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The geothermal heating system at Taupo Hospital, New Zealand

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ABSTRACT

Taupo Township is located in the south western apex of the Taupo Volcanic Zone (TVZ), in the centre North Island of New Zealand, which has an abundance of high temperature geothermal resources. The Taupo Hospital sits in the south-east of the Taupo township located on the outflow zone from the Wairakei–Tauhara geothermal system. The direct-use of geothermal energy in the hospital was commissioned in August 2010 to provide space heating and domestic hot water supplies. Previously, two coal fired boilers that consumed around 340 t/year of coal were used. By converting to geothermal energy, significant savings were made in terms of operation (fuel) and maintenance costs, while no greenhouse gases are emitted to the environment. Geothermal fluid production fluctuates depending on the season. Minimum production during summer is 59 t/day and maximum production during winter is 279 t/day. The geothermal and heat exchanger system has now been running for more than four years, with no issues pertaining to scaling and corrosion. This is due to a combination of good maintenance practices and the favourable chemical composition of the geothermal fluid.

1. Introduction

Utilization and optimization of geothermal energy for direct-use in a country that has an abundance of geothermal resources has become a matter of great interest. With the crises and uncertainty surrounding fossil fuels, the use of geothermal energy has become more popular, and has the potential for significant growth. As one of the largest geothermal energy sources in the world, New Zealand has a steady growth for geothermal direct use and accelerated growth (until 2014) for power generation (Bromley, 2014).

The geothermal direct-use discussed in this paper is for space heating and domestic hot water supply in the Taupo Hospital building. Comparisons of direct-use of geothermal energy for some space heating from different systems around the world are presented in Table 1.

Compared to other sources of energy, the use of geothermal energy for district, individual or building space heating, requires high capital investment upfront. These costs include production and reinjection well drilling, system equipment such as down-hole and circulation pumps, heat exchangers, pipelines and distribution networks, flow metres, valves, and control equipment, and building retrofitting. However, the operating cost is lower, approximately 30–50% per annum of the cost of natural gas (Lund, 2011).

Comparisons between the Taupo Hospital geothermal heating system with the geothermal heating system at Rotorua hospital (Steins and Zarrouk, 2012) show that:

- The Rotorua system has 300% redundancy in production wells while the Taupo system has no redundant wells. This makes the Taupo system more vulnerable in the event of well/pump failure.
- The Rotorua production wells are self-discharging while the Taupo system production well has a down-hole pump. This makes the Taupo system more vulnerable in the event of pump failure.
- Given that the Rotorua production wells produce two phase fluid only Shell and tube heat exchangers can be used with a much lower heat transfer coefficient. This means much larger and more expensive heat exchangers are needed compared with those used in the Taupo system.
- The higher temperature loss in the two phase self-discharging wells of the Rotorua system as the fluid travels against gravity (Zarrouk and Moon, 2014) compared with pumped wells in Taupo. At the same time there is no need for the non-condensable gases to be released in the Taupo system as the fluid is pressurised when compared with that of Rororua wells.

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Table 1
Examples of space heating systems in the world.

Country	City	Space area	Prodwells	RI wells	Flow rate (l/s)	*T* geo in (°C)	HE	Year built	Energy capacity	Energy saving
Turkey	Afyon[1]	513,683 m^2 (district)	3	1	42–61	93–99	Plate	NA	NA	NA
USA	Oregon[2]	55,700 m^2 (university)	3	2	62	89	Plate	1964	0.53 to 5.6 MWt	1650 t/year oil
New Zealand	Taupo	4205 m^2 (hospital)	1	1	2–9	100–105	Plate	2010	183 kW (average)	340 t/year coal
New Zealand	Rotorua[3]	NA (hospital)	4	2	2–7.5	128	Shell & tube	1977	689.7 kW (Oct 2009)	>800 t/year coal

[1] Keçebaş (2011).
[2] Boyd (1999).
[3] Steins and Zarrouk (2012).

- There are no monitoring wells between the production and reinjection wells in the Taupo system while there is one monitoring well in the Rotorua system.

Taupo Township is located in the heart of the Taupo Volcanic Zone (TVZ), in the North Island of New Zealand (Fig. 1). Taupo sits within the Wairakei (NE)–Tauhara (SW) geothermal system, which is delineated by the resistivity boundary shown in Fig. 2. The Tauhara part of the connected fields has an upflow near Mt Tauhara and a shallow outflow to the south-west towards Lake Taupo.

Since many production and reinjection wells were drilled, stratigraphic knowledge of Wairakei–Tauhara has been improving for over 50 years (Bignall et al., 2010). The geology formations and fluid states under the Tauhara field are described by Hunt and Graham (2009) in Fig. 3.

