

Analysis of Uniejów Geothermal Water Reservoirs Modeling in View of Various Aspects of Geothermal Water and Heat Management

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ABSTRACT

The results of modeling a geothermal water reservoir in Uniejów (C-Poland), obtained with the use of a numerical simulator TOUGH2.0, are presented in the paper. The behavior of the reservoir was analyzed for three exploitation variants. A number of heat and water management exploitation scenarios were accounted for.

Simulations were made for the following assumptions:

- Present rate of geothermal water production (120 m³/h); water is cooled and injected into two injection wells;
- Double-size geothermal water production with an additional geothermal well (240 m³/h); water is cooled and injected into two injection wells at a rate of 120 m³/h. The remaining water is treated and discharged to a surface water course;
- Double-size geothermal water production with an additional geothermal well (240 m³/h); water is cooled and injected into two injection wells.

These simulations enabled one to determine the influence of the flow rate of exploited and injected water on the formation pressure value. On this basis a multivariant method of managing geothermal heat and water in Uniejów has been worked out.

1. INTRODUCTION

One of the most prospective geothermal areas in Poland is the Polish Lowland. It covers, among others, the Mogilno-Łódź Synclinorium, where the Lower Cretaceous geothermal waters are exploited in Uniejów (Wojnarowski et al. 2007). Presently waters are exploited through a triplet: Uniejów PIG/AGH-2 - a production well, Uniejów PIG/AGH-1 and Uniejów IGH-1 - injection wells. Wells are localized along a SW-NE nearly straight line. The distance between the furthestmost wells (Uniejów PIG/AGH-2 and Uniejów IGH-1) is 1950 m. Uniejów PIG/AGH-2 and Uniejów PIG/AGH-1 wells are 1120 m from each other. The temperature in the layer top at a depth of 1780 m b.s.l. (Uniejów PIG/AGH-2) is ca. 70°C. According to Altowski-Szwiec classification, the Uniejów geothermal waters are of chloride-sodium type and their mineralization is ca. 6.8 to 8.8 g/dm³ (Bentkowski et al. 2001, 2005).

2. HYDROGEOLOGICAL CONDITIONS

The Lower Cretaceous aquifer, from which the geothermal waters are produced, are built of sandstones of various granulation, interbedded with mudstones and siltstones. The

Lower Cretaceous sandstones (Barrem – Middle Alb) in the entire Mogilno-Łódź Synclinorium are a good water-bearing horizon. The Lower Cretaceous sandstones are porous rocks. The effective porosity at the top varies from 18 to 20%. Very small differences between effective and total porosity can be indicated, which speaks for the existence of great hydraulic connection among the pores (Bojarski, Sokołowski 1991).

The natural regional water flow generally has the SE to NW trend (Haładus, Reicher 1990; Górecki et al. 1995).

3. COMPUTER SIMULATION OF EXPLOITATION

Owing to the magnitude of the Lower Cretaceous geothermal water reservoir, an area of 221 km² was distinguished to enable observations of pressure and temperature changes in the course of exploitation. A numerical model was designed for this area followed by simulations with the use of specialized software TOUGH 2.0 (Preuss et al. 1999) for three variants, and accounting for various possibilities of managing heat and water in Uniejów.

3.1. Design of Numerical Model of the Field

The area was divided into 8580 blocks of varying size. The magnitude of blocks towards x and y varied from $\Delta x = \Delta y = 250$ m close to the boreholes, to $\Delta x = \Delta y = 1000$ m at the edge of the simulation area. Ten layers were distinguished in the vertical profile, four of which belonged to the main water-bearing horizon; three layers of lower permeability were assumed to be present above and under the aquifer. The following assumptions were made: thickness of impermeable layers equal to 600 m, the productive water-bearing horizon 120 m ($\Delta z = 4\text{--}30$ m), the assumed thermal conductivity 2.4 W/m² and thermal capacity of rocks of 1000 J/(kg·K). In all simulations the total time of exploitation was 100 years, and the geothermal waters were to be cooled to a temperature of 35°C (Sapińska-Śliwa 2009).

