Effects of the long-term thermal water utilizations on the aquifer in SE-Hungary

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ABSTRACT

Hungary has great (thermal)water potential, compared to the European countries. The water is utilized for different purposes, the most important and everyday usages are the: drinking water, balneological-, and agricultural/energy purpose utilizations. In SE-Hungary, in the Great Plain, the thermal water utilization has more than 60-70 history. In the Szentes and Szeged regions, the thermal water of the Upper Pannonian porous aquifer is used for greenhouse heating by several agricultural companies.

From the 1950s, only in Szentes about 35-40 wells, in Szeged region more than 70 thermal wells were established on the Upper Pannonian aquifer. The long-term and intensive thermal water production caused regional (from 10-15 to 30-40 meter) depressions in both regions in the cca. 1500 meter-thick porous thermal aquifer.

To determine the current state of the thermal systems, 3D numerical models were built. The finite element FEFLOW code was used, which combined and simultaneously managed the hydrodynamic and heat transport processes of the thermal system. The model buildings are based on the geological, hydrodynamic and geothermal characteristic of the aquifers. The models have been calibrated by the help of the thermal productions of the areas.

By the help of the numerical models we were able to examine and determine the effects of the more than 50 year-long operation of the thermal wells and the depressions formed in the two regions above. After determining the current state of the system and the aquifer, we examined the future effects of the agricultural greenhouse heating utilizations in both areas. In Szeged region, great system(s) with reinjection wells, while in Szentes region small system(s) (with 1-2 well(s) without reinjection) were examined.

1. INTRODUCTION

Hungary is situated in Middle-Eastern Europe, in the Carpathian Basin. Due to the tectonic situation and the thick, insulating sedimentary series the geothermal conditions are very good (Dövényi, et al., 2002).

By the end of the Miocene a sedimentary basin (Pannonian lake) was formed by the isolation from the sea and thick sedimentary sequence was formed during the Pannonian age, when the lake was filling by the rivers. Consequently, in the Hungarian Great Plain the thickness of the whole Pannonian sequence varies 3000 up to 4500-5000 m. Here the thickness of the high-porosity Upper Pannonian formations can reach up to 2000 meters.

In the large horizontal and vertical extended of the high-porosity Upper Pannonian series - contain mainly sandstones and sands - gravity-driven regional flow system is existed. In greater depth, in the fine-grained sequence pressure-drivel flow system is taken place.

Thanks to high geothermal gradient of the region, from the depth of 300-350 meter thermal water (>30 °C) can be found, while the temperature of the stored water in the bottom of the Upper Pannonian aquifer can reach 130-150 °C.

2. GEOTHERMAL ENERGY USAGE IN SE-HUNGARY

Although the first thermal wells were drilled in Hungary in the second half of the XIX. century, the large wave of the well drilling started only in the second part of the XX. century partly due to the hydrocarbon research. In the Szentes and Szeged region in the SE-Great Plain the first thermal wells were drilled in the end of the 1950's. The water was used in the agriculture for the heating of the greenhouses. In the area currently also the agricultural utilizations are the most common, but because of the natural arsenic content of the shallow (300-350 m) aquifers, around Szeged lukewarm (30-32 °C) water is used for drinking water purpose. Besides the agricultural (and drinking water) usage, the most common utilization is the balneological use: numerous

baths and spas can be found in the area. Since the 1990's, the water is used for district heating in several cities. These high temperature utilizations are cascade systems.

According to the current regulations the thermal water used for energetic purpose cannot injected back to the aquifer, although approx. 20 injection well was drilled due to the previous legal regulations in Hungary.

The more than 50-year long production of the lot of (cca. 950 operating) thermal wells caused regional pressure drop in the area of the Great Plain (Tóth, 2009, Szanyi et al, 2009). It seemed, that the water level started to stop, to stabilize.

In this paper we presented two areas - Szentes and Szeged regions - where the thermal water is used for agricultural and drinking water purpose more than 50-year-long. In both cases, due to the long term productions regional water level can be observed. The today-state of the aquifer is studied by the help of numerical modelling. The problems of these areas can illustrate how necessary is the sustainable utilization of the geothermal energy.