Taupo Hospital is located in the central western part of the Tauhara geothermal field (see Fig. 2), and the south-eastern part of Taupo Township (see Fig. 4). In terms of the geothermal system, it is located in an outflow zone of the Tauhara field.

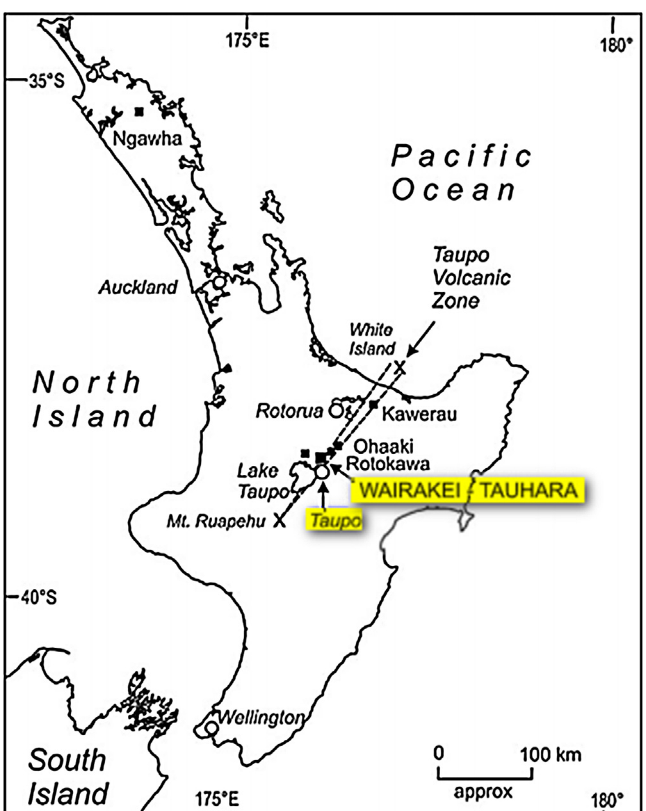

Fig. 1. The North Island of New Zealand, showing the Taupo Volcanic Zone (from Hunt and Graham, 2009 as cited by Bignall et al., 2010).

Allis (1982) and Rosenberg et al. (2010) suggested that TH 3 (shown in Fig. 2) is located in the up-flow region of the Tauhara system. Therefore the hydrology of this part of system can be represented in cross-section as shown in Fig. 5.

Based on the chemistry of the fluid taken from domestic wells and springs in Taupo, the waters can be categorized in one of two groups. One group being the steam-heated waters located in North and East Taupo and the other, the dilute chloride waters located in the Waipahihi area (Fig. 4), which is close to Taupo Hospital (Henley and Stewart, 1983). The characteristics of the latter type of waters are a relatively high concentration of chloride and bicarbonate and a low concentration of sulphate. This occurs due to mixing between the deep chloride water with the fresh groundwater and flow that occurs naturally by gravity to Lake Taupo. Hot water utilised for domestic use in North and East Taupo are supplied from the overlying (perched) shallow aquifer, within the surficial pumiceous alluvium and breccias. The fresh ground water is recharged by rainfall and then heated by the steam coming from the reservoir. Henley and Stewart (1983) also mentioned that the waters' pH is nearly neutral due to mineral–fluid equilibria. A description of the conceptual model of the Tauhara field and its aquifers can be found in Rosenberg et al. (2010) and Bromley et al. (2009).

This work provides an overview on the doublet geothermal system which provides direct-use space heating in Taupo Hospital, Waikato region of New Zealand, and then relates the system's production to local ambient temperature trends.

2. Taupo Hospital

The Taupo Hospital is the main public hospital in Taupo Township. The hospital provides health services to the residents and visitors of the town consisting of a population of around 22,000 residents. It was built in the 1960s and has a current capacity of 27 beds. Use of the geothermal system commenced in August 2010, supplying the main hospital with space heating and the maternity hospital with domestic hot water. Prior to that, the hospital ran hot water heating boiler until 1983, then upgraded to a coal fired boiler with 2 × 100% duty with a maximum thermal load of 600 kW. The circulating fluid outlet temperature range was 80 °C to 85 °C and the heating system normally operated with a temperature difference of 5 °C. Therefore, the hot water circulation rate at maximum thermal output was 29 l/s. The two 100% duty main circulating pumps served the hospital heat exchanger system and the two small circulating pumps delivered service hot water to the maternity hospital. All circulating water was returned to the common return header before making its way back to the coal fired boiler units.

A major operational difference between the coal fired heating system and the geothermal system that replaced it (see Section 3) is the delta *T* (temperature). The coal fired system operated at 5 °C and the new geothermal system operates at 20 °C. Consequently, the circulating water flow rate required to meet the maximum thermal load was reduced to 7.2 l/s.

When the coal boilers were in use, the annual coal consumption was 340 t/year. With the North Island coal price in 2009 equal to