GEYSER OBSERVATIONS AT ORAKEIKORAKO, NEW ZEALAND

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SUMMARY – Since 1995, eruptions of geysers at Orakeikorako have been instrumentally recorded several times a year. The aim is to provide quantitative information about the performance of most active geysers there and to show any variations of activity over successive years. Graphs of data are provided and show results through time. Analyses of recordings show changes through time but without any clear overall trends. To date no meteorological records have been collected at Orakeikorako although such information may indicate factors that could directly relate to variations in geyser performance..

1. INTRODUCTION

Orakeikorako has long been known for its geysers and geothermal activity, with many written accounts dating back to the middle and late 19th century. Detailed descriptions and maps of the geology, hot springs and geysers was published by Lloyd (1972). That work also includes much historical information about geyser activity, particularly in the early to middle 20th century. Under the Resource Management Act (RMA) 1991, Waikato Regional Council, also known as Environment Waikato (EW) has a statutory requirement to understand the status and condition of, among other parameters, the geothermal fields and areas within its jurisdiction.

As part of this obligation EW has a continuing program of observations and measurements for geothermal areas, which includes measured and recorded conditions of hot springs and geysers. Inspections are made routinely about every two months. Computer based records of data are maintained in addition to periodic reports on observations, changes and other issues that may impinge on sustainable use of these areas and features.

Data logged records of geysers have been collected for EW since 1995 but have not previously been processed into any summary of results other than for statements in annual reports. This paper gives some results of geyser records from Orakeikorako, but is not a complete summary of all geysers there, nor a complete analysis of all geyser data collected, but is data for several geysers in some detail.

Geysers are rare phenomena of nature restricted to few countries worldwide. A summary of geyser occurrences and numbers is given by Bryan (1995), in which USA and Russia (formerly USSR) rate as the most abundant sites, followed by New Zealand, Iceland, Chile and Tibet. Fewer numbers occur in several other countries. In New Zealand, some 220 geysers existed in the early twentieth century but by 1980 only about 65 geysers remained. Human activity has been directly implicated in all instances of loss.

During 1995-2004, NZ geysers were active at Orakeikorako (35), Rotorua (12), Waimangu (2), Rotomahana (5), Waiotapu (4) and Tokaanu (2). Geysers have a strong tourism value and attract ~2 million visitors annually to Rotorua (Butcher, et al., 2000) and a similar number to the Waikato region (Luketina, 2002).

Geysers can be very sensitive to local ground water fluctuations and are easily extinguished. In the Geological timescale they are usually short lived phenomena, persisting for perhaps only a few 100s of years. Because of their rarity, scenic and intrinsic values, they gain attention from both statutory authorities and public alike. Detailed records of activity and changes provide transparent information about their presence and characteristics.

2.0 GEYSER RECORDINGS

Reliable data logged records require several factors to be determined prior to deployment of a recorder in order to have confidence in the subsequent results. Typically a geyser is recorded for 10-25 days in the EW monitoring programme, or until the recorder storage is full. This provides a dataset of about 100-300 eruptions.

2.1 Data Collection

Geyser eruption records are collected using SAPAC data loggers, which are robust and inexpensive (~$675). Temperature, date and time are recorded at preset intervals. Geyser records do not require precise temperature values but do need dependable detection of sudden changes from ambient to boiling temperature and back again. Any geyser to be recorded firstly needs to be observed through one or more eruptive cycle in order to gain some indication of length of each

eruption. The frequency of recordings can then be chosen to provide well defined plots of eruptions. For example, a geyser that erupts for about 10-40 minutes would be recorded at one minute intervals, whereas 1-3 minute eruptions might be recorded at ten second intervals.

An outflow or splash zone must be chosen for placement of the thermocouple sensor where outflows are going to indicate reliably the true start and stop of each eruption. The sensor also needs to be securely anchored to prevent washing away, yet positioned unobtrusively to avoid detection by the public.

