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Concurrent Land Use in Geothermal Steamfield Developments

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ABSTRACT

In this paper the land uses in and around New Zealand's geothermal power plant developments are discussed. The effects of the development on land use are also addressed. In some cases the development of the geothermal resources has enhanced the activities such as tourism near the developments; however, in other cases developments have had limiting effects.

1. SURVEY METHOD

The land uses in and around each development area was estimated from aerial photos (Land Information New Zealand, 1995–97, Google Earth 2009), topographic maps and field observation.

The area exclusive to the Development Area (DA) for each development was defined as land which would not be practical for the station developer to grant exclusive access to another party; for example, the fenced off land around the power house, along pipe routes or on well sites. Within the DA other parties may have access; however, the use of the land would be at the discretion of the operator. The DA was taken to be 5m each side of the pipelines.

An Affected Area (AA) is defined as the area 100m out from the DA. The AA is arbitrary and in practice the effects of the development would be felt further away; for example, subsidence (Bloomer 2001) or not at all within the AA is dependent on the location.

The DA and AA do not include remote not connected well sites or allowance for future steamfield expansion. Actual land ownership or access agreements held by the developer were not considered. Power lines were not included in the calculations.

Refer to Figure 3 for an example of the AAs and DAs illustration.

For each steamfield the area of the DA and AA were divided by the installed power generation capacity (MW). This gives an indication of land use efficiency and is an interesting comparison between fields (Refer to Table 1 and Figure 1).

Within each DA and AA, the area of each primary land use activity type was calculated (Refer to Table 2 and Figure 2). Secondary land use has also been noted.

2. DEVELOPED FIELDS

There are seven geothermal steamfields in New Zealand which have either power generation plant and/or large direct heating systems operating. This paper records the staged development in some of the steamfields.

2.1 Wairakei Power Station

Wairakei was the first and is the largest steamfiled development of geothermal energy in New Zealand. In the mid 1940s, New Zealand suffered shortages of electricity resulting from economic growth and low hydro generation in two dry years. A government report published in 1947 proposed using geothermal energy to generate electricity to overcome these shortages. Wairakei was chosen for the first development as the surface geothermal activity demonstrated good potential. The adjacent Waikato River as a source of cooling water was another factor. Wairakei steamfield was built on government land. It was reported that, apart from the tourist hotel and its grounds and golf course, Wairakei was an unproductive wasteland'. As the land belonged to the government, no private landowners were involved and being remote from habitation it was expected not to impact on people or the tourist attractions of the Taupo area. But geothermal surface features have been affected and Tangata Whenua (native peoples) have felt aggrieved.

Since 1947 a considerable development has taken place within and next to the AA. Wairakei has a most diverse set of current land use, including light industry, tourism, a major State Highway, forestry and farming. While the station is owned by a listed company, most of the steamfield is still in public ownership. This ownership means there is more public and business user access to this land.

Wairakei has a large number of wells which are connected by a considerable amount of piping. Land isolated between the pipelines has been included in the DA calculation.

The Wairakei Power Station consists of a number of steam turbines. A binary plant uses separated geothermal water for power generation. Therefore, the DA for the generation plant is large. The consents for new station in the western area of the field have been consented but the develop has not advanced at the time of writing this report.

The Poihipi Station is located on the west edge of the resource. It was originally commissioned using nearby dry steam wells. There is now a pipeline supplying steam to the station from the main Wairakei steam field. The buried condensate reinjection pipeline has been included in the DA and AA.

2.2 Kawerau

The Kawerau steamfield supplies steam to Tasman Pulp and Paper Mill. The steam is used for process heat and the geothermal separated water is used for power generation. There are also two binary plants generating power from the separated geothermal water. The steam supply to the mill is equivalent to a 40MW power plant. In 2008 a 100MW power station was commissioned. There are also two small binary plants using separated geothermal water from the

mill supply system. A third binary plant (KA24) operates independently of the mill supply and the 100MW station.

