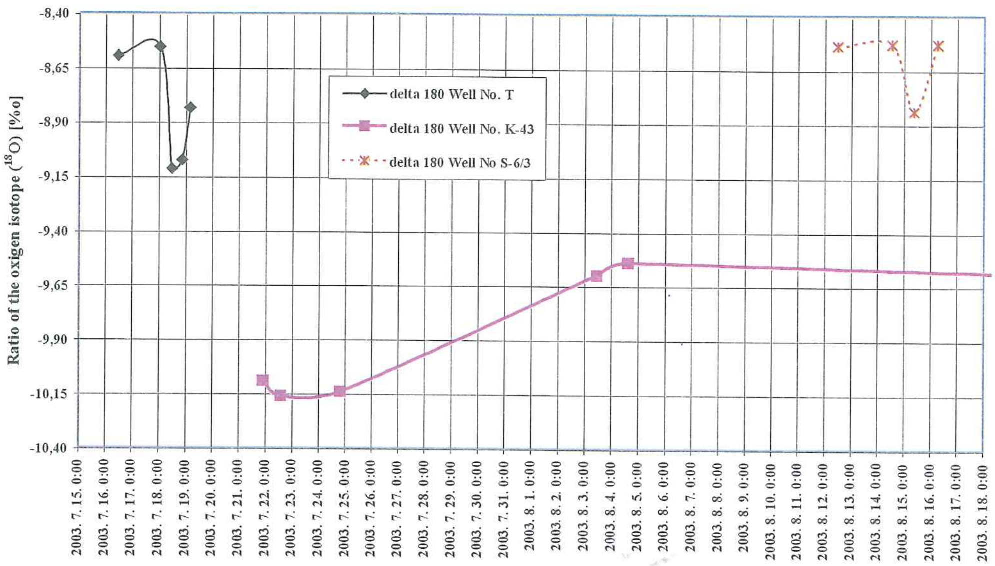


Fig. 14 *Ratio of the oxygen isotope (Error: 0,2 ‰) (Szatmárcseke No.1 - Well No.T; Szatmárcseke No.2 - Well S-6/3; Csenger Well K-43).*

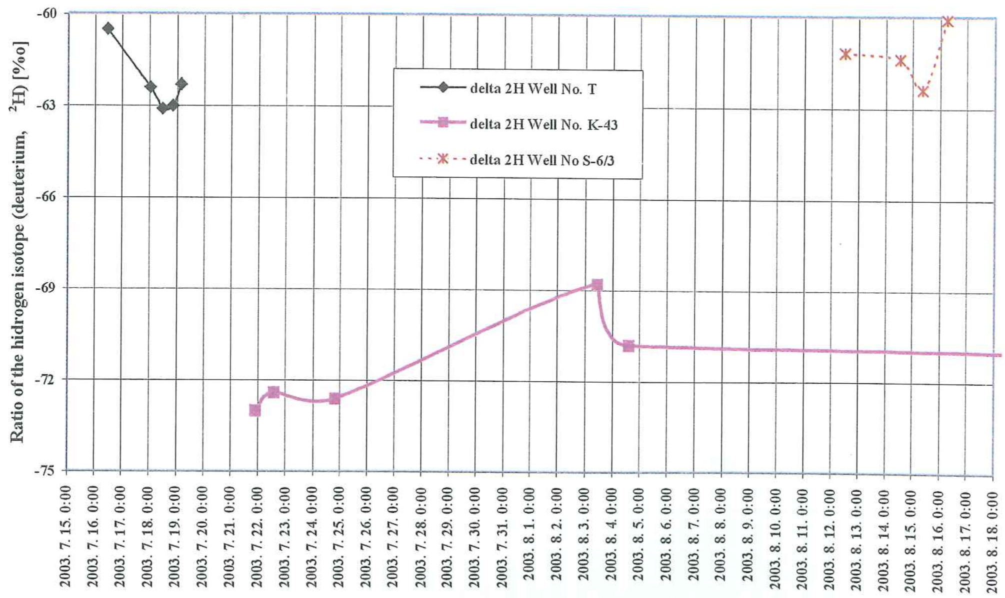


Fig. 15 *Ratio of the hydrogen isotope (deuterium) (Error: 2) (Szatmárcseke No.1 - Well No.T; Szatmárcseke No.2 - Well S-6/3; Csenger Well K-43).*

