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Side-by-Side and Opposing Fields: Simultaneous Geothermal Protection and Development – The Case Study of Ngātamariki, New Zealand

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ABSTRACT

The Ngātamariki geothermal field is located within the Waikato Region in the Taupo Volcanic Zone, New Zealand. Whilst the Ngātamariki field is identified for development under the relevant statutory planning framework, its resource boundary is located as little as 2.5 km from resource boundary of the famous Orākei Korāko geothermal field. Orākei Korāko is identified for total protection. It is known as the birthplace of the local Māori tribe (Ngāti Tahu-Ngāti Whaoa) and possesses impressive geothermal features of immense cultural value to Māori that also provide significant geodiversity, biodiversity, scientific and tourism values to New Zealanders more generally.

This paper will discuss the various technical, regulatory and stakeholder challenges that Rotokawa Joint Venture (a partnership between Tauhara North No.2 Trust and Mercury NZ Limited) faced as it embarked on the large-scale greenfield Ngātamariki generation project. The paper will focus on the challenges specific to Ngātamariki and Orākei Korāko's opposing classifications and small separation distances. This paper will also document how Rotokawa Joint Venture overcame the challenges presented by these circumstances, and in doing so, will provide an example of development success for others in similar predicaments.

1. INTRODUCTION

Ngātamariki is one of a number of high temperature geothermal systems within New Zealand's Taupo Volcanic Zone (TVZ). It is surrounded by other high temperature systems including; Wairakei and Ohaaki - where Contact Energy Limited have long running geothermal power stations, Orākei Korāko centred approximately six kilometres to the north - a system protected from large scale development, and Rotokawa to the south - where Rotokawa Joint Venture (RJV)[1] has two operating geothermal power stations (Rotokawa and Nga Awa Purua). Figure 1 shows the location of Ngātamariki in relation to other geothermal systems within the TVZ.

Ngātamariki, Orākei Korāko, Ohaaki and Rotokawa are all located within the rohe (tribal area) of Ngāti Tahu-Ngāti Whaoa – a relatively small Iwi (Māori tribe) located in the central North Island of New Zealand. Beneficiaries of the Tauhara North No.2 Trust, who own and administer land overlying the Rotokawa geothermal resource, and who as partners to RJV, partly own the geothermal power stations on that resource, are themselves of Ngāti Tahu-Ngāti Whaoa descent.

Compared with the other nearby systems, Ngātamariki has few surface thermal features and only a small surface outflow of geothermal fluid. The main surface thermal features lie along the Orakonui Stream and the banks of the Waikato River in the north-western part of the field (Figure 6). These features comprise areas of sinter, small springs and associated geothermal pools. One of the pools is formed within a hydrothermal eruption crater which has recorded eruptions in 1948 and 2005. Recent observations and older scientific reports indicate the Ngātamariki surface thermal features show considerable variability over time with a general decline in activity over the last 70 years.

Ngātamariki was first explored by the New Zealand Government in the mid-1980s with four wells being drilled: NM1 (1,302m), NM2 (2,403m), NM3 (2,158m) and NM4 (2,742m). NM2 and NM3 successfully identified the presence of a permeable geothermal resource with temperatures around 280ºC. Despite this, the government did not proceed with any development, due to the availability of other more promising geothermal resources and the discovery of the large Maui gas field offshore of Taranaki.

The Orākei Korāko geothermal field was investigated by the Government in the mid-1960s to assess its electrical power potential. Four wells were drilled in the Orākei Korāko area, about 1.5 km apart: OK1 (1403.6m deep), OK2 (1155.2m), OK4 (1374.6m) and OK6 (1219.8m). All of these four wells encountered the geothermal system, with OK2 and OK6 having higher temperatures between 260ºC and 270°C. Orākei Korāko is currently a popular New Zealand tourist attraction, containing a wide range of geothermal surface features available for public viewing.

Since 1991, sustainable geothermal energy usage and its effects have been controlled by a single piece of legislation, the Resource Management Act 1991 (RMA). This differs from the approach taken in many countries in two main ways: by integrating resource allocation and effects under a single Act, and by requiring sustainable management as its central purpose. Under the RMA "sustainable management" means; managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while—

(a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

[1] Rather than referring to individual Rotokawa Joint Venture partners and their respective roles in the Ngātamariki development, and instead of detailing the various subsidiary companies set up for different aspects of the development, for the purpose of simplicity, the parent company, and resource consent holder, Rotokawa Joint Venture Ltd (RJV) is used as a proxy for them all.

(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment.

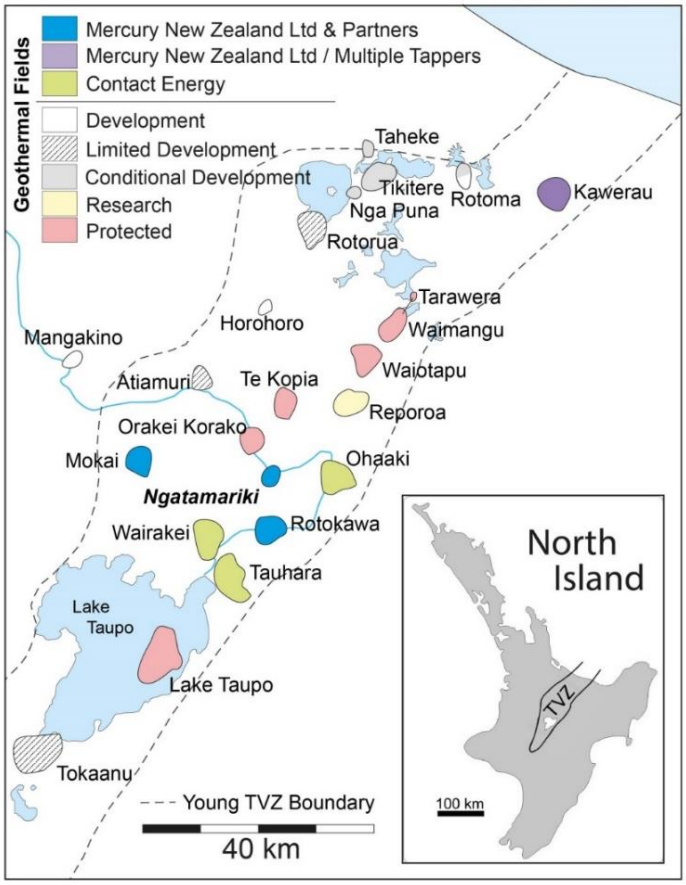

Figure 1: Location of Ngātamariki, Orākei Korāko and other geothermal systems of the Taupo Volcanic Zone (New Zealand).

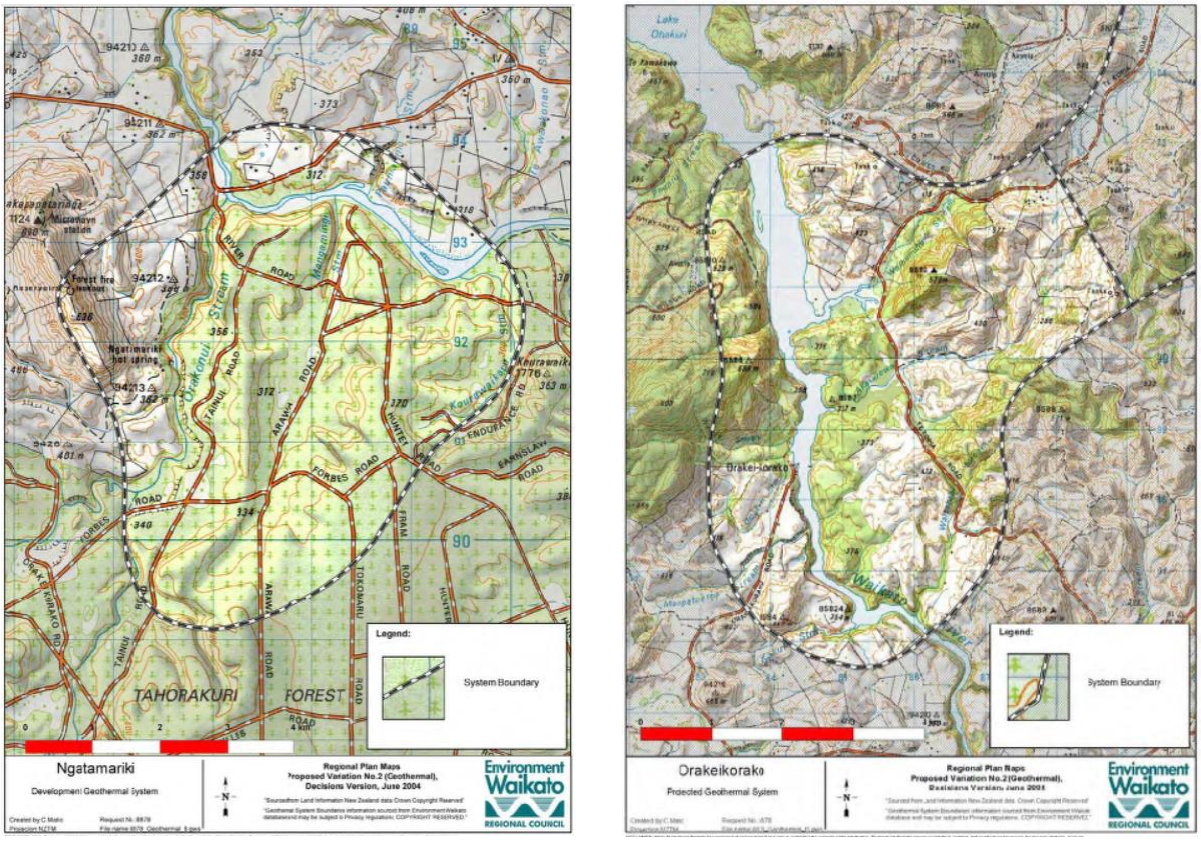

Figure 2: Maps of the Ngātamariki Geothermal System (left) and Orākei Korāko Geothermal System (right) (Waikato Regional Plan - November 2008). System Boundary inferred by Schlumberger survey.

2. BACKGROUND

2.1 Cultural Context

Māori have had an enduring and intimate association with the land, sea, and terrestrial waters since time immemorial. That connection is both physical and spiritual. Papatūānuku (Mother Earth) provided unity and uniqueness to her people.

