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WAIRAKEI 40 PLUS YEARS OF GENERATION

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ABSTRACT

This paper reviews the remarkable milestone of over 40 years of electricity generation from the Wairakei Geothermal Field. The paper reviews the context, the development and the changes that have occurred at the Wairakei Geothermal Power Station since commissioning in 1958.

1 INTRODUCTION

Generation officially commenced from the Wairakei Geothermal Power Station at a ceremony at 3pm on 15 November 1958. Assistant superintendent C D Elvines loaded the first high pressure turbine generator, G2, to 1.7 MW.

Over 40 years of generation have elapsed at Wairakei.

Wairakei the place of adorning, sparkling water where the pools were used as mirrors is a modest understated name for a location where the raw power of nature from deep underground penetrates the surface. The Wairakei system is a complex creation of volcanic eruptions, flows and sedimention spanning over half to one million years in time. We look back over more than 40 years and review the harnessing of the energy and raw power from this amazing complex.

2 WHY WAIRAKEI ?

The use of geothermal energy in New Zealand emerged on a large scale as a result of the post World War II demand for energy and in particular electrical energy.

During the war brown outs and supply disruption occurred as the demand for electricity out stripped the available supply. New plant was unprocurable and even if it could have been sourced, it could not have been installed because industry was focussed on the war effort. The situation continued to deteriorate in the post World War II period. 1945 saw coal in short supply and the level of Lake Taupo, the main hydro electric storage reservoir for the North Island, reduced to low levels. Power restrictions were imposed to avoid a breakdown of the North Island generating system. Periods of drought were experienced during 1946 and 1947, with low inflows to the hydro catchments. Power cuts of up to 20% were imposed over the two winters of 1946 and 1947. All the while demand for electricity was increasing at a rate of about 6 % per annum.

The development of Wairakei was undertaken to meet this growing demand for electrical energy in the North Island, to utilise indigenous resources and to reduce the dependence on hydro electricity generation.

At that time, the New Zealand government was responsible for the planning and construction of the power developments. The ministers in charge of the Public Works Department and the State Hydro Electric Department had pivotal roles in the development of electricity generation facilities. Two ministers the Hon. R Semple and the Hon. W Gooseman over saw the inception and initial development at Wairakei from 1948 to 1957.

2.1 Hon R Semple (Labour MP) 1935 to 1949

Semple was the Minister of the Public Works Department and the Minister of the State Hydro-Electric Department when it was formed in 1946.

He was a hydro man at heart. "Other countries without water power resources look with envy upon the immense water-power potential of New Zealand which only awaits development in order to place this country beyond the possibility of power-shortages for a considerable time to come."

In 1948 he understood that hydro generation had to be supplemented with generation from other energy sources to meet the demand for electricity and provide continuity in supply. Geothermal energy started to emerge as a strong contender. He stated "At the same time that this investigation of hydro-electric sites is being prosecuted, the Department of Scientific and Industrial Research has undertaken the investigation of the possibility of making use of geothermal steam."

Semple was responsible for commencing the intensive investigations at Wairakei in the late 1940's.

2.2 Hon W Gooseman (National MP) 1949 to 1957

Gooseman was the Minister of the Public Works Department and the State Hydro Electric Department from 1949 to 1957.

Demand for electricity was continuing to grow rapidly and he pledged that he would work towards eliminating power shortages. Under questioning in parliament on 12 July 1949 he stated "Immediately this government took office the subject of power supply was investigated. The completion of the hydro-electric generating plants under construction is being expedited and all possible methods of overcoming the present power shortage, and thereafter of maintaining generating capacity above demand, are being examined. ....Investigations into the possibility of generating power from geothermal steam are in hand also and are being pushed ahead so that the Government may know as early as possible whether, and if so, how much, power might accrue from this source."

In the next year he stated "An investigation into the possibility of harnessing geothermal steam is proceeding very actively. If this source of power proves to be available, then it will have a profound effect upon the future of this country."

In 1953 he committed the government in principle to the installation of generation plant at Wairakei.

2.3 Geothermal Legislation

Acts of parliament were specifically passed to enable the Wairakei development to proceed. 1952 saw the enacting of the Geothermal Steam Act, followed a year later by the Geothermal Energy Act.

