Karst aquifer restoration after abandonment of bauxite mines at Nyirad region, and conclusions

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Abstract: Ten years ago, bauxite mines have been closed at Nyirád region, Hungary. These mines applied preventive water drainage (4-5 m^3/s). The water was utilized for water supply, hatcheries etc. At that time, the governmental decision to close the mines was based on the strong recharge-decreasing of the therapeutic thermal lake Héviz. This paper presents extracts from the analysis of karst water pressure/head rebuilding, as well as conclusions on the features of the impacted aquifer system with special attention to the impacts of the mine drainage to the recharge of Héviz thermal lake. The observations on the rebuilding period have displayed strong differences between the water pressure rebuilding at different tectonic blocks. This feature of the aquifer did not appear during drainage due to the coincidence of a long dry period. The observations refer to quasi-separated recharge conditions of Héviz thermal lake from Nyirád region. The restoration of the quasi-virgin conditions of the Héviz thermal lake should consider the role of new thermal water outputs at the close surrounding area. Some non-site specific conclusions were also derived.

1 INTRODUCTION

Ten years ago bauxite mines have been closed at Nyirád region, Hungary. These mines applied preventive water drainage (4-5 m^3/s) against karst water hazard. The drained water was utilized for water supply, hatcheries etc. Details on the drainage, the utilization and on the first period of the rebuilding were presented in several IMWA publications (BBV 1982, Toth 1982, Böcker & Höriszt 1988, Farkas 1985, 1987, 1994).

The extreme volume of drainage (4-5 m^3/s) impacted a large, karst aquifer, where among several major cold water springs, an important, therapeutic thermal lake, called Héviz is also situated. (38 ^oC, 0.55 m^3/s). A lot of cold water springs and the Tapolca underground lukewarm lake (19,5 ^oC, 0.45 m^3/s) dried during the mine drainage period (Böcker & Höriszt 1988). The recharge of the Hévíz thermal lake decreased to 0.3 m^3/s.

The situation had been seen to be quite “simple”. The main karst aquifer (cc. .5000 km^2) of the Transdanubian region has been regarded as a single aquifer (e.g. Böcker & Höriszt 1988, VITUKI 1989. All changes were blamed on the mining. The author and the Mining Faculty of Miskolc contradicted this general opinion (UM 1990 Farkas 1989) At that time the governmental decision to close the mines was based on the strong recharge-decreasing of the therapeutic thermal lake Héviz.

As a result of the integrated evaluation of the observations on the drainage and rebuilding, the first simplified assumptions should be substituted by a more sophisticated view. This paper presents selected details on this analysis.

2 GEOLOGICAL SETTING

Figure 1/A presents the geologic map without Kainozoic cover according to the G.S. of Hungary. Figure 1/B presents a simplified geological cross section along an assumed water pathway from Nyirád to Héviz, as marked on the map. Other geological details on this region (Nyirád, Halimba, Csabpuszta), are presented in several IMWA publications listed in the references.

