KAWERAU GEOTHERMAL DEVELOPMENT: A CASE STUDY

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DEVELOPMENT HISTORY

The Kawerau geothermal field covers an area of 19 to 35 km^2. Fluid temperatures exceed 310°C. Drilling began at the end of 1952, using experience gained at the Wairakei geothermal field. A significant area of the field to the south and east lying within the resistivity boundary is virtually unexplored. Production is currently limited to an area of about a square km located just north of the mill (Figure 1).

The steamfield is owned by the New Zealand Government (who under New Zealand law, owns all geothermal resources). The steamfield is managed by the engineering firm Connell Wagner, with day-to-day operations and maintenance being contracted to Downer Energy.

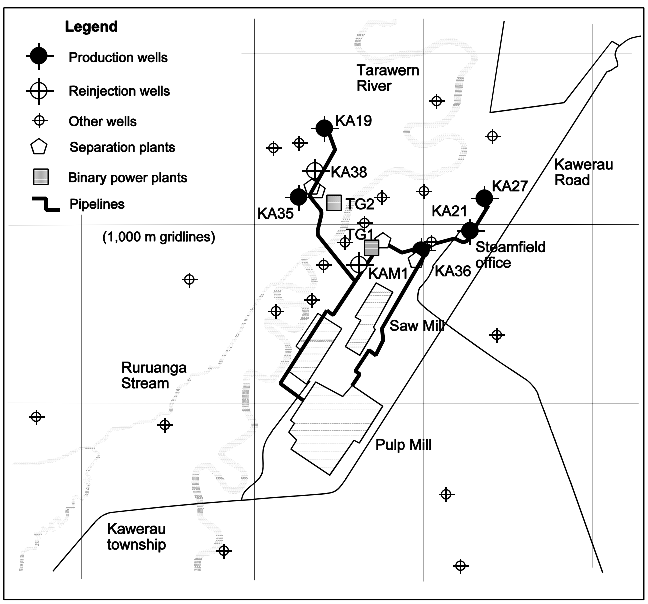

Figure 1. Kawerau geothermal steamfield.

Mill

The Tasman Pulp and Paper Company Ltd. mill is sited at Kawerau, partly because of the presence of the geothermal steamfield. The steamfield has been supplying geothermal steam since 1957.

Geothermal provides 30% of the mill's process steam and 5% of electrical energy. Steam flow is up to 320 t/h with a total annual supply of about 2.3 million tonnes; that is a mean flow of around 265 tonnes/hour. The peak flow is equivalent to 40 to 45 MW(e).

Geothermal steam is the cheapest external energy source at Kawerau. (The cheapest fuel is "black liquor" and timber waste). The geothermal steam price is determined on the basis of the next cheapest energy option, with benefits being shared between supplier and user.

Geothermal steam is used both directly in the mill processes, and in heat exchangers. Electricity is generated in an 8-MW turbo alternator (T/A), with the exhaust steam being further used to heat process water. The T/A is used to balance process steam flows, so does not have a high-load factor.

An interesting by-product of the geothermal process is the condensed steam. All the condensate from within the mill is collected, after having the non-condensable gases stripped out it, is used to provide high-quality boiler feed water. The ammonia naturally present in the steam provides a built-in corrosion inhibitor, so that dosing with amines is no longer required (Carter and Hotson, 1992).

Other Uses

High-pressure steam is also supplied to the Fletcher Challenge Forests sawmill for drying timber in kilns. In line with increasing demand for kiln dried lumber, Fletcher Challenge Forests propose installing a further five geothermal-heated kilns and converting the non-geothermal kilns to geothermal (Figure 2).

Some of the separated geothermal water is used to generate electricity in two "binary cycle" electricity generating plants with a total capacity of about 6 MW(e). Small quantities of steam are also used for greenhouse heating.

OPERATIONAL ASPECTS

Characteristics

Production of steam from the steamfield is a continuous operation: 24 hours per day, 360 plus days per year. Currently, five wells are producing and two are used for reinjection. Other wells are used for monitoring on a continuous or periodic basis.

Steam is supplied for process heat and to power a turbo alternator. Unlike a power plant providing base load, the mill operation fluctuates, so the steamfield has been designed for load following. Changes in demand can be very sudden with changes in the pulp and paper process–although, the demand is smoothed to some extent by the turbo alternator, which usually runs off maximum load.

