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PARAKAI GEOTHERMAL GROUNDWATER

RESOURCE STATEMENT AND MANAGEMENT PLAN

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ACKNOWLEDGEMENTS

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SUMMARY

(a) The Geothermal Field

Parakai is located at the mouth of the Kaipara River, approximately 50 km NW of Auckland City by road. The land is flat with an elevation of approximately 2.5m above mean sea level. Over 90 bores are recorded to be tapping the Parakai geothermal field. The geothermal aquifer predominantly lies in the fractured Waitemata sandstones and compacted alluvial sediments. Artesian bore flows occur if the water level in the confined aquifer system rises above ground level.

Chemical analyses of groundwater from 35 bores at Parakai show that there are two composition types. Bores over most of the field yield chemically unmixed geothermal water with chloride concentrations 950-1050 g/m^3 and temperatures 23-65^{o}C. Bores on the west and south margins of the field show mixing with up to 30% cold non-geothermal groundwater, with subsequent reductions in production temperatures.

Bore production temperature contours are elongated to the north-east suggesting that the geothermal water flows out of the system in this direction. Deep bores tap significantly hotter temperatures than shallow bores.

Pump testing suggests that the aquifer is highly transmissive due to rock faulting and fracturing with estimated transmissivity values 270-2430 m^2/day. Therefore pumping any one bore will affect surrounding bores.

There is a coherent continuous water level record back to 1978 from monitoring bores tapping the deep geothermal production zone. There is an annual fluctuation in water level, with minimum levels in the winter period of greatest abstraction. Since 1979 the aquifer has shown a significant increase in average water levels of up to three metres in the centre of the field and up to two metres towards the margins of the field. This is probably the aquifer response to declining water use over the past thirteen years. ARC monitoring bore nos 86 and 87 show the changing relationship between deep and shallow geothermal bore water levels since 1985. At a detailed scale, the water level responds to the daily pumping cycle of Aquatic Park and the weekend pumping by Parkhurst Corporation.

The source of the geothermal fluid at Parakai is probably groundwater - originating as rainfall on surrounding hills - that percolates down to depth in the greywacke rock, and is heated by the Earth's natural geothermal gradient while acquiring its characteristic chemical composition. The heated water then rises due to increased buoyancy through a fault or fracture system to the Waitemata sandstone and overlying alluvium which forms the geothermal aquifer.

(b) Geothermal Groundwater Use

Geothermal water at Parakai is used for recreational purposes in swimming pools. Over 90 bores have been drilled for geothermal water supply.

The main users of geothermal groundwater are the three public pool complexes: Aquatic Park 55%, Palm Springs 18%, and Parkhurst Corporation 12%. Other major users are the four motels: Parakai-Hinemoa Motels Ltd., Moturemu Lodge Motel (N. & E. Olsen), Craigwell House Ltd. and Mineral Park Motel (K. & A. Douglas). Water is also used by some farms for stockwater and in private pools.

The main issues related to the use of the Parakai geothermal field are:

- production and disused bores that are flowing artesian with hot water running to waste
- non compliance with water permit conditions
- thermally inefficient use of hot water by pool operators
- use of warm geothermal water for stockwatering
- discharge of geothermal water

Coherent returns of water use from the major users (public pools and motels) which account for 95% of resource abstraction are only available from 1985 onwards, with a significant gap from 1988-1991. There are strong seasonal variations which closely follow water use variations in Aquatic Park's use.

Greatest use is in winter due to higher heat losses from the pool surfaces. Total water use over the 1985-1993 period has generally decreased with the following average daily use in cubic metres: 1985, 587; 1986, 603; 1987, 614; 1991, 502; 1992, 564. Current use is therefore slightly lower than the current total allocation of an average 620 m3/day.

(c) Water Availability

To determine the relationship between aquifer use and water levels, a series of statistical models that relate levels to use on a monthly basis were developed. The periods of use data 1985-87 and 1991-92 were treated separately. The model showed that concurrent rather than antecedent use has the dominant effect on water levels. The long term water level rise between 1985 and 1992 cannot solely be attributed to a decrease in use over this period. Rather, the aquifer system is probably still in a recovery phase from unsustainable overabstraction in the 1960s and early 1970s, but is approaching a new equilibrium.

The amount of water available for sustainable abstraction is dependent on the water level that is required to be maintained in the aquifer. The main threat to the geothermal field is the potential for cold water inflow and a consequential lowering of the temperature of the geothermal resource if water levels in the aquifer are allowed to drop below those of the surrounding cold non-geothermal groundwater. These effects will be predominant at the margins of the field.

Maintaining a water level at 2.5m above mean sea level (msl) in the ARC monitoring bore no. 86 will maintain an upward hydraulic gradient and groundwater flow from the geothermal aquifer to the cold non-geothermal groundwater system over most of the field. Utilising the earlier correlation model, a water level of 2.5m above msl equates to a usage of approximately 700 m^3/day. This rate is a yearly average. This corresponds to a geothermal water level of 1.5m above msl at the margin of the field, approximately equal to the cold groundwater level in winter. A peak daily usage of 800 m^3/day is recommended for winter.

(d) Management and Allocation Policies 1993

The Resource Management Act 1991 (RMA) gives the ARC the responsibility of establishing and implementing policies and methods for the integrated and sustainable management of natural and physical resources including the Parakai Geothermal Resource. This includes controlling water levels and setting minimum water levels in water bodies such as the Parakai Geothermal Resource.

In achieving "sustainable management" the ARC must have regard to (amongst other matters): Kaitiakitanga (exercise of guardianship by Tangata Whenua), efficient use of resources, maintenance and enhancement of amenity values and the quality of the environment, and finite characteristics of resource.

Policies on the following management issues of the Parakai Geothermal Groundwater Resource are presented in the plan:

- Area to be covered by management plan
- Hot water availability based on long term sustainable use
- Priorities of use amongst potential and existing users
- How should allocations be determined for existing commercial and private pools, stockwater users, and proposed developments
- What should be done with any hot water, surplus to present demand
- What conditions should be placed on permits
- How should non-compliance with permit conditions be treated
- What ongoing monitoring and review of the geothermal field and its use is needed
- Conservation of the geothermal resource: artesianing bores and inefficient use
- How should geothermal water discharges be authorised

1. INTRODUCTION

1.1 Background

The Parakai geothermal field was undoubtedly known to the Ngati Whatua because of the hot springs found near Awaroa (Helensville). The springs only received attention among pakeha settlers when prominent Whangarei personality, Robert Mair, brother of the famous soldiers Gilbert and William, reported his visit some time after his 1864 "discovery" of the hot springs (Rockel 1992).

There was only one natural hot pool, although other springs rose through a creek bed. The area was gazetted as a recreation reserve in 1883. A report to the Tourist Department's Superintendent in 1902 noted "there is at present only one good spring ... enclosed by a struggling building of nondescript character". The natural spring was a timber lined hole 0.7 m square and 2.4 m deep.

A bore was sunk to 20 m in 1905. A new bathhouse was built in 1906 and opened in June 1907. Mrs Goad's accommodation house (the first of four) was established in 1908. When a large swimming pool in the domain was built in 1909 another bore was sunk to supply it with hot water. The transformation of the Reserve began in 1910 with the planting of an avenue from the road to the baths. The Domain Board also completed bowling and croquet greens, a tennis court, 6 ha of flower beds and shrubbery. A second accommodation house Parakai House (now site of Parkhurst Corp complex) opened, and a third Hinemoa House in 1914. These were very much larger than the 1908 building reflecting visitors response to better bath facilities. Although the Government didn't take over Parakai, it greatly enlarged the private bathouse in 1916, and provided a women's swimming bath in 1924. More bores were sunk and a tea kiosk built. Springside House (now Palm Springs complex) was opened, and a pool was built at Hinemoa House.

The late 1920's was the high point in Parakai's spa history. The garden area of "The Avenue" had become an attractive park. The Reserve contained 24 private baths, mens and womens swimming baths and a Massage Institute. The four boarding houses also had baths and this took custom away from the Domain. The onset of the Depression caused a decline in visitor numbers and by WWII the Spa was run down. Two of the boarding houses burned down and the swimming baths were closed in 1958. (Rockel 1986).

Redevelopment began in the 1960's with an Olympic sized swimming pool being opened in the Domain in 1965. Meetings were held between local users and representatives of Waitemata County Council and the Government in 1966 and 1968 regarding the effects that pumping the County Domain bores were having on aquifer water levels. The County reduced its pumping and water levels increased. The Rickard Family Trust applied in July 1971, and G and C Harkness (Moturemu Lodge) applied in December 1971 to the Ministry of Works for water rights under the Water and Soil Conservation Act 1967. In April 1973 the Auckland Regional Authority was designated the Water Board for the Auckland Region. Further applications for water rights were received but most were deferred until the safe sustainable yield of the geothermal field had been determined and an Allocation Plan prepared. An investigation was completed by the Auckland Regional Water Board (ARWB) from 1975-80 in co-operation with Rodney District Council and local users.

In September 1981 the ARWB published the findings of the study in a report "Parakai Water Resource Survey and Management Proposals" (ARWB 1981). Investigations continued. A preliminary study of thermal efficiency was initiated by the ARWB in 1982 and was conducted by staff of the Ministry of Works and Development (MWD) Hamilton. In December 1983 the "Interim Parakai Thermal Water Allocation and Management Plan" (ARWB 1983) was published and associated water right applications were granted by the ARWB in accordance with the policies.

The ARWB drilled two new water level monitoring bores in 1984 to replace the private bore, No. 25, that had been used for automatic recording of water level since 1978. On 31 December 1985 the Interim Allocation and Management Plan, and all the water rights to take geothermal water, expired. Applications for replacement rights were received and a reassessment of the geothermal field was published "Parakai Thermal Water Management and Allocation Plan 1987" (ARWB 1987). Water rights were granted or deferred in accordance with the Plan in November 1987.

In October 1987 the "Auckland Regional Authority Water Bore Bylaw 1987" was introduced. A previous bylaw which affected Parakai, the ARA Water Bore Bylaw 1983, was revoked. The 1987 Bylaw prohibits the installation or altering of bores without a permit. It also requires that users fit measuring and sampling apparati to bores, maintain bores, and keep such records as may be required by the ARC. The Bylaw further allows the ARC to control the inefficient and wasteful use or pollution of groundwater, and prohibits the use of "thermal water" for irrigation, any domestic purpose or needs of animals without a water permit. "Thermal water" was defined as all underground water having a temperature greater than 25^{o}C or a boron concentration greater than 1.0 g/m^3. Under the Resource Management Act 1991 this bylaw became a provision in a transitional Regional Plan.

Also as part of the Auckland Regional Council restructuring the Auckland Regional Water Board (ARWB) became ARC Environment although the responsibilities remain very much the same.

The water rights granted in 1987 expired on 31 December 1992. Applications for replacement water permits were requested and received by 30 September 1992 to gauge future demand for geothermal water and allow review of the 1987 Management Plan.

1.2 Resource Management Act 1991 (RMA) and Parakai

The Resource Management Act 1991 (RMA) integrates existing laws and sets up a resource management system that promotes sustainable management of natural and physical resources.

The Act's central concept of sustainable management encompasses the themes of use, development and protection. Sustainable management is defined in Section 5 of the Act as meaning the management of resources in a way or at a rate which enables people and communities to provide for their social, economic and cultural well-being while sustaining the potential of resources to meet the reasonably foreseeable needs of future generations; and avoiding, remedying or mitigating adverse effects of activities on the environment.

In exercising its functions and powers under the Act, Section 7 requires the ARC EMD to have particular regard to: Kaitiakitanga (exercise of guardianship by Tangata Whenua); the efficient use and development of natural and physical resources; maintenance and enhancement of amenity values and the quality of the environment; and any finite characteristics of natural and physical resources. Many of these matters are of particular relevance in considering the Parakai water permit applications.

Section 2 of the Act provides some definitions: "geothermal water" means water heated within the earth by natural phenomena to a temperature of 30^{o}C or more; "fresh water" means all water except coastal sea-water and geothermal water; and the "Environment" includes ecosystems and all natural and physical resources (such as the Parakai geothermal field). These definitions are important and used throughout this report.

Under Section 14 a person without a water permit may take "fresh water" if required for reasonable domestic needs, reasonable needs for an individual's animal's drinking water AND if the taking does not or is not likely to have an adverse effect on the environment. Water permits are required for taking any geothermal water.

Under Section 30, the Auckland Regional Council has responsibility for managing the Parakai geothermal resource which includes:

- The establishment, implementation and review of objectives, policies and methods to achieve integrated management of the natural and physical resources of the region.
- Controlling the taking or use of geothermal water and energy,
- Controlling water quantities and levels in the geothermal field
- Setting any maximum or minimum water levels

Further information may be required from an applicant under Section 92 of the Act. Where the ARC is of the opinion that the activity may result in significant adverse effects on the environment (e.g. reduction in water levels) the ARC may require an explanation of possible alternative methods for undertaking the activity and the applicants reasons for making the proposed choice; OR commission a report on any matters raised in relation to an application.

In order to encourage the integrated consideration of consents, in Section 102 joint hearings are proposed where several resource consents, in relation to the same proposal, have been lodged with different agencies. The consent authorities shall jointly hear and consider those applications unless the consent authorities agree that a joint hearing need not be held. The regional council will act as the co-ordinating agency unless the consent authorities agree otherwise. A combined hearing will also be required in Section 103 where several consents related to the same proposal have been lodged with the same authority.

The Act states that unless a resource consent is given effect within 2 years of the date of the commencement of the consent it lapses, unless an application is made within 3 months after the expiry of that period and the consent is extended. The situations in which a consent authority may fix a longer period are specified in section 125. In Parakai, this ensures that consent holders do not tie up a limited resource indefinitely for either some possible future use or for the capital gain associated with their property value being greater due to having an allocation. If on lapse of the right it is found that development has not taken place, then the allocation could be redistributed to either existing users or new applicants.

1.3 Aims of this Report

The Resource Management Act 1991 promotes "sustainable" management of natural and physical resources. A Groundwater Management and Allocation Plan provides a mechanism by which the intent of the Act can be implemented through the system of water permits for geothermal water.

The 1987 Parakai Thermal Water Management and Allocation Plan showed that the geothermal field was still degraded by intrusion of cold fresh groundwater on the edge of the field; but water levels were recovering.

The aims of this report are to:

(i) Update and review information on the nature of the geothermal field and its response to use.

(ii) Present the ARC Environmental Management Department's policies for the sustainable management, allocation and use of the geothermal water resource.

(iii). Provide guide-lines for processing present and future water permit applications, and indicate how individual allocations will be made.

2.0 PARAKAI GEOTHERMAL FIELD

2.1 Introduction

Parakai is located at the mouth of the Kaipara River, approximately 50 km northwest of Auckland City by road (Figure 1). The land is flat with an elevation of approximately 2.5m above mean sea level. The land rises to 167m at Pureora Hill 6 km to the west and to 117m at Patukuri Hill 2 km to the east across the Kaipara River. The area is subject to local flooding particularly during high tides. There is a network of deep floodgate - controlled drainage ditches.