Early Māori society did not have a concept of absolute ownership of land, and certainly, no individual owned land. The natural resources were the means of sustaining the collective livelihood of all. Before depletion of a resource, a "rāhui" (ban) would be placed on that area until sustainability returned. Then there is the concept of "tūrangawaewae" or having one's place to stand. In the Māori world view, much of life is about finding one's foundation and position in the world. This was traditionally expressed through a people's relationship or connection with particular places, such as a mountain, a range, a river, a lake or ngāwha (geothermal surface features). Māori express this connection through kaitiakitanga – a way of managing the environment through stewardship or guardianship. Today there is growing interest in kaitiakitanga as Iwi are restoring their environment and culture and using traditional ideas in the modern world. Kaitiakitanga is also included in the RMA as a matter for regulatory authorities to have particular regard to when making decisions regarding management of natural and physical resources.

Geothermal resources are special to Māori and were prized for their many uses. Iwi within the central North Island of New Zealand often settled near geothermal areas to cope with the notorious cold weather of this region. Different ngāwha were dedicated to specific uses - cooking pools, bathing pools, healing mud for skin conditions and arthritis, and ngāwhā with mineral properties for dying and preserving wood.

Since Ngātamariki and Orākei Korāko sit within the rohe of Ngāti Tahu-Ngāti Whaoa, the people of that Iwi are mana whenua (people with the authority to speak on behalf of the land), and kaitiaki (guardians of the land and its resources). Geothermal resources, in particular, are regarded by the Ngāti Tahu-Ngāti Whaoa people as taonga (treasures), due largely to the wide range of benefits and uses they provide to the health and well-being of the Iwi.

Orākei Korāko is the place where Ngāti Tahu-Ngāti Whaoa Iwi first settled, from around 1250AD. Orākei Korāko is, therefore, considered the birthplace of Ngāti Tahu-Ngāti Whaoa. It follows that, Orākei Korāko, and the geothermal surface features found there are of significant cultural importance and value to the Iwi.

2.2 Historical Context

Since settling at Orākei Korāko at around 1250AD, Ngāti Tahu-Ngāti Whaoa then dispersed and created other settlements elsewhere within their rohe. Although they faced increasing competition among Māori for the resources of the central North Island, often resulting in increasing skirmishes and conflict, they lived relatively peaceful lives.

Following the arrival of British colonialism, the lives of Ngāti Tahu-Ngāti Whaoa people changed in many ways. The Crown's concept of land ownership was thrust upon them via unjust legislation and unfair process, in the form of the Native Land Acts of 1862 and 1865, causing massive upheaval. They also experienced a flood of foreign tourists, keen to marvel at the unique geothermal features within their rohe. The 'Hidden Valley' at Orākei Korāko (Figure 3) was one of the first geothermal tourist attractions of the region, with recorded visits from the mid-1800s. It was estimated that a third of Earth's active geysers were located there, of which two were some of the world's largest (Minginui Geyser and Orākei Korāko Geyser). The Minginui Geyser was once observed erupting up to 90m high.

Although tourism may have brought some brief economic benefits to the Ngāti Tahu-Ngāti Whaoa people, they have sadly had to witness the destruction and degradation of their precious geothermal resources over time, mainly as a result of the New Zealand government's large-scale power development activities from the mid-20th century. As part of the hydro-electric developments on the Waikato River, the construction of the Ohakuri dam from 1956 and commissioning of the hydro power station in 1961, resulted in the flooding of approximately two-thirds of the Orākei Korāko geothermal area, drowning most of its geysers and geothermal features, along with many culturally significant sites. Prior to the lake being filled, Ngāti Tahu-Ngāti Whaoa people were evicted from their homes at Orākei Korāko, having to watch their homes being burnt to the ground as they left. Most of these people re-settled in the nearby Ohaaki geothermal area.

Then, the geothermal systems themselves became a focus for electricity generation development. In New Zealand, geothermal power development began in the 1950's at Wairākei, followed by the Ohaaki geothermal power station in 1989. These developments resulted in severe impacts on Ngāti Tahu-Ngāti Whaoa people. Natural geothermal springs suffered irreparable damage at Ohaaki, land subsidence and associated river bank erosion, flooded urupa (burial grounds) and threatened the Ohaaki Marae (meeting house).

Historically, the adverse impacts of these early developments on prized geothermal features has been devastating for the Iwi. They have had to witness the destruction of these resources and sites while receiving no benefit from the developments, while others exploited and profited from them.

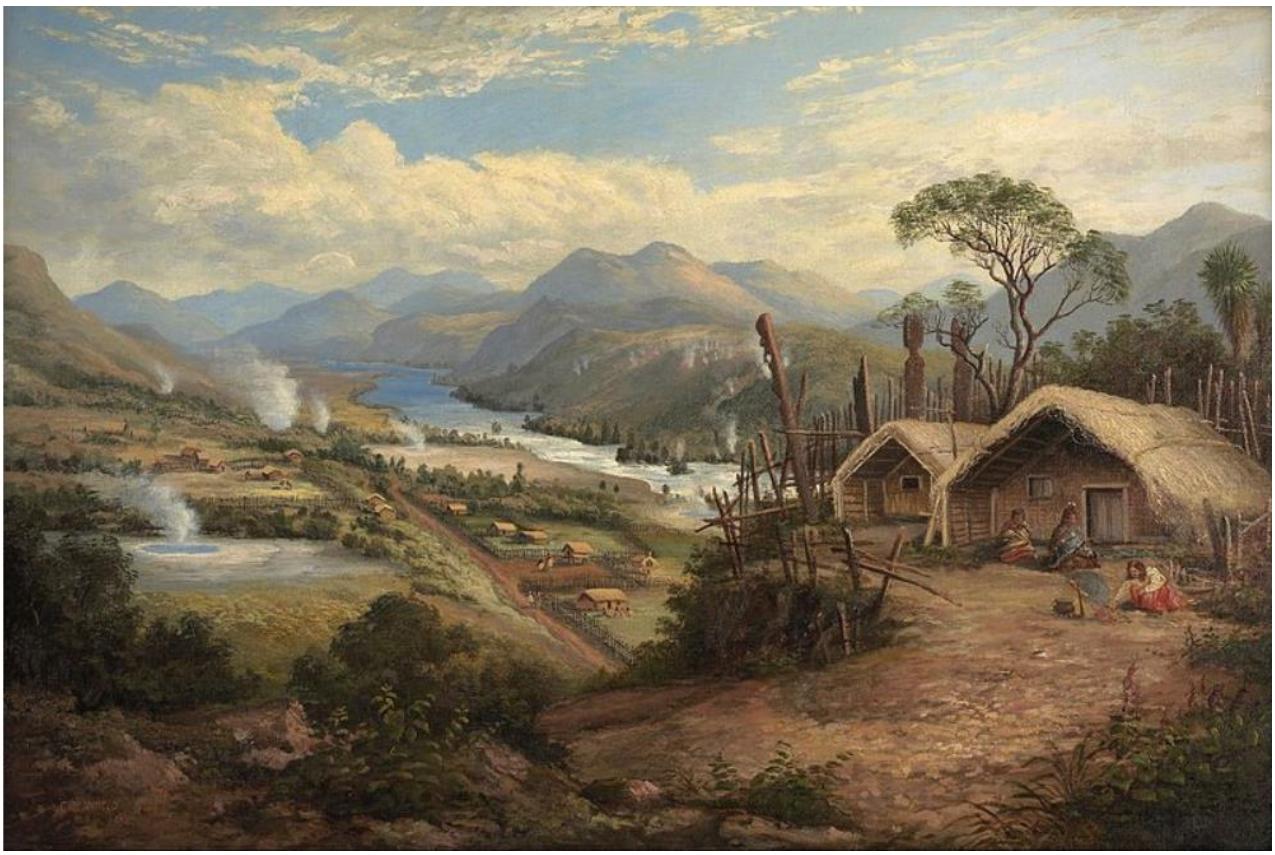

Figure 3: Charles Blomfield - Orākei Korāko on the Waikato River 1885, from the Museum of New Zealand Te Papa Tongarewa.

Figure 4: Left - Rainbow Terrace 1943, Right - Golden Fleece Terrace 1950

3. LAND ACCESS

An outcome of the design of the RMA, is that, unlike in most countries, there is no concept of an exclusive exploration or development license. Therefore, a geothermal developer must make private arrangements with landowners under civil law to secure access to the resource (unless that developer already owns land necessary for access).

Prior to 1999, the land sitting above the Ngātamariki geothermal resource was owned by Fletcher Challenge, a multinational corporation, and formerly the largest company in New Zealand, with holdings in construction, forestry, building, and energy. While recognising the energy development potential of the Ngātamariki geothermal resource, Fletcher Challenge arranged for comprehensive energy development rights to be attached to the land title via one of its subsidiary companies, Fletcher Energy. These rights were set in the form of encumbrances, easements and a *profit a prendre*. Subject to securing all necessary resource consents and permits, these instruments provided for a wide range of future geothermal exploration and development activities.

However, in 1999, the Fletcher Challenge Board of Directors resolved to dismantle the parent company and establish various separate companies. As part of this process, the land at Ngātamariki, along with its plantation forest and energy development rights, were all placed on the market. The land and trees were purchased by Wairakei Pastoral Limited, who had significant plans to convert the plantation forest at Ngātamariki (and other large tracts of forested land nearby) to dairy farms. The energy development rights were sold separately and in 2000 were purchased by Rotokawa Joint Venture, the partners of which, at that time, operated the Rotokawa A geothermal power station, but had longer term aspirations of expanding their geothermal development portfolio.

4. STATUTORY PLANNING

4.1 Resource Management Act (RMA)

In 1991, the RMA was enacted in New Zealand with its over-arching principle of sustainable management. In New Zealand, geothermal resources are not owned by anyone. Under common law, flowing water (including geothermal water), is not owned, and the only rights are those of management. These rights are held by the Crown and the role of managing natural resources is then devolved from the Crown to regional councils.

The RMA is a meta-policy, with detail expanded through optional national policy statements (NPS) developed by the Crown and mandatory regional policy statements developed by regional councils for each region in New Zealand. The purpose of a regional policy statement is to identify the main resource management issues and provide policies and methods to achieve integrated and sustainable management of resources of the region. Each regional council may also develop a regional plan, which provides rules about the use, development or protection of natural and physical resources. At the time of authorisations being granted for development of the Ngātamariki geothermal resource, there was not any NPS that applied to the use or protection of geothermal resources, and all applicable management and regulatory controls were found in the Waikato Regional Policy Statement (RPS) and the Waikato Regional Plan (Regional Plan).