3.2. Simulations for Selected Variants

Simulations were made for three conditions (Sapińska-Śliwa 2009):

1. Exploitation of geothermal water at a rate of 120 m³/h; after cooling water is injected into two injection wells;
2. Doubled production of geothermal water with an additional, new geothermal well (240 m³/h); after cooling water is injected into two injection wells, and the flow rate of the injected water is 120 m³/h; the remaining water is treated and discharged to a surface water course;

3. Exploitation of geothermal water at a rate of 240 m³/h (as in variant 2); after cooling water is injected into two injection wells.

3.2.1. Forecast 1 – Actual Conditions, Complete Use of the Heat

The assumed water production of 120 m³/h was congruent with the certified documentation of wells Uniejów PIG/AGH-2. Water was planned to be injected into wells Uniejów PIG/AGH-1 and Uniejów IGH-1 at a rate of 66.24 m³/h and 53.76 m³/h, respectively. Such a division of wells is justified by the proportions obtained from injection tests carried out simultaneously in both wells. The injection capacities of Uniejów PIG/AGH-1 and Uniejów IGH-1 were 55.2% and 44.8% injected brine, respectively. No idle time spent on conservation and maintenance of the rig was accounted for in the forecast.

The results of simulations revealed that the pressure changes in the production well were very small. Owing to the high permeability of the reservoir, the assumed production yield causes minor drops of pressure in the near-well zone. In the case of injection wells the pressure changes are slightly bigger (Figs. 1 and 2). It was assumed

for the simulation that the injection would be performed in conditions that do not damage the near-well zone. Erroneously performed injection causes a drop of permeability in the well neighborhood, resulting in a considerable increase of injection pressure, which in the long run may hinder the process.

The observations of temperature changes in the near-injection well zone reveal that the rocks surrounding the wells have cooled over a 30-year period (Figs. 3 and 4). Later on, minimum temperature decreases are observed and the reservoir reaches the temperature of the injected water. The injected water minimally affects the temperature. The impact starts being visible after ca. 50 years, to later decrease very slowly. After 100 years, the reservoir temperature in the neighborhood of the production well drops by ca. 0.25°C (Fig. 5).

Hence, a conclusion that this configuration of wells exploitation, accounting for the hazard that cool water flows into the production well, is appropriate. This effect can be counteracted by the natural flow direction of reservoir waters (Haładus, Reicher 1990). At the assumed wells configuration, the cool water front is moving in the opposite direction as the natural water flow.

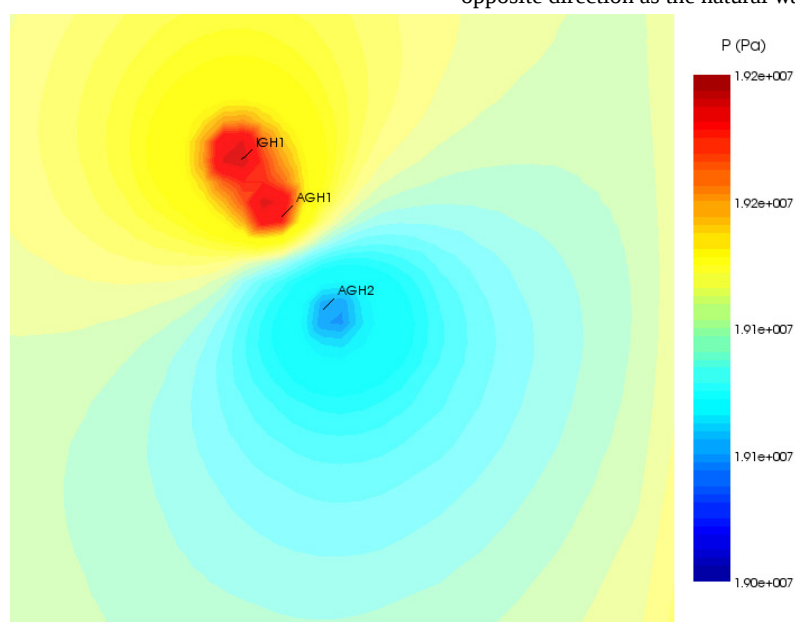


Figure 1: Distribution of pressure in the reservoir top after 100 years of exploitation.