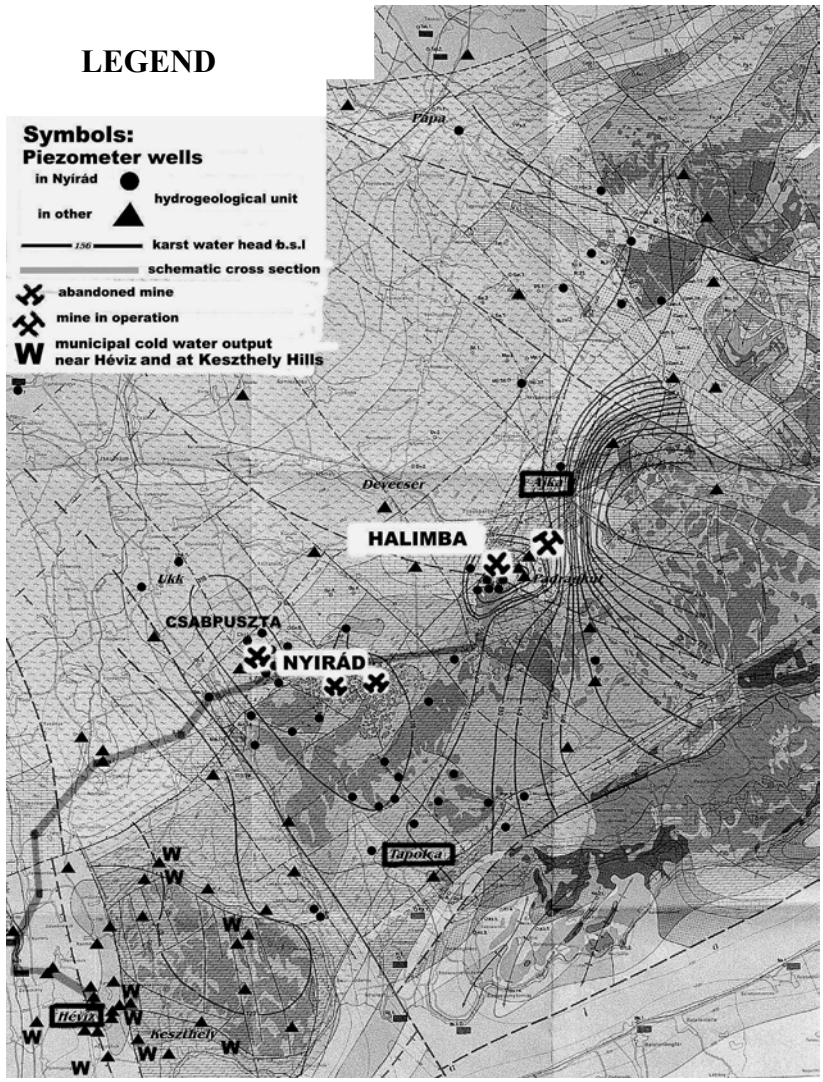

Figure 1/A Geological map without Kainozoic strata according to the GS of Hungary

The dominating aquifer is the Upper Triassic dolomite formation, that belongs to “Main Karst Aquifer” (MKA).

Other karstified-fissured aquifers are the Upper Cretaceous Ugod Limestone the Eocene limestone (Böcker and Hegedüs 1988) and the Miocene limestone situating at the border area of the Nyirád Region.

The faulting (including several kilometers of horizontal translations) and denudation have formed a sophisticated aquifer system. Aquifers and aquitards of different features and geological ages are juxtaposed along faults Figure 1/B. (e.g. Farkas 1989, 1990, 1997). Due to these juxtapositions upper-laying limestone and sandy aquifers are hydraulically connected with the MKA at some locations. The large displacements and juxtaposed aquitards also formed partial hydraulic barriers or low conductive zones inside the MKA.

The outcrops serve as windows for recharge from the rainfall. Transfers between the different aquifers depend on the actual gradient direction according to the natural and human induced drainage.

The thermal springs indicate the existence of long and deep water-pathways.

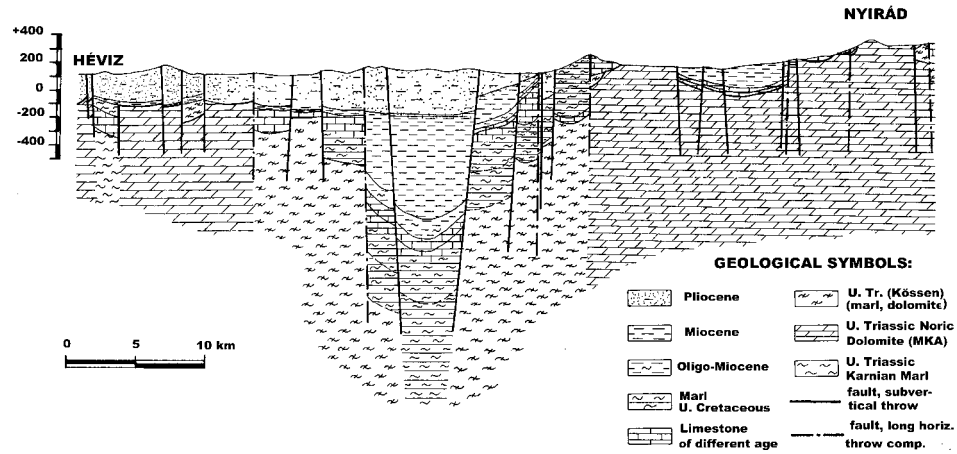

Figure 1/B Schematised geological cross section

3 MINE DRAINAGE VERSUS OTHER KARST WATER OUTPUTS

The dominant karst-water related human activities are listed here with references to the figures and to (IMWA-published) literature sources on the details.