3 SCIENTIFIC AND DRILLING INVESTIGATIONS

Scientific investigations commenced at Wairakei in the late 1940's and major organised drilling commenced in 1950. The early holes were drilled by the Department of Scientific and Industrial Research (DSIR) and the Ministry of Works (MOW) using truck mounted Sullivan 37 rigs. (Dawson, 1989, Bolton, 1998). Wairakei bore one was completed to 183m on 2 May 1950. A Mines department Failing 1500 rig was brought from the West Coast of the South Island to Wairakei and put into service. Two other Failing rigs were procured. In 1952 two National T12 rigs capable of drilling up to about 1500m were procured and put into service (Bolton, 1998). By early 1953 resource capacity to support 20 MW had been proven (Stacey and Thain 1983). Tools, equipment and techniques were being developed to enable the geothermal energy to be tapped and harnessed.

4 POWER PLANT

The government in conjunction with the United Kingdom Atomic Energy Authority (UKAEA) gave approval in principle for the construction of a combined power plant and heavy water distillation plant (Figure 1). In 1954 the Prime Minister announced in his July budget speech the decision to proceed with the stage 1 plant (Bolton 1998). Design and equipment procurement were well under way, when in 1956 the UKAEA withdrew from the project. It was too late to redesign the project, and so two intermediate pressure power turbines were ordered to take the place of the distillation vessels. The power plant capacity became 69 MW.

Towards the end of 1955 a proposal to develop a pilot hot water scheme resulted in an additional LP turbine being installed in 'A' station. The scheme was designed to collect geothermal water from production wells and produce additional IP and LP steam from the geothermal water. This proposal was called stage 1A and is shown diagrammatically in Figure 2. This increased the capacity of 'A' station to 80.2 MWe.

The 6.5 MW HP turbine generator, G2, first produced power to the North Island grid during November 1958. The power generation equipment in stage 1 and 1A in the 'A' station was installed and commissioned by September 1960.

The steam winning had progressed so satisfactorily that in 1956 extensions to stage 1 were proposed. These extensions saw two 11.2 MW HP turbines installed in 'A' station and three 30 MW mixed pressure sets (MP) installed in the 'B' station turbine hall, bringing the installed capacity of the plant up to 192.6 MW. The plant configuration is shown in Figure 3. All the machines in this extension were commissioned by 7 October 1963. The commissioning dates for the turbine generators are detailed in Table 1.

Further stages were considered in the mid 1950's to bring the total installed capacity up to between 252 and 282 MW. These plans were never progressed through to construction.

5 40 PLUS YEARS OF ACHIEVEMENT

5.1 Pressure Changes

Pressure change occurred in the liquid reservoir as a result of the production of geothermal fluid. Figure 4 plots the change with time. Boiling was stimulated in the reservoir as a result of the reduced liquid pressures and vapour zones developed at shallower levels in parts of the reservoir.

5.2 Optimisation and Efficient Utilisation

More efficient utilisation of the geothermal energy and in particular the utilisation of the geothermal water underlies the engineering of the Wairakei development.

The Wairakei development initially was a two pressure system with steam supplied at HP and IP pressures (Turbine Inlet pressures of 12.5 and 3.5 bar g.). 20" diameter HP and IP pipelines carried steam from the steamfield to the power station. 3 larger 30" diameter steam lines were installed later. The reservoir fluid was separated at individual wellhead separators, with the steam transmitted to the power station and the water discharged to the drainage system.

It was recognised that additional steam could be produced from the discharged water. The pilot hot water scheme was one of the early efficiency projects. The scheme was designed to collect water from several eastern borefield wells, transmit it to the power station and produce additional IP and LP steam. The scheme was installed but as the enthalpy of the eastern field wells rose once production commenced, the amount of water available for processing decreased significantly and the scheme never functioned properly. After about a year of operation the pilot hot water scheme was decommissioned.

Further engineering improvements were developed and implemented by 1974. A 48" diameter low pressure steam main was installed to bring low pressure steam from the field down to the power station. Flash plants were installed to flash additional steam off from the water prior to discharge. A three pressure system was in operation in the Wairakei steamfield at this time with steam being supplied to the power station at HP, IP and LP conditions (Stacey and Thain 1983).