Over 90 bores are recorded for the Paraki geothermal field (Figure 2). A great deal of information on the geothermal field has been presented in previous reports: RF Hay (1946), J Healy (1955), J Healy (1957a), J Healy (1957b), RB Glover (undated), DR Petty (1972); and in ARWB management plans:

> "Parakai Water Resource Survey and Management Proposals", ARWB Technical Publication No. 20 September 1981 (ARWB 1981)
>
> "Parakai Thermal Water - Management & Allocation Plan 1987", ARWB Technical Publication No. 43 (ARWB 1987)

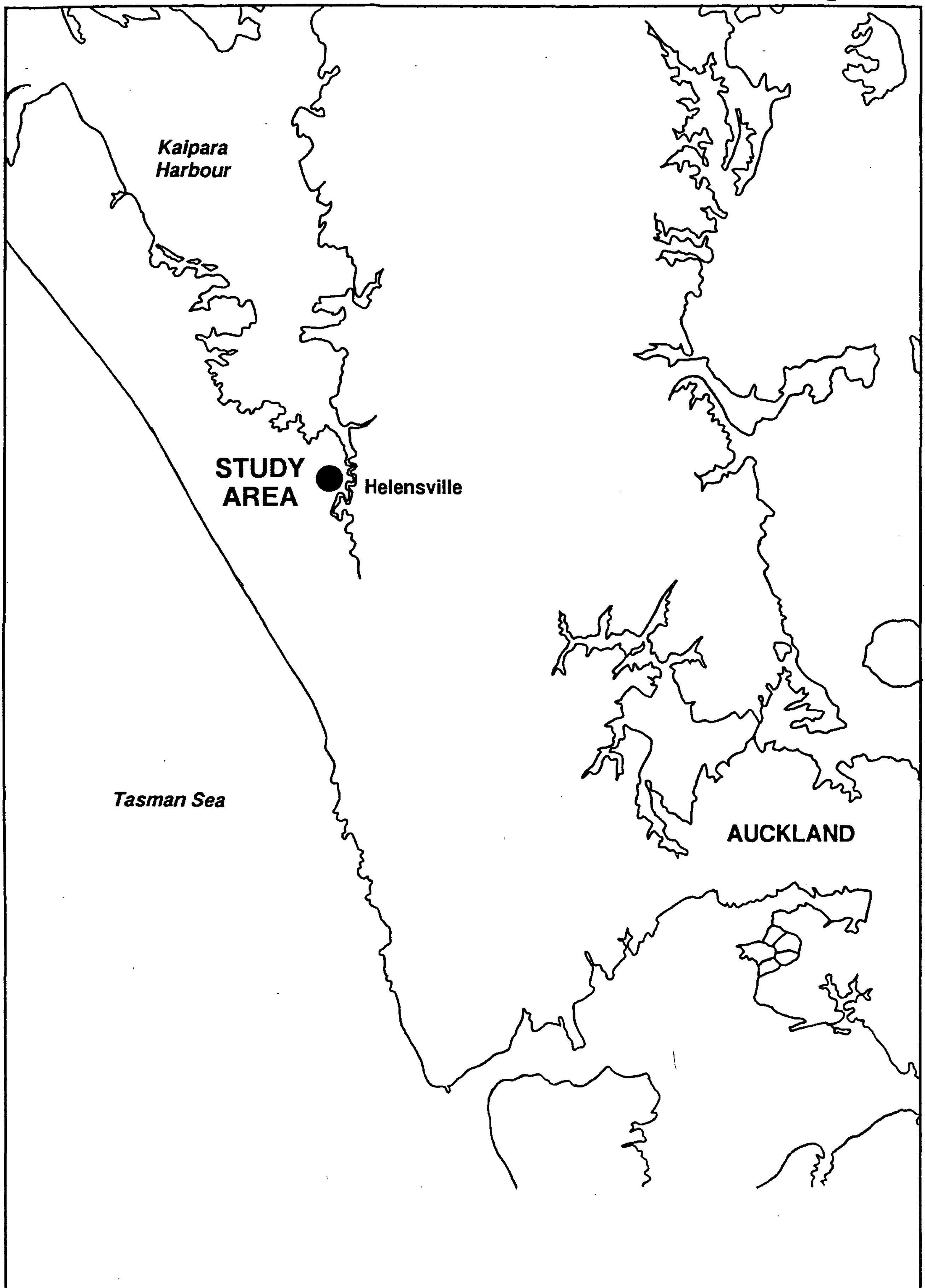
Together the ARWB Management Plans present information on: bore locations, geology, gravity and resistivity surveys, water levels including a major survey in 1979, aquifer parameters from pump tests, ground temperatures, bore production temperatures, downhole bore temperature profiles, water chemistry, thermal efficiency, hot water availability, the volume of hot water used by each water permit holder, and management policies.

Therefore the present report will present only a summary of previous findings and highlight any refinements of previous understanding.

In this discussion the term "geothermal" refers to any groundwater containing a component with the chemical characteristics of geothermal water, even though that component may have mixed with other non-geothermal water or cooled off. The relevance of this will become apparent.

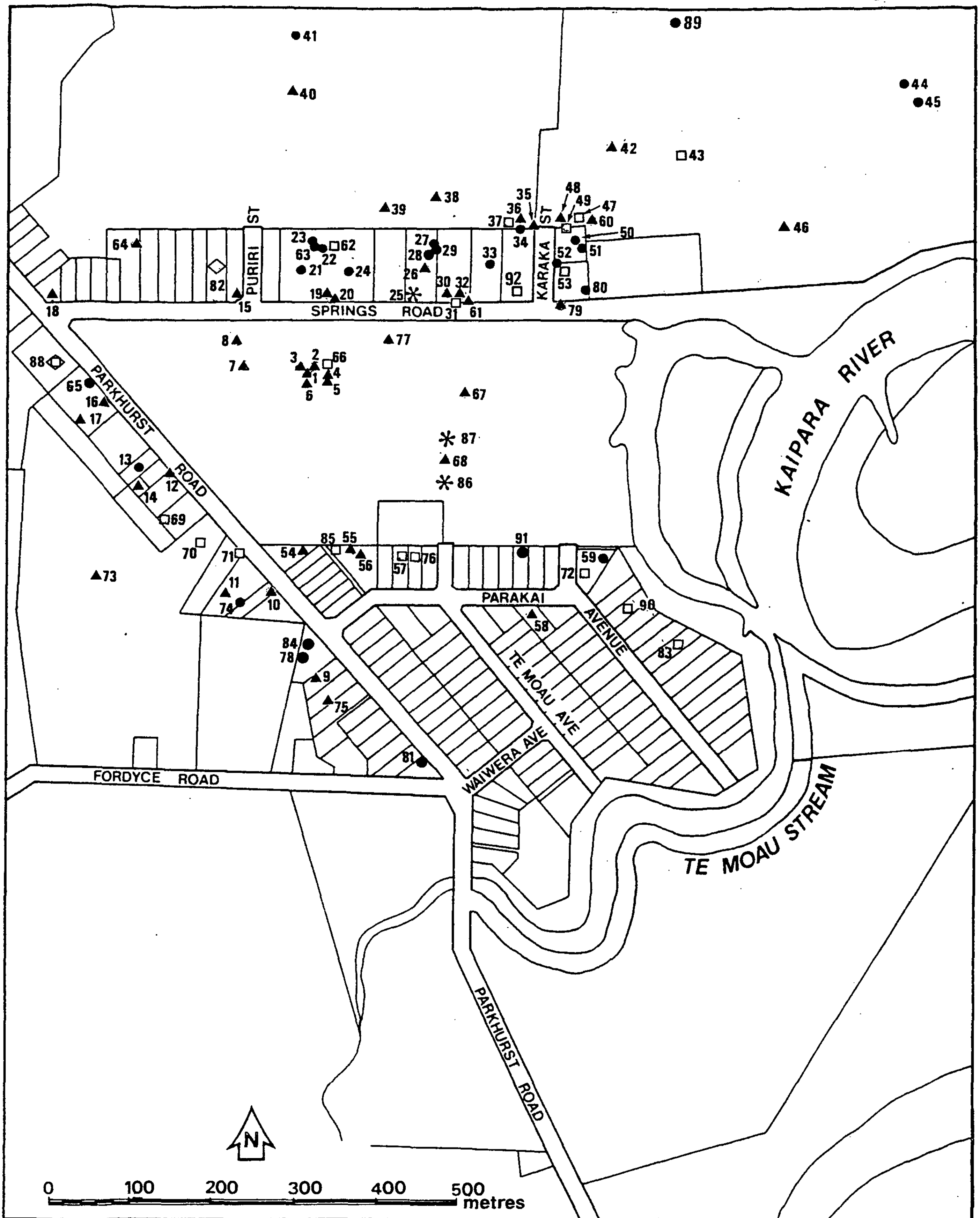
2.2 Geological Setting

The geothermal aquifer predominantly lies in the fractured Waitemata sandstones and compacted alluvial sediments, but some shallow bores (10 to 35m) near the centre of the field tap hot water in the overlying alluvials. A 10 to 15 metre thick layer of impermeable marine silts at the surface provides a confining cap to the system and consequently, artesian flows occur from the bores if the water level in the aquifer rises above ground level.



LOCATION OF STUDY AREA
Parakai Water Resource Study

Figure 2



Bore Locations

Parakai Water Resource Study

A.R.W.B.

Key

- 67 Bore Number.
- □ Bores with Current Water Right Applications.
- ◇ Proposed Bores.
- ✳ Monitoring Bores.
- ▲ Bores sealed or unable to be located and presumably sealed.
- ● Other bores.

Analysis of borelogs in the area suggests that to the north-west, in the vicinity of the Springs Rd / Parkhurst Rd intersection, the Waitemata Group rocks have been downfaulted by up to 250 metres and bores drilled in this area have been unsatisfactory and therefore not used.

North-south and some minor north-east faulting have been postulated through the Parakai area, with the gravity data supporting the presence of vertical displacement across a north-south trending fault, with a stepping down of the Waitemata Group to the west. (ARWB 1981 p57, Schofield 1989).

2.3 Water Chemistry

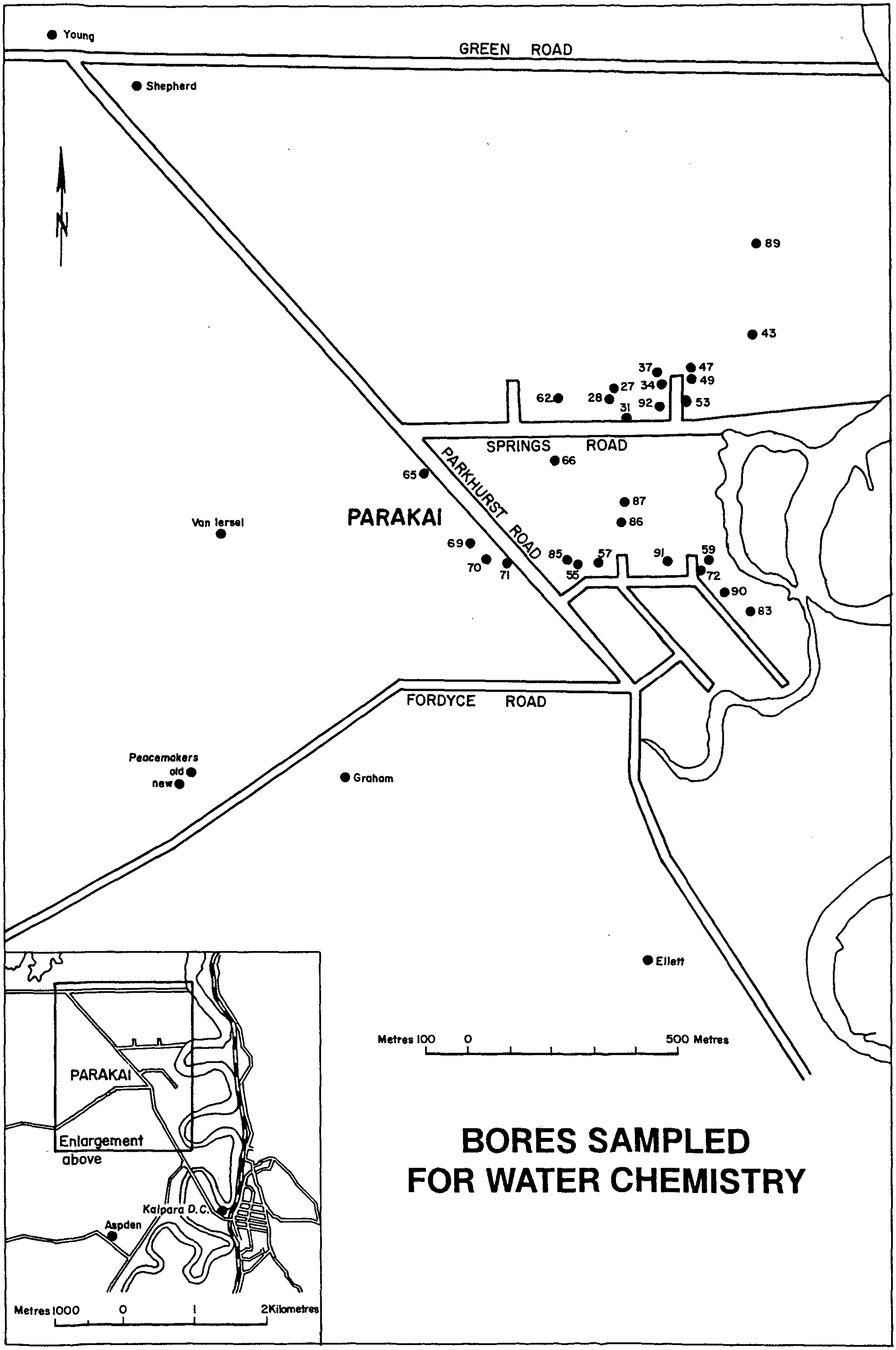
Water chemistry is useful in distinguishing between and understanding the origins of different groundwaters, based on their chemical constituents. Groundwater from 35 bores (both warm and cold) at Parakai have been analysed over a period of 14 years (Figure 3). The most recent analyses for each bore are presented in Appendix A Tables 1 and 2.

2.3.1 Types of Geothermal Groundwater

Geothermal groundwater is characterised by concentrations of boron, lithium and fluoride significantly greater than for non-geothermal fresh groundwater. These "thermal constituents" are derived from reaction of rock-forming minerals with groundwater at depths where temperatures are sufficient to bring these elements into solution (ARWB 1986 p.74). In non-geothermal fresh groundwater, the concentration of these constituents is less than 0.2 g/m^3.

Geothermal groundwater in the vicinity of Parakai shows considerable variation in chemical composition, but can be classed into two types based on chemical composition (particularly chloride and total alkalinity concentrations). A third type, geothermal groundwater mixed with sea-water, was identified in the coastal Waiwera geothermal field, but does not appear to be present at Parakai. Total alkalinity (present as bicarbonate and carbonate anions) is a measure of the total rock minerals dissolved into solution. The values presented below are a guide only:

Type	Temperature ^oC	Chloride (g/m^3Cl)	Total Alkalinity (g/m^3 CaCO3)	Boron (g/m^3B)	Fluoride (g/m^3F)
-					
Unmixed geothermal	23-65	950-1050	55-70	12-15	1.9-2.2
Geothermal mixed with cold fresh groundwater	16-43	130-960	30-450	0.2-9	0.2-2.1



BORES SAMPLED FOR WATER CHEMISTRY

(a) Unmixed geothermal groundwater

Unmixed geothermal groundwater, although not of exactly the same composition as deep source geothermal fluid, is the least mixed with cold non-geothermal groundwater of the two composition types. The composition (sodium, calcium, potassium, magnesium, chloride, alkalinity and silica), particularly of water over 55°C, is fairly uniform suggesting that the water has a single source. Most of the high chloride content is probably derived from leaching of ancient sea-water in marine deposited sedimentary rocks.

The total hardness (calcium and magnesium expressed as g/m^3 $CaCO_3$) is approximately twice the total alkalinity. Therefore calcium is derived from both mineral dissolution and cation exchange of calcium absorbed on clay minerals due to the high sodium concentration in the geothermal water. The low magnesium concentration is due to its absorption onto clay minerals at the high temperatures encountered in geothermal systems.

Water from bore no. 66 (Aquatic Park) with the highest production temperature, boron and fluoride concentrations best represents unmixed geothermal groundwater. All bores yielding unmixed geothermal groundwater are located in an elliptical shaped zone, orientated NE-SW.

Parakai unmixed geothermal groundwater is similar in composition to that at Waiwera (both mainly sodium and chloride) and quite different from that at other geothermal areas in East Tamaki and Whitford (mainly sodium and bicarbonate).

The temperature of samples from some bores is less than 50°C e.g. bore numbers 43, 49, 53, 57, 87 and 89. The chloride concentrations show that these lower temperatures are not due to dilution by cold non-thermal groundwater. Rather they are due to conductive heat loss to surrounding cooler rock because the bores are shallow (e.g. bore no. 87, 58m deep) or are located on the periphery of the geothermal field (e.g. bore no. 89).

Since ARC sampling began in 1979 there has been a slight but consistent chloride concentration gradient increasing from bores 69, 70 and 71 in the SW toward the NE. If geothermal water dissolves additional chloride along its flow path, then this concentration gradient suggests that geothermal water flow may be in a NE direction.

(b) Geothermal groundwater mixed with cold fresh groundwater

This type of geothermal water has a very wide range in temperature (16-43°C) and composition (chloride 130-960 g/m^3). It has higher total alkalinity and lower chloride, boron, fluoride and lithium concentrations, and lower temperatures than unmixed geothermal groundwater.

The lower chloride and high total alkalinity is due to mixing of geothermal water with cold non-geothermal fresh groundwater which itself has low chloride (approximately 40 g/m^3) and high total alkalinity (in the range 150-300 g/m^3 $CaCO_3$) concentrations. The lower temperatures are due to both mixing and conductive heat loss. The lower boron and fluoride concentrations are due to mixing and absorption of these elements onto clay minerals.

Bores 59, 72 and 90 (the first three in Table 2) yield mixed geothermal groundwater with a chloride concentration lower than predicted by simple mixing. This suggests that the water from these three bores may be a mixture of cold non-geothermal groundwater and a second different geothermal water upflow which has a high boron and fluoride concentration but a lower chloride concentration than that typified by bore no. 66 (Aquatic Park).

Bores yielding mixed geothermal groundwater are all located on the edge of the geothermal field. Bore no. 89 located 700m NE of the hottest bore no. 66, yields cool unmixed geothermal groundwater. Yet bores 91 and 83 located 300m and 550m respectively SE of bore 66 yield water with lower chloride concentrations of 760 and 640 g/m^3 respectively. This indicates there is 25% cold non-geothermal groundwater mixing with the geothermal groundwater on the SE side of the field thereby substantially reducing production temperatures below the potential 60-65^oC achieved in bores 66 and 86. The Van Iersel bore located 800m WSW of bore 66 yields cool water with a chloride concentration of 700 g/m^3 indicating that the low production temperature of 22^oC is due to conductive cooling and mixing with 30% cold non-thermal groundwater.

Some bores and wells yielding mixed geothermal groundwater (Graham ex Quarrie, Young and Shepherd) or unmixed geothermal ground water (Ayres ex Reyland no. 49 and Parkhurst Corp. no. 65) have sulphate concentrations elevated above the norm. This is probably due to hydogen sulphide gas from the geothermal water being oxidised to sulphate anions in the upper part of the aquifer where oxygen is available.

The reaction is

$$H_2S + 2O_2 = 2H^+ + SO_4^{-2}$$

The hydrogen ions produced may result in a very acid water with low pH.

