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BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

KAWERAU GEOTHERMAL SYSTEM MANAGEMENT PLAN

February 2018

Prepared in Collaboration with

Tuwharetoa Geothermal Kawerau
Mercury
Eastland Generation
Te Ahi O Maui Geothermal Project

Executive Summary

The Kawerau Geothermal System is located to the north-east of Kawerau within the Bay of Plenty Region, and partially underlies the township of Kawerau. It has been substantially developed for industrial purposes pursuant to resource consents granted by the Bay of Plenty Regional Council (BOPRC) under the Resource Management Act 1991 (RMA). This includes geothermal energy being used for electricity generation, industrial processes (direct heat) and cultural purposes.

Bay of Plenty Regional Council has functions under Section 30 of the RMA for the management of geothermal resources. The Bay of Plenty Regional Policy Statement (RPS) requires the preparation of a System Management Plan (SMP) for the Kawerau Geothermal System as a key part of the way in which BOPRC intends to manage the Kawerau Geothermal System. This SMP has been prepared in collaboration with the four consent holders authorised to take more than 1,000 tonnes per day of geothermal fluid from the Kawerau Geothermal System, being:

- Mercury NZ Limited,
- Ngāti Tūwharetoa Geothermal Assets Limited,
- Geothermal Developments Ltd, and
- Te Ahi O Māui Partnership.

Engagement has also been undertaken with tangata whenua and interested and potentially affected parties, including industrial operators using the geothermal resource.

The purpose of this SMP is to ensure that the Kawerau Geothermal System is managed in a sustainable manner in accordance with the requirements of the RMA and the relevant policy and planning documents prepared under the RMA.

The content anticipated in an SMP is set out in Policy GR7B of the RPS and includes objectives for its overall management and strategies to achieve the objectives

The SMP is a non-statutory document and will be periodically reviewed and updated to ensure that it remains relevant and fit for purpose.

Contents

Table of acronyms and abbreviations

BOPRC	Bay of Plenty Regional Council
DoC	Department of Conservation
GDL	Geothermal Developments Ltd
KDC	Kawerau District Council
IMP	Information Management Protocol
Mercury	Mercury NZ Limited
NTST	Ngati Tūwharetoa (BOP) Settlement Trust
NTEL	Ngati Tūwharetoa Electricity Limited
KGL	Kawerau Geothermal Limited (Kawerau Power Station owned by Mercury)
MWe	Net Megawatts of electrical energy generated from a power station
NTGA	Ngāti Tuwharetoa Geothermal Assets Limited
OMP	Operational Management Plan
PRP	Peer Review Panel
RMA	Resource Management Act 1991
RPS	Bay of Plenty Regional Policy Statement
RNRP	Bay of Plenty Regional Natural Resources Plan
SGF	Significant Geothermal Feature
SMP	System Management Plan
TAOM	Te Ahi O Māui Partnership
TVZ	Taupō Volcanic Zone

Part 1: Introduction

1.1 The Kawerau Geothermal System

The Kawerau Geothermal System[1] is located predominantly to the north-east of Kawerau within the Bay of Plenty Region, and is within both the Whakatāne and Kawerau Districts (see Figure 1).

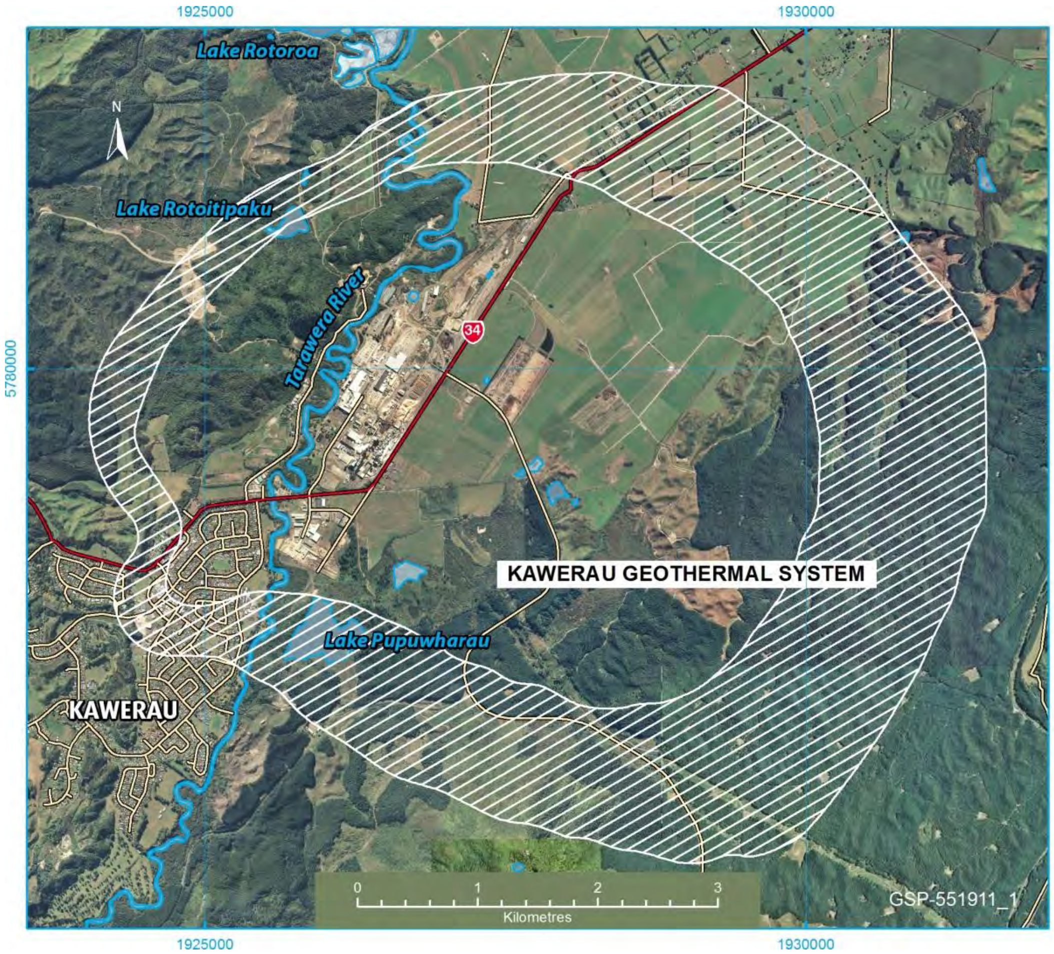

Figure 1 The location of the Kawerau Geothermal System (Based on inferred resistivity boundary) (Based on Milicich et al 2015, after Allis 1997).

The Kawerau Geothermal System forms part of the Taupō Volcanic Zone (TVZ) which extends from the Tongariro National Park to Whakaari (White Island). Based on the inferred resistivity[2] boundary at a depth of 500 m, the Kawerau Geothermal System extends over an area of approximately 35 km^2.

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[1] *A geothermal system comprises geothermal energy stored as geothermal water and/or steam, the host rocks within which most of the heat resides and associated geothermal surface features. This is distinct from the reservoir which is usually understood to be part of the system that can be economically exploited to produce fluid or heat.*

2 Resistivity quantifies how strongly a material opposes the flow of electric current. A low resistivity indicates a material that readily allows the flow of electric current. In geothermal exploration, low resistivity indicates the potential of geological material to contain or have potential to contain geothermal fluid.

The land overlying the Kawerau Geothermal System is a mix of rural, industrial and urban land uses with part of the Kawerau township located over the south western part of the system.

The system has been developed since the 1950s and understanding of the system has evolved over nearly 70 years. The Kawerau Geothermal System is the only geothermal system in the Bay of Plenty Region that has been the subject of large takes and discharges of geothermal fluid for electricity generation, and industrial direct heat purposes.

The importance of the sustainable management of the Kawerau Geothermal System to the region's economy is substantial and strategic initiatives such as the Bay of Plenty Regional Growth Strategy (Geothermal) seek to support continued use and development of geothermal resources.

1.2 Purpose of the System Management Plan

The purpose of this SMP is to ensure that the Kawerau Geothermal System is managed in an integrated and sustainable manner in accordance with the requirements of the RMA, and in particular Objective 8 and Policies GR 2A, GR3A and GR 7B of the RPS.

The Kawerau Geothermal System is classified in the Bay of Plenty Regional Policy Statement (RPS) as Development System 4. The focus of this SMP is therefore to guide how the Kawerau Geothermal System is managed to meet the geothermal needs of current and future generations in a sustainable manner. This includes agreed operational protocols between consent holders and between consent holders and BOPRC to achieve sustainable and integrated development of the Kawerau Geothermal System.

This SMP is intended to provide an integrated approach to sustainable management of the Kawerau Geothermal System, including an understanding of the actual and potential adverse effects of the use of the geothermal resource (including cumulative effects over time), and how these can be managed.

The SMP will also provide guidance to BOPRC in its decision making processes, in the administration of existing consents, and the processing of resource consent applications (including changes to existing consents, new consents and reviews), where conditions of consent should reflect the requirements of this SMP.

1.3 Content of the System Management Plan

The content of the SMP is guided by Policy 7B of the RPS that requires the following:

- System management objective,
- Adaptive management parameters,
- Reservoir and subsidence predictions,
- Discharge strategy,

- Mechanisms to ensure cooperation between all consent holders for large takes,
- Buffer distances between production and injection or reinjection wells of adjacent operators,
- Mechanisms to remedy or mitigate significant adverse effects on significant geothermal features (SGFs),
- Research, monitoring and reporting of the system, its potentials, attributes and qualities and effects of exercising consents,
- Provisions for system liaison groups, and
- The use of peer review panels to assist BOPRC.

1.4 Scope of the System Management Plan

The focus of this SMP is on the sustainable management of the Kawerau Geothermal System. The wider environment is referenced only where directly related to management of the reservoir, due either to natural processes (e.g. natural discharges to the Tarawera River), the effects of production (e.g. geothermal discharges to land, air or water) or surface effects directly related to take and discharges (e.g. subsidence and surface features). Wider environmental effects such as noise, amenity, infrastructure, access, and earthworks are not addressed in the SMP.

1.5 Parties to the System Management Plan

The parties to this SMP are:

- The Bay of Plenty Regional Council;
- The four parties that currently hold resource consents authorising the take of more than 1,000 tonnes per day of geothermal water from the Kawerau Geothermal System (referred to as the consent holders), being:
  - Mercury NZ Limited,
  - Ngāti Tūwharetoa Geothermal Assets Limited,
  - Geothermal Developments Ltd, and
  - Te Ahi O Māui Partnership.

Each of the parties' roles, activities and/or interests in the Kawerau Geothermal System are briefly summarised as follows.

1.5.1 Bay of Plenty Regional Council

Bay of Plenty Regional Council (BOPRC) has functions under Section 30 of the RMA including in relation to the management of geothermal resources. Sections 5, 14 and 15 of the RMA are also particularly relevant in relation to the assessment and determination of resource consent applications by BOPRC for the take (including heat and energy), use and discharge of geothermal fluid.

The preparation of this SMP, in collaboration with the four major consent holders listed above, is a key part of the way in which BOPRC intends to manage the Kawerau Geothermal System on behalf of the community.

1.5.2 The consent holders

Ngāti Tūwharetoa Geothermal Assets Limited

Ngāti Tūwharetoa Geothermal Assets Limited (NTGA) is a 100 % wholly owned subsidiary of Ngāti Tūwharetoa Settlement Trust (NTST). At the time of its formation, NTGA purchased the Crown assets including take, injection and monitoring wells, supporting infrastructure and the historical supply contracts and consents relating to the Kawerau Geothermal System. Ngati Tuwharetoa Geothermal Asset Limited continues to develop and grow its field wide assets whilst maintaining those historical obligations inherited from the Crown.

Ngāti Tūwharetoa Geothermal Assets Limited's role is as a wholesale supplier of geothermal energy and fluid, supporting Kawerau industry for use in industrial applications, particularly process heat and electricity generation. To the extent that NTGA is a steamfield developer that distributes geothermal energy to industrial geothermal users, its business model differs from that normally seen within the New Zealand geothermal industry, which is dominated by electricity generation. The geothermal energy currently supplied by NTGA is driven by, and is a function of, the current and future needs and demands of the industry in Kawerau. Ngati Tuwharetoa Geothermal Asset Limited has recently formed a wholly owned subsidiary Ngāti Tūwharetoa Electricity Limited (NTEL) which has purchased the previously Norske Skog owned TOPP1 power plant. Ngati Tuwharetoa Geothermal Asset Limited remains the sole supplier of steam and brine to TOPP1. Like all geothermal operators, it must also adhere to those fundamental principles and kaitiaki responsibilities held by NTST (discussed in the next section of this SMP).

Mercury NZ Limited (Mercury)

Mercury NZ Limited (Mercury) is one of New Zealand's largest electricity companies. It is listed on the New Zealand Stock Exchange and has approximately 95,000 shareholders. Mercury generates 100% if its electricity from renewable sources. It has nine hydro-electric power stations on the Waikato River and, along with partners, owns and operates five geothermal power stations in the central North Island. The latter includes a 100MWe geothermal power station on the Kawerau Geothermal System which was commissioned in 2008.

Geothermal Developments Limited

Geothermal Developments Ltd (GDL) is a wholly owned subsidiary of Eastland Generation Ltd which is owned by Eastland Group Ltd which is owned by the Eastland Community Trust.

GDL operates a 9MWe binary geothermal power plant located on the western side of the Tarawera River. The power station is supplied by one production well (KA24). Once used in the power plant, the geothermal fluid is injected back into the Kawerau Geothermal System.

Te Ahi O Māui Partnership

Te Ahi O Māui Partnership (TAOM) is a partnership of Eastland Generation Ltd and land owners and tangata whenua through the Kawerau A8D Ahu Whenua Trust (part of the Ngāti Tūwharetoa ki Kawerau iwi).

Once completed in 2018, the Te Ahi O Maui Geothermal Power Plant will generate approximately 25 MWe from a site 2.3 kms north of the Kawerau township on the western side of the Tarawera River.

1.6 Kaitiaki/Tangata whenua interests

1.6.1 Iwi Authorities/Governance Bodies

Ngāti Tūwharetoa (BOP) Settlement Trust

Ngāti Tūwharetoa (BOP) Settlement Trust (NTST) was established from a Deed of Settlement with the Crown in order to give effect to a Treaty Settlement received in 2005. NTST acts on behalf of its beneficiaries and its main vision is to maintain and grow the assets of Ngāti Tūwharetoa. Seven elected Trustees are responsible overall for the group, assets, policy, cultural outcomes, distribution, Deeds of Recognition, and upholding the tribe's role as a kaitiaki over the Kawerau Geothermal System. The Kawerau Geothermal System has a high degree of cultural significance for NTST.

Ngāti Tūwharetoa (BOP) Settlement Trust holds a statutory acknowledgement over the Kawerau Geothermal System. As a kaitiaki of the taonga, NTST has mandated responsibilities to manage and protect the cultural, spiritual, historical and customary connections held, and to ensure that the knowledge of this connection is passed down from generation to generation. NTST must act in the best interests of the taonga to ensure it is managed in a culturally appropriate and sustainable manner, consistent with tikanga for present and future generations. The Kawerau Geothermal System includes culturally significant areas, including Parimahāna, Te Taukahiwi o Tirotirowhetu, Otukoiroa, Okākaru, Waiwera, and Ruruanga. Although these areas are identified separately with their own historical stories and waiata, Ngāti Tūwharetoa connect themselves to all and believe that each intertwines to become one.

Te Rūnanga o Ngāti Awa

Te Rūnanga o Ngāti Awa was first established as a Maori Trust Board in 1988, and in 2005 legislation settling Ngāti Awa's Treaty of Waitangi claims resulted in the establishment of Te Rūnanga o Ngāti Awa as a governing body.

Te Rūnanga o Ngāti Awa is the mandated entity that manages the collective affairs of the members of Ngāti Awa working for and on behalf of Ngāti Awa members, including 22 hapū.

Te Runanga o Ngāti Awa holds the statutory acknowledgement for the Tarawera River as outlined in Section 2.9.3.

Te Mana o Ngāti Rangitihi Trust

Ngāti Rangitihi has not settled their Treaty Claim with the Crown. However, they are recognised as having a relationship with the Tarawera River and an interest in the Kawerau area that will be further described through settlement legislation. The iwi has lodged an Iwi Environmental Management Plan with BOPRC (discussed in Chapter 2 of this SMP).

1.6.2 Tangata whenua

In addition to the iwi authorities described above, a number of hapū (e.g. Ngai Tamarangi) identify strongly with the environment around the Kawerau area. They consider that they have a responsibility for resources in their rohe, and a kaitiaki role, whether or not the land is within their possession. Also, Māori land owners and trusts within the Kawerau area (that may affiliate to one or more iwi), may be directly or indirectly involved in, or affected by activities relating to geothermal development on the Kawerau Geothermal System. Some specifically express a kaitiaki interest in sustainable management of the geothermal resource. While detailed descriptions of these relationships are not within the scope of the SMP, principles to recognise and provide for kaitiakitanga are included in Section 2.10.

1.7 Other stakeholders/Interested parties

There are a number of other parties who potentially have an interest in the management of the Kawerau Geothermal System, including:

- The general public.
- Other small consent holders on the Kawerau Geothermal Field.
- Industrial and commercial operators (including Norske Skog Tasman, Asaleo and Oji).
- Landowners overlying the Kawerau Geothermal System including Māori land trusts.
- Kawerau District Council and Whakatāne District Council.
- Central Government Agencies (e.g. MBIE, Department of Conservation).

1.8 Status and use of the System Management Plan

This SMP will be used in the following ways:

(a) To provide interested and potentially affected parties with an understanding of how BOPRC will manage the Kawerau Geothermal System,

(b) To provide transparency around existing processes for the management of the Kawerau Geothermal System,

(c) As a guide for resource consent applicants, including when seeking to demonstrate how any proposal is consistent with the intended overall management of the Kawerau Geothermal System as documented in the SMP,

(d) To be a non-statutory document that should be taken into account in relation to the assessment and determination of resource consent applications (including the nature of consent conditions) for any activities within the Kawerau Geothermal System (under Section 104(1)(c) of the RMA),

(e) To be used by the Kawerau Peer Review Panel (PRP) to guide recommendations in relation to the management of the natural and physical aspects of the Kawerau Geothermal System and the exercise of resource consents,

(f) To be used in the development of operational management plans (required by the conditions of some resource consents), to ensure consistency with the objectives and principles of the SMP,

(g) To be used by BOPRC in administering and monitoring consents relating to the use of the Kawerau Geothermal System, and

(h) To inform development or reviews of policy and planning documents prepared under the RMA and/or other legislation that relate to the Kawerau Geothermal System.