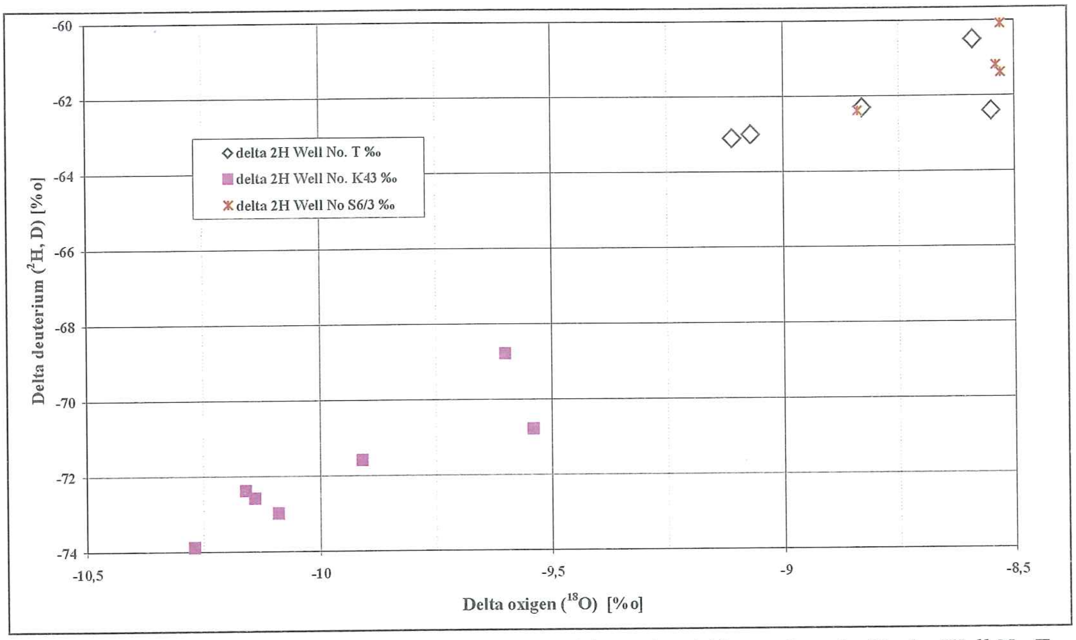


Fig. 16 Ratio of the oxygen and hydrogen isotopes (deuterium) (Szatmárcseke No.1 - Well No.T; Szatmárcseke No.2 - Well S-6/3; Csenger Well K-43).

2. Field campaign in Romania

The purpose of this field campaign (spring and autumn 2003) was to undertake pumping tests and tracer tests in the selected suitable locations (Figure 17).

For the tracer tests in Romania, due to the necessity of a continuous monitoring of the equipment in the field, an important number of participants were mobilised: 7 from NIMH, 1 from TUCEB, and 3 specialists from Satu-Mare end-user. A specialist from Somes-Tisa Directorate was asked to help during the field campaign not only for his experience, but also for company specialised equipment (mammoth pumps, electric generator etc.).

The field campaign was organized with the support and the participation of the Belgian team wich was in charge for the training of the local specialists to the methodology of tracer tests and to the effective work in the field in order to perform these tracer tests.

In order to take advantage of the presence of Belgian team and of its experience in performing tracer tests, personnel from the University of Miskolc participated at the field campaign in Romania for more than 2 weeks.

The objectives of the field campaign in Romania were to realize:

