APPLYING TEMPERATURE AND PRESSURE MEASUREMENTS FOR ESTIMATING THE SIZE OF A WATER RESERVOIR

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Beside geological methods for determination of the size of a water reservoir, temperature and pressure records in boreholes are used as complementary means. They can be applied, if several wells are available. If a hydraulic connection exists between two given wells, a variation in one well can also be monitored in the second one. On the other hand, a displacement of an aquifer can be found, if a change in one borehole does not affect the temperature or water level in another borehole.
The water reservoirs in and near to Tbilisi are separated aquifers for which the hydraulic connection exists between the wells in every reservoir. Additionally, strong pressure changes in the more distant Samgori oil reservoir affect also the hydrothermal field of the central thermal water reservoir at Tbilisi.

Keywords: Micro-temperature, oil and water reservoir

Introduction

A sustainable exploitation of a water reservoir is based on the knowledge of several structural, petrophysical, hydrogeological and meteorological data that can affect a water balance. One important part of them is the size of the reservoir. Its extent determines the accumulated capacity, i.e. the total volume, if water should be used for drinking or baths or the heat capacity, if thermal energy is to be extracted from hot water.

Geological mapping provides the structure near to the surface and the subdivision into blocks by visible faults. Geophysical prospecting methods can clear up the deeper structure, so that a layered model can be estimated. For more detailed studies, boreholes are necessary in order to make hydrogeological experiments and to monitor the water movement which is caused by geodynamical effects, by tectonic activities, by changes of recharge conditions and at least by man-made activities which affect the hydrological pressure in the subground. The aim of this paper is to demonstrate in which way continuous temperature and pressure measurements can be used to determine boundaries of water reservoirs.

Method

Temperature measurements are performed in such a way that highly resolving Quatz-thermometers are placed at one or more depths and monitoring is extended over several months by reading the thermometer three or four times an hour or twice as a minimum. A few readings are stored in the instrument and every three hours they are transmitted to the laboratory using the local GSM network. In the case of lacking a GSM net which can occur in mountainous areas or if no electricity is available, the onboard data logger can keep the data for several weeks until they are read by a computer.

For precise measurements of the temperature, it must be known how much is the measured value affected by variations of the ambient temperature. Because this temperature is also recorded, its influence can easily be determined. Fig. 1 displays a record of the instrument temperature and a contemporary record of a temperature sensor. The strong coincidence of the variations is free from doubt and the analysis yields a temperature sensitivity of $\Delta T/T = \pm 0.35$ mK/K, if the used time base has a stability of ± 1 ppm at16 MHz within $0 < T < 70$ °C. If the instrument is kept within the borehole, the diurnal temperature affects the measurements within $\Delta T = \pm 0.5$ mK. This effect can be eliminated, if daily mean values are calculated. Longer weather periods can also be filtered out, if the date and time are used together with the instrument temperature in order to determine a function of correction. For more precise measurements, i.e. if climate variations are to be monitored, a more stable time base must be installed, e.g. an oven Quartz-oscillator.

During a given time interval records are necessary at two boreholes at least. The fluctuations and the trend of records in both boreholes provide the arguments whether the wells are hydrologically connected or not. If the boreholes intersect the same aquifer, the temperature records correlate between themselves. This correlation even does not need any mathematical treatment. The inspection by eyes is sufficient for a decision whether a hydrological connection can be realized or not.

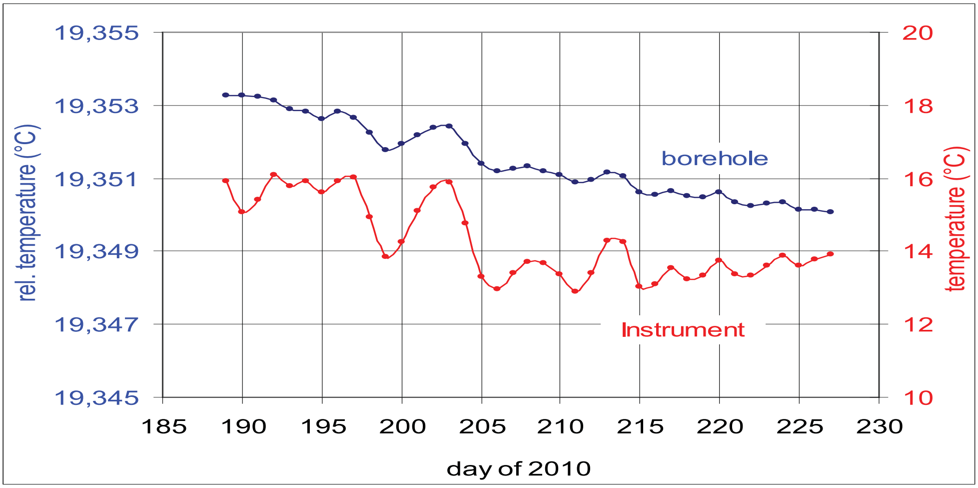

Fig. 1: Influence of the instrumental temperature changes on the measurements

In the case, if a reservoir is used discontinuously by pumping water from wells and the temperature is monitored at another borehole, the records would display whether a connection exists between the exploitation area and the borehole of monitoring.