1.9 Process for the development of the System Management Plan

The SMP has been prepared by BOPRC in collaboration with the four consent holders identified in Section 1.5 above. It has been developed through a non-RMA process that reflects the documents operational nature, with the benefit of input from kaitiaki and key stakeholders including those identified in Section 1.5 and 1.6.

The process by which this SMP has been developed is illustrated in Appendix 1.

1.10 Structure of the System Management Plan

The structure of the SMP is as follows:

- Part 2 summarises the key elements of the statutory and policy context relating to the management of the Kawerau Geothermal System.
- Part 3 provides a description of the Kawerau Geothermal System.
- Part 4 provides a summary of the key aspects of the resource consents held by the four parties that hold resource consents for the large scale take and discharge of geothermal fluid from the Kawerau Geothermal System.
- Part 5 documents the key resource management issues that the SMP seeks to address.
- Part 6 specifies the objectives for the overall management of the Kawerau Geothermal System.
- Part 7 documents the strategies to achieve the objectives of the SMP including strategies in relation to:
  - operational flexibility and adaptive management
  - predicting effects through modelling
  - geothermal fluid take
  - a discharge strategy (discharges to land, air and water)
  - integrated management and co-operation between users
  - buffer distances between wells or adjacent operators
  - management of adverse effects, including remedying and mitigating significant adverse effects on SGFs
  - research, monitoring and reporting
  - consultation/stakeholder involvement
  - review of the SMP.

Part 2: Statutory and policy context

The following summarises the key elements of the statutory and policy context that are particularly relevant to the management of the Kawerau Geothermal System and the development of this SMP. Key sections of the RMA and relevant objectives and policies are presented in Appendix 2.

2.1 Resource Management Act 1991

The Kawerau Geothermal System is managed in accordance with the purpose and principles of the RMA which is:

To promote the sustainable management of natural and physical resources.

Bay of Plenty Regional Council addresses its functions under the RMA including those relating to the sustainable management of geothermal resources, under Section 30 of the RMA. These functions include the integrated management of resources, the control of the taking and use of water and heat, and the control of discharges of contaminants.

Council's functions, powers and duties in relation to geothermal management have been addressed, in part, in the RPS, regional plans and consent conditions.[3]

2.2 National Policy Statement for Renewable Electricity Generation

The National Policy Statement for Renewable Electricity Generation 2011 (NPS REG) has the objective:

To recognise the national significance of renewable electricity generation activities by providing for the development, operation, maintenance and upgrading of new and existing renewable electricity generation activities, such that the proportion of New Zealand's electricity generated from renewable energy sources increases to a level that meets or exceeds the New Zealand Government's national target for renewable electricity generation.[4]

The NPS REG is part of New Zealand's wider response to climate change. It ensures that the national benefits of renewable electricity generation are taken into account in consenting decisions. It also requires decision makers to have particular regard to the locational requirements, the logistical or technical practicalities, and infrastructure requirements associated with developing, upgrading, operating or maintaining renewable electricity generation activities.

[3] *Bay of Plenty Regional Council addresses its functions, powers and duties in relation to the management of geothermal resources through the assessment and determination of resource consent applications (in relation to sections 14 and 15 of the RMA) including the imposition of consent conditions specifying the manner in which geothermal resources may be utilised.*
[4] *The Government's national target for renewable electricity generation is 90 per cent of electricity from renewable sources by 2025.*

2.3 Bay of Plenty Regional Policy Statement

The RPS includes a suite of policies relating to the management of the regional geothermal resource which is made up of at least 12 separate geothermal systems.

Policy GR 1A of the RPS categorises identified geothermal systems into different geothermal 'management groups'. The Kawerau Geothermal System is classified as one of the Group 4 – Development Systems. The management purpose stated for Group 4 – Development Geothermal Systems in Table 12 of the RPS is:

System management that provides for extractive use, provided significant adverse effects[5] on Significant Geothermal Features are remedied or mitigated.

Policy GR2A requires integrated system management for significant geothermal system use[6] and for Development Systems, through the use of a single SMP. A single SMP is intended to provide a holistic approach to managing the geothermal system, including an integrated understanding of the actual and potential adverse effects of extractive use of the geothermal system (including cumulative effects), and how these can be managed.

Policy GR3A of the RPS also provides for the sustainable use of a geothermal system, if it is consistent with the management purposes for each system and if the system is operated under an SMP. The contents of SMPs are specified in Policy GR7B, while Policy GR8B covers the contents of a discharge strategy, which is also an integral part of the SMP. This SMP seeks to address all of the matters which are set out in Policies GR3A, GR7B, and GR8B.

The RPS anticipates (in the explanation of policy GR3A) that where there are a small number of large consent holders, BOPRC will generally require users to prepare SMPs. However, in the case of Kawerau Geothermal System, a large part of the resource has already been allocated and BOPRC has facilitated this process.

The RPS also provides that sustainable management of geothermal resources is achieved at the 'regional' level, within the context of a systems classification (i.e. 'Development' in the case of the Kawerau Geothermal System). A 'sustainable' take of geothermal fluid is one that manages depletion over a long period of time (i.e. at least 50 years) to make some provision for its use by future generations.

Allocation decisions must be made on the basis of taking the energy and fluid at a sustainable rate by one or more consent holders within the same system, and take account of potential effects on SGFs within the system. Policy GR3A requires, in Group 4 Geothermal Systems, that significant adverse effects caused by consented activities on SGFs are remedied or mitigated. To allocate the resource efficiently requires a holistic understanding of the allocation parameters and impacts of all users, thus an SMP that is common to the entire system is necessary.

2.4 Regional Natural Resources Plan

Rules for the allocation of geothermal fluid and energy and freshwater, and discharges to land and water are set out in the Bay of Plenty Regional Natural Resources Plan (RNRP). Under the RNRP, the Kawerau Geothermal System is

[5] *Appendix G of the RPS includes criteria guide how the significance of adverse effects may be determined.*

[6] *Where the cumulative abstractive development uses 1,000 tonnes or more geothermal water per day.*

classified in ‘Geothermal Management Group 4’ and the plan provides for its development, including large takes and discharges of geothermal fluid.

Bay of Plenty Regional Council is currently in the process of reviewing the geothermal provisions of the RNRP to give effect to the RPS. As noted in Section 1.8, some of the principles of this SMP may be reflected in the objectives, policies and methods (including rules) in the Proposed RNRP.

2.5 Regional Air Plan

Discharges to air as a result of geothermal developments are managed under Section 15 of the RMA and the Regional Air Plan. In relation to geothermal consents, the plan controls discharges of non-condensable gases, including hydrogen sulphide (H_2S), carbon dioxide (CO_2), mercury and steam which result from the discharge of geothermal steam and gases to air.

2.6 Regional Plan for the Tarawera River Catchment 2004

The Tarawera River Catchment Plan (TRCP) overlaps with the RNRP, and currently the provisions of both documents apply. The objectives and policies of the TRCP are mainly related to the management and continuous improvement of the Tarawera River water quality. The geothermal policies in the TRCP promote the injection of spent geothermal water back into the reservoir. The plan encourages cascade use while discouraging development that may adversely affect Significant Geothermal Features.

2.7 District plans

Under Section 31 of the RMA, district council functions include the control of any actual or potential effects of the use, development, or protection of land. These matters are managed under district plans, which for the Kawerau Geothermal System are the Whakatāne District Plan and the Kawerau District Plan. These plans contain objectives, policies and rules (including assessment criteria) for land use activities relating to geothermal use and development, such as infrastructure (e.g. pipelines), earthworks (e.g. access, plant and well pads), protection of natural and cultural values, and amenity (e.g. noise, vibrations).

Because the use and development of geothermal energy and fluid generally requires consents from both regional and district councils, they usually involve joint processing of resource consent applications.

2.8 Relationship of System Management Plan to existing consents and consent conditions

Each of the existing consent holders has rights and obligations set out in the conditions of their resource consents. There are some consent conditions that are included in all consents, some which are similar in intent but with slight variations in drafting between consents (as a result of separate consent application processes) and some that are particular to individual consents. This SMP does not seek to undermine those rights, but rather to ensure that activities are undertaken in an integrated manner, in accordance with those rights and obligations and with the RPS, without duplicating documentation that already exists.

The SMP will provide the guiding principles for the integrated and sustainable management of the Kawerau Geothermal System as required by the RPS. In doing so the SMP does not pre-empt or limit BOPRC's statutory discretion, including the manner in which it discharges its functions in granting consents or administering and/or enforcing existing consent conditions. Bay of Plenty Regional Council has the ability under Section 128 of the RMA to review consent conditions at any time, if required and appropriate. This could include a review following the completion of the SMP to meet the requirements of the SMP (this being specifically provided for in some of the existing consent conditions).

2.9 Statutory Acknowledgements

Bay of Plenty Regional Council's document Nga Tikanga Tiaki i te Taiao - Maori Environmental Management in the Bay of Plenty includes all statutory acknowledgements in the Bay of Plenty Region. There is only one statutory acknowledgement relating to the Kawerau Geothermal System, held by NTST. Other natural resources within the Kawerau area are also discussed below for completeness.

2.9.1 Statutory Acknowledgement - Kawerau Geothermal System

NTST holds a statutory acknowledgement over the Kawerau Geothermal System as shown on SO61730 and appended in Appendix 3.

Other areas relevant to the Kawerau Geothermal System and recognised as part of NTST's cultural redress include:

- Te Taukahiwi o Tirotirowhetu - 10 ha of vested title as shown on SO 61718 in Appendix 3.
- Owhakatihi Area - Parimahana Scenic Reserve[7] - NTST have a Statutory Acknowledgement in respect of Owhakatihi Area as shown on SO 61719 in Appendix 3.

2.9.2 Statutory Acknowledgements – Tarawera River

The Tarawera River flows through the Kawerau area where the Kawerau Geothermal System is located. There are two statutory acknowledgements held over the Tarawera River:

- Ngati Tuwharetoa (BOP) Settlement Trust- As shown on SO 61729 in Appendix 3
- Ngati Awa - As shown on SO 61403 in Appendix 3

2.9.3 Relevance of Statutory Acknowledgments to the System Management Plan

The statutory acknowledgements confirm the status of the named iwi entities with kaitiaki responsibilities over specified areas and/or resources and natural features. The statutory acknowledgements reinforce the need for regulatory agencies such as BOPRC to consult in statutory decision making processes associated with the management of the natural resources addressed in this SMP. The geothermal

[7] *NTST should be contacted for further information about these areas.*

statutory acknowledgement does not affect the lawful rights or interests of a person who is not a party to the deed of settlement that the statutory acknowledgement was created under. Nor does it have the effect of granting, creating, or providing evidence of an estate or interest in, or rights relating to the Kawerau Geothermal System itself.

2.10 Provisions for Kaitiakitanga

As described in Section 1.6 there are a number of iwi, hapu and other groups with an interest in the Kawerau Geothermal System and/or a relationship with the surrounding area. It is the prerogative of tangata whenua, not BOPRC, to determine their role and responsibilities as kaitiaki over resources within an area. However, it is noted that kaitiaki relationships from multiple groups have been expressed and demonstrated through successive consent processes in relation to the Kawerau Geothermal System.

The statutory expression of kaitiakitanga in geothermal management has already been traversed in the development of the RPS geothermal provisions, and as part of the resource consent application processes. Examples of providing for kaitiakitanga can be seen in some consent conditions (e.g. the establishment of Paapaki Ngawha, and protocols to access Parimahāna Scenic Reserve). It is not the role of the SMP to re-litigate or undermine these provisions. However, kaitiaki have an interest and cultural expertise in the management of the resource. As such BOPRC will, as appropriate, provide opportunities for kaitiaki to exercise their roles and responsibilities in regards to the Kawerau Geothermal System (and the wider environment in which it is located) in the following ways:

1 Acknowledge tangata whenua as interested and potentially affected parties in relation to the management of the Kawerau Geothermal System,

2 Provide opportunities for kaitiaki to participate in any review of the SMP,

3 Provide for matauranga Māori and tikanga in assessing the overall sustainability of a proposed use of resources,

4 Provide copies of reports produced (excluding commercially sensitive information) in relation to Kawerau Geothermal System (to the extent that tangata whenua wish to see such reports),

5 Notify Statutory Acknowledgement holders of any resource consent applications in relation to Kawerau Geothermal System,

6 Consider imposing consent conditions on any consents granted to address any actual or potential adverse effects on aspects of the environment of importance to tangata whenua,

7 Provide opportunities to tangata whenua to participate in the preparation of policy and planning documents relating to the management of the Kawerau Geothermal System, and

8 Hold hui between BOPRC, the PRP and kaitiaki as required to discuss sustainable management of the Kawerau Geothermal System and seek feedback as appropriate.

2.11 Iwi management plans

At this point in time, there are no iwi management plans specifically relating to the Kawerau Geothermal System. There are a number of iwi/hapū documents that relate to the area within which the Kawerau Geothermal System is located including:

- Ngāi Tamarangi Ngā Tikanga Whakahaeire Taonga Environmental Management Plan 2016.
- Ngāti Tūwharetoa ki Kawerau Strategic Plan 1991.
- Ngāti Rangitihi Iwi Environmental Management Plan.
- Ngāti Umutahi Whenua Resource Management Plan.
- Ngāti Awa Tarawera River document.

These documents are likely to be relevant to the assessment and determination of resource consent applications for any activities within the area of the Kawerau Geothermal System (under Section 104(1)(c) of the RMA).

Part 3: Description of the Kawerau Geothermal System

3.1 Location

The Kawerau Geothermal System is located approximately 15 km inland from the Bay of Plenty coastline, immediately northeast of Kawerau township (see Figure 1.1). It is located within the flood plains of the Tarawera River between Putauaki (Edgecumbe) volcano to the south east and the Onepu Hills in the north-west. The Tarawera River runs through the centre of the system, with its flood deposits forming much of the surficial geology.

The highest measured subsurface geothermal fluid temperatures and pressures at Kawerau occur towards the southern part of the system, in the vicinity of the Putauaki volcano. This is consistent with the deep upflow and major heat source occurring in this part of the system.

3.2 Extent of the Kawerau Geothermal System

Early surveys in the area (1969 – 1970) indicated a resource area of 10 km^2 at ~250 m depth, centred on the site of the Tasman Mill (Macdonald et al., 1970; Macdonald and Muffler, 1972). Surveys, from 1969–70 and extended in 1989, have revealed that the geothermal resource is present over a greater area (Allis et al., 1995). Depending on your point of reference, the extent of the geothermal reservoir is considered to be between 19 and 35 km^2 with the effective exploitable production area thought to be approximately 9 km^2 (Bignall and Harvey, 2005)[8]. Over the past 70 years, knowledge of the system and its boundaries has been gained through development and monitoring. It is not thought that Kawerau Geothermal System is connected to any other geothermal system.

3.3 Land ownership

Land tenure in Kawerau includes both general and Māori title private land, Māori Reserve land[9], as well as land owned by district councils and the Crown, and is represented by multiple owners. The majority of the current geothermal operations occur on private land and private access agreements are in place between consent holders and landowners for operations. These agreements are critical to the adaptive management of the system, but are outside of the scope of consents and this SMP. It is also noted that for the purposes of geothermal prospecting and use, land title boundaries extend to the centre of the Earth.

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[8] *A number of resistivity surveys have been carried out since the 1970s. These surveys provide indicative boundaries to the geothermal system (Figure 1). More recently Magnetotelluric8 surveys (an electro-magnetic geophysical survey method) have been carried out to determine the extent of the reservoir. However the results of these surveys (which are not required by consent) are commercially sensitive and are currently not publicly available, although the information is used to inform modelling and is available to the BOPRC (and the PRP) where necessary for management of the system.*

[9] *For example, Te Taukahiwi o Tirotirowhetu which is owned by Ngati Tuwharetoa Custodian Limited.*

3.4 Historical patterns of development

The development of the Kawerau Geothermal System has occurred in a staged manner. Development was initiated in the early 1950s, with a Government programme of scientific surveys and shallow drilling to investigate its geothermal potential. The first production wells were drilled in 1952 to provide heat for paper and timber drying and electricity for the Tasman Pulp and Paper Mill. A total of 17 wells were drilled and production commenced by 1957. At this time, drilling was limited to a relatively small area north of the mill and wells were typically relatively shallow, at about 500 m. The shallow nature of the earliest wells resulted in pressure drawn down and quenching of induced two-phase fluid conditions due to cold recharge resulting in failure of the production wells.

The Kawerau Geothermal System has since gone through a range of drilling programmes to both deepen existing wells and develop new wells, in order to maintain steam supply and investigate expansion of geothermal supplied industries (see Section 3.5 below). In the 1960s, wells found more reliable production at approximately 800 m and from the 1970s to mid-1980s, production wells were drilled at depths ranging from 1,200-1,600 m. These were cased through the volcanic strata overlying the basement to prevent cooler water entering wells. Most recent production wells have been drilled to over 1,000 m (with consents generally requiring casing to greywacke or 1,000m unless approval is otherwise given) and injection wells to over 1,500 m.

The pattern of discharge has also changed considerably over time. Originally all separated geothermal water at Kawerau was discharged to the Tarawera River. However, reinjection to the geothermal system began in 1991 with several shallow wells of <400 m being drilled to inject brine. The current discharge strategy now uses a mix of shallow infield reinjection and deep peripheral field reinjection to the north (with wells ranging from approximately 300-3,000 m depth), with typical injectate temperatures of around 120^{0}C. Most of the fluid is now injected, however, some geothermal water from the system continues to be discharged into the Tarawera River (consented up to 20,880 tonnes per day) after passing through a cooling channel. Current resource consents require ongoing efforts to reduce the discharge of geothermal fluid direct to the river.

3.5 Current land use patterns

The land over the Kawerau Geothermal System is used for urban, industrial and rural (mainly pastoral farming) purposes. Northeast of the Kawerau township is a large industrial area currently including the Norske Skog Tasman Mill and Oji Fibre Solutions (pulp and paper production), Asaleo (manufacture of personal hygiene products), and Sequal Lumber (timber drying), all of which are supplied geothermal energy to utilise the heat directly. Other surface land uses include the infrastructure associated with geothermal development, wells, pipelines and geothermal power stations.

Reserve land includes land owned by Kawerau District Council and the Department of Conservation, including Parimahāna Scenic Reserve (which is managed by protocols between Department of Conservation and Owhakatihi with NTST). Te Taukahiwi o Tirotirowhetu is a private scenic reserve owned by Ngati Tuwharetoa Custodian Limited.