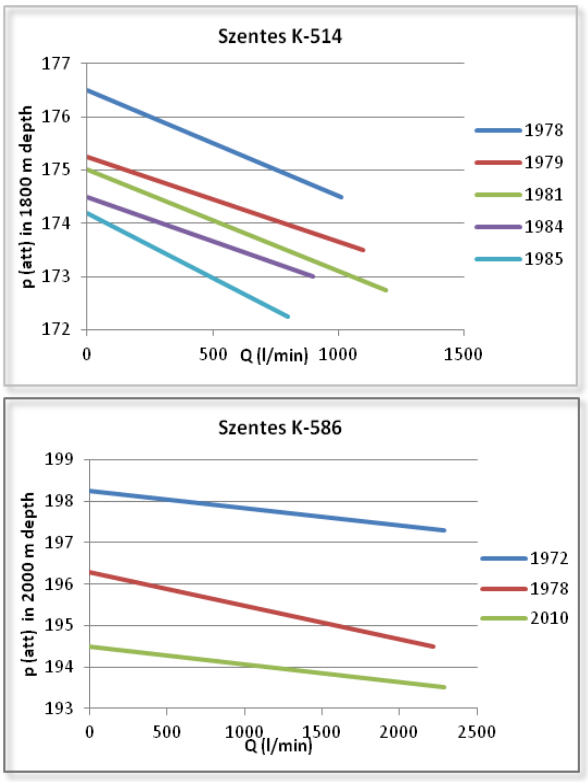

Figure 1. Rating curves of the Szentes K-514 (1.a) and K-586 wells (1.b)

3. SZENTES REGION - REGIONAL WATER LEVEL DROP DUE TO THE 50-YEAR-LONG UTILIZATION

In the wider region of the Szentes area cca. 165 thermal wells (30-100 °C) can be found and 94 of the drilled for the Upper Pannonian porous thermal aquifer. Nearly half of the wells (200-1100 m) produce thermal water with <60 °C temperature, while the deep wells (1200-2300 m) produce 60-100 °C water. The thermal water has mainly has $NaHCO_3$ type and <2000 mg/l TDS, but from 1800-1900 m depth the TDS can reach 3800 mg/l.

The subsurface regional water flows in the area of SE-Hungary is basically determined by the great river, named Tisza and the fairly simple topography. The zone of the river is a discharge area of the regional flow systems.

The well-utilizations are mainly agricultural (greenhouse heating, poultry yards, etc.), but also geothermal district heating systems and spas are also operating in the region. The thermal water is utilized without reinjection, which resulted up to 3-4 bar pressure drop in the thermal aquifer (Fig.1.)

To investigate the effect of the long term production of these wells on the pressure conditions of the regional thermal aquifer, a 3D numerical hydraulic- and heat transport FEFLOW model was built. The studied area is approx. 3640 km^2, the total volume of the model is 10 000 km^3.