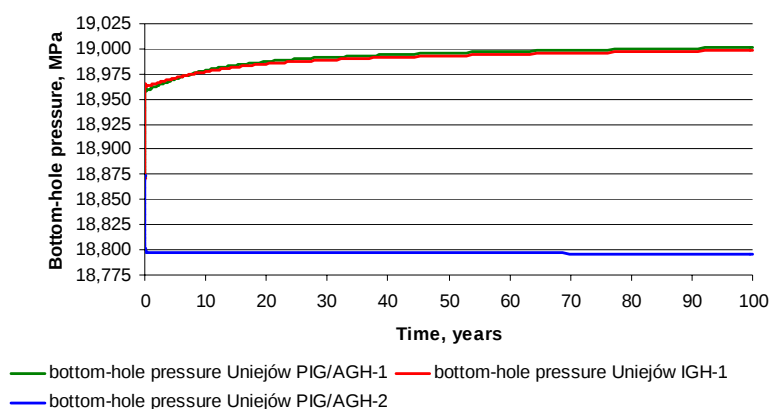


Figure 2: Changes of pressure in the reservoir top in the near-well zone of Uniejów PIG/AGH-1, Uniejów PIG/AGH-2 and Uniejów IGH-1.

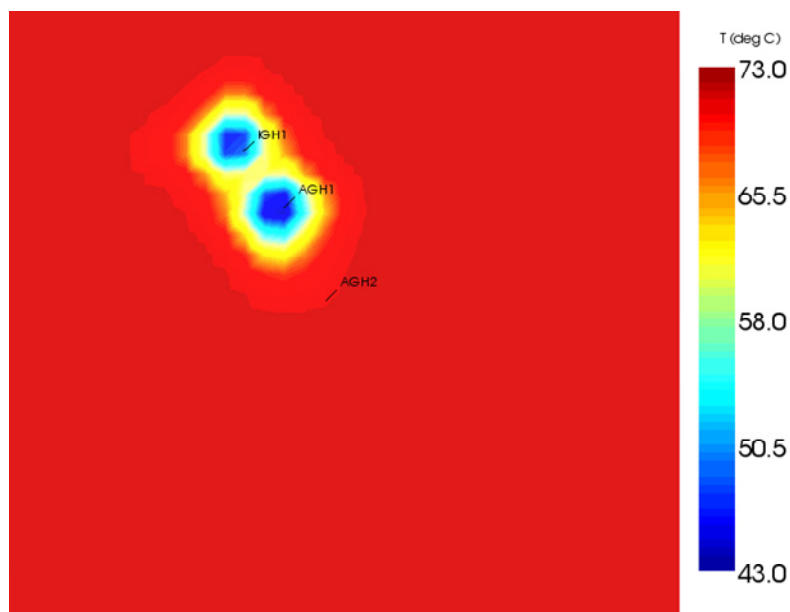


Figure: 3. Distribution of temperature in the reservoir top after 100 years of exploitation.

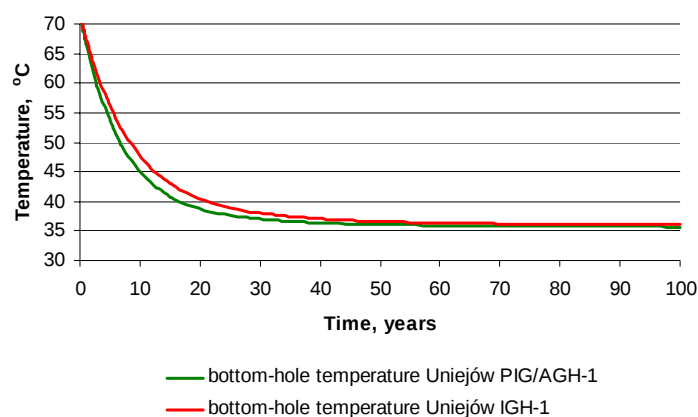


Figure: 4. Changes of temperature in the reservoir top in the near-injection well zone of PIG/AGH-1 and Uniejów IGH-1.