4.2 Proposed Waikato Regional Policy Statement and Regional Plan - Geothermal

Ngātamariki falls within the jurisdiction of the Waikato Regional Council (WRC). WRC has developed a RPS and a Regional Plan that include explicit policies and rules for management of all geothermal resources in its region. The development of these important planning documents used an open process of public consultation and participation. For geothermal resources, in 2003, WRC proposed policies and plans that were focused at a regional level, whereby changes, or some level of adverse impacts to the resource and surface features in some geothermal systems were accepted, provided other geothermal systems were protected and preserved. This was proposed in the form of a classification scheme for the various geothermal systems in the Waikato region. The proposed scheme classified geothermal systems into one of five categories summarized below;

- Development Geothermal Systems - large systems where development of geothermal resources will be allowed to occur because there is no evidence of a subsurface connection of geothermal fluid to or from a Protected System (see below); and the system contains few geothermal features of moderate to high vulnerability; or geothermal features are already adversely affected by lawfully established geothermal development already occurring; or the system is already subject to large-scale energy use and development;
- Limited Development Geothermal Systems - large systems where there are Significant Geothermal Features that could be adversely affected by large-scale development but where smaller-scale development is unlikely to adversely affect those features;
- Protected Geothermal Systems - large systems where care must be taken to ensure use of the geothermal resource is sustainable and has **no adverse effect** on significant natural geothermal characteristics because the system supports a substantial number of geothermal features that are moderately to highly vulnerable to the extraction of fluid and/or or there is evidence of a subsurface connection of geothermal fluid to or from a system Development or Limited Development system;
- Research Geothermal Systems are all other large geothermal systems where there is insufficient information to identify them as Development, Limited Development, Protected Geothermal Systems or Small Geothermal Systems or are not yet discovered.
- Small Geothermal Systems are those that does not produce water with a temperature equal to or greater than 100°C or does not occupy a volume of greater than 10 km^3.

WRC proposed that Orākei Korāko be classified as a Protected Geothermal System due to; the high geodiversity values and high vulnerability of the Significant Geothermal Features present, the positive social and commercial values the geothermal features provided through tourism, and the cultural heritage values the geothermal features possessed by virtue of their importance to local Māori. WRC also proposed that Ngātamariki be a Protected Geothermal System, even though it has few geothermal features, because it was considered that any large-scale development of Ngātamariki, located so close to Orākei Korāko, posed an unacceptable risk of adversely impacting Orākei Korāko and its geothermal surface features if, as postulated at that time, the two systems were hydraulically connected.

The proposed policies and rules for geothermal resource management attracted 41 submissions from a variety of groups. Among the submitters, RJV supported the proposed geothermal system classification scheme but opposed the proposal to protect Ngātamariki from development. RJV instead argued that Ngātamariki should be classified as a Development Geothermal System. Having previously secured necessary land access arrangements for future development of Ngātamariki, RJV knew a protected classification for that system would be fatal to their aspirations. Conversely, the Department of Conservation[2] (DOC) supported the protected classification for Ngātamariki. DOC's conservation advocacy role meant they strongly aligned and agreed with WRC's rationale to protect Ngātamariki from development, thereby, eliminating unnecessary risk to the nearby Orākei Korāko system associated with possible hydraulic connections between the two systems.

[2] The Department of Conservation is a Central Government department responsible for administering New Zealand's conservation land estate and advocating for conservation, biodiversity and geodiversity values within New Zealand.

4.3 Public Hearings and Regional Policy Statement and Regional Plan Outcomes

For decisions to be made on the RPS and Regional Plan, mediation, public hearings and Environment Court proceedings were required. Given geothermal electricity generation was RJV's core business, they had a lot at stake. Planning decision outcomes had the potential to significantly impact RJV's future success. Accordingly, RJV participated fully in this planning process, and invested heavily to develop a robust science-based case in support of their submission that the classification for the Ngātamariki Geothermal System should be changed from "Protected" to "Development". RJVs case was based on the following key planks as presented in evidence;

- Resistivity survey data available at the time showed no evidence for fluid flows to or from the two systems. There was no coherent low resistivity connection, as would be expected, if thermal fluids passed between the systems.
- Geochemical studies reveal that Orākei Korāko and Ngātamariki fluids are, overall, chemically different and distinct.
- Isotherms indicate separate heat sources for Orākei Korāko and Ngātamariki, and temperatures in wells in both fields show significant lower temperature in the zone between the fields. Both these factors indicate there is no fluid flow between the fields.
- The pressures of Orākei Korāko wells when plotted together form a gradient which was 6 bar lower than that formed by Ngātamariki wells. If they were connected, the pressures would have formed a single gradient.
- Geothermal surface features at Ngātamariki showed a modest level of activity with some sinter deposition, however, the thermal activity was not outstanding and better met the criteria for Development systems.

Geothermal decisions regarding the RPS and the Waikato Regional Plan were notified concurrently in May 2004. These decisions included the following; "*Ngātamariki was postulated to have a hydrological connection to Orakeikorako; however resistivity measurement and other data have effectively ruled that out"*. Accordingly, to the delight of RJV, Ngātamariki was reclassified as a Development Geothermal System (Figure 5). This was an extremely important moment in the development pathway for this resource. It marked, and documented, an expectation of the public of New Zealand that, the resource at Ngātamariki was available (in a resource planning and allocation sense) for appropriate and sustainable future development (subject to all necessary resource consents being obtained). It was an especially important milestone for RJV, who had already secured exclusive land access rights to the resource.

System	Reason
Horohoro	Few surface outflows vigorously depositing sinter. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Mangakino	Few surface outflows vigorously depositing sinter. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Mokai	The system is already subject to large scale energy use and development. No surface outflows vigorously depositing sinter. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Ngatamariki	No surface outflows vigorously depositing sinter. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Ohaaki	The system is already subject to large scale energy use and development. Existing surface features significantly impaired by legally established large takes. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Rotokawa	The system is already subject to large scale energy use and development. Few surface outflows vigorously depositing sinter. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.
Wairakei- Tauhara	The system is already subject to large scale energy use and development. Existing surface features significantly impaired by legally established large takes. No evidence of a flow of subsurface geothermal fluid to or from a Protected Geothermal System.

Figure 5: Waikato Regional Council Development Geothermal Systems (Table 7-1 of the Decisions Version of the Waikato Regional Plan (May 2004).

5. CONSENTING FOR DEVELOPMENT

Prior to any take, use or discharge of geothermal fluid associated with large scale development, resource consents must be applied for and secured (noting resource consents do not secure access to land). These are either granted or declined in accordance with relevant provisions of the RMA. To secure resource consents, the proposed development must meet the sustainable management purpose of the RMA.

To get a large-scale geothermal development proposal to a stage where a resource consent applicant can show and convince a regulatory authority, the local community, Iwi and other stakeholders that it meets the purpose of the RMA, requires a multi-million dollar programme of resource investigations, deep geothermal well drilling, well testing, resource assessments and environmental impact assessments along with appropriate stakeholder consultation.

In 2004, following the outcome of the RPS and Regional Plan process, RJV embarked on a comprehensive programme of non-evasive scientific investigations of the Ngātamariki geothermal resource. This involved; geological studies, geochemical surveys, and Magneto-tellurics and time domain electro-magnetics (MT-TDEM) resistivity sounding surveys. These surveys focused on the Ngātamariki resource and the area to the north between Ngātamariki and Orākei Korāko. The purpose of this work was to inform a review of the early conceptual model of the Ngātamariki system, to better understand development potential and development risk, and to position potential future exploration drilling targets.

The new geophysical and geochemical survey data provided useful information about the deep resource, and the conceptual model of the resource was revised accordingly. The model indicated that the productive exploration wells drilled in the 1980's were actually located close to the northern edge of the field, and that the potentially productive area of the Ngātamariki resource extended significantly further to the south (Figure 6). The previous resistivity survey had only mapped the area of a flow from the deep reservoir to a shallower aquifer, and not the deep geothermal resource.

Armed with extensive and new scientific information, RJV had the confidence to commence a new phase of exploration drilling effort at Ngātamariki in early 2008, constructing three further wells: NM5 (2,980m), NM6 (3,367m) and NM7 (2,845m). The exploration programme had two main objectives: to determine the full extent of the deep high temperature resource; and to better understand the connection between the deep resource, shallow intermediate temperature aquifers and overlying cold groundwater.

In the early stages, other than reconsidering previous evidence, no concerted additional effort was given to understanding more about Orākei Korāko to the north, or any potential hydraulic connections between the two geothermal systems. For all intents and purposes, it was assumed such matters were dealt with through the previous Regional Plan process, and that by virtue of Ngātamariki's development classification status, there was no requirement to seriously reconsider these types of risks in the resource consenting phase.

Overall, exploration drilling and testing proved very successful, with both key objectives being met. The drilling indicated a proven area of productive reservoir of 5 km^2 and an additional probable area of 2 km^2 for a total of 7 km^2. The work also highlighted a development risk associated with potential cold water downflow through a "leak" near to NM2 where mixed thermal-groundwater was fed by deep high temperature reservoir fluid. This water then flowed northward to support the thermal features along the Orakonui Stream and Waikato River. Reduced deep reservoir pressures had the potential to reverse this flow, thereby requiring careful deep pressure management as part of any development plan.

The exploration work also enabled another review of the conceptual model and the development of a numerical model. The model was used for assessing potential development configurations, scoping the project and testing the potential cold water downflow risk.

5.1 Design and Scope of the Development

To ensure the development proposed would be the "best" option for Ngātamariki, key potential impacts of a greenfield geothermal development were identified early on – such as adverse effects on reservoir sustainability, subsidence and geothermal surface features. A scientific approach was taken, focusing on targeted data collection, reservoir modelling and ongoing data review and interpretation. This was an iterative process designed to optimise the sustainability of the development. Along the way, the process resulted in several changes to the project description, development philosophy, and monitoring and exploration programmes. Some of these changes resulted in project delay, but all were considered necessary to achieve the right balance between economic viability, resource sustainability and environmental effects.

