Proceedings World Geothermal Congress 2023
Beijing, China, September 4 - 6, 2023

Planning Preparation for Six Kilometre Deep Geothermal Wells in the Taupō Volcanic Zone, New Zealand.

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Keywords: Deep Geothermal Wells, exploratory well drilling, Geothermal the Next Generation, Planning and Regulatory, Resource Management Reform, consent analysis, New Zealand.

ABSTRACT

Geothermal wells as deep as 6000m are being investigated as part of the GNS Science led *Geothermal: the Next Generation* (GNG) research programme. Indications are that wells at ~6km deep, at specific locations in the Taupō Volcanic Zone, will encounter superhot conditions with temperatures upwards of 500ºC. Determining if these sources of geothermal energy have more than theoretical potential to become a useful energy source for New Zealand requires exploratory drilling.

Resource consents are required for exploratory drilling activities to be undertaken. The consenting requirements have been assessed and documented in a Regulatory Assessment by Kissick et al (2023). This work explores the relevant planning and regulatory framework applicable at several locations in the Taupō Volcanic Zone that might be considered for exploratory drilling. The report identifies the likely resource consents required to enable the drilling and testing activities.

Reform of New Zealand's legislative planning framework, the Resource Management Act 1991 (RMA), is ongoing through 2022 and beyond. The GNG Planning team is participating in the regulatory reform process with a focus on ensuring that precaution does not exclude deep exploratory geothermal activity which, if successful, will open up more renewable energy resources for New Zealand.

1. INTRODUCTION

In New Zealand, the RMA is the current overarching legislation for the management of effects on the environment from activities, with the concepts of sustainable management, integrated management of resources and public participation at its core. There is a hierarchy of policy and plans developed to implement the RMA. Kissick et al (2021) provides a more detailed overview of the RMA statutory framework that applies to the management and use of geothermal resources in New Zealand. It also identifies how the statutory framework has been interpreted by Regional Councils in New Zealand where high temperature geothermal resources are present.

Well drilling and testing activities at different potential scenario sites are assessed against the relevant planning rule framework to determine the resource consents that are needed to enable the activities to be undertaken. There are a number of pre-drilling activities required including:

- Earthworks associated with establishing the drill site, drill pad, drill ponds,
- Site access / roading,
- Controls for sediment, dust and erosion,
- Management of noise, and
- Management traffic effects.

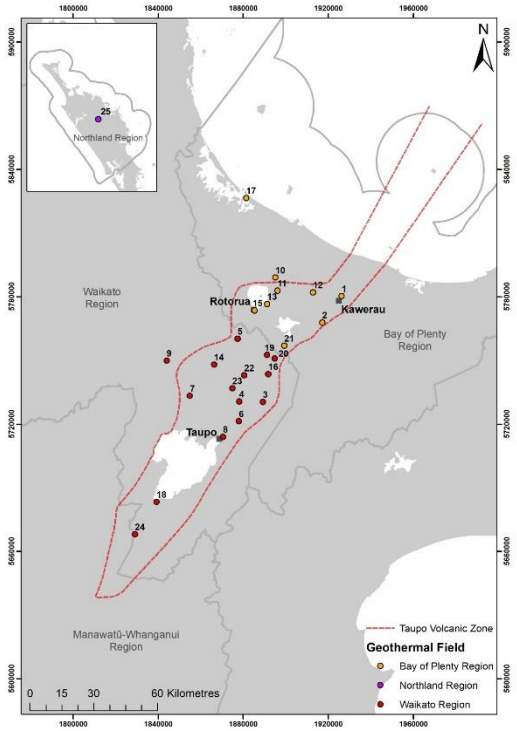
These activities are typically managed at a local level through the relevant District Plan. As these activities are likely to be similar in nature to the requirements of current geothermal drilling operations undertaken in the Taupō, Rotorua Lakes or Kawerau Districts, they have not been addressed in detail as part of the consenting analysis.