The Mill, which first used geothermal steam in 1957, about a year before Wairakei, was sited at Kawerau partly because of the potential use of geothermal energy. Nearby Murupara was also considered, being the centre of the Kaingaroa plantation forest; an alternative site was Mt Maunganui, because of its shipping port. However, Kawerau was promoted by the Commissioner of Works, E.R. McKillop, who recognized the potential use of geothermal energy. Sir James Fletcher, chairman of the Tasman board, witnessed testing of the early bores in 1952 and commented that the geothermal energy would be a consideration in siting the mill.

The DA has been measured from the contractual points along the steam mains that demarcate between the steamfield and the mill.

The Tasman Mill and other log processing dominate land use within the AA. When the field was first developed the production wells were some distance away from the mill. The Mill operation now uses steam from the production wells surrounded by the east bank of the Tarawera River. On the west side of the river the AA includes mostly regenerating bush and some housing.

The mill supply DA is relatively small as there are no long reinjection pipelines. The DA includes the two binary plants and two ponds used for cooling separated geothermal water.

The 100MW development overlaps with the mill supply which also includes long reinjection lines. Some of the 100MW power plant production wells are located within the mill area and pipelines run close to and through mill facilities.

2.3 Ohaaki

The Ohaaki Power Station development straddles the Waikato River. The steamfield covers mostly grazing land on the east bank. The west bank is mostly forestry. On the west bank the DA includes the power station. Forest is permitted up to a few meters of the pipelines but there are no other land users around the steamfield and well sites.

On the east bank, the pipelines are not fenced and the land is farmed. A timber drying plant is located within the AA on the east bank

The AA includes two separated geothermal water holding ponds

2.4 Ngawha

The Ngawha Power Station (Koorey, 2008) is the only development outside the central North Island. The AA is extensive for the MW capacity because of the long reinjection pipelines. The expansion of the project in 2008 did not add greatly to the DA as the same reinjection pipe route was used.

The land use is mostly grazing and forestry. The reinjection pipelines skirt a large wet land with high conservation values.

The fresh water reservoir/dam built to hold supplementary injection water was added to the DA and AA.

2.5 Rotokawa

The first development of the Rotokawa Station used a back pressure steam turbine in combination with binary units for power generation. There were two production wells and three reinjection wells.

The first Rotokawa Station had a small AA. The reinjection wells were close to the production wells. Later, more remote reinjection wells were used and as a result the AA increased considerably.

In the late 2009, the 130MW Nga Awa Purua Station is to be commissioned on the field. This plant is included in this paper. This station's AA overlaps with the original station.

The AA land is used mainly for grazing and forestry. Grazing is permitted right up to the pipelines and wellheads.

2.6 Mokai

Like Rotokawa, Mokai uses a steam turbines and binary plant for power generation. Originally there were four production wells and three reinjection wells. The Station has been expanded and now uses nine production and five reinjection wells. The expansion used the same production and reinjection areas and therefore the AA did not greatly increase. A later well in the new reinjection area has increased the AA.

A greenhouse operation uses steam from a remote production well for heat and the station reinjection system for reinjection of waste geothermal water.

Mokai has a large AA. The reinjection wells are located some distance away from the station. The greenhouse operation and the production wells are included in the DA. The current use of the DA is mostly for pastoral farming. There are two minor public roads running through the AA.

2.7 Tauhara

The Tauhara field is located at the west of Wairakei and forms a part of the Taupo Township. The shallow parts of the resource are used for domestic heating.

There is one development using the deep resource. This supplies process heat to timber drying kilns and a small flow to a plant nursery. This development uses two production and two reinjection wells.

A small 20MW power station will be commissioned on the field in 2010. This plant is not included in this paper but the land uses will be similar to the kiln supply. A large power station development is also planned for the field.

3. LAND USE

3.1 Forestry

Exotic timber planting can be found in most of the AAs. Most of these plantings can be seen growing close to the pipelines. Occasionally the planting has been restricted to give a fall clearance from steamfield structures. Well sites are not planted.