The high pressure turbine inlet pressure was reduced, over time to enable more fluid and energy to be produced from the available production wells to compensate, in some measure, for the decline in reservoir pressure. Figure 4 plots the HP turbine inlet pressure with time. On the 30 November 1982 the HP steam system was decommissioned (Morris 1983). The HP pipeline system was converted to IP and the 4 HP turbines decommissioned. The installed capacity of the plant became 157.2 MW. The steamfield returned back to a two pressure system supplying IP and LP steam to the power station.

Additional wells were connected up to the power station in the early 1980's and additional drilling and connection of wells has been undertaken since that time.

A 1.2m (48") diameter intermediate pressure steam pipeline was constructed and commissioned in December 1992.

Further efficiency gains have been achieved by replacing the pressure reducing valves in the low pressure steam system. A refurbished turbine and induction generator (G14) capable of producing up to about 3.5 MW was installed and synchronised on the 5 May 1996 (Figure 5). The installed capacity of the plant increased to 161 MW.

The Prawn Park operated by New Zealand Prawns Limited uses heat from some of the discharged geothermal water to rear prawns in 6 hectares of ponds on land adjacent to the Wairakei Power Plant.

The use of Organic Rankine Cycle heat recovery systems (Binary Plant) are being applied to geothermal installations. Planning to install a 14 MW Binary Plant to utilise the geothermal water that is discharged from the steamfield LP system was permitted under the Resource Management Act in May 1999. The economic climate will determine when the binary plant is constructed.

5.3 Environmental Enhancement

Scientific investigation and testing of reinjection of separated geothermal water has been undertaken at Wairakei since about 1978. Initial work was focused on seeking to better understand fluid flow in the reservoir.

From 1980 to 1984 six trial injection tests were undertaken. Consents for a larger test were applied for in 1986 and granted in 1988. This involved reinjection of up to 15% of the separated geothermal water into a well (WK62) in the eastern field from April 1988 to May 1989.

Consents for the next stage of reinjection of up to 60,000 tonnes per day were applied for in January 1992 and issued in August 1996. Construction and well drilling was undertaken. Injection under the granted consents is being undertaken with the water being injected to the east of the production area.

Reinjection is a significant reservoir management challenge at Wairakei because it has the potential to cool the underground resource, suppress hot recharge and consequently reduce the production capability of the field.

5.4 Consistent and Reliable

Wairakei is now a consistent and reliable producer of electrical energy. But it wasn't always like this. In 1958 with only a few wells connected to the steam supply network the generation plant was vulnerable to minor pressure fluctuations in the steam system. Various plant items were also unreliable. A notable example of this was the high speed rotary gas exhausters installed on the 'A' station LP condensing turbines. These units were unstable and unreliable. They were subsequently replaced with steam jet ejectors. Modifications to other pieces of plant to improve their reliability have also been undertaken through the years.

The focus of seeking to be consistently generating, through high availability, high load factors and low forced outage rates has been the driver for the achievements at Wairakei. Figure 6 is a plot of availability with time showing availabilities of greater than 80% being consistently achieved. Availabilities consistently above 95% have been achieved in the mid to late 1990's.

The annual energy production from the plant is plotted in Figure 7. During the early 1960's Wairakei supplied up to 50% of the North Island generation at times of low summer load. The generation from Wairakei peaked at 173 megawatts in 1965 and in that year Wairakei generated 12% of the New Zealand's annual electricity demand. Figure 8 is a plot of the annual generation contribution from Wairakei.

Currently the plant produces about 1300 GWH per annum enabling Wairakei to contribute about 3.5 % of the electricity produced for New Zealand.

Focus on steam supply availability, high load factors and plant reliability has resulted in the maximum annual energy generation ever of 1353 GWh nett being produced during 1998. Peak generation levels of 170 Mwe have been achieved during 1999.

5.5 Management Changes

The operation of the plant has been undertaken under various management regimes.

From 1958 to 1987 the plant was run by the Government who where responsible for electricity generation in New Zealand. The Minister of Electricity over saw the government department that generated electricity and maintained the high voltage grid for the nation. The Wairakei Geothermal Plant was controlled by the Minister's department.

