Cultural Impact Assessment

Top Energy's proposed expansion of geothermal electricity generation capacity on Ngawha geothermal reservoir (*Ngawha Waiariki*)

Prepared for Parahirahi C1 Trust
by Shea Pita & Associates Ltd

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Prepared by Morris Pita, Shea Pita & Associates Ltd

morris@sheapita.co.nz

021 628615

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Nga Whakatauki

Ko Moi te maunga.

Ko Ngawha te tangata.

He aroaro wahine he ara wahine

(Moi is the mountain - Ngawha, a person. The passage to the womb of a lady is wonderfully warm)

Ko te Ngawha, te kanohi o te taonga.

Engari ko tona whatumanawa, ko tona mana hauora no raro

(Ngawha is the eye, the centre piece, the ethos of this treasure, this gift from our ancestors. However, its throbbing life giving heart, its living ethos, its LIFE, its heartbeat, its goodness lies within its warm subterranean depths)

1. Introduction

Parahirahi C1 Trust (Trust) represents the descendants of the original eleven non-selling owners of the Parahirahi C1 block. This parcel of land is unique as it includes the Ngawha springs, a complex of geothermal pools visited by between 15,000 and 18,000 people annually.

Top Energy owns and operates two geothermal power stations on the Ngawha geothermal reservoir – the same reservoir that feeds Ngawha hot springs. It plans to increase its generation capacity on the reservoir by a factor of three in the coming years and requires a resource consent from Northland Regional Council to do so. On that basis, Top Energy has made preliminary contact with the Trust and seeks its support for the project. As a result the Trust commissioned this report to determine the cultural impact(s) of what Top Energy proposes and establish a platform for further consultation between the parties.

Accordingly, Shea Pita & Associates Ltd (Shea Pita) was contracted by the Trust (with the financial support of Top Energy) to carry out this Cultural Impact Assessment (CIA) to ascertain the level of cultural impact Top Energy's intended geothermal developmental activities may have on the Ngawha geothermal reservoir and in particular Ngawha springs, better known to tangata whenua as Ngawha Waiariki. In order to accurately ascertain the level (if any) of cultural impact further development may have, it was important for the Trust to also understand the technical aspects of what Top Energy is proposing and what physical impact it may have on the hot springs and reservoir which feeds them.[1] With this framework in mind, Shea Pita completed two complementary pieces of analysis (sections 3 and 4):

- A "Cultural Context" review premised on a combination of historical research as well as interviews with kaumatua regarding Ngawha Waiariki
- A "Geoscientific Assessment" of Top Energy's proposal, examining the technical and potential physical impact(s) of Top Energy's generation expansion proposal on Ngawha Waiariki

By way of context we also carried out a high level review of relevant planning regulation and rules which is set out in section 5.

Our conclusions and recommendations on the way forward are provided in sections 6 and 7.

[1] For instance, if the project was to cause the pools to drop in level or cool off, there would likely be a material cultural impact, but in order to understand this risk a robust technical assessment from a geoscience standpoint was first required.

2. Methodology

Cultural context

Interviews were held in people's homes with the following Ngapuhi kaumatua:

- Ronald Wihongi
- Taoko Wihongi
- Renata Tane

Each interviewee provided detailed descriptions of the korero and teachings of their old people and their old peoples' old people (nga tupuna) pertaining to the history and unique qualities of Ngawha springs and the Ngawha geothermal reservoir. They also shared recollections of the springs and rohe[2] as children dating back to the 1930s. Interviews were structured using a tool developed by Shea Pita to enable interviewees to address the issues most important to them in respect to the cultural significance of Ngawha Waiariki.

The results of interviews were supplemented by research including documentation from the Waitangi Tribunal and papers supplied by trustees containing written historical accounts related to Ngawha Waiariki.

Geoscientific assessment

Shea Pita has significant expertise in geothermal energy projects in addition to networks of technical experts in this specialised field. The scientific lead was taken by the highly experienced and former Mighty River Power head geoscientist, Tom Powell, with support from internationally recognised geophysicist, William Cumming, both of whom have spent several decades working globally on geothermal electricity developments.

An assessment of the potential technical impact of Top Energy's proposal would not have been possible if it were not for its willingness to provide Shea Pita with access to reservoir, subsidence and other data. We wish to take this opportunity express our gratitude to Top Energy for its proactive and open-handed approach.

Our geoscientific analysis also involved communicating directly with Top Energy's technical advisors both by email and in person via a meeting held in Wairakei on 4 August 2014 between Tom Powell, Allan Burdett (Top Energy) and John Burnell, providing an important opportunity to clarify issues "kanohi ki te kanohi".

[2] Surrounding area.

3. Cultural context

This section of the document describes the unique history, philosophy, values and beliefs of tangata whenua regarding their taonga Ngawha Waiariki (Ngawha geothermal reservoir and hot springs). It consists largely of quotes taken during interviews with key kaumatua who are holders of the history and knowledge of Ngawha and its place within the lore, traditions and identity of the people of Ngapuhi nui tonu. These primary sources are also complemented where appropriate by references to earlier pieces of scholarly work and research examining the significance and background of Ngawha Waiariki and the land under which it sits.

We have structured this section under the following main headings:

1. The origins and history of Ngawha Waiariki (Ngawha Geothermal reservoir and Springs)
2. Takauere
3. Above surface context: Land alienation
4. Assessment of effects of geothermal energy development on cultural values

The origins and history of Ngawha Waiariki

Taoko Wihongi provides a description of the origins of the Ngawha Waiariki (Ngawha geothermal reservoir and springs), as he relates his evidence at the Waitangi Tribunal hearing held in [location] in [1993 –Morris confirm year]

> “Two maidens left Hawaiki for a new land; they came on a white bird [named] Mokihi. Their flight to Aotearoa was so swift it took them just one day to get here. They landed at Ngawha. They experienced the temperature here – a lot different, a lot cooler than their home. They feared they would not last the night so they performed a karakia to their Ariki in Hawaiki asking him to send them heat. And the Ariki immediately blew some heat from Hawaiki under the sea that bubbled up at Ngawha to keep them warm. They [also] had nothing to cook their kai with so prayed again to the Ariki who blew more heat sufficient to cook their food.” (Taoko Wihongi, 5 August 2014)

The use of Ngawha Waiariki for cooking also has a far more recent place in people’s memories including Ngapuhi kaumatua Ronald Wihongi, who recalled:

> “On the rock there [Ngawha Waiariki] we used to cook food. Where the dressing rooms are now, on that bit of rock towards the end of it there - that was really hot, hot!” (R Wihongi, Interviews 2014)

More so than cooking, however, the pools are, to this day, known and used for their recuperative and healing qualities which were first understood by a woman named Kareariki who is recognised as the first person to discover:

> “…that these pools had curative properties in them, particularly for woman’s health issues, for example after giving birth” (R Wihongi, Interviews 2014)

The significance of Kareariki to the people of Ngawha and Ngapuhi as a whole, becomes all the more vivid when we look at tribal whakapapa, revealing that she was the wife of Uenuku, son of Rahiri, the eponymous ancestor of Ngapuhi. Thus we can begin to gain some insights into the significant length of time that the hapu of Ngapuhi have been associated with Ngawha Waiariki through tribal genealogy:

> "Kareariki is the founder of the curative pools of Ngawha – now 15 generations to… myself" (R Wihongi, Ngawha Corrections Facility Hearing Evidence)

Given Ronald Wihongi is now in his eighties, this would suggest Kareariki made her discoveries on the special healing qualities of the pools some 400-500 years ago.

Taoko Wihongi recalls as a child around the time of World War Two spending time camped at Ngawha with his whanau and using the pools as a means of treating skin ailments such as *tapa* and *hakihaki*.[3]

> "The springs were the cure for us. We used to stay at the pools for a week or two weeks if we were lucky. There were huts there used at certain times of the year. We'd go home relieved of those ailments"

When interviewed, Ronald Wihongi also talked about the healing he had observed during his lifetime at Ngawha Waiariki:

> "I've seen certain ailments and diseases cured….it's good for eczema, joints, sores, arthritis, the place had those healing properties. I believe there are certain minerals in the water that gives those healing properties their power. People go there on crutches – they come back healed. Old people, young people. I've seen a pakeha man there with skin peeling and falling off his face. He was there bathing, bathing, bathing in the Milky Way pool. After two or three years he was cured of the disease." (R Wihongi Interviews, 2014)

He went on to note the special status of the pools as a taonga or gifted treasure from the ancestors with special restorative qualities:

> "They [Ngawha pools] were passed down to our people…it's a taonga tuku iho. They [our tupuna] said you have to keep this taonga because it is a place for the healing of the people" (R Wihongi Interviews, 2014)

Each of the pools at Ngawha has its own name e.g. Baby, Doctor, Solomon, The Favourite, etc. However, possibly the most unique of these is *Pahou*, more commonly known as "Bulldog" and sometimes *Purutoke* (a transliteration for Bulldog). Pahou was originally named after one of Kareariki's kuri (dogs) which went missing. Its bark could once be heard sometimes from as much as 2 kilometres away as Ronald Wihongi recounts:

> "Bulldog once had a ledge overhanging it (where the building is now) and as the water percolated and lapped up against it made a sound like a dog – hou, hou" (R Wihongi Interviews, 2014)

Taoko Wihongi also made mention of Kareariki's kuri and its direct connection to the name of this particular pool:

> "Kareariki had a kaitiaki kuri, and they say the barking of the Bulldog [pool] is one of her dogs still barking centuries later" (T Wihongi, Interviews 2014)

Whilst Bulldog, the hottest of the pools, still exists, this particular "barking" feature was covered over when the administration and changing rooms were built. These we erected by the Trust in the 19 [date?]s to prevent Government from carrying out exploration drilling on the springs themselves. That is why they sit above the hottest part or ngakau (heart) of Ngawha Waiariki.

[3] "Tapa" is a type of foot ailment; "hakihaki" refers to sores on the skin.

Taoko Wihongi also recalls how the pools that you see today were there when he was a child:

> "The pools today are old pools – were there when I was a child [although] they were just holes in the ground with a bit of manuka to stop the bank caving when you stepped in"

During interviews, kaumatua also referred to the sensitivity and history of the whenua above the reservoir in and around the area Top Energy plans to build its further production and injection wells, pipeline and power plants.

> "You have got some of the biggest wahi tapu in that area. Umutakiura is one, Karangahape is the other…..those bones there came from the pakanga they had during the time of those battles with the British…those bones were either just left there as was the custom, or hung in trees." (R Tane Interviews, 2014)

> "We know there used to be wars there……when there is a battlefield there is blood as well and how far we go with that I am not too sure. Some will call it tapu" (T Wihongi Interviews, 2014)

Takauere

Kaitiaki are the guardians of the Maori world. The kaitiaki for Ngawha and some of the waterways of Ngapuhi is a taniwha named *Takauere*.

> "His association with man has been right from the beginning of the Ngapuhi people, and before that to Hawaiki. Takauere can take many forms. It can manifest itself as a kauri log or as a tuna [eel], and can appear in any waterway – above the ground and under it" (R Wihongi, Evidence, Corrections Facility Hearing, 2)

> "Nukutawhiti, the mokopuna of Kupe, was left in a dilemma by having no waka to take the great journey to the land of Kupe, Aotearoa. He turned to his tupuna matua and asked for his waka Matahourua. After some modifications with two adzes, the waka was renamed Ngatokimatawhaorua. The kaihoe were tama toa. They left with their precious tapu cargo leaving Nukutawhiti's daughter, Moerewarewa, alone and in despair on the shores of Hawaiki. Feeling heartbroken and having no one to turn to, Moerewarewa attracted the "essence" of a kaitiaki of Hawaiki, Takauere, one of the few which had not already been utilised. Later, Takauere evolved as a tohora. Ngati Moerewarewa, a sub tribe of Ngapuhi found in Tautoro, takes its name from this tupuna." (R Tane, Interviews 2014)

Ronald Wihongi also stated when interviewed for this report, that:

> "These [Ngawha] waters are frequented by that taniwha, Takauere. Takauere isn't a tangible thing; you can't necessarily see it. But that wairua, that taniwha is there – the guardian of the waterways of all of Ngapuhi ki roto"

Takauere is often referred to as being not just in, but also of, Northland's water bodies themselves. In particular, Ngawha holds a special place of significance as "the eye [and] brain" of Takauere: (Te Ahi Ko Mau submission)

> "The springs, streams, rivers and lakes are all a part of his body; Lake Omapere being his heart and belly, *Ngawha* his eye and head, with his major limbs being the Waitangi River to the east and the Utakura and Waima rivers to the west. The numerous springs throughout the north are regarded also as indications of his presence……The Utakura and Orukiruki waters find their

way to the Hokianga…and the Waipapa waters find their way to Waitangi – and wherever the waters flow, the relationship of tangata to whenua and of tangata to tangata is implicit. Thus the presence of Takauere unifies nga hapu of Ngapuhi-nui-tonu." [Emphasis added] (Te Ahi Ko Mau submission)

The stream which runs down alongside Ngawha Springs is *Tuwhakino*, which together with many other small streams in the area flows into the Waiaruhe River and ultimately out to sea at Waitangi.

