Proc. 10th New Zealand Geothermal Workshop 1988

USE OF THE SHALLOW HYDROTHERMAL RESOURCE AT TAUHARA GEOTHERMAL FIELD, TAUPO

R J Curtis

Waikato Catchment Board, Hamilton

ABSTRACT

A survey in 1986/87 established that in excess of 500 bores exist in Taupo, providing energy for commercial and domestic heating. Approximately 90% of those bores are currently used; nearly half of which utilise downhole heat exchangers. It has been estimated that the total energy consumption from thermal ground water is around 2.76×10^{8}MJ.y^{-1} , 4.5% of the natural heat flow of around 200MW. Eighty-five percent of that consumption comes from a few large commercial users. The heat resource is therefore not stressed by current use and it is perceived that the primary management problem in the near future will be interference between users.

Pumping tests are being undertaken to determine aquifer characteristics and initial indications are that interference is unlikely in the southern, Waipahihi area of Taupo, where transmissivities are high (=700m^{2}.d^{-1}). However, at the northern end of Taupo the aquifer appears to be less permeable and problems may occur in this area with resource use. Some drawdown effects have already occurred in this area.

INTRODUCTION

The Waikato Catchment Board has statutory responsibilities to manage the water and soil resources within its area and to produce management plans for the ongoing maintenance of these resources. The Upper Waikato River Management Plan is one such plan for which investigations are being undertaken. The area of study (Fig.l) is the Waikato River catchment above the Huka Falls, covering 44km^2 and includes Taupo township. Within the catchment several issues of environmental concern are being examined including the discharge of sewage and industrial waste to the river, river and ground water abstractions, discharge of geothermal fluid and chemicals to small streams and the river, and the potential for development of the Tauhara Geothermal Field.

There are a substantial number of small users of the shallow, hydrothermal ground water resource. This is the most intensively used, low temperature hydrothermal resource in New Zealand , with a high density of bores and heat and mass abstractions requiring significant management emphasis. Potential conflicts may arise not only in terms of stress on the aquifer, but also from interference between users.

This paper provides a brief assessment of the current level of use of the Taupo hot ground water and examines some of the hydrologic characteristics of the aquifer which may create management difficulties.

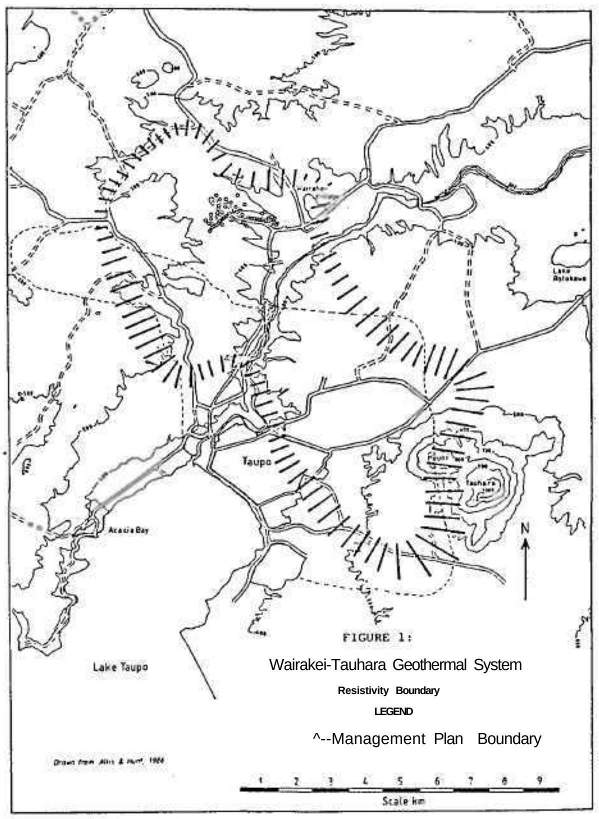

FIGURE 1:
Wairakei-Tauhara Geothermal System
Resistivity Boundary
LEGEND
^--Management Plan Boundary

BACKGROUND

The hot ground water utilised by Taupo residents comes from the Wairakei aquifer which is the shallowest of a sequence of three aquifers beneath Taupo, each separated by mudstone and siltstone aquicludes. Water within the aquifer is largely infiltrated rainwater which has been heated by steam rising from the geothermal reservoir beneath. The water flows from Mt Tauhara in the east, down a shallow gradient to Lake Taupo and the Waikato River.

