

# **A large-scale investigation for active and passive protection of vulnerable aquifers against contamination of communal and industrial origin in the Gyöngyös-Atkár Area, Hungary**

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## **Abstract**

The „National Program of Diagnostics of Water-works Established in Vulnerable Geological Formations” is dedicated to perform straightforward hydrogeological investigations on the most important water works of Hungary. In frame of the project the Water Works of Gyöngyös was investigated where the sustainable water production nearby Hungary’s biggest open pit mine and with a town of more than 50 000 inhabitants on the catchment and infiltration zone is a big problem. To do the job a large-scale GW modeling was performed based on 2 years of hydrogeological prospecting. The paper introduces into the details of this case study.

## **Keywords**

Large-scale investigation, Well-head protection, Groundwater contamination; GW flow modeling

## **1. Introduction**

The Gyöngyös-Atkár area was investigated in frame of the „National Program of Diagnostics of Water-works Established in Vulnerable Geological Formations” in 1998-2001. The three years long project’s aim was the determination of well-head protection area of more than 40 wells of the Gyöngyös-Nagyréde basin using groundwater flow models and to establish a new, sustainable pumping scheme for the changing water demands of the population and the industry of the area.

The investigated area lies in Hungary, approx. 70 km NE from Budapest at the hill-slopes of the volcanic Mátra Mountains. In the region there is a characteristic mining activity for lignite, the poorest quality brown coal. The demand is cca. 4.5 Million m<sup>3</sup> drinking water per annum, and there is another about 2.5 Million m<sup>3</sup> water pumped out from the 100-120 km<sup>2</sup> area caused by the drawdown of the open pits dewatering activities (Since mining is performed in dry pit, the aquifers crossed are dewatered by series of temporary wells.) Due to the high pumping rates the wellhead pressures

dramatically decreased in the last decades in the area, moreover there were traces of PAHs found by chemical analysis in the shallow wells of the area. The rapidly increasing environmental problems forced the straightforward investigation of the area, the delineation of well-head protection areas and to develop new pumping schemes for sustainable water production.

## 2. Geological and hydrogeological conditions

The geological conditions of the shallow layers (upper 200 m) are rather well known from the more than 720 lignite research drillings and about 180 other wells and observation objects. In each drilling there was an accurate geophysical sounding performed which helped a lot in layer identification and in estimation of hydraulic behaviour of the sediments.

The underlayers of the sediments settled in the Gyöngyös-Nagyréde basin are rhyolitic and andesitic volcanic formations of the Mátra, which forms a steep slope: they are on the surface on the Northern part of the area, and 5 km to the south the volcanites they were reached in more than 400 m depth. On the volcanic rocks lower and upper pannonian layers are settled, the lower pannonian layer are mainly clayey sediments, but the upper pannonian formations consists of clayey, sandy and organic layer series. The inclining aquifers are sands with 1-50 m/d (but generally 1-5 m/d) horizontal, 0,01-0,001 m/d vertical hydraulic conductivity and effective porosity 0,16-0,2 depending on the grain size distribution. Between the aquifers clayey, silty and organic layers are bedded, which are the main aquitards of the site. (Fig.1.)

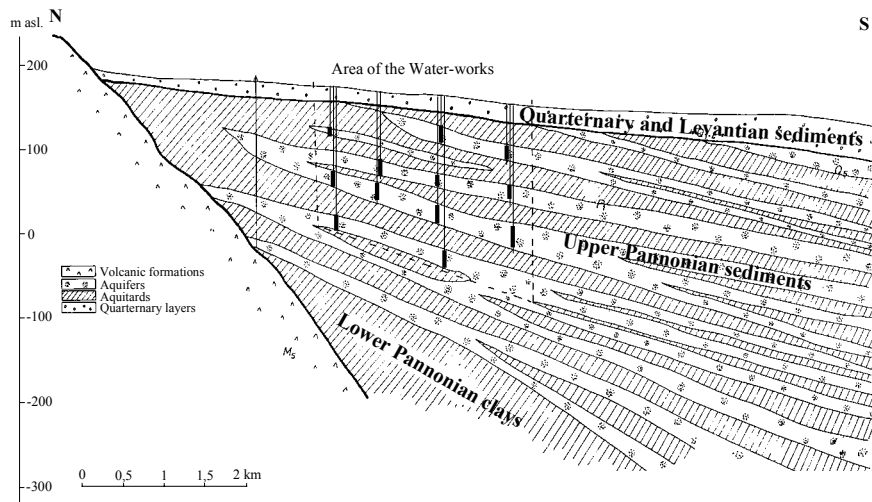


Fig.1.: The geological scheme of the area (GEOSERVICE, 1995)