This theme and deep-set belief of interconnectedness between not just water bodies above and below the earth's surface, but also between ancestors and the people of today is described by Ron Wihongi:

> "The presence of Takauere is shown by surface manifestations of springs, streams, ponds and lakes. All are connected by the underground aquifer. Many of those waterways have suffered greatly through interference with their natural state. ***If Takauere is weakened, Ngapuhi is weakened***". [Emphasis added] (R Wihongi, Evidence, Corrections Facility Hearing, 2)

The Waitangi Tribunal's Ngawha Geothermal Resource Report 1993 (Wai 304) also refers to the significance of Takauere and the Maori view that the wider geothermal reservoir and the springs are inseparable and in effect part of the same body:

> "One of the more profound aspects of the taniwha phenomenon is that it expresses the traditional view, confirmed by kaumatua Karewa Marsh, Ronald Wihongi, Anaru Sarich, Ngatihaua Witehira and others, that the underground resource and its surface manifestation is holistic and undivided. There can be no springs with all their miraculous healing powers that do not derive from a source deep within Papatuanuku. Karewa Marsh quotes the following aphorism:
>
> Ko te Ngawha te kanohi o te taonga, engari ko tona whatumanawa, ko tona mana hauora no raro – Ngawha is the eye of the taonga, but its heart, its life giving power, lies beneath (the surface)…
>
> And she adds that "I know in my heart that this is so"" (Ngawha Geothermal Resource Report 1993 (Wai 304), 17)

Kaitiaki responsibilities do not, however, solely reside with Takauere. Rather, these are very much seen as complementary roles also held by tangata whenua.

> "[T]he people also had a responsibility to the taniwha, to respect him, to do nothing that would diminish his special properties in any way, to be a kaitiaki to him. A contract of equal partnership in the same manner as in the intent of the Treaty of Waitangi – and of mutual benefit. Maori have no option but to fight for the wellbeing of taniwha for neglect of our duties has always led to disaster for the people."

Ronald Wihongi has a very similar view on the symbiosis of people and Takauere:

> "If something goes wrong [for Takauere] it will be a grave loss physically and spiritually and culturally not only to the taonga (reservoir) - the power of those pools [Ngawha] would be no more…if you kill the strength of those pools, if you kill that taniwha, that wairua, then the people will suffer with it" (R Wihongi Interviews, 2014)

> "The Ngawha Waiariki are healing waters. They heal physically, which is a blessing in itself but of far greater value is their ability to give sustenance to our wairua. When we look at the ills that beset Maori today, we know our wairua is struggling. We cannot afford to abandon the

taonga left to us by our tupuna ***Keareariki***." [Emphasis added] (R Wihongi, Evidence, Corrections Facility Hearing, 2)

Above surface context: Land alienation

Parahirahi C1 Trust owns the block upon which approximately half of the current Ngawha hot-pools complex sits.[4] This is however, only a small portion of the original Parahirahi block which was aggressively targeted by the Crown for acquisition on behalf of settlers in the latter part of the 19th century, as the following excerpt from a report prepared by [historian] Paratene Tane reveals:

> "For Ngawha in particular, the process of surveying and awarding of title was encouraged by prospecting Europeans interested in exploiting mineral resources….Titling of the land containing the majority of the springs (Parahirahi) began in 1873. The Parahirahi land block consisted [of] three blocks totalling 5097 acres….What ensued was a complex series of subdivisions, succession orders, partitions and alienation. By 1894 Parahirahi land holdings totalled 804 acres….and by the 1960s only three acres [0.06%] remained in Maori ownership…." (P Tane, 2, Section 3.2.2; refer Waitangi Tribunal, 1993, 48)

Tane also cites a letter from one of the early settler lessees (and subsequent purchasers from the Crown) of Parahirahi lands, George Patterson, which describes in plain terms his strategy to increase his interest in Parahirahi C block for commercial purposes:

> "The [Parahirahi C block] I pointed out to you on the map in the land office cuts right into my block and tends to damage the sale or floating of a company as long as it is in the native hands. I would like to get this piece, also about 50 or 100 acres adjoining it…" (P Tane, p10, Section 3.2.2; refer Waitangi Tribunal, 1993, p48)

Alienations across the wider Parahirahi block continued in other ways also. For example, the Government took 380 acres on behalf of Northland College, and as recently as 1981 took a further 134 acres for scientific and industrial research under the Public Works Act 1928 (P Tane, 17, Section 3.3).

Each of these events (and the many others not listed here) is an example of resource depletion, and an intrinsic part of the historical and cultural narrative of the people of Ngawha, offering invaluable cultural insights into the perceptions and concerns of kaumatua as they describe their fear of further loss of precious taonga and the negative consequences, both spiritual and tangible, to the whanau and hapu they represent.

Moreover, there is a strongly held view that notwithstanding the loss of so much land, they have to this day retained ownership and rangatiratanga over the whole of the Ngawha geothermal resource, including the hot springs on the Tuwhakino and Parahirahi B blocks.

[4] The other half of the pools complex sits on what is known as the "four acres", land which presently is legally owned by the Crown via DOC, and "administered" by the Far North District Council (although in practice the entire pools complex is managed by Parahirahi C1 Trust). In 1993 the Waitangi Tribunal heard a claim on this block of land and related geothermal issues, and recommended that the Crown arrange for this land to be returned. To date this has not occurred although in April 2014 FNDC unanimously voted to return the block by way of a 33 year lease with a nominal rental to Parahirahi C1 Trust until such time as the final handover of full title is completed as part of the comprehensive Ngapuhi Treaty settlement.

Assessment of effects of geothermal energy development on cultural values

Kaumatua made a number of comments about their concerns regarding what the proposed expansion by Top energy could mean in reality. There was a deep sense of the need to be and act as kaitiaki in a meaningful manner. This was coupled with a steadfast commitment to the overall wellbeing of the Ngawha geothermal reservoir as an integral component of the water bodies of their rohe, which, in turn, are integral to the wellbeing of their people.

This included a determination not to stand by and observe negative chains of events unfold in their lifetimes - on “their watch” so to speak - in a way which did not honour that sacred obligation of resource stewardship handed down to them from their old people, and their old people’s old people, and so on. They saw a substantial part of their role as being one that was centred on ensuring the *manawa* and *mauri* of Ngawha were not in any way diminished from the balanced state in which the taonga was handed down to them by their forebears for safe keeping. It is difficult to measure potential harm to *manawa* and *mauri* solely in physical terms. This sentiment was perhaps best summed up during interviews by Renata Tane when he said:

> “Kaua tatou he tukuna te taiha hei patu te tatou ano nei taonga, Takauere
>
> “We don’t want to become the harpoon that kills our taonga, Takauere”

In response to suggestions they had previously heard from Top Energy that geothermal development would be run sustainably through reinjection and careful technical monitoring including the springs themselves, Ronald Wihongi stated:

> “If we build all these power stations one day we are going to lose the power of the reservoir – and what if the experts who assure us all will be fine are wrong? My concern is the taonga, I’m not concerned about electricity generation – my desire is that the springs be there forever as a living monument from our tupuna to be left to our children, our children’s children, and that those springs may remain until the end of time” (R Wihongi Interviews, 2014)

Another issue raised by kaumatua is that Ngawha Waiariki (the Ngawha geothermal reservoir) was never sold and remains, in the eyes of tangata whenua, a taonga handed down to them by their tupuna to protect and to utilise for the benefit of their people both today and tomorrow. This, however, sits in stark contrast with the current and planned activities of Top Energy – a non-Maori legal entity lacking any whakapapa or genealogical connection (or corresponding customary rights) to the geothermal reservoir, which creates large economic returns with little or no perceptible benefits shared with the people to whom the resource belongs. The following interview note sums up this deeply felt sense of injustice metaphorically:

> “ Ki aau ano hoki e penei ki te tangata haututu, te tangata tahae motoka. Ka haeremai tenei tangata marunga i taua motoka ka kitea e ia tenei Maori kua kaumatua nei e hokoi ana (hitch hiking) ka aroha ia ki a ia. Ka tu ka mea atu ki te koroheka nei, " Kake mai e kara. Maku koe e awhi." Me te tino mohio o te kaumatua nei nana kee, te motoka.”
>
> (To me it is like the car thief is using my car and picking me up and then taking me somewhere and abandoning me there. The taonga that was handed down to us is being taken away and used by Top Energy for its benefit in front of my own eyes)” (R Tane, 2014)

Interviewees also felt as though Top Energy was only really ever interested in tangata whenua, particularly at Ngawha, and a relationship “of sorts”, when it suited Top Energy – that is when Top Energy was looking for the support of Maori in the lead up to resource consents for plans to access the energy (and therefore economic) potential of Takauere. Top Energy's approach was described as imbalanced on two grounds. First, its offers of economic support to the people are perceived as token in nature and immaterial relative to the wealth it is able to gain from access to free energy and fuel created by their taniwha and taonga.[5]

> "They [Top Energy] say they spent $6 million on a single geothermal well that failed and seem to just brush that off as small bickies, and yet they offer us Maori tiny levels of compensation by comparison for access to our taonga that gives them free fuel for their power plants – that's just insulting." (R Tane, Interviews 2014)

Second, kaumatua felt Maori were left on "the outer" when it came to the future and ongoing sustainable management and preservation of their geothermal taonga, and were instead in a position of having to accept decisions made and assurances given by others. Kaumatua were genuinely frustrated by the lack of a meaningful partnership with Top Energy, all of which (perhaps unintentionally, though inevitably) resulted in the trampling of the mana of the people of Ngawha by impeding their ability to fulfil their collective and immutable obligations as kaitiaki:

> "We want to be around the table with Top Energy making the decisions about our taonga and how it is used sustainably, but at the moment we find ourselves left sitting outside barking" (T Wihongi, Interviews 2014)

Summary

A common theme which continued to reappear both in our research and in the interviews with kaumatua, was the importance of *connections* – connections created through whakapapa that establish a collective sense of place and identity for tangata whenua, which are both metaphysically and practically entwined in their feelings for Ngawha Waiariki.

For example, the roto[6] link to tupuna and their connection to the people of today and the generations of tomorrow; the connection of Ngawha springs and the Ngawha reservoir to one another; and, the mutual obligation between tangata whenua and *Takauere*, and the importance of supporting their taniwha in its role as kaitiaki of their waterways, including their taonga, Ngawha Waiariki.

Therefore, the frustration elders expressed regarding Top Energy's proposed project expansion was, we think, founded at least in part, on the threat of cultural *disconnection* and the resulting sense of disempowerment and marginalisation which would accompany such an outcome. We pick up on these and other relevant cultural threads later in the concluding section of this report.

[5] Research indicates that deep production and reinjection geothermal wells cost significantly more than this and typically require in the order of $10-15 million of capital to complete.

[6] Blood based

4. Geoscientific assessment

Introduction

This report addresses concerns about the impact that additional generation the Ngawha Geothermal Power Project may have on the hot springs at Ngawha. Top Energy is planning to apply for additional resource consents which will allow an expansion of generation capacity at some future date. Recent numerical modelling studies indicate that this expansion will be from the existing nominal 25 MW generation capacity in stages to 50 MW and ultimately 75 MW. This will represent a three-fold increase in geothermal fluid take from production wells and concomitant injection discharge to injection wells.

There are two principal threats to the hot spring spa developments presented by an expansion at the geothermal power plant:

1) change in flow to the hot springs, and
2) subsidence causing damage to the built environment.

A change in flow to the hot springs would disrupt normal spa operations, requiring additional operations and maintenance costs. Increased geothermal fluid flow would require additional surface water to control temperature and could cause the hot spring area to expand, threatening the local built environment. Decreased flow might would remove the resource on which the spas depend for their existence.

Subsidence, which is a common surface phenomena in geothermal areas developed for power generation, could cause damage to the built environment and changes to local surface water drainage, affecting the area's response to flood events.

The threat of each of these processes, which might be introduced or exacerbated by an increase in fluid take and injection, will be discussed in turn.

Top Energy Proposal

Top Energy is planning a two stage expansion of the existing geothermal power plant at Ngawha. A map of the expansion is presented in Figure 1. The first stage will add another 25 MW generation to the field, essentially doubling existing generation. The new plant station (OEC4) is planned to be adjacent to existing plant OEC3, about 1 km southeast of the Ngawha Springs Township. The first stage expansion is planned to include two new wells (designated P1 & P2 in Figure 1) and a connection to existing well, NG21. The first stage also includes development of a new injection field east of the township, using 3 existing wells and 2 new wells (I1 & I7).

The second stage will add a further 25 MW to the field (OEC5), giving a total of 75 MW in generation capacity. The new plant will be located east of the township, near well NG14. The bore field will be expanded north to include a new well P3 and additional injection wells. Both developments include plans to continue supplemental injection of surface water into NG2 in order to maintain reservoir pressure within presently consented limits.

Changes in Hot Spring Discharge

The analysis presented here is based upon technical materials supplied by Top Energy, the most important of which are listed in the Reference section at the end of this report. As a general statement, I found the supplied information to be reasonably complete and of satisfactory quality, and the analyses to be competently conducted and well-reasoned. This information was sufficient for the formulation of the recommendations presented here, with what I consider to be a high degree of certainty.