There is limited private and light commercial use of the resource. Recreational and cultural uses of the geothermal resource include the Savage Whānau Pool which is used directly for bathing, and the Kawerau Town Pool which is geothermally heated.

3.6 Geothermal industrial and commercial surface activities

In the early 1950s Kawerau was chosen as the most suitable site to manufacture pulp and paper partly due to its central location, access to forests and natural resources, including the river and geothermal heat. The first well (KA1) was drilled in 1952 with steam being supplied for power production and direct process heat to the Tasman Mill in 1957. In 1961 full supply to the Tasman Mill commenced and in 1966 the Tasman Mill installed a generator to produce electricity from geothermal steam (TA3). Upgrades have been made over the years and the mill complex is now supplied with geothermal heat and steam by NTGA who purchased the geothermal field assets and steam supply business as part of their settlement process in 2005.

Bay of Plenty Energy Plant - TG1 was developed in 1989 and was the first binary cycle plant in New Zealand, using waste geothermal water from the industrial supply. TG2 was installed in 1993 on the western side of the Tarawera River and generates 29 GWh per year of electricity. TG1 and TG2 are now owned by NOVA Energy and TG1 was decommissioned in 2014. Supply is provided by NTGA via historic agreements.

The 100MWe Kawerau Geothermal Power Station owned by Mercury opened in November 2008. The power station is a conventional condensing turbine power plant, supplied by high-pressure and low-pressure steam coming from a double-flash separation system. It generates approximately 100-110 megawatts (MWe) of electricity. Ngati Tuwharetoa Geothermal Asset Limited and Mercury hold a fluid flexibility arrangement to assist with top up supply to either Mercury's power plant or reciprocal for NTGA's operations.

GDL owns a binary power plant (8.3 MWe) that was developed in 2008 (KA24 Station) and TAOM is currently in the process of developing a 23 MWe binary plant.

TOPP1 which generates 24 MWe was commissioned in 2013. Originally owned by Norske Skog with supply agreements with NTGA, this plant has recently been purchased by Ngāti Tūwharetoa Electricity Limited.

Industry relies on direct heat, provided by NTGA which takes geothermal fluid to supply steam and brine to customers for process heat. It also supplies clean steam to Asaleo for paper drying. In addition Sequal Lumber uses low pressure steam for two timber drying kilns, Oji Fibre Solutions uses heat for Kraft pulp, and Norske Skog Tasman for thermomechanical pulp (which subsequently supplies Carter Holt Harvey (CHH) Woodproducts heat for timber drying).

The schematic diagram in Figure 3.1 below shows the various uses of geothermal fluid and energy.

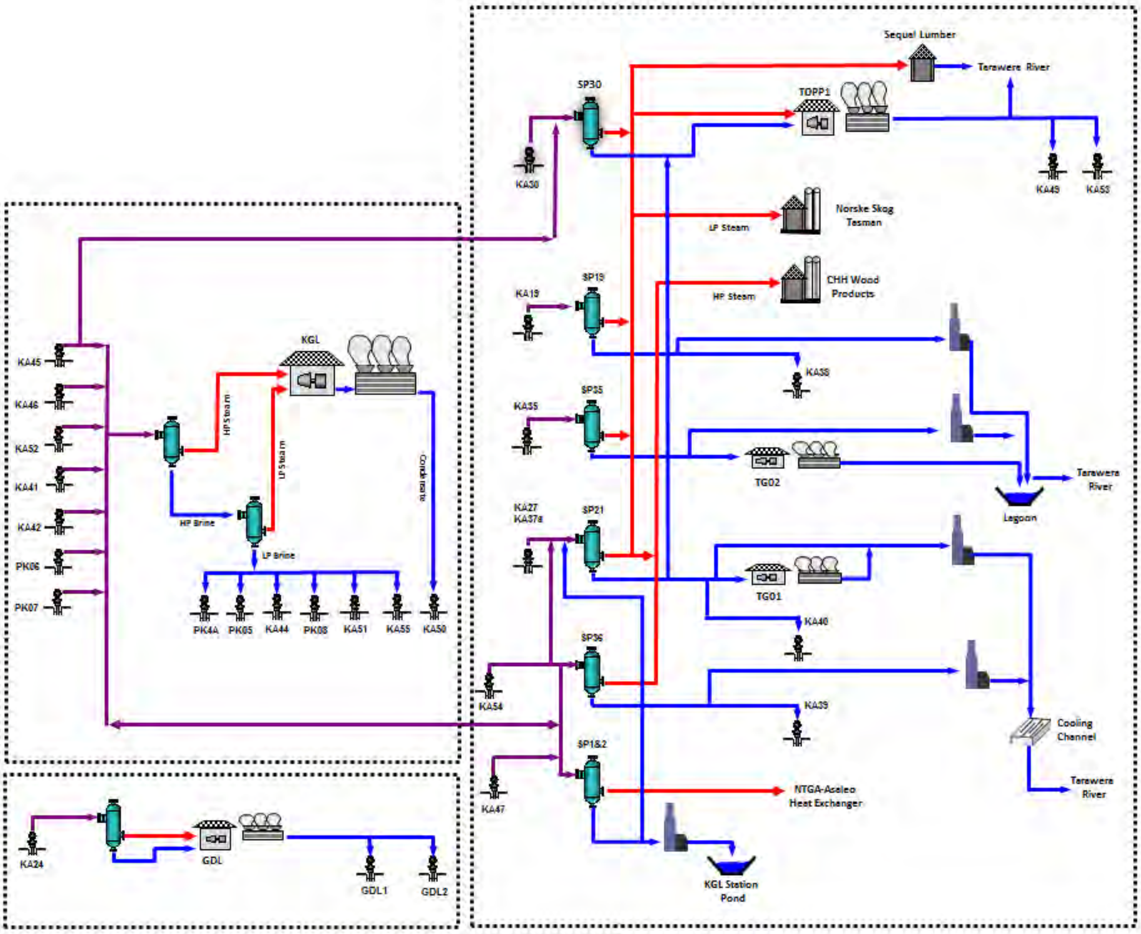

Figure 3.1 *Schematic Diagram of Energy Supply and use on the Kawerau Geothermal System.*

3.7 Physical characteristics

3.7.1 Surface geology

Surface mapping and examination of shallow drillcores reveal the Kawerau area is covered by: (i) debris from recent Tarawera eruptions; (ii) sediments deposited from Tarawera River flooding, and (iii) hydrothermal eruption breccia, associated with ~14,500 to 9,000 year-old hydrothermal events (Nairn and Solia 1980), interbedded with pyroclastic rocks.

Putauaki is a Holocene, multiple vent dacite-andesite volcano, located near the southern boundary of the Kawerau Geothermal System. It has a youngest dated eruption of 2,400 years B.C. (Carroll et al., 1997). The main cone is <5,000 years old, which is much younger than the inferred lifetime of the Kawerau Geothermal System. The Onepu domes (Onepu Formation on the western margin of the field are older rhyodacite, which erupted 138,000 to 150,000 years ago.

There is little evidence of surface fault traces within the Kawerau Geothermal System, as the area is covered by young surface deposits. The surface trace of the Onepu Fault, along which displacement occurred during the 1987 Edgecumbe Earthquake, is evident ~1 km from the northwest margin of the system.

3.7.2 Field stratigraphy

Differentiation of rock units encountered by geothermal drilling is based on logging cores and cuttings recovered during drilling, which has added to knowledge of the subsurface stratigraphy, controls on the distribution of the formations, and structural framework of the geothermal field.

In 2010 a major review of Kawerau geology drill hole data was completed, with re-logging of some units as necessary, including the shallow (<500 mVD) geology (Milicich et al., 2010; Bignall and Milicich, 2012). The purpose of the review was to ensure consistency of geological interpretations from recent and past drilling. The Kawerau stratigraphy and a geological cross-section, highlighting stratigraphic relationships across the field, is shown in Appendix 4.

3.7.3 Reservoir conditions

Pressure measurements from geothermal wells have been interpreted (Grant, 2005) to indicate a horizontal pressure gradient in a north-northwest direction. The highest pressures are in the Putauaki area. Deep geothermal upflow is thought to occur in the southeast of the system near the Putauaki volcano. (Bignall and Harvey, 2005). Up flowing geothermal fluid (>300^{0}C) moves across and flows north into the field through faults and fractures in otherwise impermeable basement greywacke and into the overlying volcano-sedimentary sequence.

Only part of the deep geothermal up-flow reaches the surface within the present Kawerau Geothermal System, with most of the natural surface outflow occurring via seepage to the Tarawera River to the northwest. Thermal inversions have been identified in basement greywacke in some wells towards the north-western extremity of the system (e.g. wells KA24, KA27 and KA32 as shown in Appendix 5), which supports lateral outflow to the north-west within the volcanic units.

Marginal recharge is understood to occur in the north western - western area of the system (introduction of peripheral fluid inflow as a response to early taking of fluid). Shallow cold fluid is also understood to be flowing across the geothermal reservoir at a depth of 250 m from Putauaki towards the Tarawera River.

The early quenching of the shallow two-phase zones in the Kawerau wells during the 1950s and 1960s (e.g. wells KA7, KA8, KA10, KA16 and KA17) in response to early production (Henley and Brown,1986) is thought to be due to the down flow of meteoric water through permeable pathways connecting the reservoir with the surface which are associated with old thermal surface features located near the southern shore of the former Lake Rotoitipaku. The earliest shallow wells were completed above the Tahuna Formation and, as such, were exposed to inflow of cold recharge from the overlying unconfined aquifer. The Tahuna Formation acts as an aquiclude inhibiting the mixing of meteoric and geothermal fluids.

There is some recent evidence that meteoric downflow in the Onepu domes area is occurring[10]. For example, well KA31 has had a temperature reversal between 450 and 1,050 m depth since it was drilled in 1980. The inversions are likely relatively recent and may be related to take drawdown that allows cold fluid to flow down the same conduits that previously allowed hot fluid to ascend. Also, since commissioning in 2013, KA30 has exhibited cooling accompanied by decreasing chloride and boron which indicate mixing with a cooler, more dilute marginal fluid from the western margin of the system.

3.7.4 Reservoir pressure - response to takes

As the Kawerau Geothermal System is known to be interconnected both vertically and laterally, pressure changes are transmitted rapidly through the reservoir. Prior to July 2008 reservoir pressure of the Kawerau Geothermal System was measured only periodically, subject to well availability. Since July 2008, reservoir pressure has been measured continuously in dedicated monitor wells. Results of this monitoring indicate that pressure in the deep reservoir has declined since 2008 in the order of about 2 to 5.3 bar.

Pressure change in the deep monitor wells has generally followed a pattern, of an initial relatively steep rate of decline in response to an increase in the rate of fluid take (due to commissioning of the 100 MWe Mercury and 8.3MWe GDL power stations) followed by a slower rate of decline as reservoir pressures approach a new equilibrium in response to fluid recharge.

3.7.5 Discharge enthalpy

Discharge mass flow rate and enthalpy of Kawerau production wells is determined by tracer flow testing and geochemical sampling. The average annual rate of enthalpy decline varies from one well to another, but the mass weighted average annual rate of enthalpy decline for the producing Kawerau wells is estimated at 0.8%. The decline is a result of geothermal takes and is considered to reflect a combination of marginal recharge and returns of fluid to the production well field.

3.7.6 Geochemistry

At initial state, hot spring waters issued from the Umupokapoka and Ruruanga Stream areas, at the south-eastern foot of the Onepu Hills and on the north-western side of the hills at Lake Rotoitipaku. These included hot and boiling springs, steaming ponds, mud pools, mud volcanoes, fumaroles, steaming ground and collapse pits. Hot spring chemistry at Kawerau indicates that the hot springs were produced by condensation and mixing of geothermal steam into shallow groundwater and surface water and included mixtures of deep neutral alkali chloride water and dilute acid sulphate and alkali bicarbonate water. Since development, there has been a decrease in chloride concentration and a move towards an acid sulphate composition which is consistent with a decline in the component of reservoir fluid feeding these features. (i.e. this chemistry occurs when steam which separates from boiling geothermal fluid ascends towards the surface and condenses back into alkali chloride water in the hot spring system near the surface).

[10] *Domes and their associated feeder networks have been shown to be permeable pathways for downflow in other fields (Rissmann, Nicol, Cole, Kennedy, Fairley, Christenson, Leybourne, Milicich, Ring, and Gravley, 2011).*

3.7.7 Shallow groundwater

Shallow groundwater within the Kawerau Geothermal System resides in an unconfined, near-surface aquifer in alluvial sediments up to 70 m thick, which flows south to north, following decreasing elevation. Further north, in the Rangitāiki Plains, there is a deeper confined aquifer at 70-400 m depth exhibiting artesian pressure at some locations. Groundwater in the area is thought to have been of poor quality prior to industrial development due to geothermal influence.

There are eight geothermal monitor wells and four groundwater monitor wells that are regularly sampled and analysed. There is evidence through tracer testing that shallow injection is interacting with the groundwater, and casing of wells into competent (hard) formation which will help avoid any adverse effects.

Groundwater temperature and pressure are monitored continuously in a number of monitor wells across the field that range in depth from 10 to 138 m. Variations in both water level and temperature have occurred and are attributed to variations in shallow injection rate.

Key geochemical parameters are also monitored. In general terms, chloride represents the extent to which the groundwater is influenced by geothermal fluids whilst magnesium represents the groundwater component. Chloride and magnesium concentrations vary markedly between wells as do temporal trends. These reflect a range of influences and physico-chemical processes. The deeper monitor wells tend to exhibit a greater chloride concentration, consistent with a larger component of geothermal fluid. In general, the concentration of magnesium (which reflects the groundwater component) in the sampled well waters varies inversely with chloride concentration, as expected.

The shallower groundwater wells have exhibited relatively stable temperature and water levels. The limited variability exhibited by the data is considered to reflect the influence of shallow hydrological processes, principally the mixing of geothermal fluids with groundwater.

Some groundwater with a geothermal component seeps into the Tarawera River. These seeps are monitored as part of consent requirements.

3.8 Information forming the conceptual model

All of the information described in Section 3.7 above provides the basis for a conceptual model of the Kawerau Geothermal System, which is a descriptive model encompassing the controls and physical processes operating in a geothermal system (e.g. the controls on the flow of fluid and heat within the system). The use of models in managing the Kawerau Geothermal System is further described in Section 7.2.

A summary of the Kawerau Conceptual Model, by Milicich, Clark, Wong and Askari (2015), is broadly represented in a schematic SE-NW profile through the Kawerau Geothermal System (Figure 3.2) which shows isotherms estimated from well temperatures. Due to physical processes occurring within a well bore, estimates may be possible at only a few depths within a particular well. Drillhole (permeability) data helps to define the reservoir in the top 0.5 to 1 km of the basement greywacke and overlying volcanics, with the field boundary inferred from geophysical surveys.

Resistivity data, combined with the inferred location of the main heat and mass outflow, is consistent with deeply-sourced thermal fluids flowing from south to north. A subsurface outflow is inferred to extend to the north, with progressive dilution and cooling of the geothermal fluid as it mixes with groundwaters in the Tarawera-Rangitāiki flood plain.

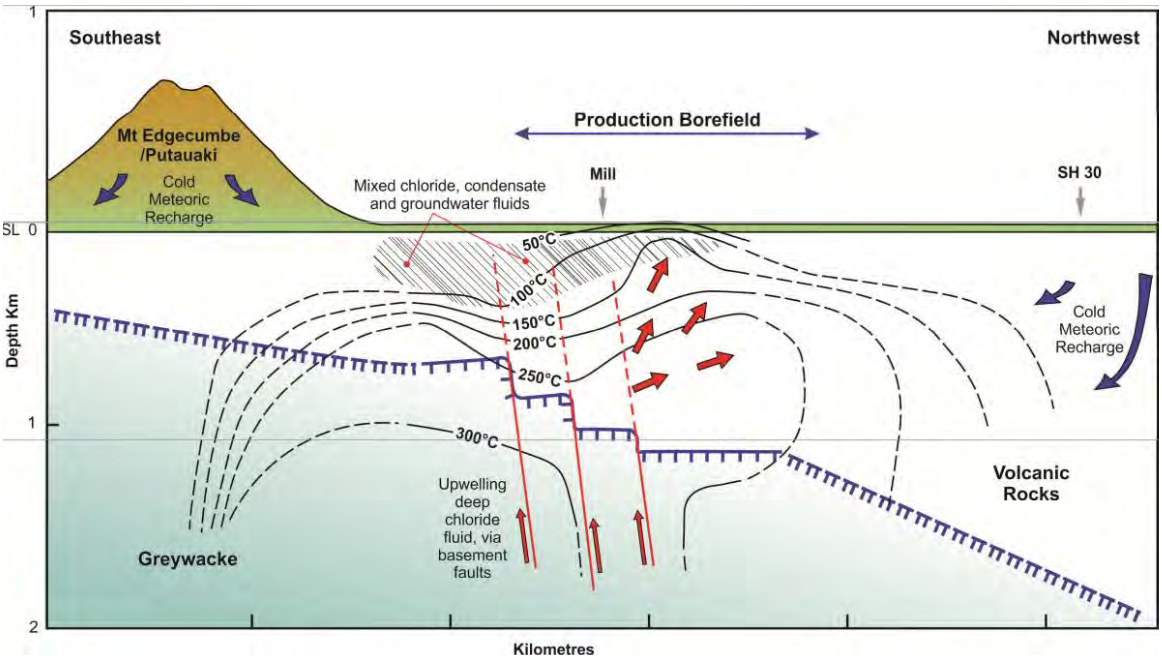

Figure 3.2 Schematic of the Kawerau Geothermal System (after Christenson, 1997 and Holt, 2007).

3.9 Subsidence

3.9.1 Pre-development

Throughout the TVZ there is non-geothermal subsidence related to regional tectonic deformation, with rates between 1-10 mm/year. The Whakatāne Graben within which Kawerau is located is actively subsiding at about 1-2 mm/yr. Volcanic material deposited around Kawerau over the last million years are now found 1 km below sea level, implying there has been a tectonic driven subsidence rate of several mm/year. Some of this movement would also have been the result of earthquakes (Berryman and Beanland, 1989).

3.9.2 Post development

Subsidence can also be induced by pressure drawdown and thermal contraction as a result of geothermal development. For this reason the Kawerau Geothermal System has been monitored for surface subsidence changes since 1970. All consent holders currently undertake precision levelling annually as part of their consent conditions and the magnitude of subsidence is determined by repeat precise levelling of benchmarks. The Kawerau Geothermal System benchmark network is now comprised of approximately 600 benchmarks. The extent of the survey varies from year to year and most of these surveys are 'partial' meaning that they include some but not all benchmarks and cover smaller areas. As of 2015, 39 precise levelling surveys have been carried out covering most of the network.

