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Improving the performance of the down-hole heat exchanger at the Alpine Motel, Rotorua, New Zealand

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ABSTRACT

The township of Rotorua is situated on top of a shallow geothermal reservoir. The resource is easily accessible and is commonly used for district heating. Excessive exploitation in the 1970s and 1980s resulted in the decline of the unique thermal natural features in the Whakarewarewa geysers area, which prompted the government to set a production moratorium within a 1.5 km area around the geysers. The production wells at the Alpine Motel had to be abandoned in 1987 and the motel resorted to gas fired heaters. A down-hole heat exchanger (DHE) was used to supply the required heat, but only 22% of the heat demand was produced. Air lifting was implemented to improve the performance of the DHE, which resulted in a 125% increase in heat output. This significant increase in heat output compared to early trials was discussed. Recommendations are given to further improve the DHE performance.

1. Introduction

The Rotorua geothermal system is located on the north western margins of the Taupo volcanic zone (TVZ) in the center of the North Island of New Zealand (Fig. 1). The city of Rotorua sits on top of the shallow liquid dominated geothermal reservoir. The shallow resource provides easy access for private users and is commonly used for domestic and commercial heating, recreation and balneology.

More than a thousand drill holes have provided enough data for a good understanding of the shallow zone of this field. The shallow aquifer consists of three regions: rhyolitic domes in the north and the south, an ignimbrite layer at the bottom of the aquifer with an overlying sedimentary layer. Furthermore, faults have been identified in the area, which enable the upflow of hot fluid from deeper regions. Two main up-flow zones are indicated by temperature maxima at about 100 m below the surface: the main one is below the Whakarewarewa geyser area (Fig. 2) and the other smaller one centered below Kurirau Park on the west side of the north rhyolite dome (Allis and Lumb, 1992). Giggenbach and Glover (1992) also reported another high chloride, high temperature up flow in the east (Ngapuna) and center of the field which is partly submerged under Lake Rotorua. Pressures at 180 m a.s.l. (100 m below the ground surface) are fairly uniform (9.5 ± 0.25 barg) over a large part of Rotorua township, with the highest pressures occurring toward the south eastern (Ngapuna) side of the field (Allis and Lumb, 1992). The main outflow is toward Lake Rotorua, which is thought to be the main cold water pressure control of the field (Allis and Lumb, 1992). Although very little is known about the field's permeability, Burnell (1992) estimated the horizontal (out flow) flow rate of the field to 120 kg/s, which would be only a quarter of the estimated discharge of 400 kg/s at Whakarewarewa. The main target depth for drilling is the upper 40 m part of the rhyolitic domes, which comprise pumiceous, brecciated and fractured rhyolite with good permeability. Below this depth the massive lava is weakly fractured and therefore nearly unproductive (Wood, 1992).

Historically, the local Maori people (Iwi) in Rotorua used the geothermal resources for heating, bathing, cooking and health care. Furthermore, the natural surface features (geysers, mud pools and hot springs) are an important part of the Maori culture and their way of life.

In the 19th and 20th centuries, with the upcoming tourism, the features, especially the geysers at Whakarewarewa, became a prime destination for visitors to Rotorua. The booming economy and increasing population, the residents utilized the cheap energy source for domestic use. The first wells were drilled in the 1920s and by 1944 there were about 50 wells in use, several hundred bores were drilled in the 1960s until 1970s into the shallow aquifer to get the geothermal fluid (Scott and Cody, 2000). Although a license was required (as stated in the Geothermal Energy Act from the central government in 1953 (Gordon and Mroczek, 2005), the field was