The activities that are in focus in this paper are those that require consents from the Regional Council such as:

- The take and use of freshwater for drilling,
- The take and use of geothermal water/fluid,
- Discharges including the discharge of drilling fluids, geothermal water, steam, wastewater and stormwater.

For the drilling site scenarios, site-specific planning provisions, likely to require resource consents to enable drilling in that location are identified alongside the characteristics of the particular site including statutory acknowledgements held by iwi over the particular site, legal encumbrances on land titles, heritage/conservation values and geothermal system classification.

Figure 1 shows part of the North Island of New Zealand, identifying the Taupō Volcanic Zone in red outline, which is the focus area for deep drilling opportunities assessed in Kissick et al (2023), along with the Regional Council Boundaries in darker grey. Although not discussed further in the paper the insert area identifies the Northland Region and the location of the Ngawha geothermal field (25).



Identified High Temperature Geothermal Areas:	
1. Kawerau	14. Atiamuri
2. Rotoma—Puhi Puhi	15. Rotorua
3. Ohaaki—Broadlands	16. Reporoa
4. Ngatamariki	17 Tauranga—Mount Maunganui
5. Horohoro	18 Tokaanu—Waihi-Hipaua
6. Rotokawa	19. Waikite
7. Mokai	20. Waiotapu
8 Wairakei—Tauhara	21. Waimangu
9 Mangakino	22. Te Kopia
10. Taheke	23. Orakei Korako
11. Tikitere—Ruahine	24. Tongariro
12. Rotoma—Tikorangi	25. Ngawha
13. Lake Rotokawa—Mokoia	

Figure 1 Twenty-five high temperature geothermal areas in the North Island. The Taupō Volcanic Zone is shown in red outline and the Region boundaries are shown in darker grey outline.

Four deep geothermal drilling site scenarios have been explored, two in each of the Waikato and Bay of Plenty regions (**Figure 2**). The sites have been selected to encompass a range of planning and site characteristic complexities.