Although there is a hydraulic communication between the layers, there is a characteristic alteration in piezometric head and its distribution. The direction of groundwater migration in the aquifers is N-S, which was previously found partly as result of a recharge from the volcanic formations (0,7 km<sup>3</sup>/yr/km horizontal distance along the Miocene border) and partly due to the recharge at the layerheads through the overlying levantian and quarter sediment bodies. The concept due to the mine

dewatering experiences changed: it was proven that the recharge due to vertical infiltration is dominant compared to the recharge from the volcanic rocks (GEOSERVICE, 1998-2000). At the site there was altogether 43 wells drilled in groups along the road Gyöngyös-Gyöngyöshalász-Atkár with 16 000 m<sup>3</sup>/d capacity. The depth of the wells is rather different, the screened horizons are between 44-368 m depth interval depending on the site. The wells pumps out daily 100-500 m<sup>3</sup> water at 3-16 m drawdown.

### 3. Description of the hydrodynamic model, results

To investigate the hydrodynamic regime of the basin a transient groundwater flow model was built using Processing MODFLOW for Windows. The model consists of 29 layers (1<sup>st</sup> layer quarternary and levantian formations, 14 aquifers and 14 aquitards). The scheme of model geometry is shown on Fig 2. Each layer was divided into cca. 3800 elements, so the complete system is formed by 110 000 cells. An adequate grid was adapted to the geological conditions and the location of the wells (Fig.3.) The elevation of the dividing surfaces between aquifers and aquitards was determined using the geological data of the research drillings and wells of the area. The hydrogeological properties of the layers were estimated using information from geophysical measurements; pumping tests were used for the validation of the indirect geophysical data. The recharge of upper pannonian layers through quarternary and levantian formations was determined upon the classification of cca. 700 shallow (geotechnical, soil mechanical and other) drillings, where the vulnerability of the layer was estimated depending on the type, thickness and estimated hydraulic conductivity of the sediments. Based on the evaluation three categories were established: territories with high, medium and low infiltration rates and as consequence high, medium and low vulnerability of the formations was predicted (Fig. 4.). As initial heads the smoothed surface of piezometric heads from the 1950-60 period (Univ. of Miskolc, 1995) were used. The yields of the wells based on the time series recorded by the authorities. Additionally to the 43 production wells the effect of another 18 wells was also simulated.

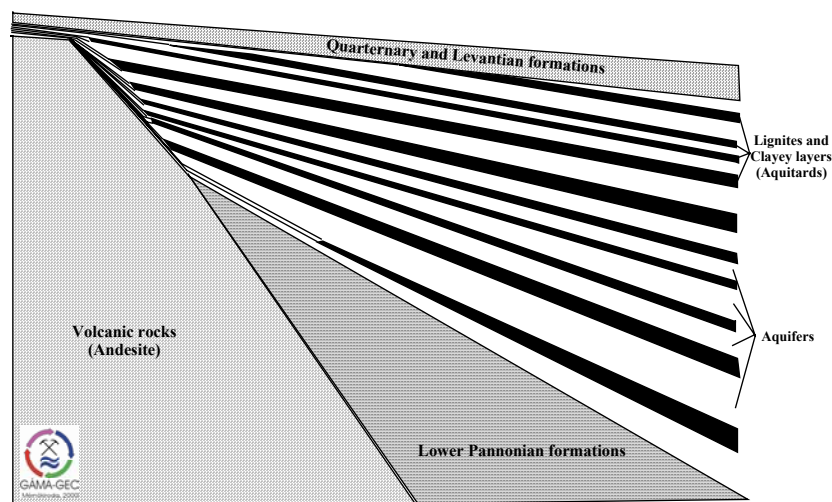


Fig.2.: The conceptual model of the area (GÁMA-GEO, 2000)