On 1 April 1987 the New Zealand government sold the government department responsible for electricity generation to the Electricity Corporation of New Zealand Limited (ECNZ) for $6.3 Billion dollars. ECNZ was a State Owned Enterprise with a board of directors who in turn were responsible to two Government Ministers, the Minister of Finance and the Minister of State Owned Enterprises. The two Ministers had 100% share holding in the enterprise. The Wairakei Geothermal Plant was sold to ECNZ as part of this transaction.

On 1 February 1996 the New Zealand government divided ECNZ up into two State Owned Enterprises. An approximate 70 / 30 percent split was made. ECNZ retained the 70 percent component and Contact Energy Limited (Contact) was formed to manage the 30 percent. Contact's total assets were valued at $NZ1.6 billion. The Wairakei Geothermal Plant was part of the assets transferred to Contact.

During 1999 the New Zealand government sold Contact. On the 24 March 1999 the government announced that a 40% shareholding (241,580,000 shares) was to be sold to Edison Mission Energy as a cornerstone investor for $NZ1.208 billion dollars . The balance of the shares (362,370,000) were sold by public float at $NZ3:10 per share, with stock exchange trading commencing on 11 May 1999.

6 THE FUTURE

The future at Wairakei is promising. The field has a proven record of supporting the power plant with over 40 years of production history behind it.

More drilling will be undertaken to makeup for production decline. Both steam and liquid wells will be drilled. The Te Mihi area is expected to be the focus of this activity.

The most important reservoir issue is the management of injection. It will be a key to ensuing longevity of the resource.

Throughout the past 40 years changes to the steamfield, plant and management have all been made. Change will continue to occur. In particular changes will continue to be made in order to more effectively utilise the geothermal resource. Economics will be the overriding driver for plant changes and modifications.

Wairakei will continue like a grandfather's axe – four new shafts, two new heads, but still the same axe. Wairakei stands as a remarkable achievement in harnessing geothermal energy.