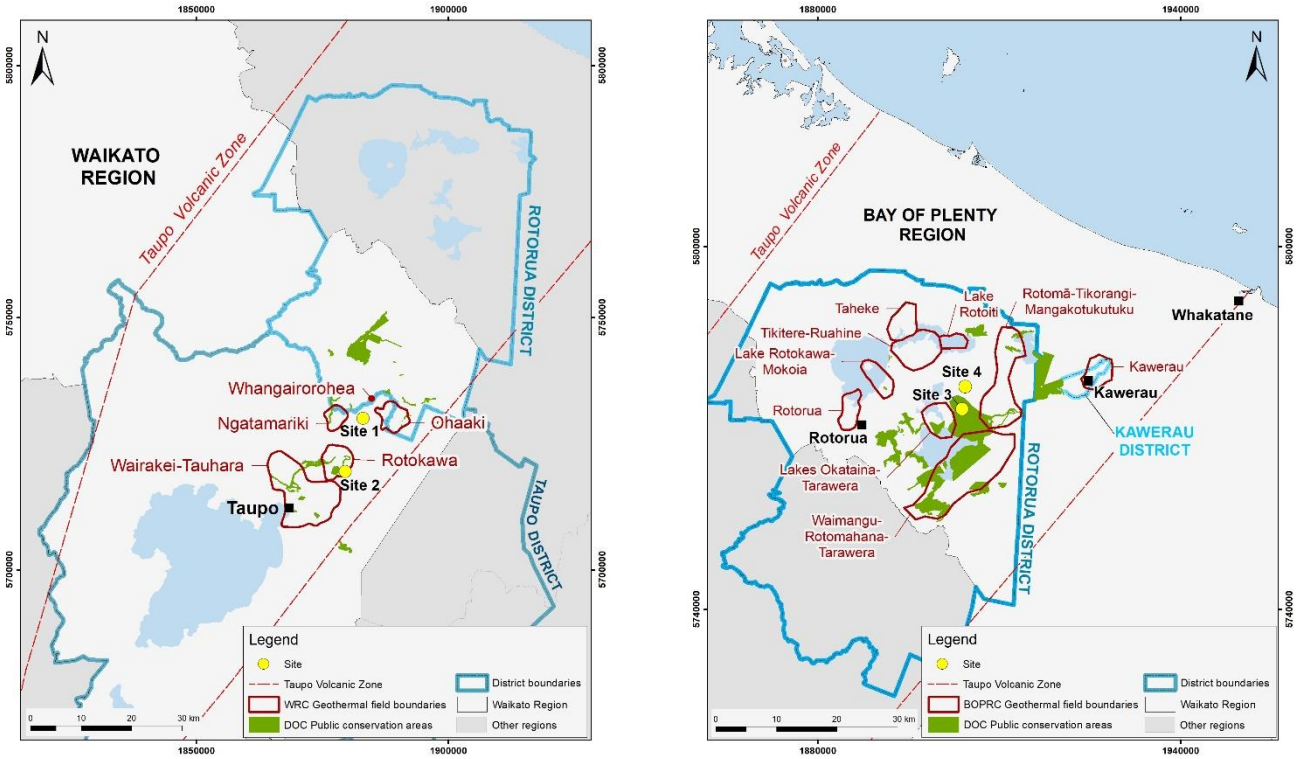


Figure 2 Left - two drilling scenario sites in the Waikato region. Right - two drilling scenario sites in the Bay of Plenty region

In addition, a review of the existing drilling consents for the Rotokawa and Tauhara geothermal development areas has been undertaken. This review seeks to identify if these existing consents would permit the drilling of a 6 km deep geothermal well inside the area covered by these consents.

Table 1 provides a summary of each of the new drilling scenario sites explored in the Kissick et al (2023) report.

Table 1 Summary of the four drilling scenario sites

Site	Region	District	Geothermal Field Classification	Overlays / land status considerations
1	Waikato Region	Taupō District	Research Geothermal System (default classification)	• Affiliate Te Arawa Iwi Statutory Acknowledgement (Part of Waikato River (Atiamuri Dam to Huka Falls)). • Ngāti Tūwharetoa Statutory Acknowledgement (Waikato River and its tributaries) • Raukawa Statutory Acknowledgement (Waikato River and its tributaries) • Property Record of Title encumbrance for geothermal exploration
2	Waikato Region	Taupō District	Rotokawa Development Geothermal System	• Affiliate Te Arawa Iwi (Rotokawa) Statutory Acknowledgement • Ngāti Tūwharetoa Statutory Acknowledgement (Waikato River and its tributaries, Lake Rotokawa and Rotokawa) • Raukawa Statutory Acknowledgement (Waikato River and its tributaries) • Property Record of Title encumbrance for geothermal exploration
3	Bay of Plenty Region	Rotorua Lakes District	Unidentified	• Scenic Reserve • Outstanding Natural Feature/Landscape (Makatiti Dome Northern Slopes) (Rotorua Lakes District Plan) • Natural Heritage Area (Rotorua Lakes District Plan) • Māori Freehold Land
4	Bay of Plenty Region	Rotorua Lakes District	Unidentified	• Māori Freehold Land

Table 2 outlines two sites where existing resource consents for geothermal resource use and development are held that have been reviewed for possible application for drilling a deep (~6000m) superhot geothermal exploratory well.

Table 2 Brief summary of the two existing consented geothermal developments considered

Existing Consent granted	Region	District	Project
2008	Waikato Region	Taupō District	Rotokawa Geothermal Development
2010	Waikato Region	Taupō District	Tauhara II Geothermal Development

2. PERMITTING EXPLORATORY DRILLING ACTIVITIES

Kissick et al (2023) identifies, at a high level, the anticipated fluid volumes required to support the drilling operation, identifying the volumes of drilling fluids and drilling wastes likely to be discharged, the freshwater pumped during well completion testing, and the quantities of geothermal fluid and energy discharged as part of flow testing to characterise the well.

