ROTORUA GEOTHERMAL SYSTEM: CURRENT AND FUTURE MANAGEMENT

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ABSTRACT

Following a history of overuse, the management of the Rotorua Geothermal System was fundamentally changed in the 1980's by the Government geothermal bore closure program and legislative changes through the Resource Management Act 1991 (RMA). The system is now managed under the Bay of Plenty Regional Council's (BOPRC) Rotorua Geothermal Regional Plan (RGRP). The plan prioritises surface feature protection and achieves this by limiting net loss of geothermal fluid to the system. While this approach changed the way the resource could be used, and imposed costs on some users, sustainable levels of abstraction are still enabled. Also, any costs have been outweighed by the opportunities presented by the recovery of surface features and a growing tourism economy.

An upcoming plan review requires analysis of reservoir response to the plan's policies. BOPRC's State of the Environment Monitoring Program has been designed to identify long term changes and includes monitoring of ground of water levels and temperature, and of specific surface features. The recovery of the system is well documented and monitoring indicates that the system is in 'dynamic equilibrium', although surface feature recovery is variable.

These results demonstrate plan effectiveness and any fundamental changes to the plan are unlikely, unless supported by robust new evidence. However ongoing refinement of our reservoir understanding and assessment of potential opportunities for more efficient resource use is crucial. The focus of the plan review will therefore be on the technical inputs, including modelling and monitoring.

The plan review also requires consideration of community values and priorities. While surface feature protection will remain a key objective of the plan, opportunities for more efficient and effective use of the available resource will be at the forefront of discussions. Future opportunities for direct use without impacting surface features will be carefully considered. This will include refinement of modelled scenarios and options to improve efficient use. Community engagement will occur through stakeholder working groups. An ongoing challenge is ensuring that community expectations about the management of the system (and opportunities for more development) are well informed and realistic.

1. INTRODUCTION

Geothermal systems within the Bay of Plenty Region form part of the Taupo Volcanic Zone (TVZ), which accounts for 95% of geothermal activity in New Zealand. The TVZ falls within the Bay of Plenty and the Waikato Regions, which are the local Government authorities responsible for geothermal management.

The characteristics of the Region's systems vary considerably, as does their management. They include for example the protected Waimungu Volcanic Valley with its multiple surface features, the offshore Whakaari (White Island), the warm groundwater aquifer in Tauranga, and the deep high temperature Kawerau System which supports an extensive industry, including electricity generation and direct heat industrial processes.

The Rotorua Geothermal System is perhaps best recognized for its surface features and strong cultural associations. The system is located at the southern end of the Rotorua Caldera, with surface activity concentrated around Whakarewarewa Valley, Ohinemutu, Kuirau Park, Sulphur Flats, Ngapuna, and Arikikapakapa. If delineated based on surface expression the system is approximately 12km^2 with electrical resistivity survey indicating the area at 500 meters depth is between 18-28km^2 (Gordon et al 2001).

Figure 1: The extent of the Rotorua System.

The Rotorua System's shallow nature has led to historical exploitation, with Rotorua City being developed around the use of the resource.

1.1 Values of the Rotorua Geothermal System

Geothermal resources have been valued and used in Rotorua for hundreds of years. Maori consider geothermal a taonga (treasure), being used traditionally for cooking, bathing, heating, ceremonial use and healing for generations. These practices continue, for example in areas such as the Whakarewarewa, Ohinemutu and Ngapuna. Tangata whenua consider themselves the kaitiaki or guardians of the resource.

The Rotorua System's geothermal vegetation is regionally and even nationally significant, being rare and vulnerable. These ecosystems and outstanding natural geothermal features such as geysers, springs and mud pools form a unique landscape. That landscape, coupled with the healing qualities of geothermal springs, made Rotorua a desirable tourism destination from the 1870s, and the city has expanded to accommodate the growing tourism industry.

In 2016/17 tourism in Rotorua was a $799 million per annum industry, of which $415.7 million came from domestic visitors and $383.3 million from international visitors. During this period there were 2.2 million visitor nights spent in Rotorua's commercial accommodation, with over 3 million visits to attractions and activities. Of those visitors surveyed, 65% associated Rotorua with geothermal attractions (Destination Rotorua, 2017), so the value of the resource to the local, regional and even national economy should not be underestimated.