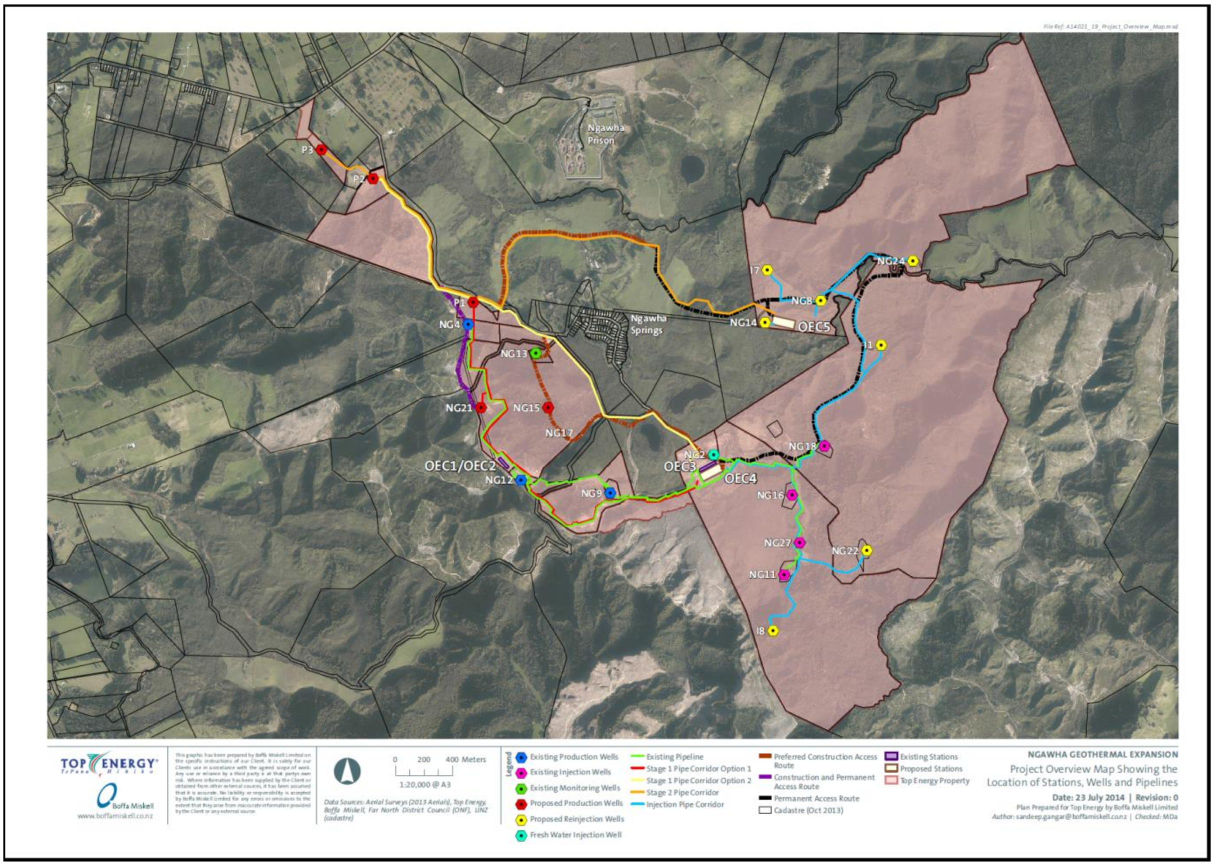

Figure 1: Top Energy development plan for the Ngawha Geothermal Field

Geological foundation of Ngawha Hot Springs

Studies of the physical character and chemistry of the Ngawha hot springs, augmented by numerical modelling studies presented at the 2006 consent hearings, yield a reasonably good understanding of the origin and mechanism of the hot springs.

The hot springs originate as mineralized waters which have flowed to the surface from an underlying geothermal reservoir in fractured basement rock. The geothermal waters themselves appear to originate from a deep intrusion of hot and perhaps molten igneous rocks. The gases dissolved in the geothermal system show elevated content of a rare, non-radioactive isotope of helium, ^{3}He, which is characteristic of active volcanoes and magmatically-heated geothermal systems. The ratio of ^{3}He to the more abundant isotope ^{4}He, when compared to the ratio in our atmosphere (a convention called "R/Ra") ranges from 7.1 to 5.3. This is similar to the helium isotope ratios found in the Taupo Volcanic Zone (for example at Ohaaki, R/Ra ranges from 5.9 to 3.5). Geothermal systems without active input of magmatic gas typically show ratios near or below one.

The deep, hot water and dissolved gas from this magmatic source upwell by buoyancy through greywacke basement rocks (hot water is less dense than surrounding cooler deep groundwater, so it tends to rise) and encounters a natural "caprock" layer, which extends to about 500m below the surface. This is shown schematically in Figure 2. The cap rock is a layer of sedimentary rock rich in clay and creates a seal over the greywacke, causing the hot geothermal water to spread laterally in the greywacke. Flow of hot water through the greywacke below the caprock layer has, over millennia, created a reservoir of hot, geothermal water that is now the geothermal resource which the power project is tapping.

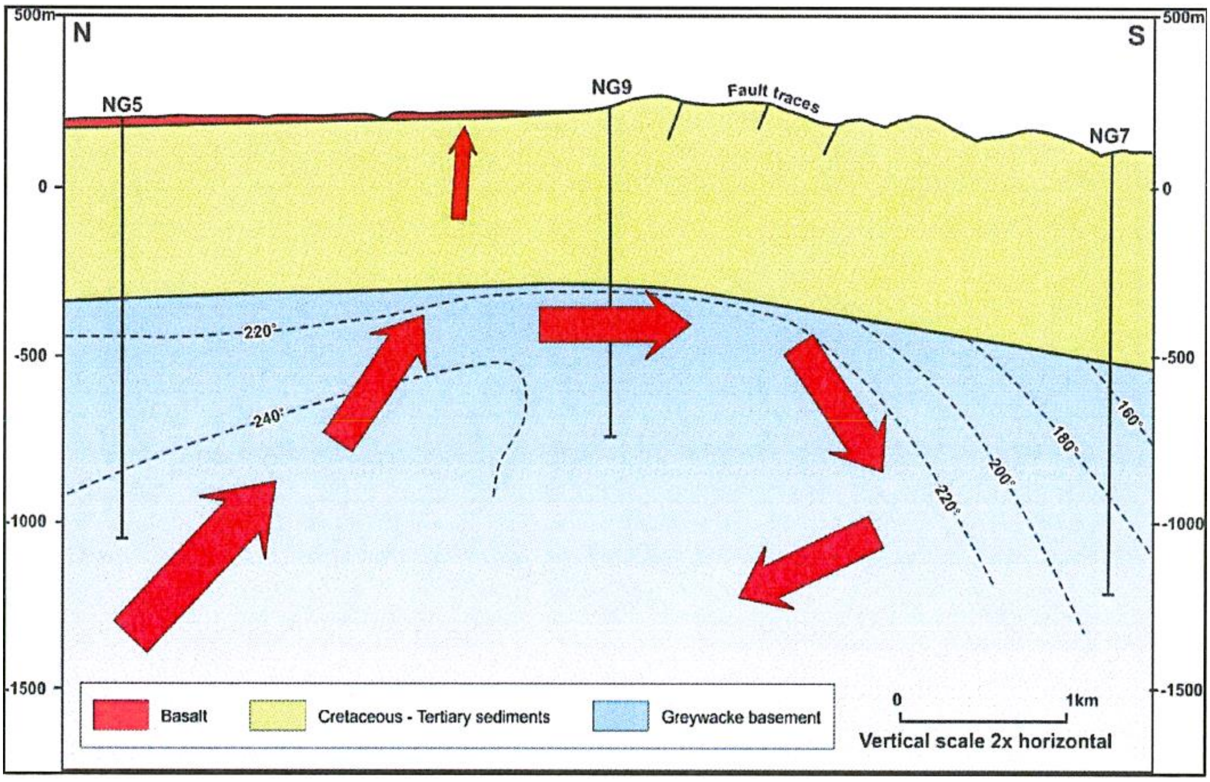

Figure 2: North-south conceptual section of the Ngawha Geothermal Reservoir. Hot fluids flow up into greywacke reservoir in the north and circulate southward, cooling at the base of the sedimentary cap rock. Some hot water leaks through the cap to hot springs at the surface (small red arrow). From Bromley et al (2014).

The hot springs at Ngawha result from cracks in the caprock that have allowed a relatively small amount of the deep geothermal water and dissolved gas to reach the surface. Chemical studies show that all of the hot springs in the Ngawha springs area contain a component of deep geothermal water, some more than others. The Jubilee Spring, for example, contains nearly pure deep geothermal water, with a small component of shallow fresh groundwater, which varies from summer to winter. The Universal Spring contains about 25% deep geothermal water, mixed with a warm, mineralized "bicarbonate-type" groundwater probably coming from an aquifer (water-bearing rock layer) in the caprock. The mineralisation of this water is indicative of the absorption of carbon dioxide gas, making it like bottled gassy mineral water. This water is mildly acidic and dissolves components of local rock, resulting in chemistry distinct from the reservoir water. Mineralized bicarbonate waters are common in shallow aquifers and springs in geothermal areas.

The Tiger Spring shows about a 50% component of the deep geothermal water, mixed with a mineralised water similar to that of the Universal spring, but in this case the water is slightly acidic and rich in the natural chemical compound sulphate. In natural geothermal settings, acid sulphate waters are formed by the oxidation of hydrogen sulphide, an odorous natural geothermal gas dissolved in the upwelling deep geothermal water. As the geothermal water rises through cracks in the cap rock, its dissolved gas bubbles out, similar to when the pressure is released on a bottle of soda water as it is opened. The geothermal gas, containing hydrogen sulphide, mixes with oxygen-rich groundwater, oxidizing hydrogen sulphide to a mild form of sulphuric acid.

In summary, the hot springs at Ngawha show the chemical fingerprint of the deep reservoir water variably mixed with groundwater. The groundwater component ranges from fresh water to groundwater modified and perhaps heated by interaction with geothermal gas dissolved in the deep reservoir water and bubbling out of the waters as they rise the surface.

The Role of Reservoir Pressure

The driving force creating the springs is relatively high pressure in the underlying deep geothermal reservoir. Wells drilled into the geothermal reservoir, when left standing with no discharge, will show water pressure at the surface about 9 bar greater than local groundwater. This degree of overpressure is significant for a natural geothermal reservoir. In their natural state, most geothermal reservoirs in the Taupo Volcanic Zone are about equal to groundwater pressure at the - surface, with some being a few bar over-pressured. For these geothermal reservoirs, the pressure drive from the reservoir to hot springs is less than at Ngawha.

Prior to geothermal development, reservoir pressure was slightly higher, at about 10.5 bar. Geothermal production at Ngawha has resulted in a reservoir pressure drop of 1.5 bar. The pressure in the deep reservoir has fallen from 10.5 bar to 9.0 bar since plant start-up in 1998.

Much larger reductions in geothermal reservoir pressure due to fluid production have resulted in drying up of hot springs at Wairakei and Ohaaki. The drop in reservoir pressure removed the driving force between the geothermal reservoir and the surface. Production withdrew water from the geothermal reservoirs without replacing it by injection water and pressures in the reservoirs fell. In contrast, hot springs continue to flow in developed fields where deep injection is practiced, such as at the Kawerau, Rotokawa and Mokai fields.

The Top Energy geothermal development at Ngawha practices full injection of all spent geothermal water, with the exception of losses due to surface spillage and removal of most dissolved gas in the power plant process. In addition, the field is one of the few in the world which “tops-up” injection with surface water to maintain reservoir pressure near to its initial state. This is a mandated Ngawha reservoir management practice since the 2006 consent, implemented to maintain hot spring flow.

Although experts who have analysed monitoring data of hot spring, creek and groundwater flow disagree, there is evidence that the 1.5 bar pressure drawdown experienced by the reservoir in the first 7 years of production did cause a slight but measureable decline in the discharge of deep reservoir water to the surface. The change appears to have been too slight to be noticed at the hot springs, due in part to the seasonal variability of spring flow and changes due to rainfall. The decline was noted in a statistical analysis of the flow of a chemical component deep geothermal water (chloride, a component of table salt) into surface creeks draining the hot spring area. Following tests to confirm that supplemental injection of surface water could arrest further reservoir pressure decline, consent conditions mandating that reservoir pressure be maintained between certain limits were specified for the 2006 project expansion as a precautionary measure.

The Reservoir – Hot Spring Connection

Changes in hot spring behaviour are not just a matter of underlying reservoir pressure. A number of other factors come into play. A key one is the nature of the pathways that feed deep reservoir water to the surface. It is clear from the pressure difference between the reservoir and the surface, and the low flow rate and temperature of the springs that these pathways create a restriction to fluid flow. The waters are constrained to flow relatively slowly to the surface, where they cool from 230°C reservoir temperature to 50°C or so hot spring temperature.

The rock property that governs fluid flow in the subsurface is called "permeability" by geothermal geoscientists. Rocks which exhibit little restriction to flow are said to have "high" permeability. An example of this might be a beach sand or river gravel, or rocks that have been fractured by earth movements. Conversely, rocks that restrict fluid flow are said to have "low" permeability. In the case of the fluid pathways feeding the hot springs at Ngawha, they might be thought of to have moderate permeability – allowing fluids to flow through them but with restriction.

The late Dr. Stephen White of Industrial Research Ltd, a Crown Research Institute, created computer models of the reservoir – hot spring connection which were presented at the 2006 Resource Consent hearings (White & Kissling, 2006). Computer models are designed to mimic or simulate the behaviour of water and vapour in rock reservoirs and as such have become important tools in study and management of geothermal resources. The modelling process incorporates all relevant knowledge about subsurface rock and fluid properties and deep pressure and temperature conditions in the creation of a computational block model that simulates observed behaviour. A key thing to keep in mind about computer models, however, is that they are non-unique – in most instances a system's behaviour can be simulated by a number of different model configurations. At best, these models give indicative results – indications of what configurations and process are reasonable and likely, without giving an exact answer. Dr. White demonstrated this by being able to adequately match the temperature, chemistry and flow rate of the three monitored hot springs at Ngawha (Tiger, Universal and Jubilee) using four different configurations in hot spring conduit permeability for each of the springs.

