Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

The Relationship between the Pumping Rate and the Piezometric Head at the Onyang Hot Spring Area, Korea

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Keywords: hot spring, pumping rate, piezometric head

ABSTRACT

There exist 38 boreholes at the Onyang hot spring area and submersible pumps are currently being used in 29 of them. The usage of hot water tends to increase in the spring and decrease in the autumn. This study analyzes the relationship between the pumping rate and the piezometric head. Data for the usage of hot water was collected for 10 months and the change of the piezometric head was observed during the same period. A sine curve (amplitude 1-2 m) of the piezometric head was observed within a day and another sine curve (amplitude 40 m) was observed within a year. The relationship between the pumping rate and the piezometric head was interpreted and its result would be useful to manage hot water resources.

1. INTRODUCTION

Onyang is famous in Korea for its hot springs. There exist 38 boreholes in the Onyang hot spring area and submersible pumps are currently being used in 29 of them. Boreholes are distributed within an area 150 m from east to west and 50 m from north to south (Figure 1). Depths of boreholes range from 124 to 303 m and their average is 264 m. The diameter of the boreholes is mainly 8 inches. A series of surveys of Onyang hot spring area was carried out by Hakcheon Kim in 1968 and 1969. In addition, Moon et al. (1999) and Lee et al. (2008) assessed the resources of the hot springs at Onyang.

Hot water is being pumped at many boreholes and temperatures, mineral compositions, piezometric heads and usage of hot water have been monitored. However, accurate information on the usage of hot water is not available. Therefore, data of the usage of hot springs were collected accurately in 1999 to analyze the relationship between the pumping rate and the piezometric head. If the change of piezometric head is known, we can estimate the usage of hot water and thus prevent leakage of hot water.

2. METHODS

The change of the piezometric head of groundwater can be divided into long-term change and short-term change. Factors controlling long-term change are mainly precipitation, long-term pumping, and change of the orbit of the Moon; factors controlling short-term change are mainly daily pumping, and tidal effect.

The piezometric head is mainly changed by the usage of hot water at the Onyang hot spring area. The piezometric head was monitored using a Diver from Eijkelcamp Corp., Netherlands. When a Diver is installed below the water level in a borehole, it measures the height of the water column and pressure (water and atmospheric pressure). Then, atmospheric pressure measured by a Baro-Diver is eliminated from pressure measured by the Diver.