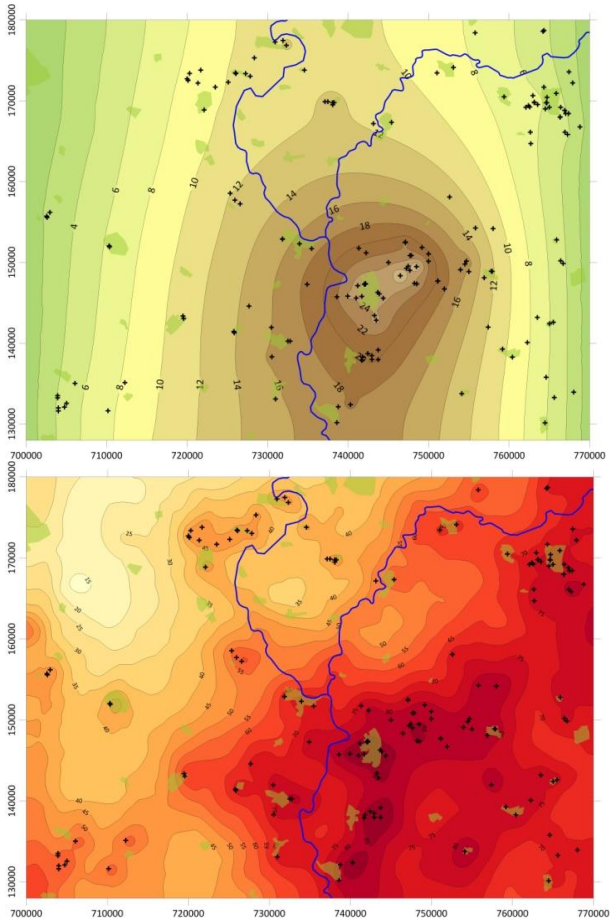

Figure 2. The modelled water level drop in 1450-1500 m depth (2.a) and the modelled temperature in the 10th model layer (2.b) in the Szentes region

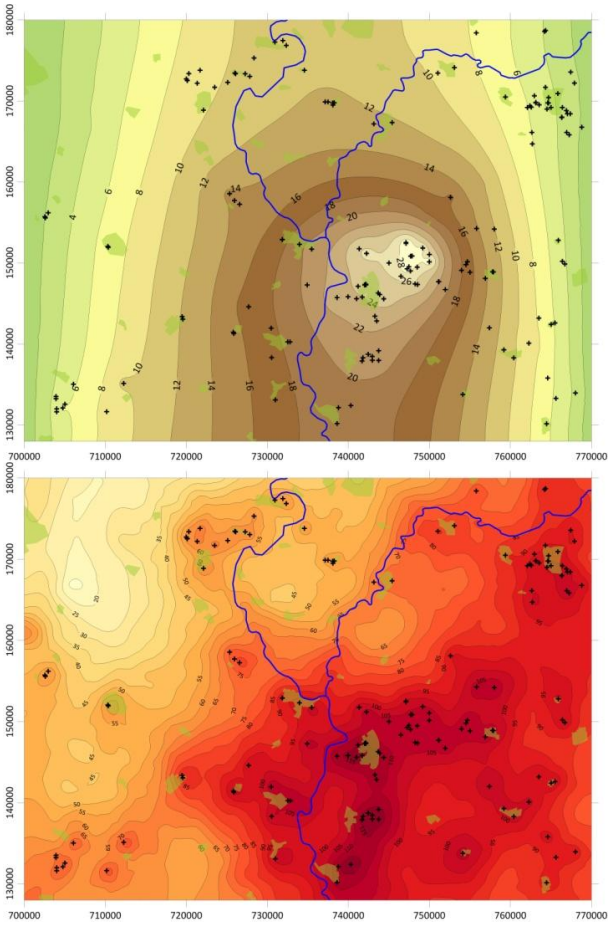

Figure 3. The modelled water level drop in 1900-1950 m depth (3.a) and the modelled temperature in the 20th model layer (3.b) in the Szentes region

To create the vertical structure of the model, geological, geophysical data, screen-depth and -length of the wells were used. By the help of these data the screens were combined, grouped, a 24-layered model was built. The top of the model is the surface topography, the model bottom is situated in the Lower Pannonian aquitard sequence. For the model calibration the water and bottom hole temperatures and the result of the well tests and literature data were used.

The results of the modelling reflect the measured water level changes. We modelled cca. 16-24 m water level drop in the shallower (900-1300 m) aquifers (Fig.2.a, 3.a) and 18-28 m drop in the deeper (1400-1900 m) thermal aquifers (Fig.2.b, 3.b).

4. SZEGED REGION - AGRICULTURAL AND DRINKING WATER PURPOSE UTILIZATIONS, EFFECTS ON THE THERMAL AQUIFER

In the Szeged region from the 1960's hundreds of thermal wells were drilled in the hydrocarbon research programs. A part of the barren, or the abandoned hydrocarbon wells were converted into thermal water-producing wells. For the purpose of thermal water abstraction numerous well were drilled in the area, so in Szeged Region more than 100 thermal wells are operating currently.

