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Soil Temperature Monitoring and Study of Geothermal Heat Pump Systems

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ABSTRACT

Shenyang is the city where groundwater heat pump systems are currently most widely used in China. About 400 groundwater heat pump systems are in use. In order to study the temperature changes in soil and the aquifer, monitoring systems are built where groundwater heat pump systems are in use. By analyzing the aquifer information and temperature curves obtained with the monitoring data, we discuss the temperature transfer in different aquifers (soil) in geothermal heat pump systems, and determine reasonable distances between pumping and injection wells.

1. INTRODUCTION

Shenyang is one of the cities in which geothermal heat pump systems are widely used in China. More than 400 systems are in use and most of them are groundwater heat pump systems. A total of 417 systems are groundwater source heat pump, and 8 systems are ground-source heat pump.

In order to study temperature changes in different directions and the influence of pumping rate, we selected one groundwater heat pump system. Pumping rate, injection rate, and soil temperature are monitored in the systems.

1.1 Introduction of the Field

The field of the heat pump system we selected is located in the middle of an alluvial fan. The main formation lithologies include planting soil, medium-coarse sand, gravelly sand, round gravel and clay with gravel. Figure 1 shows the geological layers. The aquifer in the site is distributed continuously and has high permeability. It is primarily composed of gravelly sand and round gravel, and is relatively uniform in all directions. The thickness of the aquifer is generally greater than 20 m. Groundwater in the aquifer is mainly recharged by the lateral flow of groundwater and the infiltration of atmospheric precipitation. The flow direction of groundwater is mainly from east to west with a hydraulic gradient of 1-2‰. The groundwater runoff condition is very suitable for the exploitation of groundwater-source heat pumps.

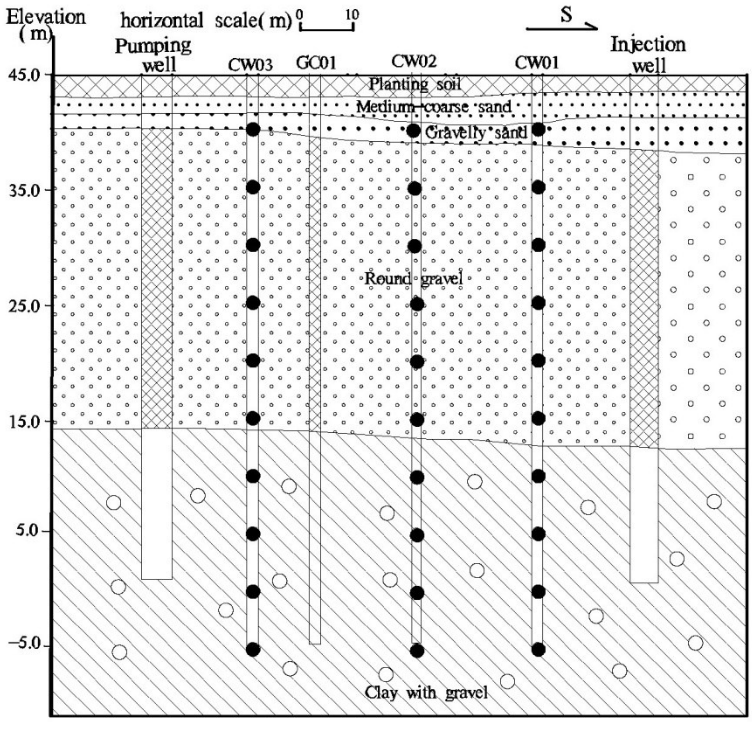

Figure 1. Profile of the monitoring system.

1.2 Heat Pump System

The system we selected is a hospital. The heating and cooling area is about 46,000 m^2. There are four pumping wells in the west side and eight injection wells in the east side of the hospital. The depths of the wells are 45 m. The diameter of each well is 0.5 m.

The elevation of strainer position for each well is between 15-36 m. The pump is located at 25 m. The distance between the pumping and injection wells is 80 m. The distance between each pumping wells is 30 m, and the distance between each injection well is also 30 m. The extracted flow rate per well is 100 m^3/h. There are about two months using one pumping well, and about three months using two pumping wells. Four injected wells are usually in use, and the other act as back-ups.