5.2 The Consent Envelope

At the completion of the project design and scoping phase, RJV had decided the best development for Ngātamariki involved up to 60,000 tonnes per day (t/d) of fluid extraction from the northern, high temperature part of the system, and injection of spent fluid into deep permeable formations at the margins of the high temperature reservoir. It also decided that fluid injection would be nominally 98% of extraction, in order to minimize reservoir pressure decline. In turn, this would act to mitigate the risk of potential cold water downflow and any potential surface impacts, particularly to Ngātamariki's surface thermal springs. Accordingly, RJV's consent application was framed to fit this envelope of activity. Figure 6 shows the areas of production and injection originally proposed in RJV's consent application and locations of Ngātamariki thermal features.

To support the consent application, RJV procured a raft of different environmental impact assessments. These included assessments of; resource sustainability, subsidence, induced seismicity, effects on surface water, groundwater and thermal features, effects on air quality, construction related impacts, noise, traffic, cultural, archaeological, ecological and landscape effects as well as potential positive impacts.

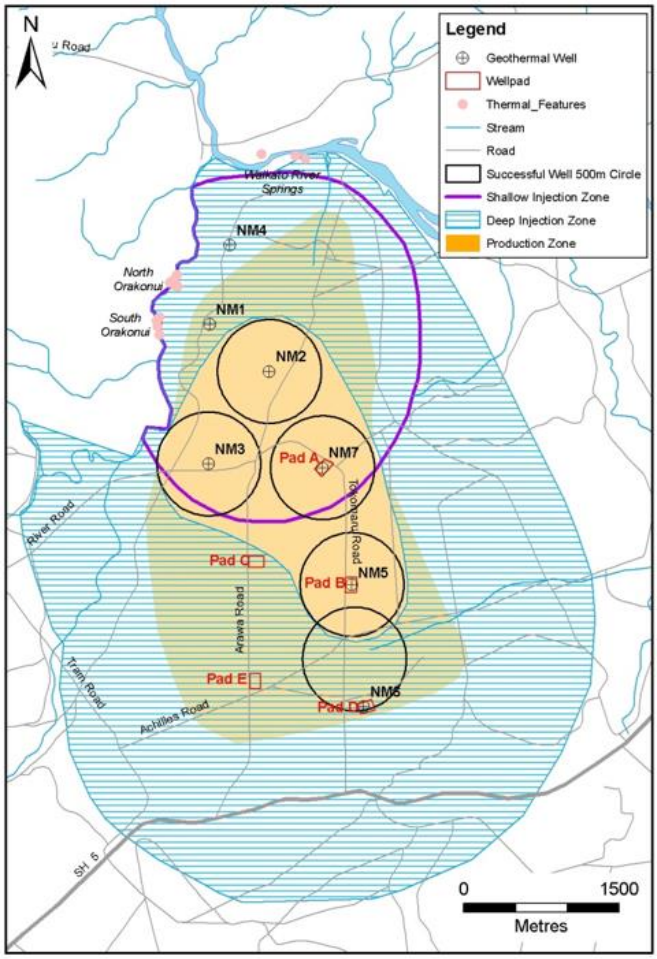

Figure 6: Originally proposed areas of production and injection. An area of shallow injection was also proposed to mitigate any declines in spring flow at the thermal areas.

5.3 A Conundrum Realised

During the detailed environmental effects assessment phase, RJV soon came to the realization that, despite all available scientific evidence supporting the absence of any hydraulic connection between Ngātamariki and Orākei Korāko, there was no expert witness who could say, with absolute certainty and in a Court of law, that no connection existed. At the end of the day, there would always be a chance that the two systems were connected, and the only way to confirm this either way was to induce a pressure drop in Ngātamariki and determine if that pressure drop promulgated toward Orākei Korāko. Inducing such a pressure drop required significant abstraction of fluid, which RJV would need resource consent for. And in any case, the thought of being responsible for adversely affecting Orākei Korāko or its features was unpalatable to RJV. Although the likelihood of this occurring was low, the risk and reputation damage would be simply too great to accept or ignore - at least without considering a management approach.

5.4 Management Approach Originally Proposed to Protect Orākei Korāko

Given the presence of the Orākei Korāko risk, as part of its original consent application, RJV proposed to re-evaluate the likelihood of a connection and to recommend the location of two "sentinel" monitor wells of differing depths between Ngātamariki and Orākei Korāko (refer area between OK4 and NM4 in Figure 7). It was also proposed that these wells be drilled at least one year prior to commissioning the power station in order to allow a reasonable time period of baseline pressure monitoring and the following management approach would be followed thereafter;

> *Should downhole pressure in the sentinel wells decline by a significant amount consistent with pressure decline at similar depths in the Ngātamariki area, the following study and mitigation plan will be activated:*
>
> 1. *Immediate notification of WRC and its Peer Review Panel,*
> 2. *Within 4 weeks RJV will prepare a report to WRC and its Peer Review Panel setting out results to date, further monitoring to be undertaken (if any) and a preferred mitigation plan,*
> 3. *The Peer Review Panel will approve the mitigation plan, recommend revisions to the plan or request further study,*
> 4. *RJV will, in good faith, implement the approved or recommended actions of the Peer Review Panel.*
> 5. *"Significant" is taken to mean variation outside three standard deviations of natural variability measured in the baseline period.*

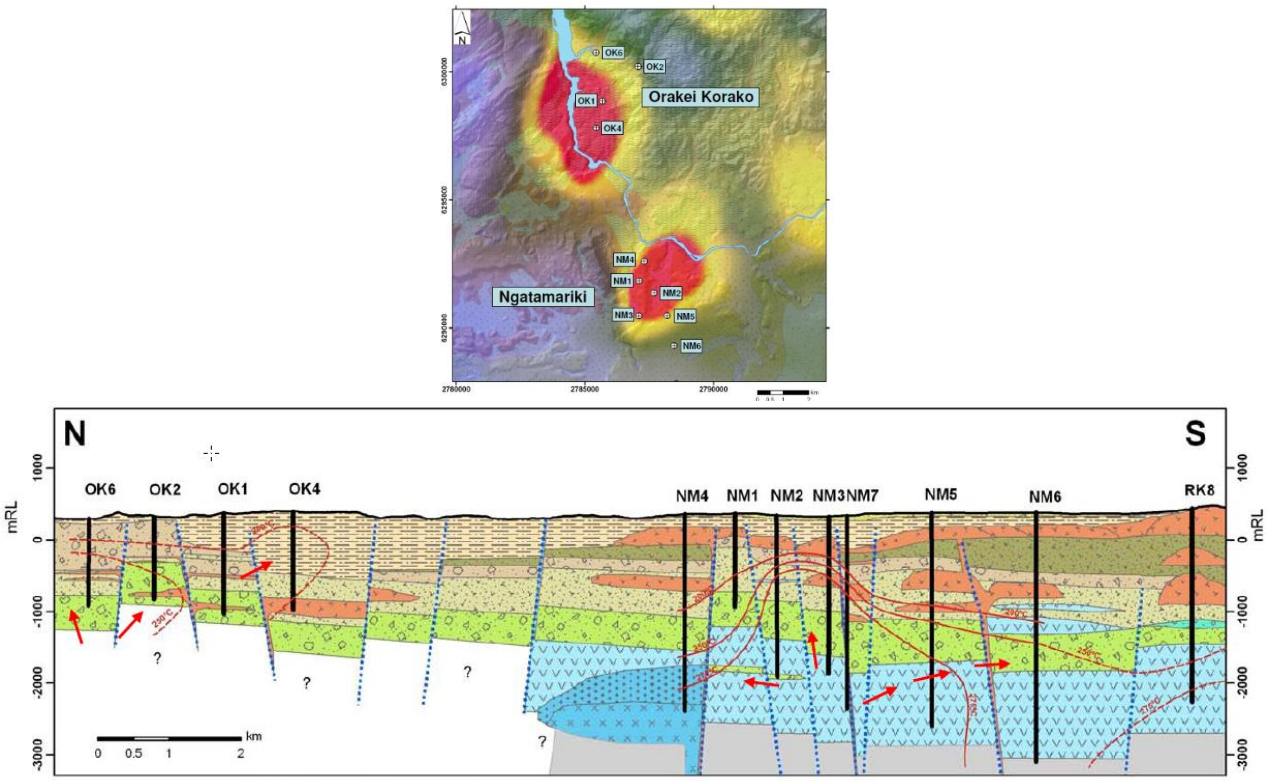

Figure 7: Conceptual model cross section extending through Orākei Korāko and Ngātamariki.

5.6 Stakeholder Consultation

Consultation with parties potentially affected by a development proposal is a common part of the consent application process in New Zealand. For large scale developments, it is considered best practice and generally expected that applicants will consult with Māori, the local community, and any relevant interest or advocacy groups. RJV's existing relationships with Ngāti Tahu-Ngāti Whaoa, the local community and landowners were able to inform the consultation approach for Ngātamariki. This was based on the following core principles:

(a) Early identification of parties who may be affected by, or interested in, the project;

(b) Preparing consultation material that introduced the project and outlined the consenting process for potentially affected parties and to seek their feedback – including concerns and suggestions;

(c) Preparing a range of technical, environmental and resource studies that inform potentially affected parties of the impacts expected on them (if any); and

(d) Remain open to mitigation solutions to allay any outstanding concerns and remain available throughout the course of the project and the consent process to any party who wishes to meet to discuss the project.

A collaborative approach to consultation was also promoted. This enabled a process of regular checks to be made on whether the right effects were being addressed, whether the mitigation RJV was proposing was adequate and whether or not there were aspects of the proposal that needed further consideration or review before being finalised.

5.7 Consent Process

RJV submitted their final application for resource consents on 9 November 2009. It was notable that, largely through the relationship and affiliations Tauhara North No.2 Trust had with Ngāti Tahu-Ngāti Whaoa, and as a result of adopting an early and ongoing process of engagement and consultation with the Iwi, RJV was able to secure Ngāti Tahu-Ngāti Whaoa written support for its consent applications.

Considering the legacy of adverse environmental and cultural impacts caused by hydro and geothermal energy development projects in the past within Ngāti Tahu-Ngāti Whaoa's rohe, their public show of support for the Ngātamariki project was a strong signal of faith and trust in RJV to develop the resource sustainably. It also showed that Ngāti Tahu-Ngāti Whaoa had come to terms with past injustices and were now looking positively towards the future, confident that this development would benefit their people and New Zealanders more generally. Their support, however, was not given lightly. RJV was under no illusions that their development performance, and in particular any potential impacts at Orākei Korāko, would be under strict scrutiny.