1.2 History of Use and Development

Initially the use of the geothermal resource in Rotorua was relatively low impact, but an increasing demand for energy in the 1950s led to extraction on a larger scale, with over 1000 geothermal wells by the 1970s. This extraction was effectively uncontrolled, and most geothermal water was discharged to waste. The effects of this high level of extraction became marked in the 1960s and 1970s with the decline or loss of many thermal features, perhaps most notably the Waikite Geyser in Whakarewarewa Valley, which last erupted in 1967.

By the mid-1980s this situation was critical and the New Zealand Government at the behest of vocal geothermal experts and proponents decided that the loss of Rotorua's geothermal features was economically untenable. A number of Government directives resulted in what is now termed the 'bore closures'. This resulted in a prohibition of fluid extraction within a 1.5km radius of Pohutu Geyser in the Whakarewarewa Valley. All other wells were required to convert to alternative sources of energy and/or to move to reinjection as soon as practicable (Gordon et al, 2001)

Bore closures resulted in a decrease of geothermal discharges to waste (ie. net loss) in the order 29,000 t/day in 1985, to 4400 t/day in 1992, and approximately 2,200 t/day in 2017 consented take (note that the estimated actual discharge to waste is considerably lower than this). The geothermal system responded to these closures almost immediately, and by the late 1980s there were significant pressure gains and increases in mass fluid outflows from springs. Monitoring has shown an average water level increase of 2.5 meters.

This recovery resulted in the bore closure regime being perpetuated under the Resource Management Act when it was enacted in 1991 (the RMA) and the development of the Rotorua Geothermal Regional Plan.

1.3 Current Direct Heat Uses in Rotorua

While takes of geothermal fluid and the discharge of geothermal fluid to waste has been greatly reduced over the last 30 years, sustainable direct use of the resource continues. There are approximately 130 consents for the take and use of geothermal water and energy in Rotorua, of which the majority are for closed loop systems (take and reinjection to source), although some still discharge some waste geothermal water to ground, lake, streams or district council storm water or sewer systems. Forty of these consents are for down hole heat exchangers (DHX), mostly within the 1.5km exclusion zone.

Individual consumption varies from 2 t/day to 600 t/day. The majority of takes are under 200 t/day, and 33% of consent holders account for 80% of total consented take. Commercial use accounts for about 50% of consents and nearly 75% of the total volume allocated (Dobbie, 2014).

Uses include geothermal fluid for bathing and wellness, particularly for commercial (eg. hotels, motels, the Polynesian Spa), but also private use. Space and water heating also accounts for a significant proportion of the use, including commercial properties, the hospital and municipal (eg. the Rotorua Lakes Council's Rotorua Aquatic Centre and the Rotorua Events Centre). Over 400 homes are heated by geothermal energy in Rotorua city. There is currently no geothermal electricity generation or industrial direct heat use.

Most consent applications received by BOPRC are for renewals (the consent timeframes being a maximum of 10 years), or for increases in take. Council receives less than 5 consents applications annually for new takes (or applications to consent existing but previously unauthorized takes).

2. MANAGEMENT FRAMEWORK

BOPRC's geothermal responsibilities stem from the RMA. Its functions include the allocation of heat and geothermal water as well as recognising and providing for the protection of significant surface features. A hierarchy of planning documents provides the framework for managing geothermal resources, including the Regional Policy Statement (RPS) and regional plans. District plans (which are administered by district councils) include rules for the protection of geothermal surface features.

2.1 The Regional Policy Statement

The RPS (which was reviewed in 2012) sets the overall direction for management through high level objectives and policies and:

- provides for the sustainable management of the geothermal resource;
- categorises geothermal systems, according to their values and use (eg. from protection to development), where the Rotorua System is classified as Group 2: Surface feature values override extractive values;

- uses a 'whole system' management approach for systems that have multiple users (ie. requires the development of a system management plan);
- requires identification and protection of significant geothermal features; and
- seeks the management of significant risks from natural hazards, including geothermal hazards.

The RPS also provides strong direction about recognising and providing for the relationship of Maori and their culture and traditions with geothermal resources.

2.2 Regional Plans

Regional plans are required to give effect to the RPS. They include rules on the status of activities (ie. whether an activity is prohibited, discretionary, controlled or permitted), specific allocation limits, and the matters that must be considered when assessing a resource consent application.