Prior to about 1950 the surface thermal activtiy of Tauhara Field could be divided into three distinct areas (Fig.2); the Spa area to the north of Taupo where hot chloride water was upflowing from the deep geothermal reservoir; the Terraces area with hot, dilute chloride water upflowing into the surface aquifer and springs; and an area at higher elevation to the east of Taupo with steam-heated thermal activity (Allis, 1983).

Henley and Stewart (1983) note that by 1978 the chloride waters had stopped discharging in the Spa area and steam flow to the surface of Tauhara Field had greatly increased (5-10 fold), increasing the volume and temperature of steam-heated waters. This was a direct consequence of exploitation and drawdown of the Wairakei Field which caused fluid drawdown and pressure reduction (15-20 bars; Allis, 1985) in the Tauhara reservoir, due to the hydrologic link between the two fields at depth. However, Henley and Stewart observed that the dilute chloride water of the Terraces' area had changed very little and DSIR (1988) note that the Terraces' thermal waters still have similar temperature and chemical characteristics in the few cases where direct comparisons to old data can be made. They conclude that the dilute chloride outflows, and steam-heated activity south of Mt Tauhara are from a part of the Tauhara Field which has not been affected by pressure reduction and drawdown and are poorly connected to the part of Tauhara Field which has been drawn down.

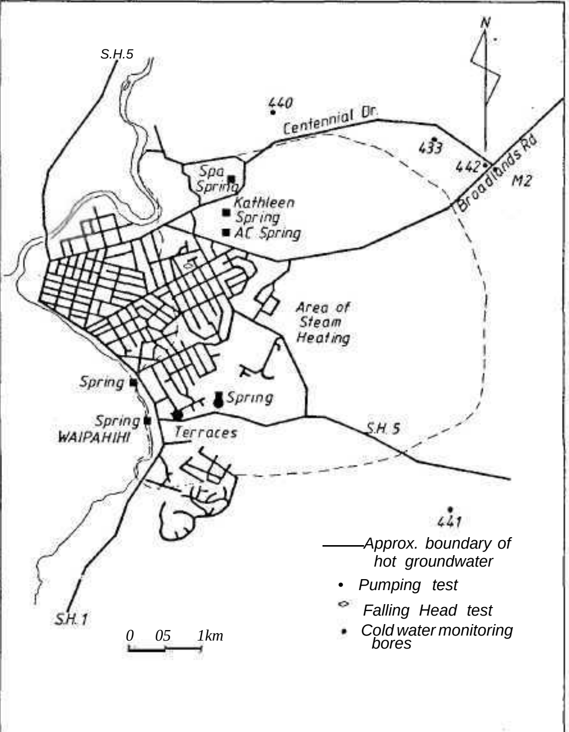

FIGURE 2: Location of springs, pumping tests and cold water monitor bores.

An additional impact from Wairakei on the Taupo shallow ground water was a marked increase in surface heat flow as a result of the increased steam flow to the surface. The total Tauhara heat flow is estimated to have doubled (Allis, 1983), from around 105 to 210MW with an associated increase in ground water temperatures. DSIR (1988) note significant temperature increases in springs and in bore waters, with temperatures now declining again, although DSIR also infer a geographic division in the data. Springs and wells at the extreme north of Taupo indicate a heating trend which may have continued past 1987, and those in the centre and to the south of Taupo show nearly constant temperatures or cooling trends during the 1980's.

USE OF THE RESOURCE

As part of ongoing investigations, a house to house survey was conducted in Taupo during the 1986/87 summer to locate ground water bores and users of the hydrothermal resource. The survey encompassed the Taupo hot water region and extended beyond Taupo into the rural environs to define the extent of the hot ground water and the degree of utilisation that the resource sustains.

In excess of 500 bores were located on the east side of Taupo in a band extending from the NE to SW of the town. Questionnaires were completed in 381 cases, from which use statistics are outlined in Table 1. Note from these statistics that nearly half the users have downhole heat exchangers, although there is clearly overlap between the classes of use. More than 50% of users abstract water or steam from the ground, but steam bores are not under pressure and abstraction is readily controlled.