Because the proposed Ngātamariki development was large in scale, greenfield in nature, and potentially resulting in more than minor environmental effects, the applications were publicly notified by the consenting authorities (Waikato Regional Council and Taupo District Council). This enabled stakeholders and members of the local community to lodge written submissions, outlining their support or opposition to the proposal or setting out their views, suggestions or requests in a neutral manner.

In total, there were 12 submitters (one submitter later withdrew). The main opposing submitters and their key concerns are summarized below;

- The Orākei Korāko Collective (OKC)
    - OKC comprised of representatives from the owners and trustees of land blocks overlying the Orākei Korāko geothermal resource (Tutukau East Z Block, B7A Block Reservation and Paeroa South 2B) and Orākei Korāko Geyserland (2000) Ltd who leased land from these landowners to run the popular Orākei Korāko Geyserland Resort and tourist operation facilities. OKC was concerned that the proposal posed unknown risks to their Orākei Korāko land and to the thermal surface features that supported an internationally renowned local tourism industry.
- Wairakei Pastoral Limited (WPL)
    - WPL are owners of the land overlying the Ngātamariki resource. At the time of RJV's consent application, WPL was in the planning phase for their forestry to dairy farm land conversion at the site. Despite substantial pre-application consultation effort by RJV, WPL remained concerned about potential incompatibilities and adverse impacts the geothermal development could have on the operation of their future dairy farms. Of particular concern was the potential for contamination of local fresh groundwater – an important resource to the success of WPL's dairy conversion venture given acquisition of consents for surface water abstraction from the nearby Waikato River were fraught with difficulty due to limited water allocation availability.
- The Department of Conservation (DOC)
    - As advocates for conservation values, DOC was mainly concerned that the proposed development would result in significant reductions in fluid and heat flow to the Ngātamariki thermal surface features located along the Orakonui Stream, resulting in reduced geodiversity and biodiversity.

RJV engaged with all submitters following receipt of their submissions. Of particular note, was RJV's post-submission effort invested to allay OKC's concerns. None of the OKC members were originally identified by RJV as potentially affected parties to consult. Once the OKC members became aware of the consent application, this omission resulted in some animosity shown from OKC towards RJV. RJV went about addressing this through a process of concentrated and regular engagement with OKC. The parties eventually agreed on a way forward that ensured OKC were more strongly connected with the project, were involved with RJV's decision-making processes, and were kept fully updated on project activities. The outcome was to shift an initially tense relationship to one where both parties could trust and work with one another moving forward.

Despite RJV's additional consultation effort, it was unable to resolve all submitters concerns (including OKC's). Therefore, the Waikato Regional and Taupo District Councils arranged for the consent applications to be heard at a public hearing presided by a panel of independent Commissioners acting as decision makers on behalf of the Councils. At the hearing, evidence was presented to the Commissioners by RJV and all submitters wishing to be heard. The Commissioners were also provided recommendations from Council staff to assist in their deliberations and decision.

Throughout large parts of the hearing, Commissioner discussion and questioning focused on potential development risks to Orākei Korāko. It was apparent that, even with RJVs proposal to construct two pressure monitoring sentinel wells in between the two systems, the Commissioners appeared sympathetic to OKC's concerns and unconvinced a decision to grant consent as sought would guarantee the avoidance of any adverse effects on Orākei Korāko and its thermal features.

In this regard, Council staff presented their view to the hearing Commissioners saying that *"the potential effect on Orākei Korāko is ……of low probability which has a high potential impact"*. They posed the question as to *"how this risk of effects is best managed in a regulatory sense"* noting that, at the time the RPS was adopted in 2006, there was less perceived risk of interference than between other systems. Furthermore, that *"had there been sufficient doubt on the matter, Ngātamariki ... would have likely been classified as a "Research" system and the Development System classification reflects a formal Council acceptance through the public policy process, that Ngātamariki and Orākei Korāko are unconnected."* Council staff concluded that it would, therefore, seem difficult to justify a decision to decline RJV's consent applications on the basis of a possible inter-system connection.

5.8 Consent Decision

Following roughly five months of deliberating, the hearing Commissioners released their written decision to grant RJV's resource consents on 30 August 2010. In their decision they addressed the Orākei Korāko risk as follows;

> *"…….rather than decline the application on the grounds of absence of absolute certainty, the proposal should be allowed, but subject to appropriate conditions and recognition that the RMA is not a "no risk" statute. Conditions also need to have regard to the likely consequences of a pressure reduction at Orākei Korāko."*
>
> *"All the expert and lay evidence we have received leads towards the conclusion that, subject to appropriate conditions that lead to ongoing advance "early warning" monitoring of potential adverse effects in "sentinel wells" at strategic locations between and within the two systems, with a back-up injection and monitoring strategy ready to respond in the unlikely event of any induced pressure change being measured, there should be no adverse effects. Conditions should be imposed to ensure smooth information flow between the applicant and the relevant landowner/operator interests. In the final event that conditions are not effective or not complied with, provisions should be put in place that enable the Regional Council to itself initiate necessary remedial or preventive measures required to protect the functioning of the Orākei Korāko system."*

The relevant consent conditions imposed by the Commissioners included the requirement that all activities were to be exercised subject to the following performance standards, each of which was to apply;

1. The avoidance of pressure drawdown in the reservoir that causes, or is likely to cause, quenching of the resource by cold water inflow.
2. The avoidance of any induced pressure or temperature response that may cause an adverse effect on surface thermal discharges in the Orākei Korāko geothermal system, and
3. The need to avoid contamination of freshwater aquifers which renders it unsuitable for consumption by farm animals.

Further consent conditions specifically addressing risks to Orākei Korāko required additional technical work and further regulatory approvals prior to commencing the development. These included;

- The requirement for RJV to provide to the Waikato Regional Council, for its approval, an Injection and Monitoring Strategy designed to ensure compliance with performance standard 2 (avoiding effects on Orākei Korāko thermal features). The Strategy needed to incorporate monitoring of subsurface pressures at depths and locations; and
- In order to inform the development of the Strategy, RJV was first required to undertake and provide to Waikato Regional Council the following:
    - A risk analysis addressing the likelihood of adverse effects on surface geothermal features in Orākei Korāko as a result of the proposed development.
    - Identification of the options available for minimising the risk to surface geothermal features in Orākei Korāko including, but not limited to, additional injection in Ngātamariki.
    - Assessment of the practicability, logistical issues, likely effectiveness and timing for implementation of the various options.
    - An implementation plan for the preferred option, including measures and steps that will be taken to minimise the time required to implement the plan in the event that pressure monitoring indicates an actual or potential effect on surface features at Orākei Korāko.

6. ORĀKEI KORĀKO RISK ASSESSMENT

To maintain momentum with the Ngātamariki development, shortly following notification of the Commissioners' consent decision, RJV began work on a comprehensive Orākei Korāko risk assessment and Injection and Monitoring Strategy. This process involved the following key work streams;

- Further Magneto-Telluric data analysis;
- Additional geologic and conceptual model interrogation and refinement;
- Scenario analyses of potential reservoir responses to Ngātamariki development. Scenarios identified were limited to;
    - deep pressure drawdown from Ngātamariki production;
    - deep pressure increase due to Ngātamariki injection; and
    - intermediate confined aquifer pressure reduction due to pressure drawdown at Ngātamariki;
- Sentinel well and Orākei Korāko monitoring well location and depth studies;
- Ongoing consultation with OKC, WRC and Ngāti Tahu-Ngāti Whaoa;
- Providing to OKC, free access to independent technical geothermal experts to review RJV's Management Plan, risk assessment documentation and Injection and Monitoring Strategy and to provide them advice and opinion on these outputs;
- Commercial land access negotiations with OKC members and other landowners of potential sentinel well locations;
- Acquisition of additional resource consents to authorize the drilling and use of new sentinel and monitoring wells;
- Drilling of new Ngātamariki sentinel wells NMM17 and NMM18 (Figures 8 and 9);
- Drilling of new Orākei Korāko monitoring wells OKM1, OKM2 and OKM3 (Figures 8 and 9);
- Testing and analysis of new sentinel and monitoring wells;
- Reviews and assessments of Orākei Korāko thermal surface features and historic monitoring data;
- Re-assessment of reservoir connection risks;
- Revision of the Ngātamariki development and Orākei Korāko risk mitigation plans and peer review of these plans by independent experts; and
- Preparation of various technical reports supporting the revised strategy for stakeholder input and Council approval.

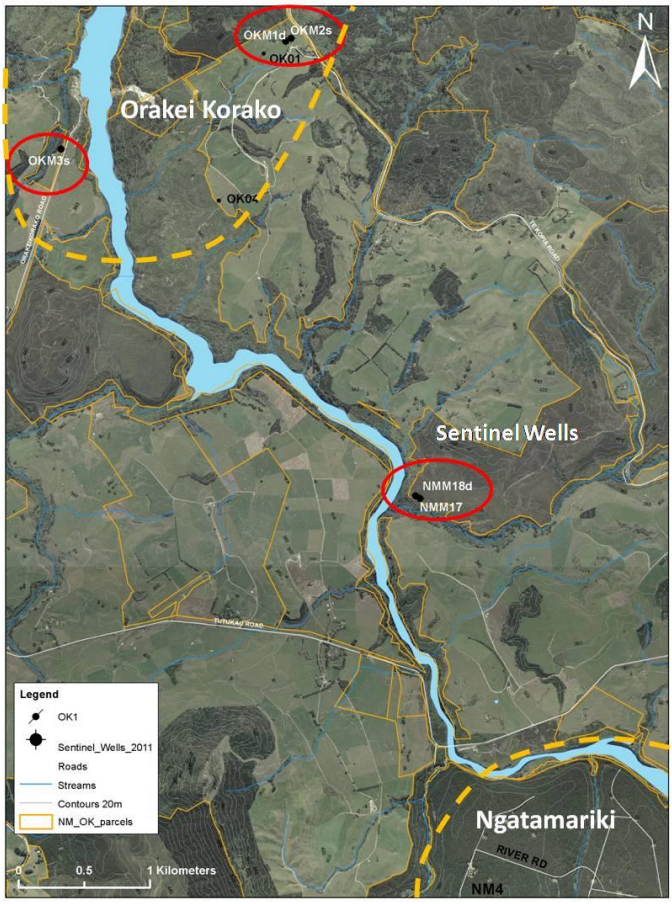

Figure 8: Locations of Ngātamariki sentinel and Orākei Korāko monitor wells. NMM18 is a deep (1570m) sentinel well and NMM17 is at intermediate depth (320m). OKM1 is a deep (1000m) monitor well drilled at Orākei Korāko and OKM2 is at intermediate depth (415m). A further shallow (30m) monitor well is located on the west side of Lake Ohakuri near to the Orākei Korāko Geyserland tourist resort.