2.3.2 Changes in chemical composition with time

Seven bores were sampled regularly between 1979 and 1987. These were numbers 31, 37, 62, 66, 69, 70 and 71. Since 1987 the emphasis has been on sampling bores that had not been tested before. Of the above 7 bores, only no. 66 and 71 were sampled in 1989 and only no. 66 in 1993. These analyses show no significant change in the composition of unmixed geothermal groundwater since 1979.

No bores yielding mixed geothermal groundwater have been sampled on a long term basis. Therefore it is not possible to determine it mixing with cold non-geothermal groundwater on the edge of the field has reduced as a result of increased water levels since 1979.

2.4 Geothermal Aquifer Temperatures

The production temperatures of bores in the geothermal aquifer for September 1992 are shown in Figure 4, together with historical temperature contour maps. The maximum production temperature of the recent survey is recorded in the Aquatic Park bore at 65^{o} C indicating that this bore is nearest to the centre of geothermal water upflow. The temperature contours are elongated to the north-east suggesting that the geothermal water flows out of the system in this direction.

The 1992 data suggests that the temperatures in the geothermal field are currently as high as have ever been measured, and certainly higher than those obtained in 1979. Unfortunately, there is some doubt as to the reliability of the 1979 measurements so no definite conclusions can be drawn. However, it is possible that the field was slightly colder in 1979 as a result of high abstraction causing low water levels in the geothermal aquifer and hence an increased inflow of cold, non-geothermal groundwater.

There is also a clear vertical geothermal gradient in the field, with the temperature in the shallow ARC monitoring bore No 87 being some ten degrees celcius lower than the neighbouring, deep ARC bore 86. This implies that in some locations, deep bores may tap significantly hotter temperatures than shallow bores.

2.5 Hydrology

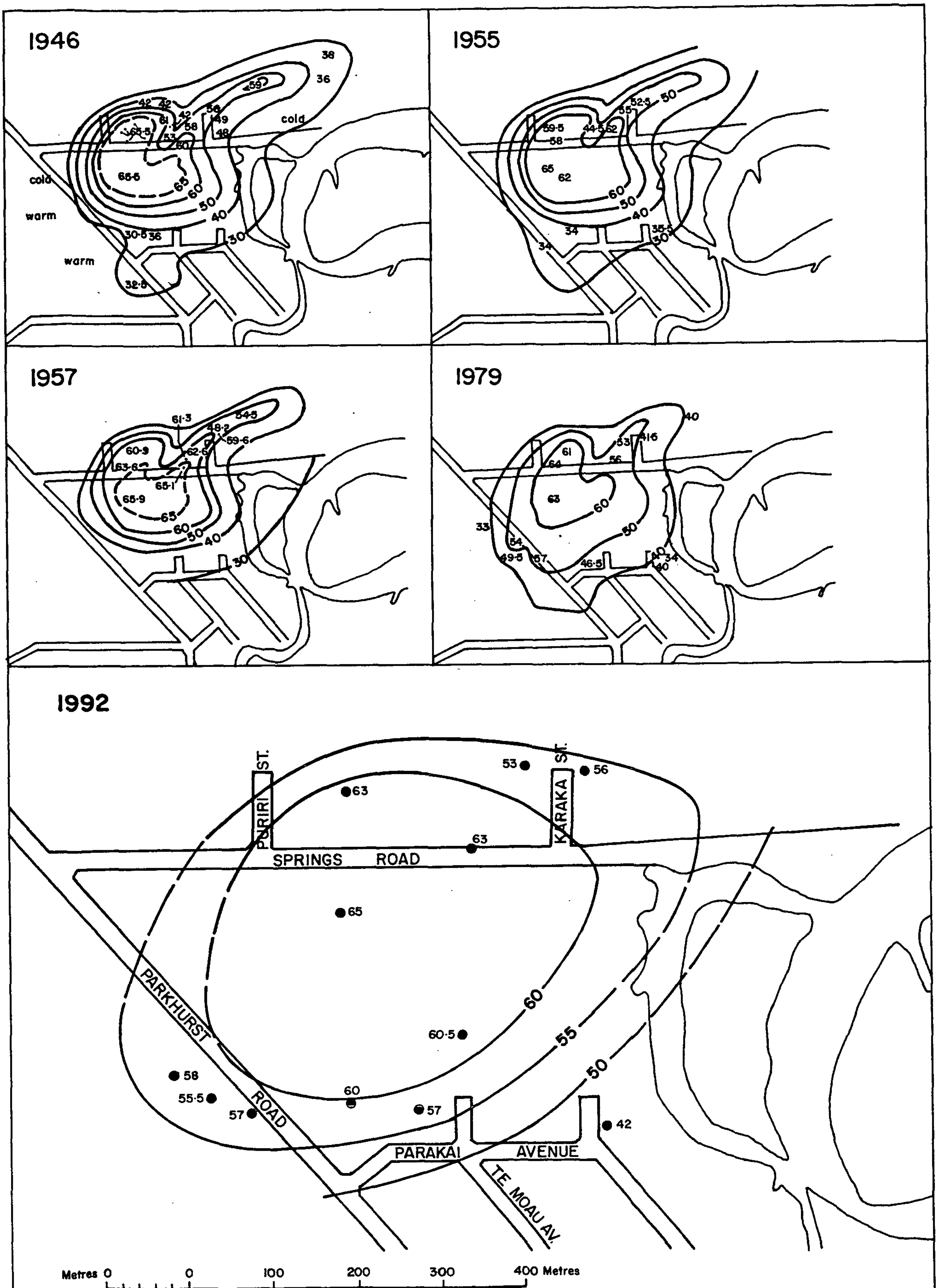
2.5.1 Aquifier Parameters

Limited pump testing has been conducted on the aquifer (ARWB 1981 p109), however, the work that has been done suggests that the aquifer is highly transmissive with estimated transmissivity values ranging from 270 to 2434 m^2/day. An average value for the aquifer appears to be about 500 m^2/day with an estimated storage coefficient of 4×10^{-3}. It is likely that this high transmissivity is associated with the faulting and the secondary fracturing in the area and the storage coefficient is representative of a confined aquifer system.

2.5.2 Groundwater Levels

Groundwater levels in the Parakai area have been continuously recorded in ARC monitoring bores since the late 1970's in the deep geothermal production zone, and also in a shallower geothermal bore (Bore 87 Tideda site 6464009) since the mid 1980's (Figure 5). Two different deep geothermal bores have been monitored - Bore 25 (Tideda site 6464001) from 1978 to 1988, and Bore 86 (Tideda site 6464007) from

Figure 4



BORE PRODUCTION TEMPERATURES

Temperature (C) from borehole observations

1984 to the present day. However, by correlating these two records for the overlapping period (r^2=0.91), the data for the current site can be extrapolated back to 1978 to provide a coherent record for the aquifer. In addition to this data, intermittent measurements have been made on local bores since 1968 which provides information on the extent and shape of the water level surface.

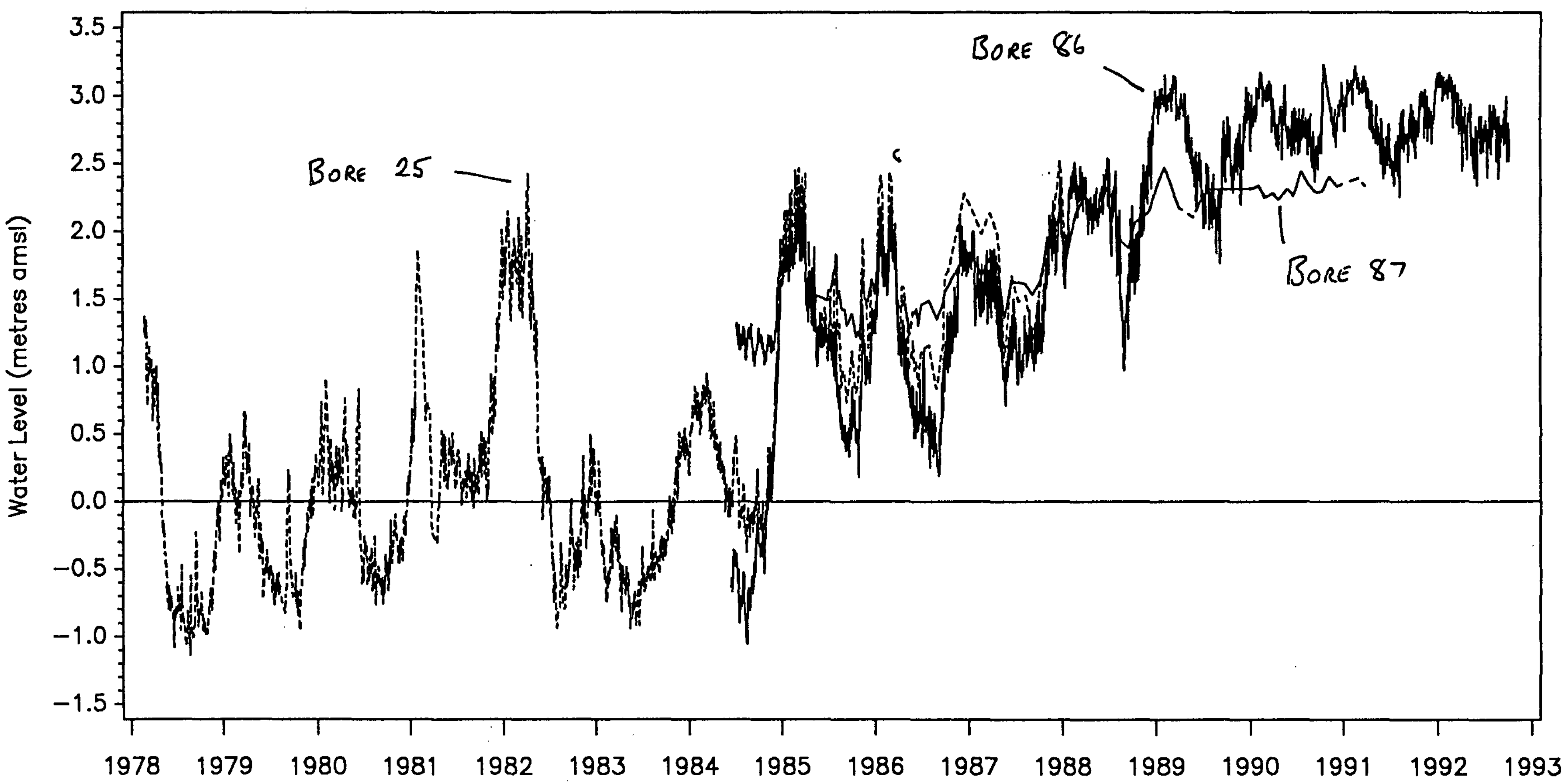
Water level fluctuations over time in the geothermal aquifer show two distinct features. The first of these is an annual fluctuation which has been up to 3 metres in 1982 and 1985, but which has stabilised over the past few years at about 0.6 metres. Clearly, the pattern of annual fluctuations has changed since the late 1970's and early 1980's with water levels fluctuating wildly in the earlier period, but becoming more regular in recent years.

The annual fluctuations observed at Parakai contrast to those observed in the cold, non geothermal groundwater systems in the Auckland region in that the maximum water levels in the geothermal aquifer at Parakai occur during the summer with minimums in the winter. Water levels in groundwater systems react to external influences such as rainfall (which is generally at a maximum in winter) and abstraction (which is generally greater in the summer due to crop irrigation requirements). Consequently, cold, non-geothermal groundwater systems that are predominantly utilised for summer irrigation have water level lows during summer, when the use is high and recharge is at a minimum, and reach their maximum levels in the winter during the period of low use and highest recharge. In the geothermal systems however, where the water is predominantly used for pool heating, greater abstraction occurs during the winter months causing the reversal of the annual fluctuations.

The second major feature seen in the water level fluctuations in the Parakai geothermal aquifer is the increase in aquifer water levels that has occurred since the late 1970's to the present day. At the commencement of the continuous water level monitoring record, water levels in the aquifer were generally below sea level, with a minimum of one metre below sea level being reached. Since that time, the levels in the aquifer have generally recovered to be at about 2.8 metres above sea level in the ARC monitoring bore No 86 (which lies to the edge of the geothermal field). This increase in water levels has resulted in a number of the local production bores near the centre of the field to artesian.

The elevation of bores and the results of 1992 water level surveys are presented in Appendix B. The recovery of the geothermal aquifer as a whole since the late 1970's is shown by the difference in the aquifer piezometric surface from September 1979 to September 1992 (Figure 6). While a number of bores in the centre of the field could not be accurately measured in 1992 due to artesian flows, it is clear that the aquifer has shown a significant increase in water levels of up to three metres in the centre of the field, and up to two metres towards the margins of the field. This increase in groundwater level is thought to be the aquifer response to declining water usage over the past thirteen years.