2.2 Data Processing

SAPAC units store 32 kilobytes of data, or 28,800 readings of temperature, date and time. They are unloaded into a computer and data is then processed to give statistics and graphs. Data can also be imported to Microsoft (MS) Excel. Threshold values can be chosen to give percentages of time above this. Data has also been manually processed to select time series that group results into a range of 20-40 classes of time intervals. This illustrates visually the range of eruption durations and allows rapid comparisons with other datasets.
Most data is graphed to show the percentage of time in each class, which is the Frequency Percent scale shown in graphs given here. For example, an eruption frequency percent of 33% for 2-4 minutes duration of eruptions means that 33% of all eruptions recorded were in that interval range.

Similar graphs are produced for subsequent dormancies, as these indicate the recovery or recharge times for a geyser. Again variations or trends through time can then be identified. Total period or duration (from start of an eruption until start of subsequent eruption) of geyser cycles is not usually plotted, because this combines the eruption and the subsequent recharge times and camouflages any trends in these two phases.

3.0 GEYSER OBSERVATIONS

Orakeikorako geothermal system has several separate geyser fields. Within Orakeikorako, this paper discusses geyser activity and recordings by discrete areas within Waipapa Valley only. No data has yet been obtained from geysers along Red Hills, which are only accessible only by boat. Maps of locations and information about springs are given by Lloyd (1972). Some geyser data is given in Table 1 and further information is in Annual Reports of geothermal monitoring to EW.

3.1 Rainbow Terrace and Scarp Geysers

Rainbow Fault scarp is 5-8 m high and >150 m long with several active geysers along its base and scarp face. A prehistorically active section of this scarp extends further southwest, upon which My Lady's Lace (S111, or Soda Fountain) is located. Geysers at the base of Rainbow Fault are the most persistently active of all at Orakeikorako and it may be significant that these are also at the lowest elevation. Those located here include Diamond (S95), Bush (S96), Cascade (S97), Sapphire (S106), S109 and S115. The last two are located on an intermediate level small terrace just east of Sapphire and informally named Coronation Terrace (T. Spitz, pers. Comm..).

Sapphire Geyser (S106)
This is located at the base of Rainbow fault scarp ~30 m north of Diamond geyser (S95). Sapphire has a vent of ~0.3 x ~0.2 m area. It typically erupts for ~2 minutes every 20-30 minutes up to ~2 m high with overflows of ~1 litre per second (lps); i.e. its erupted volume is ~0.12 m^3 per eruption. It has been almost continually active during 1992-2004. Strongly steaming phases sometimes accompanied by noisy boiling and water levels to ~0.3 m below overflow may occur every few minutes between eruptions.

It has no apparent relationship with any other geysers or nearby spring activity, the nearest being Cascade geyser (S97), ~7 m south and several metres up the Rainbow fault scarp. Cascade has had many episodes of noisy cyclical boiling with occasional eruptions to ~1 m high and <0.5 lps overflow. In the 1950s it had much larger eruptions, at which times it visibly erupted in concert with both Sapphire and Hochstetter Pool (S98).

Diamond Geyser (S95)
The most frequently active and visible of all geysers in Waipapa Valley, it is located near the southern end of Rainbow Fault ~3 m above its base. Diamond has a surface pool of ~2.55 m^2 area and typically erupts 2-3 m high for 20 minutes up to >3 hours, with subsequent dormancies of 20 minutes or more (Figure 1). Outflows are usually ~1-2 lps but occasionally it can erupt 7-8 m high with copious overflows (>10 lps) that may flood over the boardwalk below. Outflows vary over 1-15 m^3 for each eruption.

A 1951 Department of Scientific and Industrial Research (DSIR) unpublished account records two eruptions observed, each c. 5 minutes long and c. 8 minutes apart. No other measured records of its activity are known from then until the 1960s, when Lloyd (1972) described its activity as having irregular eruptions that lasted from a few minutes up to several hours each. These were <3 m high but sometimes up to 9 m high.