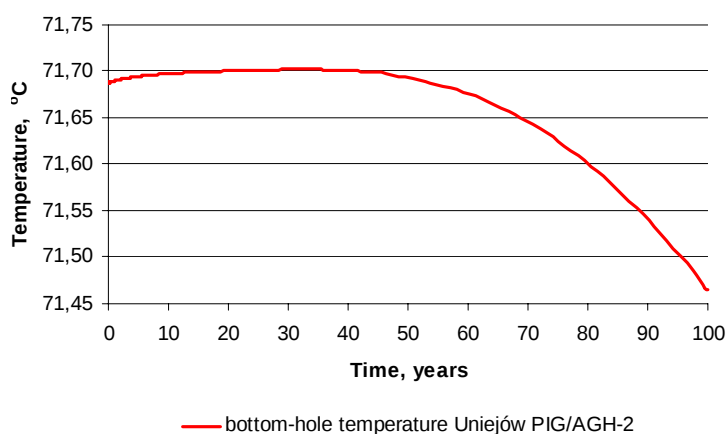


Figure: 5. Changes of temperature in the reservoir top in the near-production well of Uniejów PIG/AGH-2.

3.2.2. Forecast 2 – Conditions of Increased Heat Recovery and Incomplete Injection of Water into the Reservoir

Water production of 120 m³/h was assumed for well Uniejów PIG/AGH-2 and additionally for the planned well Uniejów PIG/AGH-3; the summaric production flow rate

equaling to 240 m³/h. The injection rate of wells Uniejów PIG/AGH-1 and Uniejów IGH-1 was assumed to be 66.24 m³/h and 53.76 m³/h, respectively.

Figs. 6 to 8 illustrate changes of pressure and temperature in the near-well zone at a depth of the reservoir top in the predicted time.

Bottom-hole pressure in injection wells Uniejów PIG/AGH-1 and Uniejów IGH-1 has stabilized after ca. 20 years (Fig. 6).

The observations of changes of temperature in the near-well zones reveal that similar to forecast no. 1, rocks

surrounding these wells are cooled after a 30-year period. Later the temperature drop is minimal and the reservoir at this part reaches the temperature of the injected water (Fig. 7). The influence of temperature of the produced water is minimal. After 100 years, the temperature in the near-well zone of Uniejów PIG/AGH-2 and Uniejów PIG/AGH-3 slightly drops by ca. 0.2°C (Fig. 8).

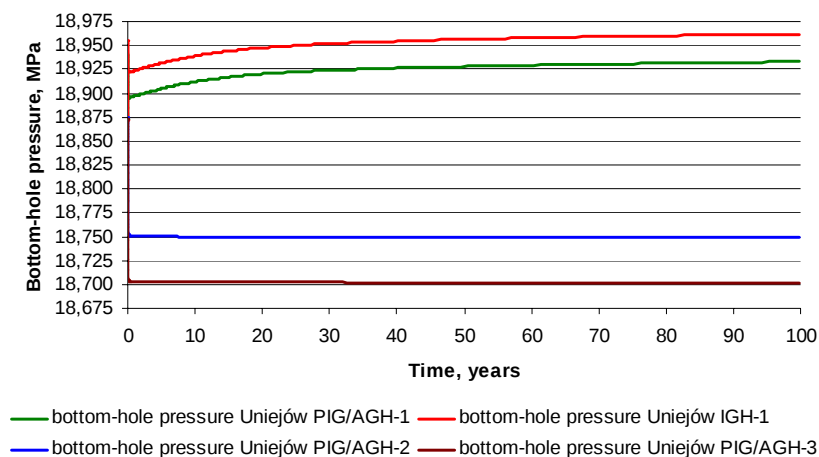


Figure 6. Changes of pressure in the reservoir top in the near-well zone for all boreholes.