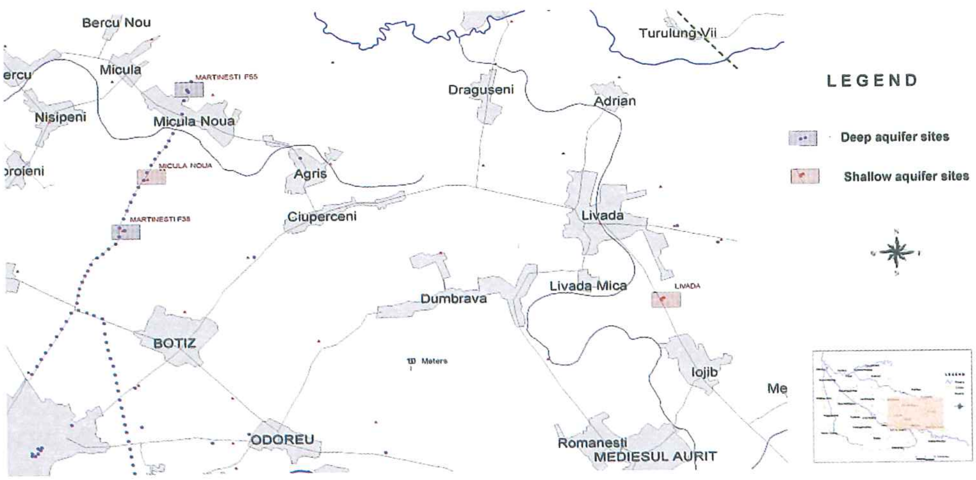


Fig. 17 Location of the tracer test sites in Romania.

a) Pumping tests in 4 sites - 2 for the deep aquifer (Martinesti F38 and F55) and 2 for the shallow aquifer (Livada F1 and Micula Noua F1). As a result hydraulic conductivity and storage coefficient values were obtained. In table 4 a synthesis of the hydraulic conductivity values for the shallow and deep aquifers is presented. Theis and Jacob interpretation methods were used to derive the hydrogeological parameters (Figures 18÷21).

b) Tracer experiments in 2 sites - one for the deep aquifer (Martinesti F38) and one for the shallow aquifer (Livada F1)

The tracer test for the deep aquifer took place in the Martinesti water works area (Figure 22). The tracer masses injected in the deep aquifer were 500 g of fluoresceine and 500 g of rhodamine.

The first sample containing fluoresceine was found after 115 hours from the injection. Rhodamine was not observed in samples. About

Well/ Method		THEIS	JACOB
MARTINESTI F38	T (m^3/day)	2237	2552
	S	0,0016	0,0013
	K (m^3/day)	43	50
MARTINESTI F55	T (m^3/day)	1557	1792
	S	0,0005	0,0003
	K (m^3/day)	31	35
LIVADA F1	T (m^3/day)	6367	8247
	S	0,097	0,08
	K (m^3/day)	209	294
MICULA NOUA F1	T (m^3/day)	5874	6219
	S	0,0006	0,0004
	K (m^3/day)	265	296

