# FUTURE PRODUCTION STRATEGY - OHAAKI GEOTHERMAL FIELD

A.W. CLOTWORTHY AND R.H. BROOKS

Geothermal Group, Electricity Corporation of New Zealand, Wairakei

**SUMMARY** - The Ohaaki geothermal reservoir had excess steam capacity at commissioning of the power plant. The available steam flow has declined steadily and has now fallen below the level required to fully load the turbines. A study has reviewed options for either increasing the steam supply by drilling additional wells or maximising electrical generation from existing wells. It was concluded that the reservoir currently utilised can not support additional make-up wells. A combination of a sliding reduction of high pressure turbine inlet pressure and de-rating individual wells to intermediate pressure was considered to be the best strategy.

## INTRODUCTION

Since commencing production in mid-1988 the Ohaaki geothermal field has suffered a decline in steam flow . This was expected from previous experience at Ohaaki and other reservoirs. On commissioning of the Ohaaki Power Station the available production capacity was greater than was required to fully load the power plant. This surplus production was the result of two factors:

1. Design - "Surplus" production wells were connected into the steam supply system to cater for some decline due to reservoir changes and to allow for some calcite deposition.

2. Capacity - The initial production capacity was greater than the requirements of the turbine generator plant installed. This was because the output of most wells was greater than indicated by measurements made in the 1970's.

The surplus capacity disappeared in mid-1993 (Figure 1). The strategy for dealing with this shortfall of steam is addressed by this paper.

Broadly, there are two alternative strategies.

1. Additional wells could be drilled to maintain both the high pressure (HP) and intermediate pressure (IP) turbines fully loaded.

2. The current wells could be used to supply a greater flow of steam by reducing the inlet pressure of the HP turbines (de-rating). This will mean a loss of generation from the HP turbines. The design life of the HP turbines was considered to be about 10 years. The predicted run-down of HP generation will take place well within this 10 year time frame.

The strategy opted for depends on the capacity of the geothermal reservoir to support continued steam flows at current turbine inlet pressures. Drilling additional wells will only be economic if the volume of the hot reservoir and its recharge by inflowing hot water is sufficient.

Monitoring of trends in downhole pressures and temperatures has provided a basis for an estimate of the extent of production decline over the next few years to be made. Longer term predictions require that processes involving the reservoir as a whole be taken into account rather than just individual wells. Predicting these processes requires a three-dimensional computer model of the reservoir and surrounding rock volume.

## COMPUTER MODELLING OF RESERVOIR

The University of Auckland have been developing a computer model of the Ohaaki reservoir over a number of years. The current model has given good matches for groups of wells representing 4 of the 5 separation plants (SP's). The SP1 wells have not been properly matched yet and so the results for SP1 were not included in predictive simulations. Other short-term predictions indicated that SP1 wells will have only a short life and so are less important in the longer-term future predictions.

Three scenarios were run on the University of Auckland model.

1. Automatic make-up for short-fall by drilling new wells while maintaining HP pressure.
2. De-rating well by well, with individual wells de-rated from HP to IP.
3. Progressive de-rating, with the inlet pressure to the HP turbines being gradually reduced.

This simulation showed that Scenario 1 will be expensive and not feasible after 1995. A very large number of wells vould be required, unless deeper permeability could be ıpped.

cenarios 2 and 3 were both shown to be feasible with IP team supply being maintained to year 2000.

'he computer simulation was valuable for predicting major 'ends over longer periods and it was clear from the imulations that the currently utilised reservoir would not ıpport continued HP steam supply. The simulation owever was not capable of predicting the behaviour of ıdividual wells. Field management over a period of 3-5 ears is better served by extrapolating the output of ıdividual wells so that various strategies can be evaluated ı detail.

## VELL BY WELL MODELLING

ı order to evaluate in detail the effects of de-rating wells it ; necessary to predict the response of each production well › varying separation pressure, governed by the HP turbine ılet pressure or alternatively the switch to IP supply. This :quires the generation of "characteristic curves" of ischarge mass flow and enthalpy versus wellhead pressure ›r each year into the future.

he "Wellsim" wellbore simulator was used to generate ıaracteristic curves for the years 1992 to 1997. The ıthalpy was estimated for each year based on past trends. he reservoir pressure was extrapolated from past ieasurements, taking into account the pressure trends redicted by the 3-D simulator.

he predicted mass flow curves were then approximated by ırve fits for use in the spreadsheet developed to simulate ıe effects of changes in surface plant, steam flow and ıbsequent electrical generation.