The thermal wells in the area are abstracting 30-90 °C water. 68 of the wells are on the Upper Pannonian thermal aquifer. Almost one-third of the wells produce 30-32 °C lukewarm water from the Quaternary thermal aquifer (400-550 m) for drinking water purpose, while the half of the Upper Pannonian wells produce 45-60 °C water from 700-1250 m depth; the deeper wells (1400-1900 m) abstracting 60-90 °C temperature thermal water. The abstracted water from the Upper Pannonian aquifer has mainly $NaHCO_3$ type and usually low, <2500 mg/l TDS, but deeper than 1400 m up to 4500 mg/l TDS can be occured.

The groundwater flow system in the Szeged region shows similar characteristics, than in the Szentes region: it is determined by the Tisza and the fairly simple surface topography. The zone of the Tisza is a regional discharge area.

The wells are abstracting thermal water for agricultural heating purpose (greenhouse heating, etc.), but besides of this geothermal district heating and spas are operating in and near Szeged. The water is utilized without reinjection, which resulted up to 1-3 bar pressure drops in the thermal aquifer (Fig. 4.).

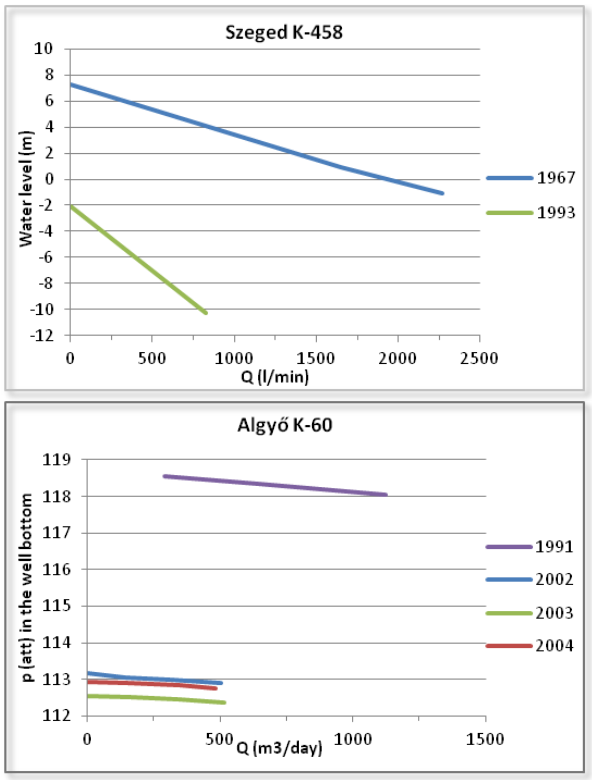

Figure 4. Rating curves of the Szeged K-458 (4.a) and Algyő K-60 wells (4.b)

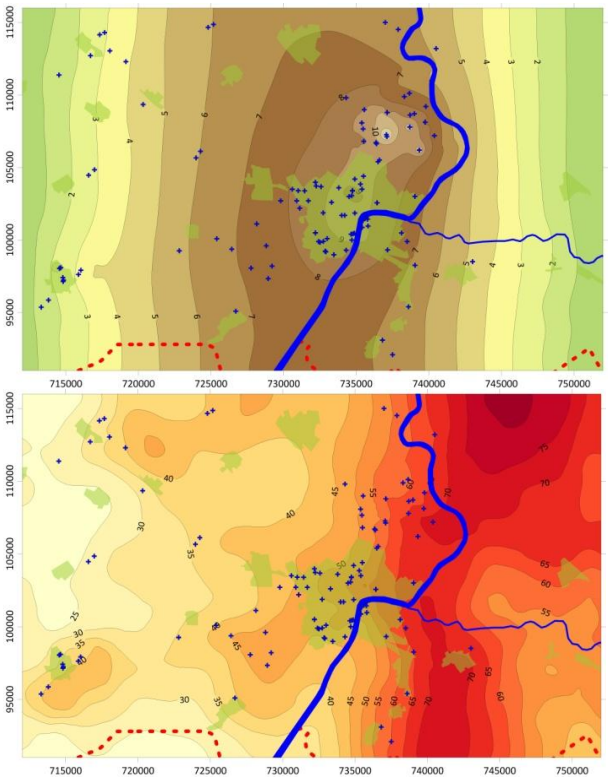

Figure 5. Modelled water level drop in the Szeged region in 700-1250 m depth (5.a) and the modelled temperature in the 10th model layer (5.b)