There are a number of subsidence bowls within the Kawerau area. One is a large bowl shaped area with subsidence of approximately 10 mm per year (as shown in Figure 3.3).This subsidence feature extends across the entire geothermal field and is tilting towards the northwest Modelling indicates that this is consistent with pressure change within the reservoir and thermal contraction of the host rocks in response to the taking of geothermal fluid. Relatively localised areas of greater subsidence occur within this bowl in the north of the field, around Onepu Springs Road, at the southern end of the Mercury Power Station, adjacent to TOPP1 plant and near the sludge ponds.

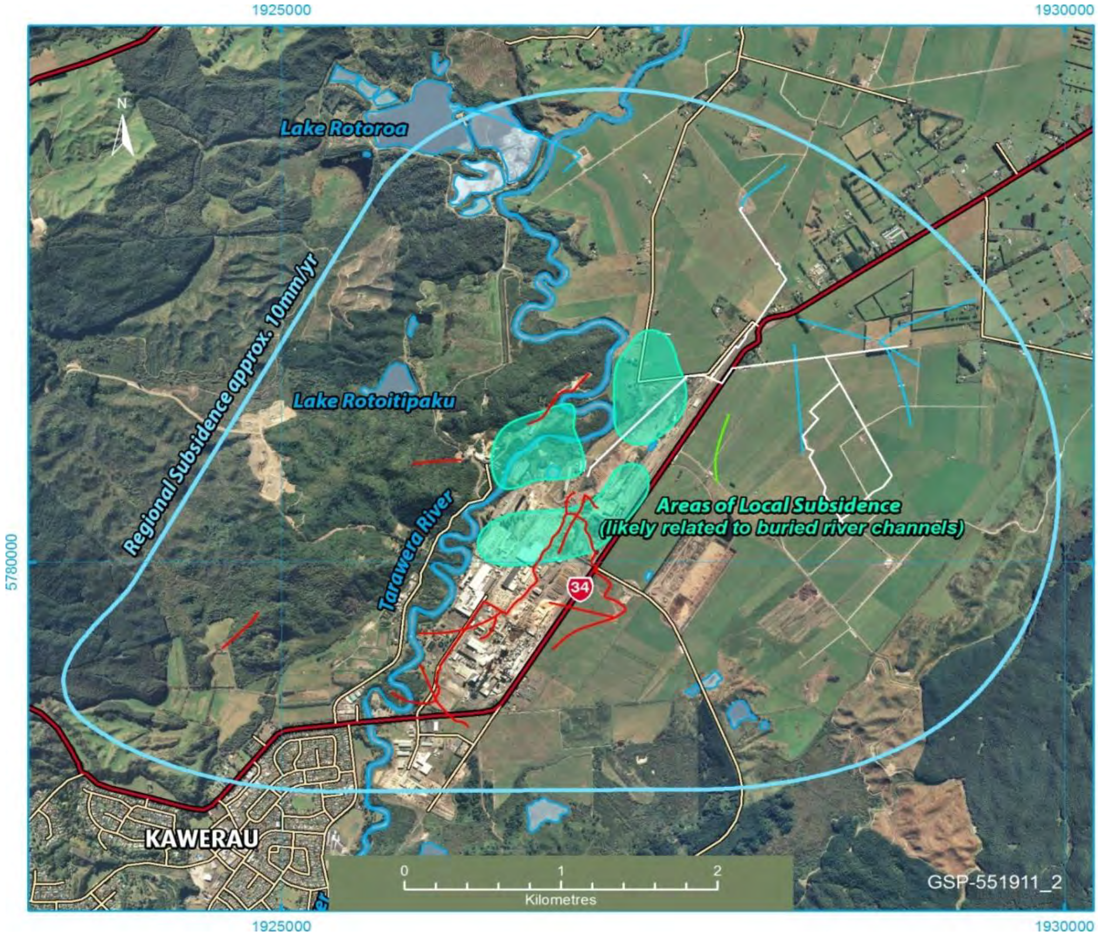

Figure 3.3 General patterns of subsidence in the Kawerau area.

The area of Kawerau was significantly affected by the 1987 Edgecumbe earthquake with the area experiencing 270-280 mm of subsidence as a result. Maximum measured subsidence rates have varied since then, ranging from 18 mm to 77 mm, and the overall rate has increased since 2008. In the area of the Norske Skog Tasman Paper Mill the subsidence rates are less, at around 2-6 mm/yr.

Maximum cumulative subsidence at Kawerau since the 1987 earthquake has been in the order of 850 mm (including the 270-280 mm subsidence that occurred following the Edgecumbe earthquake). The most recent predictions for maximum subsidence for the period 2011 to 2065 are about 2.65 m or an average rate of about 49 mm per year.

Tilt is computed from the subsidence contour model triangles; the steeper the gradient across the contours the greater the amount of tilt. Total tilt within the area affected by geothermal development since 1982 is 19.5 mm/100 m, of which 19% occurred as a result of the 1987 earthquake. Differential subsidence or tilt is important because it has potential to result in damage to infrastructure. In the case of sensitive machinery, tilt can (depending upon rate) usually be accommodated by making adjustments to the machinery. Rates of computed tilt at Kawerau vary from one bowl to another and are highest within the localised subsidence bowls.

3.10 Seismicity

Micro-earthquakes are a common occurrence at Kawerau. A review of earthquakes over a 20 year period shows the number of earthquakes that were large enough and close enough to be felt at Kawerau tended to cluster and occur in swarms. On average felt earthquakes in Kawerau occur about two times every month.

The take and discharge of geothermal fluid may induce micro seismicity, for example, by an increase in pressure due to injection, temperature change due to injection, or volume change caused by take and discharge processes. However, distinguishing natural from induced seismicity is difficult at Kawerau because of the level of natural micro-earthquake activity (seismicity). Discharge strategies which spread location of injection can help reduce the incremental risk of induced seismicity.

3.11 Hydrothermal eruptions

Hydrothermal Eruptions can occur naturally or be induced by the taking of geothermal fluid. The most recent documented hydrothermal eruptions within the Kawerau Geothermal System occurred approximately 14,500 and 9,000 years ago. Drill holes indicate that these eruptions originated at a depth of approximately 190 m. A changing temperature regime within the shallow reservoir section of the field means that the likelihood of such an eruption occurring in the present day is low.

3.12 Geothermal surface features - geological

The Kawerau Geothermal System's geothermal surface features are located mainly along the Tarawera River and on the hills west of the river. Prior to lowering of the Tarawera River (cut out to sea in early 1900s) the development of the land for industrial purposes and the development of the Kawerau Geothermal System, there were hot springs[11], seepages, steaming ponds, mud pools, mud volcanoes, sinters, hydrothermal eruption vents, steaming ground and small fumaroles, located mainly along the banks of the Tarawera River and around the southern shore of Te Wharekitoetoe/Rotoitipaku) and the hills southwest of Onepu and west of Kawerau, in the Ruruanga thermal area (Studt 1958).

Most of the geothermal surface features are believed to have been in a natural state of decline prior to development of the field in the 1950s (Studt 1958, Mingillo 1998). Further degradation of geothermal features in the Kawerau Geothermal System has occurred as a result of construction of effluent ponds, waste dumps, and further development, including the area around Lake Rotoitipaku. Some of these features have been covered by mill waste and are no longer visible.

[11] Hot spring chemistry at Kawerau indicates that the hot springs were produced by condensation and mixing of geothermal steam into shallow groundwater and surface water.

The Kawerau Geothermal System now contains a limited range and extent of geothermal surface features, as recognised in the RPS which identifies the field as Geothermal Management Group 4, a Development System with few or no surface geothermal features. Of those features remaining the Parimahāna Scenic Reserve and Te Taukahiwi o Tirotirowhetu Scenic Reserve, located north of the Kawerau town, contain the most extensive group of features. In particular, there are areas of hot ground, some barren and some with small steaming solfataras and associated geothermally influenced vegetation. The north facing hill slope on the adjacent A8D block also contains an area of 'steaming' ground. Te Wai u o Tūwharetoa Spring (which is not a geothermal spring) in the north eastern part of the site is culturally significant and plays a large role in traditional history.

Surface thermal features in the Rūnanga Stream, Parimahāna Reserve and Te Taukahiwi o Tirotirowhetu Scenic Reserve are monitored in accordance with consent conditions (see also Section 7.10.2). Ground temperature is measured annually at a depth of 1 m at each corner of two rectangular survey plots which were established in 1997. Temperatures reported since 2008 fall largely within the range about 75° to 100° and show no significant trend.

Monitoring of two springs described as non-flowing has been undertaken six monthly since 2008. A significant decrease in chloride concentration (and a move towards an acid sulphate composition) is common to both springs and represents a decline in the component of reservoir fluid feeding these features.

3.13 Geothermal surface features - geothermal vegetation

The Kawerau Geothermal System lies in two ecological districts: Rotorua Lakes and Te Teko. In the vicinity of the Kawerau Geothermal System there are large areas of indigenous vegetation, with small pockets of geothermally influenced vegetation. The extent of areas of geothermal vegetation in the field is shown in Figure 3.4

Most geothermal vegetation lies within the Parimahāna Scenic Reserve and Te Taukahiwi o Tirotirowhetu Scenic Reserve, and land to the north. The hills west of the Tarawera River contain warm soils and steaming ground which support specialised native plants such as prostrate kanuka, dwarf mistletoe, ferns and orchids. Most of this area is protected as part of the Parimahāna Scenic Reserve and has been identified as being of national significance as it is a good quality representative example of geothermal vegetation with a high diversity of geothermal species. Geothermal vegetation and habitats are geographically restricted and the Parimahāna Scenic Reserve and Te Taukahiwi o Tirotirowhetu Scenic Reserve is an example of an originally rare terrestrial ecosystem type.

Monitoring of geothermally influenced vegetation is required by consents, including mapping of geothermal vegetation, monitoring of plots (for example plots in Te Taukahiwi o Tirotirowhetu Scenic Reserve), two yearly photographic surveys and ground temperature surveys.

Figure 3.4 Areas of geothermally influenced vegetation.

3.14 Significance of geothermal surface features

Bay of Plenty Regional Council is undertaking a region wide project to determine which of the geothermal surface features in the region are to be classified as Significant Geothermal Features (SGFs) using criteria in Appendix F, set 7 of the RPS. The criteria include an assessment of the geothermal geological features as well as geothermal vegetation and habitat. The results of this project will then be used to guide implementation of RPS Policy GR3A, which for Kawerau requires that significant adverse effects on SGFs are remedied or mitigated.

While this work is still under development, it is noted that a number of features in Kawerau have previously been assessed as ‘significant’ based on similar ecological/biodiversity criteria in the RPS, due to the natural rarity and increased threat of extinction. As such it is anticipated that a number of SGFs will be confirmed within the Kawerau Geothermal System.

Part 4: Geothermal authorisations and key conditions

The following provides a summary of the key aspects of the resource consents held by the four parties that hold resource consents for the large scale take and discharge of geothermal fluid on the Kawerau Geothermal System.

4.1 Consented take and discharge volumes

The volumes of geothermal fluid that can be taken and discharged by the four consent holders on the Kawerau Geothermal System are set out in Table 4.1 below.

Table 4.1 Consent volumes of geothermal fluid able to be taken and discharged on the Kawerau Geothermal System

Consent holder	Consent no.	Date excised	Expiry date	Purpose	Maximum take volume (t/day)	Maximum discharge volume (t/day)
Mercury/KGL	63295	29 Sept 2006	30 Nov 2040	Take and discharge	45,000[1]	45,000[1]
	67335	30 Nov 2040	30 Nov 2040	Take and discharge	20,000	20,000
NTGA	24598	2 May 2006	30 Sept 2030	Take and discharge	44,400[2]	24,000[3]
	67151	1 June 2016	31 Dec 2050	Discharge (to Tarawera River)	-	20,880
	66862	17 Feb 2014	35 yrs post commencement	Take and discharge	45,000	45,000
GDL	67161	24 Jan 2014	35 yrs post commencement	Take and discharge	5,280[4]	5,280
TAOM	67340	12 Sept 2016	35 yrs post commencement	Take and discharge	15,000[5]	15,000
Total take and discharge volumes					**174,680**	**175,160**

Notes:

1 The consent allows for the take and discharge of up to 55,000 t/day of geothermal fluid, but requires the average annual daily volume of geothermal water taken and discharged to not exceed 45,000 t/day.

2 The consent allows for the take of up to 53,280 t/day of geothermal fluid, but requires the average annual daily volume of geothermal water taken to not exceed 44,400 t/day.

3 The consent allows for the discharge of up to 28,800 t/day of geothermal fluid, but requires the average annual daily volume of geothermal water discharged to not exceed 24,000 t/day.

4 The consent allows for the take of up to 6,340 t/day of geothermal fluid, but requires the average annual daily volume of geothermal water taken to not exceed 5,280 t/day.

5 The consent allows for the take of up to 16,000 t/day of geothermal fluid, but requires the average annual daily volume of geothermal water taken to not exceed 15,000 t/day.

In addition to the take and discharge consents listed in Table 4.1, the consent holders also hold a range of resource consents allowing discharges to air as set out in Table 4.2 below:

Table 4.2 Discharges to air

Consent holder	Consent No	Purpose	Maximum discharge volume (t/day)
Mercury	63298	Discharge geothermal vapour to air	10.8 (H_2S)
NTGA	30126	Discharge of geothermal vapour to air	Field wide and 480 (steam to mill)
GDL	67086	Discharge of geothermal vapour to air	0.65 (H_2S)
TAOM	67340	Discharge of geothermal vapour to air	2.16 (H_2S)

Consents for, fresh water takes, and land use consents (the latter granted by district councils) are also held by all consent holders.

4.2 Key consent conditions

In addition to specifying the maximum amount of take and discharge and matters relating to well management, the key conditions contained within consents (which are fairly consistent across all the consents) include requirements in relation to:

- The nature and location of wells, including casing depths and buffer distances (see Section 7.5).
- The establishment and operation of a Peer Review Panel (see Section 7.13).
- The maintenance and use of a geothermal reservoir and subsidence model for the Kawerau Geothermal System (see Section 7.2).
- Monitoring and reporting (see Section 7.10).
- The preparation of an Operational Management Plan.
- The establishment of various liaison groups.
- A procedure to assess and address property damage (see Section 7.6).
- A key aspect of the consent conditions is to provide for an adaptive management approach (see Section 7).

4.3 Unitisation of consents

Unitised management allows for flexibility and control of a collective output of fluid to match client requirements. In 2010 BOPRC approved an application for Mercury and NTGA to unitise their consents, authorising Mercury to utilise consented fluid when not in direct use by NTGA, with reciprocal rights. Mercury consent 63295 states that the quantity of fluid taken is not to exceed 55,000t/day, with an average annual volume not exceeding 45,000t/day. Ngati Tuwharetoa Geothermal Asset Limited consent 24598 states that the quantity of fluid taken (for production and well testing) shall not exceed 53,280 t/day, with an average annual daily volume not exceeding 44,400 t/day. Consents 24598 and 63295 further state that the amount of geothermal fluid taken by the consent holder via wells owned by Mercury is not to exceed 65,000 t/day. This unitisation or 'fluid flexibility' arrangement means that the combined daily maximum consented take under the original NTGA and Mercury consents is 108,280 t/day (although note that maximum daily take under Mercury's two consents is 75,000 t/day, annualised to 65,000 t/day)

4.4 Well location and type

The location of consented geothermal wells on the Kawerau Geothermal System (including take and injection wells, and monitoring wells) is shown in Appendix 5. Table 4.2 shows wells currently in service. It is noted that this information will change over time (e.g. due to new wells and abandonment) and Operational Management Plans should be referred to for updated information. Appendix 6 provides more detailed information on all wells.

Table 4.3 Wells on the Kawerau Geothermal System

Consent holder	Production wells	Injection wells	Groundwater monitoring wells	Deep monitoring wells
Mercury	8	7	4	2
NTGA	9[12]	5	4	11[13]
GDL	1	2	0	0
TAOM	2	2	0	0
Total	**20**	**16**	**8**	**13**

4.5 Operational Management Plans

Future steamfield developments are documented in Operational Management Plans, which are a requirement of consents[14] and have been developed by all consent holders. These plans have a five-yearly horizon. Information relevant to the future development of the system includes: location of infrastructure, proposed wells, workovers and abandonments, proposed pipelines, changes in infrastructure, earthworks and activities relating to waterways. Operational Management Plans also identify proposed significant changes to fluid output or operations of the industrial processes and/or power plants that utilise geothermal fluid supplied by the consent holder.

[12] *Two NTGA production wells are currently offline*
[13] *KAM3 may be abandoned in the near future*
[14] *Note that older consents for Mercury and NTGA do not require an OMP, although one has been prepared by Mercury to cover its operations under both consents and a draft OMP has been developed by NTGA to cover its operations under both consents.*

Part 5: Key Issues for the Management of the Kawerau Geothermal System

Development of the Kawerau Geothermal System has occurred in a staged manner over nearly 70 years, involving multiple tappers, complex industrial processes, and many stakeholders. Generally speaking, management of the system has been achieved through operational flexibility and adaptive management, as well as co-operation and flexibility among consent holders. It is expected that this careful management will continue, by addressing key issues associated with management of the Kawerau Geothermal System as follows.

5.1 The sustainability of the Kawerau Geothermal System

Sustainability is central to management of the Kawerau Geothermal System (i.e. the continued take of high temperature fluid from the geothermal system over intergenerational timeframes). If takes and discharges are not managed appropriately, excessive pressure draw down might occur, potentially resulting in the ingress of cool recharge with a consequent decline in discharge enthalpy and reduced production.

5.2 Complexity associated with multiple resource consent holders

Four consent holders currently operate on the Kawerau Geothermal System, which is known as a 'multi-tapper situation'. Key issues (or categories of issues) resulting from this situation are:

- The potential for the operations of one consent holder to adversely affect those of another which can have flow on effects in terms of operational efficiency. This can arise due to situations such as:
    - Taking of geothermal fluid from a location, and at a rate and/or amount that deprives or reduces the take of another consent holder (in terms of quantity or temperature),
    - Cool returns of discharged fluid reaching and cooling the production wells of another consent holder,
    - Loss of permeability due to mineral deposition,
    - The attribution and/or apportionment of responsibility for any adverse effects (e.g. effects caused by subsidence),
    - Commercial sensitivity, for example around modelling, research, data and monitoring, reducing the ability to obtain a field wide perspective,
    - Different and competing interests in terms of the development of the resource resulting in reduced opportunity to collectively optimise takes and discharges and efficiency in use of the resource, and
    - The potential for running duplicate, inconsistent or conflicting processes (e.g. monitoring, modelling, reporting).