Pressure is controlled by venting steam when demand decreases, as it is not possible to throttle the wells in the short time required. Well are, however, throttled if demand is to be reduced for some period, to reduce the amount of steam lost through the steam vents. Resource consents are required for discharge to atmosphere–a condition of the consents is to minimize venting. This arises from the requirement to maximize efficient use of the geothermal resource. In

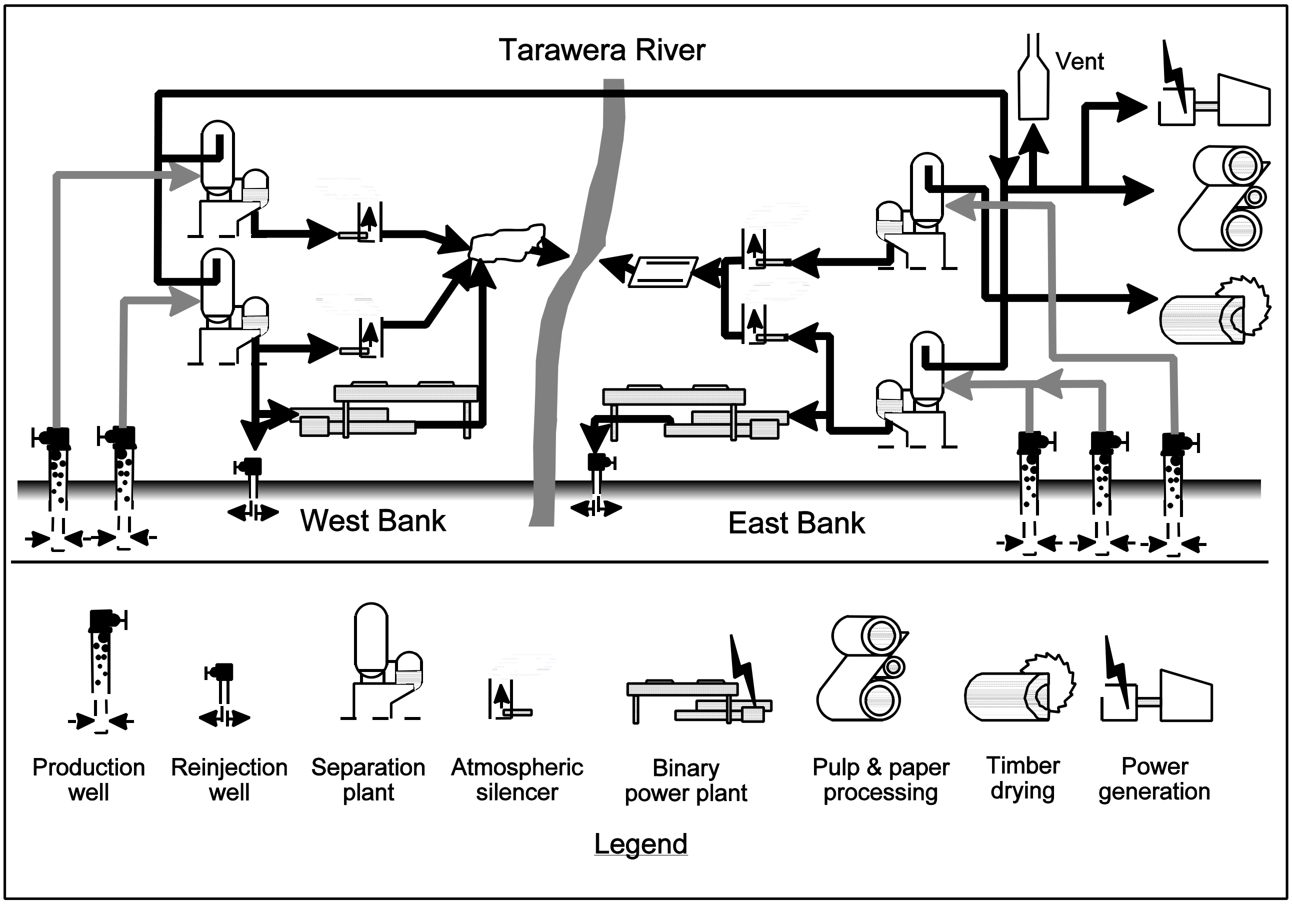

Figure 2. Kawerau geothermal steamfield schematic.

addition, the steamfield owner receives no payment for steam vented.