Hot Spring Sensitivity to Reservoir Changes

Dr. White's models give some important insights into the plumbing of the hot springs. One important finding is that there is a significant delay time between reservoir and surface. Pressure changes in the reservoir due to changes in production and injection management will not be seen at the surface for about a year. This is an important consideration when attempting to correlate changes at the hot springs to changes in the reservoir.

Dr. White also found that, among a number of changes in reservoir conditions that might be brought about by production and injection, by far the most important to hot spring flow is reservoir pressure. A decrease in reservoir pressure by 1 bar caused a few percent change in hot spring temperature and flow rate at the surface when observed 6 years later. Likewise, an increase in pressure of 1 bar over the initial state increased temperature and flow rate by a few percent.

Declines in gas concentration and temperature of reservoir fluid, both of which are expected long term consequences of production and injection, resulted in about one-tenth the change in hot spring temperature and flow compared to the 1 bar change in pressure. This is important, because maintaining reservoir temperature and gas content would be not be possible under the current reservoir production strategy.

The 2006 hot spring models of Dr. White can be correlated with reservoir numerical model results in order to see what changes to the hot springs might be expected with project expansion. A 10°C drop in reservoir temperature, as modelled by Dr. White in the hot spring models, is close to the reservoir temperature drops predicted by the current numerical model prepared by GNS Science (Burnell and Weir, 2014). Both under the current production scenario and with an additional 25 MW generation capacity, reservoir temperature is predicted to drop 13°C by 2050. This might be minimized by moving injection and production to optimize heat recovery from the geothermal reservoir, which was done using new wells in the 25 MW added generation scenario. With 50 MW added generation capacity, the reservoir temperature drops 20°C by 2050.

A 10°C drop in reservoir temperature results in maximum 0.5% drop in flow rate in one of the Jubilee spring models and a maximum 0.05% drop in temperature. The other model configurations and other hot springs show less change. So, the predicted future drop in reservoir temperature is expected to have very little effect on hot spring flow. The apparent reason for this is that there is sufficient stored heat in the reservoir cap rock to maintain hot spring temperature even though the reservoir temperature cools.

Gas concentration is particularly important because the gas concentration in reservoir water has already dropped to about half its pre-production concentration due to release of gas at the surface due to the production – injection cycle. A number of investigators have suggested that gas bubbling in the conduit of ascending reservoir water on its way to the hot springs results in a "gas lift" effect, which promotes the hot springs to flow. We've all seen this gas lift effect when we open a bottle of carbonated water after it has been shaken. The gas expands and lifts the water out of the bottle with the gas.

Dr. White ran a special model scenario to investigate this, with a model that allowed gas to freely flow up the hot spring conduit once it bubbled out of solution. In most water-saturated permeable rocks, gas is held up in the rocks until it reaches enough volume to push water out of small interconnected pore spaces. A model where gas is allowed to freely flow through the conduit would maximize the gas lift effect, probably to a greater degree than would be seen in nature. Results of this model configuration show that, for the three hot springs, decreased gas content resulted in a very small change in fluid flow (less than ±1%) and small but uniform increases in temperature in the three hot springs.

Based upon the model results, these small changes would likely be imperceptible at the surface, but it is important to keep in mind that these results are only indicative. Due to the non-uniqueness inherent in numerical models, the changes may be *greater* or *less*. What these models do tell us, however, is that reservoir pressure is expected to be the major driver in hot spring flow and temperature, with increased pressure causing increased flow and temperature and decreased pressure causing decreased flow and temperature.

The model predictions would seem to explain the apparent success of the current resource management practice of reservoir pressure maintenance in preventing significant long term changes to the Ngawha hot springs. Injection of supplemental surface water has maintained reservoir pressure within consented limits and is a relatively cheap and easy operation. Since reservoir pressure maintenance is specified in the last resource consent, there is little latitude for it to be discontinued. If long term changes to the hot springs, such as a drop in flow and temperature, are observed it is likely that they could be actively managed by subtle changes in reservoir pressure, giving due regard to the expected year-long delay between reservoir changes and surface expression.

Historic Changes in Hot Spring Temperature

The three monitored hot springs at Ngawha have shown subtle changes in temperature and chemistry since start-up of the geothermal project in July 1998. The temperature history of these three springs are shown in Figure 3.

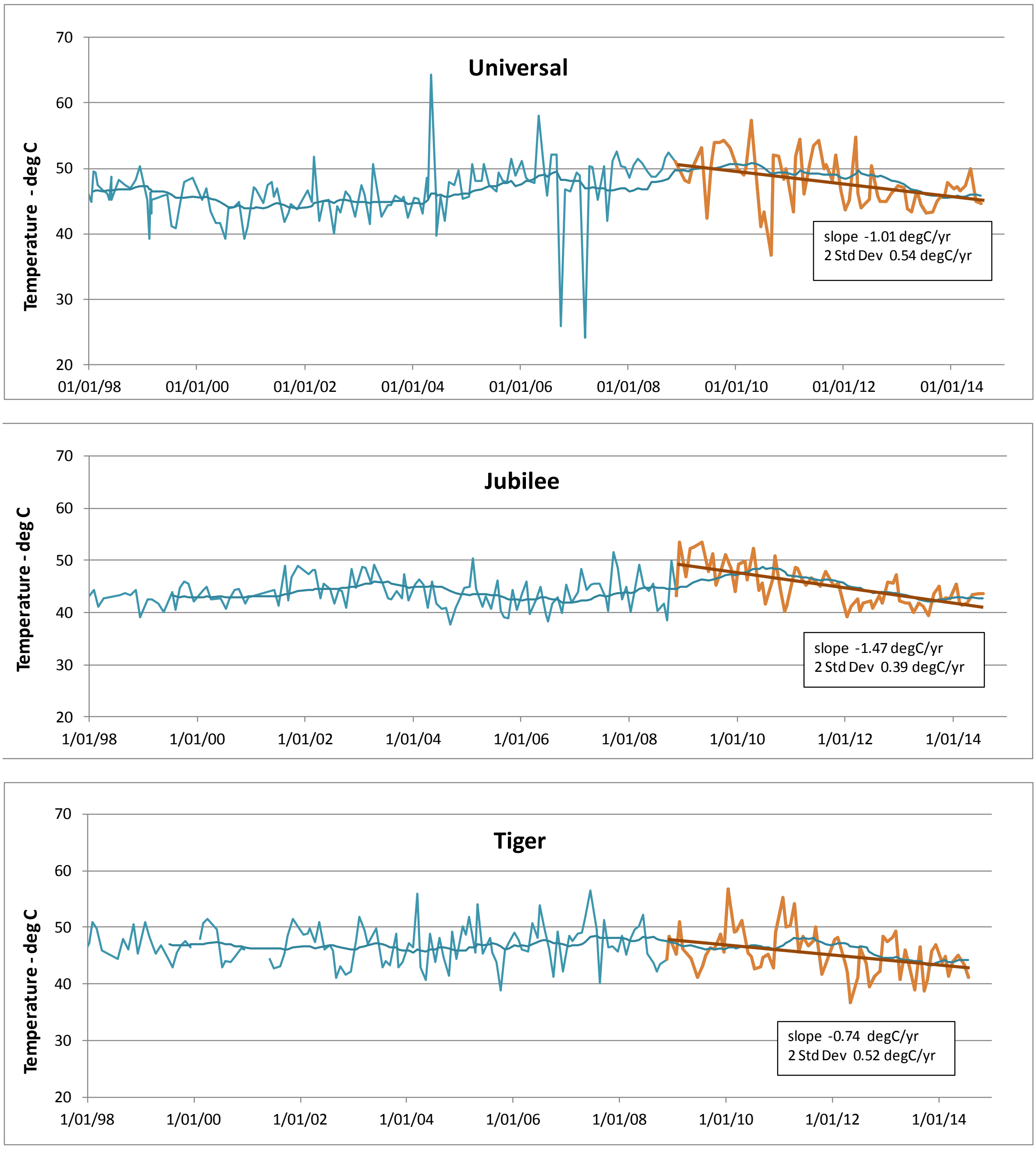

Figure 3: Hot spring temperatures at Ngawha. Temperatures since before startup of the 10 MW plant are in blue, with a 20-point running average line to smooth data. Temperatures since startup of the 15 MW expansion in October 2008 are in brown, with linear regression line. Slope and 95% confidence limit of slope (2nd standard deviation) are given in the text box.

All three springs show declines in temperature ranging from 0.74 to 1.47 deg C per year since start-up of the 15 MW expansion in October 2008. These trends are greater than the second standard deviation of the slope of the regression lines, which represents the 95% confidence limit on the regression slope. In other words, the trend in temperature at the Universal spring since October 2008 has been -1.01 deg C/year ± 0.54 deg C/year. This shows that even though there is variability in the data defining the trends line, the temperature declines are real to within 95% confidence, which is the usual accepted standard for scientific certainty.

It should be noted, however, that spring temperatures have shown long-term upward and downward trends since the initial 10 MW project start-up in July 1998, as illustrated by the 20 point running averages in Figure 3. Temperature in the Universal spring shows a gentle decline from 1998 to 2004, then began a rise which lasted until about 2011. Jubilee shows a similar gentle rise starting in about 2007 and peaking in late 2010. Both of these springs reached near historic temperature highs a few years after the 15 MW expansion. Tiger spring shows no similar rise, but shows a decline starting in 2011.

Although there could be many explanations for these temperature trends, in our opinion, they are likely due to changes in reservoir pressure, shown as the wellhead pressure in monitor well NG13, in Figure 4. Reservoir pressure showed a steady decline until supplemental injection tests started in July 2005. At this point reservoir pressure stabilised, but with brief periods of high pressure, as the rate of supplemental injection was "fine-tuned" to maintain stable reservoir pressure. It is likely that the period of relatively high spring temperature peaking in 2010-2011 is due to the pulse in pressure rebound from early supplemental injection in 2005 to 2009, before reservoir pressure stabilized. Spring temperatures may now declining to pre-expansion levels in response to stable reservoir pressure. The continued downward trends may indicate that the present level of pressure support is not enough to maintain hot spring temperatures at pre-development levels. The reservoir lost 1.5 bar pressure between 1998 and 2005, and the declining temperature trend at the hot springs may, in part, be a delayed response to this pressure decline. Additional reservoir pressure support may be needed to arrest this temperature decline.

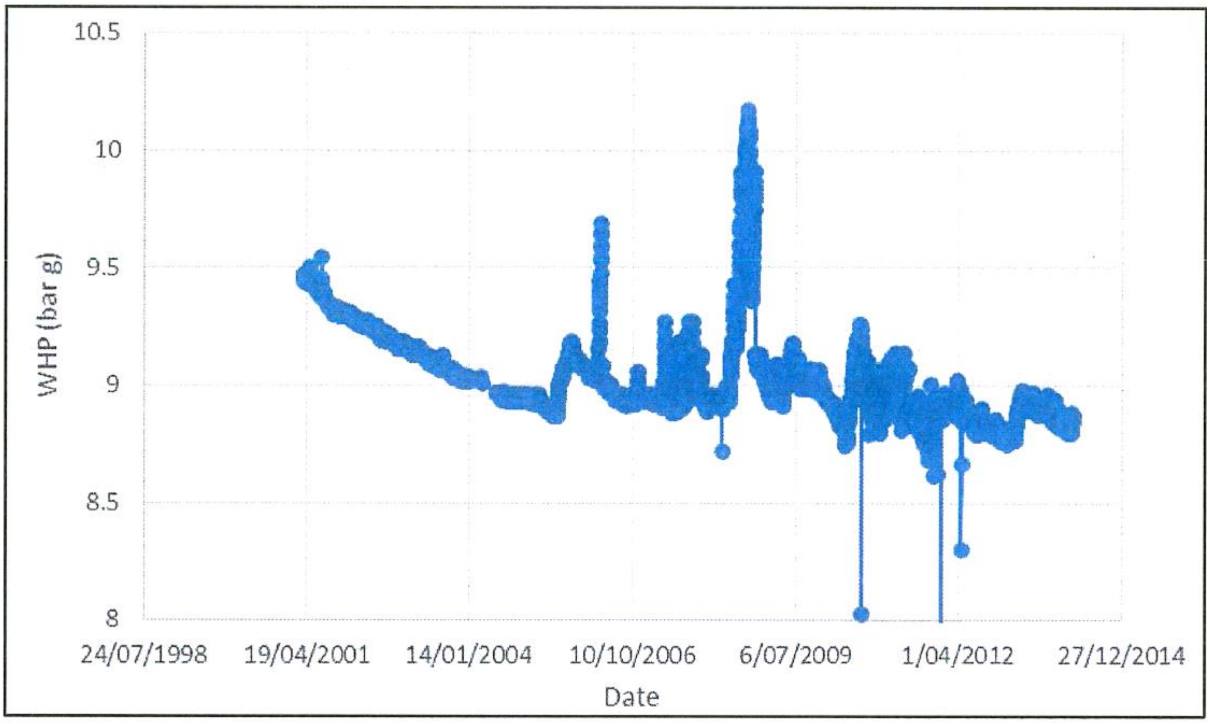

Figure 4: Wellhead pressure in monitor well NG13. NG13 wellhead pressure was approximately 10.5 bar at startup in July 1998. Monitored pressure indicate a steady reservoir pressure decline of 1.5 bar to July 2005 when tests of supplemental injection began. Reservoir pressure has since stabilized. From Burnell and Weir (2014)

During this time, hot spring chemistries have remained relatively stable, with the only notable trends being gentle increases in chloride concentration in the Universal spring since around 2006 and an increase in chloride in Tiger spring since 2002. The trends of spring chemistry are shown in

Figure 5.