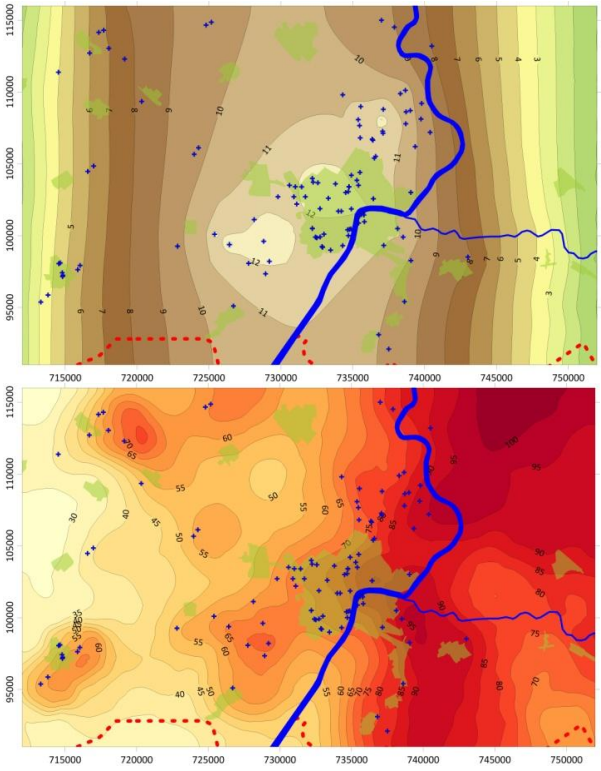

Figure 6. Modelled water level drop in the Szeged region in 1650-1700 m depth (6.a) and the modelled temperature in the 19th model layer (6.b)

The water level changes in the region are studied also by the help of numerical modelling. A cca. 1025 km^2 and 3000 km^3 29 layered water flow- and heat transport FEFLOW model was built. The model was built up as described in the previous chapter.

Based on the numerical model in the Quaternary thermal aquifer (400-550 m) 3-6 m, in the shallower part of the Upper Pannonian aquifer (700-1250 m) 6-12 m, while in the deeper part (1400-1900 m) of the Upper Pannonian thermal aquifer 10-20 m water level drop was caused by the 30-40-year-long production (Fig 5-6.).

5. CASE STUDIES IN BOTH REGIONS

According to the current regulations today in Hungary there are no laws to reinject the energetic used thermal water into the aquifers. During our work, we studied the effects of thermal water abstractions with, or without reinjection, so two cases are presented here in this paper.

5.1. Case study in Szentes Region - without reinjection

In Szentes we studied a small thermal system (with 1 abstraction well), without injection well. The annual thermal water abstraction of the well is 125 000 m^3/year. Approx. 90 °C thermal water are utilized from the depth of 1890-2175 meters. The well is operating in winter (15. Oct - 15 April) and there are no abstraction during the summer month (16 April - 14 Oct.).

Of course, the summer - no pumping - period is helping the regeneration of the aquifer: the head drop in the well, in the winter time, is around 6.5 meter, but after summer, by the end of the resting months, the detected water level drop less than 0.3 meter. After 50 years of operation, the model predicts more than 9 meter head drop in the well by the end of the summer - no pumping - period. This means, that around 9 meter drop will be happen in the thermal aquifer. The radius of the impact area (1 meter head drop) of the water abstraction is approx. 500 meter (Fig. 7) by the end of the 50. year.