While resource consents are usually required for the taking and use of geothermal water and energy (and the discharge of geothermal water), the RMA permits 'cultural takes' without the need for consent. These takes are in accordance with tikanga Maori (traditional practices), are for the communal benefit of tangata whenua and are considered to have no adverse effect on the environment. This includes, for example, using geothermal water and heat for cooking (eg. cook boxes), healing, and bathing (eg. communal bathhouses).

2.2.1 Rotorua Geothermal Regional Plan

There are two key regional plans that contain geothermal provisions for the Bay of Plenty Region: the Regional Water and Land Plan, which covers all geothermal systems other than the Rotorua System; and the Rotorua Geothermal Regional Plan (RGRP) which contains provisions for the Rotorua Geothermal System only. This plan acts as a system management plan, in that is provides a whole system management approach.

The RGRP was introduced to continue managing the recovery of the geothermal features. Key policies are:

- an allocation limit of 4400 tonnes per day net mass abstraction from the system (ie. loss to the system);
- Prohibited activity status for takes of geothermal water within 1.5km radius of Pohutu Geyser (ie. the exclusion zone);
- Requirement for reinjection of geothermal water to source (except in exceptional circumstance); and
- The establishment of Minimum and Critical Aquifer Water Levels (MGWL), which are an indicator that the effects of extraction may be having an adverse effect on surface features, and at which point BOPRC may require reduction of consented takes (ie. an emergency response mechanism).

Note that the taking of heat using DHX and closed loop systems is managed as a discretionary activity under the RGRP and requires consent. However the plan sets no upper limits on an increase in the taking of heat in this manner (except within the 1.5 exclusion zone).

3. REVIEWING THE ROTORUA GEOTHERMAL REGIONAL PLAN

The RGRP was operative in 1999 and is overdue for a formal review. This review will be carried out under Schedule 1 of the RMA, and will include a number of key phases:

1. Technical Inputs: building an understanding of the resource available for allocation, current use, and system responses to inform planning decisions (ie. knowledge-based decision making);
2. Policy Development: review of effectiveness of current planning provisions, and an assessment of the efficiency and effectiveness of various policy options (ie. section 32 of the RMA). It will include modelling of the system capacity and potential impacts of use (eg. different scenarios) with the goal to achieve the best use of the resource for the most people.
3. Community Input: engagement with stakeholders, affected parties and the community to inform policy development (ie. providing for a range of community values). The aim is for participation by a connected and informed community.

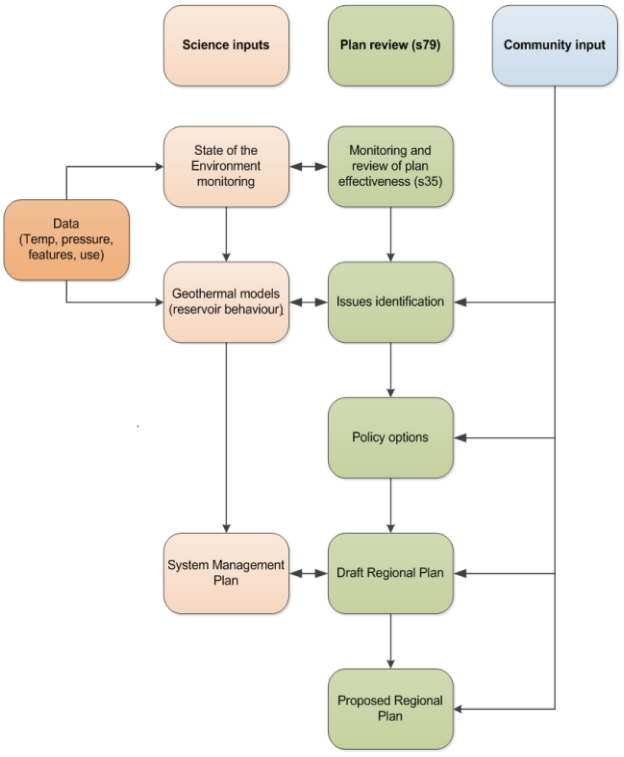

Figure 2: Broad Outline of the key phases of plan development

It is intended that new provisions for Rotorua Geothermal System will be incorporated into the Regional Council's

Natural Resources Regional Plan (currently called the Regional Water and Land Plan), with a plan change scheduled to be publicly notified in late 2018.