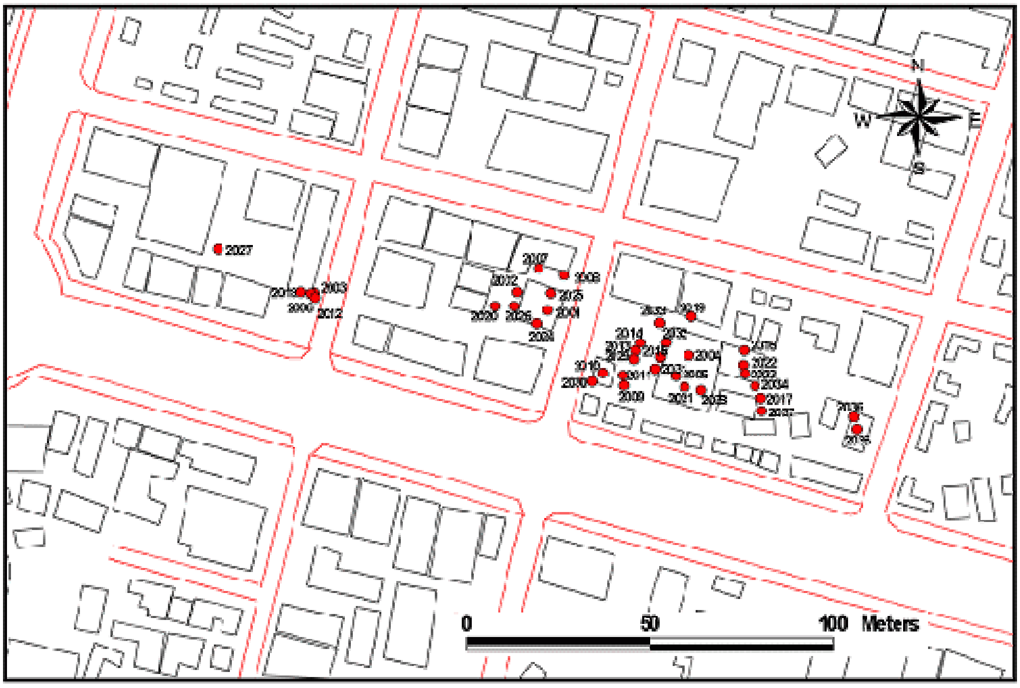

Figure 1: The distribution of boreholes at the Onyang hot spring area in Korea.

The piezometric head and atmospheric pressure were measured every 20 minutes and the piezometric head was also measured by a dipper occasionally at the study area. The value of a flowmeter was recorded daily.

The piezometric head is highest around 3 AM and lowest around 3 PM during the day (Figure 2). It is thought that the submersible pump is turned on around 3 AM and turned off around 9 PM. The average DTW (Depth To Water) is defined as an average of the piezometric head during a day; the minimum DTW is defined as the highest level of the piezometric head before a submersible pump is turned on. The ΔDTW is defined as the difference between the average DTW and the minimum DTW. Longer pumping time has bigger ΔDTW. Therefore, the ΔDTW is proportional to the quantity of hot water pumped. If we know the ΔDTW, we can estimate the usage of hot water in a day, and we can finally make an empirical formula.

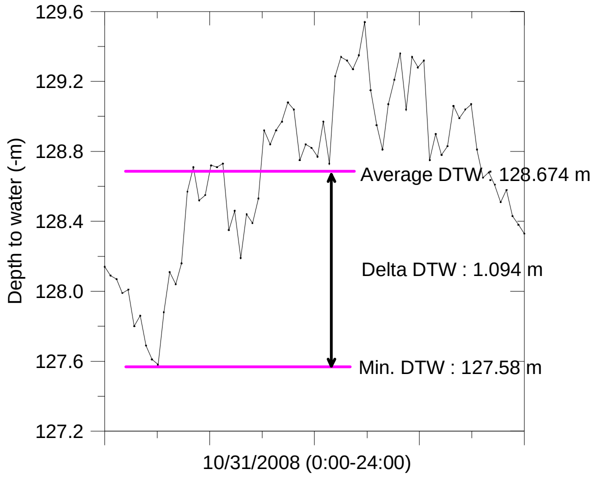

Figure 2: The change of the piezometric head during a day at well 2034.

Figure 3 shows the change of the piezometric head during January, 1999. The piezometric head continues to be low and the pumping quantity continues to be increased. The increase of the piezometric head during weekends looks like steps because the pumping quantity is increased during weekends. DTW values during weekdays were used for analysis because the pumping quantity during weekdays is a constant.

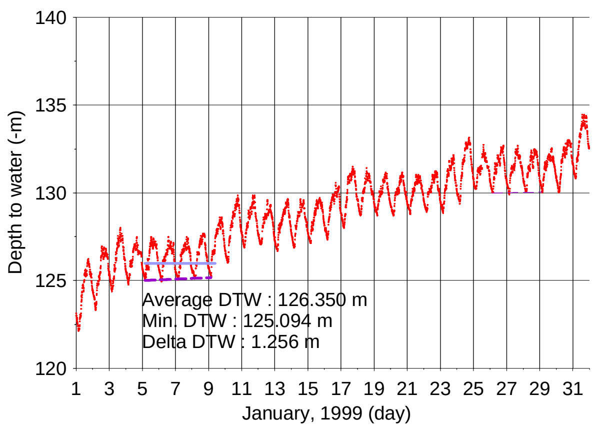

Figure 3: DTW during January, 1999. The average DTW, min. DTW and Δ DTW from the constant pumping quantity of hot water during a weekday are 126.35 m, 125.094 m, and 1.256 m, respectively.