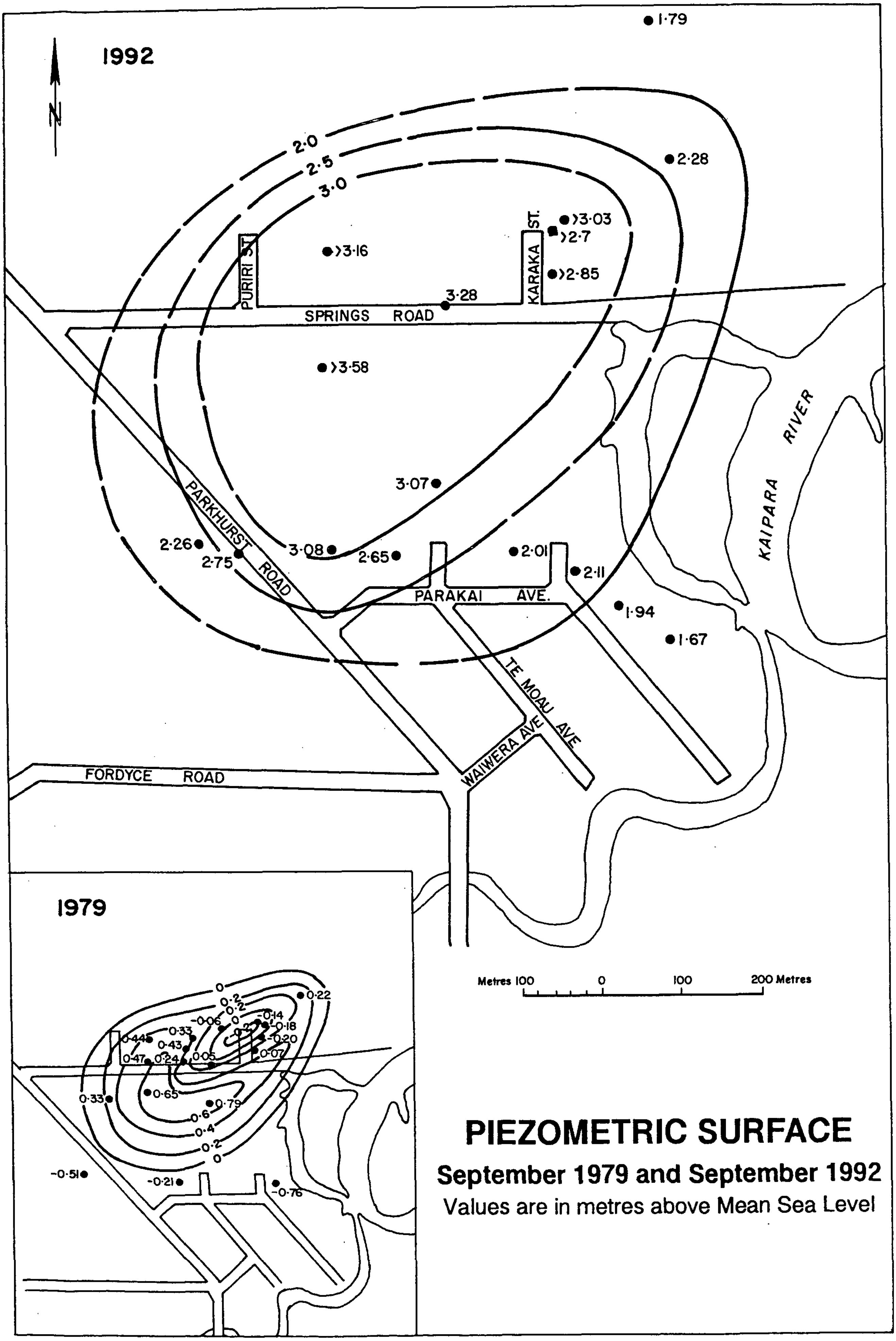
Figure 5



PARAKAI GEOTHERMAL GROUNDWATER STUDY

Geothermal Groundwater Levels

Figure 6



PIEZOMETRIC SURFACE

September 1979 and September 1992

Values are in metres above Mean Sea Level

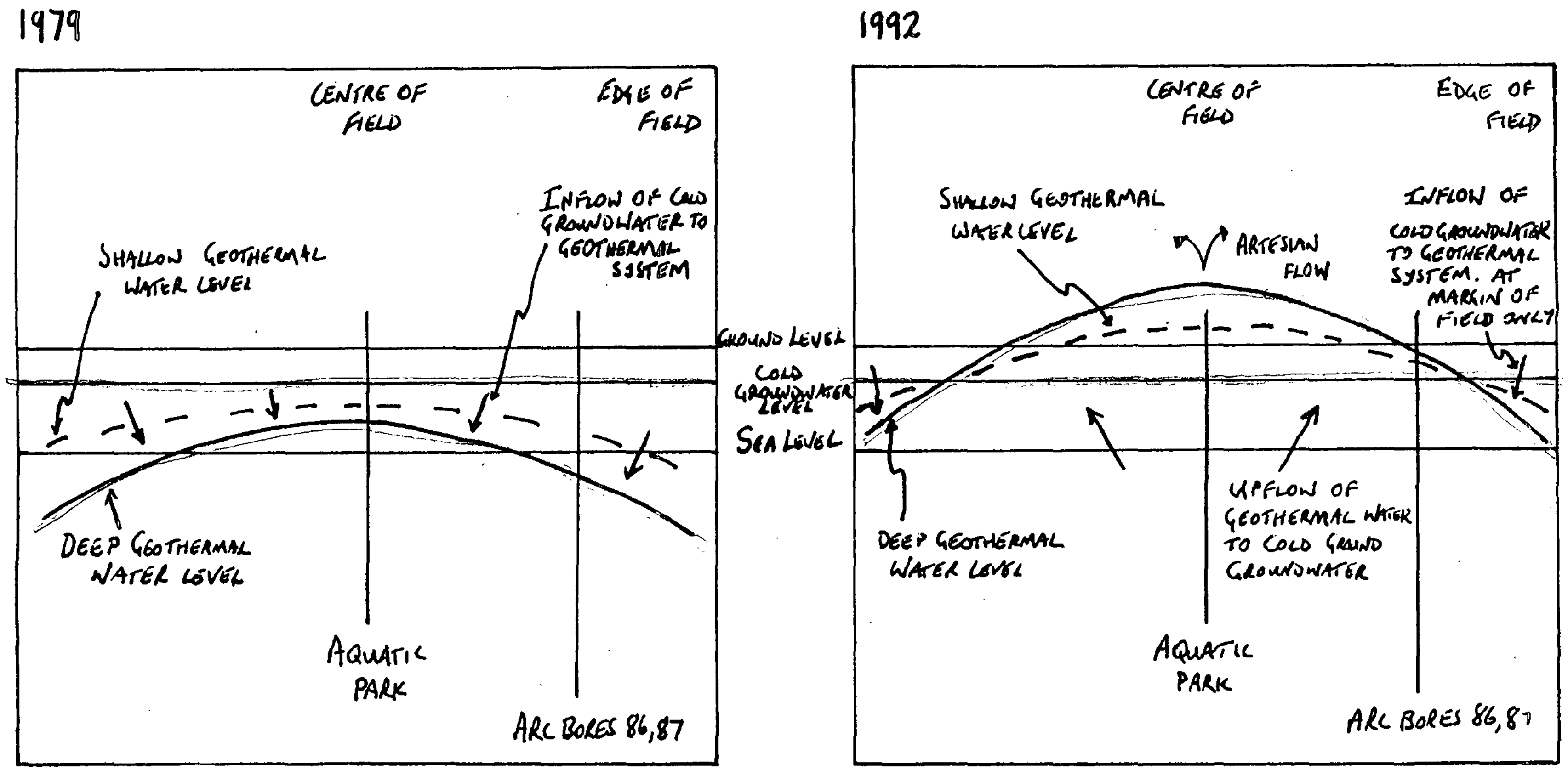
In addition to the recovery of the deep geothermal aquifer, levels in the shallower monitoring bore, ARC bore No 87, have also showed a gradual increase since 1984 - but at a lesser rate than that of the deep bore. The relationship between bore 87 and the rest of the geothermal field is unclear. While bore 87 is at a similar depth to some of the most utilised production bores, it shows only a small correlation with the water level changes in the geothermal aquifer as indicated by the deeper monitoring bore No 86. This suggests that Bore 87 is affected by a lateral change in the properties of the aquifer and does not respond rapidly to changes in the production zone of the aquifer. However, Bore 87 provides useful information on the vertical hydraulic gradient, and hence vertical movement of groundwater, within the geothermal aquifer system.

When water levels in the shallow bore No 87 are higher than those in the deep bore No 86, as occurred from 1985 to 1989, there is downward hydraulic gradient in the aquifer system and downward flow will occur from the cold, non geothermal system to the geothermal aquifer. When the water levels in bore No 87 are lower than those in bore No 86 (as has been the case since 1989), this indicates that there is an upward hydraulic gradient and therefore upward flow is occurring from the geothermal aquifer to the cold non-geothermal groundwater system. The relationship between the cold and geothermal groundwater levels in 1979 and 1992 is presented in Figure 7.

The relationship between the geothermal and cold, non-geothermal groundwater levels has important implications on the geothermal aquifer response to abstraction. If abstraction rates are such that water levels in the geothermal aquifer are maintained higher than those of the cold, non-geothermal groundwater, geothermal water will recharge the shallow, cold, non-geothermal groundwater system. However, if water levels in the geothermal aquifer are allowed to drop significantly below those of the cold, non-geothermal groundwater, cold water will move into the geothermal system causing possible temperature declines at the margins of the field.

At the margins of the field, some cold, non-geothermal water inflow is already occurring as indicated by the water chemistry results. This occurs because the water level of the geothermal aquifer at the edge of the field is naturally lower than the water levels of the surrounding cold, non-geothermal groundwater which was approximately 1.5m above mean sea level in the 1979 survey.

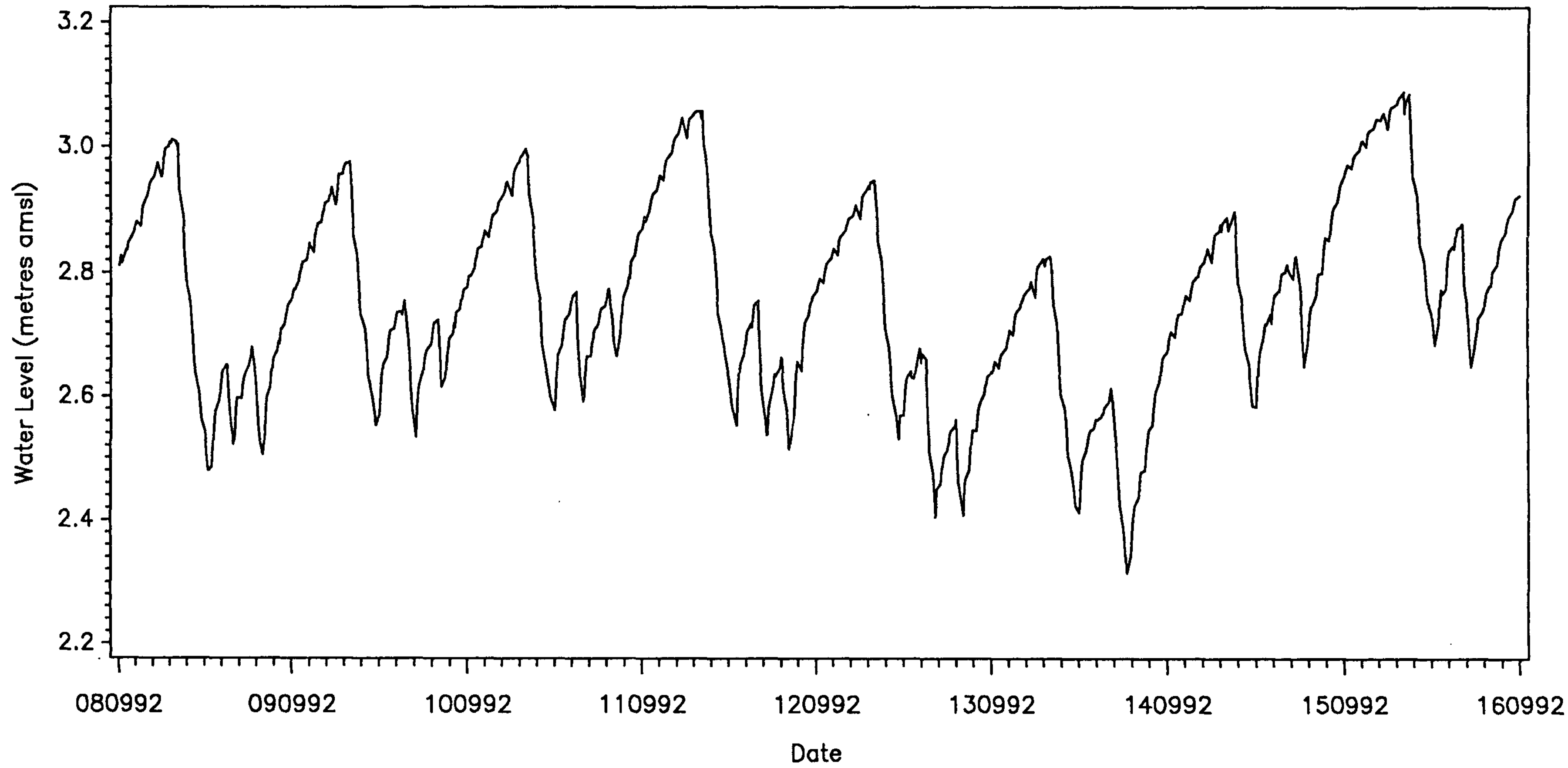
At a detailed scale, effects of pumping by Aquatic Park can be seen in the monitoring bore record (Figure 8). Information from the operators of the Aquatic Park bore indicate that their normal operating routine is to switch the bore on at about 8:00 am and pump for about four hours before switching off. The bore is then used again late in the afternoon to maintain pool temperatures as required. The effects of these abstractions are clearly identifiable in the monitoring bore record which shows regular drawdown and recovery curves in accordance with the Aquatic Park pumping regime.



PARAKAI GEOTHERMAL GROUNDWATER STUDY

RELATIONSHIP BETWEEN COLD AND GEOTHERMAL GROUNDWATER LEVELS

Figure 8



PARAKAI GEOTHERMAL GROUNDWATER STUDY

Aquifer Response to Aquatic Park Pumping

The effect of other water users on the aquifer water levels is also apparent in the plot. A decline in the water levels, over the 11, 12 and 13th September 1992, is superimposed on the drawdown and recovery pattern. These days correspond to a Friday, Saturday and Sunday when the remainder of the use is at a peak and therefore, while individual effects of the other users cannot be identified, the total effect of this extra weekend use is to lower the overall aquifer water levels.

2.6 Conceptual Model of the Aquifer System

As with the two other major geothermal fields in the Auckland area (Waiwera and Whitford), the source of the geothermal fluid at Parakai is probably groundwater - originating as rainfall on surrounding hills - that percolates down to depth in the greywacke basement rock, and is heated by the Earth's natural geothermal gradient while acquiring its characteristic chemical composition. The heated water then rises due to increased buoyancy through a fault or fracture system to the Waitemata sandstone and overlying alluvium which forms the geothermal aquifer. An impermeable capping layer overlies the system and artesian flows occur from bores where water levels are higher than ground level.

Temperature, resistivity, water level and water chemistry data delineate a low temperature (up to 65^{o}C) geothermal field centred on the Aquatic Park bore and elongated to the north-east suggesting that the orientation of the field is possibly fault controlled and that there is an outflow of geothermal fluid in this direction.

The aquifer is highly transmissive which is due to secondary permeability from faulting and fracturing suggesting that the ARC monitoring bore 86 rapidly responds to geothermal water use.

3.0 GEOTHERMAL GROUNDWATER USE

3.1 Introduction

Geothermal water in Parakai is mainly used for recreational purposes, i.e. swimming pools. The quality of the water makes it unsuitable for potable water supply. Rodney District Council (RDC) has provided a reticulated potable supply from reservoirs on the hill behind Helensville, fed from dams and a springfed stream.

The exploitation of Parakai groundwater has been piecemeal with over 90 bores being drilled, almost all of these were for geothermal groundwater supply. The location of bores at Parakai is shown in Figure 2. This Figure continues the same numbering system used in earlier reports. Bores 1-59 were located by Healy (1955), bores 60-79 were located from 1975 to 1979 and bores 79 onwards have been drilled or identified since 1979. Due to the small scales used on the original maps and the unknown accuracy of the plotting, it is possible that there may have been some duplication (e.g. bore 61 may be the same as bore 32). The bores are listed in Appendix A in ARWB (1987 p67).

Very few drillers bore logs exist for Parakai bores and the bore depths are generally not documented. Where known the depths vary from 25m near the centre of the field to 270m at the edge of the field. Many abandoned bores have been filled in by the Parakai Water Users Committee.

The main users of geothermal groundwater are the three public pool complexes: Aquatic Park, Palm Springs and Parkhurst Corporation. Other major users are the four motels: Parakai-Hinemoa Motels Ltd., Moturemu Lodge Motel (N. & E. Olsen), Craigwell House Ltd. and Mineral Park Motel (K. & A. Douglas). Use by some farms for stockwater and in some private pools has been large in the past, although their allocations are small, because users have not monitored their use and have exceeded their allocations. Water permit applicants are listed in Table 1.

The main issues related to the use of the Parakai geothermal field are:

- production and disused bores that are flowing artesian with hot water running to waste

- non-compliance with water permit conditions

- thermally inefficient use of hot water by pool operators

- use of warm geothermal water for stockwatering

- disposal of waste geothermal water

Table 1

WATER PERMIT APPLICATIONS

Name	Application No.	Bore No.	Previous Allocation (m^3/day)	Quantity Applied For (m^3/day)
Commercial Users				
Aquatic Parks NZ Ltd.	4856	66	309	308
GA Phillips (Palm Springs)	4695	69	110	150
Parkhurst Corporation Ltd.	7120	31	85	85
Craigwell House Ltd.	4977	71	16	20
Parakai - Himemoa Motels Ltd.	4933	62	22	30
K & A Douglas (Mineral Park Motel)	4830	85	15	15
N & E Olsen (Moturemu Lodge Motel)	7119	37	19	19
A Gosling & G Oxton	4991	-	-	6
G Horwood	7101	25	-	20
C & R Draper	4698	37	2 Spa 5 Stock	20
Forrestwright Enterprises Ltd.	Pending	71	4	-
Private				
G & M Hoare	4682	70	2 spa 2 Stock	5
J McNab	8590	47	2 Spa	2
J McNab	8591	43	7 Stock	7
L. Cunningham	5527	53	2	2
A & C Pengelly	4934	62	2	2
R MacAlister	7144	76	2	2
AE Manson	4651	83	2	2
RH Ayers	4711	49	2	2
SJ Glander	4838	72	2	2
I & G Smith	5435	72	2	2
C & N Thomas	7121	90	2	2
FR Weaver	4693	57	2	2
H & D Cooper	6973	92	2	2

The 1987 Parakai Management Plan (ARWB 1987 p. 31) presented information on: pumping, reticulation systems, methods of measuring water use, water treatment, waste geothermal water disposal including reinjection, and comprehensive details of thermal conservation techniques and the dollar value of the hot water.

3.2 Artesian Bores

Water levels in the geothermal field respond dramatically to pumping by Aquatic Park's bore no. 66. Overnight, when Aquatic Park do not pump, water levels increase to the point where they stand above ground level in the NE sector of the field. Bore numbers 66, 62, 37, 53, 49 and 47 are flowing artesian overnight and in the morning until pumping by Aquatic Park reduces the water level again. Disused bores in this sector such as bore no. 33 also artesian with hot water flowing to waste. Allowing bores to artesian and hot water to flow to waste is an offence under the Auckland Regional Authority 1987 Water Bore Transitional Regional Plan (formerly a bylaw). One property owner was prosecuted by the ARC for such an offence and convicted.

3.3 Non Compliance With Water Permit Conditions

Conditions on water permits are few and simple. They require the grantee to:

- install and maintain a water meter (or, in the case of a few private users an electrical hour meter) in working condition
- read the meter daily and forward readings to the ARC within a fortnight of the elapse of each quarter
- ensure water use remains within the maximum and average daily allocations specified on the permit.

As of 1 January 1992 the following hot water users at Parakai were not complying with these conditions but have done so by March 1993. This lack of compliance has resulted in a major gap in the water use record, and insufficient supporting use data for some applications.

Palm Springs: 1992 - no meter and exceeding allocation; 1993 - meter fitted January 1992, and returns show use within allocation by December 1992.

Parkhurst Corporation: 1992 - power meter but no flow meter, 1993 - flow meter fitted June 1992 use within allocation.

Craigwell House: 1992 - meter fitted but no returns, 1993 - returns show use within allocation May-December 1992.

Draper: 1992 - no meter to measure total bore use, 1993 - meter fitted March 1993.

McNab: 1992 - no returns for two bores supplying stock and spa use, 1993 - returns for stock use October - December 1992.

Cunningham: 1992 - no meter, 1993 - hour meter fitted.

Pengelly: 1992 - meter not working, 1993 - meter repaired November 1992, returns for use December 1992 - March 1993.

Glander: 1992 - meter fitted but not returns, 1993 meter returns in.

The water use information obtained from users is important in ensuring that no-one is using more than their allocated fair share of the resource, and in enabling the ARC to provide a more accurate estimate of the total quantity of hot water that is available for allocation amongst all users.

3.4 Thermally Inefficient Use of Hot Water

A preliminary study of thermal efficiency was initiated by the ARWB in 1982 and conducted by staff of the Ministry of Works and Development (MWD) Hamilton. Their findings were reported in May 1983 (Shannon and Birch 1983).