Pressure measurements below the water table or within artesian wells are also used in the same manner as temperature records, because in both cases the physical properties are caused by water movements up or down. However, the fluctuations of pressure are higher near the water table than that of the temperature at 100 or 200 m of depth. The variations are reasoned by geodynamical effects like Earth's tides as well as by tectonic activities. Additional changes are monitored according to variations of the atmospheric pressure and after rainfall in recharge areas.

The atmospheric pressure is resolved with Δp= 1 mbar (= 1 hPa) and the measurement of water pressure with Δp= 0.1 mbar (= 0.1 hPa). The onboard temperature of the instrument as well as date and time are recorded additionally to the pressure.

The recorded data are kept at the instrument and stored in the memory for a few hours until they are transmitted as a SMS to the laboratory. The data can also be stored for several weeks, if the transmission mode via GSM is not possible. In this case, they are read to a computer every 2 or 3 weeks.

The visual inspection of the records of two boreholes already determines whether the wells are hydrologically connected or not. In the case that a reservoir is exploited more or less discontinuously and a further borehole intersects the same reservoir, the pressure variations within the reservoir also occur in the borehole of observation.

Near Tbilisi three water rsp. Thermal water reservoirs are located, i.e. the Central Thermal Field, the Saburtalo field and the Samgori field. During the time of monitoring, three boreholes could be used for measurements. They are located within the areas which are assumed as the water reservoirs by the geological structure. However, there is no proof whether the visible faults separate the reservoirs at the depth of the aquifer. The wells are located near to the villages of Lisi and Varketili as well as in the centre of Tbilisi at the Botanical Garden. Three records may demonstrate in which way the reservoirs can be discriminated.

The well Botanical Garden shows a high fluctuation of the temperature of which the shape repeats diurnally and additional peaks, more or less continuously, are realized. These changes coincide with the exploitation of the thermal water for the baths in the centre of Tbilisi. If less water is used, the temperature increases. It occurs regularly during the evening and in the night. In the early morning when the demand of water increases, the temperature decreases. The onset of the pumps for filling basins creates sharp peaks in the temperature records as demonstrated with fig. 2. The changes of the instrument temperature with ΔT= 5 °C would cause a variation of 1.5 mK which cannot be recognized at the total variation of 20 mK. It can be concluded that the borehole Botanical Garden is very well connected at a high permeability with the thermal water reservoir under exploitation.

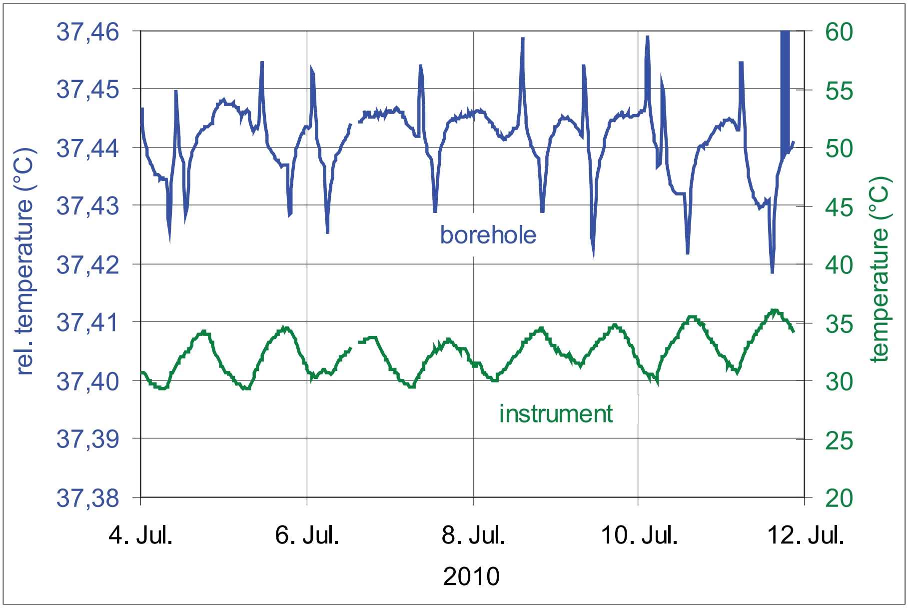

Fig. 2: Depth of the water level in the borehole Botanical Garden (Central Thermal Field)

Pressure records at the Saburtalo thermal water reservoir and at the Central Thermal Field do not display any coincidence at the first glance as fig. 3 shows. However, the time delayed increase of the water level of four days at the Botanical Garden in comparison to that one at Lisi may suggest a weak connection between the regions of high permeability. Even the regions are separated by a mapped fault zone their vertical dislocation is, probably, not so large that the aquifer is interrupted.

