Proc. 10th New Zealand Geothermal Workshop 1988

INSTRUMENTAL MONITORING OF HYDROTHERMAL SURFACE FEATURES

3 T McLeod

Physics Department, University of Auckland

ABSTRACT

The geothermal environment is possibly one of the most demanding environments in which to operate recording equipment. Not only are high temperatures, high pressures and corrosive atmospheres encountered but mains power supply is generally unavailable.

A recording system has been designed and constructed for such an environment as part of a mass and energy flow study at Waimangu Geothermal Reserve. This study requires the monitoring of diverse physical parameters for a period of approximately 12 months. A similar system has been installed and operated on Geyser Flat, Whakarewarewa as part of the 1987-1988 Rotorua Monitoring Program.

This paper gives a brief introduction to the above recording sites, describes the recording and analysis system and presents examples of data obtained.

INTRODUCTION

Waimangu

The Waimangu hydrothermal system is located 26 km south-east of Rotorua on the south-western shores of Lake Rotomahana. This hydrothermal system is the only intense hot chloride water system in New Zealand that has not been significantly disturbed artifically.

Surface manifestations of the hydrothermal system have developed in and around craters formed during the 1886 Tarawera eruption. This development has been characterised by violent hydrothermal outbursts such as the eruptions of Waimangu Geyser (1900-1904) and by less violent sporadic events. (Keam)

The two main geothermal features at Waimangu are the hot lakes, Frying Pan and Inferno Crater. They show remarkable sympathetic variations in outflow and water level respectively. The amplitude (up to 12metres) of water level changes experienced by Inferno Crater Lake are unparalleled by that of any known hot spring.

Continuous instrumental monitoring at Waimangu of water level and water temperature in Inferno Crater Lake and the water temperature and outflow from Frying Pan Lake were initiated by the Rotorua Geological Survey in 1983. Unfortunately the high humidity and acidic nature of the environment caused continual instrument problems resulting in the procurement of sporadic records. These discontinuous records did however provide an outline of a cycle of activity at Waimangu which was very intriguing. Inferno Crater Lake appears to exhibit a cycle of very complex water level and water temperature changes. (Scott and Lloyd)

The Present research intends to establish a compre - hensive data base and to develop a procedure for processing this data to ascertain the variations occurring in the proportions of steam and water within the immediate hydrothermal system. A careful study of the water level and temperature cycles of Inferno Crater Lake should provide information about the size, shape, material and dynamic states occurring inside the feeder reservoir. Such a study should lead on to the development of a quantitative model for Waimangu and other similar geothermal systems.

Whakarewarewa

Geyser Flat, centrally located at Whakarewarewa contains the last remaining concentration of geysers in New Zealand. It is a gently sloping sinter sheet with a prominent linear vertical fracture tending roughly NNW-SSE. Along the fracture are seven features which are or have recently been, geysers. South-south-east from Puarenga Stream they are: Kereru, Prince of Wales Feathers, Pohutu, Te Horu, Waikorohihi, Mahanga and Wairoa. These features have all been described by Lloyd. (1975)

For thirty years, falling geothermal aquifer pressures induced by artificial withdrawl of geothermal energy, adversely modified this geyser field. Lloyd (1974) outlined the interactions between Price of Wales Feathers, Pohutu, Te Horu and Waikorohihi. Cody (1986) presented evidence of major changes in these interactions.

To assess the effectiveness of remedial measures such as bore closures, it was proposed that the program initiated in 1984, to monitor pressures in the geo - thermal aquifer, be expanded to directly monitor the main features of interest, the geysers and other adjacent surface springs.

Historically, sporadic observational monitoring of some of these features at Whakarewarewa has occurred. Isolated features have also been monitored instrument - ally from time to time. On 1 April 1987, an expanded monitoring program commenced. As part of this program an intensive study of Geyser Flat was initiated. The present program is unique as it involves the continuous ans simultaneous monitoring of several parameters for a selected number of the main hydrothermal features.

RECORDING SYSTEM

Initially the recording instrumentation used at Waimangu and Whakarewarewa was either circular or strip chart records. These instruments had at most two channels and recorded data as analog traces, so before processing could proceed the charts required manual reading and digitization.