Mine drainage

The *Nyirád Bauxite Mines* entered into operation in 1957. The MKA is the only karst aquifer in this area at the bottom of the karst-bauxite lenses (Figure 1/B). However the spontaneous drainage starts in 1957, the first drainage-haulage drift, inside the uppermost zone of the Noric Dolomite of the KMA (as a pilot

operation) has provided the first underground experience on the site features of MKA. The high conductivity of the intersected fault zones allowed the application of surface based drainage holes at the non-productive zones between the bauxite lenses. For these reasons a surface based well system for drainage was applied. Large diameter wells equipped with 1-4 submersible pumps have given adequate flexibility for drainage and adequate drinking water quality for a large regional water supply system (BBV 1982, Farkas 1985, Toth 1982). This system operated until 1991. In magnitude the water output exceeds all other water outputs in this region (curve a in Figure 2/A). After flooding the mines some drainage holes operate continuously as water supply wells for municipal purposes.

The overwhelming area of the operations of *Csabpuszta bauxite mine* (Figure 1/A) is situated dominantly on surface of the Cretaceous limestone. A smaller area of this extraction is situated on the Triassic dolomite. The major part of the Cretaceous limestone is hydraulically connected with the Triassic dolomite. The overwhelming area of the Eocene limestone at the overburden has dried. The bauxite operations at Csabpuszta were started above the karst water head in 1986. During the last period of the Csabpuszta mining operations the bottom aquifer was drained according to the Authority licenses. (The water outputs from mine Csabpuszta is included in curve a of Figure 2/A). The Csabpuszta operations were terminated in 1995. This drainage period was in coincidence with the rebuilding period in Nyírád region.

The coal mining at *Ajka Coalfield* and the *Halimba bauxite mine* (Figure 1/A) drained some quasi-separated blocks of the Eocene Limestone in the overburden of the mineable bauxite or coal seams as well as the uppermost Triassic limestone layer of the MKA beneath the mineral resources (BBM 1982). This bottom aquifer is partly separated from the Noric dolomite aquifer by the Kössen Marl and by translations along faults. The total mine water outputs of Halimba mine and Ajka coal field are presented in curves b and c in Figure 2/A.

Thermal and lukewarm water utilization

The Héviz thermal lake (Figure 1) is recharging continuously from a bottom spring (see details in Böcker and Höriszt 1988). The chemical/radiological content of the water, as well as the observations on temperature and water-yield refer to three recharge sources (VITUKI 1989). The dominating hot water stream surely originates from long and deep channels inside the MKA. Due to the hydraulic connections of the thermal channels with the upper cold water containing system of the MKA, a part of the water output surely originates from near surface cold water sreams. The lake is situated in the Kainozoic cover, consequently an unknown part of the recharge may originate from Kainozoic aquifers. The time plot of yield of the bottom spring is presented in Figure 1/A (curve d). The last ten years period is presented in Figure 2/B.

Several thermal wells are also operating for supplying the needs of in-door medical treatments of several thermal hotels at Héviz. Thermal water withdrawal

from these wells and cold water outputs in the vicinity of Héviz are also presented in Figure 2/B. The location of the cold water outputs are marked in the map (Figure 1/A).
Tapolca underground lukewarm lake is situated in a karstic cave of the Miocene limestone just at the "downtown" of Tapolca. This block of the Miocene limestone is connected hydraulically to the MKA. This lake dried during the drainage period (curve e in Figureure 2/A). This lake has been restored, by applying special bulkhead structures.

Cold water springs from KMA and connected aquifers

Prior to mining, the cold water springs represented the main discharge-term of the KMA. Information on the virgin terms was presented e.g. by (Böcker and Höriszt 1988). Other virgin discharge-terms were the lateral transfers to the sedimentary basins as well as several bogs.

4 EXTREME PERIOD OF NATURAL RECHARGE

The mine drainage period at Nyirád was in coincidence with an extreme dry period. The deficit of the natural recharge has caused several meters water head drops even in virgin karst e.g. in North Hungary and Slovakia as well. The rainfall values (averaged from 1960 and the yearly values measured near Héviz (at Keszthely) is presented in curves g and f in Figure 2/A.