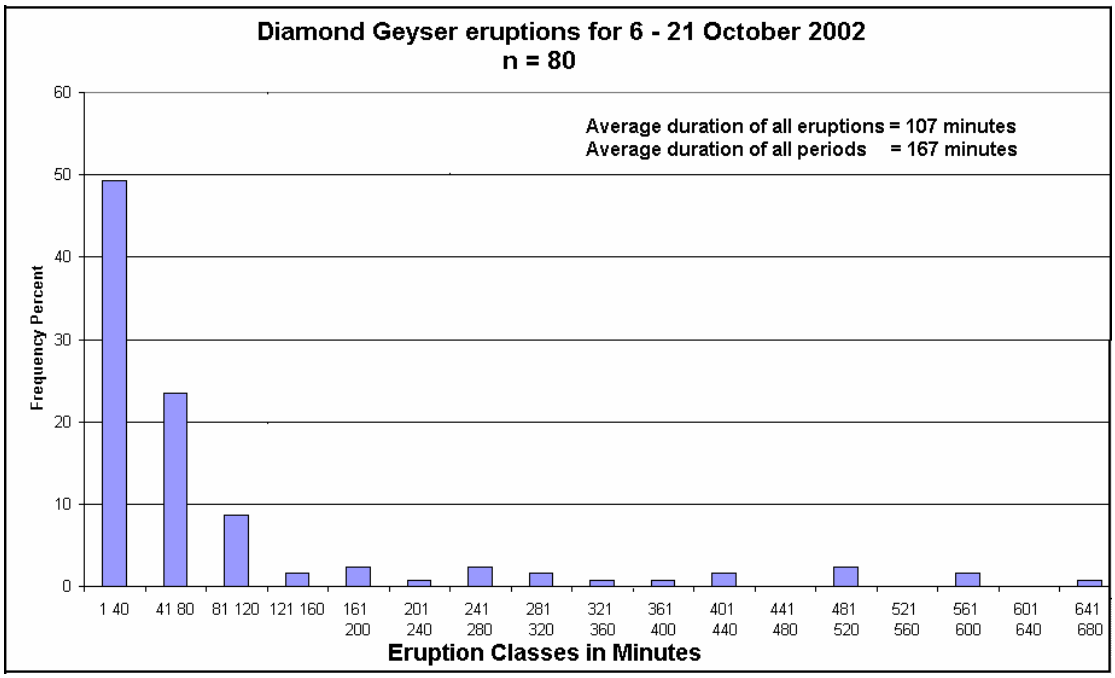

Figure 1: Plot of frequency percent eruption durations for Diamond geyser (S95) in February to March 2002. Recording population of 80 eruptions and subsequent dormancies. See also Table 1 for further data summaries.