4. TECHNICAL INPUTS

The plan review will be strongly influenced and informed by science. Consolidation of modelling and monitoring inputs began in 2014/15 and this remains the focus of the review.

In 2014 GNS was contracted to construct a new 3-D model framework for the Rotorua caldera. Data sources (new and historical) included geological mapping; bore log lithology; topographic data; hydrological data; temperature, and seismic data sets (Alcaraz, 2014).

The current reservoir model for Rotorua was constructed in 1993 (and updated in 2004) (Burnell, 2005) and will also need to be reviewed, or alternative models considered. Analysing policy options will require developing and simulating detailed scenarios to determine the likely response to increased production in various parts of the field.

Technical inputs will include thermal infra-red, hydrology, geo-chemistry, surface feature responses, and heat flow survey. Much of this data is provided through BOPRC's State of the Environment Monitoring Programme which includes water level and temperature profiles within designated geothermal monitoring bores, and observation records of specific surface features.

4.1 Geothermal and Ground Water Bore Monitoring

The bore monitoring program currently includes five geothermal bores and four shallow groundwater bores. GNS Science was recently commissioned to assess the entire monitoring bore dataset for water level and temperature profiles (Kissling, 2014). This assessment provided BOPRC with a 'health check' on the system.

It was concluded that the temperature profiles from early 1990 to 2014 had altered very little and are now relatively stable. Water levels within the monitoring bores have remained within the range of drawdown and recovery from geothermal bore water abstractions. It is considered that the field has entered into 'dynamic equilibrium'; stable within the range of acceptable variance for the geothermal system.

4.2 Surface Features Monitoring

BOPRC have maintained an uninterrupted monitoring program since 2008 for 40 selected geothermal surface features in the Rotorua field. The monitoring programme has shown that the recovery of surface feature activity has been slower that the recovery of aquifer pressure (Gordon et al, 2005). The first surface features to reactivate were in the northern field area of Kuirau Park/Ohinemutu (1992-2001). Progressively surface feature activity has improved in the southern field area of Whakarewarewa/Te Puia (2005-2017).

GNS reviewed this programme in 2015, noting that it was difficult to identify observed trends for features due to their dynamic nature, and that recovery across the field is mixed. Several features show positive changes, increased flows and temperatures, while others have not. For example, some geysers are erupting for longer periods, activity is increasing in a few, while other geysers have not re-activated. However geysers that were active at bore closure have been retained and activity improved over time (Pearson-Grant et. al. 2015).

4.3 Heat Flow Survey

One of the important parameter data-sets in the Rotorua Reservoir Model was heat flows and pressure gradients. However at the time the model was constructed the only information available were two heat-flow surveys undertaken at specific features within Whakarewarewa only. A comprehensive heat-flow survey of the entire field is now considered necessary.

A program of work is underway and will progress in two stages; the first stage being the entire Whakarewarewa area; the second stage being the remainder of the field (Ōhinemutu, Kuirau, Sulphur Point, Ngapuna). The program requires the monitoring and quantifying of heat loss from significant geothermal areas via remote sensing and ground-truthing.

Accurate assessment of natural heat loss from significant geothermal areas is essential for providing data to improve reservoir simulation and model calibration. Monitoring of surface heat-loss changes during production (use) is equally important for history-matching of reservoir models and for assessment of environmental effects.

High-resolution air-borne infrared surveys and repeat ground measurements of shallow temperatures and calorimeter heat-fluxes are expected to achieve a long term improvement in the quantification of natural and induced changes in surface heat loss. This will assist in calibrating the reservoir simulation model and predicting the effects on surface thermal features of different reservoir development scenarios (use).

5. TECHNICAL CHALLENGES

5.1 Obtaining Data on Actual Resource Use

While BOPRC has data from consented geothermal takes in Rotorua, it has little robust information on the actual use of the resource. Consent holders are required to provide measurement of use, but this data is only required twice in the life cycle of a consent (ie. twice in 10 years) and is not a long term measurement (ie. a 'bucket and stop watch' method is often used).

For this reason Council has no way of proving whether consented take accurately represents the fluid actually being used by consent holders. Primarily a compliance matter, this is also important for inputs into the reservoir model.