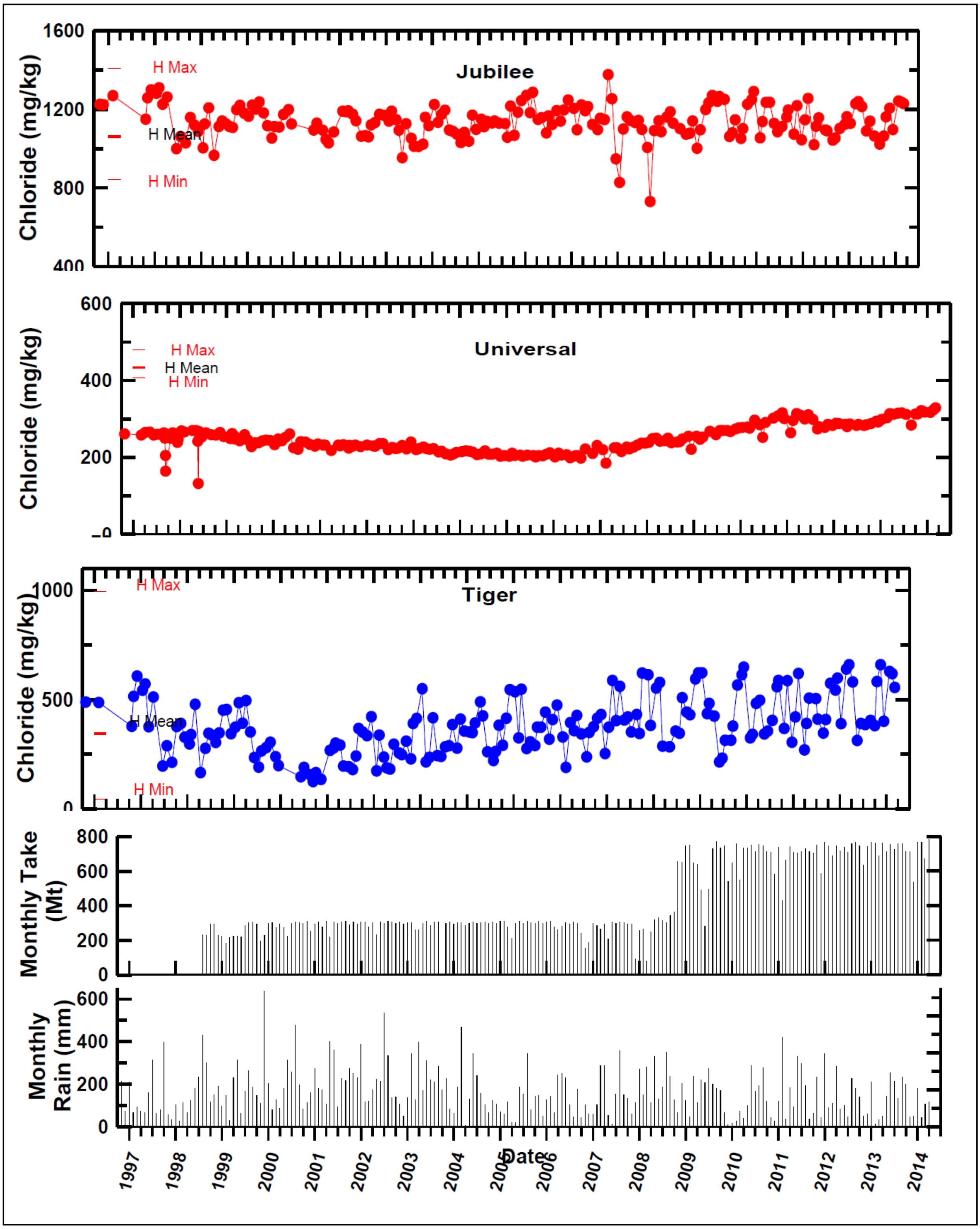

Figure 5: **Chloride concentration changes at the Jubilee, Universal and Tiger springs from NZ Environmental (2014).**

An increase in chloride concentration is indicative of an increase in the deep reservoir component in these springs. These trends are not consistent with the long term trends in temperature and reservoir pressure suggesting that other, possibly local hydrologic or geologic factors have greater influence on spring chemistry. Monitoring suggests that chloride in the Jubilee and Tiger springs are influenced by recent rainfall, but the Universal spring is not. In any event, the changes in hot spring chemistry observed to date appear too small to impact their quality for spa use.

In conclusion, it appears that the monitored hot springs at Ngawha have shown a response to reservoir pressure changes. The largest response appears to have been a period of heating which peaked in 2010 and was due to the initiation of reservoir pressure maintenance tests and subsequent supplemental injection, starting in 2005. Recent trends show the Jubilee and Universal hot springs cooling to about their pre-development temperature and to slightly lower temperature at the Tiger hot spring. *These trends suggest that the present level of pressure maintenance may not enough to keep spring temperatures at pre-development values*.

Natural Hot Spring Behaviour

A noteworthy consideration to the active management of hot springs through subsurface pressure control is that hot springs are ephemeral features; they tend to come and go over a period of decades or even just a few years.

Apart from man-made changes, such as drawdown of thermal aquifer pressure and bulldozing at the surface, earthquakes are the principal process known to influence hot spring behaviour. For example, the 1959 Hebgen Lake earthquake near Yellowstone Park in Wyoming, U.S.A. resulted in the formation of a number of new geysers in Yellowstone Park thermal areas. This is understandable, since earthquake shaking would be expected to break open partially or wholly sealed fractures in shallow hot spring conduits.

Beyond this, hot springs in a number of natural thermal areas will change for reasons that we don’t yet understand. In the Taupo Volcanic Zone there are numerous examples of hot springs drying up, migrating to new locations, popping up in previously stable ground or blowing up unexpectedly in hydrothermal eruptions. Thankfully for the Ngawha springs, their low temperature precludes any hydrothermal eruptions. These only occur where there are boiling hot springs

Oral history over the past few hundred years and physical monitoring over the past seven decades suggests that the Ngawha springs are remarkably persistent, however. Natural variability may be less of a factor in hot spring behaviour than that observed in active tectonic areas, such as the Taupo Volcanic Zone or Yellowstone Park.

Subsidence

Subsidence is a gradual, local drop in ground level observed above bodies of compacting rocks. It is common in fields of fluid extraction, such as in oil and geothermal fields and in areas of groundwater extraction, due to the loss of fluid pressure within the pore space of the rock. As the fluid pressure decreases, porous sedimentary and volcanic rocks will compact under the weight of overlying rocks. In some instances, subsidence also results from decreases in subsurface temperature, causing rocks to undergo thermal contraction. This type of subsidence is rare and generally observed only in areas of shallow (<500m depth) injection of cool water into hot geothermal rocks.

Subsidence is generally too subtle to be observed at the surface without precise measurements of elevation. In dramatic cases, such as has occurred at the Wairakei Geothermal Field near Taupo, subsidence has resulted in the ponding of surface water, and noticeable tilt in power poles and in the water level in swimming pools. Significant subsidence can lead to foundation damage in built structures, particularly where the ground tilt across the foundation is not uniform (i.e. differential subsidence). This type of damage tends to be concentrated near the centre and margins of the area of subsidence.

As a general rule, the degree of tilt and differential subsidence observed at the surface is a function of the diameter and depth of the compacting rock formations. Shallow compaction, such as that at Wairakei, leads to the most dramatic instances of tilt and potential structural damage. Fields where the compacting rock formations are deep lead to subsidence that is spread out and low in tilt. At Ngawha, the majority of future compaction and cooling contraction is expected to be deep (<500m).

Levelling surveys designed to detect ground level changes due to subsidence have been conducted in the Ngawha geothermal area since 1979. Follow-up levelling surveys were subsequently conducted in 1984, 1998 (pre-power plant start-up), 2000, 2002, 2008 and 2012. The next survey is scheduled for 2016-2017. A map of levelling benchmarks at Ngawha is presented in Figure 6.

To date, subsidence at Ngawha has been relatively small. The maximum elevation change between 2008 and 2012 was -5.6 mm/yr near NG18 at the eastern edge of the field. The mean (average) elevation change in the survey area was -1.7 mm/yr. The highest 2008-2012 subsidence rate in the hot spring area was -4.3 mm/yr at benchmark G75, and the lowest rate was -0.9 mm/yr at benchmark G53.

Figure 7 shows the history of elevation changes for benchmark in the Ngawha hot springs area relative to origin benchmark G14 outside the area at SH 12. Table 1 shows the rate of subsidence calculated before and after plant start-up in 1998 and to 2012. Three benchmarks were surveyed in the 1979 survey, which used a different origin benchmark, and these are plotted relative to the G14 elevation in that survey. The 1998 survey was just before start-up of the initial 10 MW plant at Ngawha.

All benchmarks except G75 show relatively consistent subsidence trends since 1984, ranging from -0.8 mm/yr (at G74) to -1.4 mm/yr (G54 & G150). Trends pre-start up (1979 or 1984 to 1998) ranged from -0.6 mm/yr (G74) to -1.2 (G87), indicating a source of natural subsidence in the area, which is not uncommon in geothermal areas. The rate of subsidence in the hot spring area increased by about 60-70% following plant start-up in 1998. The 1998-2012 rate ranged from -1.0 mm/yr (G74) to -2.1 mm/yr (G54). Benchmark G75 is on the western edge of the hot spring area and has shown somewhat erratic elevation, suggesting the benchmark may be on unstable ground.

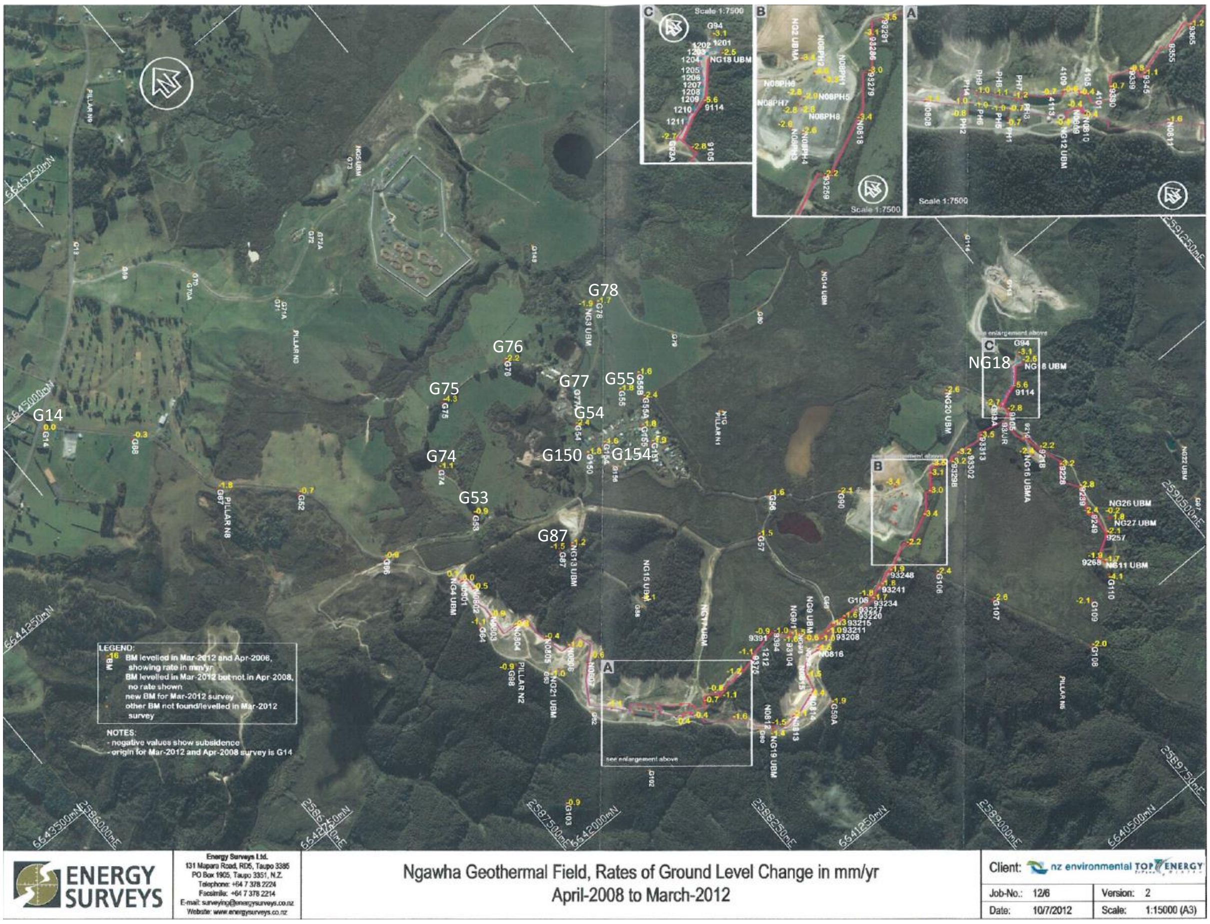

Figure 6: **Airphoto map of leveling benchmarks (in white) and change in elevation in mm/yr since 2008 (yellow). The benchmarks in Figure 7 show large captions in white. From Energy Surveys 2012.**

Table 1: **Subsidence rates of Ngawha Hot Spring area benchmarks, in mm/year. Preproduction subsidence at benchmarks G53, G54 & G55 were calculated using 1979 elevations. No elevation was taken at benchmark G77 in 2012 (due to its destruction) so its subsidence rate is to 2008.**

Benchmark	1979/1984-1998	1998-2012	1984-2012
G53	-0.9	-1.1	-0.9
G54	-1.0	-2.1	-1.4
G55	-1.0	-1.4	-1.1
G74	-0.6	-1.0	-0.8
G75	-2.7	-1.3	-2.0
G76	-1.1	-1.2	-1.1
G77	-0.9	-1.5	-1.2
G78	-0.9	-1.2	-1.0
G87	-1.2	-1.4	-1.3
G150	-1.1	-1.8	-1.4
G154	-0.7	-1.6	-1.1

These rates of subsidence are quite low and, in that they are uniform across the hot spring area, do not suggest a risk to the foundation of spa structures or to drainage in the area, which might worsen flooding. Essentially, the whole of the hot spring area is subsiding at about the same rate with a very subtle tilt toward the centre of the geothermal field to the east. This direction of tilt is perpendicular to the dominant north-eastward direction of drainage, so continued tilt in this direction is not expected to create additional ponding in the hot spring area.