The report provides an outline of the anticipated resources used:

- Take and use of freshwater
- Take and use of geothermal water and fluid and associated energy
- Discharge of drilling fluids to ground
- Discharge of water underground
- Discharge of water, heat and gases to air
- Discharge of stormwater to ground

A reliable water supply is fundamental for a successful geothermal drilling operation to be efficiently and safely undertaken. When drilling into geothermal reservoirs in New Zealand, the permeability in the formations being drilled often results in all the water pumped into the well, being lost underground. The New Zealand Code of Practice for Deep Geothermal Wells (NZ2403:2015) references a well drilled with an 8½" inch diameter requiring a minimum of 2,000 litres/minute (2,800 tonnes/day) of water. For a superhot 6000m well, a larger pumping capacity will be required such as that supplied using the Taranaki based 450 Bentec Todd Energy rig. When drilling with complete circulation losses, the pump capacity on this Bentec rig could pump upwards of 9000

m^3/day. This is at the high end, and a water supply system designed to provide ~4,000 lpm (6,000 tonnes/day), would be expected to be sufficient for almost all drilling needs for a 6000m deep well.

Discharges to ground occur as part of the drilling operation. These are shown schematically in Figure 3.

Mud drilling in the upper sections of a geothermal well, where a casing will be cemented to the formation, will likely see an estimated 100 m^3 per day of water (containing rock cuttings and other contaminants) discharged to ground including to the drilling pond (refer Figure 3).

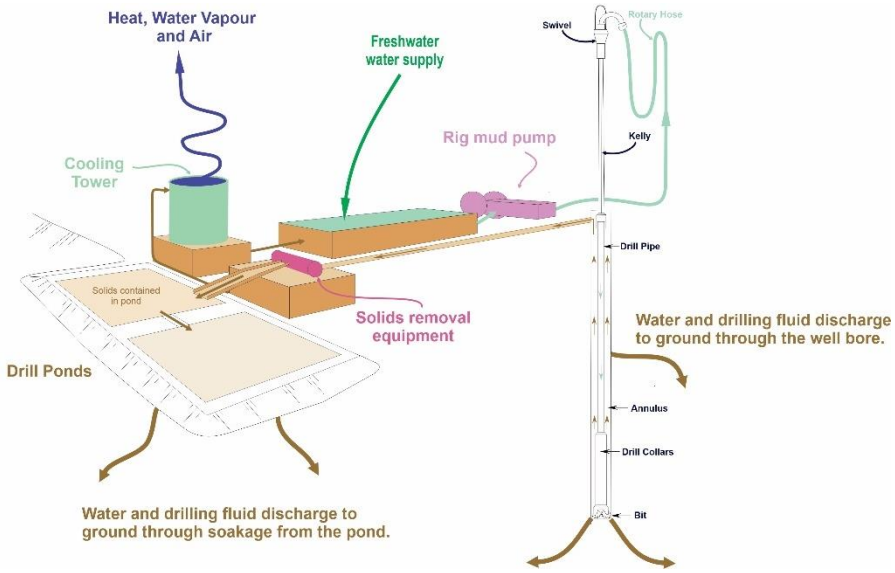


Figure 3 Drilling rig water take, use and discharge schematic. Identified are water discharges to ground through the well bore or with drilled solids into a drilling pond with the drilled solids settling in the pond and the water percolating from the pond (Kissick et al 2023).

As part of casing cementing operations, up to 300 m^3 per day of water-based slurry is likely to be discharged to a drilling pond. Each casing cementing operation usually takes less than 24 hours. Four or five of these operations may be needed for a 6000m well.