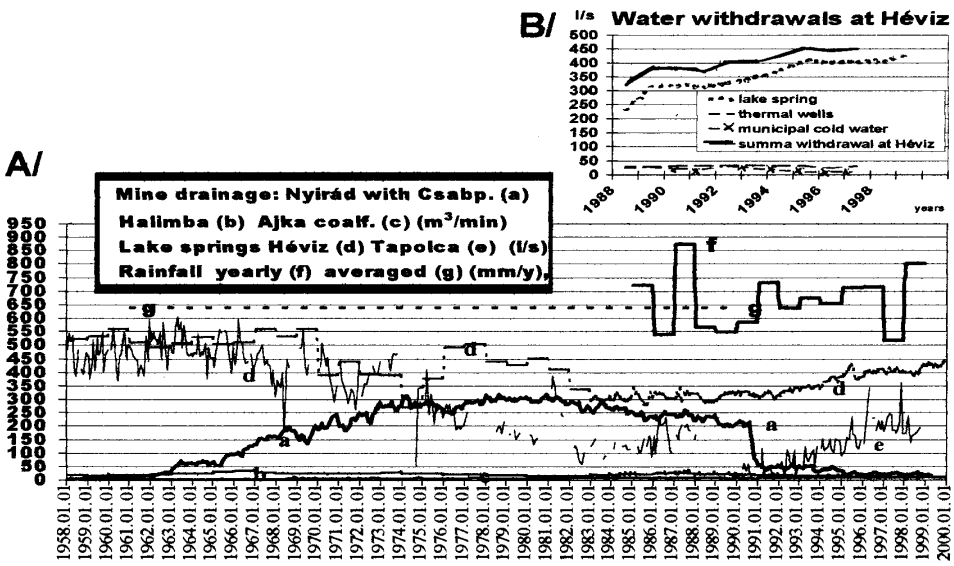

Figure 2 The water outputs and the rainfall

5 KEY OBSERVATIONS

The multilateral field history analysis is based on a significant amount of data namely:

- Upgraded information on the geology originated from the mining, mineral exploration and from surface geophysical survey in the region and its surroundings.
- Several well tests were made at mine drainage regions (e.g. Böcker & Hegedüs 1988, Farkas 1996).
- Daily rainfall measurements at several meteorological stations have been available during a century long period, (Figure 2/A curves **g** and **f)**.
- Occasional/ordinary flow measurements were made at the important cold water springs, and mine water.
- Figure 2/A (curves **a, b** and **c**) presents the water outputs from the different mines.
- The thermal water outputs at Héviz are presented in Figure 2/B).
- Water head records or occasional measured data are available on 160 surface-based piezometer holes, however, information on the virgin water head conditions are quite poor. Figure 3 presents selected time plots at the different sites around Nyirád, as well as at Héviz lake.

6 BRIEF ANALYSIS ON SOME WATER HEAD PLOTS AND DISCUSSION

All former field history analyses, including numerical model studies, as well as estimations on the future were based on the same assumption (e.g. Böcker & Höriszt 1988). The Main Karst Aquifer (MKA) was regarded as one large reservoir without any important hydraulic resistance between the large tectonic blocks of long vertical fault throws. The observations of the drainage period seem to support this simplified hydrogeological model. In spite of an enormous drainage, "partitioning" between the tectonic blocks was not detected. The rainfall plots (**g**. and **f** in Figure 2/A) demonstrate, that the main drainage period, as well as the first part of the rebuilding period were continuously dry. The long-term deficit of the rainfall recharge-term might cover the partitioning. This fact and other evidence supported the doubt of the author on the simplified model of the MKA in Nyirád region.

The water-head rebuilding records at the different tectonic blocks allow some useful statements:

1/ Characteristic and quick water-head rebuilding was detected in all directions. (Selected curve sets s a, b, and c in Figure 3 illustrate this statement. This area should be regarded as one "hydrodynamic" unit for drainage and rebuilding at Nyirád, namely:

- the main recharge area of the former Nyirád drainage is situated at the South Bakony.

- The bottom aquifer at Halimba bauxite mine belongs to the Nyirád unit, however, the hydraulic resistance in the bottom strongly limits the bottom inflow.
- The Miocene limestone that is the host rock of Tapolca underground lake is also connected hydraulically to the Nyirád unit of MKA. The water head rebuilding plot is a good basis for planning the restoration of this lake (see Tapolca plots in Figure 3/a).
- The bottom aquifer of the closed Csabpuszta mine is also connected with the MKA of Nyirád unit.