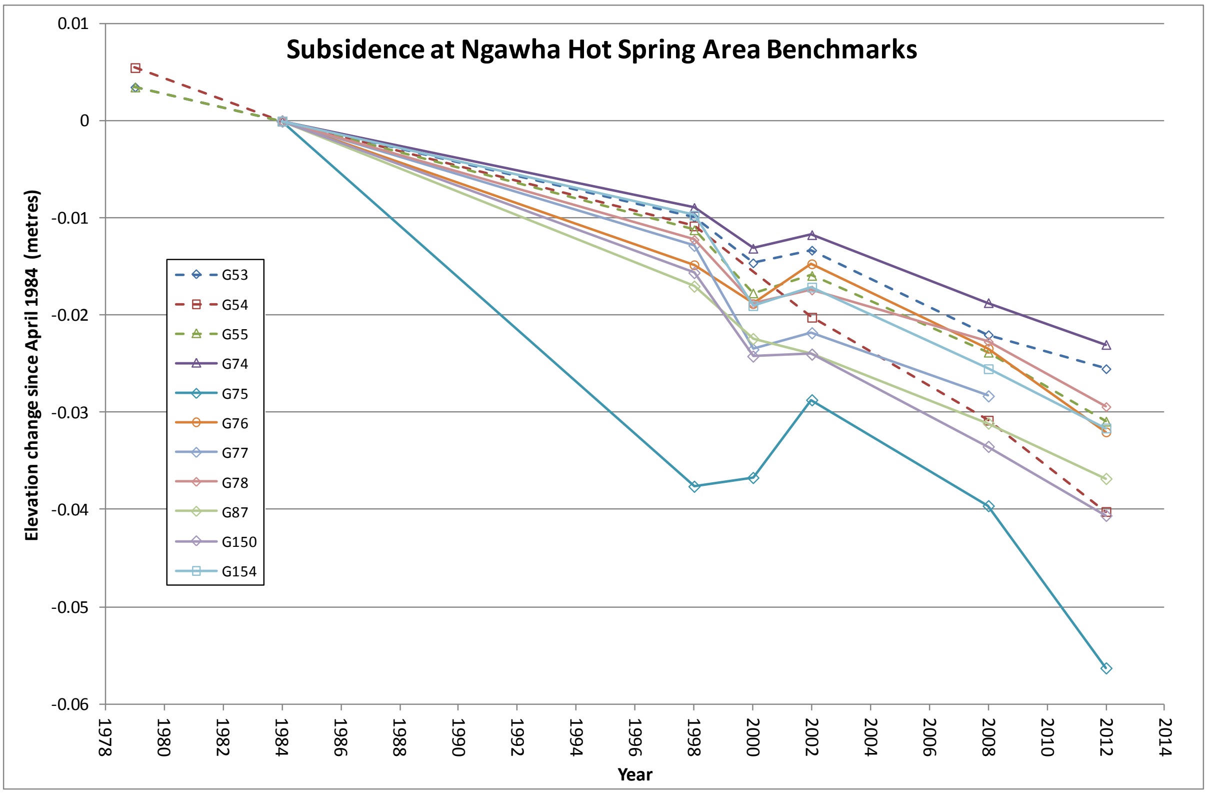

Figure 7: Elevation of benchmarks in the Ngawha hot spring area relative to benchmark G14, located at the intersection of Ngawha Rd and SH 12. The 1979 survey used a different origin benchmark, so 1979 relative elevations of BM G53, G54 and G55 have been corrected to G14.

GNS Science conducted detailed predictions of subsidence trends at Ngawha using the field numerical model in order to show the distribution of predicted subsidence around the field, including in the hot spring spa area (Bromley & Burnell, 2014). The analysis used the changes in rock temperature and fluid pressure predicted to occur throughout the field by the reservoir numerical model. The rock properties of compressibility (change in volume with change in fluid pressure) and thermal expansion (change in volume with change in rock temperature) were assigned to grid blocks in the numerical model and changes in rock volume at the individual grid blocks in the model were then calculated from model changes in fluid pressure and rock temperature. The subsidence effect of each of these changes in grid block volume were then summed to yield the subsidence effect at the surface. The rock properties were calibrated by matching the historic subsidence due to production and injection to that predicted by the model. The calibration history match at 3 wells is shown in Figure 8.

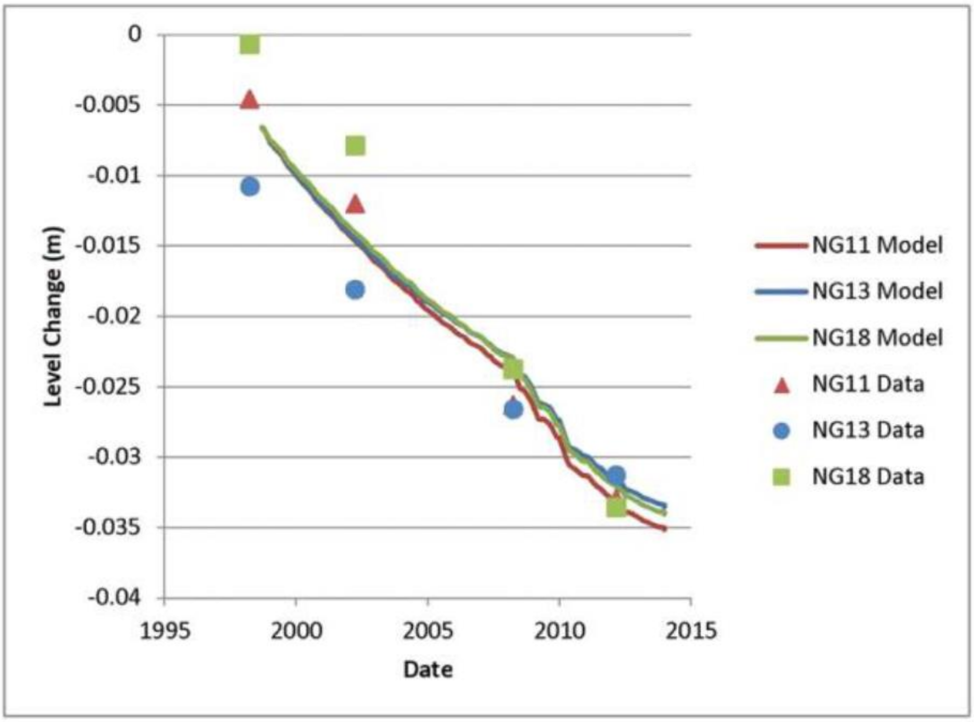

Figure 8: History match of modeled subsidence (solid lines) with subsidence observed at benchmarks located near 3 wells in the field. NG11 and NG18 are located in the injection area and NG13 is located near the hot springs. Model subsidence has been adjusted to include background subsidence of 0.51mm/year, observed near Ngawha Village. (From Bromley & Burnell, 2014)

The history match is, in my opinion, satisfactory, although it appears to over-predict the rate of subsidence at NG13, near to the hot spring spas, and under-predict the rate near the injection wells (NG11 & NG18). Based upon this, I believe that the model will tend to over-predict subsidence due to pressure change (which would be nearly the same for all three benchmarks) and under-predict subsidence due injection cooling, which is a larger factor in the injection area. For the purposes of this analysis, I believe the net outcome is that the model will slightly over-predict subsidence in the hot spring spa area.

The model's prediction of subsidence trends through 2050 for the existing project is shown in Figure 9 and for a 50 MW expansion in 2020-2023, in Figure 10. In the prediction for the existing project (Figure 9) the subsidence rate decreases after 2010. This is explained by the modellers as due to the diffusion of the initial 1998-2005 reservoir pressure drop through the cap rock to the system, which they estimate to have taken around 10 years. The subsidence in the cap rock due to the 1.5 bar pressure decrease came later than subsidence in the reservoir. Subsidence rates decrease after this due to pressure stabilization in the reservoir.

Subsidence in the 50 MW expansion case is predicted to continue at roughly its present rate through 2050.

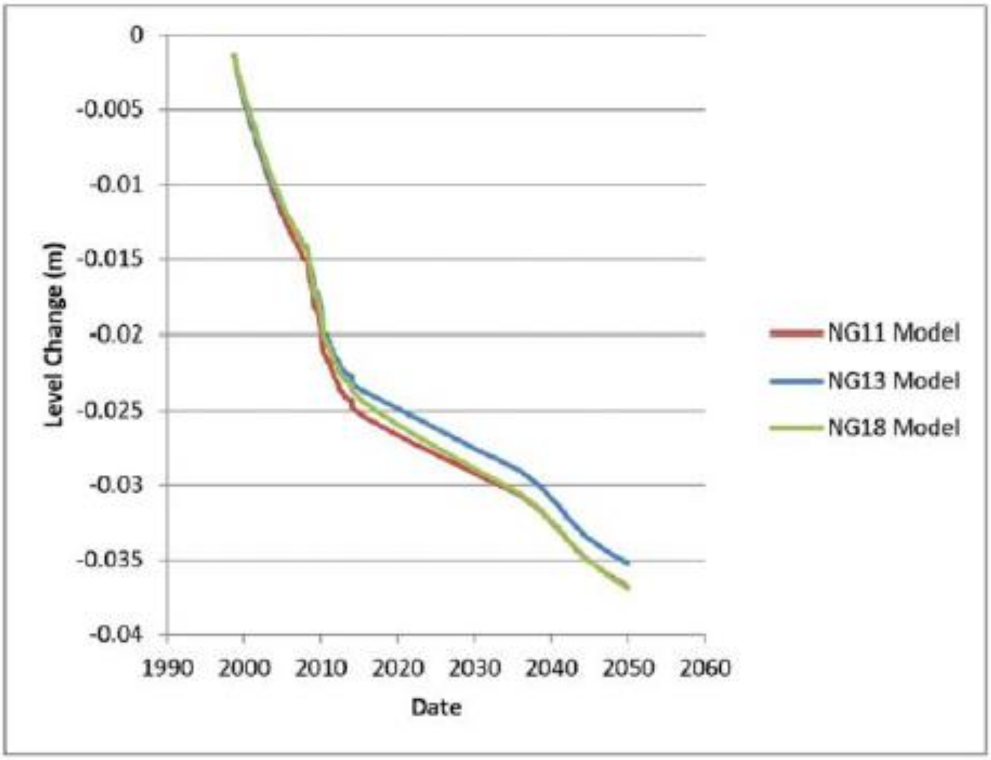

Figure 9: **Subsidence due to geothermal fluid extraction and injection at benchmarks near 3 wells assuming continuation of the existing 25 MW project. Trends do not include background subsidence.**

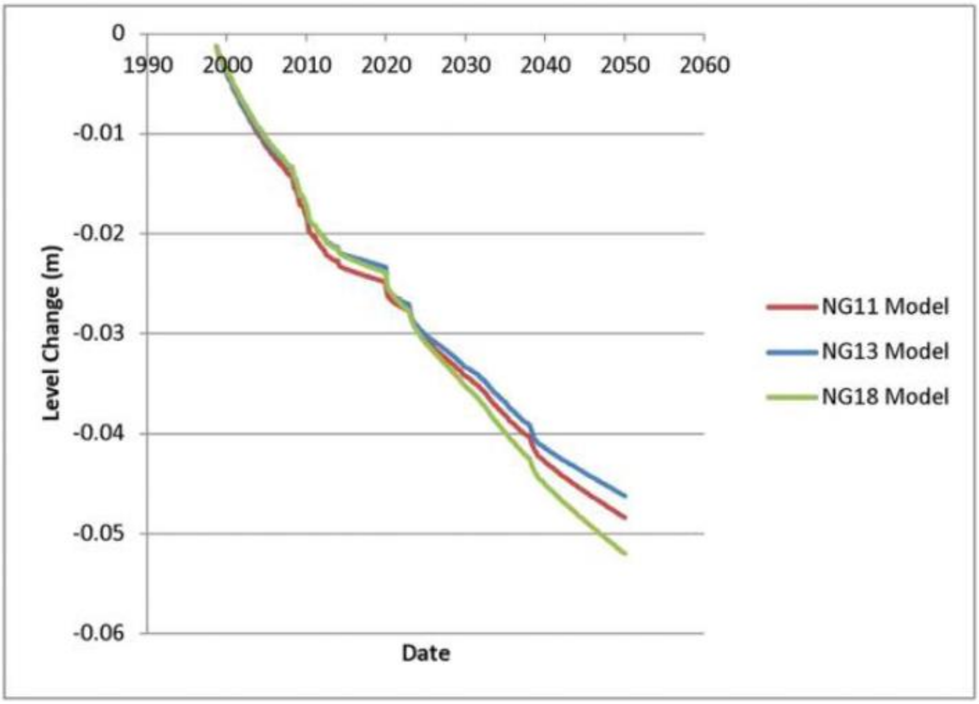

Figure 10: **Subsidence due to geothermal fluid extraction and injection at benchmarks near 3 wells assuming startup of a 50 MW expansion in 2020-2023. Trends do not include background subsidence.**

Maps of predicted subsidence around the field for both the continuation of the existing project and a 50 MW expansion in 2020-2023 are presented in Figure 11 and Figure 12.