5.3 The management of actual or potential adverse surface environmental effects

The large scale taking, use and discharging of geothermal fluid can give rise to a range of actual or potential adverse effects on the environment, including on surface water, groundwater, atmosphere, geothermal surface features, surface activities and effects on the sustainability of the geothermal reservoir (discussed above). Some of these effects can occur quickly, others may be time delayed.

Environmental effects addressed in this SMP are as follows.

5.3.1 Effects on surface structures and activities

Subsidence and hydrothermal eruptions are potential outcomes arising from geothermal takes. Whether or not an adverse effect arises as a result of subsidence or hydrothermal eruptions will depend on the nature of the environment and the sensitivity of the land use(s) occurring on the surface of the affected land. In the case of Kawerau, industrial operations such as Asaleo's Kawerau mill rely upon extremely sensitive precision technology. It is therefore important that the effects of ground movement, subsidence and tilt on building, plant and machinery are managed carefully.

5.3.2 Effects on surface geothermal features

Geothermal surface features, and SGFs in particular, are highly valued and the policy regime in the RPS requires that significant adverse effects[15] on SGFs in Kawerau be remedied or mitigated. Potential effects on surface features from fluid takes include changes in the location and extent of steaming ground, acid sulphate features, the temperature of hot ground, the number and chemistry of chloride springs or other general changes in activity. Monitoring requirements for the geothermal surface features within the Kawerau Geothermal System are outlined in Section 7.10.2, including the requirement for a monitoring plan for the Parimahāna Reserve and the Te Taukahiwi o Tirotirowhetu Scenic Reserve.

[15] Significant adverse effect is not defined in the RMA. Policy MN 7B of the RPS provides criteria to be used when assessing the appropriateness of development sought via consent applications. Matters included are character, degree of modification, magnitude or reversibility of effects, probability, and opportunities to avoid, remedy or mitigate effects.

Part 6: System Management Objectives

6.1 Overall objective

Overall objective:

The Kawerau Geothermal System is managed in a manner that:

- *Provides for the geothermal needs of present and future generations*
- *Remedies or mitigates significant adverse effects on Significant Geothermal Features, and*
- *Avoids, remedies or mitigates significant adverse effects on the surface built environment.*

6.2 Operational flexibility and adaptive management

Objective:

Operational flexibility to facilitate adaptive management of the Kawerau Geothermal System.

6.3 Integrated management and co-operation between all consent holders

Objective:

The integrated management of the Kawerau Geothermal System achieved by the implementation of mechanisms, operations and processes that ensure co-operation between all consent holders for large takes on the Kawerau Geothermal System.

Part 7: Strategies to Achieve Objectives

7.1 Operational flexibility and adaptive management

Reservoir management decisions are based on the best knowledge available at the time – where Operational Management Plans are adapted to respond to newly acquired knowledge. This includes:

- Maintaining models of the system and modelling development scenarios to predict system response,
- Monitoring key parameters and system characteristics,
- Assessment of monitoring data against modelled predictions,
- Reporting monitoring results,
- Development of appropriate avoidance, remediation and/or mitigation strategies for unpredicted as well as expected effects,
- Monitoring of the effect of remediation and/or mitigation strategies,
- Modelling, monitoring and reporting feedback,
- Revision of models where actual field performance differs significantly from that predicted by the model, and
- Rerunning models for the most current scenarios (consented takes and injection rates) to assess actual and potential adverse effects on the system and environment.

Adaptive management is responding to unpredicted effects in a way that optimises long-term use of the system and is integral to the management of geothermal systems. It requires operational flexibility which is generally provided for in consents (e.g. where drilling takes place and to what depth, take and discharge points, and management of plant infrastructure through Operational Management Plans).

The management of a geothermal field such as Kawerau is influenced by the level of allocation. As a system becomes fully allocated, opportunities for adaptive management to address effects becomes less effective or potentially lead to greater consequences for consent holders (i.e. there is less room for flexibility).

7.1.1 Principles of adaptive management

Adaptive Management:

- Is used to optimise sustainability or manage adverse effects on the environment
- Is a response to an unforeseen circumstance
- Can include a response to unexpected positive effects and opportunities to optimise production
- Is used to manage lawfully obtained allocation of the resource and is not intended as a method of 'informally' altering a consented discharge or take strategy or as a tool to divert from intended use.

- Requires good baseline information about the receiving environment and should include effective monitoring of potential adverse effects using appropriate indicators
- Should be supported by thresholds to trigger remedial action before the effects become overly damaging, and to ensure effects can be remedied before they become irreversible
- May require changes to consent conditions to facilitate the best outcome for the management of the system.

7.1.2 Managing material effects through adaptive management

The concept of adaptive management is inherent in many of the consent conditions related to existing resource consents. Specifically all consents require (with some variation in terminology) the Consent Holder to implement an appropriate (adaptive) management response to the satisfaction of BOPRC:

- if the results of monitoring indicate that the properties (well discharge enthalpy, system pressures, temperatures and chemistry) of the Kawerau Geothermal System have varied to a **material degree** from what was predicted by the Kawerau Reservoir Model[16], and
- if the variation is likely to result in a **material adverse effect**.

Defining what might constitute a '**material degree**' or a '**material adverse effect**' will be influenced by scale and context, and will involve an overall judgement on a case by case basis. However, broadly:

- A material adverse effect is an effect that is relevant and appreciable enough to require a management response
- The 'significance' of the material adverse effect will have a bearing on the nature of the management response
- A material adverse effect may be determined by the degree of departure from the baseline effects considered and deemed acceptable/tolerable over time based on the knowledge available at the time relative to modelling predictions provided during the consent application process
- A material adverse effect may initially be localised, rather than system wide, but may require a management response to reduce risk to overall sustainability of the system
- A material adverse effect on the sustainability and efficient use of the reservoir can include material adverse effects on the utilisation of the resource by other consent holders beyond what was modelled as part of consent process (i.e. where this would frustrate the lawful rights of an existing consent holder), and
- A material departure between observations and modelled predictions should be considered in the context of overall system sustainability and efficient use and is likely to be incremental.

[16] *Or there is a **significant difference** from steamfield model predictions.*

For avoidance of doubt, these criteria are not intended to include material changes to pressure and discharge enthalpy or other effects on the reservoir (or interference between wells of different consent holders), that was predicted to result from an increase in take and been taken into account and anticipated in the consent process. This is largely an operational matter. From time to time private agreements might be entered into by consent holders to address such issues.

7.1.3 Processes to be followed

In the event that properties of the Kawerau Geothermal reservoir vary to a **material degree** from those predicted and this variation is likely to result in a **material adverse effect**, the following broad process will apply:

1. The Consent Holder/s will notify BOPRC at the earliest opportunity of the variance they have identified.
2. The Consent Holder/s will, in consultation with each other as necessary, assess the likely cause of the variation and likely responses necessary to mitigate the effect/resolve the issue.
3. An explanation of the suspected cause and preferred management response will be agreed by consent holders.
4. The preferred approach will be evaluated by the PRP in discussion with consent holders.
5. If consent holders cannot agree, they will separately and in a timely manner propose their alternative management responses for consideration by the PRP.
6. Following approval by BOPRC, the PRP's recommended response will be put in place, in accordance with specified timeframes that reflect the urgency of the issue.
7. Monitoring will be undertaken by consent holders in order to assess the success of the response (and potentially updates to model/s), with any necessary changes following the broad process above.

If the consent holder does not implement the response which BOPRC considers appropriate, having regard to the PRP's recommendations, then the consent holder must be in a position to justify its position to the satisfaction of Council. Where a response cannot be agreed then appropriate RMA processes will be followed.

Where BOPRC considers it appropriate to depart from a recommendation of the PRP, it will provide appropriate supporting documentation to justify this approach.

This process is broadly described in Figure 7.1 below:

Figure 7.1 Process to address a material adverse effect as part of adaptive management process.

7.1.4 Periodic applications for approvals for adaptive management

Some consent conditions provide for approval by BOPRC, on advice from the PRP, of changes to particular operational parameters[17] without the requirement for a statutory process to be followed (e.g. an RMA s127 and s128 review). The broad process to be followed is outlined below:

1 The application will be made in writing to BOPRC supported by appropriate assessment of the effects of the proposal on the environment and other consent holders.

2 Other consent holders will be provided a copy of the application by the applicant.

3 Bay of Plenty Regional Council will make a determination as to whether the application falls within the ambit of the existing consents held by the applicant or requires an RMA Section 88 or Section 127 application.

4 Bay of Plenty Regional Council will (in discussion with the applicant) determine any minimum requirement for engagement with other consent holders in order to inform its decision, and in doing so will consider matters such as:

- The degree to which the activity and/or effects are likely to differ from those proposed or predicted as part of the resource consent granted.
- The likelihood that and the degree to which the application would result in a material adverse effect on the reservoir or another Consent Holder
- Whether the application requires/would benefit from additional modelling, including data or input from other consent holders to determine potential effects.
- Any request for engagement in the process by other consent holders.

5 If engagement with other consent holders is considered appropriate by BOPRC, the applicant will undertake the consultation and provide BOPRC with written advice as to the outcome of the consultation.

6 Bay of Plenty Regional Council will seek recommendations from the PRP on whether the application should be approved and the applicant will make available all information the PRP considers necessary to adequately review the application.

7 The consent holder will be notified of BOPRC's decision, and a copy of the PRP recommendations (and a copy of any consultation request by any other consent holder) made available to the applicant.

7.2 Modelled reservoir and subsidence predictions

Modelling is important to sustainably managing the Kawerau Geothermal System, and avoiding, remedying and/or mitigating effects resulting from consented activities. Three interlinked models are used to manage the system (conceptual, reservoir, subsidence), as broadly described below:

7.2.1 Conceptual model

Conceptual models are an important tool for the exploration, development and utilisation of geothermal systems. They are used in system development planning

[17] *For example the casing requirements for production and injection wells*

and well siting. They also form the basis for numerical reservoir modelling and resource assessment. Conceptual models are descriptive models that encompass the essential physical features which control the flow of fluid and heat and the physical and physico-chemical processes operating within a geothermal system. The conceptual model currently used for Kawerau is described in Section 3.

Conceptual models are used to hypothesise the heat source for the reservoir, controls on the flow of fluid and heat within the system, location of recharge zones, the main fluid flow paths within the reservoir including outflows and resource boundaries, as well as the reservoir temperature distribution and physico-chemical processes such as boiling and steam separation. Conceptual models combine insights from various disciplines and are often presented visually through surface maps, subsurface slices, cross-sections and 3D visualisation software to aid the understanding of complex technical and scientific concepts (see Section 3).

It is possible for more than one conceptual model to be considered with the most likely model(s) being tested and evaluated in an iterative process using simple process models and numerical reservoir simulations to evaluate the sensitivity of reservoir responses to key reservoir parameters. Numerical modelling provides input into the development and revision of conceptual models and vice versa.

Conceptual models are not static and as new relevant information and data becomes available they are revisited for consistency with data and updated where necessary. They are kept current to incorporate data which may require changes in the reservoir model.

7.2.2 Numerical reservoir model

The Kawerau Conceptual Model provides the basis for a dual porosity[18] Numerical Reservoir Model[19], in which some components of the Conceptual Model are represented. This provides quantitative estimates of the physical processes (mainly transport of fluid mass and energy) encompassed by the model. Model verification and calibration is carried out by comparing theoretical predictions of surface heat flow, temperature and pressure distribution in the reservoir, discharge enthalpy and fluid gas and salinity content, etc., with available data.

Numerical reservoir models are used to assess and evaluate reservoir performance through periodic comparison of reservoir predictions with measured changes in reservoir parameters. A significant difference would serve as an alert that the conceptual model needs to be reviewed, that an adaptive management response

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[18] *A dual porosity model uses two interacting continua, the fractures and the matrix. The concept was introduced by Barenblatt et al. (1960) for representing the seepage of homogenous fluids in fissured rocks. In the dual porosity approach it is assumed that the fluid flows mainly through the fractures and hence the matrix to matrix flow is negligible (Warren and Root, 1963; Zimmerman et al., 1996). The single porosity approach is an idealization of flow in fractured media where the physical quantities in the fracture and the adjacent rock matrix, such as permeability, porosity, pressure and temperature, are averaged over large blocks of materials containing a large number of fractures (Narasimhan, 1982).(Austria and O'Sullivan 2015).*

[19] *Numerical models are built in a stepwise fashion. The process begins with the dissection of the reservoir and surrounding volume of rock into a series of blocks. Rock and fluid properties are assigned to each block and boundary set. Once the rock properties and boundary flows are set, the temperatures and pressures are then set to background hydrostatic conditions. The model is then run to simulate tens of thousands of years to approximate the geothermal system prior to any development (the "natural" or "steady" state). The model results are checked to ensure that they provide reasonable matches to the pre-production natural state temperatures and pressures. If not the model parameters are adjusted iteratively and the model is re-run to natural state until a reasonable match is obtained. The model is calibrated not only on the basis of natural state conditions but also (where one exists) the extraction history including reservoir pressure, discharge enthalpy, tracer test data, chloride change etc.*

might be required or that changes to consented activities are needed. Most recent consents were granted using the 2012 Holt Model, built by Geothermal Science. The Holt model was last revised in 2012 to reflect historical well data and changes to the conceptual model.[20]

7.2.3 Subsidence model

The Kawerau 3D Subsidence Model is used to predict the effects of the take and discharge of geothermal fluid on subsidence, relative to natural subsidence due to subduction processes, with a primary focus on the industrial area. As with reservoir modelling, a significant difference between observed and predicted subsidence levels would serve as an alert that the model should be reviewed, or that an adaptive management response might be required.

Temporal changes in reservoir pressure and temperature predicted for certain production scenarios from reservoir simulations are used as input for the Subsidence Model. The results from the model provide an indication of potential land deformation from the reservoir development. The current model Bruno (2012) has been calibrated against field measurements from levelling surveys carried out as a requirement of all consents over a 21 year period, from 1990 – 2011.

7.2.4 Principles for modelling

A single model approach

For integrated and sustainable management all consent holders must collectively retain access to a calibrated and validated (peer reviewed) single geothermal numerical reservoir model and a 3D subsidence model (the 'authoritative' models). These models are maintained to accurately reflect monitoring information and other new information from the geothermal system.

Any changes to the model architecture, making it different from that used in consent applications, or any new model will be reviewed by BOPRC, on advice from the PRP, and its use must meet the approval of BOPRC. The models currently approved for use through the resource consent process are:

- Kawerau Reservoir Model v3 (KRMv3)
- Kawerau 3D Subsidence Model (Bruno, 2012) Terralog Technologies USA Incorporated.

They are the authoritative models that are used in decision making. However, other models may be used to develop and test ideas for management of the system, with proven ideas incorporated into the authoritative models over time.

These models were developed for Mercury, and are operated and maintained by Mercury using data from all consent holders[21].

Access to models by all consent holders

[20] *It is noted that this model is considered insufficiently calibrated in relation to shallow depths to enable effects of takes on surface discharges or groundwater to be predicted.)*
[21] *Subject to appropriate management and protection of commercially sensitive information.*

Under consent conditions, Mercury are required to make available to any third party who has resource consents to abstract geothermal fluid from the Kawerau Geothermal System the accepted Kawerau Reservoir Model.

To avoid potential trade competition effects for those with an existing or potential commercial interest in the Kawerau Geothermal System, access to the model is reliant on becoming a party to a management agreement, which includes private commercial terms and internal processes for the supply of data and modelling information (e.g. scenarios).

Bay of Plenty Regional Council is not a party to these commercial arrangements but has an interest in seeing the acceptance of a single reservoir model, this being a key principle of this SMP. In the unlikely event that commercial agreement to access the model cannot be reached, the specific reasons for this will be documented clearly to BOPRC, including the process that will be followed by users to resolve the issue within reasonable timeframes (which may include mediation).

Running scenarios

Models are used to explore and predict various effects of resource use. Reservoir models do so by testing various take and discharge scenarios. A scenario is an inquiry of a geothermal model using specified parameters (e.g. take and discharge rate and quantity, injection fluid temperature, well location, depths including feed zones) to predict the effect of resource use on the geothermal reservoir, and/or any localised effects. Sometimes scenarios involving much higher than planned rates of abstraction are simulated. These are known as 'stress tests' and are used to provide an indication of the sensitivity of the reservoir responses to higher rates of take.

Using the authoritative models, the Kawerau resource consents require that scenarios are simulated to predict changes to the Kawerau geothermal reservoir, at five yearly intervals, for the following five, ten, twenty five and fifty years. Such scenarios will incorporate realistic take and discharge scenarios for all consent holders. In order to do this, monitoring data must be regularly input to the reservoir model.

As the current operator of the authoritative models, Mercury may be requested to run scenarios:

1 By other system consent holders where relevant to their operations (subject to commercial agreements). Mercury has some discretion to exclude 'fishing expeditions'[22],

2 By potential consent holders (e.g. to support an application for resource consent, subject to commercial agreements and excluding 'fishing expeditions'), or

3 By BOPRC (e.g. on recommendation by the PRP and to inform the sustainable management of the Kawerau Reservoir).

The acceptance or rejection of a scenario to be tested is a matter for the model operator. If the model operator is to reject a scenario, then the reasons for this need to be documented and advice may be sought from the PRP in the event of any

[22] Where one consent holder seeks an enquiry of the model which is not directly relevant to its operations, or likely proposed operations.

dispute. Running a scenario confers no guarantee of the accuracy of the predicted outcomes.

Updating models

The running of realistic scenarios requires that the reservoir (and subsidence) models be first updated with new data, including new take and discharge data, geophysical, geochemical, data, well configurations, well profiles and well drilling and testing data. These data are integrated firstly into the conceptual model, and subsequently into the reservoir and subsidence models. Consent conditions require that this be done at least five yearly or on request from the BOPRC following significant events in the system.

However, ideally the agreed models should be updated regularly with all relevant data.

Effective modelling relies on all consent holders supplying relevant data in a timely fashion. Data required by resource consents is provided to Mercury as per commercial agreements.

Revision of models

The conceptual model reflects the collective scientific understanding of the geothermal system. The approved numerical Reservoir Model may require consequential revisions from time to time to ensure consistency with any revised conceptual understanding.