***Table 4** Comparative table of the hydrogeological parameters.*

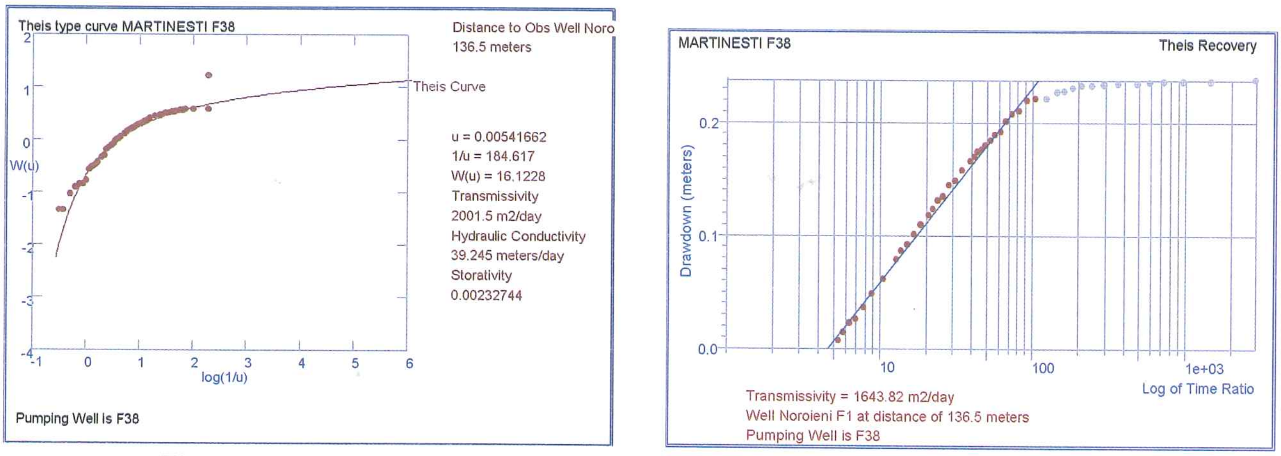


***Fig. 18** Evaluation of the hydrogeological parameters. MARTINESTI F38 - deep aquifer.*

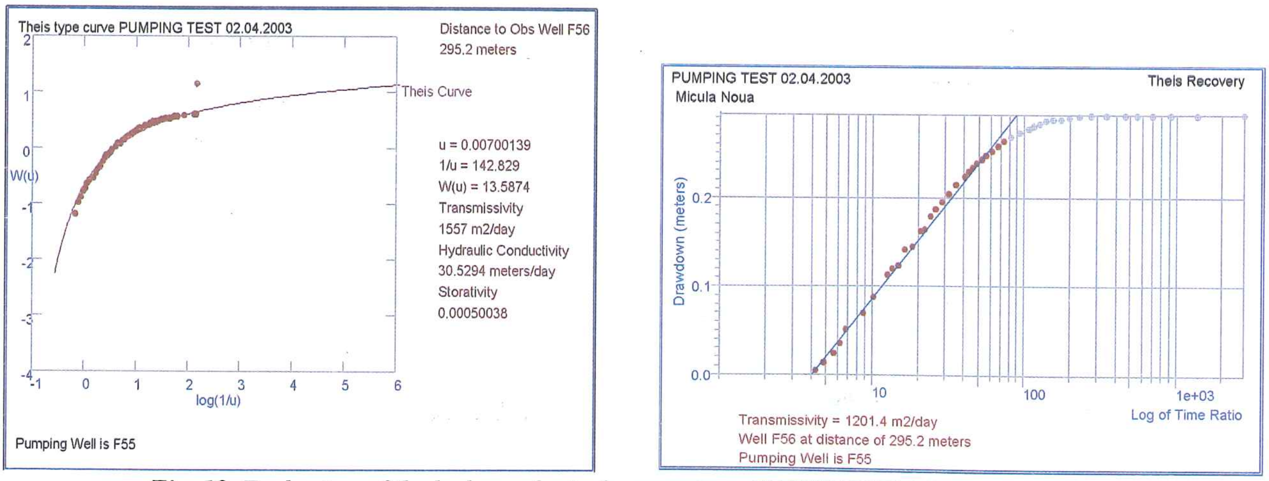


***Fig. 19** Evaluation of the hydrogeological parameters. MARTINESTI F55 - deep aquifer.*

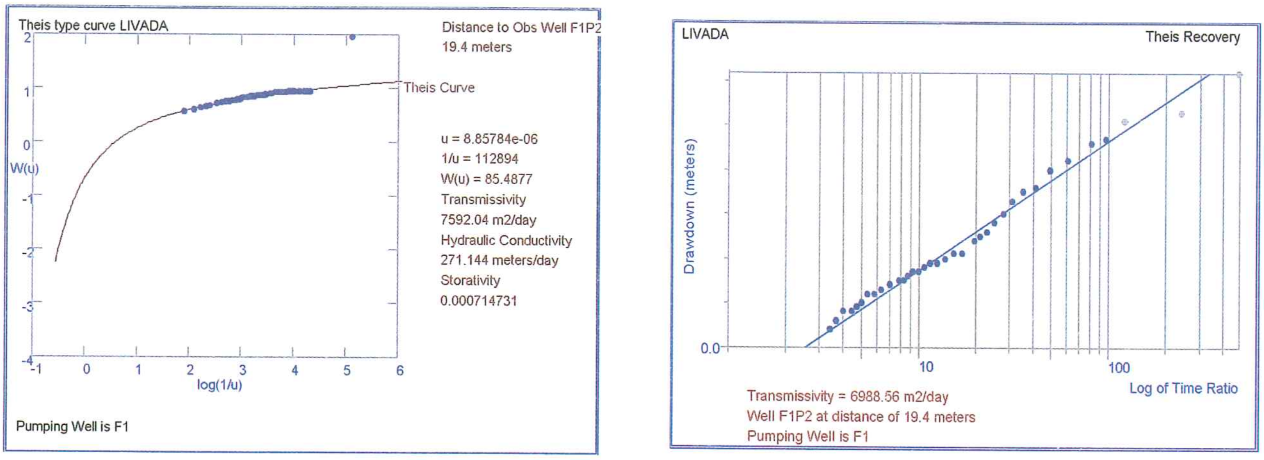


Fig. 20 Evaluation of the hydrogeological parameters. LIVADA F1 - Shallow aquifer.