Water drilling with losses in the open hole section of a 6000m geothermal exploratory well is expected to require up to ~6000 m^3/day (tonnes per day) of water. For the purpose of providing realistic consenting scenarios, the overall duration of drilling a 6000m well is of the order of 140 days assessed on the basis of drilling progressing at an average rate of 50m per day and five operations running and cementing casing strings.

Completion testing, which could be of a duration up to 48 hours for a 6000m well, requires freshwater pumped in steps at rates of up to 3500 litres per minute (~5000 tonne per day). The water is injected into the well to assess the capacity of the well to take fluid under different conditions. Downhole logging tools are run the length of the well bore at the different flow rates measuring; pressure, temperature and fluid velocity. All the water pumped into the well during these tests moves out into the underground formations through the permeable zones in the well.

For a well flow test of a superhot geothermal well, it is estimated that up to 70 kg/sec of superheated steam at ~3000 J/g (Rivera and Carey 2022) might be discharged for a number of weeks, to months, for measurement, assessment and sampling purposes. This equates to a water (as steam) discharge of 6000 tonnes per day with an associated heat discharge of 210 MW thermal. In the early phase of flow testing two phase geothermal fluids at rates of up to 7000 tonnes per day might be expected to be produced at the surface whilst the well is heating up and the formations surrounding the well are also brought up to temperature. The atmospheric steam discharges are expected to contain some entrained gas. This includes gases such as carbon dioxide, hydrogen sulphide and methane amongst others, variously depending on what is dissolved in the geothermal fluids deep underground.

Table 3 is a summary of the maximum daily take and discharge quantities associated with the drilling and testing of a 6000m exploratory well.

Table 3 Summary of largest fluid takes and discharges.

Operation	Take (tonnes/day)	Discharge (tonnes/day)
Water Drilling	6000 (freshwater)	6000
Mud Drilling		100
Cementing		300

Operation	Take (tonnes/day)	Discharge (tonnes/day)
Completion testing	5000 (freshwater)	5000
Flow testing	7000 (geothermal water)	7000

Consent Application and Assessment of Environmental Effects Requirements

Kissick et al (2023) outlines at a high-level, activities associated with construction of a well site and associated infrastructure. This includes establishment of access roads, a water supply and drilling waste ponds, the drilling of a 6000m well, completion testing of the well immediately after drilling and longer-term flow testing to determine the characteristics of the well. The report explores the potential for a deep well on four stand-alone scenario well sites. The report also looks at the potential to utilise and / or adapt existing consents at Rotokawa for 6,000m deep drilling and explores the same utilising the Tauhara II consents.

A resource consent is the legal mechanism for allowing an activity to be undertaken that would otherwise contravene a rule in a regional plan, district plan or in a National Environmental Standard. Schedule 4 of the Resource Management Act specifics the information required for a resource consent application including a description of the activity, and the site on which the activity will occur among other things. The application must be accompanied by an assessment of the activity against the relevant objectives, policies and rules in the relevant Plan as well as an assessment of the activity's effects on the environment including actual or potential effects of the activity on natural and physical resources, communities, physical effects including landscape and visual effects, effects on ecosystems, specific values of the site, effects of any discharge of contaminants and any risks to neighbourhoods or the wider community.

Comprehensive technical information is required to support the preparation of an assessment of environmental effects which in the case of an application for a deep exploratory geothermal well, will include interpretative material from subject matter experts.

As outlined in Kissick et al (2021), there are specific requirements for determining whether or not a resource consent application should be notified to the public. Resource consent applications for a deep geothermal well are likely to be publicly notified due to the nature and scale of the actual or potential effects associated with the requirements for the well drilling and testing.