Proven effective conservation techniques include:

- avoid use of large uninsulated degassing tanks where water can loose heat.
- avoid long or uninsulated pipe runs from bore to pool complex.
- joint reticulation of several uses from one well constructed bore, particularly in the case of small private users.
- insulate all pipework, water treatment and filtration systems with low thermal conductivity material protected against moisture.
- good pool design with outlets well away from hot water inlets, and cascading water from smallest pool into larger pool before being recycled or discharged.
- ensure discharge temperature is no hotter than the coolest pool.
- part draining and refilling tepid pools in the morning to heat them up is much more efficient than a continuous through flow overnight.
- time-switches and thermo-stats to avoid unnecessary overheating of pools in periods of low use.

- use of pool covers, building enclosures, and screen like fences rather than solid walls to reduce heat loss due to the cooling effect on wind, particularly on the hottest pools.

- regular daily reading of meters to monitor use and check for leaks and equipment failure.

Thermal inefficiencies that still occurred in 1992 include: very long pipe runs to Moturemu Lodge Motel and Parkhurst Corporation, large degassing and storage tanks where hot water loses heat at Parkhurst Corporation and Palm Springs, and continuous throughflow of hot water overnight at Palm Springs. Users should work toward eliminating such inefficiencies.

3.5 Use of Geothermal Water for Stockwatering Use

A survey of the source of farm stockwater in the Parakai area has been completed. At present three farms use geothermal water (over 30°C) from bores for stockwatering:

- G. Hoare west of Parkhurst Road, bore no. 70.

- R. & C. Draper ex Keane Farms Ltd. north of Springs Road, bore no. 37.

- J. & S. McNab ex Holloway northwest of Karaka Street, bore no. 43.

The two farms immediately to the NW of Parakai but south of Green Road (D. Shepherd and A. & S. Osbourne) have shallow cold water wells. The farms to the west of G. Hoare and south to Fordyce Road (A. McKnight, C. & M. Marr, A. & A. Hargreaves and T. & D. Hallam) all use town supply for stockwater. The farms south of Fordyce Road use either town supply (N. Baker and M. Hill and S. Williams) or cold borewater (K. Graham) for stockwater.

Rodney District Council do not have any policy at present of not supplying potable municipal water to farms for stockwatering. Any application to RDC for this purpose as an alternative to geothermal groundwater would probably be given favourable consideration by Council. However, municipal supply costs in excess of $2/m^3 and this is likely to be a disincentive to farms ceasing use of geothermal groundwater and changing to municipal supply.

The use of shallow cold water wells by farms in the vicinity of Green Road suggests that such wells may be a viable alternative to deep geothermal bores. They would be inexpensive to construct and yield acceptable quality water. The ARC has had chemical analyses completed on the water from two such wells. The results show that the water was of suitable quality for stock use.

3.6 Discharge of Geothermal Water

Section 15 of the Resource Management Act states that no person may discharge any "contaminant" into water, or onto or into land where the contaminant may enter water - unless the discharge is allowed by a regional plan or resource consent (water permit). A contaminant includes any substance that is likely to change the physical, chemical or biological condition of the water.

Pool complexes at Parakai dispose of their waste geothermal water into large open stormwater drains which discharge into the Kaipara River. These are illustrated in Figure 6 in the 1980 Parakai Water Resource Survey (ARWB 1980 p20). Disposal to the RDC sewerage system is not permitted although a small proportion may get in through infiltration and cracked or broken pipes.

The impact of the unauthorised discharges on the Kaipara River environment is not known. One concern would be the effect of the chemicals which are added to treat the pool water. Staff of ARC Environment will need to investigate the impact of these discharges and discuss them with users and Rodney District Council with a view to either seeking discharge water permit applications where there are significant impacts or possibly authorising discharges with minor impacts under a provision of a Regional Plan. The Department of Conservation also has responsibility for the "Coastal Marine Area", below mean high water springs.

3.7 Water Meters

In order to more accurately relate changes in temperature, chemical composition and aquifer water level to water use, most previous water permits required that a flow meter be installed on bores, be read daily, and water use records be kept and submitted quarterly to the ARC.

A water flow meter is the only accurate method of measuring water use. Trials by the ARC and users showed that the Kent Helix 3000 would withstand the corrosive nature and high temperatures of the geothermal water. Correct installation is important. Guide-lines for ordering and fitting water meters are presented in Appendix C.

Some users at Parakai have electrical hour meters to calculate water use, by multiplying pumping hours by pumping rate (m3/hour). To be reliable this method requires the pumping rate to be calibrated by the user at regular intervals. In no case has this been done. Hour meters are not as accurate as flow meters because the pumping rate can vary with changes in water level and back pressure. Private users with individual supplies may use hours meters. All other users were required to fit flow meters as condition of their permit granted in 1987.

As noted in Section 3.3 above, several users with large allocations and use did not fit water flow meters until 1992. Palm Springs fitted a flow meter in January 1992. Hour meter readings are available from 1985 to 1988 but there are no concurrent flow meter readings or accurate pump calibration to allow accurate conversion of hour to use figures. Parkhurst Corporation fitted a flow meter in June 1992 and overlap of power and flow meter records allow an accurate calibration of previous records. Aquatic Park and the four motels have use records since 1985.

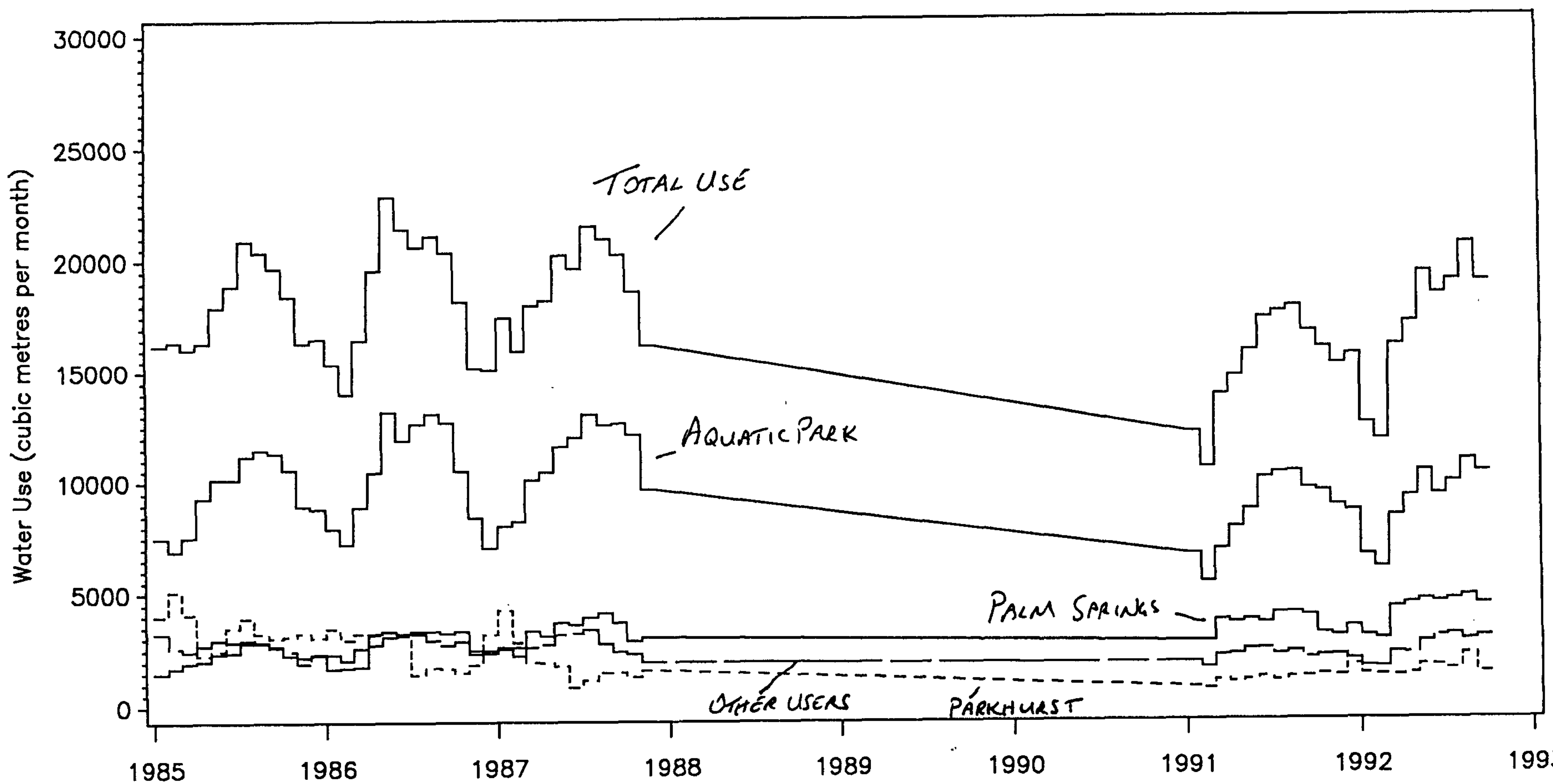
3.8 Groundwater Quantities Used

Groundwater use returns have been submitted by some users prior to 1985, but coherent returns from the major users (public pools and motels), which account for approximately 95% of the resource abstraction, are only available since 1985. However, the water use record since 1985 is also incomplete as some of the large users have not consistently provided use returns. Where possible, small gaps in the records have been filled by interpolating between known readings and by estimating individual user's water use from previous data. Unfortunately, large gaps in a number of use returns, combined with an apparent change in use patterns, has meant that the data for 1988 to 1991 cannot be synthesized.

Generally, water use returns are in the form of water meter readings but historically, hour meter and sometimes kilowatt hour meter readings have been taken. These latter readings have been converted to water use by calibrating the hour meters against flow meters, or by measuring the volume of water that equates to a certain time or power use.

The total monthly water use is shown in Figure 9, together with the use from the large users. On average Aquatic Park accounts for some 55% of the use from the geothermal field, Palm Springs accounts for 18%, Parkhurst Corporation uses about 12%, and the remainder of the users account for 15% of the total use. As a result, the total use for the field is dominated by the use of Aquatic Park.

As can be seen from the graph the water use shows a strong seasonality, ie there is significantly more water used in winter than in summer with a maximum use of 22847m^3/month (737m^3day) in May 1986, and a minimum use of 10553m^3/month (377m^3/day) in February 1991. These seasonal variations in water use closely follow those of Aquatic Park, who presumably utilise more water in the winter to maintain hotter pool temperatures in the cooler ambient air temperatures.



PARAKAI GEOTHERMAL GROUNDWATER STUDY

Water Use

Figure 9

Total water use over the 1985-1993 period has generally decreased due to the reduction in use by Aquatic Park and Parkhurst Corporation, with Palm Springs' use increasing and the remainder of the use staying fairly constant. Average daily uses from the system over this period were:

1985	-	587 m^3/day
1986	-	603 m^3/day
1987	-	614 m^3/day
1991	-	502 m^3/day
1992	-	564 m^3/day

This usage is significantly lower than for the years prior to 1980 estimated in the 1981 "Parakai Water Resource Survey" (ARWB 1981). In that report it was estimated that water use was about 300 m^3/day in the 1930's and 40's, 600 m^3/day in the 1950's and early 1960's, and peaking as high as 1650 m^3/day for periods of up to several years in the late 1960's and 1970's.

Clearly, the Parakai geothermal resource has been subjected to a variety of abstraction rates over the past fifty years, but in the last eight years has remained relatively constant at about 500 - 620 m^3/day. This current level of use is generally slightly lower than the current total allocation of 620 m^3/day, suggesting that the majority of users do not utilise their full allocations at this time. When considering the effects of geothermal water abstraction on the aquifer, it is important to consider the total allocation as this represents the total potential use, rather than just current usage levels.

4.0 WATER AVAILABILITY

4.1 Introduction

The basis for water allocation and management of the geothermal field is the quantity of water which can be safely abstracted from the field without adversely affecting it, i.e. the sustainable yield.

In the ARWB 1981 Management Plan for the Parakai geothermal field, the safe yield of the resource was considered to be the condition where the volume extracted from the resource creates a pressure in the geothermal field which is equal to the pressure of the surrounding cold non-geothermal waters. It was determined that this equal pressure corresponded to a geo-thermal water level of 1.7 to 2.2m above mean sea level (msl), with presumably 1.7m above msl at the margin of the field. It was predicted that a usage of 570m^3/day would achieve this geothermal water level.

In the ARWB 1983 Management Plan it was considered that, if the construction and maintenance of bores in the area provided an adequate seal against cold water leaking to the geothermal water, then the need for such a high geothermal water level might be partially removed. However, it was concluded that there was still a need to exclude saltwater intrusion by maintaining the geothermal water level above sea level. On that basis a slightly lower geothermal water level of 0.7 to 1.7m above msl (winter/summer), as measured in the then monitoring bore no. 25, was accepted. This corresponded to an average daily abstraction of 660 m^3/day. Only 620 m^3/day was granted in water permits.

In the 1987 Management Plan it was decided to continue maintaining geothermal water levels above sea level rather than above the cold non-geothermal water levels. The desired geothermal water level equated to a minimum level of 0.5m above msl in the new ARC monitoring bore no. 86. Comparison of metered water use since 1985 with water levels suggested that the minimum water level corresponded to a maximum usage of 700 m^3/day. Due to the seasonal fluctuations in use from summer to winter, no more than an average 620m^3/day was available for allocation.

The investigations since 1987 have shown that the principle established in 1981, of maintaining the geothermal water pressure greater than that of cold groundwater, has a better basis than maintaining the pressure greater than surrounding seawater.

4.2 Correlations between Water Use and Aquifer Water Levels

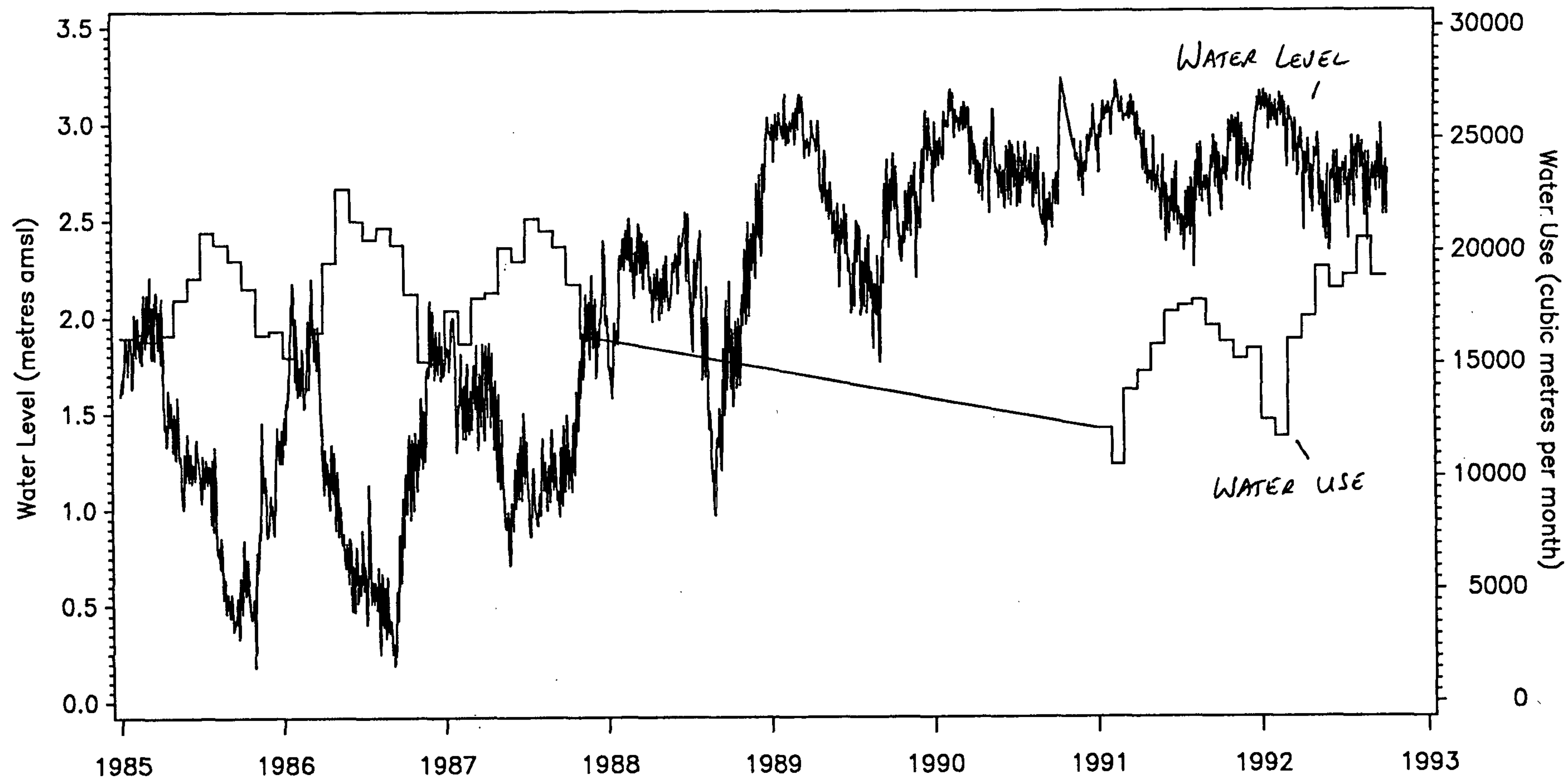
It is apparent that the water levels in the Parakai geothermal aquifer respond to fluctuations in use. This relationship is shown in Figure 10 for the period from the start of 1985 to the end of 1988. There is a clear negative correlation between the use and aquifer water levels, that is, when the use is high during the winter and large volumes of water are being taken from the aquifer, the water levels are reduced accordingly. Conversely, when the use is reduced during the summer, the aquifer recovers to reach its maximum levels.