The system works about 150 days in winter and 90 days in summer every year. The annual heating demand is about 2200 kW, and the annual cooling demand is about 2760 kW.

2. ARRANGEMENT FOR MONITORING SYSTEM

Three boreholes（CW01, CW02, and CW03）are constructed between the pumping and injection wells. Each borehole is 50 m deep. In each borehole, ten temperature sensors are installed every 5 m along the well. During the time that pumping systems are in operation, the temperature is measured once per day. There is also a well（GC01）in the monitoring system,which is used to monitor water level and water quality.

Temperature monitoring lasted more than two years. In this article, we use the dates from November 1, 2011 to October 31, 2012. Through analysis of the aquifer information, pumping rate and temperature curve, we discuss some questions such as temperature transfer in different aquifer (soil) in geothermal heat pump system, and reasonable distance between pumping and injection wells.

3. ANALYSIS OF MONITORING DATA

3.1 Soil Temperature Changes during Heating Period

In order to analyze the change of soil temperature better, we consider 1 °C as the region of temperature change. Table 1 shows the monitoring time when soil temperature changed 1 °C in different depth. In addition, we constructed a temperature curve in each hole, using the monitoring data during heating period (Figure 2 to Figure 4).

Upper soil temperature is affected by weather and some manmade factor (such as heating pipe line). The ground water level is mostly deeper than 5 m. Therefore, the monitoring data of less than 5 m is not analyzed here.

Table 1. Monitoring time of temperature changing 1 °C in different monitoring depth.

depth(m) \ Monitoring time (day)	CW01	CW02	CW03
-10m	10	10	65
-15m	16	24	109
-20m	14	146	69
-25m	21	-	-
-30m	41	-	-
-35m	26	-	-
-40m	154	-	-
-45m	-	-	-
-50m	-	-	-

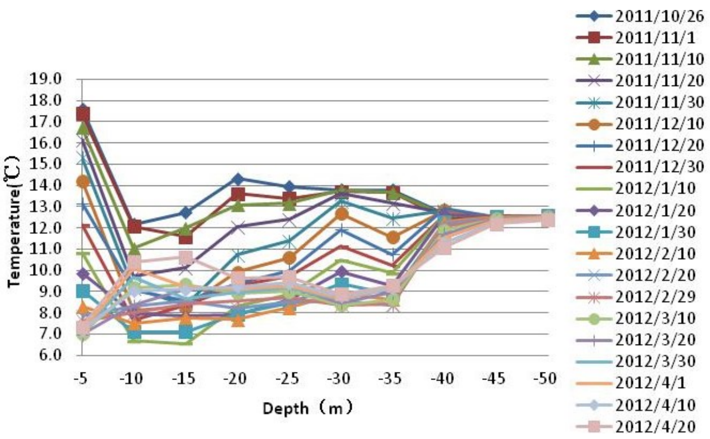

Figure 2. The heating period temperature curve of different depth in CW01.

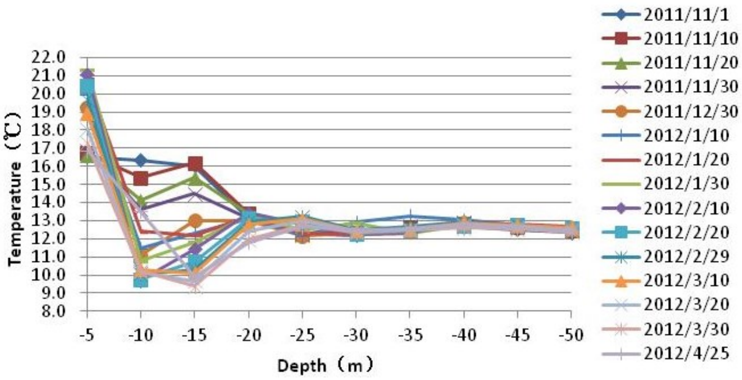

Figure 3. The heating period temperature curve of different depth in CW02.