At the area of the Samgori water reservoir, the borehole Varketili is located and reaches a depth at which the Lower Eocene is encountered. It is the same lithology which contains the Central Thermal Field. A contemporary record at this well and at the borehole Botanical Garden is plotted at fig. 4. During September, the water level descends at the Botanical Garden by Δz= 10 cm, but at Varketili by Δz= 25 cm. However, the subfollowing

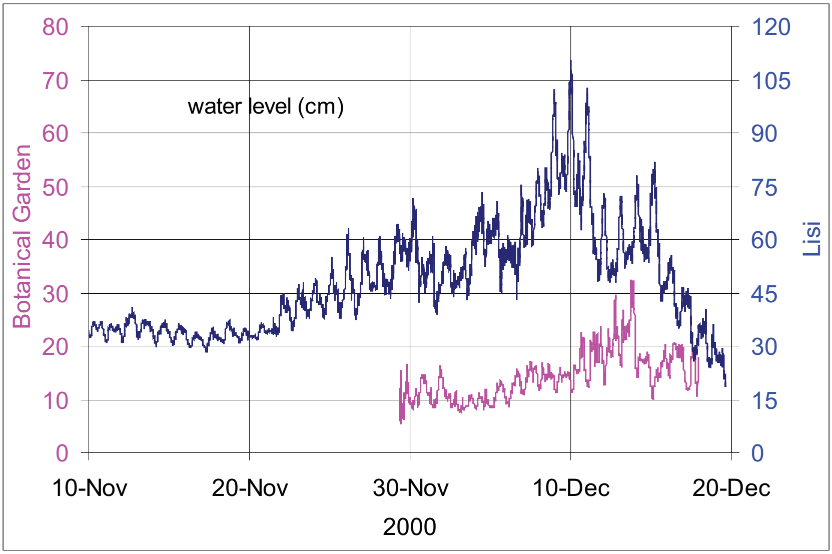

Fig. 3: Depth of the water level in the boreholes Botanical Garden (Central Thermal Field) and Lisi (Saburtalo Thermal Field)

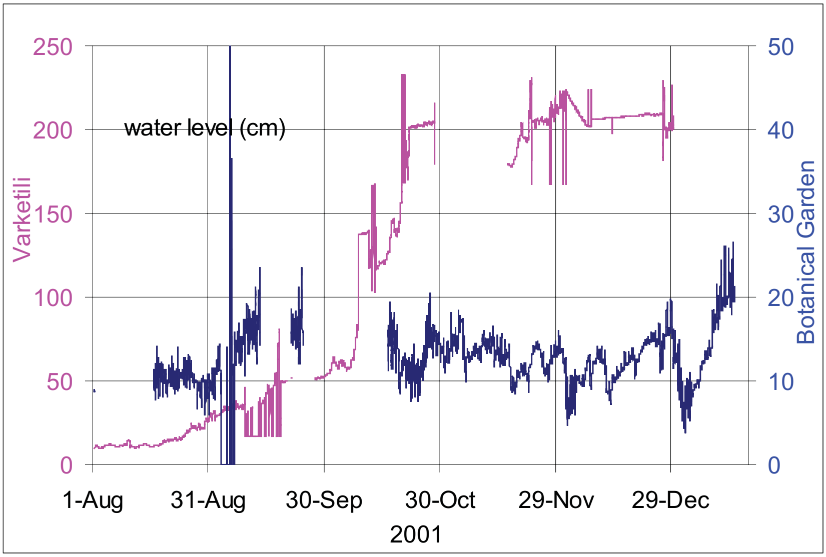

Fig. 4: Depth of the water level in the boreholes Botanical Garden (Central Thermal Field) and Varketili (Samgori Thermal Field)

large descend of Δz= 150 cm at Varketili corresponds with the small ascend of Δz= 10 cm at the Botanical Garden in October.

The first descend is in phase and seems to be caused by the effect with a connection of low permeability between both reservoirs. The second water level changes are contrary and have quite different amplitudes. It seems that the drop down at the Samgori field has no effect at the Botanical Garden within two months. Buntebarth et al. (2005) report a longterm influence of the oil exploitation which occurred in the eighties of the last century. The more oil was extracted from the oil reservoir the less thermal water could be exploited at the central field. Finally, the thermal water ceased. These data also supports the assumption that a weak connection between both water reservoirs exists. They are separated by a zone of high permeability. This conclusion is also supported by the high frequency changes which occur in the Central Thermal Field and which are not recorded at the Samgori water reservoir.

Conclusion

Temperature and pressure records are useful means in order to get complementary information on the extent of a water reservoir. In the case of different adjacent reservoirs, the recorded physical properties yield the degree to which the fields are interconnected. Using pressure and temperature measurements which express the water movement in the subground can provide a rough qualitative estimation of the permeability within a water reservoir and between adjacent reservoirs.

References

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