To determine the relationship between aquifer use and water levels, a series of statistical models that relate water levels to water use on a monthly basis were developed. Due to the gap in water use returns between 1987 and 1991, the periods from 1985 to the end of 1987 and from 1991 to the end of 1992 were treated separately. Generally, the models that were developed described the water levels as a combination of one or more of the current months groundwater use, antecedent use (that is, use from preceding months), total rainfall, and a time variable. Analyses on the effect of tidal influences on the aquifer water levels were conducted but these showed effectively no correlation and were not continued with.

From these models, a number of conclusions can be drawn. For both time periods, the groundwater use in any one month has the dominant effect on the water levels of that month - with antecedent use apparently playing a lesser role in determining aquifer water levels. This would be expected given the high transmissivity of the geothermal aquifer and the near immediate response of the monitoring bore to abstraction by Aquatic Park and the increased use on the weekends. The addition of a rainfall component to the model did not improve the correlation suggesting that fluctuations in rainfall have little effect on the aquifer water levels. The correlations between the use and water levels are not great with $R^2=0.63$ for 1985-1987, and $R^2=0.64$ for the 1991-1992 period if one month prior use is considered.

While the 1985-87 and the 1991-92 use data show a similar level of correlation with the observed water levels, it is clear that these correlations are significantly different and that the long term water level rise that is observed between 1985 and 1992 cannot solely be attributed to a decrease in use over this period. This is displayed in Figure 11 which shows the predicted water levels from the 1985-87 data and also from the 1991-92 data. As can be seen from this diagram, utilising the 1985-87 data to predict current water levels from current use results in significantly lower water levels than those which are observed. Similarly, the use of 1991-92 data to predict historical water levels results in somewhat higher water levels than were observed at the time.

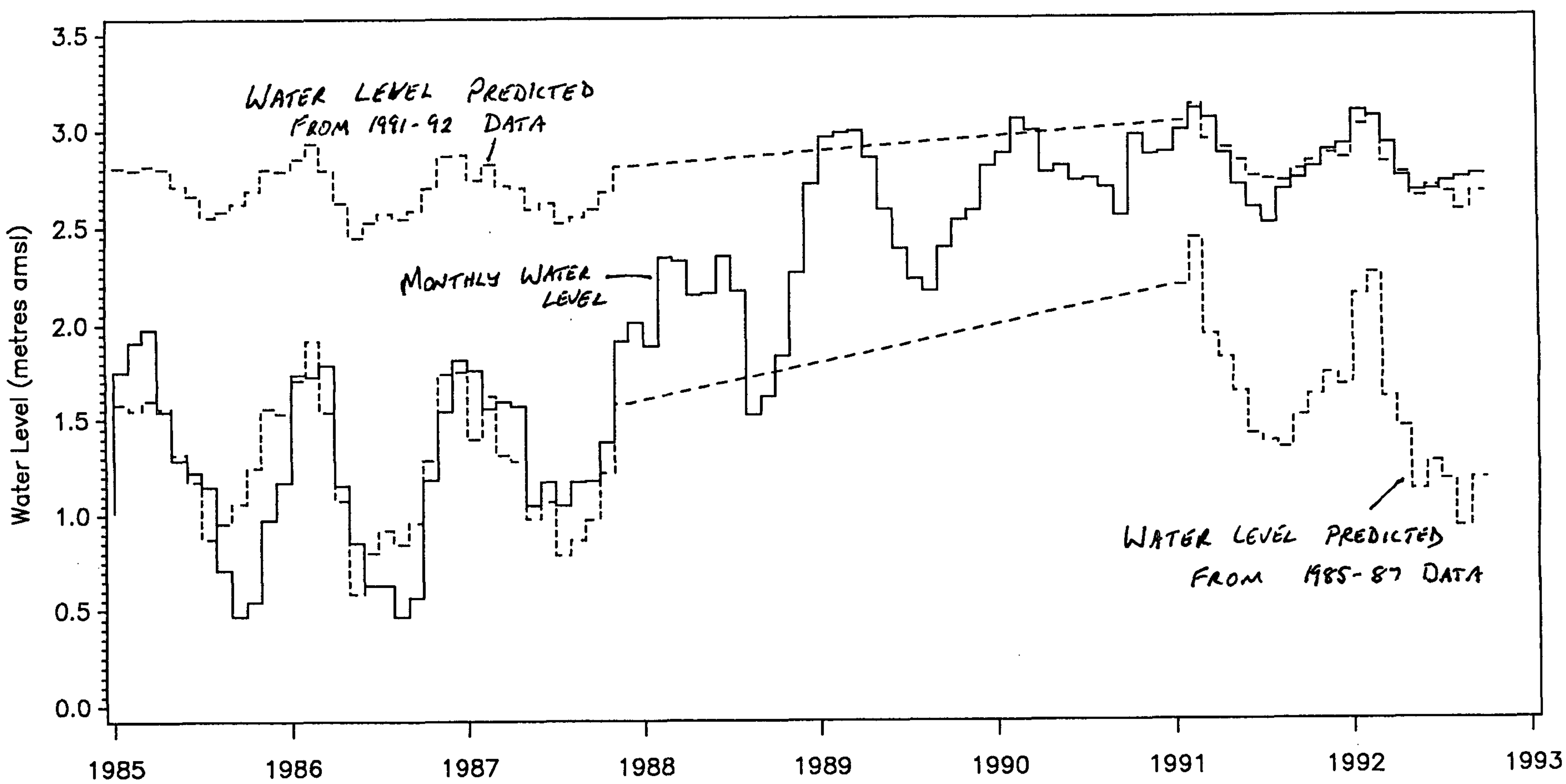
Figure 10



PARAKAI GEOTHERMAL GROUNDWATER STUDY

Water Use and Water Level Correlation

Figure 11



PARAKAI GEOTHERMAL GROUNDWATER STUDY

Water Level Predictions from 1985-87 and 1991-92 Data

To account for this discrepancy between the earlier and later data, a time component was included into the model. This component represents long term trends in the water levels that cannot be attributed to fluctuations in use. Fitting this model to the observed data results in a much higher correlation ($R^2 = 0.92$) over the entire period, indicating that this long term component is an important factor in predicting water levels in the geothermal aquifer. To investigate the cause of this trend in the water levels, the time component was replaced by rainfall to determine if rainfall fluctuations were the cause of the increase in water levels. While an improved fit to the observed data was obtained, it was only small, suggesting that rainfall fluctuations have only a minor influence on long term water levels.

A more likely explanation for the increase in water levels is that the aquifer system is still in a recovery phase from the substantial over-abstraction that occurred in the 1960's and early 1970's when water levels appear to have been significantly below sea level. Water levels in the system have continued to show a general increase since the start of the monitoring bore records in 1978.

Therefore, while the aquifer system shows a near immediate response to short term fluctuations in use, large scale changes in usage result in long term effects on the aquifer water levels. However, water levels have stayed at approximately the same level for the past four years suggesting that a new equilibrium may have been reached.

4.3 Present Estimate of Groundwater Availability

It is apparent that geothermal water abstraction is the dominant component in determining the water levels in the Parakai geothermal aquifer. As it has been demonstrated above, the aquifer responds rapidly to short term fluctuations in water use, but the effects of large scale changes in use can take a number of years to occur.

The amount of water available for abstraction from the Parakai geothermal aquifer is therefore dependent on the water level that is required to be maintained in the aquifer. The main threat to the Parakai aquifer appears to be the potential for coldwater inflow and a consequential lowering of the temperature of the geothermal resource if water levels in the aquifer are allowed to drop below those of the surrounding cold non-geothermal groundwater. These effects will be predominant at the marginal areas of the field where temperatures are already significantly lower than at the centre of the field. Bores at the centre of the field near the geothermal upflow are unlikely to be significantly affected unless serious over-abstraction occurs.

At current levels of usage, bores in the central area of the geothermal field are flowing artesian and at the moment, significant volumes of geothermal water are being discharged onto the ground and into drains. There are a number of management practises to control this waste of the geothermal resource including the addition of stand pipes to existing bores. However, there appears to be no management reason why aquifer water levels need to be maintained at such a high level. If increased abstraction from the aquifer is allowed, then aquifer water levels will decline, and the number of artesianing bores will be reduced. Those bores that remain flowing artesian however, should be sealed or have their casing extended to avoid unnecessary wastage of the geothermal resource.

The aim of increasing the abstraction from the aquifer is to increase the utilisation of the resource, but only to the extent where cold water inflow to the system is still minimal. For practical management of the resource, it is appropriate to set a desired level in the ARC monitoring bore No. 86 designed to achieve this aim.

From the analysis of the relationship between the shallow and deeper geothermal water levels, it has been shown that the water level in the shallow ARC monitoring bore No 87 presently lies at about 2.3 metres above mean sea level (msl). Therefore, the water level in the deep monitoring bore No 86 could be allowed to decrease to this level before cold water inflow will occur at this point. However, while the ARC bores lie toward the edge of the geothermal field, there are bores further out and it is therefore considered prudent to set the desired water level slightly higher, at 2.5 metres above msl. Maintaining this water level in the ARC monitoring bore No 86 in the deep geothermal aquifer should mean that the water level over the majority of the geothermal aquifer should remain above that of the cold, non-geothermal groundwater and hence minimise cold water inflow and the reduction of bore production temperatures (see Figure 7).

By utilising the correlation model developed previously, a level of 2.5 metres above msl in the ARC monitoring bore No 86 equates to a level of usage of approximately 700 m^3/day from the geothermal field. This rate is a yearly average rate, rather than a peak daily rate, and is 80 m^3/day higher than the availability determined in the 1987 management plan. However, since 1987, water levels in the aquifer have increased by over a metre.

In the 1987 Parakai allocation plan, peak daily abstraction rates were set at about 115 % of the average daily rate for any 3 consecutive month period and this appears to be a workable level. Therefore, it is recommended that 115 % be used again giving a peak daily rate of 800 m^3/day for the aquifer. At this level of use, water levels in the aquifer will go below 2.5 m above msl in the ARC monitoring bore No 86 , and possibly below the cold non-geothermal groundwater levels at some locations at the margins of the field. However, this will only occur over a short period of time and is unlikely to have any noticeable effect on the aquifer.

It is considered that the increase in water availability to 700 m^3/day is conservative given the recovery of the aquifer over the past few years, and it is possible that more geothermal water is available from the aquifer. However, the response of the aquifer to large increases in abstraction is difficult to predict given the long term aquifer response to abstraction changes that has been observed in the past. It is therefore recommended that the average abstraction rate be increased to 700 m^3/day with a peak daily rate of 800 m^3/day and maintained at this level for several years while temperatures and water levels in the geothermal field are monitored to assess the results of this change.

5. MANAGEMENT AND ALLOCATION POLICIES 1993

5.1 Introduction

This chapter presents the ARC policies for the management and allocation of the Parakai geothermal resource. As discussed previously in Section 1.2 of this report, the Resource Management Act 1991 (RMA) gives the ARC the responsibility of establishing and implementing policies and methods for the integrated and sustainable management of natural and physical resources including the Parakai Geothermal Resource. This includes controlling water levels and setting minimum water levels in water bodies such as the Parakai Geothermal Resource.

In achieving "sustainable management" of the Parakai geothermal resource and determining policy, Part II of RMA sets out several matters of particular relevance to Parakai, that the ARC must have regard to:

- Kaitiakitanga (exercise of guardianship by Tangata Whenua)
- Efficient use of resources
- Maintenance and enhancement of amenity values and the quality of the environment
- Finite characteristics of resource

The main issues relating to the management of the Parakai Geothermal Groundwater Resource are:

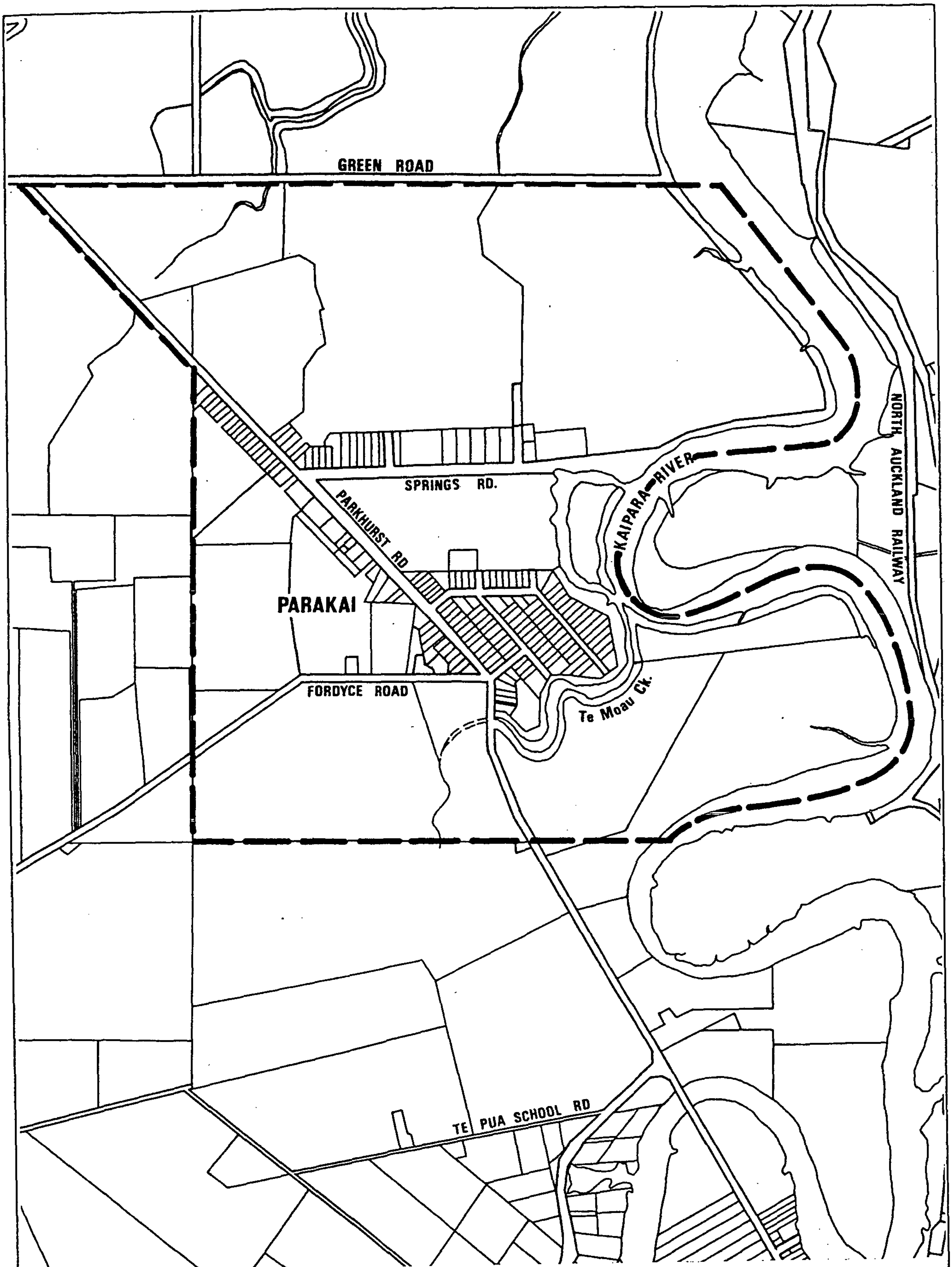
- Area to be covered by management plan
- Hot water availability based on long term sustainable use
- Priorities of use amongst potential and existing users
- How should allocations be determined for existing commercial and private pools, stockwater users, and proposed developments
- What should be done with any hot water, surplus to present demand
- What conditions should be placed on permits
- How should non-compliance with permit conditions be treated
- What ongoing monitoring and review of the geothermal field and its use is needed
- Conservation of the geothermal resource: artesianing bores and inefficient use
- How should geothermal water discharges be authorised

5.2 Management Plan Area of Coverage

Policy 1 Management Plan Area

That the Parakai Geothermal Groundwater Management Plan policies apply to all bores: - that lie within the study area as shown in Figure 12 of the management Plan report and - that intercept geothermal water (having a temperature of 30°C or more)

Figure 12



LOCATION OF MANAGEMENT PLAN AREA

The Resource Management Act 1991 defines geothermal water as water heated within the earth by natural phenomena to a temperature of 30°C Celsius or more. Some bores on the edge of the field may have a "down-hole" temperature of 30°C or more but yield water of less than 30°C because the water cools as it is slowly pumped to the surface. Use of such bores never-the-less affects the geothermal field and any abstraction must be authorised by a water permit.

5.3 Hot water Availability

Policy 2 Hot Water Availability

That the total quantity of geothermal groundwater (greater than 30°C) available for sustainable abstraction over the entire Parakai Geothermal field is 700 m^3/day as an annual average and 800 m^3/day as a daily maximum.

The quantity of 700 m^3/day as an annual average abstraction should sustain a mean water level of 2.5m above mean sea level in the ARC deep monitoring bore no. 86. This in turn corresponds to a water level of approximately 1.5m above msl at the margins of the field as defined by water chemistry and production temperatures. This water level at the margin should reduce the potential for lateral and vertical cold groundwater intrusion which has been shown to reduce production temperatures.