3. RESULTS

Figure 4 and Figure 5 show the change of the pumping quantity and the piezometric head. The pumping quantity was greater in January and less in July and August. The pumping quantity became less and less year after year. The piezometric head ranged from 100 m to 140 m depth to water. It was high in September and low in February. The change of the piezometric head seems to be delayed by a month from the pumping quantity.

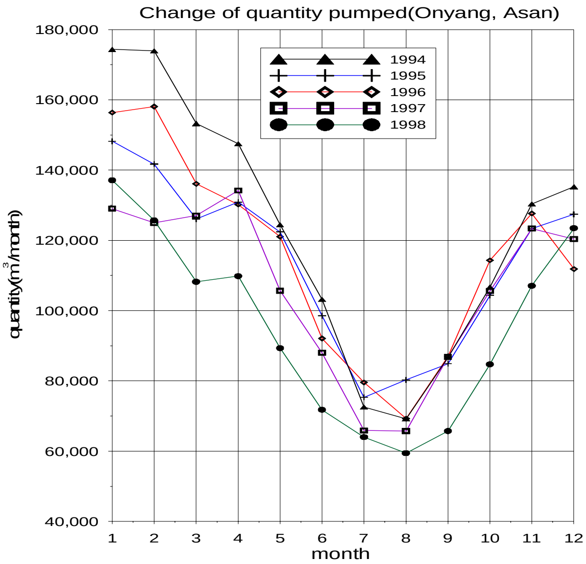

Figure 4: The monthly quantity of hot water during 5 years.

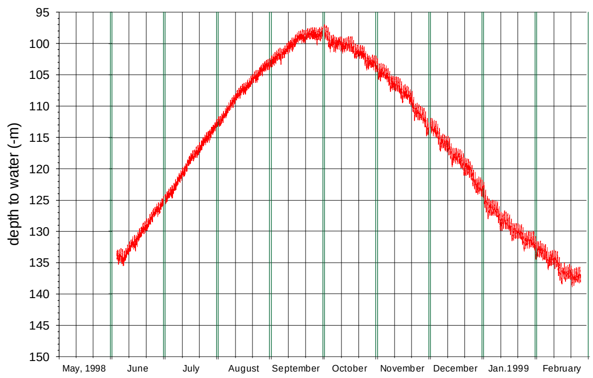

Figure 5: The change of the piezometric head from June, 1998 to February, 1999.

The pumping quantity was 137,000 m^3/month in January, 60,000 m^3/month in August, 1998. Table 1 shows values of ΔDTW for each quantity. ΔDTW was analyzed over a wide range of pumping quantity to improve the reliability.

Table 1. The values of the pumping quantity and ΔDTW

Quantity (m^3/day)	1916.94	2120.13	3453.77	4115.47
ΔDTW (m)	0.755	0.802	1.101	1.256

Figure 6 shows the relationship between ΔDTW and the pumping quantity. The ΔDTW is proportional to the pumping quantity and the relationship is found to be:

$$Q = 4404.49\Delta DTW - 1408.21 \qquad (1)$$

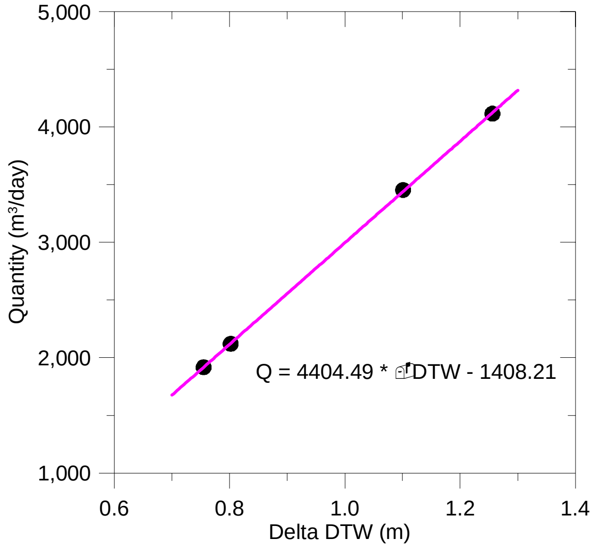

Figure 6: The relationship between the ΔDTW and the pumping quantity.