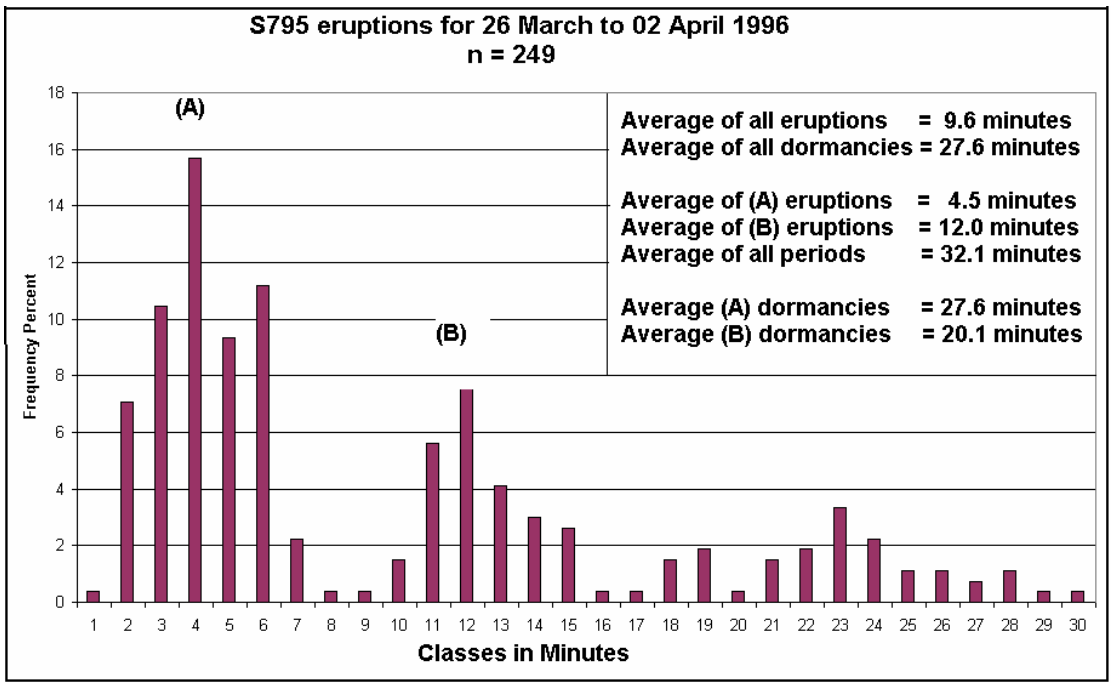

Figure 2: Plot of frequency percent eruption durations for geyser S795 on Artist's Palette Terrace. See also Table 1. Plot shows two eruption duration maxima, yet both these have identical durations of their subsequent periods and all eruptions show an unfaltering regular alternation from the long to short eruptions, all with identical dormancies and periods. This activity may be unique worldwide.

Table 1: Summaries of eruption records for some geysers. All eruptions between dates of each dataset were recorded. Duration of eruptions and dormancies are in decimal minutes. This is not the complete records of all data collected.

Geyser No. and Name	Recording **Dates**	**Average Eruption (minutes)**	**Average Dormancy (minutes)**	**Percent of Day in Eruption**	**Number of Eruptions per Day**
S106 Sapphire	16--27 Nov 2003	2.04	41.33	4.7	33.2
	25--27 June 2001	2.43	27.1	8.43	50.0
	24 Aug--12 Sept 1995	4.77	21.41	17.29	52.2
S95 Diamond	3--23 March 2004	147.5	38.2	83.7	8.18
	14 Oct--5 Nov 2003	63.2	36.1	62.09	14.1
	6--21 October 2002	107.2	59.7	65.42	8.78
	18 Feb--12 Mar 2002	280	127	68.91	3.545
	14--29 Nov 2001	307	121.2	70.04	3.28
	25 Jun--9 July 2001	369	128	74.78	2.92
	13--21 October 2000	226	86.3	73.85	4.71
	9--20 February 1996	829	216	83.8	1.46
	5--19 May 1995	1037	185	87.4	1.21
S96 Bush	9--20 February 1996	4.41	48.17	9.24	30.17
S126 Wairiri	4--18 March 2003	15	345	4.17	4.0
	17 Nov--4 Dec 2002	17	220	8.1	7.0
S708 Kurapai	3--23 March 2004	22.5	948	2.35	1.5
	16 Nov--9 Dec 2003	26.2	1071	2.2	1.21
	4--17 March 2003	13.0	259.5	4.96	5.33
	18 Nov--5 Dec 2002	11.7	205	5.35	6.56
S735	27 Feb -- 7 March 1997	3.4	48.5	6.50	27.6
S795	26 Mar--02 Apr 1996	4.5 (short)	27.6	26.07	39.2
		12.0 (long)	20.1	26.07	39.2

Based upon recordings during the 1995-2004, Diamond has sometimes had short eruptions (4-10 minutes) interspersed with much longer duration ones of 40-500 minutes. Therefore visual accounts of a few eruptions 4-10 minutes long with dormancies of 5-20 minutes may be misleading, because it commonly had these types of eruptions during 1995-2004, which were interspersed with much longer eruptions and dormancies. These short eruptions are considered to be "failed" longer eruptions, as they often repeatedly occur before a long eruption.