In late 1982, a magnetic recorder was installed at Inferno Crater Lake. The recorder used cassette tapes for storing the records, had eight sensors attached, required two 12 volt lead-acid batteries and was part of a metre high, bulky rack of instrumentation.

As part of the 1984 Rotorua Monitoring Program, a mini computer system was installed at Whakarewarewa. This system was connected to 11 sensors, recorded the data on floppy disks, required mains power supply and occupied a small room.

Both recorders used large amounts of power, were unreliable, inflexible and required specialist technical support. These systems also required minicomputers for reading the recorded data and the subsequent analysis. To seriously pursue the intended research in the geothermal areas, an enhanced recording and analysis system was required.

The system chosen consisted of a collection of subsystems that could be reorganised for various tasks.

Sensors

Various types of sensors were required for sensing the physical parameters of interest. The sensors mentioned below were required for sensing surface geothermal features at both Whakarewarewa and Waimangu.

(a) Temperature Sensors
Temperature sensors are used for measuring water temperatures, air temperatures and for detecting geyser activity. The sensors are situated next to the geyser and detect the flood of erupted water.

(b) Pressure Sensors
The water levels are measured by means of a gas purge system. Dry nitrogen gas is continually bubbled through a submerged fixed pipe. As the water level varies the pressure required to bubble the gas varies proportionally. This pressure variation is converted into a voltage variation and recorded. Ambient air pressure is measured using an absolute pressure transducer.

(c) Overflows
At Waimangu there are two Parshall Flumes located in the outflows of Frying Pan Lake and Inferno Crater Lake. These flumes are hydraulically connected to still wells in adjacent huts. The water level in the still wells is sensed by using a balanced float and pulley system. The pulley is attached to a multi-turn pot.

Loggers

For each site, two Taupo-F, 16 channel data loggers are used for recording the data. The Taupo-F is a small sealed field data recorder designed for unattended operation in harsh environments. It does not have external controls or a display screen. Readings are taken from its inputs and stored in internal memory. Subsequently the data is retrieved through a serial communication channel.

A computer or visual display unit connected to the communication channel is necessary for instructing the logger and starting the logging.

There are a number of advantages in having two loggers for each site:

(a) The data from one logger can be copied directly into a host computer, while the other logger continues recording.

(b) The batteries in the loggers can be recharged from the mains power supply. This means that the loggers are independent of the sensor power supply, hence if the sensors malfunction the recorded data is unaffected.

(c) A logger is free to use on a portable system for taking "snap shots" of the activity at features that are not directly sensed by a primary system. It also enables specific features to be studied in greater detail.

(d) In case of problems with one logger, there is another immediately available for the primary monitoring site.

Computers

Computing facilities used to support the loggers are described below.

(a) EPSON HX20
The HX20 is a portable computer used to communicate with the logners while in the field.

(b) ZENITH Z-181
The Z-181 is a lap-top IBM PC compatible computer used to analyse and process the data while in the field. It is capable of running programs constructed on the desk-top computer. Though not as fast as the desk-top machine, this computer allows the recorded data to be reviewed while on location.

(c) CONCORD XTurbo
The Concord is a 10MHz IBM PC compatible desk-top computer. This is the main development, archiving, communication and analysis computer.

(d) VAX
The DSIR VAX network is used for archiving the data collected by the Whakarewarewa recording system.

Software

Various programs have been constructed for transferring translating and analysing the collected data. Three software packages have been selected, one for each of the above tasks.

(a) Taupo Interface
For communicating with the Taupo-F data loggers, a compiled BASIC program, TAUPO was constructed. This program enables an operator to instruct the Taupo-F and to transfer the recorded data from the logger to the interrogating computer.

(b) Translator Software
The compressed binary format produced by TAUPO is translated into a binary format more suitable for archiving and analysis. The generated format enables the analysis software to quickly access the data.

(c) Analysis Software
ASYSTANT, a software package constructed from FORTH was selected for analysing the data. ASYSTANT has powerful graphics abilities and advanced signal analysis and statistics functions.