The reservoir and subsidence models may also need to be revised at any time if they are not performing satisfactorily in relation to overall representation of the system. For example, divergence of measured well discharge enthalpy, reservoir temperature and or reservoir pressure from that predicted, divergence in the extent or rate of measured subsidence from that predicted, divergence between the conditions predicted in a new well to those measured.

In most instances model performance will be:

- Assessed by consent holders by comparing take data, and monitoring and other field measurement data with model predictions, and
- Reported on through annual reports, with recommendations for any review (for consideration by the PRP and BOPRC).

If numerical reservoir predictions deviate from measured reservoir response it will be necessary to revise the numerical reservoir model to address the deficiencies (see Appendix 7). This may also require a revision of the subsidence model. If revision is required, this involves a step wise approach comprising process modelling (e.g. to explore sensitivity of the reservoir responses to changes to input values for key parameters, field based testing (e.g. tracer tests) and additional measurements, testing, interpretation and/or analysis.

The process for revision of a model is broadly outlined below:

1 Bay of Plenty Regional Council will be advised and updated on the preferred process for the revision.

2 Full documentation will be provided to BOPRC of the revised model including all calibration data (natural state and history matches) and all other information necessary to determine its adequacy[23], including evidence of consultation with other consent holders

3 Bay of Plenty Regional Council may seek PRP review and recommendations about the adequacy of the revised model and may seek additional expertise to assist it in its recommendations. All information the PRP considers relevant and necessary to adequately review the proposed model will be made available to it (including running scenarios). The PRP may seek additional expertise (e.g. reservoir modelling) to assist in its review of the revised model

4 The PRP review will include a written report and recommendations which will be made available to all consent holders, and

5 A revision of the conceptual or reservoir model may require that subsidence predictions be updated using updated predictions of reservoir temperature and pressure changes[24]. Any changes that could affect the subsidence model calibration would potentially trigger a revision of the subsidence model.

7.2.5 Process for the approval of new models

Improved modelling technology and commercial decisions may justify consent holders seeking to develop and use a new model. A request to replace the authoritative reservoir and subsidence models may be initiated either by Mercury as the operator of the Model, by the BOPRC (on advice from the PRP) or by other consent holders if the models are not performing satisfactorily.

Bay of Plenty Regional Council, and other consent holders, will be advised if a new model is under development. An application for a replacement will then be made in writing to BOPRC. This should follow the broad process above for model revision. The applicant will also ensure that there is an opportunity for other consent holders to be familiarised with the new model and any implications of the change. Consistent with a ‘single model’ approach, the use of a new model by other consent holders will need to be formalised.

A change to the numerical reservoir model is unlikely to lead to a completely different understanding of the sustainable level of take from the reservoir. However it could influence understanding of the rates of change expected for takes and discharges and may require adaptive management responses from consent holders at some point.

7.3 Production strategy

7.3.1 Current practice

Production strategies are described in each of the consent holders’ Operational Management Plans, and in consent conditions. These generally reflect what is considered best practice at the time consents were granted. Consent conditions seek to optimise long term resource potential and to proactively minimise adverse

[23] To determine its performance, the reservoir model will generally be assessed against the quality of matches to calibration criteria including natural state, production and any other applicable data such as tracer test and reservoir geochemical data as agreed between consent holders and BOPRC.
[24] As these are inputs to the subsidence model and affect subsidence predictions

effects, including interference between operators through the design and location of wells. As such, current practice ensures identification of take and discharge zones, minimum well separation distances, and depth of casing. This approach is also embedded in the SMP principles below.

7.3.2 Principles

To ensure that the Kawerau Geothermal System is sustainably managed, principles of the production strategy are to:

- Use modelling predictions to assist with take and discharge adaptation decisions,
- Provide an ongoing supply of high temperature fluid while minimising the risk of excessive pressure drawdown or cooling and associated effects on production,
- Build flexibility into the production system,
- Support long term sustainable high temperature fluid take and to avoid material adverse effects on the geothermal system, by identifying separation of take and discharge zones (see Figure 7.2), and by the design and location of future wells to avoid unexpected material interference with other consent holder's existing wells, and
- Implement a range of adaptive management responses to manage adverse subsidence effects or any significant adverse effects on SGFs that may result from takes, should they arise.

These principles of production will be considered as part of the review of any consent conditions, for new consent applications and to guide decision making in the management of existing consents. These principles will be reviewed in the event that modelling and monitoring results indicate an alternative approach for the sustainable management of the system.

7.4 Discharge strategy

Policy GR8 of the RPS includes the following matters as content for a discharge strategy:

- disposal of geothermal water
- return of geothermal water to the system
- facilitation of further extraction from the system
- avoidance, remediation and mitigation of subsidence
- minimising the risk of hydrothermal eruptions
- remediation or mitigation of significant adverse effects on SGFs
- Avoidance, remediation or mitigation of contamination of surface or ground water, and
- Investigation, research, monitoring and reporting on implementation of the discharge strategy.

7.4.1 Current practice

The current discharge strategy for Kawerau incorporates a range of methods, including:

- Deep injection: injection into the greywacke formation or 1,000 m,
- Intermediate injection: injection above the greywacke but beneath the Tahuna Formation,
- Shallow reinjection: injection into the unconfined aquifer above the Tahuna Formation,
- Discharges to land via ground soakage, and
- Discharge to surface water.

More specifically, current practices are as follows:

- Mercury's flash plant discharges to the atmosphere 23% of its take with all remaining fluid returned to the periphery of the field through deep reinjection,
- Ngati Tuwharetoa Geothermal Asset Limited injects approximately 50% of its take under its older consent via shallow, and intermediate injection in the centre of the reservoir and deep injection to the periphery of the reservoir. The balance of separated water is discharged to the Tarawera River. Under its new consent 77% of fluid is to be returned to the Kawerau Geothermal System via deep injection. Approximately 5% is discharged to the atmosphere across its various operations,
- GDL returns nearly 100% of its fluid via shallow injection into the unconfined aquifer, and
- TAOM, when producing, will return nearly 100% of its take via deep reinjection to the periphery of the field.

7.4.2 Principles

To ensure that the Kawerau Geothermal System is sustainably managed, the broad principles for developing and then implementing flexible, adaptive injection strategies are:

- The use of numerical reservoir model predictions and reservoir monitoring data
- Management of reservoir fluid and heat recharge while minimising risk of unexpected thermal breakthrough and consequential reductions in reservoir fluid temperature
- Deep injection to maintain pressure support, to avoid contamination of surface or ground water and minimise the risk of hydrothermal eruptions, except where the need for targeted shallow or intermediate injection is demonstrated to be necessary to avoid, remedy or mitigate any significant adverse effects resulting from takes and discharges (e.g. cool down flows, subsidence, effects on SGFs) or to support long term sustainable fluid take

- Identification and implementation of adaptive management responses to optimise the injection of geothermal fluids, including consideration of the quantity, location and depth of injection
- Minimisation of discharge of extracted geothermal fluid to the surface or atmospheric environment (e.g. Tarawera River), while retaining natural discharges

Discharge practices in Kawerau have evolved to reflect improved understanding of the system. Due to historical decisions, current discharge practices do not (and cannot easily) reflect all of the principles outlined above. However, the principles will be considered as part of the review of any consent conditions, for new consent applications and to guide decision making in the administration of existing consents. These principles will be reviewed in the event that modelling and monitoring results indicate an alternative approach for the sustainable management of the system.

7.5 Implementing principles of production and discharge strategies

7.5.1 Design and location of production and injection wells

Operational flexibility is required to locate new wells, pipelines and infrastructure to respond to changing conditions in the Kawerau Geothermal System. Interpreted field boundaries (take and discharge zones) may change as additional knowledge of the field is obtained. Access to land will determine how and where the resource can be accessed. However, in general production and injection, wells will be designed and located to:

- Optimise the long term high temperature fluid take from the reservoir,
- Avoid remedy or mitigate material adverse surface effects, and
- Avoid, to the extent practicable, material adverse effects between consent holders.

This is achieved as outlined below.

7.5.2 Location of injection

Injection wells are generally required to be located on the margin of the field in the northern and north-eastern, and more recently the north western part, of the Kawerau Geothermal System to provide pressure support across the field and minimise cooling of the Production Reservoir.

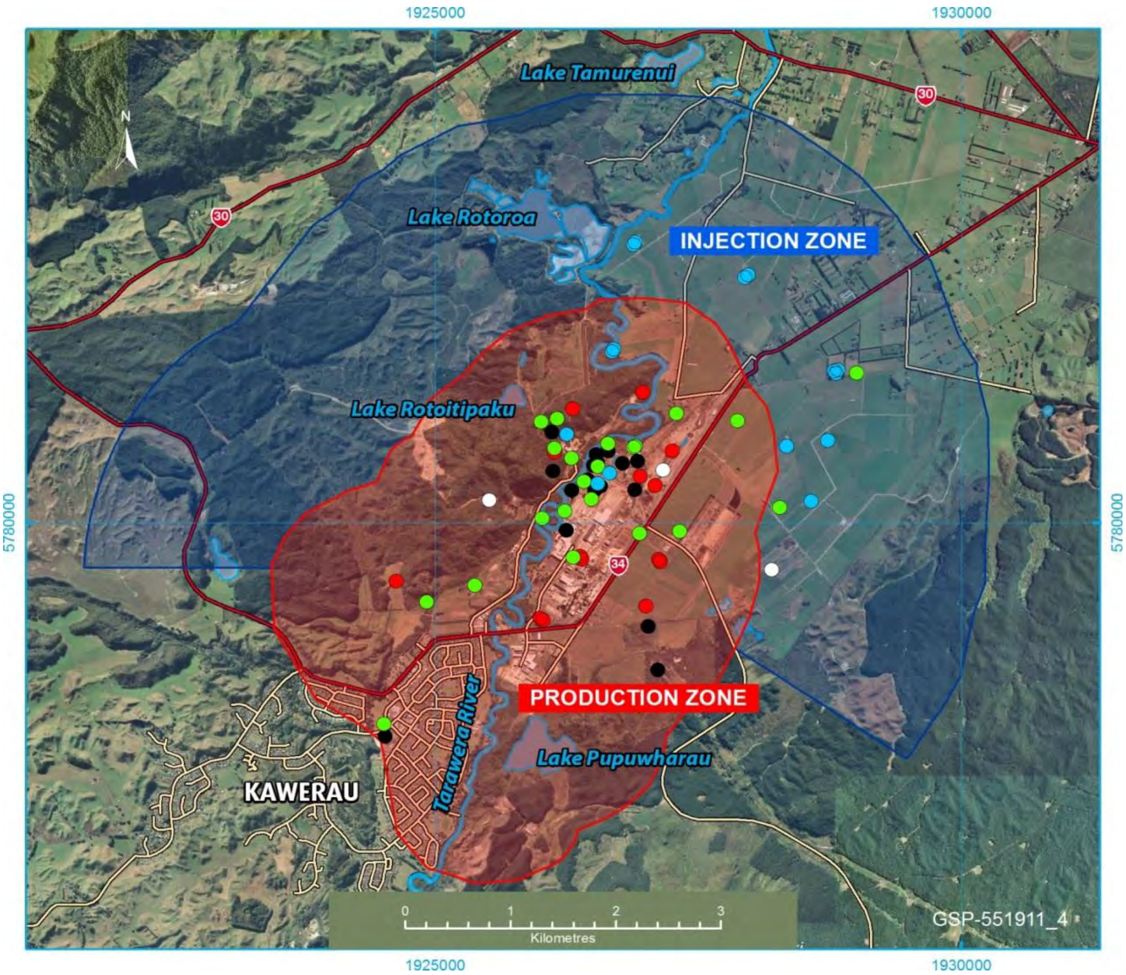

Figure 7.2 Map showing production and Injection Zones.

The boundary in Figure 7.2 represents a 1,000 m setback from existing production wells. As such it may change as a result of new production wells being developed. Any change to the production and reinjection zone would require modelling and input from the PRP. It is indicative only of the area potentially available for reinjection, and does not reflect constraints to reinjection created by land access, topography, geology etc.

It is noted that spatial distance between discharge and take points will not guarantee that there is no interference with the high temperature permeable zone, and adaptive management strategies may be required in the event a well is proven to have an unexpected material adverse effect on the reservoir or another consent holder.

7.5.3 Depth of production and injection (casing)

New production wells must be cased into the basement greywacke or at a depth of not less than 1,000 m[25] below ground surface (whichever is the deeper), except where approval is given by the BOPRC upon taking advice of the PRP[26].

Similarly, new injection wells will generally be cased into the basement greywacke except where approval is given by BOPRC upon taking advice of the PRP that a different casing depth is required for targeted reinjection to mitigate subsidence or surface effects or for other purposes such as adverse effects on the reservoir or other consent holders[27].

This involves the approval by BOPRC (having regard to the recommendations of the PRP). A broad process for the departure from this requirement is outlined in Section 7.1.3.

7.5.4 Buffer distances

New production or injection wells that are drilled in the Kawerau Geothermal System must maintain separation distances from any other existing wells owned by different consent holders that have already been drilled. The minimum vertical and horizontal separation distance between future and existing wells must be at least 320 m as measured between the closest point of the open hole (the perforated liner) sections of the wells.

The minimum horizontal and vertical separation distances for production wells and/or injection wells are shown on the drawings in Figure 7.3. The same minimum separation distances apply to injection wells.

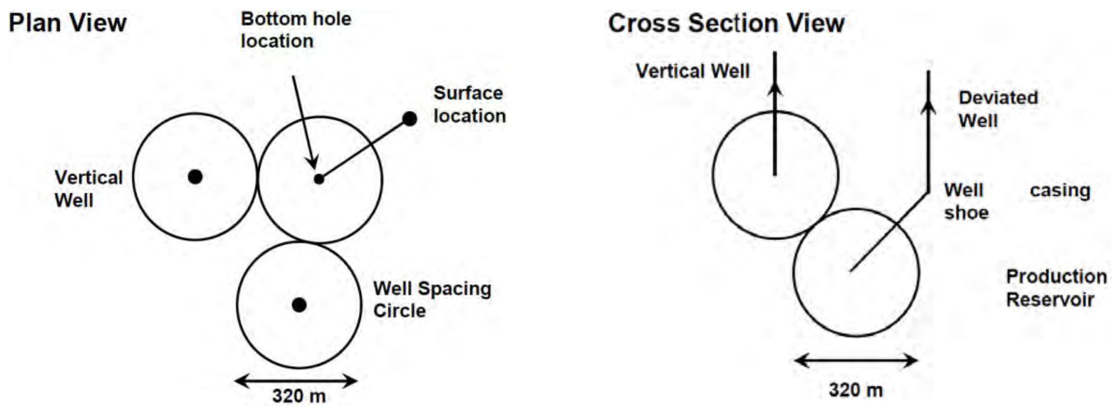

Figure 7.3 Schematic Diagram showing separation distances for production and/or injection wells in Kawerau.

[25] *1,100 m for TAOM.*

[26] *Under the four most recent consents, production wells must be cased to at least 1,000 m, except where approval is given by BOPRC. However, Mercury consent 63295 and NTGA consent 24598 do not currently require this.*

27 It is not intended that this provision will be used to avoid issues that primarily arise through drilling (e.g. drill losses/costs).

Consent holders can depart from this approach, where agreed in writing by the other Consent Holder/s whose wells are potentially affected. Where agreement is reached, BOPRC will be provided with a copy of this agreement[28].

7.5.5 Notification processes and procedures for new wells

Any consent holder drilling a new well will provide written notification to the BOPRC and the other consent holders at least 30 days[29] prior to such drilling activities commencing.

7.6 Management of surface adverse effects

The taking, use and discharge of geothermal fluid can give rise to a range of surface effects, including on surface activities (built environment), surface and shallow groundwater (and groundwater users), hydrothermal eruptions, and geothermal surface features. This SMP addresses these as follows.

7.6.1 Adverse effects on the built environment

Significant adverse effects on the overlying built structures are to be avoided, remedied or mitigated. A focus of the resource consents and the SMP is to compare measured cumulative subsidence and tilt with predicted cumulative subsidence and tilt. Such departures do not necessarily mean that a significant effect will result. The focus should be on comparing measured cumulative tilt at sensitive locations with predicted cumulative tilt and whether the maximum cumulative tilt is acceptable bearing in mind that sensitive machinery can be and is adjusted as required to accommodate tilt. Uniform subsidence is less likely to adversely affect surface installations.

When subsidence occurs and causes an adverse effect on surface activities within a geothermal system with more than one Consent Holder, the main difficulty that can arise is the apportionment of responsibility for remedying or mitigating the adverse effect.

Where it is clear that the activities of one Consent Holder are the sole cause of the adverse effect, they should be responsible for whatever remediation or mitigation is required in the circumstances. However, where an effect arises which is not attributable to the actions of any one tapper and is more the result of the cumulative effects of the various tappers (e.g. subsidence being caused by a gradual decline in reservoir pressure and thermal contraction as a result of geothermal takes), responsibility can be apportioned on some rational basis. One way would be for the apportionment of responsibility (in terms of the cost of remediation or mitigation) in accordance with the proportion of the amount of geothermal fluid extracted by each consent holder.

Alternatives include: assessment of surface distance from the effect, assessing which operation has the most sensitive pressure connection.

Processes to address any adverse effects on the built environment are set out in consent conditions.

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[28] Not all consents provide for this.

[29] This is consistent with notification requirements for Details of Works Notice under the Geothermal Energy Regulations 1961

7.6.2 Mechanisms to remedy or mitigate significant adverse effects on geothermal surface features

Significant adverse effects on SGFs are to be remedied or mitigated (refer Section 5.3.2). Monitoring and Mitigation Plans for geothermal surface features are required by consent conditions as outlined in Section 7.10.2.

Principles contained in the take and discharge strategies also apply for the management of adverse effects. In particular, deep injection of fluids into the greywacke basement will provide pressure support and potentially reduce risk of changes in the shallow reservoir (above the Tahuna Formation). In the event that significant adverse effects on SGFs arise due to fluid abstraction, remediation and mitigation could include strategies such as targeted shallow injection.

As for adverse effects on the built environment, responsibility for any remediation or mitigation of adverse effects will be determined by the likely cause of that effect, and whether this is attributable to one or multiple consent holders.

7.7 Private agreements

Consent holders operate their business subject to a number of private commercial agreements, including agreements over matters such as land access, supply of fluid/energy, sharing of data, monitoring and access to modelling. An example which is important in the management of the field is the Steamfield Management Agreement, which includes Norske Skog, Mercury and NTGA as parties.