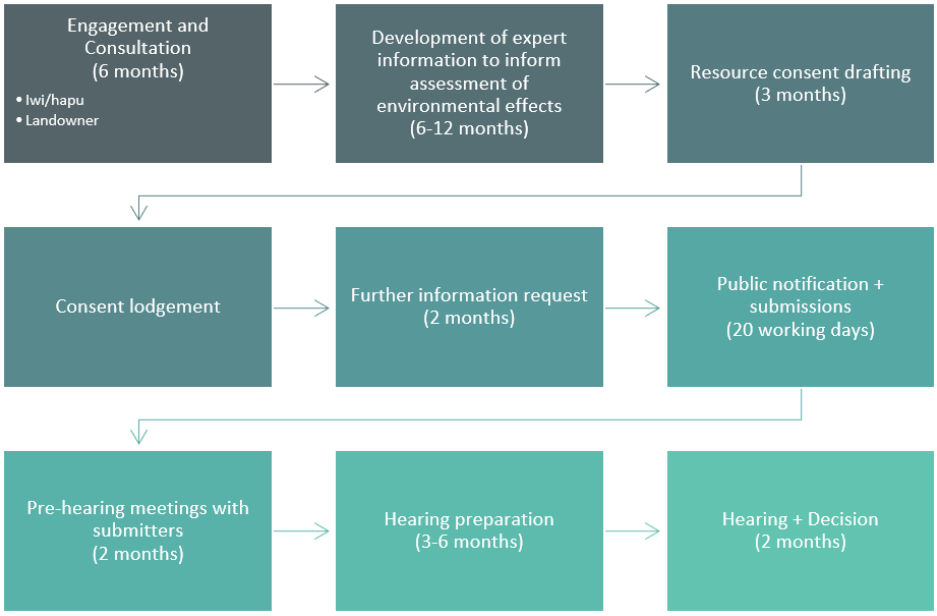


Figure 4**Fehler! Verweisquelle konnte nicht gefunden werden.** provides an overview of the likely timeline for an application for a deep exploratory geothermal well on a site where a geothermal development does not yet exist. It starts from initial engagement with landowners, through the development of technical information about the site and the preparation of the resource consent applications, including the assessment of environmental effects. The timeframe then includes an estimate of the time required by the consenting authority (Regional Council) to publicly notify the application, for a hearing to be held and a decision made. Overall, a period of ~12-18 months is likely realistic from the time from initial landowner engagement through to a decision on the resource consent applications. Three of the four stand-alone drilling scenario sites (Table 1) would likely follow a similar process and associated timeframe for consenting to be considered as shown in Figure 4. The exception being a site currently identified as being reserve land, which would require additional approvals and likely a change of reserve classification before the below process could then be followed. An additional 7 - 12 months could be added to the ~12-18 month timeframe to account for time to gain the additional approvals if such is possible.

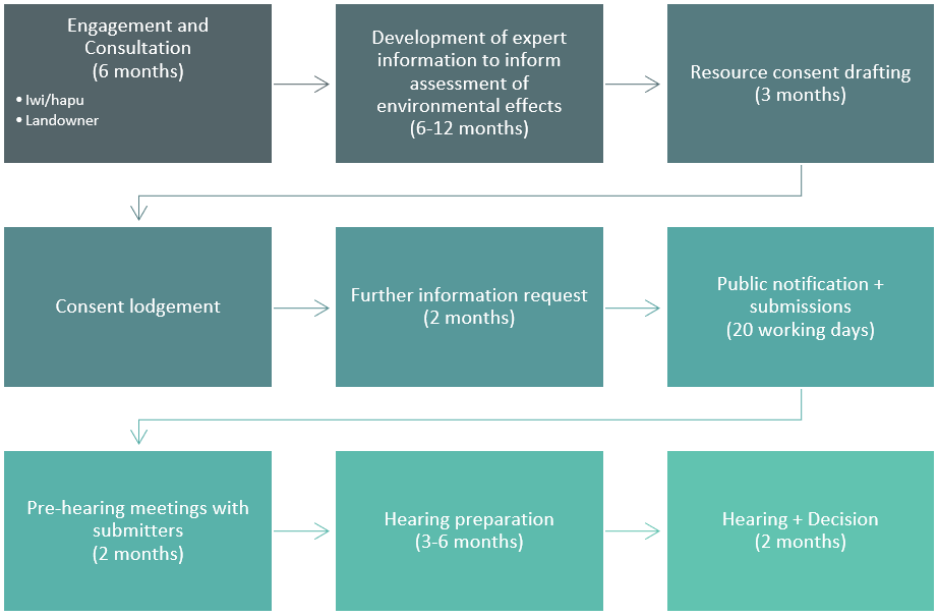


Figure 4 Preliminary process timeline for a geothermal exploratory well application