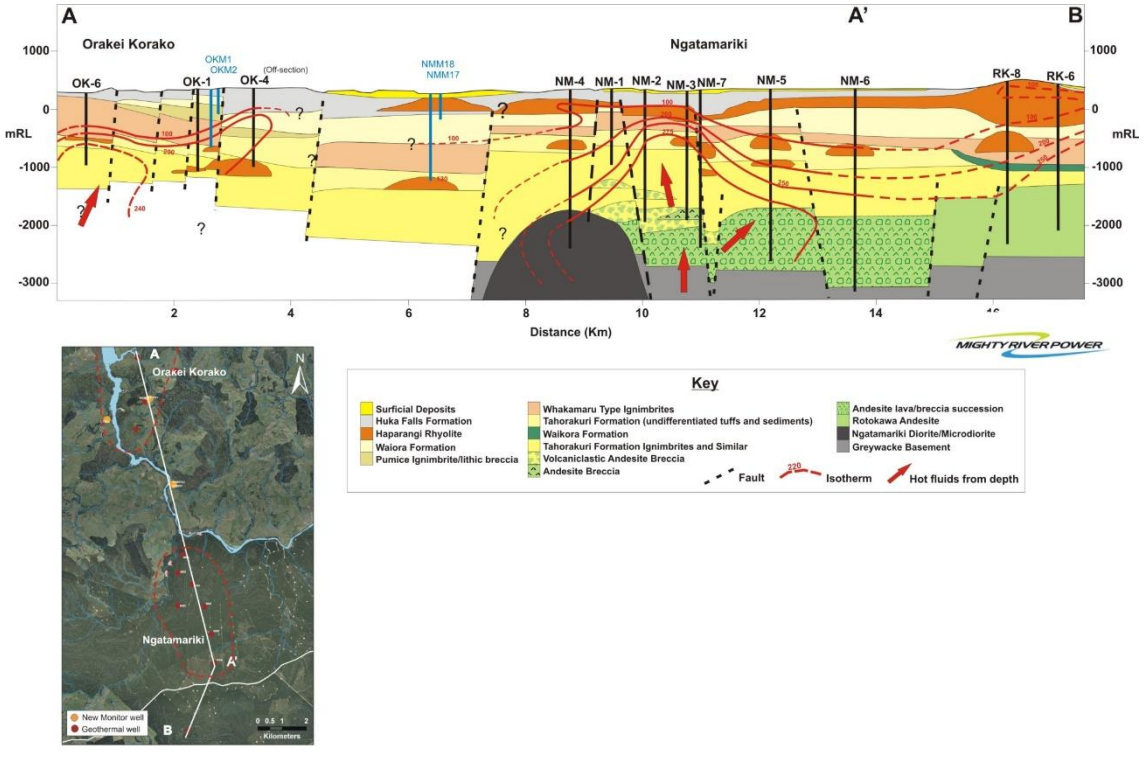

Figure 9: NNW-SSE cross-section through the Ngātamariki geothermal field showing Ngātamariki sentinel wells and Orākei Korāko monitor wells, stratigraphy, inferred fault locations (denoted by black dashed lines), isotherms and interpreted fluid flow paths in the system. Well NM2 at Ngātamariki is a dedicated deep pressure monitoring well.

7. REVISED NGĀTAMARIKI DEVELOPMENT STRATEGY

Since all identified scenarios by which production at Ngātamariki potentially impacts Orākei Korāko are based upon a subsurface change in hydraulic pressure, the only logical development strategy was to focus on hydraulic pressure management and adaptive injection. Accordingly, informed by the risk reassessment work undertaken, the following strategy was proposed and approved;

1. Conservatively initiating the development at an abstraction rate of 50,000 t/d, being 10,000 t/d less than the consent provided for;
2. Continuously monitoring deep Ngātamariki reservoir pressure at well NM2 to provide a reference for other outfield pressure data;
3. Maintaining an injection rate of no less than 98% of the daily abstraction to maximise Ngātamariki reservoir pressure support;
4. Focusing more injection to the north of the Ngātamariki production area (with the pipework designed to allow for 100% of injectate to go North) to create a pressure barrier between the Ngātamariki reservoir and deep aquifers to the north (i.e. in the direction of Orākei Korāko), and provide stand-by injection in the south (Figure 10); and
5. Implement an outfield pressure monitoring programme by continuously monitoring pressures at Ngātamariki sentinel wells and Orākei Korāko monitoring wells (OKM1 and OKM2).

Overall, if a hydraulic connection did exist between Orākei Korāko and Ngātamariki, if anything, this revised strategy was likely to result in an increase in Orākei Korāko pressures – not a reduction. In this event, the change could be mitigated by shifting a greater portion of injection south of Ngātamariki production area (i.e. further away from Orākei Korāko). If monitoring showed this strategy was not working and adverse effects on Orākei Korāko were occurring or imminent, RJV would reduce production or ultimately turn Ngātamariki off altogether.

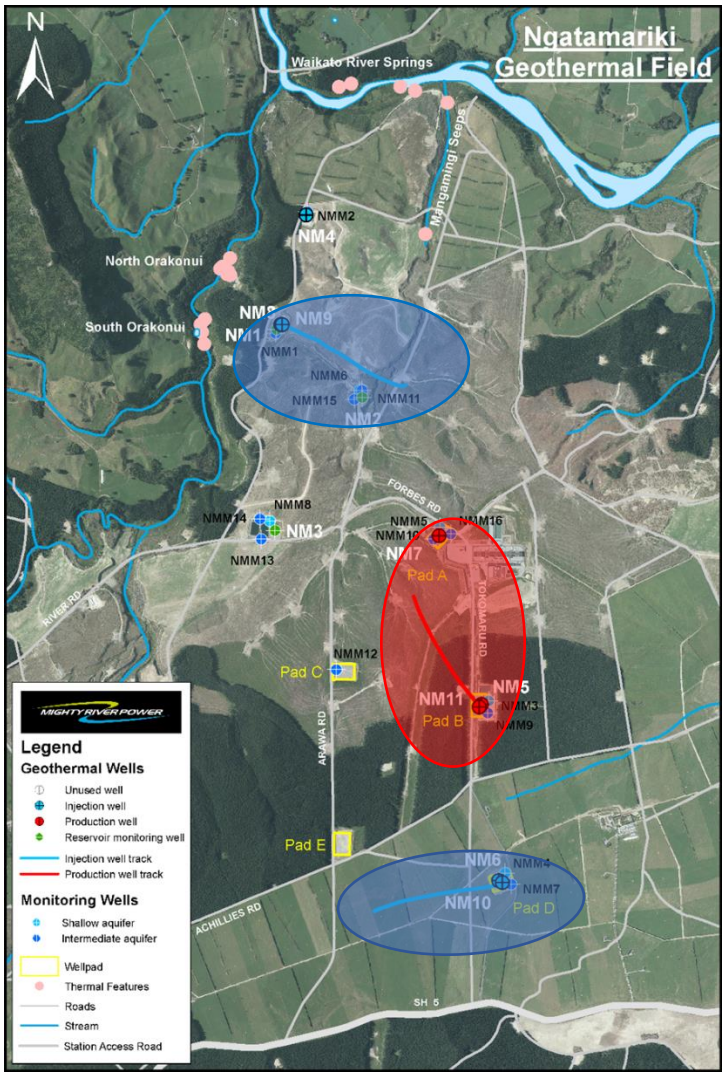

Figure 10: Map of Ngātamariki showing the revised development strategy following the Orākei Korāko risk assessment - including focused injection in the north and further injection in the south (blue circles) with production from the centre of the field (red circle).

Long term discharge testing of NM7 in 2010 was conducted to enable pilot plant testing of various plant configurations. As part of this testing a reservoir interference test was also conducted. The results concluded the deep Ngātamariki reservoir was highly permeable across the whole field, thereby avoiding the need for full injection in the North, as pressure support could be actively provided by injection in the South.

8. MONITORING STRATEGY

To ensure the development strategy was achieving its desired purpose, the following programme of monitoring was proposed;

- Pressure, temperature and chemistry monitoring in reservoir depth aquifers between Orākei Korāko and Ngātamariki, at the most likely location of a connection (sentinel well NMM18 to 1570m depth, completed October 2011). This was to provide early warning of deep pressure drawdown from Ngātamariki production or increase due to Ngātamariki injection.
- Pressure, temperature and chemistry monitoring in the northward extension of the Ngātamariki intermediate aquifer, between Orākei Korāko and Ngātamariki (sentinel well NMM17 to 320m depth, completed November 2011). This was to provide early warning of intermediate aquifer pressure drawdown.
- Pressure, temperature and chemistry monitoring within the deep reservoir at Orākei Korāko, to provide early detection of a pressure change (monitor well OKM1 to 1000m depth, completed December 2011).
- Pressure, temperature and chemistry monitoring in the intermediate depth groundwater aquifer at Orākei Korāko, to provide early detection of a pressure change (monitor well OKM2 to 415m depth, completed December 2011).
- Pressure, temperature and chemistry monitoring of the unconfined groundwater aquifer at Orākei Korāko, to determine the influence of seasonal and lake level influences on pressure monitoring results from the deep and intermediate depth aquifers (monitor well OKM3 to 30m depth, completed November 2011).
- Monitoring of hot springs at Orākei Korāko and Ngātamariki to allow a comparison of deep, intermediate depth and shallow pressure changes to changes in thermal features, including continuous flow monitoring at Utility Pool at Orākei Korāko (Figure 11) and at South Orākonui Crater at Ngātamariki (Figure 6). Refer to Figure 11 for the full suite of Orākei Korāko features monitored.
- Continuous temperature monitoring of the Kurapai Geyer on the eastern side of the river to record eruption frequency;
- Monitoring of rainfall and barometric pressure at a weather station at Ngātamariki. This will allow us to correct data and analyse seasonal variations in more detail.

All monitoring to include a target 12 month pre-development baseline period and provide flexibility to adapt over time in response to observed results.