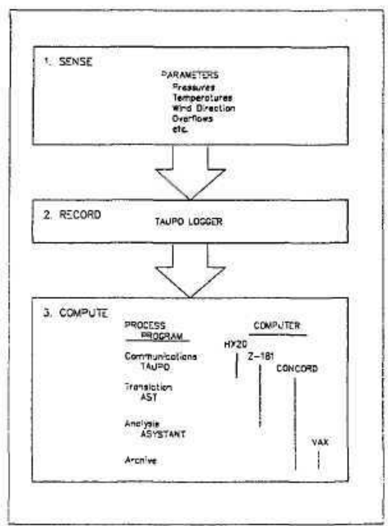

Fig 1: Data Flow Path

LOCATION

Waimangu

Three sets of parameters are currently being recorded at Waimangu. These are :

(a) Inferno Crater Lake
Automatic measurements are made of the water level, water temperature and the amount of overflow from Inferno Crater Lake. The lake water level is measured by a gas purge system as described above, and lake overflew is measured with a flume and still well arrangement.

(b) Frying Pan Lake
Water temperature and the continuous overflow from Frying Pan Lake are recorded at a flume located 100 metres down the outflow stream.

(c) Environmental
To help determine the effect of air pressure on the lake water level, barometric pressure is monitored in the vicinity of Inferno Crater. Nett incident radiation is also measured at the same site to establish whether any diurnal effects are present in the records.

Previous research (Stanton) has shown that seismic noise in the proximity of Inferno Crater varies with the lake water level. To further explore this observation, a geophone has been included in the sensor array.

In addition to the problems of non-mains power supply and an environment hostile to electronic equipment, an accepted constraint has been that Waimangu is also a scenic reserve of considerable tourist potential. Hence, every effort has been made to keep instrumentation as inconspicuous as possible to avoid degrading the reserve and to discourage inquisitive interference.

Weekly maintenance visits include the manual measurement of the various parameters being measured. This provides a check on the electronic instruments and complementary visual observations.

EXAMPLES OF DATA

Four parameters for a cycle of Inferno Crater Lake are provided. The time span starts at 19 April 1988 at 17:00 hours and continues for 1000 hours, (about six weeks) The data is from a two minute data base, 29 of every 30 points have been discarded and no data smoothing has been applied.

Details of interest are :

(a) The two dominant spikes in the Frying Pan Overflow data are due to heavy rain. These two events are also discernible in the Inferno Water Level and Seismic Noise data.

(b) Inferno Water Level reaches overflow at 0.06m at which point there is a noticeable increase in the seismic noise. This noise is in part due to a four metre water fall in the' overflow channel.

(c) A correlation is apparent between the water level in Inferno Crater Lake and the overflow from Frying Pan Lake.

(d) The minor water level oscillations in Inferno Crater Lake are accompanied by oscillations in the water temperature and increases in the seismic noise.

The data at present being collected from Waimangu is to be used with bathymetric information collected by Keam (1981a, 1981b) to calculate the energy and mass flows occurring in Inferno Crater and Frying Pan Lakes.

It is intended that the gross characteristics of Inferno Crater Lake's cycle of activity will be modelled and it is hoped that the intriguing detail evident in the Inferno water level records will be understood. A model that describes the approximate six weekly cycle should serve as a tool to explore the nature of the feeding aquifer.