Where it may be possible to utilise resource consents for existing consented well drilling activities at some sites, new consents or variations to some of the existing consents might be needed to enable deeper drilling at these sites depending on the way the activity was described in the original application. Depending on the nature of the changes needed to the existing consent documents to enable deeper drilling, a process similar to that outlined in Figure 4 could be anticipated. This process would likely have a much reduced time requirement given that geothermal use of a site is already consented, and the existing consents provide a permitted baseline level of geothermal resource use and development activity anticipated on the site against which the new activity would be compared.

Kissick et al (2023) considers, at a high-level, permitting requirements for any ongoing development and production should useful energy be found as part of the exploration activities. Investment in exploration activity is more likely to be encouraged if there is a clear line of sight for consenting approvals beyond the exploratory phase.

Consenting Summary

Following the evaluation of resource consent requirements for each of the four scenario sites, the requirements between all four sites (**Table 1**) are very similar, even between different Regional Plans for the Waikato and Bay of Plenty Regions.

Access to freshwater is essential to enable well drilling to be undertaken. The availability of freshwater, at the volumes (up to 6000 m^3/day) required to enable well drilling, is likely to be a significant and critical consideration at all of the identified sites. The management of freshwater resources in New Zealand is subject to increased analysis under the National Policy Statement for Freshwater Management recently amended in 2020.

While the consenting requirements for a new exploratory well on each of the four stand-alone scenario sites are similar, the characteristics of each site will have significant implications for the viability of applying for resource consents at each site. This includes requirements to consider legal encumbrances for geothermal development, land status as reserve and the classification of the geothermal system at each location. These additional land characteristics are likely to contribute to the complexity of seeking resource consent for deep exploratory drilling.

Of the sites in **Table 1,** where there is no existing geothermal development, it is anticipated that the Site 4 in the Bay of Plenty has the potential to have the least limitations in terms of future development for a geothermal production operation, provided that landowner approval can be secured and a suitable and available water source identified to enable the quantities of water needed for well drilling to be accessed. Site 1 outside of a classified Development Geothermal System in the Waikato Region would be the likely second preference of the sites. Site 3 would likely be quite difficult to develop due to the reserve status of this site.

For the site where geothermal consents are already operative (**Table 2**), it is anticipated that adaptation of the existing consents for the Rotokawa Geothermal Power Development is the most straight forward approach to enable drilling of a ~6km deep geothermal well. An amended or new consent is likely needed for additional freshwater to support the well drilling.

The Contact Energy Tauhara II consents have also been reviewed and these could be used to support the drilling of a deep exploratory well. This is all subject to the consents being in a suitable location which is as yet unknown. There are some conditions that would need to be evaluated relative the operations that are already being undertaken under these consents to ensure condition compliance or an application for a change to some conditions might need to be embarked upon to facilitate the deep drilling and well testing.

Out of all the options considered, utilising the existing Rotokawa Geothermal Power Development consents is likely the quickest and simplest way of consenting a superhot deep exploratory geothermal well.

3. REGULATORY REFORM

In 2021, the New Zealand Government announced its intent to repeal the RMA and replace it with new legislation.

This decision follows an independent review of the RMA undertaken with the view to *"…improving environmental outcomes and better enable urban and other development within environmental limits"* reported in "New Directions for Resource Management in New Zealand" (MFE 2020) ("the Randerson Report").