2/ The values and delay of the water head rebuilding refer to quasi-separated conditions from Nyirád at the following areas:

- Ajka Coalfield is situated in a quasi-separated block.
- The block of Keszthely Mountain seems to be a zone, quasi-separated from the South Bakony and Nyírád region. (see curve sets **c** and **e** as well as Héviz observation hole in **c** curve set of Figure 3) This is due to the long vertical displacements at the tectonically formed Uzsa-ditch. This displacement and denudations formed a low conductive zone between Nyirád and the Keszthely Hills. A similar situation can be seen in Figure 1/B that was also an assumed potential pathway between Nyirád and Héviz. The "rebuilding" at some piezometers near Heviz was due to terminating the cold karst water withdrawal of
  some local municipal waterworks at the Keszthely dolomite block. The strong connection of these municipal water outputs has been determined by (VITUKI 1989).
- The Kehida piezometer (Figure 3/d) detected water pressure rising several years prior of terminating the mine drainage at Nyirád. It sems, that this block is separated from Nyirád "hydrodynamic" unit, however the origin of this water pressure rising is unknown. Borgáta piezometer (that is a thermal well), refers to interconnection with Nyirád drainage and rebuilding.

3/ The water head records at the deeply buried area of MKA did not detect the seasonal changes of the rainfall recharge

4/ Quick changes in the drained water yield due to the closing of Nyirád mines have caused well-type rebuilding curves in a confined aquifer. This evidence refers to a quasi-cylindrical flow pattern. This observation has practical importance for simplified drainage-calculations as well as for further numerical model studies.

5/ The quasi-separated situation of the Keszthely mountains and the Héviz thermal lake from Nyirád call for a new interpretation on the changes at Héviz. It seems that the past yield-drop of the bottom spring under quasi-constant temperature originated form two simultaneous impacts, namely:

– decreasing of the cold water recharge term due to rainfall deficit, as well as the cold karst water productions and
– decreasing of the hot water recharge term due to increasing the hot water production from wells in the close vicinity of the bottom-spring.