To address the unique situation in Rotorua of many small commercial and residential (often single household) users, the Council has been working to develop a safe, cost effective, transferable, and robust method to test wells in Rotorua using a removable flow loop, inline meter and data logger. A field trial is being carried out in September 2017, and if successful this system will be extended to additional sites. The data will then be used to inform the Rotorua Geothermal Reservoir Model.

As part of this project down hole pressure and temperature data is also being obtained on 15 wells.

5.2 Well Maintenance

The flow testing project described above identified that many of the geothermal wells in Rotorua could not be tested because they failed to meet WorkSafe NZ's Health and Safety Guidelines for Shallow Geothermal Wells, and were

considered too unsafe for testing. Also some wellheads and casing were not designed to allow testing. This has been a matter for three agencies: WorkSafe NZ; Rotorua Lakes Council and the BOPRC, whose roles around geothermal well maintenance overlap.

In order that flow and downhole testing could proceed for the plan review, a comprehensive wellhead audit and compliance process has since been carried out in Rotorua City by BOPRC and RLC. An education project is also underway to ensure that well owners are informed of their legal obligations. Further work is required to ensure casing testing is carried out to best practice standards.

6. HOW WILL THE COMMUNITY ENGAGE IN THE PLAN REVIEW PROCESS?

Because the Rotorua Geothermal System contributes significantly to the social, economic and cultural wellbeing of the people of Rotorua, engagement of the community throughout the plan review process is crucial. The technical nature of geothermal management, and in particular the complexity of geothermal monitoring and modelling, makes meaningful engagement challenging.

BOPRC has therefore developed a staged engagement process as outlined in Figure 3, starting by raising community awareness through provision of information, before moving to more meaningful discussion around realistic policy options.

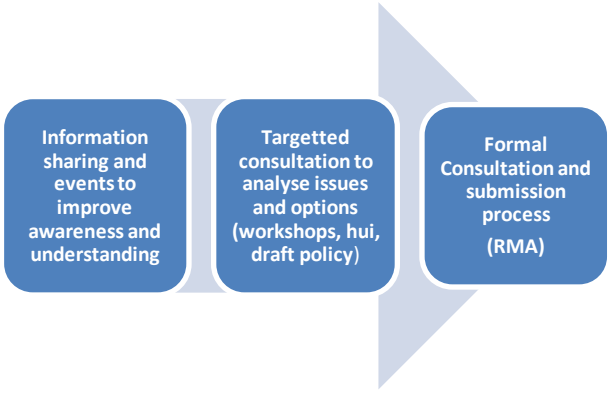

Figure 3: Staged engagement process for regional plan review process

To support this engagement process BOPRC has established a Rotorua Geothermal Liaison Group. This is a Governance level group, including elected members from BOPRC and Rotorua Lakes Council, representatives from the Department of Conservation, the Waikato Regional Council and from the Waiariki Maori Geothermal Advisory Group. The group's mandate is to provide early guidance and advice on matters likely to be of concern to the community, however it has no decision making authority.

This liaison group will be complimented by targeted stakeholder workshops with key interest groups (eg. well owners, direct heat users, tourism operators), and later the wider community. Hui with tangata whenua, Iwi, and Maori land trusts will also be held. These key stakeholders are shown in Figure 4.

The multiple interests of Maori in geothermal management must be provided for through this process. This includes recognising their unique relationship with the resource as kaitiaki (stewards), their role as landowners who may be potentially affected by policy decisions and as industry partners, investors and developers.

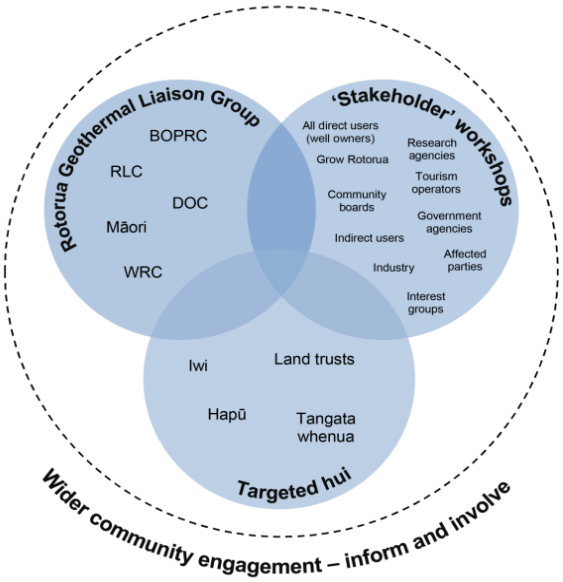

Figure 4: Engagement Approach for Plan Review

7 ARE CHANGES TO MANAGEMENT EXPECTED?

System demonstrates the effectiveness of the Regional Plan and therefore, whilst it may appear on the surface to be somewhat pre-determined, significant changes to the plan are unlikely unless new research supports a greater degree of change.