3.2 Farming

Pastoral faming is present in all the AAs. In most cases, grazing of beef and dairy cattle, sheep and deer takes place right up to the pipelines and wellheads with no fencing. Farming seems to be able to continue unabated within the

AA and some parts of the DA with just some physical access issues.

There is little crop farming within any of the AAs. Crop farming is also uncommon in the general area of the developments.

A fresh water prawn farm with an on-site restaurant is located next to the Wairakei station and uses separated water from the steamfield for heating.

A large greenhouse complex is located at Mokai. This facility uses a production well which is not required by the station. There are smaller greenhouses at Wairakei, Poihipi and Tauhara. Greenhouses have also operated at Ohaaki and Kawerau.

3.3 Roading

Public roads that pass though the Wairakei, Ohaaki, Tauhara, Kawerau and Mokai AAs overlap the DAs where pipelines cross under roads (and railway tracks at Kawerau).

Where the roads existed before the geothermal steamfield developments were built, the development covered the cost of constructing under passes. Where a road is new (for example the Eastern Taupo Arterial roading project that passes over the Wairakei and Tauhara steamfield piping), there have been considerable extra costs to accommodate the steamfield facilities.

3.4 Industry

Industrial areas exist within the DAs of the Kawerau, Wairakei, Ohaaki and Tauhara fields.

At Kawerau, the large pulp and paper mill was built to take advantage of the geothermal resource. The geothermal surface piping and power plants are now surrounded by the mill and its operational activities.

At Tauhara, the timber processing plant, however, was not built on the steamfield to take advantage of the geothermal resource. The geothermal energy supply was added many years after the plant was built.

Light industry is located within the Wairakei AA. These facilities mostly service the Wairakei Station and other field construction, drilling, maintenance, science and research requirements. Some of the infrastructure developed to service the Station is now used for other activities.

A small timber processing plant is located at Ohaaki and uses heat from separated water for timer drying.

3.5 Tourism

Tourism enterprises operate within the AA at Wairakei.

The hotel and the conference centre at Wairakei were in operation before the resource was developed and continues to operate and grow.

The tourism activities at Wairakei include;

- The constructed silica terraces and Maori Cultural Experience. These were developed from the Wairakei Station Visitor Centre and the steamfield maintenance buildings.
- The Volcanic Activity Centre and shops in buildings once used for the steamfield design and drilling support.
- The Prawn Park and jet boat rides up the river close to the power station.
- The Craters of the Moon natural geothermal feature is just outside the AA.
- A road and lookout located in the steamfield for pubic viewing.
- A café operating near a site of thermal features and also allows access to these features.

At Ngawha a geothermal pool complex is located on the field but outside the AA.

3.6 Natural Geothermal Features

Most of the fields have natural geothermal surface activity within or close to the AA. In general these features have not been affected by surface works but in most fields the use of the steamfield resource has affected the surface activity.

3.7 Recreation

There are no designated recreation areas within the field's AAs except at Wairakei. The Wairakei Tourist Park is a designated recreational area. Many walking and mountain biking tracks are located within the tree plantations and in and around the Wairakei AA. It is possible to follow these tracks right into the station steamfield. There are also walking/biking tracks along the Waikato River close to the power station.

Sports fields for cricket and polo cross are located next to the Wairakei Power Station. A recent new reinjection pipeline has encroached into this area.

Two golf courses are also just outside the Wairakei AA.

The Tauhara reinjection wells are close to walking and biking tracks.

3.8 Residential Housing

There are very few houses within the AAs. The pipelines for the Kawerau KA24 station runs close to two houses.

3.9 Conservation Areas and Waterways

Land set aside for conservation is located in many of the steamfields.

The Ngawha reinjection lines are located next to a protected wet land which prohibits some operating practices that are acceptable in other fields.

Native forest on the western boundary of the Kawerau AA is in contrast to the heavy industry within the AA.

Rivers run through a number of the AAs. Both Wairakei and Kawerau steamfields discharge waste geothermal water into the rivers. This practice is being phased out. At Ohaaki subsidence has widened the river. Pipelines cross the rivers on road bridges at Ohaaki and Kawerau. There is a long single pipe span crossing the river at Kawerau.