## URFACE PLANT MODELLING

ı order to integrate the effects of changing conditions of ıe surface plant and the changes taking place in the ;eothermal reservoir a model was constructed using a ›readsheet. The flows from the wells depend on the ;paration Plant pressure, which is affected by the turbine let pressures and pressure drops through the pipeline stem.

he spreadsheet model had four distinct areas:

- WELLS - grouped according to the SP they feed. The mass flow and enthalpy for each well are calculated from the SP pressure.

- SEPARATION PLANTS - steam and separated water flows are calculated. The rated capacities were used to limit individual flows.

- PIPELINES - the HP and IP steam flows and velocities for each SP and the East and West Bank lines were computed. The velocities were used to check for any flow choking or excessive pressure drop.

- POWER PLANT - the electrical generation was calculated as a function of turbine inlet pressure and available steam flow, with constant back pressure. The consumption rates for the HP turbines was a linear function of inlet pressure based on theoretical values from the turbine manuals. The theoretical no-load and full-load values were combined with consumption rates to produce characteristic curves for the HP and IP turbines. Excess HP steam, if any, was used to supplement the IP steam requirements, modelling the use of the installed pressure reducing valves. If the HP steam available was less than the middle of the operating range, then one HP machine was shut off and the steam diverted to the second HP turbine.

## STUDY RESULTS

Four management strategies were modelled using the spreadsheet. The results are shown in Figure 2.

- NO CHANGE - HP turbine inlet pressure maintained at 12.5 bar.g and no additional wells drilled.

- SLIDING PRESSURE - HP turbine inlet pressure was decreased with time, which reduced pressures throughout the system and hence increased the mass flow from the wells.

- INDIVIDUAL WELL DE-RATING - wells were de-rated from HP to IP supply, while the HP turbine inlet pressure was maintained at 12.5 bar.g. This option maintained IP supply while allowing HP generation to fall.

- MIXED DE-RATING & SLIDING PRESSURE - individual wells were de-rated from HP to IP supply, while the HP turbine inlet pressure was reduced if necessary to optimise generation.

No Change

The fall in electrical generation is non-linear with steam flow because of no-load requirements, giving a large drop in 1996.

Sliding Pressure

The HP steam supply is maintained until 1997, but with the turbine pressure falling below the economically efficient level in 1996. The IP turbines are not fully loaded from 1995.

Well De-rating

A smooth decline in generation takes place to 86 MWe by 1997, with reduced IP generation from 1996.

Mixed Sliding & De-rating

Very similar to straight de-rating, but there is a gain of 7 MWe in 1996.

## CONCLUSIONS

- The Ohaaki geothermal reservoir will not sustain full generation beyond 1993 and there will be a substantial decline in generation after 1993 unless action is taken.
- It is not economically feasible to drill additional make-up wells within the currently utilised reservoir to extend full HP and IP generation beyond 1993. Drilling additional wells into the same limited resource will only give a short-term increases in steam flows.
- Limited HP generation can be sustained until 1996 by either step de-rating individual wells or by sliding the HP turbine inlet pressure.
- The best option for de-rating appears to be a mixture of well de-rating and sliding the HP inlet pressure.
- The best option for maintaining a long-term steam supply is to drill exploratory wells to investigate deep permeability in the high temperature resource below the level currently utilised.