Bush Geyser (S96)
S96 is located at the base of Rainbow fault scarp, ~10 m north of Diamond geyser. It is concealed by manuka shrubs and not visible from the path, but when active it can be heard vigorously boiling. Its vent is ~0.25 m^2 with mamillary sinter surroundings. When active, it erupts every <50 minutes for <4 minutes, with <0.1 lps splashing overflow. Between eruptions its water level retreats ~1 m below overflow. No interaction with Diamond or Sapphire geysers has been recognised.

3.2 Golden Fleece (Te Kapua) Terrace

All geysers here are close to the scarp base. Since routine EW monitoring began in 1995, S122, Prince of Wales Feathers (PWF, S123), Dreadnought (S125) and Wairiri (S126) geysers have all been active for varying times. In the late 1940s both Cauldron (S124) and Dreadnought (S125) were geysering and in 1954-55 Petrifying Pool (S121) also geysered. During 2002-2003 PWF was active, coincident with high waterlevels in all surrounding springs. PWF erupted every 5-8 minutes to <0.7 m high for <1 minute, with ~0.3 lps overflow into Cauldron.

Kurapai Geyser (S708)
This is an isolated geyser located on the southern end of Golden Fleece (or Te Kapua) fault scarp. When active it is visible from the main reception building, but is not accessible to visitors in Waipapa Valley. There is little recorded about this geyser. Lloyd (1972) described its activity in late 1962 and that it was also then known as Bendix Washer geyser, in allusion to its eruptions simulating the actions of a then popular washing machine.

In late 1961 Kurupai geyser was modified by having a ~2.5 m length of 100 mm dia. steel pipe cemented upright into its vent, in order to exclude cooler waters from its surrounding pool. It then commenced eruptions ~18 m high (p.81 in Lloyd, 1972). Lloyd observed how the pool previously would fill with water, which then quenched incipient geysering activity. Since 1961 it has geysered on numerous occasions through the following decades. In 1983 or 1984, Kurapai erupted continuously for 80 days, then was inactive for about 1½ years. It erupted in July and August 1992 on many occasions, as recorded by Koenig (1992). However, when Tim Boddie and Terry Spitz sold the tourist resort to Craig and Pippa Gibson in 2001, Kurapai had not been seen erupting for several years. Craig found the steel pipe had corroded and collapsed, so that its erupted waters were being dispersed laterally and were unable to erupt vertically. He removed the steel pipe remnants and since then Kurapai has resumed vertical eruptions 6-10 m high..

Wairiri Geyser (S126)
Located on the southern edge of Golden Fleece Terrace, ~5 m west from the fault scarp base. Episodes of geysering activity coincide with high water levels in nearby pools. It geysered for c. six months in 1982-83 (Allis, 1983) and again during late 2001 until March 2003.

3.3 Artist's Palette Terrace

Many geysers have been active here through 1995-2004, with detailed earlier accounts of geyser activity given by Lloyd (1972). Some of these have been instrumentally recorded and many photographed, but while areas of the terrace are boiling and/or overflowing it is considered unsafe to walk about on. Therefore few geysers have been recorded and seldom on repeated occasions. Few features are named on this terrace and they are referred to by their catalogued numbers (p.84 in Lloyd, 1972). Many of these springs occasionally exhibit spectacular geysering, but they are generally inaccessible. During 1995-2004 there have always been active geysers on Artist's Palette. Those observed include: 735, 736, 742, 766, 772, 777, 778, 788, 789, 792, 795, 798, 806, 812, 817 and 1012. Wet surfaces around vents are clues they are actively geysering, in which case waiting an hour or so may be rewarded with observed eruptions.