Control System

The steamfield functions are monitored by a Distributed Control System (DCS). This fills a primarily monitoring role of operational aspects such as steam flows and pressures. It also monitors environmental and reservoir parameters, such as geothermal water discharges and reinjection flows, and temperatures.

The DCS raises alarms, the major ones of which dial up a pager to alert the duty steamfield operator that attention is required.

Three of the production wells can be remotely throttled through the DCS to assist with load following. Other aspects are automatically controlled at a local level, such as the water levels in the separation plants. The automatic control functions are being extended to provide greater efficiency in operation.

Plant Maintenance

Steamfield plant inspection and maintenance is integrated with mill maintenance and "marine" inspections to minimize disruption to the steam supply. (Marine inspections are annual safety inspections of pressure vessels carried out by the statutory authority.)

The mill has biennial total shuts lasting three or four days. Consequently, no steam is required an all wells are shut in. Inspection and maintenance of essential or unique items is carried out during this time. Other items of plant, such as the separation plants or production wells, are taken out of service sequentially–coinciding with programmed reductions in mill demand whenever possible.

The two staff, in addition to operating the steamfield, schedule and supervise maintenance which is done under contract.

Wellbore Scaling

An operational problem with the Kawerau production wells is a tendency for calcite scale to form, restricting flow in the well. In the worst affected well, this caused a run down of about 70% output over a year. The scale can be effectively removed with a drilling rig; but of course, production is reduced through most of the year and there is a significant cost involved in the drilling operation. Two forms of well clean out have been employed: pulling the liner, or reaming it in-situ. Traditionally, the slotted liner has been reamed, then withdrawn from the well. The slots have been cleaned on the surface. More recently, the liner has been cleaned in place by jet washing. This is a quicker operation and is more effective in some wells.

Monitoring

Extensive monitoring is carried out. This includes monitoring of environmental impacts such as heat and chemicals discharged to the Tarawera River and subsidence. It also includes extensive reservoir monitoring. Information from this is used to prepare and update a model of the geothermal reservoir. This in turn is used to predict future changes in the reservoir from different resource management strategies –such as increased production or reinjection into different locations (White, et al., 1997).

HOW THE STEAMFIELD HAS REACTED TO DEVELOPMENT

Wells

The years of production have had little effect on the reservoir itself, pressure decline in the deep reservoir is less than measurement error; though, there has been some decline in temperature (Allis, 1997).

Not every management strategy is successful; but, the less successful are useful for learning more about the resource and development techniques. (Kawerau was using geothermal steam a couple of years before Wairakei, and these fields were the first wet geothermal fields to be developed in the world.) Cold groundwater inflows caused the demise of some of the earliest wells with their relatively shallow casings. Wells are now drilled and cased through the volcanic strata overlying the basement to prevent the intrusion of cooler water. Wells drilled in this manner have been very successful. KA19 is now into its 27th year of production, still producing over 70 t/h of steam.

KA21 has been producing for over 20 years and puts out well in excess of 100 t/h of steam-equivalent to 18MW electrical. KA27 has produced for 17 years, KA35 for 10 years and KA36 for 5 years. However, well KA28 which was linked into the system in 1986, was retired two years later owing to a long-term cyclic reductions in output.

Reinjection

Unlike all current or future geothermal field developments in New Zealand, where reinjection will be incorporated into the process from the start, waste water at Kawerau has been traditionally discharged to the Tarawera River. Reinjection has been under investigation for about 12 years, including reservoir studies and field trials.

Reinjection, commenced in 1991, has increased up to peak flow rates in excess of 300 t/h. However, the annual average is about 250 t/h or about a quarter of the separated water. Separated water from the separation plants is piped under pressure to the reinjection wells. Currently, there are two separate systems, with a reinjection well on each bank of the Tarawera River, receiving water from an individual separation plant.

The east bank reinjection flow is passed through binary generating plant "TG1 prior to reinjection; this removes heat from the water. Injection temperature being around 110 to 130^{o}C. The flow to the west bank reinjection well is not used in binary plant; so, the reinjection temperature is higher–about 180^{o}C. However, part of the flow from the separation plants on the bank is used in binary generating plant "TG2."

The injectivity of the first well, KAM1, has declined over time. The well now swallows about 60 t/h compared to about 130 t/h when first commissioned. It is believed that this decline is caused by deposition of super-saturated silica within the formation. On the other hand, reinjection well KA38 increased in swallowing capacity over the first three years–increasing from about 100 t/h to over 200 t/h. Its injectivity has since remained over 200 t/h.