The Rotokawa reinjection lines cross the outflow of Lake Rotokawa.

3.10 Other

A Maori Urupa (cemetery) and a Marae (meeting house) are located within the Ohaaki AA. These are being affected

by subsidence. Land areas important to Maori are also within the Kawerau AA.

National grid 220kV power lines run through the Rotokawa AA and over the steamfield piping.

4. CONCLUSIONS

Figure 1 shows the land use efficiency in terms of how many hectares of land is required to produce 1MW of geothermal power generation. Figure 1 shows that in most cases larger power generation plants have smaller Ha/MW ratios for AAs implying in general AAs of large steamfields have been used more efficiently. However, similar patterns of results do not seem to appear for DAs. The AA required for a pipeline is the same regardless of the size of the pipeline. Larger stations require large pipelines for the same AA.

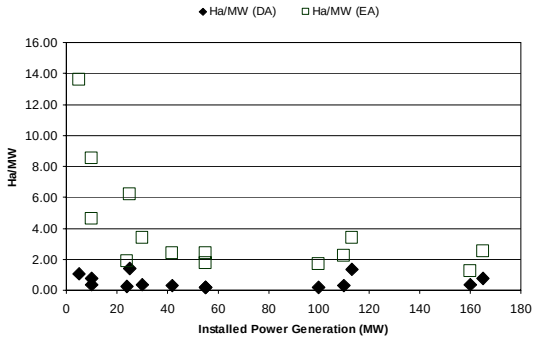

Figure 1: Land Use Efficiency: Ha/MW vs. Installed Power Generation (MW).

Table 2 and Figure 2 show the land use per activity for all New Zealand steamfields. The Wairakei steamfield has the highest number of land use activities spread over the AA. Tauhara has the lowest number of activities. Similarly, 42% of all New Zealand AAs are taken up by pastoral farming and as low as 0.2% is taken up by residential housing. The DA amounts to 22% of all New Zealand AAs.

When comparing the land use patterns, it can be noticed that there is a little difference in land use inside and outside the AA. Farming, forestry, recreation and industry activities take place as much the same way as it does away from the developments.

Little residential housing is located within the AAs. Visual and noise issues would deter housing. Town planning rules, station operator objections and land ownership would also hinder housing development.

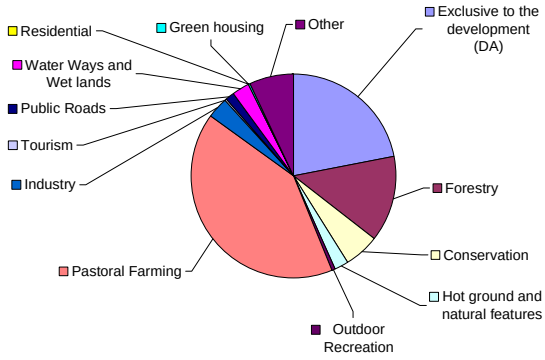

Figure 2: Land Use by Activity - All Steamfields.

The presence of the geothermal development has created opportunities for new land activities such as greenhousing.