At an average abstraction rate of 700m^3/day the water level in the vicinity of Springs Road, at the centre of the field, will still lie above ground level during the evening when Aquatic Park cease pumping. To require users to pump 24 hours/day, including evenings when there is no use of the pools, in order to maintain aquifer water levels below ground level would be an inefficient use of the valuable resource. Some other solution to the problem of artesianing bores is necessary.

A maximum total daily allocation is necessary so that water levels are not drawn down during winter months to the extent that the margins of the hot water field retreat and do not recover the following summer. Long term sustainable allocation is the criteria that is applied and some seasonal fluctuation is provided for.

The distribution of major abstraction points over the extent of the geothermal field has been considered. It is proposed at present that the total quantity of hot water available not be divided up between zones of the geothermal field eg. 50% allocated north of Springs Road and 50% south of Springs Road. At present the major abstraction is from near the centre of the field (Aquatic Park). Any applications that would substantially increase abstractions on the edge of the field must be considered on a case-by-case basis.

5.4 Priorities of Hot Water Use

Policy 3 Priorities of Use

> That in considering water permit applications to take geothermal water at Parakai, the order of priority shall be:
>
> * existing recreational and therapeutic bathing users
> * proposed recreational and therapeutic bathing uses
> * stockwatering users
>
> No allocations shall be made for showers, home heating, water heating, ablution facilities, glasshouse heating, and other non-bathing uses.

In the Transitional Auckland Regional Planning Scheme (ARA 1985) policy 7.15 states that:

"In determining the allocation of thermal waters, preference shall be given to those uses which are in the public interest and, once allocated, the waters shall be used efficiently".

The "public interest" is open to wide interpretation, and does not restrict the use of water to bathing pools.

Under Section 31 of the RMA, Rodney District Council (RDC) has responsibility for the establishment, implementation and review of objectives, policies and methods to achieve integrated management of the effects of the use, development or protection of land and associated natural and physical resources of the district. RDC has prepared a District Plan operative from 15 March 1993 to assist in this management (RDC 1993).

In this District Plan, most land in Parakai is zoned as either Residential 2, Rural 1 or Recreation 4. The Residential 2 zoning applies to parts of the larger urban Rodney communities in locations close to areas of high physical amenity (eg beaches and reserves), commercial, community and education facilities, and major transport routes. Higher intensity residential development is allowed as a discretionary activity on suitable sites. Residential 2 zoning is applied to parts of Orewa, Waiwera and Parakai. Some land (Lots 1,2 & 5 DP 66235) to the west of Parkhurst Road and presently in pastoral farming is zoned Residential 2.

The Rural 1 (rural general) zone applies to most of the inland rural parts of Rodney District. The purpose of the zone is to preserve the capacity of the land for food and other forms of primary production, and also to permit a wide range of activities compatible with, but not necessarily essential to productive land uses. Land north of the residential use on Springs Road is zoned Rural 1.

Land within the geothermal field then is zoned for Residential, Rural and Recreational uses. Therefore, in addition to existing use for bathing pools, there are several potential competing uses such as glasshouse heating for horticulture. There are several established plastichouse enterprises in nearby Fordyce Road.

The Rodney District Council "South West Rodney Draft District Strategy (Rodney District Council 1992 p68,77) proposes a strategy of "investment and planning to accommodate further urban settlement focussed on Helensville". "Recognising that much of Helensville's growth in the recent past reflects the low price of land and the low level of economic activity, further stimulative effects may need to be taken to encourage the release of further sections onto a depressed market. This should be accompanied by attention to the quality of urban form and opportunities for encouraging further local employment".

This strategy of Helensville urban growth is in line with goals expressed in the "Auckland Regional Development Strategy" (ARC 1990 p8) for the rural north, of continuing to promote rural towns for the retention and enhancement of social economic, productive, and administrative services to the surrounding localities.

Historically, the presence of geothermal water at Parakai had led to the development of therapeutic and bathing pools. The availability of geothermal water at Parakai has an important role to play in the promotion of Helensville as a focus for tourism and recreational purposes. The public perception of the geothermal water is that it has therapeutic benefits not offered by non-geothermal borewater or municipal supply water that has been heated by other than natural geothermal earth processes. There are many factors that may favour the growth of Parakai as part of the Helensville urban growth strategy.

There are good road and rail links to Auckland, with the possibility of passenger rail services. The setting of Helensville is not unlike Warkworth, with potential activities adjacent to the river and harbour. If sufficient accommodation is available, tourist coaches could stop overnight on their way north along provincial state highway 16. Recreational/tourist opportunities exist with the West Coast beaches, nearby forest, Muriwai gannet colony wildlife tours, boat excursions on the Kaipara harbour, the Mt Auckland walkway, and airfield with parachute jumps etc.

Opportunities exist elsewhere in the Auckland Region at Whitford and East Tamaki to utilise geothermal groundwater for purposes other than bathing pools in a rural environment and not associated with a rural urban centre. Therefore it is proposed that allocations be made only for existing and proposed recreational and therapeutic bathing uses at Parakai.

The demand for geothermal water is only a little less than that which is available for allocation. Therefore, uses such as showers, home heating, water heating, ablution facilities, glasshouse heating and other non-bathing purposes which can be catered for by RDC municipal supply or by alternative heating methods, should not be given geothermal water allocations. Warm water discharged from pool complexes at 30-40^{o}C may be reused for other purposes.

5.5 Allocation Strategy Options and Water Permits

Water permits granted under the Resource Management Act 1991 are a means of achieving a fair allocation of hot geothermal water amongst all existing and potential users.

As discussed in the Introduction Section 5.1 above, Part II of RMA sets out the matters that must be considered in determining policy and considering water permit applications.

Under Section 136 of the RMA a holder of a water permit to take geothermal water may transfer the whole or any part of the holder's interest in the permit to another person on another site if both sites are in the same geothermal field and the transfer has been approved by the ARC as the consent authority.

This then presents the opportunity for "tradeable" water permits, which was not possible under the previous Water and Soil Conservation Act. "Economic instruments" may therefore be used in managing and allocating water resources. Some of the options available for determining how water is allocated at Parakai are:

(i) Economic Instrument e.g. Auction

The total quantity of water available for allocation is still determined by the ARC. This quantity would be put up for auction, and each user or potential user could bid for the annual allocation they desire. The highest bid would determine the price of an allocation. Once purchased, allocations could be traded amongst users.

Key requirements for trade in water permits to be workable are(Fenemor 1991):

* a scarce resource where demand exceeds supply;
* detailed knowledge of the availability and dynamics of the water resource, so that constraints to trade are well defined; and
* the probability that the tradeable permits system leads to more efficient water management than a fully regulatory approach.

Although in 1987 demand exceeded supply, at present there is more hot water available than quantities applied for. If an auction were implemented pool operators that generate the greatest income per cubic metre may purchase more hot water than is needed to operate pools in a thermally efficient manner. Public pools that provide an important social amenity may be disadvantaged. Section 5 of RMA requires that people and communities be able to provide for their social and cultural as well as economic wellbeing. An auction system of determining allocations is not seen as feasible at present.

(ii) On the Basis of Pool Volumes

Allocations granted in 1984 were calculated by multiplying the volume of pools that each complex had in 1980 by a factor of 0.40 to give the average daily allocation in cubic metres. The factor of 0.40 was derived from the total daily water availability, estimated as 570m^3 in 1980, divided by the total volume of all Parakai pools of 1460 m^3.

However, by 1987 water use records showed that the water needs of the four motels was in excess of their allocations.

The reason for this is that the majority of heat loss occurs through the surface of the pools at Parakai. Therefore heat loss (the major factor in determining geothermal water use) is proportional to the surface area of the pool rather than its volume. In the case of the public pool complexes with large relatively deep pools the volume is approximately 1 to 1.4 times the pools surface area, whereas for the motel complexes, with smaller shallower pools, the volume is only 0.5 to 0.8 times the surface area.

Therefore under the 1984 allocations, although the motel complexes had pools with proportionally more surface area than the public pool complexes, and therefore could expect proportionally larger heat losses, they were not allocated proportionally more geothermal water.

(iii) On the Basis of Past Water Use

In 1987 allocations were based more on past water use than actual pool volumes. Aquatic Park, Palm Springs and Parkhurst Corporation were granted slightly reduced allocations and three of the motels (Mineral Park, Craigwell House and Moturemu Lodge) were granted increased allocations.

However since 1987 Craigwell House for example has experienced demand for use of pools that exceeded the number they were able to maintain in operation within their allocation. Some pools remain disused. Palm Springs have used hot water inefficiently running water through filters before entering the pools and allowing hot water to run into pools overnight. Parkhurst Corporation have used substantially less than their annual allocation because pools were only filled at weekends and no accurate metering of water use occurred. Therefore the amount of hot water needed to run a pool complex efficiently may be more or less than actual use in 1992.

(iv) <u>On the Basis of Thermally Efficient Use</u>

This basis for allocation recognises the need for efficient use of finite resources as required by Section 7 of RMA and is the preferred option. The amenity value of the variety of pool facilities present in Parakai must be recognised.

Under Policy 4 any allocations for replacement permits for existing facilities and new permits for proposed facilities will be no more than is sufficient for their needs provided that heat conservation techniques are practised. Pool sizes and periods that pools are at operating temperature should be reasonable in terms of the facility that they serve, and the numbers of people using the pools at different times of the day and week. Actual rates of heat loss both overnight and during the day can be measured, and water needs calculated. Use in excess of these calculated needs suggests inefficient pool operation.

Policy 4 Basis for Pool Allocations - Non Private Users

That geothermal groundwater allocations to all existing and proposed public pool, commercial pool and communally owned private pool facilities at Parakai shall be made on the basis at thermally efficient use and shall take into account:
- bore production temperature
- pool size
- reasonable desired pool temperatures
- hours of pool use
- the number of people using the pool at various times of the week and year
- heat loss during the day and overnight
- alternative methods of water reticulation and pool operation

Under Section 92 (2) of the Resource Management Act 1991 the ARC may require information on the applicants reasons for their chosen method of pool operation and quantity required. The ARC may postpone hearing of the application until the information is received.

Policy 5 Basis for Pool Allocations - private users

That geothermal groundwater average daily allocation to individually owned private pools at Parakai existing on 31 December 1992 shall be the pool volume rounded off to the nearest 0.5 m^3 unless the application is for less or the pool is jointly used, and with a minimum allocation of 2 m3/day, and a maximum allocation of 3 m^3/day.

That geothermal groundwater average daily allocation to individually owned proposed private pools at Parakai shall be 2 m^3.

In 1984, private users were granted an allocation according to the size of their pool, the larger the pool, the larger the allocation. This method led to the problem of a private user getting an allocation greater than a Motel complex, and is not equitable amongst private users. In 1987 all private users were allocated an equal quantity of 730 m^3/year. With the recovery of the geothermal field this quantity is increased with allocations up to 1095 m^3/year (3 m^3/day) for existing pools.

Each private user can decide on when and how that allocation is to be used. This quantity should be adequate for a small pool to be filled once per day as long as heat conservation methods are adopted. Alternatively the user may decide to fill a larger pool less often, or run hot water from a small spa pools or partitioned part of the large pool into the cooler body of the large pool.

Policy 6 Allocations Non-Bathing Users

That geothermal groundwater allocations at Parakai for non-bathing uses including stock watering be made on a case-by-case basis. The ARC will encourage and facilititateuse of stockwater sources other than hot geothermal groundwater.

No set criteria is proposed for deciding allocations for uses other than bathing pools. It is not necessary to use geothermal water for stockwatering. Other sources are available. However municipal supply costs in excess of $2/$m^3$ and this is a disincentive to ceasing use of hot bores. Shallow wells are known to produce acceptable quality water, and these may be a more feasible alternative. There is a cold water bore #89 on the McNab farm and ARC tests show this to be of acceptable quality.

Any allocations for stockwatering should, it possible, be based upon previous actual use figures. Only G Hoare has complied with the conditions of the permit which require metering of use and water use returns. However this bore #70 supplies both bathing pool and stock, so no figures for stock use only are available.

Policy 7 Deferral of Applications

That water permit applications for proposed thermally efficient pool facilities, both private and commercial, be accepted and considered concurrently with applications for existing facilities. Hearing of any water permit applications may be deferred pending application for any additional consents required. Proposed pool facilities will be assessed by the same criteria applied to existing pool facilities.

In the 1987 Management Plan, applications for new proposed pool facilities were accepted to gauge future demand, but deferred for consideration when the Plan expired in December 1992. Those deferred applications must now be considered. They must be assessed by the same criteria applied to existing pool facilities (see Policy 4 and 5 above), and therefore similar supporting information must be provided although heat loss must be estimated since there will be no actual water use data.

Under Section 91 of RMA the ARC may determine not to proceed with the hearing of an application if other resource consents (eg land use consents) are required for the proposal and will provide a better understanding of the nature of the proposal. If the underlying zoning in the operative Rodney District Plan is Rural then a proposed commercial motel or pool complex is classed as a discretionary activity (formerly a conditional use under the Town and Country Planning Act) and a Land Use Consent must be applied for and obtained.

Policy 8 Surplus Water

Any surplus quantity of geothermal water, in excess of the total quantity recommended to be granted for applications to hand, shall be kept in reserve for possible future allocation to other new uses e.g. new pools that may be part of existing facilities, to proposed new pool complexes and private users.

The quantity of hot water available for allocation is in excess of the total applied for. It is not proposed to grant, to existing users, allocations in excess of that requested in their present applications or in excess of the quantity of hot water needed to run present facilities in a thermally efficient manner, simply in order to "dispose" of the surplus. This would encourage inefficient use of the hot water. If existing users believe they can justify a quantity greater than that presently applied for, then they can apply for an increased quantity. The surplus hot water may be better utilised in unused or new pools forming part of existing pool complexes, or used in new pools in proposed pool complexes on other properties.

Under Section 104 of the RMA regarding matters to be considered when arriving at a decision on an application, the ARC must not take into account the effects of trade competition on trade competitors. Therefore water cannot be allocated to existing users simply in order to "shut out" other potential competitors.

Policy 9 Water Permit Conditions

That water permits to take geothermal groundwater at Parakai be subject to the following minimum special conditions.

1. That provision at the top of the bore for water level measurements shall be made and be maintained in accordance with the details outlined in this water permit (see Note 1).

2. That provision at the top of the bore for water quality sampling shall be made and be maintained in accordance with the details outlined in this water permit (see Note 2).

3a. (for all commercial users and all users who share bores with other users)

That the Grantee(s) shall install, within one month and maintain on the outlet of the pump a meter which shall measure the total daily quantity of water being taken. The water meter, its installation and maintenance, shall be in accordance with the details outlined in this water permit (see Note 3).

3b. (for private users with separate bores)

That the Grantee shall install, within one month, and maintain a meter which shall measure the total daily number of hours which their pump operates. The meter, its installation and maintenance shall be in accordance with details outlined in this water permit (see Note 3).

3c. (for private users with separate bores)

That, if required in writing by the Manager, Environmental Management Department, Auckland Regional Council, the Grantees shall install, within three months, and maintain on the outlet of the pump, a meter which shall measure the total daily quantity of water being taken. The water meter, its installation and maintenance, shall be in accordance with the details outlined in this water permit (see Note 3).

3d. (for private users with separate bores)

That the grantee shall calibrate the pumping rate to an accuracy of at least plus or minus 5% using the meter required under Condition 3b above at annual intervals. This calibration shall be submitted annually to the Manager, Environmental Management Department, Auckland Regional Council by 14 January.

4. That the Grantees shall read the meter required under Condition 3 above, at daily intervals (for allocations equal to or exceeding 20 m^3/day)/weekly intervals (for allocations less than 20 m^3/day) and keep records of each date and corresponding water meter reading. These records for the preceding 3 months shall be submitted quarterly to the Manager, Environment Management Department, Auckland Regional Council, with 14 days of the elapse of quarterly periods ending 31 March, 30 June, 30 September and 31 December.

5. That maximum production temperature, measures as close as practicable to the bore head, be recorded on a monthly basis by the Grantee(s) and that records of these temperature measurements be forwarded to the Manager, Environmental Management Department, Auckland Regional Council, in accordance with the timetable for water use records.

6. That any necessary permanent modifications to the bore head shall be made and maintained, as approved by the Manager, Environmental Management Department, Auckland Regional Council, to ensure that geothermal water from the bore does not flow to waste.

7. That, in addition to Standard Condition 2, the conditions of this permit may be reviewed by the consent authority in 1997 and subsequently at not less than five yearly intervals in order to vary the monitoring requirements or the quantity in the light of changed circumstances.

Note 1

Adequate provision must be made at the wellhead so that a probe can be lowered vertically into the bore between the riser tube and casing to measure the static water level in the bore. This can be achieved by having an access hole of at least 2 centimetres in diameter at the top of the bore. In order to keep our foreign matter, the hole should be fitted with an easily removed plug. The probe hole shall be maintained to the specified dimensions and in working order at all times.

Note 2

Adequate provision must be made at the wellhead so that a sample of water can be taken from the bore for water quality analysis. This can be achieved by fitting a tap or hand valve as close to the pump outlet as possible and before the water enters any storage tank or filter, and it should have approximately 0.3 metre clearance above ground level or other obstruction to allow a sample bottle to be filled. Provision for sampling shall be maintained to the specified dimensions and in working order at all times.