## ACKNOWLEDGEMENTS

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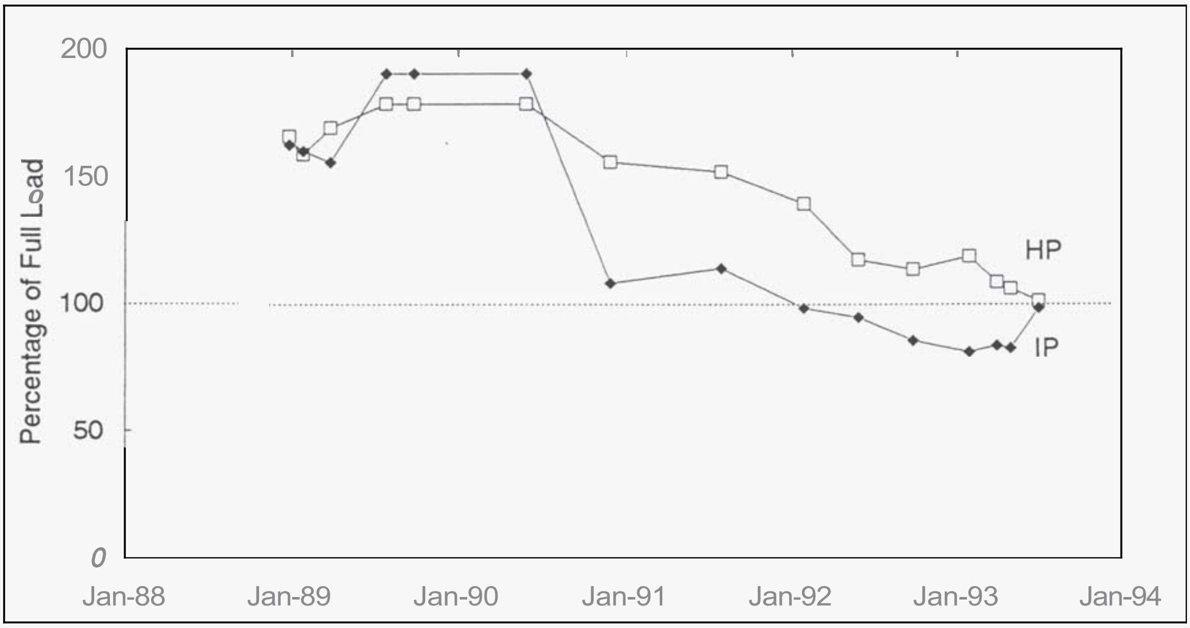


**Figure 1-** HP and IP steam flows as a percentage of full load requirements

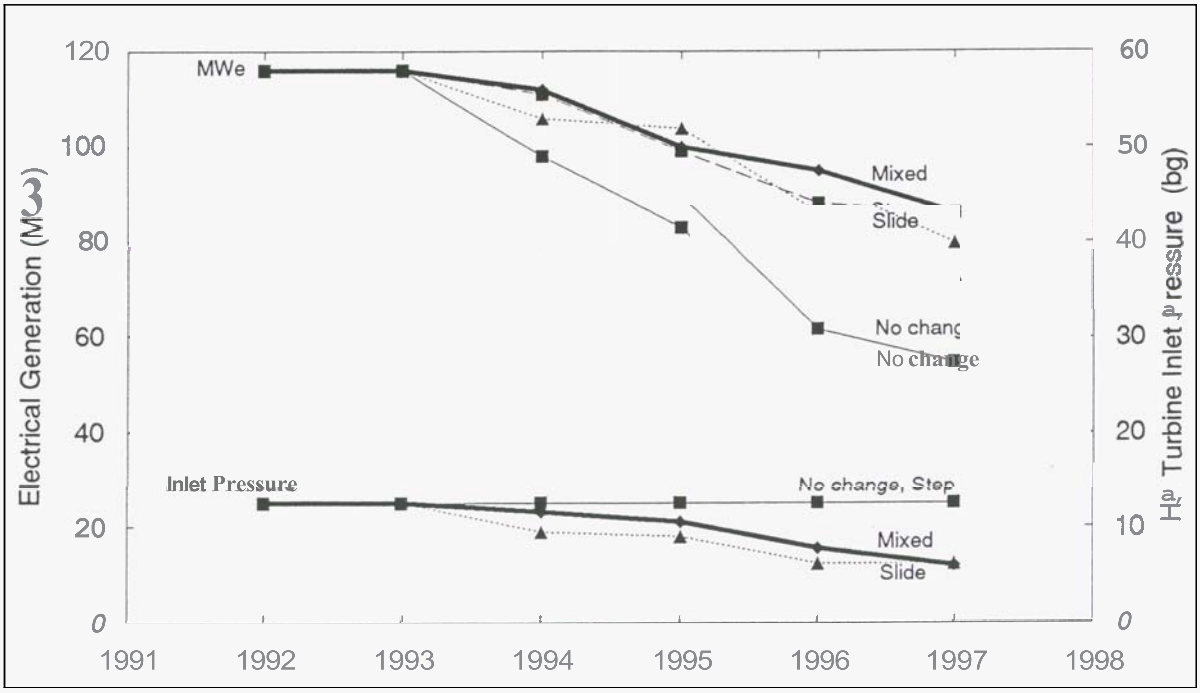


**Figure 2-** Predicted generation and HP turbine inlet pressure from modelling of 4 scenarios