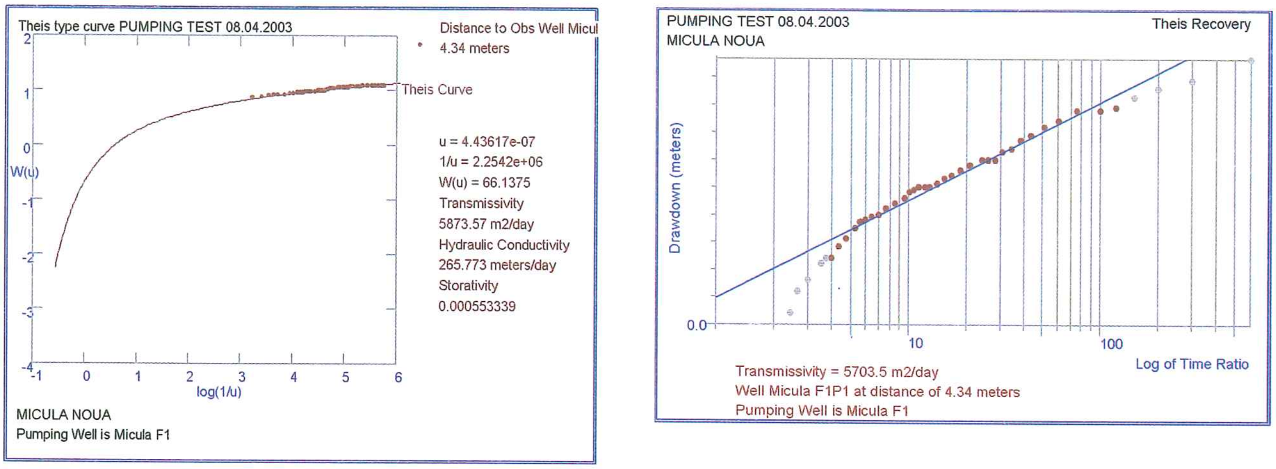


Fig. 21 Evaluation of the hydrogeological parameters. MICULA NOUA F1 - shallow aquifer.

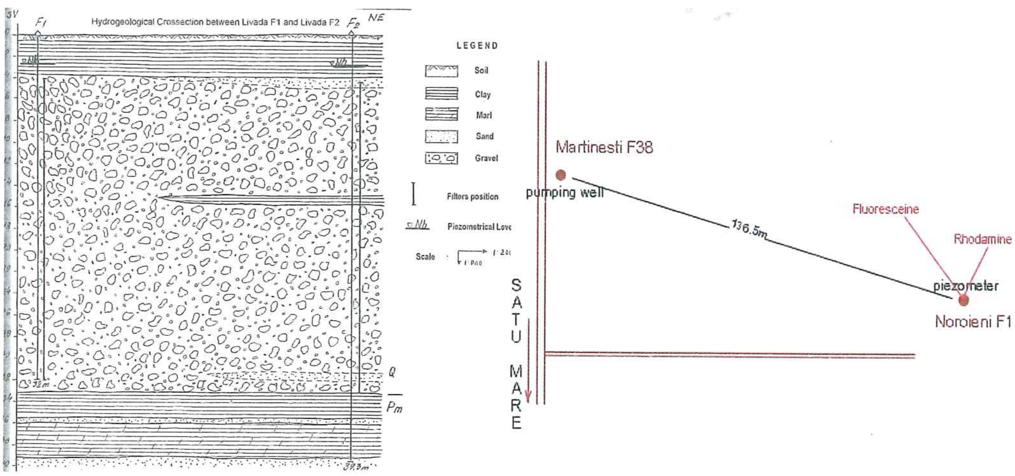


Fig. 22 Tracer test in the deep aquifer: location of the wells and cross-section.