Table 1. Ground water use in Taupo and immediate surrounds. Note the overlap between the categories of use identified (ie. % Total >100)

TYPE OF RESOURCE US	PERCENTAGE OF USERS
Heat Exchangers	45
Water Abstraction	48
Steam Bores	9
Cold Water Bores	3
Unused Bores	11
PURPOSE OF USE	
Domestic Hot Water	54
Central Heating	41
Spa/Pool Heating	41
Other (glasshouse, irrigation, Industrial, etc).	4

Total energy abstraction from the hydrothermal resource was estimated to be approximately 2.764×10^8 $MJ.y^{-1}$ for all users of hot water, including those abstracting from surface streams and springs (Curtis, 1988). Domestic use accounts for only 14% of the total with the remainder being commercial use. A few large commercial abstractions account for 78% of the total energy consumption.

The total energy abstraction amounts to approximately 4% of the Tauhara Field natural heat flow of 6.6×10^9 $MJ.y^{-1}$ (210 MW), and as such the heat resource is not considered to be stressed. Of more concern is the potential for interference between users in areas with a high bore density, and of localised drawdown effects from mass abstractions. Large scale drawdown is unlikely given an estimate for user abstractions of <7% of the mean annual quantity of water available for recharge from precipitation (WCB in prep).

AQUIFER CHARACTERISTICS

Two pumping tests were conducted on a shallow and deep bore located near the Terraces' springs and the Napier Rd-S.H.l intersection (Waipahihi Stream mouth) respectively (Fig. 2). The shallow bore near the springs tapped a perched water table feeding the Waipahihi Stream in highly permeable, pumiceous sediments, while the deeper bore penetrated more consolidated, but highly fractured pumice breccia.

Results from the shallow test indicated a very transmissive, unconfined aquifer(refer Table 2). The second, deeper test gave somewhat tenuous results because of problems with bore development and minimal drawdown, but was indicative of a confined aquifer with a high transmissivity of about 700 $m^2.d^{-1}$ (830 d-m). Under such conditions interference between users in the Waipahihi area is unlikely given the quantities of water being abstracted.

Table 2. Aquifer characteristics.

LOCATION	BORE DEPTH (m)	TEST	HYDRAULIC CONDUCTIVITY (cms^{-1})	AVERAGE TRANSMISSIVITY (m^2d^{-1})
De Bretts Napier Rd	21	pumping-constant rate	6.8×10^{-2} (70 d)	585 (700 d-m)
Napier Rd	60	pumping-constant rate	8×10^{-3} * (8 d)	700 (830 d-m)
Rifle Range Rd	37	falling head	9.5×10^{-6} (10^{-2} d)	—

* Assumed aquifer thickness of 100m.

A falling head test was conducted on a 75mm diameter domestic bore and yielded a value for hydraulic conductivity of 9.5×10^{-6}, several orders of magnitude less than k values for the two bores tested in south Taupo. The finding suggests a considerably less permeable northern aquifer, which was confirmed by a recently drilled bore at the A.C Baths. This bore encountered hard, cemented breccia with a notable lack of fracturing. The potential for drawdown and interference is therefore more likely in north Taupo> and additional pumping tests are yet to be undertaken there.

WATER LEVEL FLUCTUATION

Ground water levels have been monitored at fortnightly intervals on 35 bores at Taupo (refer Figs. 2 & 3) for a year. Four of these were cold water bores. Water level fluctuations and trends at the end of this period divided the bores into two groups (Fig.3).

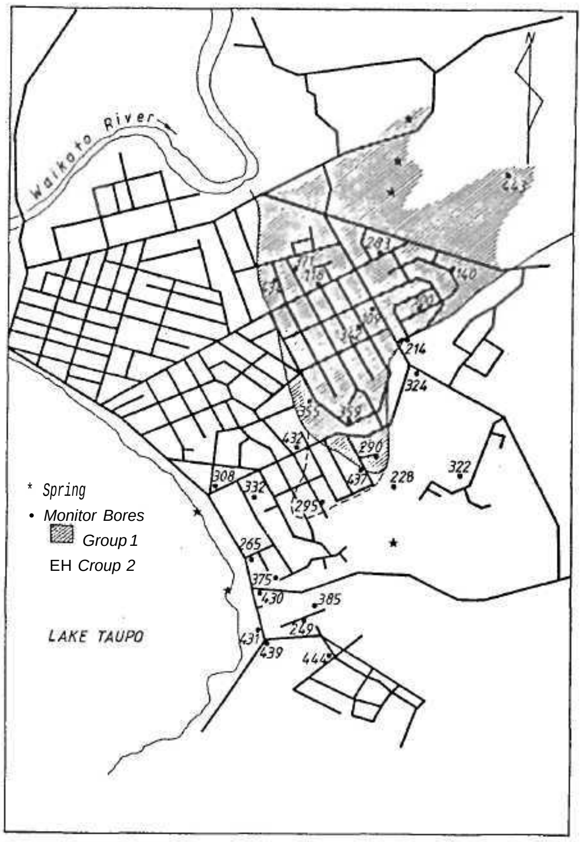

FIGURE 3: Location of monitor bores and the division of surface aquifers into two groups based on hydraulic characteristics and drawdown.