4.0 DISCUSSION

Most geysers at Orakeikorako have eruptions of typically only a 1-5 minutes duration, with subsequent dormancies lasting many hours. From observations of outflows it can be inferred that most of these geysers discharge only small volumes (<3 m^3) of water in each eruption.

Estimated discharge volumes per eruption for some of these geysers are: S96, S106, S109, S115, S788, S795, (all <0.3 m^3); and S735, S772, S777, S778, S806 (all <0.5 m^3). By contrast S126 (Wairiri) and S708 (Kurupai) erupt 3-5 m^3 and S95 (Diamond) erupts 10-100 m^3. These latter three all have long eruption durations (20-500 minutes) and consequently greater quantities of water are erupted.

Lloyd (1972) described geyser activity before, during and after Lake Ohakuri was filled in January 1961. This raised the Waikato River by 18 m alongside Waipapa Valley. Many springs and geysers underwent highly variable activity about that time; some were briefly reactivated and most (approximately 75%) permanently drowned. Others had hydrothermal eruptions that greatly modified their vents and outflows.

An unnamed geyser (S795) on Artist's Palette Terrace is perhaps unique worldwide because it has a bimodal eruption duration, for which both eruption lengths still have the same period durations (Figure 2). This is interpreted as being two separate geyser chambers supplied by one upflow and sharing a common vent. Boiling occurs at the same interval but one chamber only erupts every second time, taking exactly twice as long to recharge and erupt. Communications with the USA based Geyser Observation and Study Association confirmed that no other such eruption style is known anywhere else, although bimodal eruption lengths are common. In NZ only Pohutu geyser is known to have had bimodal eruptions, during 1985-1989 (Cody and Lumb, 1992).

Observations in NZ and overseas have found that earthquakes can sometimes be related to sudden changes of geyser eruption styles. Changes in local rainfall patterns, groundwater levels and sudden air pressure fluctuations have also been correlated to changed geyser activity both here (e.g. Allis, 1983) and overseas. At Orakeikorako, recorded geysers sometimes show trends of gradually changing eruption styles over several years then reverting to earlier styles without clear cause or explanation (e.g. Diamond geyser, Table 1). Seismicity is also suspected as significant in causing some changes of activity here.

Artist's Palette Terrace geysers continually vary over months to years, with some vents abruptly ceasing all activity and becoming dry, cold and empty. At such times another area of the Terrace usually commences boiling overflows and geysering, suggesting that an exchange of function occurs between vents. Both here and elsewhere at Waipapa Valley, several geysers are invariably recorded simultaneously in order to detect interactions or sympathetic eruption mechanisms. To date geysers along Rainbow Terrace scarp have not shown any such connections, although those on Artist's Palette Terrace often play in unison.

5.0 ACKNOWLEDGEMENTS

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6.0 REFERENCES

Allis, R.G. (1983). The eruption characteristics of a recently active geyser at Orakeikorako geothermal area. *Proc.5th NZ Geothermal Workshop* 1983, 43-48.

Bryan, T.S. (1995) *The geysers of Yellowstone.* 3rd ed. University Press of Colorado.

Butcher, G., Fairweather, J.R. and Simmons, D.G. (2000). *The economic impact of tourism on Rotorua.* Tourism Research and Education Centre Report No.17/2000, Lincoln University.

Cody, A.D. and Lumb, J.T. (1992). Changes in thermal activity in the Rotorua geothermal field. *Geothermics,* Vol.21(1/2), 215-230.

Koenig, E.(1992) “Field observations of Diamond and Bendix geysers, Orakeikorako, New Zealand”. *Proc. 14th NZ Geothermal Workshop* 1992, pp.127-131.

Lloyd, E.F. (1972). Geology and hot springs of Orakeikorako. *DSIR NZ Geological Survey Bulletin 86,* Wellington, 164pp.

Luketina, K.M. (2002). Numbers of visitors to Waikato geothermal attractions. *Proc.24th NZ Geothermal* Workshop 2002, 11-16.