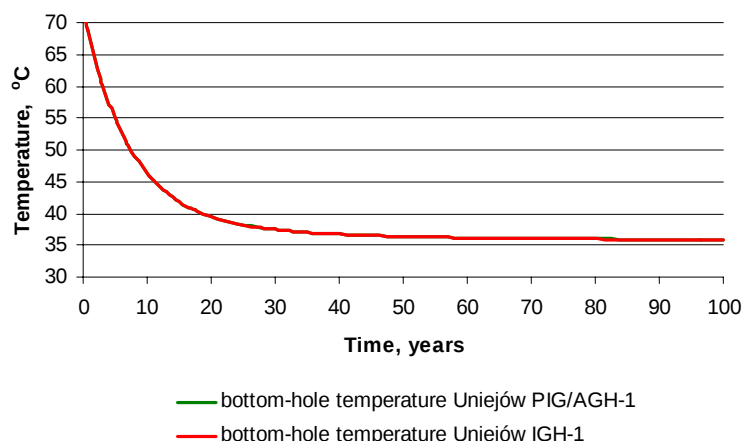


Figure 7. Changes of temperature in the reservoir top in the near-well zone of injection wells Uniejów PIG/AGH-1 and Uniejów IGH-1.

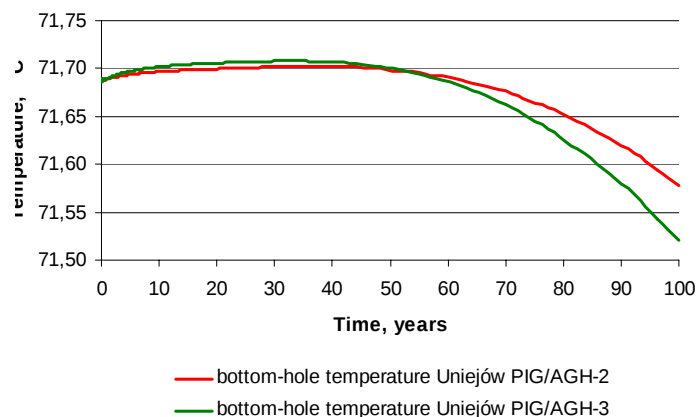


Figure 8. Changes of temperature in the reservoir top in the near-well zone of production wells Uniejów PIG/AGH-2 and Uniejów PIG/AGH-3.

3.2.3. Forecast 3 – Conditions of Increased Heat Recovery and Complete Water Injection into the Reservoir

The assumed water production rate was the same as in forecast no. 2. For Uniejów PIG/AGH-1 and Uniejów IGH-1 the planned injection rate was 132.48 m³/h and 107.52 m³/h, respectively.

Figs. 9 to 11 illustrate changes of pressure and temperature in the near-well zone at a depth of the reservoir top in the forecast period.

Owing to the bigger flow rate of exploited and injected geothermal water (240 m³/h), this forecast accounts for faster cooling of the near-zone of injection wells Uniejów PIG/AGH-1 and Uniejów IGH-1 after only 10 years (Fig. 10). In the near-well zone of production boreholes Uniejów PIG/AGH-2 and Uniejów PIG/AGH-3, the temperature drop is visible after 40 years. After 100 years of exploitation the temperature decreases by 1.4°C (Fig. 11).