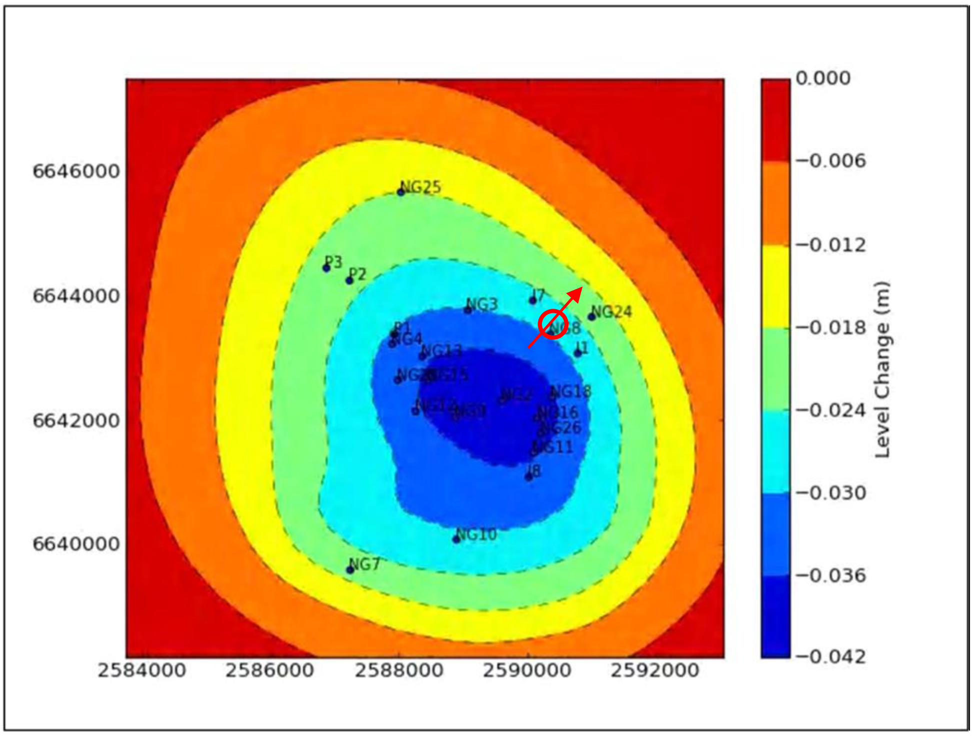

Figure 11: Subsidence change predicted for 2050, assuming continuation of the existing 25 MW development. The hot spring spas are located at the red circle. Red arrow shows the direction of drainage.

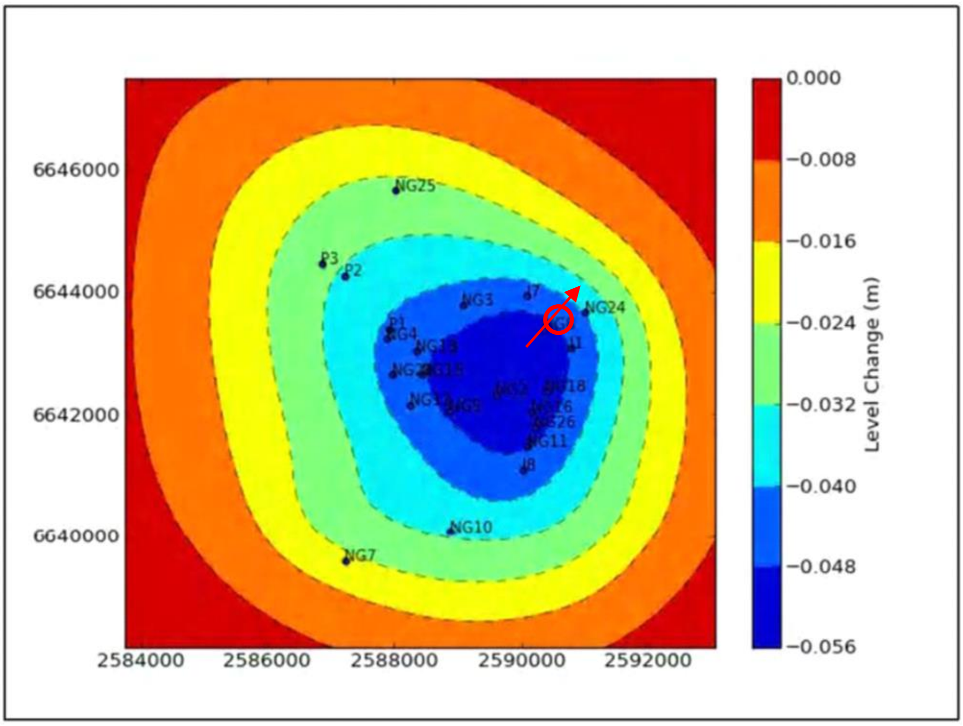

Figure 12: Subsidence change predicted for 2050 assuming a 50MW expansion in 2020-2023. The hot spring spas are located at the red circle. Red arrow shows the direction of drainage.

The maps of predicted subsidence show the spa area to subside by about 32 mm under the existing production and injection and by about 46 mm assuming a 50 MW expansion in 2020-2023. This magnitude is too small, and the distribution of subsidence too broad, to result in any structural damage to spa complex buildings or baths.

Actual subsidence at the spa will be greater, due to background subsidence, which amounts to about 1.0 mm/year. This is the rate of subsidence measured in spa area benchmarks before start-up of the geothermal project in 1998 (see Table 1). The rate of subsidence is measured relative to a benchmark outside the geothermal area. Therefore, assuming only continued operations of the existing project, subsidence due to a combination of geothermal production and natural subsidence through 2050 will result in about 84 mm subsidence at the spa since 1998. With the proposed 50 MW expansion in 2020-2023, total subsidence during this period will be about 98 mm.

The key factors with respect to drainage in the spa area, and the potential for worsened flooding, are magnitude and orientation of subsidence. Ground level changes that decrease the ground slope in the direction of drainage would be expected to worsen flooding, whereas increases in ground slope in the direction of drainage would be expected to alleviate flooding.

In the case of the spa area, drainage is directed northeast, shown as red arrows in Figure 11 and Figure 12. In both predictions, the orientation of drainage is roughly parallel to the contours of subsidence, suggesting that the slope of drainage is expected to be largely unchanged by subsidence due to the project.

Assuming a worst case scenario for subsidence rates and orientation, drainage in the spa area is still expected to be largely unaffected. Google Earth shows the terrain around the spa to be very flat, with a drainage gradient of about 10 metres per kilometre distance, sloping to the northeast. The maximum slope of the 2050 subsidence "bowl" in Figure 12 is about 12 mm per kilometre, measured on the northeast edge of the bowl. If for some reason this maximum gradient of subsidence tilt becomes oriented against drainage in the spa area, the change in slope would represent about one tenth of one percent of the existing slope (1.2 mm/1000mm). This degree of change in drainage slope would not have a measureable effect on drainage and potential flooding.

In conclusion, based upon modelling studies, the magnitude and orientation of subsidence due to the proposed project expansion is expected to be very small and is not expected to worsen flooding problems in the spa area.

Issues Arising from Proposed Expansion and Recommendations

1. Based upon monitoring results up to April 2014, the reservoir pressure maintenance program *since* 2005 appears to have prevented any significant decline in hot spring discharge or temperature which might have otherwise occurred due to continued reservoir pressure decline in the absence of supplemental injection.

2. After a period of relatively high temperature at the Jubilee and Universal springs in 2010-2011, the temperature trends of the three principal monitored hot springs is downward. There is the possibility that the 9 bar target pressure will be too low for maintaining hot spring temperatures long term. Due to the long delay in hot spring response to reservoir pressure changes, reservoir pressure management designed to stabilize or restore hot spring temperature should increase pressure by only a few tenths of a bar at a time.

3. Natural variability is a risk to the supply of natural hot water to the hot spring spas at Ngawha, although history suggests the springs are uncommonly persistent. It is recommended that spa owners support scientific efforts to better understand hot spring hydrology and structure

to assist any future efforts at mitigating hot spring changes, either natural or induced by the geothermal development.

4. The spacial distribution and magnitude of future subsidence based upon numerical modelling predictions for the Ngawha reservoir suggests that future subsidence due to the proposed expansion will not cause structural damage nor worsen flooding problems in the spa area.

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5. Regulatory framework

Introduction

We believe there are four primary statutory and regulatory components to bear in mind when looking at the interests of Parahirahi C1 Trust:

- Resource Management Act 1991
- Far North District Plan
- Regional Water and Soil Plan for Northland
- Regional Policy statement

Resource Management Act 1991 (RMA)

Taking, using, damming and diverting water (including geothermal water) are activities subject to s.14 of the RMA, and generally require 'authorisation' by means of rules in a plan or a resource consent, as is the case for Top Energy. Subsection 3 however (which may apply to the Trust) provides circumstances where there is no prohibition on such activities, including:

> (c) in the case of geothermal water, the water, heat, or energy is taken or used in accordance with tikanga Maori for the communal benefit of the tangata whenua of the area and does not have an adverse effect on the environment.

Far North District Plan

At a high level the *Tangata whenua* section of the Far North District Plan (Chapter 2) states:

> 2.6.1 To the extent possible, the rights guaranteed to Maori by ***Te Tiriti O Waitangi*** (Treaty of Waitangi) are given effect in the Plan……….
>
> 2.6.3 Development on ancestral land occurs in a way that achieves sustainable management of natural and physical resources, and ***protects Sites of Cultural Significance*** to Maori and other taonga. [emphasis added]

Specific objectives intended to achieve this include:

> 2.7.1 Through the provisions of the Resource Management Act, to give effect to the rights guaranteed to Maori by Te Tiriti O Waitangi (Treaty of Waitangi).
>
> 2.7.2 To enable Maori to develop and manage their land in a manner which is consistent with sustainable management of the natural and physical resources of the District as a whole.
>
> 2.7.3 To recognise and provide for the protection of waahi tapu and other ancestral sites and the ***mauri*** (life force) of natural and physical resources [emphasis added]

These in turn are accompanied by policies including:

> 2.8.1 That Council will provide opportunities for the ***involvement*** of tangata whenua in the ***sustainable management*** of the natural and physical resources of the District.
>
> 2.8.2 That tangata whenua be ***consulted*** over the use, development or protection of natural resources where these affect their taonga.
>
> 2.8.3 That the Council will ***have regard*** to relevant provisions of any whanau, hapu or iwi resource management plans, taiapure plans or mahinga mataitai plans.

2.8.4 That development on ancestral land will be provided for, consistent with the requirement for ***sustainable management*** of resources.