The Randerson Report recommended that the RMA be replaced with three pieces of legislation which the Government has adopted which will see the following new Acts developed:

- Natural and Built Environments Act ("NBA") – the primary piece of legislation to replace the RMA. Designed to work alongside the Spatial Planning Act, the NBA will set out how the environment will be protected and enhanced in future, ensuring that people and communities use the environment in a way that not only supports their well-being but also that of future generations.

- Spatial Planning Act ("SPA") – provides strategic and long-term approach to how the planning for land use and for use of the coastal marine area.

- Climate Adaptation Act ("CAA") – this act will support New Zealand's response to the effects of climate change.

In late 2021, an 'exposure draft' of the NBA was released. This document intended to provide an "early look" at key aspects of the new legislation and was open to public comment through a submission process. Submitters were able to verbally present their views on the exposure draft to a Select Committee of the government, who then made recommendations to the Ministry for the Environment staff drafting the bill.

The Geothermal: the Next Generation programme team worked alongside members of the New Zealand Geothermal Association ("NZGA") to prepare a submission on the NBA exposure draft (Siratovich 2021). The submission raised the importance of geothermal development in achieving the low-carbon aspirations of the country. The submission also identified the risks posed to geothermal resource use and development from taking an overly precautionary approach in the legislation. Geothermal development, by its nature, has elements of uncertainty resulting from the variability in characteristics of geothermal systems along with challenges of acquiring subsurface information. A flexible approach to resource exploration to increase knowledge and understanding of geothermal resources is therefore needed.

The submission also highlighted the good practice that the current New Zealand regulatory framework is recognised for globally and the leading role New Zealand has in this space. While there is always room for improvement, the submission sought not to lose our good practice experience through the reform process. The current system enables an adaptive effects management framework for geothermal resource use. To achieve this, the regulatory processes allow for the management of effects to be adapted as new information becomes available. This is achieved through the development of reservoir management plans, robust and ongoing monitoring and the oversight of expert peer review panels to assist the regulatory agencies, all as conditions of resource consents.

The release of the full NBA and SPA bills was announced in late November 2022. NZGA provided submissions on each proposed bill on 1 February 2023 (Tsui 2023a, Tsui 2023b) and presented these at the Select Committee process in early March 2023. Reporting from this process is expected early in June 2023 before being confirmed via Royal Assent, being signed by the Governor-General, the King's representative in New Zealand which is expected later in 2023, likely ahead of the central government elections which are set to be held in October 2023.

4. CONCLUSION

Kissick et al 2023 provides a summary of the likely deep exploratory drilling process and analysis of the anticipated consenting requirements associated with establishing a ~6km geothermal well at four scenario sites.

Of the sites where there is no existing geothermal development, it is anticipated that:

- Site 4 in the Bay of Plenty has the potential to have the least limitations in terms of development for a future geothermal production operation, provided that a suitable and available water source could be identified to enable the quantities of water needed for safe and efficient well drilling to be accessed.
- Site 1 outside of an as yet classified Development Geothermal System in the Waikato Region would likely be the second preference of the sites.
- Site 3 would likely be very difficult to develop due to the reserve status of this site.

It is anticipated that adaptation of the existing consents for Rotokawa is likely the most straight forward approach to enable drilling of a ~6km deep exploratory superhot geothermal well at Site 2.

The current New Zealand regulatory framework is recognised globally for its good practice and leading role. The current system enables an adaptive effects management framework for geothermal resource use and it will be important to retain the adaptive nature of the existing framework through into the new environmental legislation to ensure geothermal exploration activity, which by its very nature, has elements of uncertainty resulting from the variability in characteristics of geothermal systems along with challenges of acquiring deep subsurface information. A flexible approach to geothermal resource exploration to increase knowledge and understanding of superhot geothermal resources is needed to assist in facilitating the opportunity that these deep geothermal resources might provide in the future for New Zealand.

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