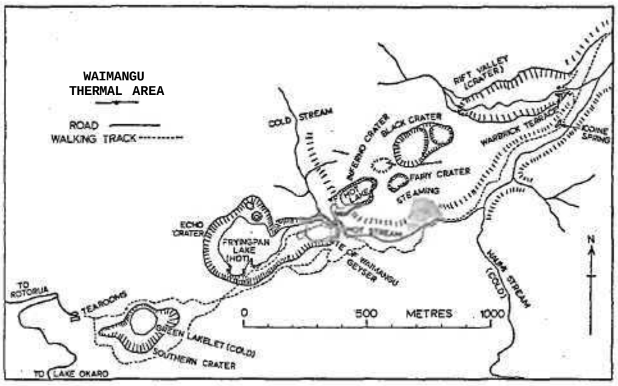

Fig 2: Main Features of the Waimangu Thermal Area

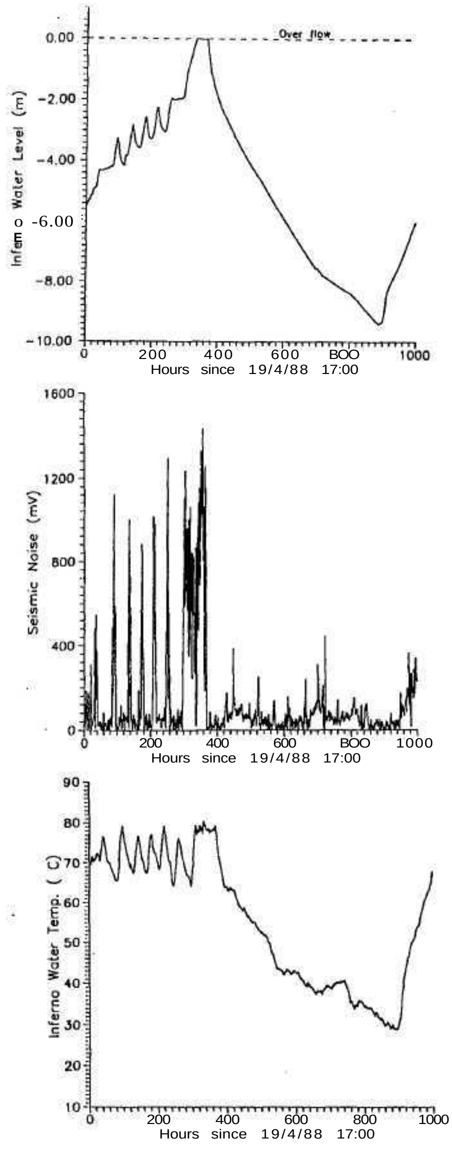

Fig 3: Inferno Data Set

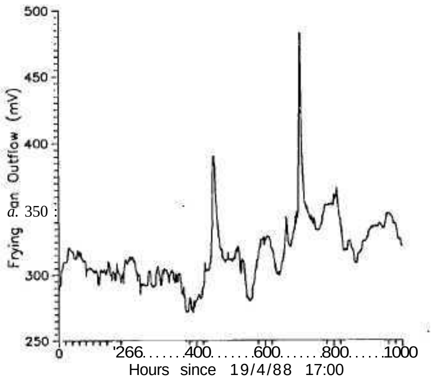

Fig 4: Frying Pan Lake data

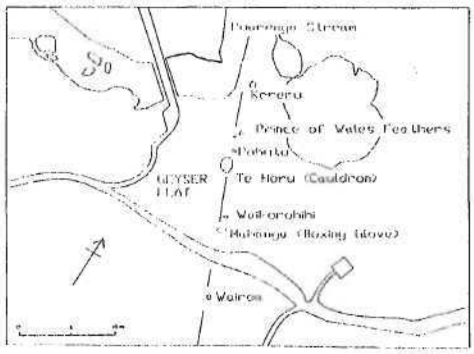

Fig 5: Main features on Geyser Flat

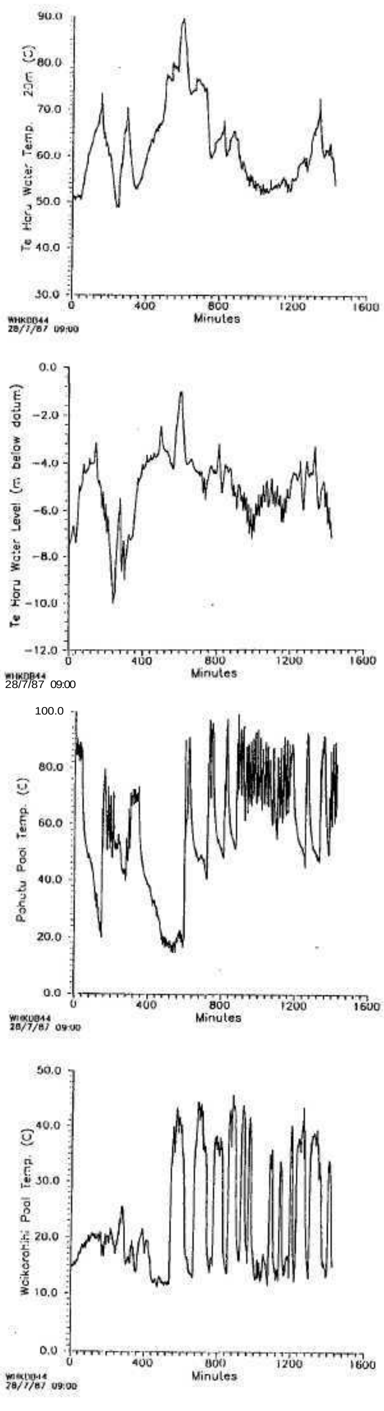

Fig 6: Whakarewarewa Data Set WHKDB44

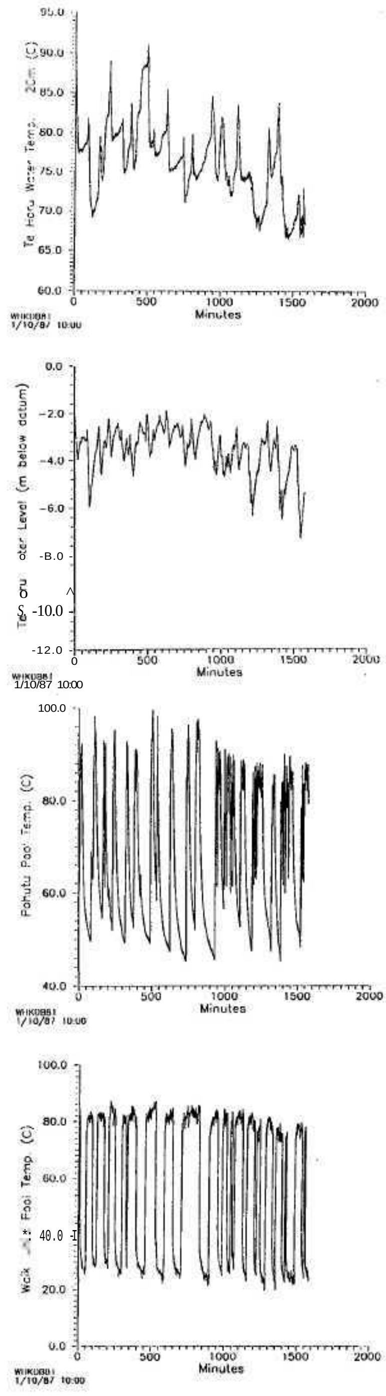

Fig 7: Whakarewarewa Data Set WHKDB81

LOCATION

Whakarewarewa

A number of features on Geyser Flat are currently being monitored. These are described below.

(a) Pohutu Geyser
Various sensors have in the past been placed around Pohutu in attempts at recording its activity. The use of a temperature sensor placed in a pool that is flooded on eruption has become the standard method and is being used again. This arrangement can roughly distinguish between the different eruptive states of Pohutu. An eruption usually commences with a flood of hot water. This immediately develops into a column of boiling water and steam reaching heights up to 21 metres. After a period of time this column decays into a shattered, spashing mound of water approximately one metre high before cessation. The temperature sensor registers the flood of hot water, and a following cooling period as the eruptive column forms. The commencement of this splashing mode is detected as the sensor is again heated.

(b) Te Horu
The main parameter measured is the water level of Te Horu relative to mean sea level. This parameter is measured with a gas purge system as described above. The records are converted from pressures to water level with respect to a datum on the rim of Te Horu, a point surveyed by the 1984 Rotorua Geothermal Monitoring Program. Water temperature at two fixed depths are also recorded. This temperature array provides information about both the hydrodynamic and thermodynamic events occurring in the vent and assists in monitoring events occurring in the vent and assists in monitoring the varying water level.

(c) Waikorohihi
A temperature sensor is located in the over - flow from the pool surrounding the geyser.

Geyser Flat is seen by thousands of people every day, therefore the visual impact of any monitoring instrumentation has to be minimised. An additional incentive for concealing equipment is to minimise the possibility of interference.

Other factors that required consideration when locating the recording system were the periodic dousing of the site with near boiling water and the presence of hydrogen sulphide gas.

Sensors are calibrated by taking manual measurements and observations. For the Te Horu water level, every couple of weeks the water level is manually measured every minute for approximately one hour. Temperature sensors are checked against a portable thermocouple device.