2.8.5 That ***waahi tapu and other taonga*** be identified and ***protected*** by provisions in the Plan. [emphasis added]

The District plan also goes on to say (12.9):

> "Council also recognises the importance of the role and responsibilities of ***kaitiaki*** and the need for their ***empowerment*** and the requests for early and effective engagement" [emphasis added]
>
> 12.9.5.9 Council may investigate ***joint*** approaches to renewable energy development and use, including the possible Transfer of Power or Joint Management Agreements, between itself and Northland Regional Council or other authorities, including Recognised Iwi Authorities and Mandated Iwi Authorities.
>
> 12.9.5.10 Council will encourage applicants to ***actively engage*** with Maori, including Recognised Iwi Authorities and Mandated Iwi Authorities, through early dialogue to ***ensure*** that ***adverse effects on the relationship of Maori with their culture, traditions and taonga are avoided, remedied or mitigated*** and will look for opportunities to ***encourage kaitiaki*** involvement in ***monitoring***. [emphasis added]

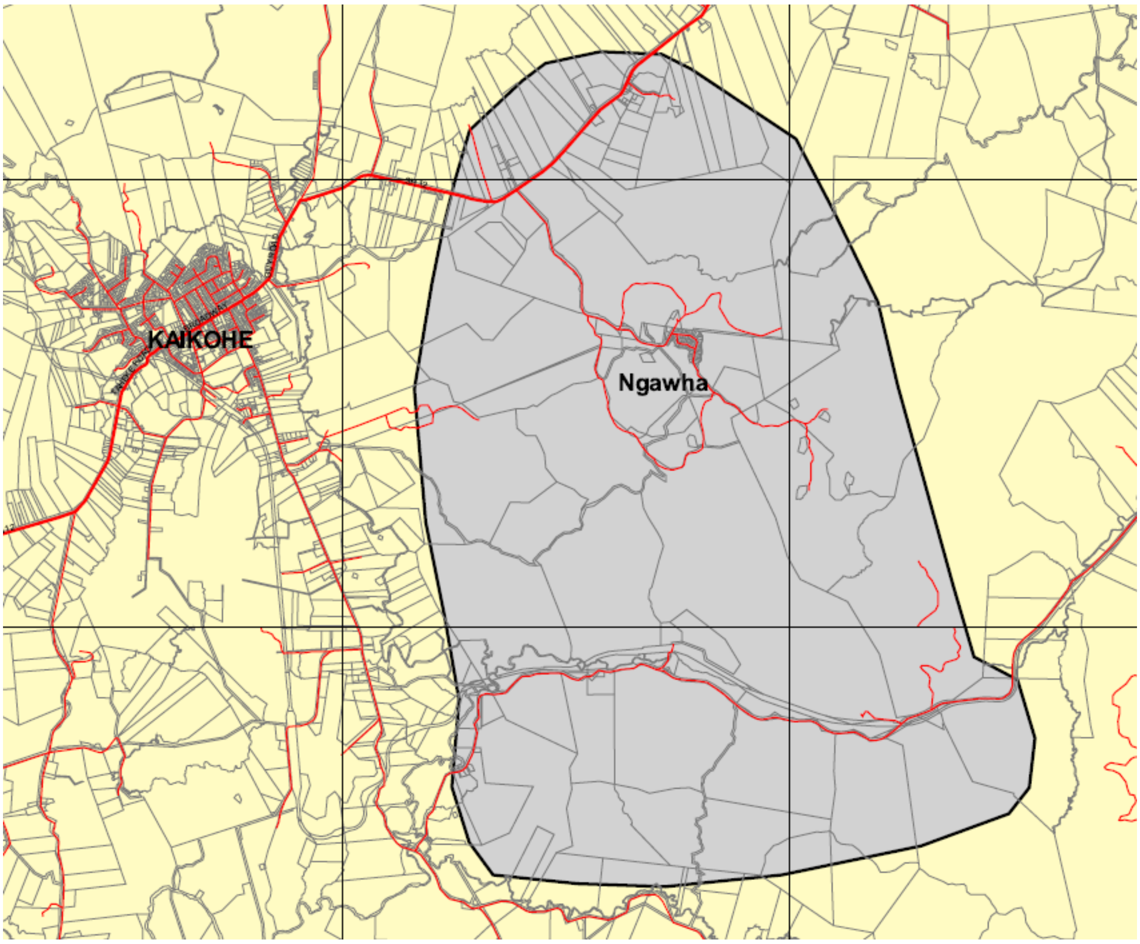
Regional Water and Soil Plan for Northland

Northland's Regional Water and Soil Plan defines geothermal water as "groundwater".[7] The rules relating to groundwater generally permit small takes for 'reasonable' domestic purposes and stock drinking uses, but if compliance with these rules cannot be achieved, a discretionary consent is necessary. If approved, installation of a water meter may be required, depending on the volume [>200m3 per day] and effects on the recharge of the aquifer and any associated surface water resource. Whilst geothermal water is not subject to the 2010 Resource Management Regulations on Measurement and Reporting of Water Takes which 'automatically' imposed metering of freshwater takes, Northland Regional Council is able to apply metering conditions to new or renewed consents for geothermal takes.

The explanation for this rule (25.3) states that it applies to the:

> "**taking** and **use** of water, **heat** or **energy** from a bore constructed in the **Ngawha Geothermal Field** as defined in Schedule C, **except** where the activity is in accordance with **tikanga Maori** for the communal benefit of the tangata whenua of the area and the activity does not have an adverse effect on the environment."

[7] **Groundwater** – Water which occurs beneath the groundwater table, including geothermal water, in soils and geologic formations which are fully saturated.



Ngawha Geothermal Field *[Schedule C, Regional Water and Soil Plan]*

Regional Policy Statement

The two versions of the Regional Policy Statement (RPS) for Northland (i.e. Operative and Proposed) have limited objectives and policies relating to *use* of geothermal water. Both however, contain general policies on promoting role of tangata whenua in resource management activities, protecting cultural values and encouraging consultation.

The *Operative* RPS includes in its policies relating to water, quantity control over uses which could adversely affect the natural character or cultural value of natural water bodies with various 'special' attributes, including being recognised by an Iwi authority as a taonga. It also requires:

> "that consultation with Tangata Whenua is undertaken over any matters specified within the Act that may affect their taonga or their use, development and protection of natural and physical resources"

The *Proposed* RPS does not distinguish groundwater in its policies and methods relating to water quantity and allocation.

6. Conclusions

Top Energy proposes a substantial potential increase in electricity generation activities on the Ngawha geothermal reservoir. The question we have worked to address for the purposes of this report is firstly, whether such development has a cultural impact on the Trust and secondly, if so, to what extent (if any).

Based on our research and particularly the first-hand narratives of respected senior Ngapuhi kaumatua, in our view the answer to the first part of this question is yes, for the following primary reasons:

1. Tangata whenua can establish a long and deeply felt connection with Ngawha Waiariki and in particular the hot springs, whose curative properties were first discovered by their ancestor Kareariki, daughter-in-law of Ngapuhi's eponymous tupuna, Rahiri. This sense of ancestral interconnection is as long as their own history and has cultural roots extending even further back to Hawaiki.
2. The kaitiaki obligations of tangata whenua who in practical terms are represented by the Trustees, appear to be as strong today as they ever have been – possibly even more so than in the past given the industrial scale of what is proposed and potential for physical and thus spiritual damage to both the springs and the people (in contrast with natural uses over the centuries for bathing, cooking and healing)
3. Given Ngawha Waiariki was handed down to them by their ancestors over many generations, kaumatua effectively regard the reservoir as the cultural property of tangata whenua. Therefore, by definition any unauthorised use of the energy and power of the Ngawha reservoir tramples the mana of the ancestors, the people of today and of those generations to come. Accordingly, kaumatua take it as an affront that Top Energy wishes to:
    a. harness the energy of their taonga to generate electricity
    b. put at risk the vitality and mauri of the reservoir through such use (including that of the pools themselves, known as the heart of Ngawha Waiariki)
    c. generate significant economic returns in the process without materially sharing the benefits with tangata whenua.

In terms of the second part of the question, or the extent to which such cultural harm is caused, we face a much more complex issue. This is because underlying beliefs and values such as ***mauri, mana*** and ***wairua*** are scientifically incalculable Maori cultural norms. Maori have lived according to their own version of "cause and effect" for generations: what Isaac Newton described as the third law of motion, Maori characterised as utu, or a state of balance through a reciprocity of action and reaction. However, like many belief systems these are fundamentally spiritual as opposed to mathematical in their origin and shape. It follows therefore, that it is not always possible to place a specific or tangible measure on the potential cultural impact kaumatua are referring to regarding Top Energy's proposed new development. What is undeniable however, is that the beliefs themselves are real as is the conviction that the consequences of "getting it wrong" (or becoming the harpoon that harms Takauere) by not fulfilling sacred obligations as kaitiaki over Ngawha Waiariki would be culturally, socially and economically devastating.

Technically, however, as we have shown in the geoscience section of this report, we can point to known and probable physical effects on the Ngawha reservoir and hot springs resulting from geothermal development, both to date and planned, based on data modelling. These are observable and scientifically measurable, and can be linked to the cultural concerns expressed by kaumatua.

For example, the forecast decline by the year 2050 in Ngawha reservoir temperatures of between 13 and 20 degrees Celsius, the increase in land subsidence rates of up to 6mm pa (from a pre-development base of approximately 1mm pa), and the observed falling pattern in temperatures at the hot springs since Top Energy's last 15MW expansion in 2008, can each be viewed as tangible and culturally unacceptable manifestations of a gradual erosion of the *mauri* of Takauere and Ngawha Waiariki – something tangata whenua are required to actively address as kaitiaki. Whilst they do not represent the full extent of the cultural harm tangata whenua fear to their taonga, they are a useful practical proxy around which discussions on ways forward which address genuine cultural imperatives and concerns, can be undertaken.

The final section of this report provides a list of recommendations for consideration in this respect.

7. Recommendations

The following recommendations have been prepared to address and mitigate the cultural impacts identified in this report. It is recommended that Top Energy and the Trust work in conjunction with Northland Regional Council to see that these are implemented as a condition of any resource consent(s) for the future expansion of geothermal electricity generation activities on the Ngawha reservoir.

Recommendations

1. **Reservoir pressure management:** Due to the long delay in Ngawha spring response to reservoir pressure changes, reservoir pressure management designed to stabilise or restore hot spring temperature should increase pressure by no more than 0.25bar at a time
2. **Subsidence:** That Top Energy indemnifies the Trust for any damages in the form of flooding , erosion, structural damage or any other damage caused to the Trust's property and/or business(s) including any loss of earnings as a result of any subsidence or movement in land levels reasonably believed to be caused by Top Energy's operation of the geothermal power plant(s) and/or related steam-field structures and wells situated on and within the Ngawha geothermal reservoir
3. **Reporting to Trust:** That the Trust is provided with annual data by Top Energy on the following:
   (a) Total mass and energy extracted on a daily basis (to be provided quarterly)
   (b) Total mass of fluid reinjected including depth and locations of such reinjection
   (c) Total mass of surface water injected including source of such water and location and depth of injection
   (d) Results of chemical monitoring of Ngawha springs and other surface features on the Ngawha reservoir (e.g. Lake Omapere)
   (e) That the Trust is provided with an annual budget to contract independent reviews of the data it is provided by Top Energy
4. **Pool monitoring**: That Top Energy also applies the same types of monitoring it currently uses at Jubilee, Tiger and Universal pools to a selection of pools on the original pool side of Ngawha Springs (the "non-Council" side)
5. **Reservoir Peer Review Panel:**
   (a) That the Regional Council establishes a Ngawha Geothermal Reservoir Peer Review Panel (Peer Review Panel) to assist Council in the supervision and monitoring of the exercise of the resource consents held by Top Energy at any point in time in relation to the use of Ngawha geothermal reservoir for electricity generation and/or other purposes; and
   (b) That two representatives from the Trust will be made members of the Peer Review Panel alongside [2] independent technical experts with relevant experience in geothermal monitoring activities
   (c) That the membership and terms of reference for the Peer Review Panel reflect those of similar entities used in the Volcanic Plateau by Waikato Regional Council for similar purposes
6. **Notice of works**: That the Trust be informed a minimum of six months in advance of any planned works on the Ngawha reservoir by Top Energy (e.g. new geothermal drilling)
7. **Regular steam field updates:** That Top Energy holds monthly conference call (or meeting) with designated representative of the Trust on any major events or changes in the past month and outlining any major events or changes planned for the coming month (in respect to

changes in production and/or reinjection/injection on any well and any other issue/s related to the steam field deemed to be relevant). In cases where materiality is unclear, Top Energy should raise the issue with the Trust to determine whether the Trust believes it is relevant/material

8. **Added chemicals**: That the Trust is provided with a list of all chemicals added by Top Energy to water and introduced to the reservoir, and that there be reasonable limits on these and their purpose (e.g. restricted to reducing contaminant discharge, limiting scaling, running tracers)
9. **Ngawha springs pool chemistry**: That if there is any material change in the chemistry of Ngawha pools which is in the opinion of independent experts considered to be the result of reinjection or other activities of Top Energy, that Top Energy will prepare and consult with the Trust on a plan to address these chemical changes with the objective of restoring the pools to their natural chemical state; and that if this is unsuccessful that Top Energy will cease whatever activity it is carrying out that is believed in the opinion of independent experts to be the cause of such changes in chemistry
10. **Top Energy response to any future impact on Ngawha Springs**: That if pressure drops or any other causative factors occur as a result of Top Energy's geothermal electricity generation or other activities on and in the reservoir, which threaten the natural state of Ngawha Springs pools (for example levels, discharge rate, temperatures, chemistry) that Top Energy will put in place any necessary measures relating to the way in which it operates its geothermal steamfield and power plant/s on the Ngawha reservoir, to preserve and protect the Ngawha Springs in their natural state (including, if need be, shutting down all or part of its total electricity generation and steamfield operations)
11. **Archaeological protocols**: That clear protocols are developed and implemented as part of the resource consent to ensure:
    (a) kaumatua and kuia are consulted in advance on any areas Top Energy wishes to undertake earthworks and or/drilling activities to ensure such works are not planned in the same location as known waahi tapu;
    (b) enable appropriate cultural rites to be performed ahead of planned works;
    (c) provide for the Trust to nominate an observer of any earthworks/drilling activities
    (d) in the event a new waahi tapu or archaeological site is discovered or disturbed, that all works on the site shall cease and Council and the Trust shall be notified immediately. Works shall not recommence until Council and the Trust are satisfied that it is appropriate to do so on cultural and archaeological grounds.
12. **Economic development**: That Top Energy shares the economic benefits it achieves from the development of additional electricity generation meaningfully through the payment of annual royalties or similar material commercial arrangements in recognition of the mana whenua status of the Trust and its beneficial owners over the Ngawha geothermal reservoir.
13. **Agreement**: That Top Energy enters into an agreement with the Trust regarding the above matters and provides support to the Trust for this purpose (advisory costs)