Figure 11: Ngātamariki sentinel well and Orākei Korāko monitoring well and thermal feature monitoring sites.

9. NGĀTAMARIKI DEVELOPMENT

The Orākei Korāko risk assessment and subsequent Injection and Monitoring strategies were endorsed by OKC and other stakeholders and eventually approved by the WRC. RJV then began construction of an 83 MWe (net) capacity Ormat binary power station in 2011 and in 2012 commenced the implementation of the pre-commissioning baseline monitoring programme. Development drilling was undertaken from 2011-2013 with the drilling of injection wells NM8, NM9 and NM10, along with production well NM11. All wells were relatively successful, and full-scale operation of the power station commenced in October of 2013 (Figure 12). Since operations began in 2013, two new production make-up wells have been drilled (NM12 and NM13), generally due to observations of production

well scaling and well mechanical issues in a well. Figure 13 provides a site map showing the current Ngātamariki power station infrastructure.

Figure 12: Ngātamariki Power Station, with Pad A (NM7) in the background

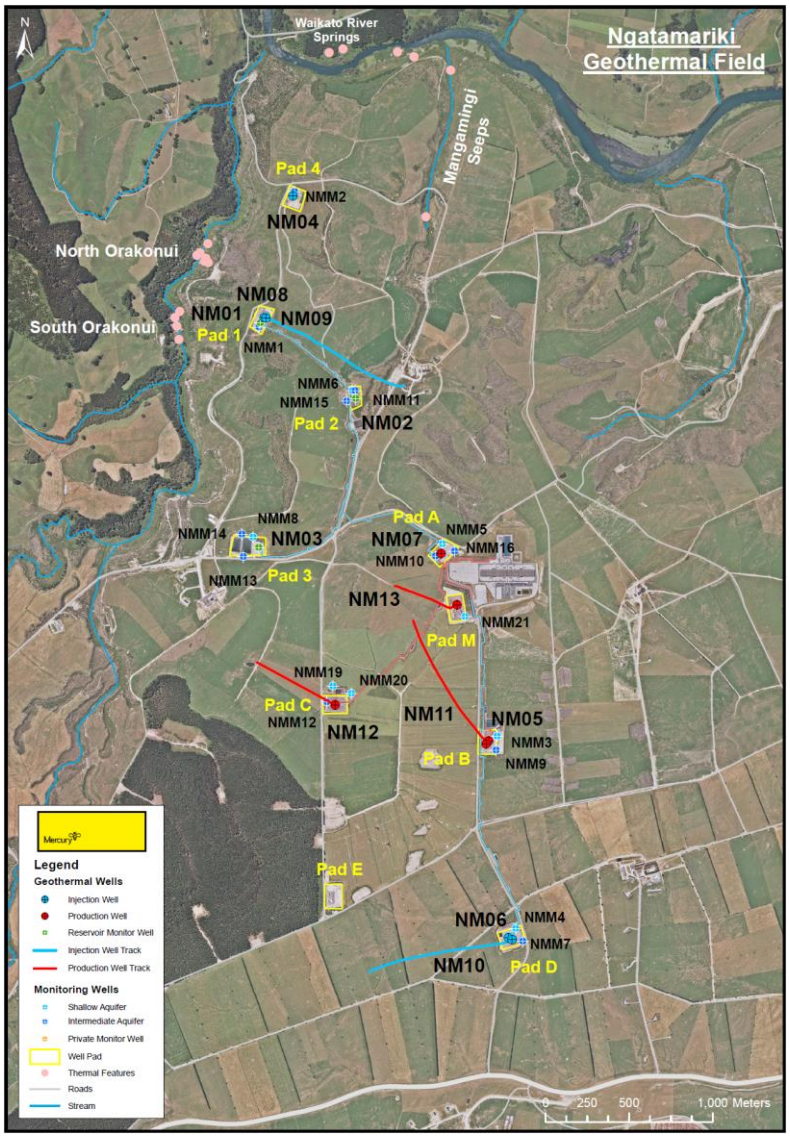

Figure 13: Ngātamariki site layout map (2018)

10. RESULTS OBSERVED

The Ngātamariki development has been operating now for close to 6 years. The reservoir's response to the development to date shows the strategy for avoiding adverse effects on Orākei Korāko has been a success.

Key observations include;

- The pressure response to the start of operations in NM2 showed a transient period of higher rate pressure decline followed by stabilization to a total pressure drawdown of approximately -2.5 bar – consistent with numerical modeling (Figure 14);
- No corresponding pressure changes seen at OKM1, OKM2, NMM17 or NMM18 (Figure 14);
- Manual measurements of flow and temperature at Fred and Maggies pool and Utility Pool show stable trends (Figure 15);
- The Kurapai geyser has shown a history of high and low eruption frequency to dormancy stage since continuous monitoring was installed in 2013. Its activity increased steadily since May 2014, reaching to more than 40 eruptions a day. After a short dormant stage in 2015, the activity resumed and peaked at the end of 2015. Since then the activity has decreased and is somewhat irregular. This trend has continued (Figure 16);
- Chemistry monitoring for the thermal features show relatively stable trends with variations in chloride and bicarbonate within the historical trends (Figure 17);
- From 2015 to 2016, pressure in NM2 began increasing. Investigations showed this was due to nearby injection at NM9. NM3 pressure was then used to monitor true Ngātamariki reservoir response (Figure 14); and
- There were also some challenges with highly automated remote monitoring equipment, which needs to be complemented with manual measurements at appropriate frequencies.

Plots of these results are provided in Figures 14 – 17. These results represent a portion of the information that RJV routinely presents and discusses with all key Ngātamariki stakeholders, including: Ngāti Tahu-Ngāti Whaoa, OKC (and their technical advisors), DOC, WPL and WRC (and Peer Review Panel). Overall, no changes in Orākei Korāko thermal surface feature activity is attributable to anything other than natural variation and pressure trends is further evidence that Orākei Korāko and Ngātamariki are not connected hydraulically.

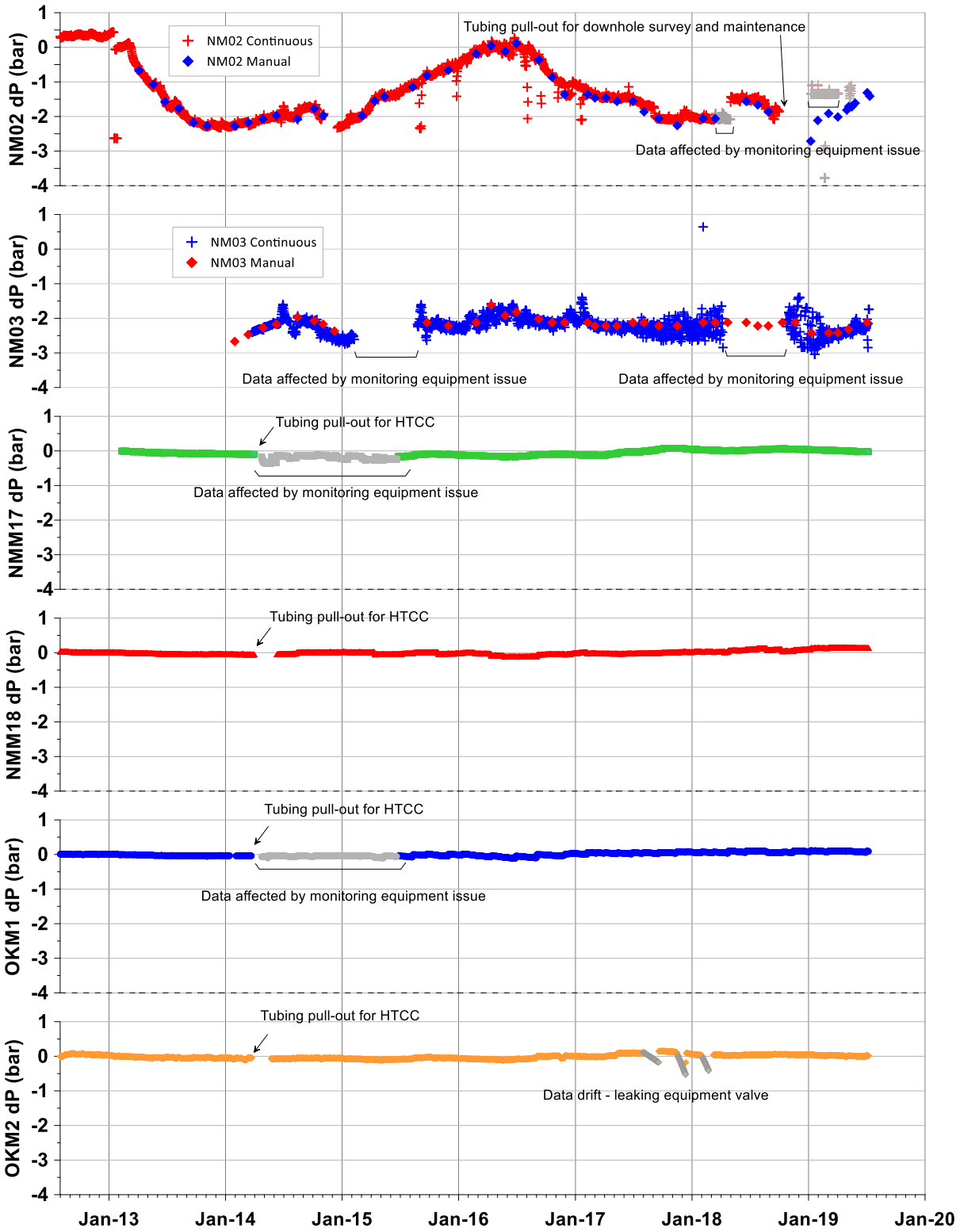

Figure 14: Pressure differentials in the Ngātamariki sentinel wells and Orākei Korāko monitoring wells versus the 2012 baseline