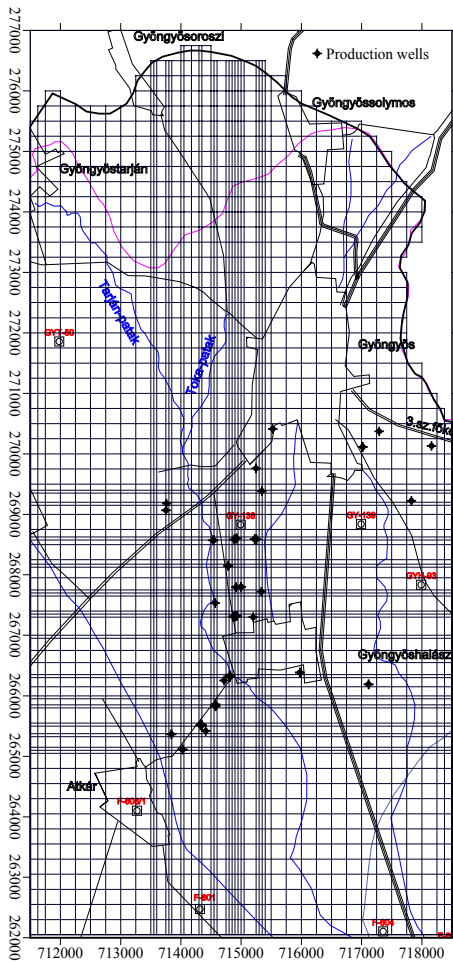


Fig. 3.: The model grid

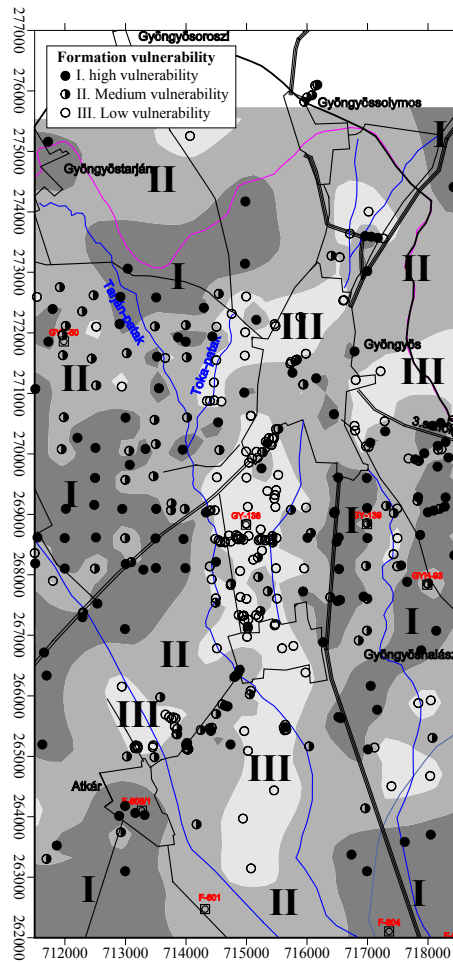


Fig. 4.: Vulnerability map of shallow layers

The calibration of the model was performed using the long term time series of several observation wells. During the simulations the present situation of piezometric heads was calculated in each layer, and the transit times of water particles to the screened parts of the wells for 20 days, 6 month, 5 and 50 years were calculated in accord with the Hungarian act for protection groundwater resources using WHPA calculations (Fig.5.). The pictures show the two main direction of water recharge: a dominant flow from north and a smaller rate of vertical infiltration. The results of the calculations were conform with the average age of the water measured upon the tritium concentration of the water. The well in shallow aquifers and that on the northern part of the basin produced significantly younger water than the others.