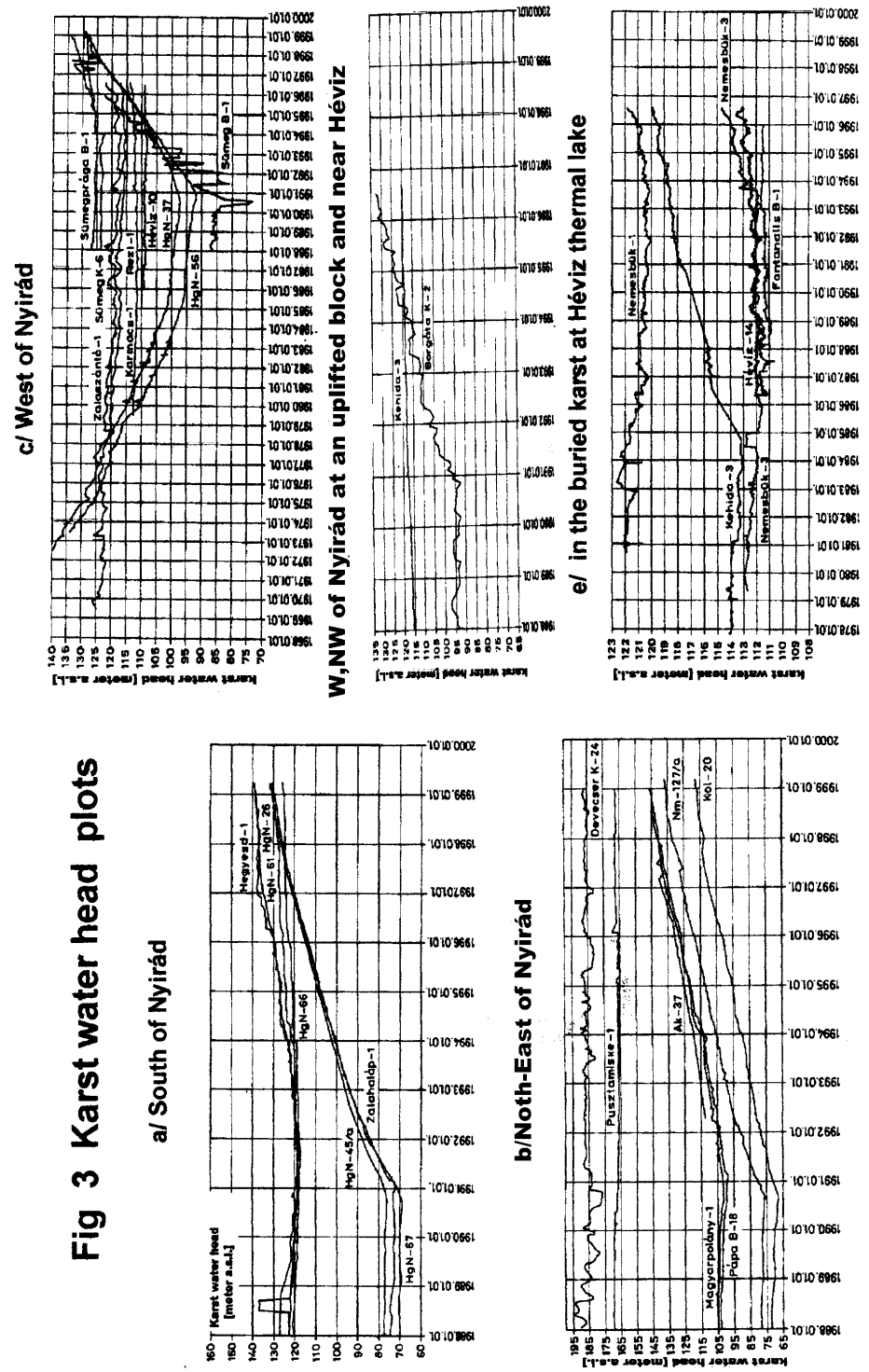

Figure 3 Karst water head plots

7 CONCLUSIONS

Site specific conclusions and proposals

1. Simplified assumptions on the geology of the Transdanubian region caused weakly based decisions. The sustainable development of this region (tourism, balneology, industry) with the priority of karst water resources, need continuous re-evaluation of the new information on the geology and the water-related observations.
2. The low conductive zones between some blocks of the MKA should be considered in more aspects:

- Further model studies should "verify" this new hydrogeological model, by using updated information on the geology as well as the whole drainage and rebuilding process.
- After such verification the water resource's management and decisions on the possibilities and environmental limits for mining should consider the quasi-separated hydro-geological units.
- The restoration of the Hévíz thermal lake should also pay more attention to the near-field conditions including the thermal water production from wells.

Non site-specific messages:

1. This case example may highlight the necessity of long term and multilateral studies for better management of karst water resources.
2. The drastic drainage and water rebuilding (due to mine drainage and closure) in the Transdanubian MKA in Hungary has provided a unique long-term and large-scale test. This "test" calls for further international analysis on behalf of better understanding the features of the karst aquifers as strategic drinking water sources. The Bakony Bauxite Mines Limited Co. has a large data bank on this unique experiment. The in-door, and out-door teams that were/are studying this unique experiment during three-four decades have also accumulated usable experience for contributing to other karst-related studies.

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Regeneracja krasowych zbiorników wodnych po zamknięciu kopalń boksytu w rejonie Nyirad

Ida Farkas

Streszczenie: Kopalnie boksytu w rejonie Nyirad (Węgry) zostały zamknięte 10 lat temu. Kopalnie te drenowały wody podziemne w ilości 4-5 m^3/s. Woda była używana dla zaopatrzenia w wodę, dla celów hodowlanych itd. Artykuł przedstawia analizę odbudowy ciśnienia hydraulicznego wód krasowych jak również wnioski odnośnie cech systemu zbiornikowego ze zwróceniem szczególnej uwagi na wpływ drenażu kopalnianego na warunki zasilania jeziora termalnego Héviz. Obserwacje poczynione w okresie odbudowy ciśnień wód wykazały duże różnice między ciśnieniem wody w różnych blokach tektonicznych. Ta cecha zbiornika nie ujawniła się podczas drenażu ze względu na bardzo długi okres suszy. Obserwacje dotyczą również warunków zasilania systemu wód podziemnych drenowanych w jeziorze termalnym Héviz w rejonie Nyirad.