If we know the ΔDTW, we can estimate the pumping quantity per day. Figure 7 shows changes of the piezometric head and the estimated pumping quantity. The pumping quantity is estimated as 5,000 m^3/day in January and 2,000 m^3day in August, 2008. The change of the piezometric head showed a range of 125 – 170 m. The piezometric head in 2008 is lower than the piezometric head in 1998 by 30 m.

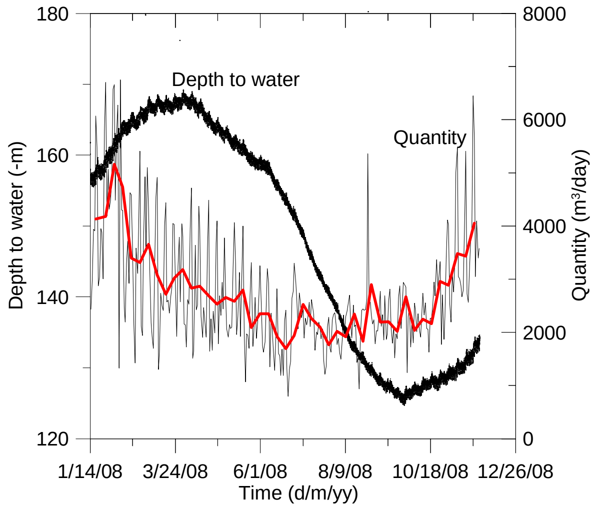

Figure 7: The change of the piezometric head and the pumping quantity estimated in 2008.

Figure 8 shows the change of the pumping quantity reported by hot spring owners in 2008. The pumping quantity is 3,300 m^3/day in February and 2,085 m^3/day in September. If these values are correct, the piezometric head in 2008 must be higher than the piezometric head in 1998. However, the piezometric head in 2008 is lower than the piezometric head in 1998 and the pumping quantity estimated in 2008 is more than the pumping quantity in 1998. Therefore, the pumping quantity reported by the hot spring owners in 2008 is not probably correct. The reason seems to be due to false information, plumbing leakages, and/or malfunction of flowmeters.

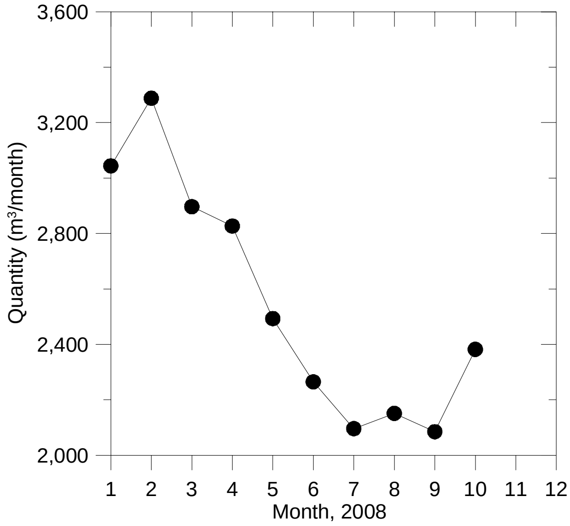

Figure 8: The change of the pumping quantity reported by hot spring owners in 2008.

4. CONCLUSIONS

Onyang is famous in Korea for its hot spring and a large quantity of hot water has been pumped. Despite the piezometric head in 2008 being lower than the piezometric head in 1998, the pumping quantity reported by hot spring owners in 2008 is less than the pumping quantity in 1998.

Therefore, we analyzed the relationship between the change of the piezometric head and the pumping quantity in 1998 and formulated a relationship between the ΔDTW and the pumping quantity. Using values of the piezometric head in 2008, we estimated the change of the pumping quantity. Comparing the estimated pumping quantity to thre reported pumping quantity, the pumping quantity reported by the hot spring owners is probably not correct. The reason seems to be due to false information, plumbing leakages, and/or malfunction of flowmeters.

ACKNOWLEDGEMENT

This research was supported by the Basic Research Project of the Korea Institute of Geoscience and Mineral Resources (KIGAM) funded by the Ministry of Knowledge and Economy

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