The first group, in northern and parts of central Taupo, show a clear trend of declining water levels (see Fig.4a), while the second group have seasonal water level fluctuations within a relatively constant range (Fig.4b). Within this second group, levels in bores near the lake correlated with variations in lake levels. However, the water levels at the northeastern end of the second group, while maintaining a relatively constant range, fluctuated more randomly showing poor correlation with seasonal climate and lake levels.

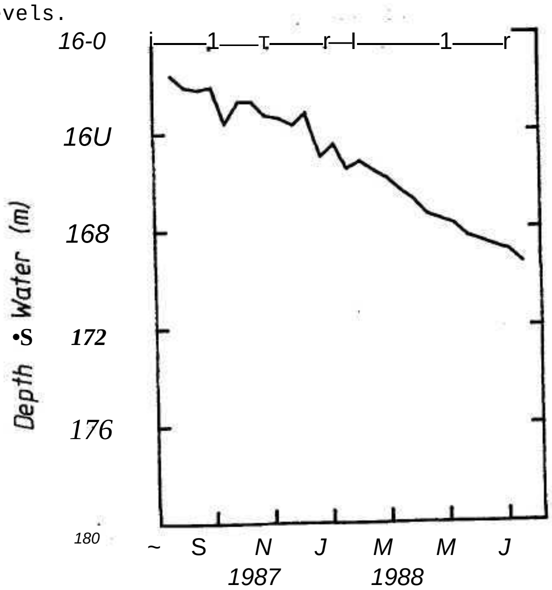

FIGURE 4a: Water level fluctuations in hot water bore 283 (group 1).

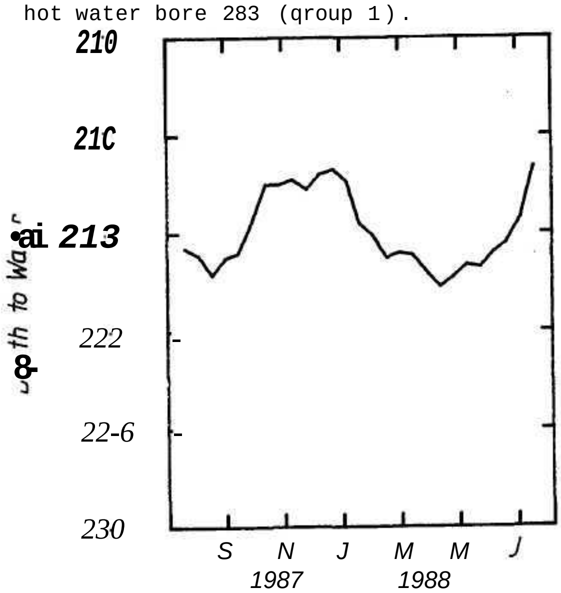

FIGURE 4b: Water level fluctuations in hot water bore 375 (group 2).

Declining water levels in the group 1 bores appear not to be caused by geothermally related factors, but are readily explained by climatic variation. Figure 5 shows a plot of 1987/88 water levels in a hot bore (290) and a cold bore (433) with net rainfall (P-E) over the same period. Ground water levels have been declining regionally for some time and figure 5 merely depicts the last year of an extended dewatering phase in response to a drier than normal climatic period. Figure 6 shows this trend over a longer term for DSIR monitor bores 100 (hot) and M2 (cold) against net rainfall. It is worth noting with respect to the 1987/88 plot in figure 5 that a continuous, drier than normal period has occurred since 1981.