300 samples were prelevated from this location, but no significant concentration of the tracer was recorded at the pumping well F38 (Figure 23).

The tracer test for the shallow aquifer was organized at Livada (Figure 24).

The tracer quantity injected in the shallow aquifer consisted in 50 g of fluoresceine and 50 g of rhodamine B. 82 samples were taken from this location.

The evolution of the concentration for these tracers is presented in Figures 25 and 26.

In the case of tracer tests the breakthrough curve was not complete for Livada, while in the case of Martinesti the tracer was not found in the pumping well.

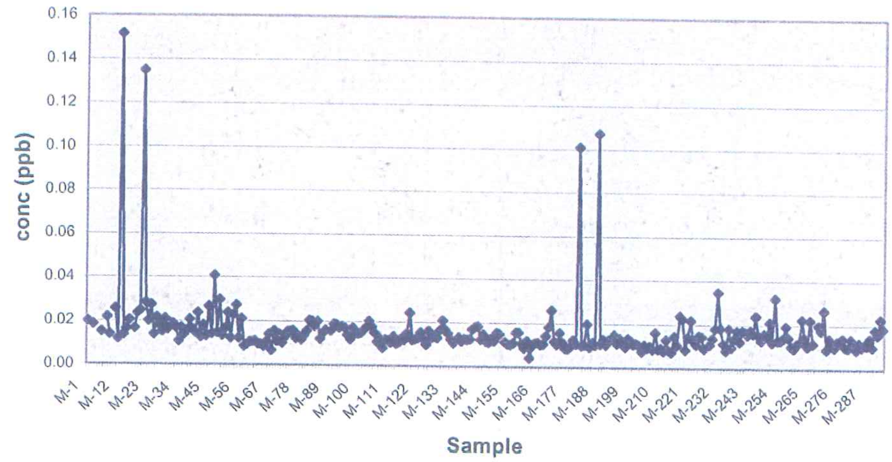


Fig. 23 Fluoresceine concentration in the pumping well Martinesti F38.

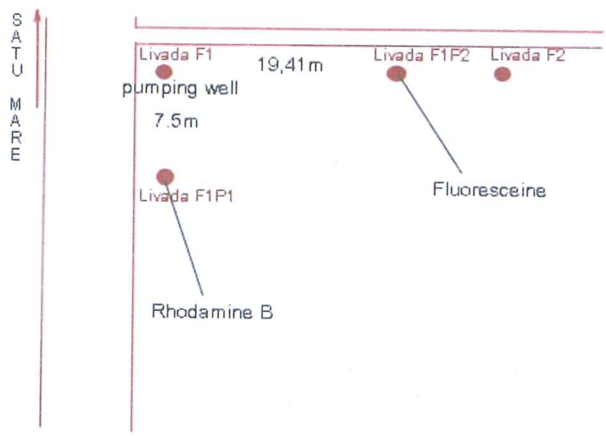


Fig. 24 Shallow aquifer - wells location for the tracer test.

c) Natural isotopes analyses. An additional purpose of the October 2003 campaign in Romania was to investigate the water exchange between the aquifer and Somes river. Water levels and velocities were measured on the Somes river in the sections Cicârlău and Satu-Mare, as well as on the existing tributaries: Ilba, Seini, Valea Vinului, Homorod and Lipău.

A number of 8 water samples from the Somes River and his tributaries and from the shallow and deep aquifer were collected for natural isotopes analyses. Until now, these samples were analised only for (incomplete) tritium and deuterium, following that the ^{18}O analyses to be undertaken further on. The isotopes analyses were performed at the National Institute of Research-Development for Criogenic and Isotopic Technologies (ICSI) - Râmnicu Vâlcea.

Regarding the analysing technique, it must be specified that the ^{3}H was determined by direct measurement (with no previous enrichment) with the LKB-Quantulus liquid scintillation spectrometer, whose detection limit is about 3,5-4,0 TU. The deuterium was determined with a VARIAN MAT 250 Mass Spectrometer.