7.8 New operators

In addition to requirements of the RMA and relevant regional policy documents, any new consent applications on the Kawerau Geothermal System should include an assessment of how the activity will be consistent with this SMP, being a relevant matter under Section 104(1)(c) of the RMA), including the processes for managing relationships between operators and integrating new activities with existing operations.

7.9 Efficiency in resource allocation and utilisation

All consents require the efficient use of the geothermal resource. If modelling indicates that further allocable resource is available, future applications will be assessed on their merits and in accordance with BOPRC policies, plan provisions and the RMA, and efficiency is a matter that will be addressed at this time. Any future allocation should represent the reasonable amount required by the Consent Holder without depriving other potential consent holders.

Avoiding ‘banking’ and thus constraining other consent holders is an important principle of the SMP. This is achieved through conditions of consent relating to timeframes for consents to be excised.

As per consent requirements, consent holders annually report on the percentage utilisation of their consented take, ensuring that any allocation is appropriately and clearly attributed.

7.10 Monitoring and reporting

All current resource consents contain conditions on research, monitoring and reporting but the conditions vary from consent to consent. Requirements for reservoir, surface feature and subsidence monitoring are reasonably consistent, as reflected in Sections 7.10.1, 7.10.2, and 7.10.3 below[30].

Changes to monitoring requirements may be necessary and recommended by the PRP from time to time to better inform sustainable management of the Kawerau Geothermal System and adaptive management responses. (e.g. monitoring of some parameters may be decreased in some areas and increased in others).

Monitoring plans may also be amended on the request of the consent holders, subject to written approval of BOPRC (on advice from the PRP).

7.10.1 Reservoir monitoring

Reservoir monitoring plans are lodged with BOPRC as part of consent holders Operational Management Plans and broadly include (see specific requirements in individual consents):

(a) Recording of pressures and temperatures for production, reinjection and monitoring wells.

(b) Recording of production and injection water (and steam) flows.

(c) Periodic chemical sampling of two phase fluid, steam and separated water.

(d) Periodic tracer tests, to determine possible returns to any production wells.

(e) Measurements of water levels, temperatures and water in groundwater monitoring wells.

(f) Completion tests on new wells.

Monitoring plans should be developed and reviewed in consultation with all other consent holders party to this SMP[31].

7.10.2 Geothermal surface feature and geothermal vegetation monitoring

A Monitoring and Mitigation Plan for the geothermal surface features and geothermal vegetation is prepared in consultation with consent holders, NTST and Department of Conservation (DoC).

The plan generally is required to address:

(a) The cultural and environmental concerns of local tangata whenua,

(b) Periodic observations of surface features in the Parimahāna Reserve and the Te Taukahiwi o Tirotirowhetu Scenic Reserve,

(c) Monitoring of the groundwater levels and temperatures surface features within the Parimahana Reserve, and the Te Taukahiwi o Tirotirowhetu Scenic Reserve,

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[30] It is noted that all consent holders also carry out monitoring of other consents takes and discharges in relation to their consents, including discharges to air, land and water

[31] Currently only TAOM is required to carry out consultation with Mercury, NTGA and GDL

(d) Monitoring of vegetative patterns (including ground temperature), in Parimahana Reserve, the Te Taukahiwi o Tirotirowhetu Scenic Reserve, and the TAOM and GDL areas,

(e) Routine photographic surveys of selected features to quantify changes to features, and

(f) Routine monitoring and reporting on temperature, flow rate and chemistry of discharging springs.

This single Monitoring Plan will be prepared jointly by the consent holders party to this SMP and approved by BOPRC. The Monitoring Plan may be amended subject to the written approval of BOPRC. For example, future monitoring plans could potentially include areas outside of the two reserves currently addressed in resource consents.

Note that access agreements and protocols with NTST are necessary to access Te Taukahiwi o Tirotirowhetu and Parimahāna Reserve to ensure Tuwharetoa tikanga is recognised and takes place.

7.10.3 Subsidence monitoring

Levelling data[32] will be collected by all consent holders in accordance with conditions of consent and as set out in Operational Management Plans and a Subsidence Monitoring Plan, including I levelling surveys of the subsidence benchmark network and annual levelling surveys of primary industrial plant and buildings located in the Oji Fibre Solutions, Asaleo, and Norske Skog Tasman industrial complexes.

Significantly greater subsidence rates including tilt and material changes in the pattern of subsidence compared to that predicted by the single Subsidence Model will trigger the need to assess whether continuation of trends will likely result in significant adverse effects on surface infrastructure, and whether an adaptive management response is necessary.

7.11 Annual reporting

Consent holders provide BOPRC with Annual Reports for review by the PRP. This provides an opportunity for the PRP to refresh their understanding of the past, present and projected state of the Kawerau Geothermal System using the information from previous years reports and from data and information supplied by consent holders.

Reporting provides an opportunity to consider the effects of resource use, and to consider alternative approaches to optimise production, ensure efficient use of the resource and minimise adverse effects if necessary.

[32] The network has grown over time. Focus of monitoring is predominantly in the industrial area where sensitive machinery may be located. Access issues can also influence where surveys are carried out.

Annual reporting on monitoring is carried out in accordance with resource consent conditions and is required by 31 March each year. Annual reports will, where possible, identify overall trends and patterns in the performance of the system, and be framed with reference to the current agreed models. They should include a critical analysis of monitoring data and information and of model performance, a comparison to the principles in the SMP, and recommendations to address any identified issues. As a minimum (as well as specific requirements of individual consents) reporting will include:

(a) Any change in reservoir pressures or temperatures,

(b) Any changes that the reservoir model may predict for the future operation and management of the Kawerau Geothermal System,

(c) The state of the Kawerau Geothermal System based on monitoring, measurements, investigations and surveys and an interpretation of those results including the enthalpy of take fluid and mass flow, subsidence predictions and subsurface changes,

(d) Comparisons of reservoir measurement data with model predictions,

(e) Monitoring results required under conditions,

(f) Complete records of well drilling, workovers, abandonments and proposed wells,

(g) Proposed geothermal developments such as pipelines, changes to infrastructure, earthworks, and activities relating to waterways,

(h) The volume of geothermal fluid taken and discharged under the consent,

(i) Any proposed significant changes to fluid take, use and discharge, and

(j) Any adaptive management or mitigation activities undertaken.

Joint reporting may be provided and this is recognised as a useful method of reporting overall system trends, which is vital for sustainable management of the resource.

7.11.1 Processes for annual reporting

The following reporting processes are to be followed:

- Bay of Plenty Regional Council provides the administrative support for annual reporting meetings, including coordination and facilitation of the PRP, notice of meetings, agenda preparation and meeting notes,
- Participants include the consent holder representatives, the PRP, and supporting staff from BOPRC. No external parties are present at the meetings, unless agreed by all parties[33],
- Meeting costs fall to the consent holder,
- Draft annual reports will be provided to BOPRC in an agreed form for distribution to the PRP,
- The PRP will provide BOPRC with an interim review of the draft reports for distribution to the consent holders prior to annual meeting(s), outlining key areas of interest or concern,

[33] Note that liaison between the PRP, BOPRC and kaitiaki to discuss cultural implication of the Annual Reports will occur through a separate process

- Following annual meetings, the PRP will provide BOPRC with a final written report including recommendations and timeframes for the resolution of any issues,
- A PRP report will be provided by BOPRC to the consent holder,
- A final annual report (amended as necessary) will then be provided to BOPRC, and
- Bay of Plenty Regional Council will report the broad outcomes of Annual Reporting and the state of the geothermal reservoir to the community (as outlined in Section 7.14.2).

The annual plan reporting cycle and process is shown in the Figure 7.4.

7.11.2 Compliance monitoring and reporting

Specific consent conditions require reporting outside of annual reports. Reporting intervals are generally monthly or quarterly depending on the parameter being measured (and additionally any specific requirements in individual consents[34]), as follows:

- Flow rates for geothermal fluid take and discharge are recorded on a daily basis and provided to BOPRC on a quarterly basis,
- Drilling logs that include geological information, and any well test completion results and heat up surveys will be provided to BOPRC for all drilling and exploratory consents, and
- For air discharge consents, consent holders report volume of steam discharged and chemical constituents within the steam, in particular H_2S discharged.

[34] *For NTGAs' consent for discharge to the Tarawera River, consent returns are required on concentrations of specified chemicals, temperature and rate of discharge. Reporting towards reinjection is provided through a discharge management report*

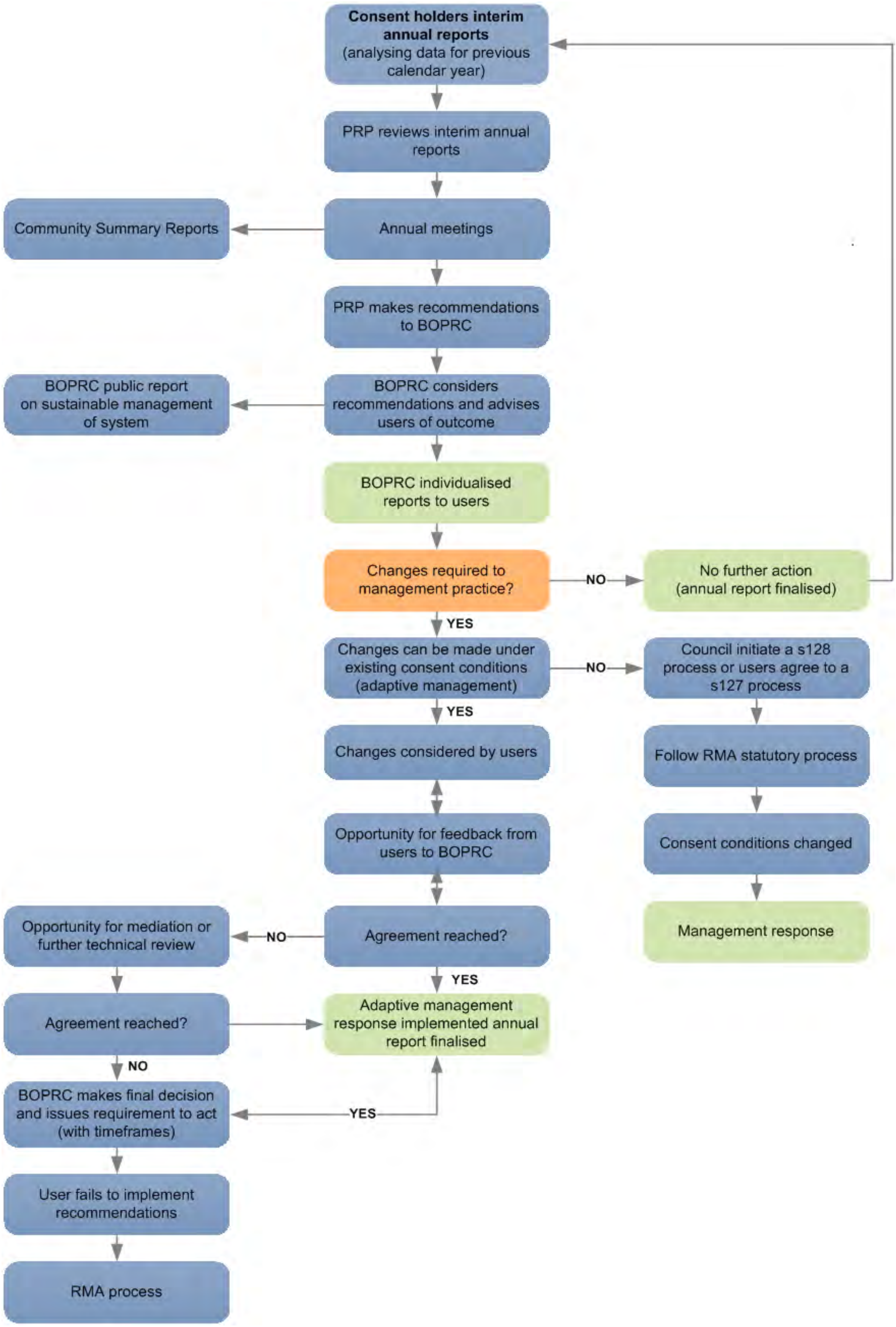


Figure 7.4 Broad process for annual reporting

7.12 Sensitive information

Consent holders are required to provide BOPRC and the PRP with any information that it reasonably requires to manage resource consents and to ensure that the geothermal system is sustainably managed. However, much of the information associated with geothermal resource consents has the potential to be commercially or culturally sensitive. BOPRC manages this information on behalf of the public under the provisions of Section 42 of the RMA (which applies during a formal proceeding under the RMA) and Section 7 of the Local Government Official Information and Meetings Act 1987 (LGOIMA).

Any information that consent holders seek to be treated as sensitive information under either Act must be clearly identified to BOPRC. Specific reasons covering commercial and/or cultural sensitivity will be provided to BOPRC if requested.

A public interest determination under the LGOIMA will be made in response to claims by consent holders of commercial or cultural sensitivity. This determination will be considered on a case by case basis, through consultation between consent holders and BOPRC. By way of guidance the following matters are relevant:

- Commercially sensitive.
- The conceptual, reservoir and subsidence models.
- The outputs of model simulations.
- Any information relating specifically to the drilling of wells, and to their performance (chemistry, temperature, pressure, permeability).
- Resistivity survey data[35].
- Any information that is specific to the operations of an individual user.
- PRP reports and recommendations.
- Information that may be in the public interest to disclose.
- Any information that affects a third party or a community interest (intent of the condition to protect a third party interest).
- Modelling and monitoring outputs to assess effects on subsidence (subsidence modelling and levelling surveys).
- Monitoring data on geothermal surface features.
- Seismicity information[36].
- Information providing a whole system picture of the sustainability of the reservoir.

7.13 Peer Review Panel

A single Peer Review Panel (PRP) is engaged to provide technical advice to BOPRC on the management of the Kawerau Geothermal System. The BOPRC appoints the PRP, in consultation with the consent holders.

[35] *Not required by consent and not all consent holder undertake these surveys*
[36] *Not required by consent and not all consent holders undertake these surveys.*

7.13.1 Membership of the Peer Review Panel

The PRP is comprised of three independent experts suitably qualified and experienced in geothermal system management and/or related environmental effects. The PRP may recommend to the BOPRC that other specialists be seconded or that technical assessments be commissioned from time to time. The decision to act on any recommendation will rest with the BOPRC after consultation with the consent holder.

The PRP does not provide advice on economic, social or cultural matters in the management of the system. The BOPRC may seek this advice elsewhere, including on matters relating to kaitiakitanga, matauranga Māori and tikanga Māori.

7.13.2 Purpose, functions and responsibilities of the Peer Review Panel

The purpose of the PRP is to assist the BOPRC with the management of the Kawerau Geothermal System in accordance with the provisions of this SMP and the management, supervision and monitoring of the exercise of consents relating to the use of the Kawerau Geothermal System. The PRP does not create original reports, but reviews data and information provided by the consent holders. It makes recommendations only and is not a decision making body.

The functions and responsibilities of the PRP are set out in the conditions of the resource consents and include:

- Review of the Kawerau Reservoir and Subsidence Models, modelling predictions and reports to make recommendations to BOPRC as to necessary modifications to the models,
- Review of annual reports, operational management plans (where one is required to be produced) or other relevant reports[37] and making recommendations to the BOPRC on the content of these plans and reports,
- Review of monitoring reports and data and providing advice as to the interpretation of monitoring results to the BOPRC, including reporting on trends, identifying any matters of concern and recommending changes to monitoring requirements,
- Review predictions of changes to reservoir conditions and predictions of the potential consequential effects of resource use (including subsidence and tilt) and making recommendations to BOPRC on the significance of such changes and effects,
- Recommend to BOPRC the appropriate management response should any actual or predicted changes in the reservoir or ground level vary to a material degree from what was predicted by the Kawerau Reservoir or Subsidence Models at the time consents were granted, and
- Recommend to BOPRC that a review of conditions be undertaken for the purpose of avoiding, remedying or mitigating adverse effects on the reservoir (including overall sustainability).

[37] *For example, Consents 66862, 67161, 67340 require that the PRP consider any report or information referred to it by BOPRC arising from the process in relation to property damage and make recommendations to BOPRC as it considers appropriate.*

7.13.3 Provision of information necessary for the management of the system

Resource consents state that consent holders are required to gather and maintain sufficient information to enable BOPRC to assess and manage any effects of resource use and to administer resource consents. As such the Consent Holder(s) will provide BOPRC with any such information (including records, data, and outputs of the modelling and monitoring programmes) that the BOPRC reasonably considers necessary for the PRP to carry out its work (see Section 7.10 in relation to monitoring and information).

7.13.4 Administration

The PRP will meet at a frequency of not less than once per 12 month period for the duration of the consent(s) to review annual reports and other information. The PRP will meet at other times as required by the BOPRC. For example, additional meetings may be necessary to ensure the PRP is aware of the current state of the reservoir and to ensure rapid response. Specifically additional input may be required in circumstances where:

- Any measured changes in the reservoir or ground level vary to a material degree from outcomes predicted by the Kawerau Reservoir or Subsidence Models.
- Any applications are made to BOPRC for approval of amendments to operating parameters specified in consent conditions.
- If there are significant changes in take or discharge (e.g. consents being fully excised).

7.13.5 Costs associated with the Peer Review Panel

The Consent Holder(s) will meet the actual and reasonable costs associated with the operation of the PRP. This includes the secondment of specialists and technical assessments as required by the PRP, provided that such costs are discussed in advance with the Consent Holder(s).

Costs are to be apportioned as follows:

1 Any fixed administrative costs[38] for meetings of the PRP, including time spent in these meetings, will be split according to the proportion of resource actual resource utilisation (annual total mass and energy take from the whole system)

2 Review, analysis and reporting of individual annual reports will be recorded and charged to consent holders on a real time basis (i.e. time spent per consent holder)

3 Any costs relating to system wide issues and assessments will be split according to the proportion of resource allocated, and

4 Any single user costs (i.e. review of single consent holder issues) will be recorded and charged to consent holders on a real time basis.

The BOPRC will facilitate the role and function of the PRP by providing reasonable organisational and administrative support for the duration of the consent(s).

7.13.6 Processes for giving effect to recommendations

[38] *Disbursements such as travel, accommodation, meeting rooms, catering, phone calls.*

All PRP reports and recommendations will be submitted in writing to BOPRC. Bay of Plenty Regional Council will provide reports, individualised if required, to consent holders. These reports will not generally be made publicly available.

The process to be followed on receipt of a substantive recommendation from the PRP or the request to review the PRP recommendations is shown in Figure 7.4: Process for Annual Reporting, above.

The decisions made by BOPRC will be in accordance with delegations as documented in the BOPRC's Delegations Manual.