Although reinjection has the potential to provide recharge to a system where mass extraction has resulted in pressure drawdown. At Kawerau, pressure drawdown over the period of field development is negligible. The task is to minimize the effect of the cold front spreading from the reinjection wells and affecting production wells.

The existing system of shallow reinjection has caused small changes in the shallow receiving aquifer as observed in monitor wells near the first reinjection well, KAM1.

It is possible that shallow reinjection may cause increased flows of geothermal water to the surface–possibly in the areas of natural springs which ceased flowing in the 1960s and 1970s; however, this has not yet been observed.

Subsidence

Ground subsidence is a concern at Kawerau because of the extreme sensitivity of the paper making machinery to tilt. Consequently, subsidence is monitored intensively.

Interestingly, the area of maximum subsidence does not coincide with the area of production however, but is more to the northwest. A maximum subsidence rate of 25 mm per year has been detected in the original Onepu hot springs area. The rate of subsidence over most of the steamfield is lower, generally between 5 and 10 mm per year or less (Allis, 1997).

Wellbore Scaling

As an alternative to removing calcite scale with a drilling rig, a well anti-scalant system has been developed. This has the double benefit of reducing annual maintenance costs while increasing steam availability. (The cost of anti-scalant is dependent on how frequently the tubing needs to be replaced; but even if it were necessary to replace the tubing annually, an anti-scalant system would be cost-effective.)

Trials to develop a suitable system having been going on for about eight years. At the time of the original trial in 1989, systems were widely used internationally; but, none were suitable for higher temperatures–270^{o}C (Robson and Stevens, 1989). Suitable chemicals were developed for Kawerau and an anti-scalant system was installed in KA35. This showed promise, but mechanical problems with the tubing that injected the chemicals to a depth of about 1,000 m in the well caused the trial to be abandoned.

About two years ago, a system using a new type of amoured tubing was installed in well KA19. The new anti-scalant system operated for over a year with no run down in steam output. Despite some further mechanical problems, this success justified installation of a similar system in KA35. This well also showed no decline in output following installation.

FUTURE DIRECTIONS

Improvements in Operating and Maintenance Methods

The steamfield operation undergoes continual improvements in methods. Many of these are quite small, some major and some more experimental.

Automation of control functions is being extended. For example, control of the venting system will reduce steam lost through venting. Automatic control of separator vessel water level is now incorporated in all separation plants. This prevents steam being lost through the separated water system.

Wellhead pipework has been rebuilt to improve flow characteristics, but also to reduce maintenance costs and reduce down time.

Two wells now have anti-scalant systems installed to reduce well rundown. These are still in the trial-stage as not all mechanical problems have been solved.

Steam Supply Expansion

The reservoir has considerable potential for expansion. The geothermal reservoir has been modeled in detail, using computer numerical models, to predict the future effects of production and reinjection over the next 30 years. The modeling indicates that doubling production will only slightly increase cooling in existing wells. Shallow reinjection (as is being used currently) does not alter this conclusion (White, et al., 1997).

Currently, steamfield equipment is located in a small area of the field, to the north of the mill, with production and reinjection wells and separation plant located on both banks of the Tarawera River (Figures 1 and 2). Other existing wells may be incorporated into the system in the future, either to makeup the steam supply as existing production wells decline in output, or to increase the supply.

Further Reinjection

The strategy is one of staged development, monitoring the effects of each stage before proceeding. Care must be exercised in the location of further reinjection to avoid affecting the temperature of production wells and to avoid contamination of groundwater aquifers. However, the success with reinjection so far indicates that it may be possible to increase the reinjection flow rate.

Separated water resulting from any increment in steam production is likely to be disposed of by reinjection, with constraints of avoiding damaging the resource and contaminating groundwater.

CONCLUSIONS

the Kawerau geothermal steamfield has provided a consistent energy supply to the Tasman Pulp and Paper mill over a long period. It is predicted that producing steam at twice the current rate would be well within the sustainable capacity of the reservoir. However, it is necessary to continually improve steamfield efficiency and cost effectiveness to remain competitive with alternative fuels such as natural gas.

An effective automatic monitoring and control system has been developed. This system reduces manpower requirements and gives both better control and better knowledge of the resource.

ACKNOWLEDGMENTS

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Figure 3. Main building of Tasman Pulp and Paper Co.

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