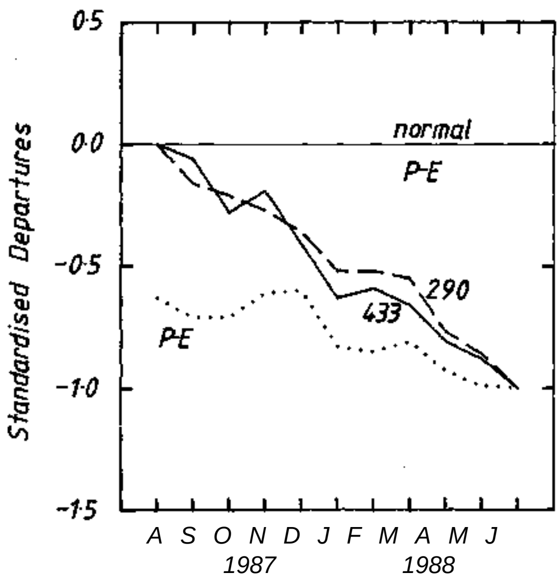

FIGURE 5: A comparison of standardised cummulative departures from normal net rainfall (P-E) with standardised water levels for bore 290 (hot) and 433 (cold) over the monitoring period.

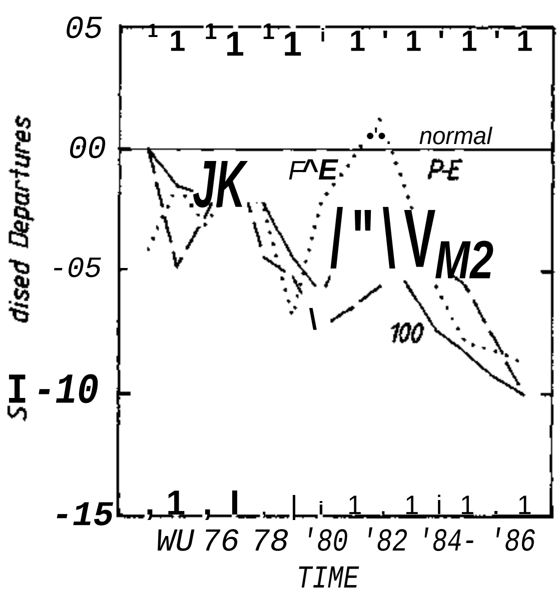

FIGURE 6: A comparison of long-term standardised cummulative departures from normal net rainfall (P-E) with standardised water levels for bore 100 (hot) and M2 (cold)

Regionally, shallow water levels are declining and bores with fluctuating water levels appear atypical. It is concluded that the maintenance of water levels in south Taupo is the result of recharge from beneath by geothermal fluid and water levels are being maintained independently of climatic trends. Such a conclusion is confirmed by DSIR (1988) findings that geothermal fluid has ceased to flow in the Spa area but continues to outflow in the Terraces' region. It also provides additional evidence for a geographic division in the surface aquifers, between north and south, with the division forming two regions as in figure 3.

Spring flow patterns around Taupo generally correspond to ground water level changes. The Kathleen spring (Fig.2) has declined significantly during the last two years, with the A.C and Spa springs declining in flow in the last year. The decline of Kathleen spring has been atypically rapid and may relate to a shift in the outflow location. In contrast, to the south, spring fed flow to the head of the Waipahihi Stream has fluctuated seasonally with minimal alteration to the flow range.

DISCUSSION

There is some discussion in the literature (Allis,1982; Donaldson,1982) as to whether the movement of geothermal fluid and steam to surface aquifers, and surface geothermal activity is influenced more by faulting or by aquifer permeability. This present study suggests there are significant geographic differences in surface aquifer permeabilities. However, a fault controlled system is suggested by the fact that geothermal fluid now appears to recharge half the Taupo surface aquifer from part of the deep reservoir that has not been drawn down. The north-south division of the surface aquifer occurs along a roughly NE trending line, corresponding to the direction of regional faulting and fault traces suggested by Donaldson (1982) and Grindley et al.(1966). Additional data are required to substantiate this hypothesis.

Irrespective of cause, the division of surface aquifers raises an interesting management issue. As noted earlier, the system is not stressed by users from either energy or mass abstraction. With the loss of geothermal upflow, drawdown in the north is due to a period of drier than normal climate. Water levels to the south are presumed to be maintained by geothermal fluid upflow, in which case the cessation of such upflow could see a rapid decline in southern water levels to that of the regional, climatically defined piezometric surface, in addition, there would presumably be a substantial increase in steam flow to the surface in the Waipahihi/Terraces area if reservoir drawdown was to occur in that region. Extension of Wairakei drawdown effects into the southern half of Tauhara Field, or the development of Tauhara Field itself could have such impacts and may be regarded as undesirable for shallow hydrothermal users in the area.

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