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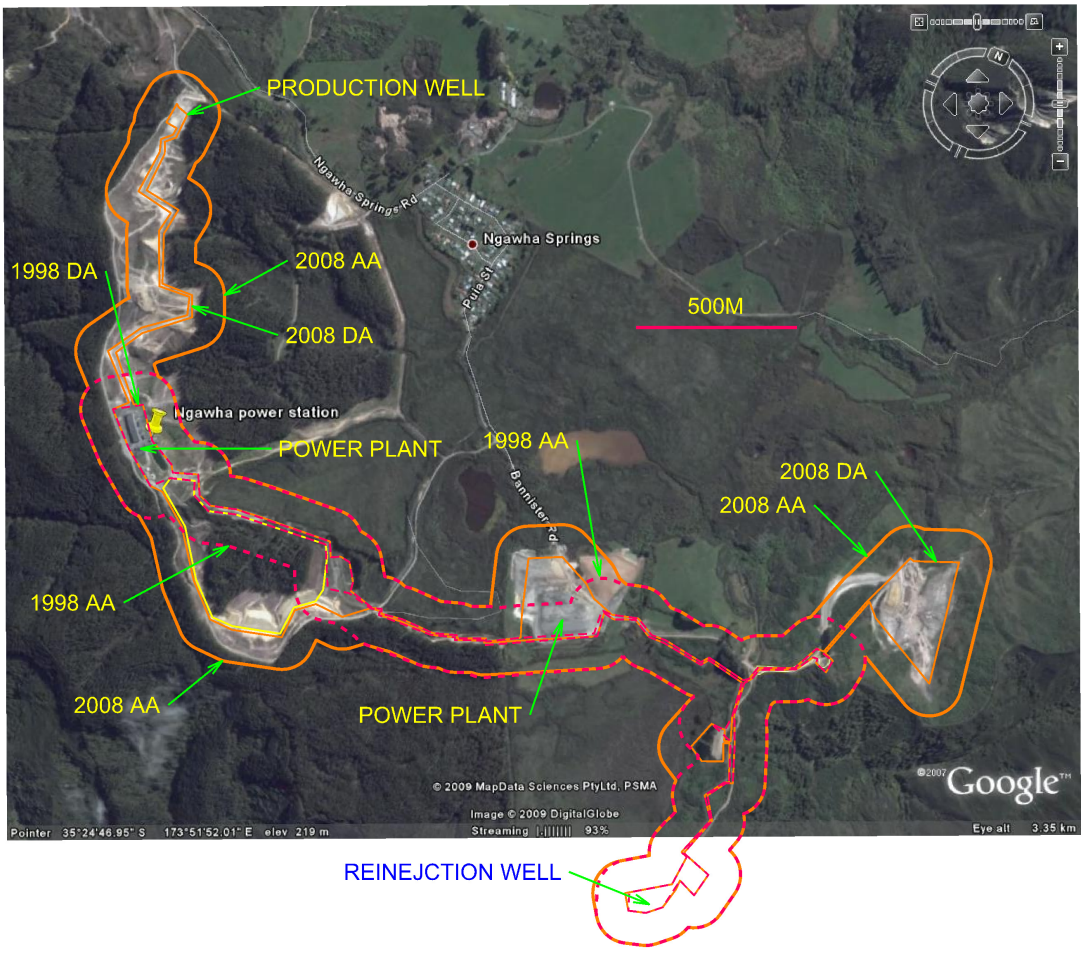

Figure 3: Illustration of AAs and DAs for Ngawha Steamfield.