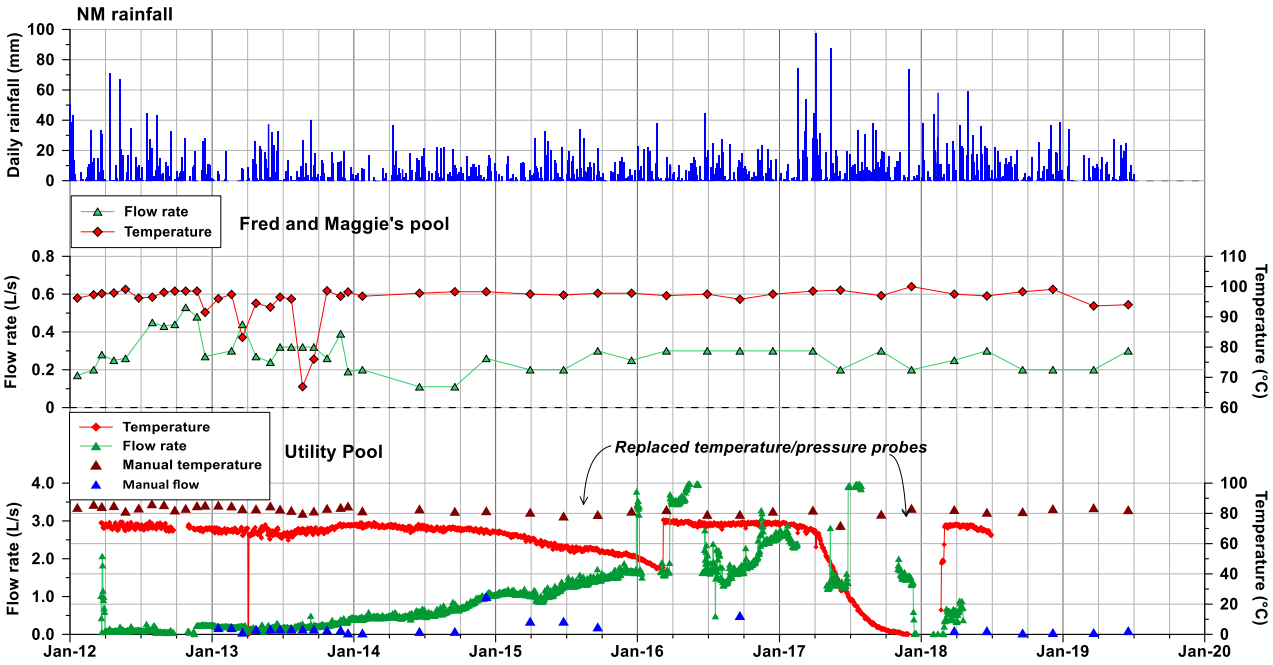

Figure 15: Physical monitoring of the thermal features at Orakei-Korako

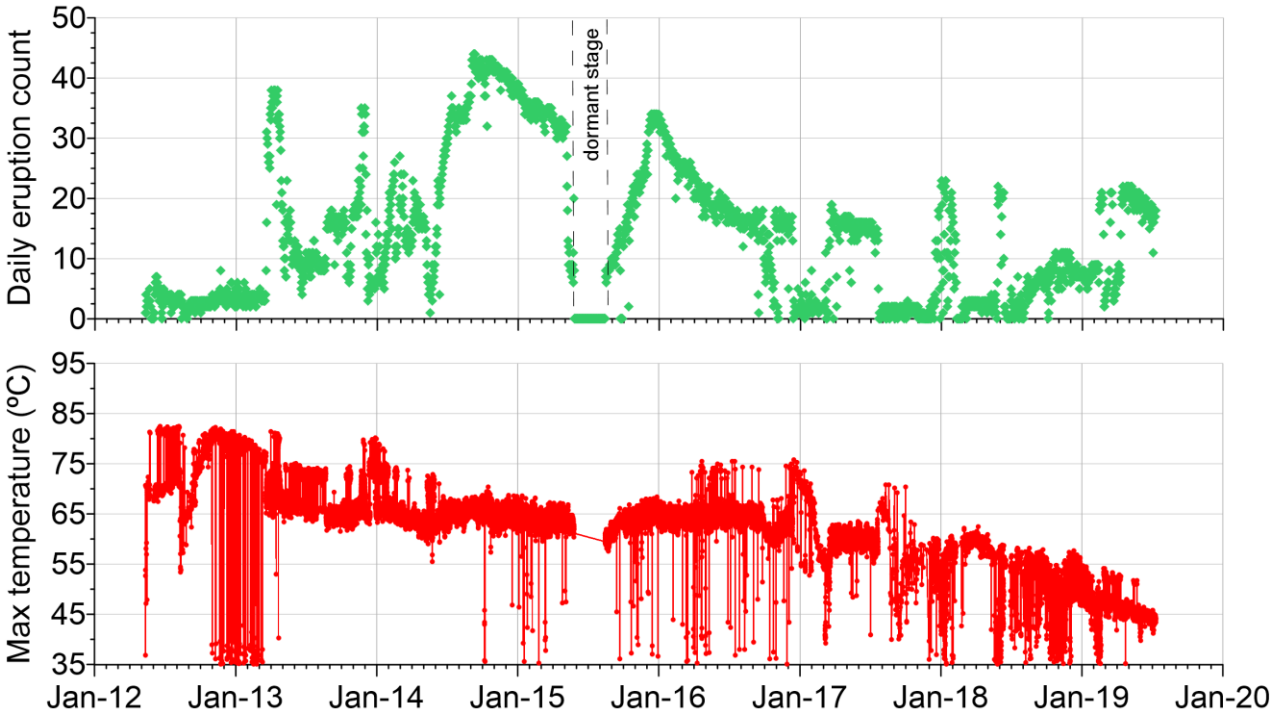

Figure 16: Kurapai Geyser daily eruption rate and maximum temperature recorded

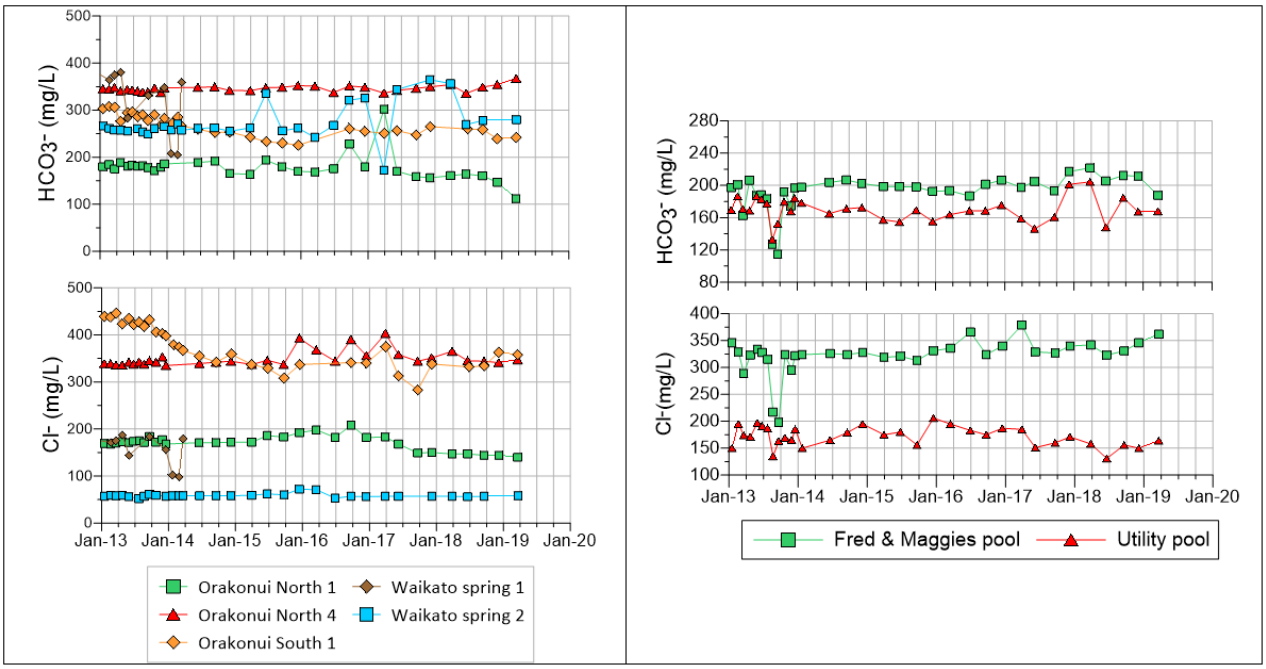

Figure 17: Chloride and bicarbonate monitoring in the thermal features at Ngātamariki and Orakei-Korako

11. CONCLUSIONS

RJV has been proactive in its geothermal development aspirations, securing land access and influencing statutory planning processes 12 and 9 years in advance of physical development respectively. This investment has helped smooth development and consenting pathways later on, however, even with a "development" classification secured for Ngātamariki, this did not provide RJV with a "100% guarantee" on consenting success or development certainty.

Each geothermal system is unique, requiring bespoke development strategies to secure consent and to ensure sustainability. In the case of Ngātamariki, its proximity to the protected Orākei Korāko system, meant significant additional research effort was required prior to development - in spite of its development classification.

Cultural and economic values that attach to geothermal resources and thermal surface features drive up development risk significantly. The cultural value of Orākei Korāko to Ngāti Tahu-Ngāti Whaoa is essentially unparalleled in their hearts and minds. This meant the quantum of risk associated with adversely affecting Orākei Korāko was extreme for RJV. Although the likelihood was very low, the consequences would be devastating. Nevertheless, RJV accepted this risk, and irrespective of Ngātamariki's development classification zone, committed to implementing a development strategy essentially designed as if Ngātamariki and Orākei Korāko were Research Systems.

The only certain way to prove the existence or absence of inter-system connectivity is to induce a reservoir response in one of the two systems and implement geoscience monitoring at the other and in between the two. Efforts should be made wherever possible to only induce a small reservoir response, with plant technologies and size of development considered. While inducing a reservoir response presents a potential risk to a development project, with the use of robust scientific analysis to inform sound development and monitoring strategies, the Ngātamariki case shows this risk can be overcome. Monitoring data has shown no signs of connection through 6 years of field operation and no adverse environmental effects have been identified at Orākei Korāko. Accordingly, RJV is considering reducing monitoring intensity in some areas.

The Ngātamariki development story also demonstrates the importance of partnerships, relationships, being transparent and acting in good faith. These attributes are particularly important to local Māori, who, in the case of Ngātamariki, have shown support for RJV's endeavors, and a willingness to trust them with the sustainable management of their geothermal taonga (treasures). This trust was gained by RJV investing in its relationship with Māori, showing them respect, being aware of relevant cultural context, being sensitive to cultural values, and ensuring the development of natural geothermal resources considered and protected such things while being undertaken in a culturally, socially and environmentally responsible manner.

12. ACKNOWLEDGEMENTS

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