Note 3

The water/hour meter must be capable of measuring to an accuracy of at least plus or minus 5% and it is to display to at least 1 cubic metre/1 hour. There meter is to be installed to the manufacturer's specifications and to the satisfaction of the Manager, Environment Management Department, Auckland Regional Council, and shall be maintained to the specified requirements and in working condition at all times.

The reassessment of water availability (Policy 2) has shown the necessity for data on geothermal aquifer water levels, chemical composition, bore production temperatures and individual and total abstraction rates. Conditions are placed on water permits to facilitate the ARC's monitoring programme described under Policy 12 and to encourage maximum use of geothermal water before discharging it to waste. Water permits for the larger users may be subject to more stringent conditions e.g. daily water meter reading, and more frequent reviews.

Policy 10 Non-compliance with permit conditions

That, where non-compliance with water permit allocations and conditions persists and cannot be resolved reasonably, the ARC will pursue legal action against the offending water permit grantees as provided for in the Resource Management Act 1991.

The allocations and conditions placed on water permits are aimed at ensuring a sustained hot water resource for all to enjoy. Non-compliance with these will only result in the over-utilisation and degradation of the resource which will affect all users, including the offenders, and their investment related to that resource.

As of 1 January 1992 eight of the sixteen current users at Parakai, were not complying with the conditions of their permits. Major users did not even have meters fitted. Parakai geothermal water management continues to demand considerable input of ARC staff time, particularly non-compliance with permit conditions.

The Resource Management Act provides for a variety of legal remedies to non-compliance with permits. An Abatement Notice may be served under Section 322 on offenders by ARC officers requiring the person to do something (e.g. fit meter) or cease doing something (e.g. stop taking geothermal water) to comply with the RMA or a resource consent. An Enforcement Order may be issued by the Planning Tribunal under Section 319 to similar effect.

Policy 11 Geothermal Water Discharges

That the ARC Environmental Management Department shall investigate the issue of geothermal water discharges from pools in conjunction with the Department of Conservation and local users.

The impact of these unauthorised discharges on the environment is unknown. Staff of the ARC Environmental Management Department will need to investigate the impact of these discharges and discuss them with users and the Department of Conservation with a view to either seeking discharge water permit applications from users with significant impacts and possibly authorising users with minor impacts under a provision of a Regional Plan. The Department of Conservation also has responsibility for the "Coastal Marine Area" below mean high water springs.

5.6 Ongoing Monitoring and Review of Allocation and Management Plan

Policy 12 Ongoing Monitoring

The ARC Environmental Management Department shall continue to:

- measure geothermal aquifer water levels in its two monitoring bores no. 86 and 87 and a network of other bores which penetrate the geothermal aquifer.
- analyse the chemical composition of groundwater from long-term monitoring bores, representing the two types of geothermal groundwater found at Parakai.
- correlate bore production temperatures measured by users.

Ongoing monitoring is necessary to detect any significant changes in the geothermal aquifer as a response to management policies and to further understand the extent and character of the aquifer.

Water level records from the ARC monitoring bore are necessary because they are the basis of the allocation and are used to assess effects of different abstraction rates on water levels, and to determines the water level at which the aquifer should be maintained. Water chemistry is the only way of identifying changes in the degree of cold fresh groundwater intrusion at the edges of the geothermal field.

Policy 13 Plan Expiry Date

That Parakai Geothermal Groundwater Allocation and Management Plan 1993 shall expire on 31 December 1997. Prior to this date an assessment will be made of the effectiveness of this Plan.

In order to allow the effective review of this Management and Allocation Plan, it is important that an expiry date be set in accordance with the review date of the associated water permits. At this time the management policies and allocations can be reviewed in terms of the results of the on-going monitoring programme. If, at the end of 1997, it is considered that no change in this Management and Allocation Plan is required, the expiry date could be extended by the ARC for a further term.

5.7 Conservation of Geothermal Water Resource

Policy 14 Flowing artesian bores

That bore owners shall ensure that geothermal water from bores does not flow to waste. Bore owners shall make any necessary permanent modifications to the bore head as approved by the Manager Environmental Management Department, Auckland Regional Council, to ensure that bores are not flowing artesian.

Under the ARC Transitional Regional Plan (formerly the 'Auckland Regional Authority Water Bore Bylaw 1987') it is an offence for any person to allow water from a bore to flow to waste. Amber Transport and Building Removals Ltd were prosecuted by the ARA for this offence in 1988 and convicted.

Water levels in the geothermal field respond dramatically to pumping by Aquatic Park's bore no. 66. Overnight, when Aquatic Park do not pump, water levels increase to the point where they stand above ground level in the NE sector of the field. Bore numbers 66, 62, 37, 53, 49 and 47 are flowing artesian overnight and in the morning with water flowing to waste until pumping by Aquatic Park reduces the water level again. Disused bores in this sector such as bore no. 33 also artesian with hot water flowing to waste. Allowing hot water to flow to waste means that there is less hot water left in the aquifer to be pumped out by users during the day when it is needed.

To pump bores overnight would be an inefficient method of having pools hot in the morning and preventing bores from artesianing. Instead, owners of bores must modify bore heads to ensure that hot water does not flow to waste. Mineral Park Motel and Craigwell House have extended their bore casing to 1.8m above ground level. This is suitable for both electric submersible and surface suction pumps.

In consultation with the Waters Users Committee, bore owners will be notified in writing of a date when this bore modification work must be completed.

Policy 15 Heat Conservation Methods

That the Auckland Regional Council Environmental Management Department will require Parakai geothermal groundwater users to adopt heat conservation methods, and use allocations in a thermally efficient manner.

The allocations made to users should be sufficient for their purposes, provided that heat conservation measures are adopted. Examples of these measures are given in Section 3 of this report and in the 1987 Management Plan report. Those users who make the greatest efforts in this respect will be able to maintain their pools at higher temperatures for longer periods than those who do not.

Policy 16 Water Users Committee

That the Parakai geothermal water users Committee continue to act as the liaison between the Auckland Regional Council and the Parakai Geothermal Water Users.

The involvement of bore owners and users at Parakai in the management of the geothermal resource is beneficial to themselves and their financial investment in the resource. Users can discuss their problems with and make recommendations to ARC staff. Under the Resource Management Act the final decision on water permits must rest with the ARC.

Policy 17 Newsletter

That the ARC Environmental Management Department shall prepare a regular newsletter for Parakai water permit holders and other interested parties.

This newsletter will keep users up-to-date with the management of the geothermal field and will supplement the meetings of the Water Users Committee. The newsletter should contain the results of the monitoring programme, and the result of the water permit holders' returns of water use and bore production temperature. The newsletter will also be used to promote the use of heat conservation measures.

5.8 Conclusion

A detailed knowledge and understanding of the nature, and response to use, of the Parakai geothermal field, has enabled a comprehensive set of policies to be formulated which should ensure the future sustainable use of the resource for the benefit and enjoyment of the people of the Region.

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APPENDIX A

PARAKAI GEOTHERMAL GROUNDWATER CHEMICAL COMPOSITION TYPE

Table 1 - Unmixed geothermal water

Name	Bore No.	Date	Temp °C	Chloride	Sulphate	Total alkalinity	Boron	Fluoride	Silica	Calcium hardness	Magnesium hardness	pH	Ammonia	Nitrate
Nutsford & Knights	27	21/2/85	62.5	1010	5.0	56.1	15.0	2.16	70.0	117.5	2.5	7.93		
Nutsford & Knights	28	25/10/88	51	1030	14.0	(160.4)	12.5	1.68	57.4	280	0.8	10.9?		
Parkhurst Corp	31	1/12/87	59.8	1000	6.8	55.6	13.8	2.12	64.9	120	2.6	8.22		
Cooper (old)	34	14/3/89	49	1030	5.1	60.8	14.0	2.06	57.8	132.5	2.9	8.19	1.18	0.002
Draper/Olsen	37	1/12/87		1000	6.4	67.6	13.2	1.98	56.3	129	3.8	8.10		
McNab	43	3/12/92	36.0	1060	20.2	58.2	11.6	2.00	48.9	156.5	11.6	7.23		
McNab	47	14/3/89	51.0	1030	7.4	53.8	14.2	2.10	61.0	127.5	2.7	7.84	1.27	0.002
Ayres ex Reyland	49	29/1/86	40.5	1000	30.8	66.6	13.4	1.94	51.5	140	2.7	7.95	1.02	0.007
Cunningham	53	3/12/92	47.0	1025	3.2	57.0	11.7	1.96	49.5	147.5	6.3	7.77		
Mineral Park Motel	55	28/6/83	46.4	1036	4.3	56.6	14.4	2.06	55.6	124	3.8	7.78		0.002
Weaver	57	3/12/92	47.0	1020	4.8	55.5	14.3	2.06	57.3	131.5	5.7	7.74		
Hinemoa	62	1/12/87	59/8	1000	2.0	53.2	14.2	2.10	65.2	117	3.3	7.97		
Parkhurst Corp	65	20/8/79	33.0	974	57.4	79.5	13.7	2.02	62.2	158	5.4	8.21	0.090	0.835
Aquatic Park	66	8/3/93	65.5	990	6	54	13.5	2.40	61.7	121	2.4	7.9	1.30	0.001
Palm Springs	69	1/12/87	56.8	960	4.8	57.8	12.9	2.10	64.8	109	2.8	8.04		
Hoare	70	1/12/87	54.5	940	4.8	62.1	13.3	2.08	65.4	.107	3.3	8.02		
Craigwell House	71	14/3/89	58	980	5.4	59.0	13.2	2.10	65.0	113.5	3.1	7.97		
Mineral Park Motel	85	14/3/89	61.0	1030	5.5	53.5	13.9	2.16	66.0	122.5	2.6	7.95		

ARC monitoring bore	86	8/3/93	60.5	1060	5.6	55.5	13.6	2.28	61.9	124	2.6	8.0	1.31	0.002
ARC monitoring bore	87	3/3/93	48	1050	<1	55.4	11.6	2.14	34.4	135	4.9	8.0	1.01	0.005
McNab	89	3/3/93	23	1050	1.8	79.8	11.3	0.52	55.7	390	101	6.8	1.16	0.016
Cooper (new)	92	22/5/91	63.0	987	<1.0	54.8	12.7	1.95	54.6	120.0	3.6	8.06	1.45	0.004

APPENDIX A

PARAKAI GEOTHERMAL GROUNDWATER CHEMICAL COMPOSITION TYPE

Table 2 - Geothermal water mixed with cold non-geothermal water

Name	Bore No.	Date	Temp °C	Chloride	Sulphate	Total alkalinity	Boron	Fluoride	Silica	Calcium hardness	Magnesium hardness	pH	Ammonia	Nitrate
Glander ex (Cold)	59	3/3/93	40	320	2.1	194	4.7	1.58	45.3	44.0	17.3	7.80	0.474	0.009
Glander ex (hot)	72	29/1/86	43.1	272	0.9	196	6.2	1.35	43.9	48.0	9.8	7.91	0.28	0.004
Thomas	90	14/3/89	43.5	274	1.4	191.2	4.6	1.20	39.0	65.5	17.2	7.86		
Manson	83	8/3/93	26	640	<1	75.2	4.3	0.35	12.4	109	17.4	8.2	0.534	0.002
McDonald	91	8/3/93	26	760	<1	102	8.8	2.12	38.0	120	20.6	8.0	0.852	0.002
Aspden		10/10/84	17.5	964	<0.5	30.6	6.7	1.9	14.0	170	0.6	9.28	0.890	0.004
Van Iersel J ex Hurst Piggeries		3/3/93	22	700	<1	167	7.3	0.63	13.0	23.2	15.3	8.6	0.294	0.035
Graham K ex Quarrie		3/3/93	16	240	578	361	0.4	0.50	61.0	394	394	6.9	1.84	0.012
Horticultural Processors Ltd ex Kaipara Dairy Co		16/10/80	19.3	312	1.7	135		0.18	21.5	51	14.8	7.14	0.119	0.01
Shepherd (well)		3/3/93	16	131	481	39.8	0.25	0.30	54.2	290	183	6.8	0.276	1.80
Young (well)		3/3/93	16	270	871	451	0.38	0.36	59.8	572	680	7.2	1.20	0.02
Peacemaker (old)		8/3/93	20	132	<1	206	2.5	0.68	10.7	2.7	0.6	9.3	0.123	0.004
W Ellett		3/3/93	19	138	<1	80.9	6.1	1.84	17.7	6.7	<0.1	9.4	0.174	0.005

APPENDIX B - WATER LEVEL SURVEYS 1992

Name	Bore No.	Bore Elevation RL (m)	Water Level 18/9/92 Below Casing (m)	Water Level 18/9/92 RL (m)	Water Level 2/10/92 Below Casing (m)
Hinemoa	62	3.385[a]	Artesian	> 3.16	Artesian
Hinemoa	24	2.514	-	-	-
Parkhurst Corp.	31	3.325	0.050	3.28	0.065
Aquatic Park	66	2.850[b]	Artesian	> 3.58	Artesian
Palm Springs	69	3.223[c]	-	-	-
Parkhurst Corp.	65	2.595	-	-	-
Cunningham	53	2.849	Artesian	> 2.85	Artesian
Cooper	92	2.823	-	-	-
Ayres	50	2.845	-	-	-
Ayres	49	2.741	Artesian	> 2.74	Artesian
McNab	60	2.718	-	-	-
McNab	47	3.026	Artesian	> 3.03	Artesian
McNab	43	2.566	0.284	2.28	0.290
McNab	89	3.152	1.360	1.79	-
Craigwell House	71	3.988	1.236	2.75	1.240
Hoare	70	3.091	0.828	2.26	0.850
Mineral Park	85	2.929[d]	1.224	3.08	1.190
Weaver	57	2.652	0.005	2.65	0.000
MacAlister	76	2.845	-	-	-
ARC	86	3.281	-	3.07	-
Glander	72	2.708	0.600	2.11	0.575
Glander	59	2.338	-	-	-
Thomas	90	2.965[e]	1.030	1.94	0.920
Manson	83	2.558	0.890	1.67	0.880
Draper/Moturemu	37	2.613	Artesian	> 2.61	Artesian
Maddern ex McDonald	91	2.785[f]	0.780	2.01	0.720

<u>Notes</u>

Datum is Lands & Survey Bench Mark RM6694. RL is level reduced to mean sea level. Bore elevation measured to top of casing unless otherwise noted. Water levels measured 7-9 am with no bores pumping.

(a) Hinemoa - Artesian overflow pipe is 0.22m below top of casing.

(b) Aquatic Park - RL measured to top of casing flange plate, not top of casing extension. Artesian overflow pipe is 0.73m above flange plate.

(c) Palm Springs - RL is to plain socket on casing. RL of concrete block to RHS of casing is 3.224m.

(d) Mineral Park - RL is to top of connector band on casing, which is 1.379m below top of casing.

(e) Thomas - RL is to invert of water level access hole.

(f) Maddern - RL is to top of largest open plug screwed into top of casing.

APPENDIX C - GUIDE-LINES FOR ORDERING AND FITTING WATER METERS

The water meter should be of a type suitable for the purpose and hence the following specifications need to be known before approaching suppliers:

- maximum rate of flow;
- typical rate of flow;
- minimum continuous flow;
- whether flow is steady or fluctuates over a given range;
- maximum operating temperature (e.g. geothermal water oC);
- inside diameter of pipe to which meter will be connected;
- any pressure or 'head loss' restrictions applying;
- any physical constraints, e.g. meter registration, orientation, size limitations, flange sizes, etc;
- accuracy required (most meters are rated within $\pm$ 2% of flow).

It is preferable to have a water meter self-operating without requiring an independent power source. It is also preferable to have a meter that indicates rate of flow or speedometer-type indication so that the unit can be seen to be functioning. To be of practical use, water meters should also be of the totalising type, similar to a kilometre counter on a car.

In most general cases, a turbine type meter is the best compromise of low cost, wide flow range, reliability, low pressure loss, totaliser with no power requirement. For low flow volumes, rates below about 7m3/hour a volumetric rotary piston meter is generally the best compromise with thermoplastic types being relatively inexpensive and resistant to corrosion. Options are also available for frost protection and inclusion of non-return valves. Where grit from bores and/or pipeline/pump servicing may be a problem, water strainers are available to fit ahead of the meter inlet which would require periodic cleaning.

Most water meters are designed for flow in one direction only with an arrow or other indication to show inlet and outlet positions. If there is likely to be reverse flow (i.e. after pump shut-down), a one-way valve should be fitted to prevent reverse flow "back monitoring" damage to the meter. The meter should be installed where it is readily accessible, located outside a building and the registration dial set where it is easily read. Water meters should ideally be set at a reticulation low point or "pipe-full" section so that possible periodic air locks will not subject the meter to unnecessary hydraulic hammer. One-way valves (e.g. riser tube, foot valves or ball valve in most submersible pumps) tend to reduce this problem.

For a water meter to read reliably, accurately and to reduce internal wear, it should be inserted along a straight section of pipe. At least a straight <u>input</u> section of length 20 times the pipe diameter, and a straight output section of length 10 times the pipe diameter should be considered minimum requirements. The meter should be located such that it will not be accidentally run over, subjected to knocks, or suffer other maltreatment such as pump vibration, freezing or vandalism. Water meters rated and fitted for geothermal reticulation should be suitably enclosed to preserve the thermal insulation qualities of the remaining installation.