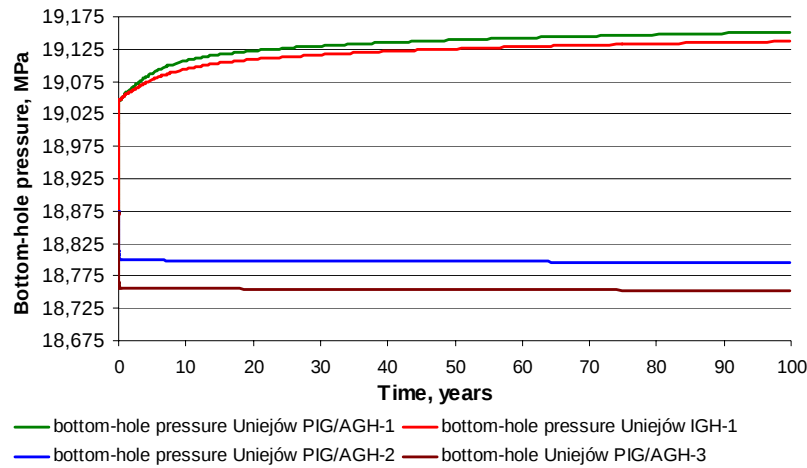


Figure 9. Changes of pressure in reservoir top of the near-well zone of Uniejów PIG/AGH-1, Uniejów PIG/AGH-2 and Uniejów IGH-1.

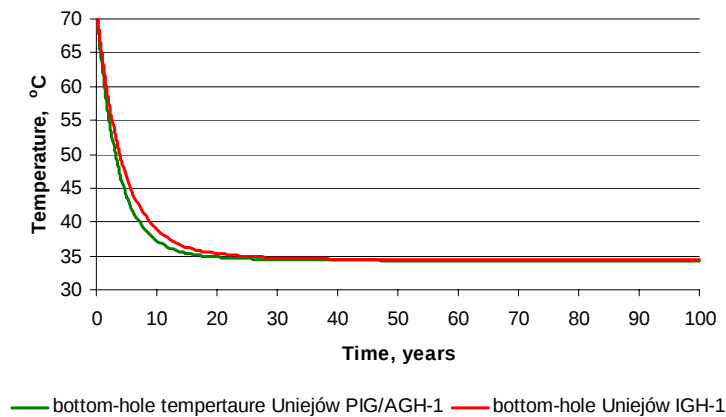


Figure 10. Changes of temperature in the reservoir top in the near-well zone of injection wells Uniejów PIG/AGH-1 and Uniejów IGH-1.

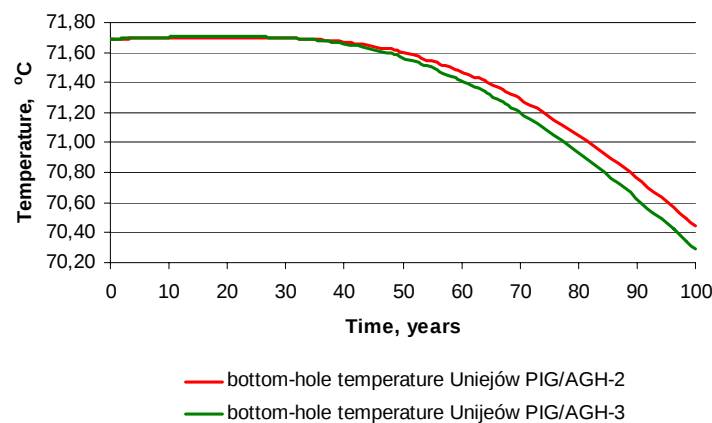


Figure 11. Changes of temperature in the reservoir top in the near-well zone of production wells.

4. CONCLUSIONS

1. Regular reservoir setting enables reservoir simulations on the basis of a numerical model. Predictions were made with the use of a simulator TOUGH 2.0 with a pre- and postprocessor PETRASIM.
2. Long-term forecast of reservoir exploitation under the conditions of the present load of the source revealed a negligible influence of long lasting (100 years) injection of cooled water to the reservoir on its parameters. The drop of water temperature in the near-well zone was ca. 0.25°C for a production yield of 120 m³/h; for the yield of 240 m³/h the temperature dropped by 1.4°C.
3. Given the distance between two wells and the natural direction of water flow, the cooled water front will not reach the production well at the assumed life of the geothermal installation (25 years).
4. Production simulations indicated that problems in Uniejów are connected with technological factors of the surface installation, not with the reservoir.

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