The analysis results were expressed in clasic units namely TU (Tritium unit) for tritium

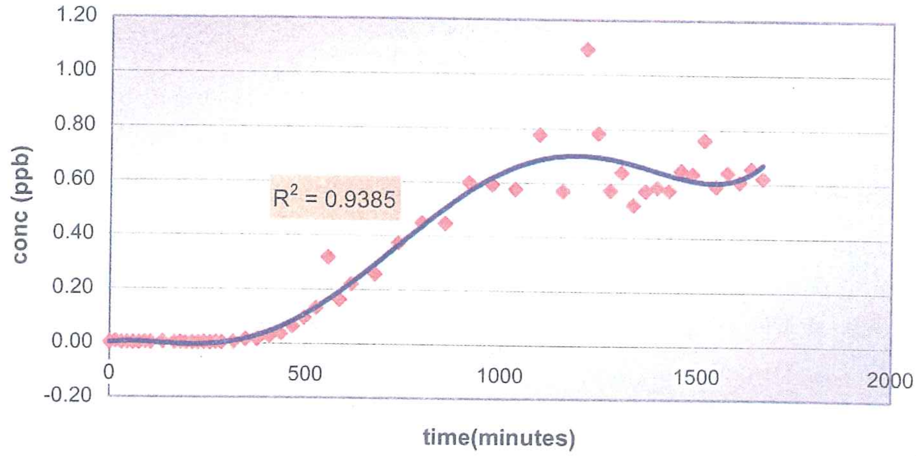


Fig. 25 Fluoresceine concentration in the pumping well Livada F1.

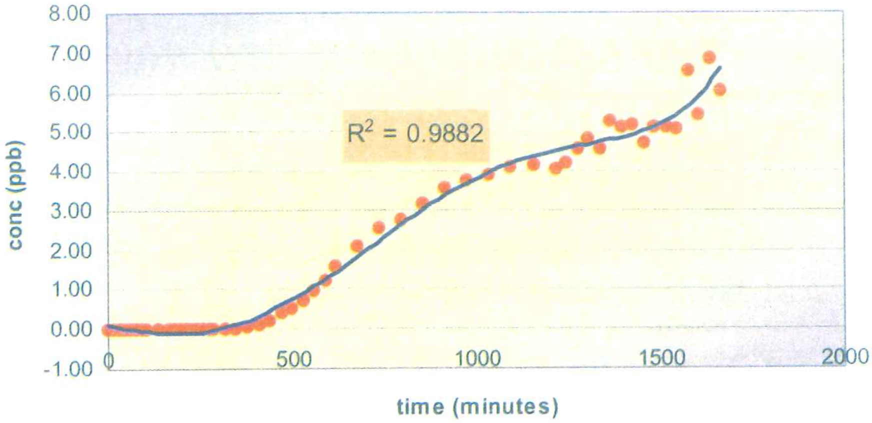


Fig. 26 Rhodamine B concentration in the pumping well Livada F1.

***Table 5** Distribution of the sample location.*

Device Type	Number of samples	TU
Surface Waters	5	7,6
Phreatic Waters	2	20,7
Depth Groundwaters	1	4,5

***Table 6** Synthetic situation of the mean content of Tritium.*

No.	Sampling Point	Location	Tritium (TU)	ΔD ‰ VS-VSMOW
1	Cicarlau	Hydrological Station, Somes	8,2	- 68,3
2	Satu Mare	Hydrological Station, Somes	7,9	
3	Csenger	Hydrological Station, Somes	6,9	
4	Ilba	Right Streamflow of Somes	5,2	
5	Homorod	Left Streamflow of Somes	9,6	
6	Lipau F2	Left phreatic drill to Somes	26,2	
7	Lipau F3	Right phreatic drill to Somes	15,3	- 56,9
8	Petin	Left depth drill to Somes	4,5	- 23,3

and δ units expressed in ‰ for deuterium as a function of Vienna SMOW.

Discussing the repartition on types of the sample locations, it is noticed that from the all 8 points, 5 points concern surface waters and 3 points groundwater (Table 5). The synthetic situation of the mean contents in ^3H is given in Table 6.

Unfortunately, the number of the measuring points and the relatively small duration of the field campaign did not allow to evaluate the water fluxes exchanged between aquifer and Somes river. Additionally, due to some meteorological events occurred during the measurements and to the difference on the discharges provided by Romanian and Hungarian hydrologic stations (25 m^3/s at Satu-Mare and 18 m^3/s at Csenger) this objective could not be reached.

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