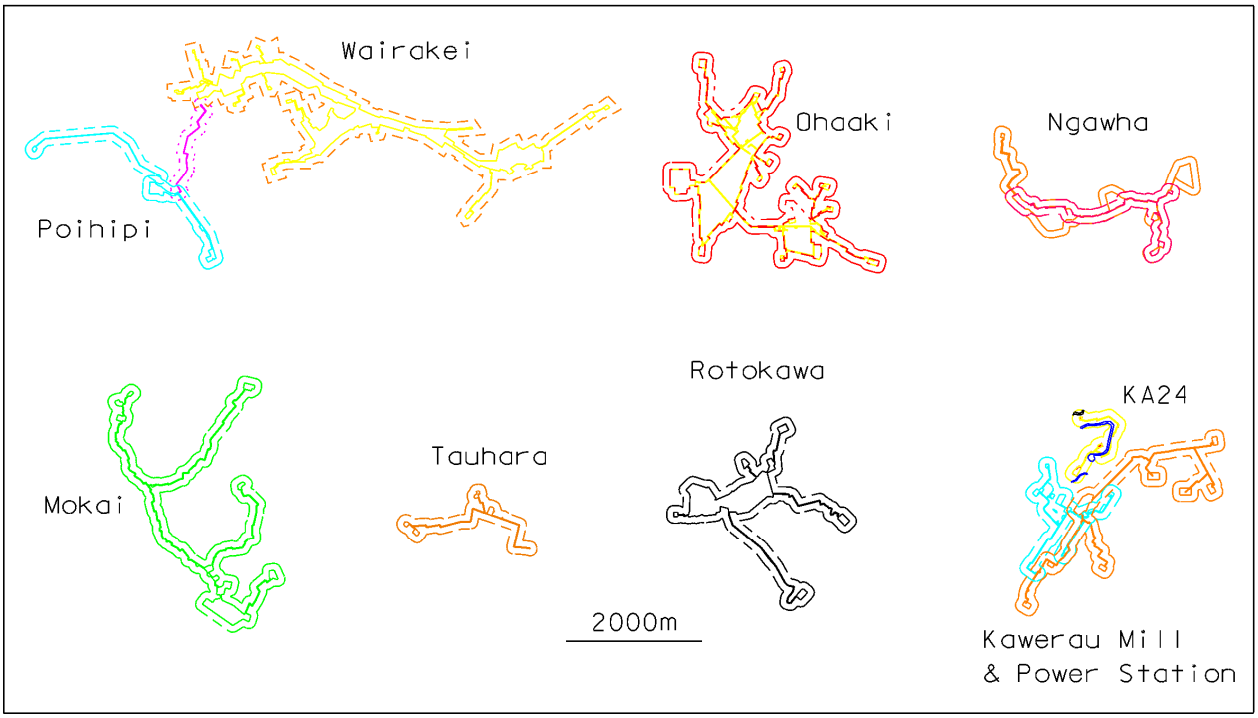

Figure 4: Outlines of each AA.

Table 1 Geothermal Power Generation (MW), Development Area (DA) and Affected Area (AA).

Project	Date Surveyed	MW*	Ha(DA)	Ha/MW (DA)	Ha (AA)	Ha/MW (AA)
Kawerau - KA24	2008	10	3	0.32	46	4.60
Kawerau - Mill Supply **	2008	42	13	0.31	101	2.41
Kawerau - Power Station	2009	100	19	0.19	169	1.69
Mokai	2009	110	32	0.29	243	2.21
Ngawha 1998	1998	10	8	0.76	85	8.50
Ngawha 2008	2008	25	35	1.40	155	6.20
Ohaaki	2008	113	152	1.35	380	3.36
Poihipi	2005	55	8	0.15	96	1.75
Poihipi expansion	2008	55	9	0.17	132	2.40
Rotokawa 1996	1996	24	6	0.25	45	1.86
Rotokawa 2008	2008	30	11	0.36	102	3.39
Rotokawa 2010	2010	160	52	0.33	194	1.21
Tauhara**	2009	5	5	1.04	68	13.60
Wairakei	2008	165	124	0.75	414	2.51
Total	2009	890	452	0.51	1998	2.24

* Installed Capacity ** Power Generation Equivalent

Table 2: Land Use by Activity.

Activity	Wairakei	Kawerau KA24	Kawerau Mill Supply	Kawerau Power Station	Ohaaki	Rotokawa 1996	Rotokawa 2008	Rotokawa 2010	Poihipi	Ngawha 1998	Ngawha 2008	Mokai	Tauhara	Total Land Use (Ha)	% Total Land Use
Exclusive to the development (DA)	123	3	13	19	152	6	11	52	9	8	35	31	5	467	22%
Forestry	41				114	21	21	48	18	10	12	3		287	14%
Conservation		12	23				3	13		40	18		9	117	6%
Hot ground and natural features	36	2			8							0.2		46	2%
Outdoor Recreation	13													13	1%
Pastoral Farming	144	17	35	119	68	18	67	81	99			188	46	883	42%
Industry	11		25	28	4								6	73	3%
Tourism	6													6	0%
Public Roads	11	1		3	7				6			3	2	28	1%
Water Ways and Wet lands	2	6	5		2			12		24	2	2		42	2%
Residential	2	1												4	0.2%
Green housing												8		8	0.4%
Other	23	6			25					3	88			145	7%
Total AA	414	46	101	169	380	45	102	194	132	85	155	234	68	2124	100%