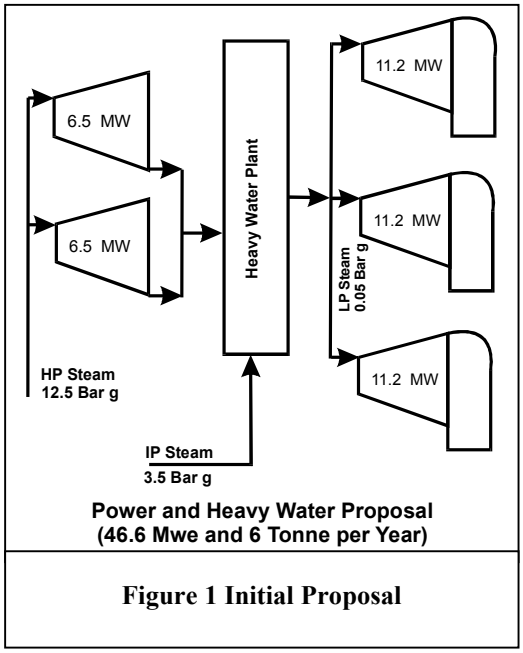

Figure 1 Initial Proposal

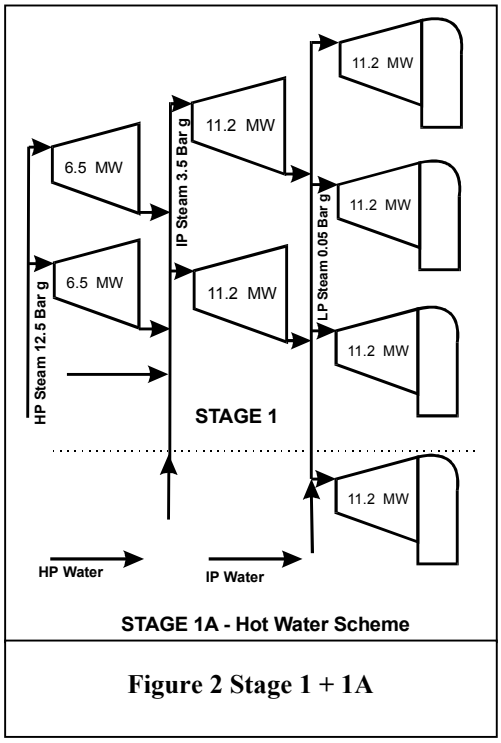

Figure 2 Stage 1 + 1A

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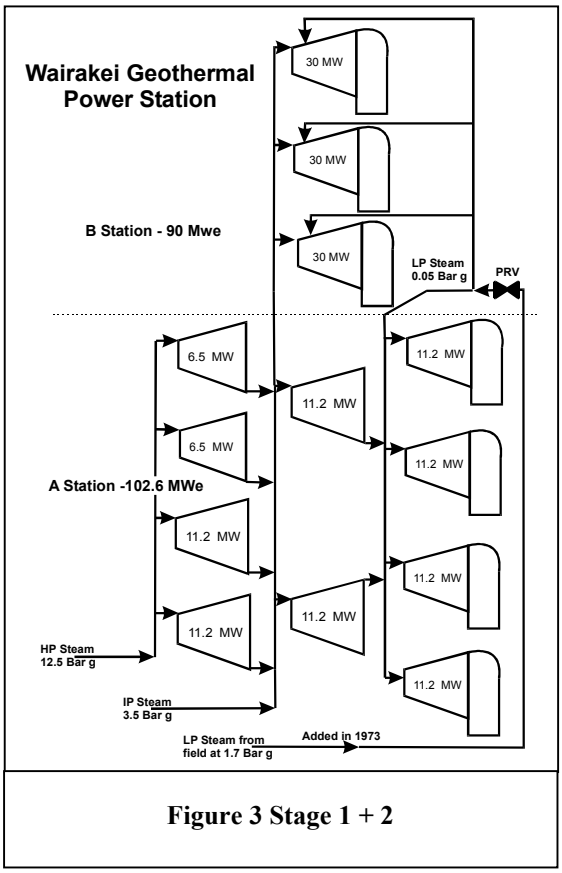