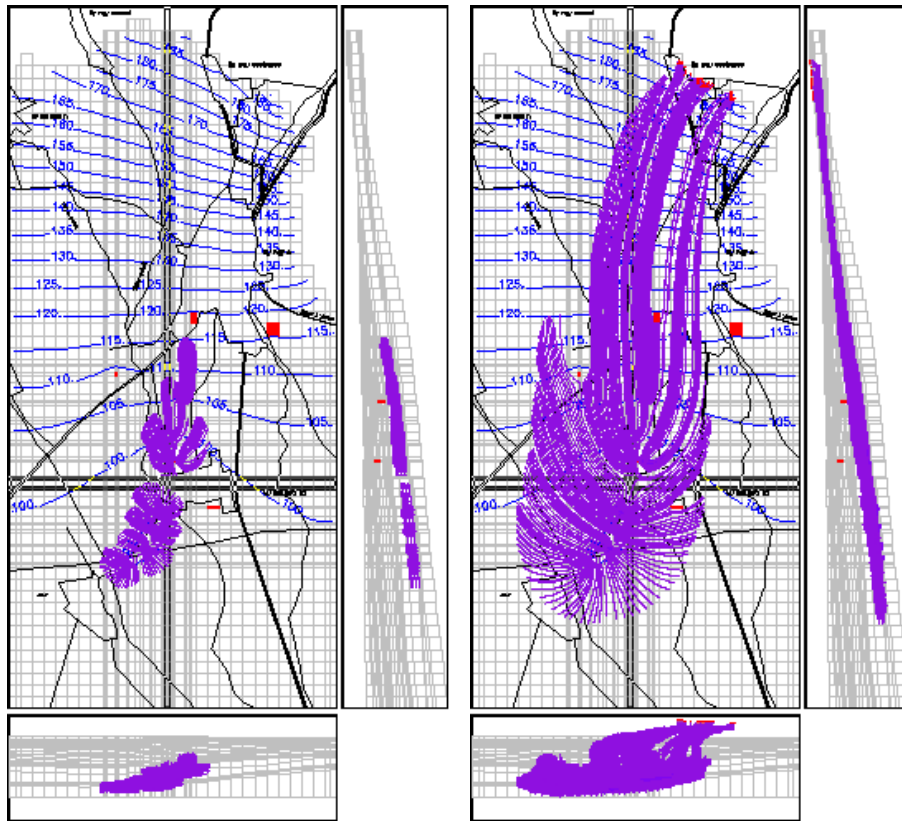


Fig.5.: The 5 and 50 years pathlines of wells screened into the deep V/-1 sand layer (main aquifer)

To avoid more serious problems in quality of produced water there was a reduction and in case of some wells termination of the production and the priority of excavation from deeper aquifers was suggested. In agreement with the authorities, the water works and the public an underground and a surface protection zone for the wells was delineated (Fig.6.). Unfortunately the whole area of Gyöngyös city and the suburbs (approx. 65000 citizens) lies on the protected area that means restrictions in land use and in development of industrial activities. This is conform to the fact that the city covers the area of the main infiltration territories of the productive pannonian aquifers. As consequence of the work already done the water works builds an automatic system of production control based upon the calculations done using the hydrodynamic model.

## Conclusions

In Gyöngyös area there is a conflict between the available water resources and the water production (public water supply, mine dewatering) that caused a dramatic decrease of heads in the area. To investigate the problem a MODFLOW based hydrodynamic model was built. The data of more than 900 drillings was evaluated and used to build the model, both geological, stratigraphical,

hydrogeological and geophysical information were collected to establish the most adequate adaptation of the complex system. Using the model the recharge directions and the most suitable water protection zones and WHPAs were determined. The developed model was further used as a tool during the planning of the automatic control of water production. The results were conform to the experiences and fitted also the tritium-based age of the water.

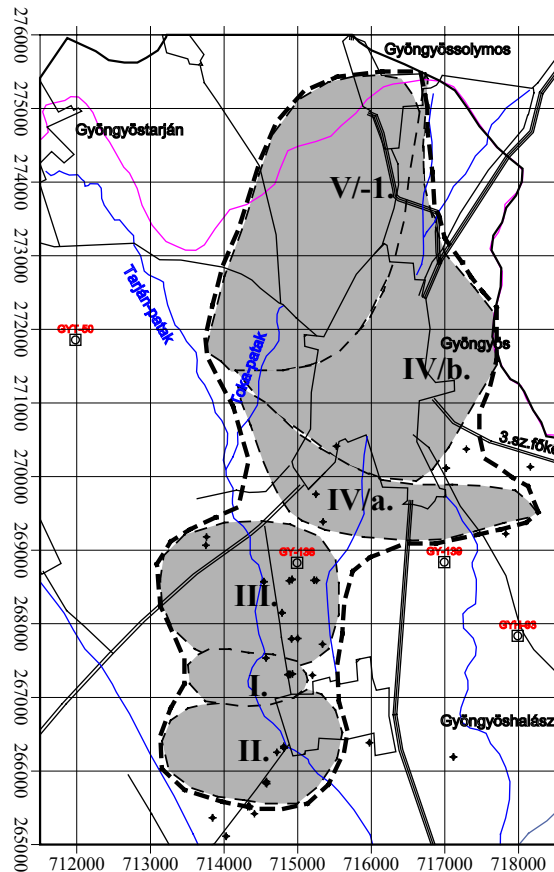


Fig.8.: The well-head protection area (WHPA) of the Gyöngyös – Atkár water-works as additive result of recharge zones of the different Pannonian aquifers' layerheads

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