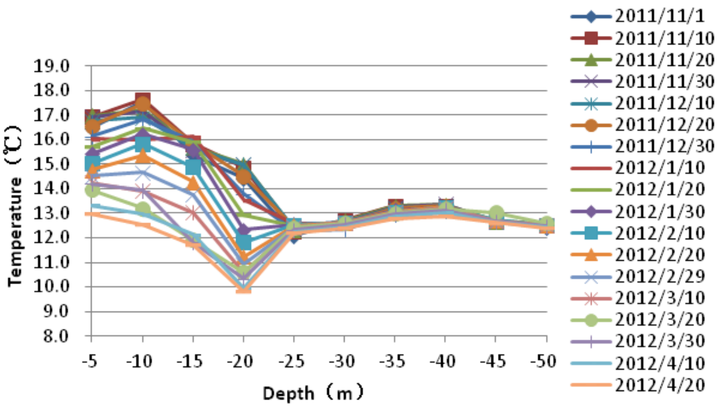

Figure 4. The heating period temperature curve of different depth in CW03.

By analyzing monitoring data and temperature curve, we provide some opinions below.

1）During the whole heating period, the system has already made the soil temperature reduce between pumping wells and injection wells, as Figures 2, 3 and 4 show.

2) Figure 2 shows that the soil temperature has been reduced around the whole depth of injection wells, and the temperature has been reduced by about 5.68 ℃ in every monitoring detector from 10m to 35m. Figures 3 and 4 show the same observation as Figure 2, and the temperature reduction is about 5~6 °C,,but the depth of soil temperature reduced are only above 25 m. This situation shows that, during the heating period, due to the groundwater funnel by the wells pumping and the higher water head of injection wells, the initial flow field in groundwater is changed, and a new flow field is formed. The path of the injection water in the scope of the new flow field is horizontal migration, which mainly spreads from injection wells to pumping wells, and the way of heat transport is heat convection, for which heat transport is relatively fast, and the monitoring data in Table 1 indicates that temperature of 10 m depth changes faster than that of deeper parts. Outside of the new flow field the mechanism of heat transfer is heat conduction, which has relatively slow heat transport, so the temperature below 25 m in borehole CW02 and CW03 does not change.

3) Although during the late portion of the heating period the temperature above 25 m in pumping well is reduced, the water inlet temperature of heat pump system did not change obviously over the same time period. This indicated that the distance between pumping wells and injection wells is proper.

3.2 Temperature Changes in Cooling and Recovery Period

We also constructed temperature curves in each hole using the monitoring data during heating period (Figs. 5 - 7).

1) Figures 5 and 7 show that groundwater temperature above 25 m changes markedly, so the groundwater and temperature transfer is still influenced by groundwater flow field change and groundwater head gradient during cooling and recovery period.

2) The groundwater temperature above 20 m is higher than the initial temperature in the final of the recovery period in CW01, and temperature between 20 and 45 m is still lower than the initial temperature. The temperature between 45 and 50 m is close to the initial temperature. This data shows that heat pump system has made slight cold accumulation between 20 and 40 m around injection wells during the system running and recovery period, and the biggest temperature difference is 2.1 °C, which occurred atn 20 and 30 m, and the temperature difference in 25, 35, and 40 m depth is 1.6 °C, 1.7 °C, and 0.875 °C.

3) Groundwater temperature in CW02 is higher than the initial temperature in the recovery period. Possible reasons are that the hot water pipeline near CW02 hole directly affects the monitoring temperature, and it also makes the air humidity in the monitoring well bigger, which causes a larger error in the temperature measurement.

4) Groundwater temperature above 25 m in CW03 is higher than the initial temperature in the final of the recovery period, and the temperature between 25 and 50 m is slightly lower than the initial temperature at the end of the recovery period. But according to the monitoring data, the temperature between 25 and 50 m was not affected by the heat pump system. The reason might be the fluctuation of the environment temperature, which was roughly 1 °C.

In conclusion, if the fluctuation of the environment temperature is 1°C, the groundwater temperature in the monitoring site is basically in a state of equilibrium through the whole period. Therefore, the distance between pumping wells and injection wells is proper.