Figure 3 Stage 1 + 2

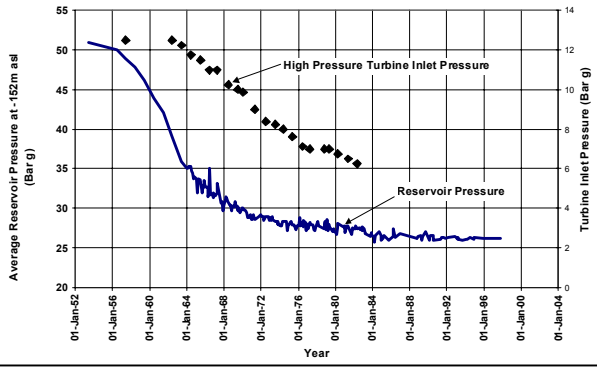

Figure 4 Pressure Change with Time

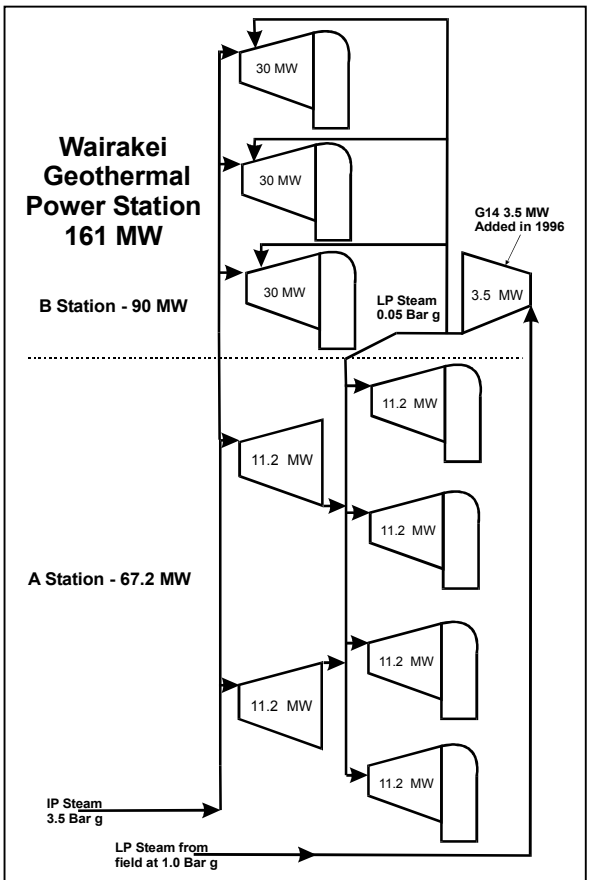

Figure 5 – Installed Plant 1996

Unit	Type	Mwe	Commissioning Date
G1	IP	11.2	11 July 1959
G2	HP	6.5	15 November 1958
G3	HP	6.5	10 April 1959
G4	IP	11.2	20 November 1959
G5	HP	11.2	14 March 1962
G6	HP	11.2	5 July 1962
G7	LP	11.2	29 June 1959
G8	LP	11.2	30 October 1959
G9	LP	11.2	30 March 1960
G10	LP	11.2	15 September 1960
G11	MP	30	28 August 1962
G12	MP	30	23 January 1963
G13	MP	30	7 October 1963
G14	LP	3.5	5 May 1996

LP	Low Pressure
IP	Intermediate Pressure
HP	High Pressure
MP	Mixed Pressure

Table 1 – Turbine Commissioning Dates

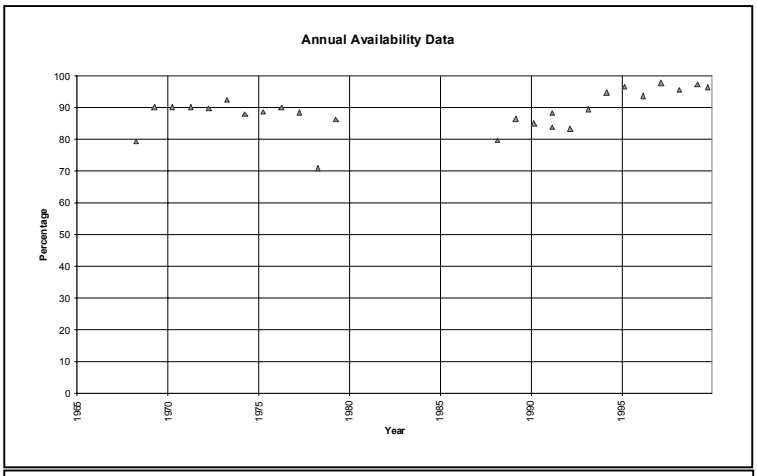

Figure 6 – Availability Data

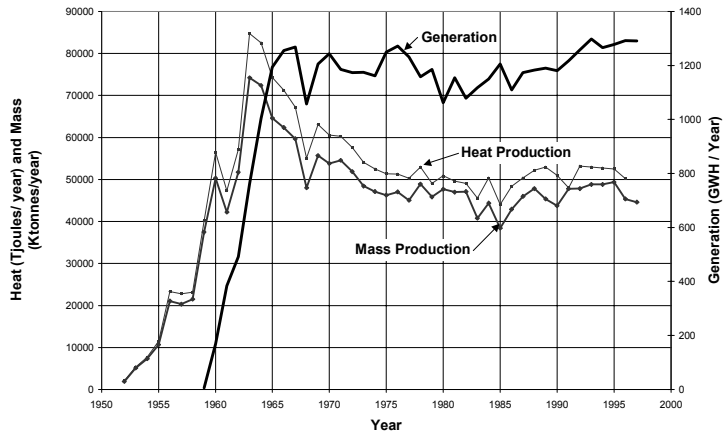

Figure 7 Wairakei Production Data

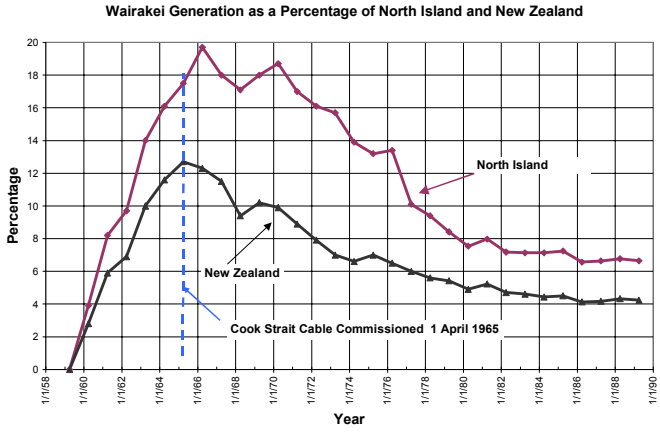

Figure 8 – Wairakei's Production Contribution