Figure 7. Impact area (1 meter head drop) of a pumping well after 50 years -Szentes Region

5.2. Case study in Szeged Region - utilization with reinjection

In Szeged there are a great holiculture with greenhouses (total area ~ 5-6 acres). The thermal system consists of 11 pumping wells and 2 injections wells, 8 of 11 pumping wells and the 2 injection wells are operating. The annual abstracted thermal water is 585 000 m^3, while 400 000 m^3/year cooled water is reinjected into the aquifer - the wells are operating with different yields. The 51-71 °C thermal water comes from the depth of 1050-1700 meter. The sandstone layers between 1490-1670 meters are used for the reinjection. The operation period is 15. Oct - 15 May, while there are no abstraction during the summer (16 May - 14 Oct.).

The summer period has positive effects on the pumped aquifers, as we seen in the previous case study. But the head drop is less here in the individual wells: 1-3.5 meter depression can be observed. The water level raise in the injection wells are approx. 1.5 meters. After a no pumping period these drop is mostly in 0.5 meter, which can reach up to 4-5 meters after a 50-year-long operation period (Fig 8.). By the help of the resting period and the reinjection, the effects of the 50-year-long operation is mostly less than 3 meters.

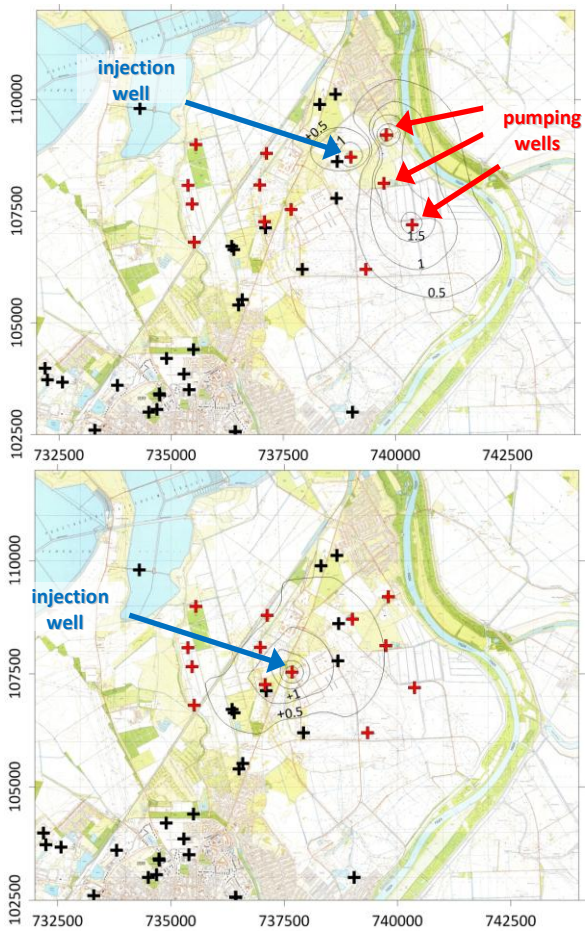

Figure 8. Effects of the operating system - head drop (0.5m) and increase (+0.5m) in the pumping and the injection wells after 50 years -Szeged Region

6. CONCLUSIONS, OUTLOOK

As we mentioned in this paper Hungary has huge thermal water potential. The thermal water of the porous thermal aquifer of the Great Plain is utilized for different purposes, but mainly agricultural/energy and also balneological- or drinking water purpose utilizations.

From the 50's-60's, hundreds of thermal wells established on the thermal aquifers of the Hungarian Great Plain. The (50-60-year) long-term and intensive thermal water production in the Szentes- and Szeged regions caused regional 10-15 - 30-40 meters depressions. After the reduction of the thermal water production, the system started to regenerate, but the water level is stagnating, rather than has an upward trend.

The real case studies shows that the summer periods, when there are no pumping, or the reinjection of the cooled down thermal water can be help in the regeneration of the thermal aquifers. But, the huge amount of the abstracted thermal water can cause a further regional head drop in both Region.

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