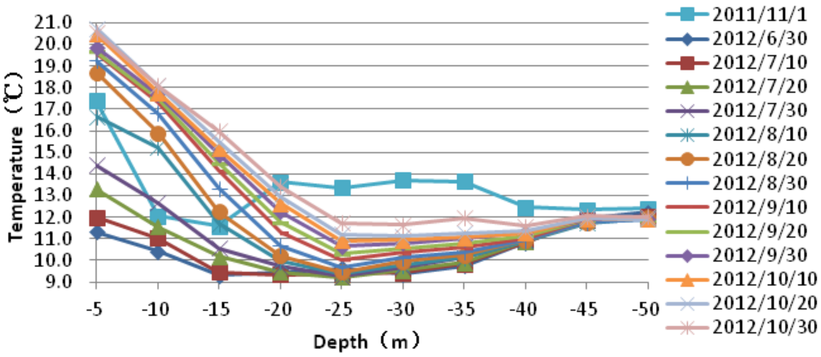

Figure 5. The Cooling and recovery period temperature curve of different depth in CW01.

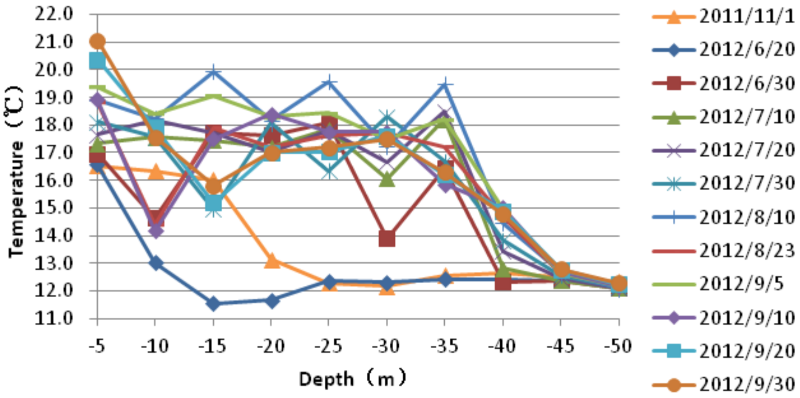

Figure 6. The Cooling period and recovery temperature curve of different depth in CW02.

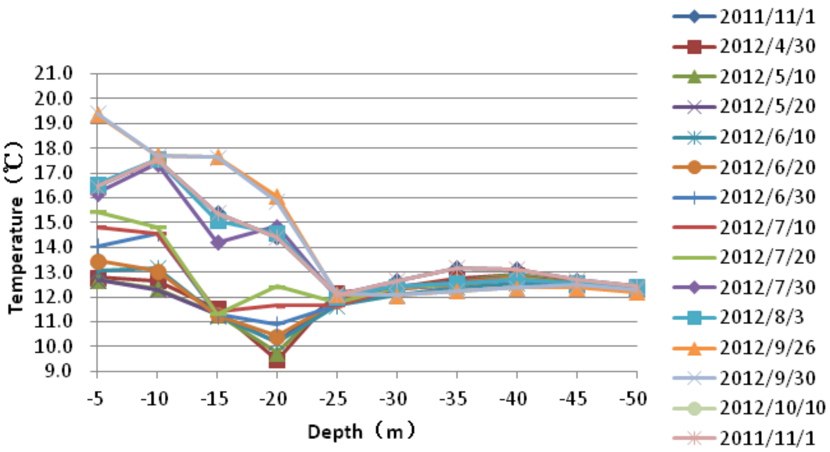

Figure 7. The Cooling period and recovery temperature curve of different depth in CW03.

4.CONCLUSION

In this paper, we used the monitoring data obtained from groundwater heat pump system field site to study the migration of groundwater flow field and temperature field, and the results show that:

1) During the heat pump system operation period, due to the groundwater funnel by the wells pumping and the higher water head of injection wells, a new groundwater flow field is formed. The path of the injection water in the scope of the new flow field is from injection wells to pumping wells, and the way of heat transport is heat convection, which is a relatively fast mechanism for heat

transfer. Outside of the new flow field, the mechanism of heat transfer is heat conduction, which is a relatively slow mechanism for heat transport.

2) The groundwater temperature in the monitoring site is basically in a state of equilibrium through the whole period. So the distance between pumping wells and injection wells is proper.

3) In east-northern of region of China, for which the heating period in winter is much longer than cooling in summer, if groundwater heat pump system uses one-sided pumping and the other injection for long term, it may make the temperature lower in deep places around injection wells. It would be better to monitor the groundwater temperature around injection wells to avoid environmental problems associated with cold accumulation. It is helpful to improve the running efficiency of heat pump to change the pumping wells and injection wells in heating period and cooling period.

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