Certainly the fundamental premise of protecting surface features will remain a driver for the regional plan review. To do otherwise would be contrary to the RPS, the purpose and principles of the RMA, and most likely the expectations of the wider community. It follows that substantial changes to allocation limits are unlikely, including any increase in the discharge of geothermal water to waste. Provisions limiting use within 1.5km of Pohutu Geyser and requiring reinjection of fluid will most likely be retained.

There are however some matters that are likely to come under closer scrutiny by the community, and through further research and modelling. For example:

- Is the limit on a net increase in extraction of energy from DHX within the 1.5km exclusion zone still appropriate, or are there opportunities to use improved technology and efficiencies within this zone?
- To what degree can an increase in heat extraction using DHX exchangers or closed loop systems be supported throughout the system, whilst avoiding adverse effects on the system's surface features?

- Is the limit on net mass abstraction from the field appropriate equally throughout the system, or can this be refined geographically (for example to what extent is this appropriate in areas of outflow on the lake edge)?

- Should greater efficiencies in use be required (and enforced) through policies and rules?

- How are 'significant' geothermal features determined (eg. what methodology is applied to determine the level of significance)?

- How is the scale of effects on significant surface features assessed and how do we determine whether these effects are appropriate?

Stakeholder and interest groups will also bring unique perspectives to 'the table' - based on their understanding of the geothermal system, their sense of place and their aspirations to improve the health and wellbeing of their community. Early engagement with members of the community has identified a number of aspirations that are likely to be raised through the plan review process, including:

- Development of a district-wide home heating scheme in Rotorua;

- Greater opportunity for the development of wellness centers to support Rotorua Lakes Council's economic growth aspirations;

- Opportunities for small scale manufacturing direct heat uses or small scale power generation;

- Pressure for investment in exploration of and abstraction from the deep resource;

- Use of matauranga Maori (traditional Maori knowledge) in monitoring and management of the resource;

- Co-management of the geothermal resource between BOPRC and Iwi.

Managing or responding to these expectations will be challenging. Firstly a greater understanding of the existing plan provisions is needed. For example, some of these enterprises are already possible under the existing plan, and are limited more by market feasibility or technology (eg. district home heating schemes). Other matters are more likely to be influenced by the political climate, relationships between BOPRC and Iwi, and legislative change.

However it is possible that the status quo (or similar) will be challenged through the plan change process and that a complete rethink of the current management regime will be demanded. There is a risk for example that recovery of the geothermal system, which is so visual and obvious to all, creates a sense of complacency and a perception that the resource again has untapped potential. This underlines the importance of a robust engagement process (where people are fully informed about the vulnerability of the system), and evidence based policy (using our knowledge of the system and its response to use to ensure that implications of changes to policy change are fully understood and are defendable).

8 CONCLUSION

The Rotorua Geothermal Regional Plan prioritises surface feature protection over extractive uses by limiting net loss of geothermal fluid to the system, and restricting use close to Whakarewarewa Valley. This management approach has been effective and the recovery of the system is well documented. The plan is now due for a review under the RMA, including formal public consultation. This will invariably lead to a close examination of the policies, and the technical or scientific justification of this policy. While the focus on surface feature protections is well entrenched, the review will provide an opportunity to carefully consider opportunities to improve efficient use of the valuable resource. An ongoing challenge will be ensuring that the community is well informed about realistic options for use of the resource, and that policy decisions are evidence-based and defendable.

ACKNOWLEDGEMENTS

This report draws on a wealth of knowledge that has been accumulated on the Rotorua Geothermal System over more than thirty years. Many experts, in particular GNS Science, have contributed to the development of the Rotorua Geothermal Regional Plan and continue to provide input to inform its review. This work could not progress without their contributions. Thanks are also extended to Freya Camburn (BOPRC) for peer review and editing of this paper.

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