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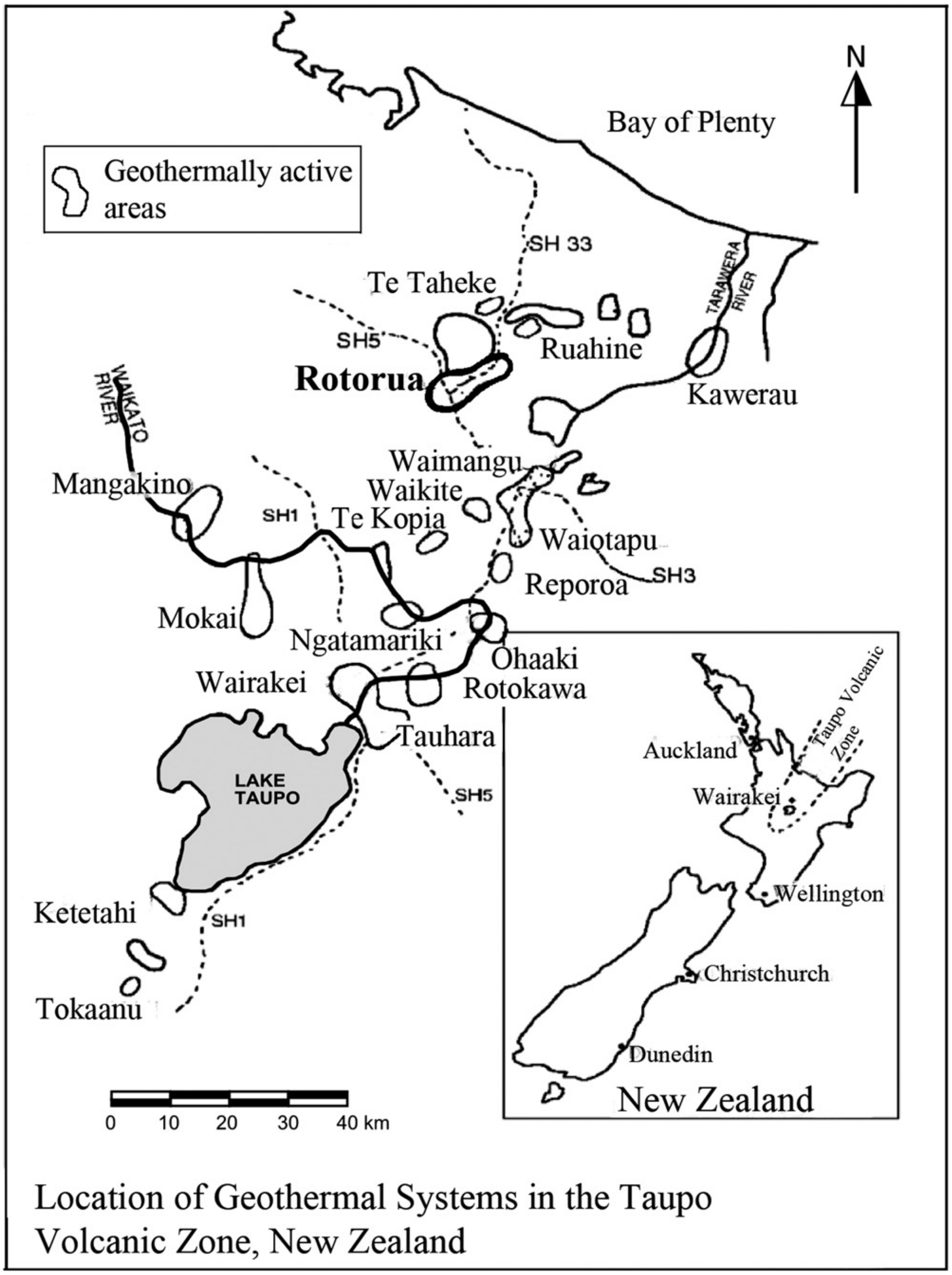

Fig. 1. Map of the Taupo volcanic zone showing location of the Rotorua geothermal system.

developed in an unplanned manner and without any considerations to the sustainability of the resource or the impact on natural surface features or the environment.

In the late 1970s and early 1980s significant decline in surface geothermal activity was noticed, especially at the geysers at Whakarewarewa. In particular, the Papakura geyser which had discharged almost continually since records began, stopped flowing (Dunstall, 1992). Therefore, in 1987 the Minister of Energy and the Rotorua District Council set guidelines for drilling and utilizing the geothermal energy. These included collecting royalty charges from uses and compulsory full reinjection of produced fluid (Scott and Cody, 2000). Furthermore, drilling of new wells within a radius of 1.5 km of the Puhutu Geyser at Whakarewarewa (Fig. 2) was forbidden and all bores (106) in the restricted area had to be closed (cemented). This was referred to as the "exclusion zone." Additionally, a monitoring program was set up to quantify the volume of fluid abstracted from the field. This included the establishment of a network of monitoring bores around the city (measuring water level, temperature, and water chemistry). It was also found that a large portion of the produced geothermal fluid was wasted through inefficient use of energy and the waste fluid being disposed of to shallow ground soakage wells (Gordon and Mroczek, 2005). This has promoted the local council to encourage the use of down-hole heat exchangers for a more efficient, sustainable and environmentally friendly way for the utilization of geothermal energy.

2. Downhole heat exchanger (DHE)

The DHE is generally a simple device, which is used to extract heat from a geothermal resource without producing (discharging)