EXAMPLES OF DATA

Two sets of selected data are provided as an example of the records being collected from Geyser Flat. Three parameters have been chosen; Te Horu water level, Waikorohihi activity, and Pohutu activity. These sets are from runs that contain 10 second samples, five points in every six have been discarded.

The data sets are not presented in chronological order. This is because early data does not exhibit characteristics that are now regarded as representing the norm.

WHKDB81

Data collected from 1 October 1987 at 9:53 hours through to 2 October 1987 12:15 hours. Points of interest to note are:

(a) Waikorohihi appears to 'normally' have eruptive periods of about eighty minutes. Its rest period is dependent on the length of time active.

(b) The pattern of activity of Pohutu and Waikorohihi changes as the water level in Te Horu changes. While the Te Horu water level averages aound -3.5 metres, the geysers play fairly regularly. The water level average falls when Pohutu starts exhibiting 'shattered' eruptions.

(c) Pohutu usually erupts when Waikorohihi stops.

(d) When Pohutu erupts, the water level in Te Horu falls.

(e) Increases in deep Te Horu water temperature are preceded by increases in water level and followed by an eruption of Pohutu.

(f) There are peaks in Te Horu water level that appear unrelated to other activity on Geyser Flat.

WHKDB44

Data points collected from 28 July 1987 at 9:03 hours through to 29 July 1987, 8:51 hours. Points of interest to note are outlined below.

(a) An obvious relationship between the Te Horu water level and the activity of Waikorohihi and Pohutu Geysers.

(b) Low average water level in Te Horu is accompanied by virtual cessation of Waikorohihi activity and is followed by an unusually long quiescent period from Pohutu.

(c) Extended time of short period Pohutu eruptions corresponding to an average Te Horu water level of around -6.0 metres below datum.

(d) Exceptionally high Te Horu water level following an above normal length eruption of Waikorohihi and accompanied by a possible 20 minute full column eruption from Pohutu.

The records of activity now available from Geyser Flat are further revealing the complex nature of the inter-connections between the features. It is intended that the data will be used to further define quantitatively the evident coupling and cyclic nature of the activity.

DISCUSSION

The described recording system has increased by an order of magnitude the resolution and reliability of records from Waimangu and Whakarewarewa. Instrumentation and programs for collecting and processing the data from both locations have benefitted from the experience gained at each. This productive association can also extend to the data analysis and modelling.

At Waimangu the activity is dominated by the approximate six weekly cycle evident in the Inferno Crater Lake water level changes, whereas at Whakarewarewa, the coupled system of Pohutu, Te Horu and Waikorohihi has a relatively faster cycle. It will be an interesting challenge to develop models that can be applied to both systems.

ACKNOWLEDGEMENTS

Some of the Rotorua data were gathered as part of the Rotorua Geothermal Monitoring Program. The contributions of the Ministry of Energy, the Department of Scientific and Industrial Research, the Tourist and Publicity Department and ESSE are gratefully acknowledged.

REFERENCES

CODY, A.D. (1986): Eruption Summaries of Pohutu and Waikorohihi Geysers in Whakarewarewa. Rotorua Monitoring Program Progress Report 30 September 1988

KEAM, R.F. (1979): Hydrothermal Disturbance at Inferno Crater and Raupo Pond Crater, Waimangu. New Zealand Volcanological Record 8, 72-74

______ (1981a) Inferno Crater Lake - Provisional Bathymetry 1:250. New Zealand Oceanographic Institute Miscellaneous Series 52

______ (1981b) Frying Pan Lake - Provisional Bathymetry 1:500. New Zealand Oceanographic Institute Miscellaneous Series 53

LLOYD, E.F. (1975) Geology of Whakarewarewa Hot Springs. DSIR Information Series No. Ill

SCOTT, B.J. and LLOYD, E.F. (1982) Hydrological Measurements, Frying Pan Lake - Inferno Crater Lake, 1970-1981, Waimangu Hydrothermal Field. New Zealand Geological Survey Report G67

STANTON, T.P. (1978) Seismic Noise Characteristics of Inferno Crater, Waimangu. MSc thesis, University of Auckland