7.14 Consultation/stakeholder involvement

7.14.1 Current situation

Current resource consents all require on-going consultation with liaison groups that represent community and stakeholder interests. The composition, reporting requirements and feedback to Bay of Plenty Regional Council varies according to the consent conditions. Each consent holder also conducts their own consultation with groups and individuals with whom they have a particular relationship. Bay of Plenty Regional Council also has ongoing relationships with groups in the community for the purpose of consultation and engagement.

The existing consents require, by condition of consent, engagement and information sharing with groups as follows:

- Community Liaison Group: including, but not limited to tangata whenua representatives, the Department of Conservation and the parties who submitted on the resource consent application
- Industry Liaison Group: Kawerau Industrial Stakeholder Group: representatives of industrial landowners in the vicinity of the Kawerau Geothermal System and as a minimum, Oji, Asaleo, Norske Skog Tasman and variously: GDL, Mercury, and NTGA[39]. Minutes are provided to BOPRC, and
- Paapaki Ngawha Forum - as part of Mercury's consent only, the make-up and protocols to be determined by Ngati Tūwharetoa Settlement Trust and the consent holder, but meetings specified as annual.

Attendance at Community Liaison Group meetings has been inconsistent and a more effective and efficient approach is promoted through this SMP (as follows).

7.14.2 Community involvement

All consent holders and BOPRC will endeavour to inform and update the Community Liaison Group, as well as interested and affected parties and the wider community about the state of the Kawerau Geothermal System on a regular basis as follows:

- A summary report will be prepared annually by consent holders from the final annual reports provided to BOPRC (excluding any parts that are considered confidential or commercially sensitive),

[39] *Note that TAOM is yet to become a member of the KSIG group.*

- The availability of the report and how to access it should be advised to the community/stakeholder groups by mail, email or other means, and
- The report may be provided by way of the consent holder's website, and/or, on request, in electronic or hard copy. A copy may be provided to the BOPRC for inclusion on the Council website.

Meetings of the Community Liaison Group are only required if requested by the representatives, in addition to the provision of information as above.

Bay of Plenty Regional Council will also ensure that its responsibilities for the sustainable management of the system are reported in community forums on a regular basis. It will provide a consolidated annual update on the overall state of the Kawerau Geothermal System to elected members, and to the community through forums such as the Eastern Bay of Plenty Joint Committee, its website, and media releases as appropriate.

7.15 Review of System Management Plan

7.15.1 Frequency of reviews

This SMP is intended to be updated on a regular basis to ensure that it continues to reflect the current state of the Kawerau Geothermal System and best practice for its management. It will be reviewed at least every five years from when it was either first produced or last reviewed. It will also be reviewed if any of the following situations occur:

- New consents are granted by BOPRC to take and/or discharge geothermal energy and fluid from the Kawerau Geothermal System,
- On review of relevant provisions of the RPS or the Regional Water and Land Plan, and/or
- The provisions of the SMP are determined by BOPRC in consultation with consent holders to be out of date and/or no longer fit for purpose[40].

The process undertaken to review the SMP would be similar to the process associated with its initial preparation (i.e. the process would be led and managed by BOPRC in collaboration with the consent holders).

7.16 Review of consent conditions

A review of consent conditions may be undertaken by BOPRC under Section 128 of the RMA in accordance with the conditions of consent[41]. This may include a review to ensure that the consent conditions are consistent with the agreed outcomes or processes set out in this SMP.

[40] Consent holders may also make recommendations to Council on alterations and/or additions to the System Management Plan as part of annual reporting.
[41] Consents processed post 2014 have explicit conditions for the review of conditions to meet requirements of the SMP. Older consents do not have this provision.

Part 8: References

Allis, R.G., Christenson, B.W., Nairn, I.A., Risk, G.F., Sheppard, D.S., White, S.P., 1995. Kawerau geothermal field: its natural state and response to development. Client Report 72436C.10, Institute of Geological & Nuclear Sciences Lower Hutt, New Zealand.

Bay of Plenty Regional Council, Nga Tikanga Tiaki i te Taiao - Maori Environmental Management in the Bay of Plenty,

Berryman, K.R., Beanland, S., 1989. Ongoing deformation of New Zealand: rates of tectonic movement from geological evidence. Transactions of the Institution of Professional Engineers, New Zealand 15, 25-35.

Bignall, G., Harvey, C.C., 2005. Geoscientific review of the Kawerau Geothermal Field. Institute of Geological & Nuclear Sciences Client Report 2005/20. 145p.

Bignall, G., Milicich, S.D., 2012. Kawerau Geothermal Field: geological framework. GNS Science consultancy report, 2012/118. Institute of Geological & Nuclear Sciences Lower Hutt, New Zealand.

Bloomer, A., 2011. Kawerau Direct Heat Use: Historical Patterns and Recent Developments. 2011 New Zealand Geothermal Workshop Proceedings, Auckland, New Zealand.

Carroll, L.D., Gamble, J.A., Houghton, B.F., Thordarson, T. Higham, T.F.G., 1997. A radiocarbon age determination for Mount Edgecumbe (Putauaki) volcano, Bay of Plenty, New Zealand. New Zealand Journal of Geology and Geophysics 40, 559–562.

Christenson, B.W., 1997. Kawerau Geothermal Field: geochemical structure of the reservoir and its response to exploitation. Geothermal Resources Council Transactions 21, 17-24.

Christenson, B.W. (1987). Fluid-Mineral Equilibria in the Kawerau Hydrothermal System, Taupō Volcanic Zone, New Zealand. University of Auckland, Auckland, New Zealand, Ph.D. Thesis.

Grindley, G.W., 1986. Subsurface geology and structure of the Kawerau Geothermal Field. In: Mongillo. M.A. (Ed.), The Kawerau Geothermal Field: contributions from the 1982 seminar and other recent scientific investigations. Department of Scientific and Industrial Research, Wellington, New Zealand, Geothermal Report 10, 49-65.

Henley, R.W., Brown, K.L., 1986. Geochemistry of the Kawerau geothermal system and its response to exploitation: past, present and future. In: Mongillo, M.A.(Ed.), The Kawerau Geothermal Field: Contributions from the 1982 Seminar and Other Recent Scientific Investigations. Department of Scientific and Industrial Research, pp. 77–96, Geothermal Report 10.

Holt, R.J., 2007. Numerical Model of the Kawerau Geothermal Reservoir. Report submitted to Mighty River Power Limited, June 18, 2007.

Macdonald, W.J.P., Muffler, L.J.P., 1972. Recent geophysical exploration of the Kawerau Geothermal Field, North Island, New Zealand. New Zealand Journal of Geology and Geophysics 15, 303-317.

Macdonald, W.J.P., Muffler, L.J.P., Dawson, G.B., 1970. Geophysical investigation at Kawerau. Geophysics Division, Department of Scientific and Industrial Research, Report 62. 21p.

MfE and DOC 2007a: Protecting our Places. Introducing the national priorities for protecting rare and threatened native biodiversity on private land. Ministry for the Environment and Department of Conservation, Wellington. 7 page brochure.

MfE and DOC 2007b: Protecting our Places. Information about the statement of natural priorities for protecting rare and threatened biodiversity on private land. Ministry for the Environment and Department of Conservation, Wellington. 51 pp.

Milicich, S.D, Bignall G., Kawerau Geothermal Field: Geological Framework, GNS Science Report 2012/33

Milicich, S.D., Fruetsch, F., Ramirez, L.E., Rae, A.J., Alcaraz, S.A., Kallenberg, B., McCoy-West, A.J., Bignall, G., 2010. Stratigraphic correlation study of the Kawerau Geothermal Field. GNS Science consultancy report 2010/23

Milicich, S. D., Clark, J. P., Wong, C., Askari, M., 2015. A review of the Kawerau Geothermal Field, New Zealand. Geothermics 59, July 2015

Mongillo, M.A., 1998. Changes in surface thermal activity at Kawerau Geothermal Field. Institute of Geological & Nuclear Sciences client report 52891C.10

Nairn, I. A., Solia, W. 1980. Late Quaternary hydrothermal explosion breccias at Kawerau Geothermal Field, New Zealand, Bulletin of Volcanology, 43 (1): 1-13

Rissmann, C., Nicol, A., Cole, J., Kennedy, B., Fairley, J., Christenson, B., Leybourne,M., Milicich, S.D., Ring, U., Gravley, D., 2011. Fluid flow associated with siliciclava domes and faults, Ohaaki hydrothermal field, New Zealand. J. Volcanology. Geothermics. Res. 204, 12–26

Studt, F.E., 1958. Geophysical Reconnaissance at Kawerau, New Zealand. New Zealand Journal of Geology and Geophysics 1, 219-246

Tulloch, A.J., 1990. Petrological Logs of Drillholes KA 27-35 and KA 10, 17(deepened), Kawerau Geothermal Field. DSIR Geology and Geophysics Contract Report 1990/11

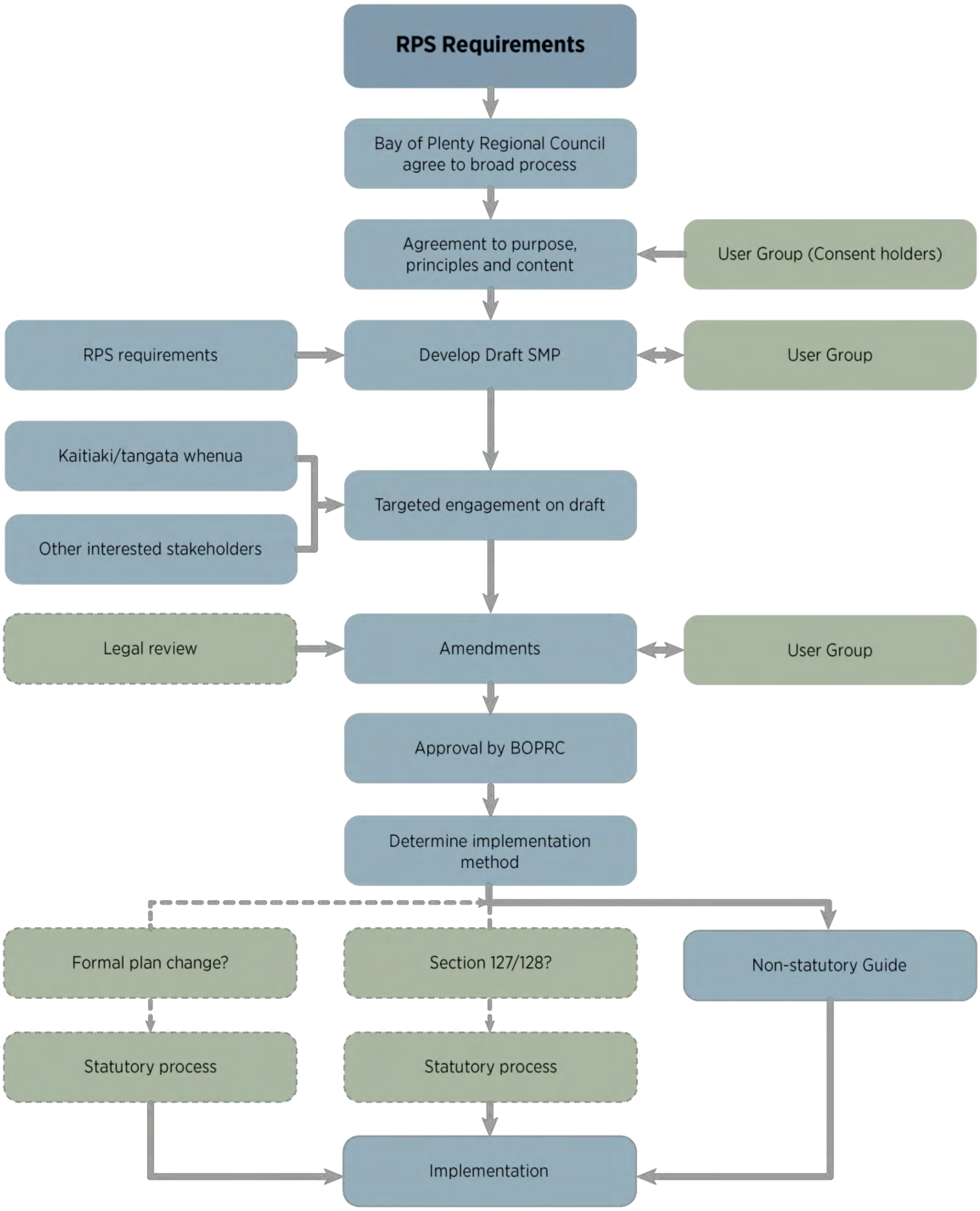
White, B., 2009, An Updated Assessment of Geothermal Direct Heat Use in New Zealand, New Zealand Geothermal Association

Wildland Consultants 2005: Geothermal vegetation of the Bay of Plenty Region based on the 2003 digital aerial photographs. Wildland Consultants Ltd Contract Report No. 1072. Prepared for Environment Bay of Plenty. 297 pp

Young, R., White, S., Kissling, W.M., and Willink, R., 2005, Impact of increased Production on the Kawerau Geothermal Field, IRL Report 1743 (Confidential)

Part 9: Appendices

Appendix 1: Process for Development of System Management Plan



Appendix 2: Summary of Statutory Provisions

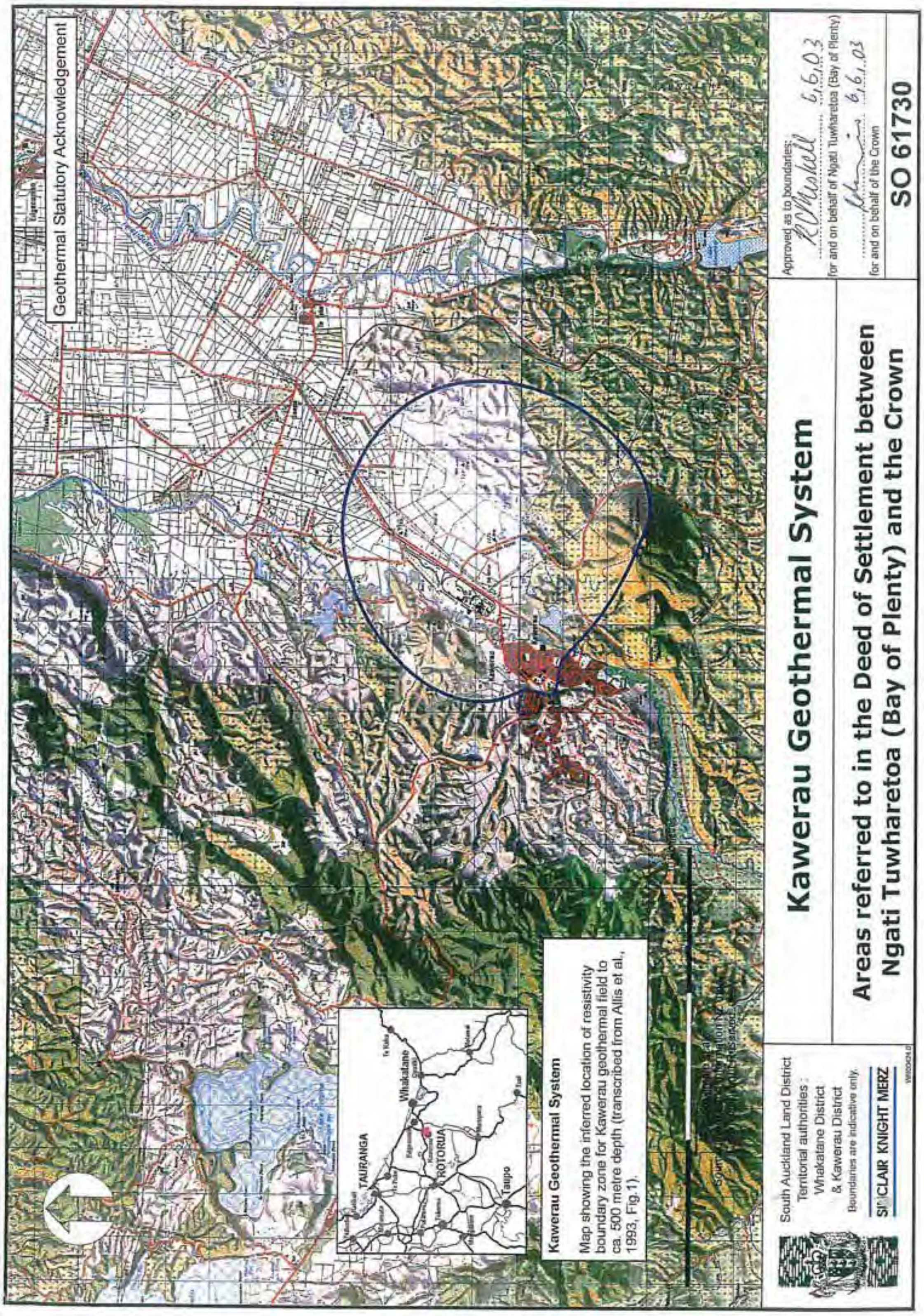
Resource Management Act 1991	
Section 5(1)	*To promote the sustainable management of natural and physical resources*
Section 5(2)	*Managing the use, development and protection of natural and physical resources in a way or at a rate which enables people and communities to provide for their social, economic, and cultural wellbeing 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* *(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*
Section 30	*"the establishment, implementation, and review of objectives, policies, and methods to achieve integrated management of the natural and physical resources of the region"* *"the control of the taking, use, … of water, … including … the control of the taking or use of geothermal energy"* *"the control of discharges of contaminants into or onto land, air, or water and discharges of water into water"* *"if appropriate, the establishment of rules in a regional plan to allocate any of the following:* *(i) the taking or use of water (other than open coastal water):* *(ii) the taking or use of heat or energy from water (other than open coastal water):* *(iii) the taking or use of heat or energy from the material surrounding geothermal water:* *(iv) the capacity of air or water to assimilate a discharge of a contaminant:"*
Regional Policy Statement – Objectives, Policies and Methods	
Objective 5	*Provide for energy efficiency and conservation and promote the use and development of renewable energy sources.*
Objective 6	*Provide for the social, economic, cultural and environmental benefits of nationally and regionally significant infrastructure and the use and development of renewable energy*
Objective 8	*Holistic and sustainable management of the regional geothermal resource by providing for:* (i) *Protection of some systems with significant geothermal features;* (ii) *Enabling use and development of some geothermal systems;* *in accordance with each system's management purpose.*
Policy GR 9B	*Assessing and managing effects on significant geothermal features* *(a) Assess geothermal features to determine which are significant, using Appendix F Set 7 "Geothermal features".*

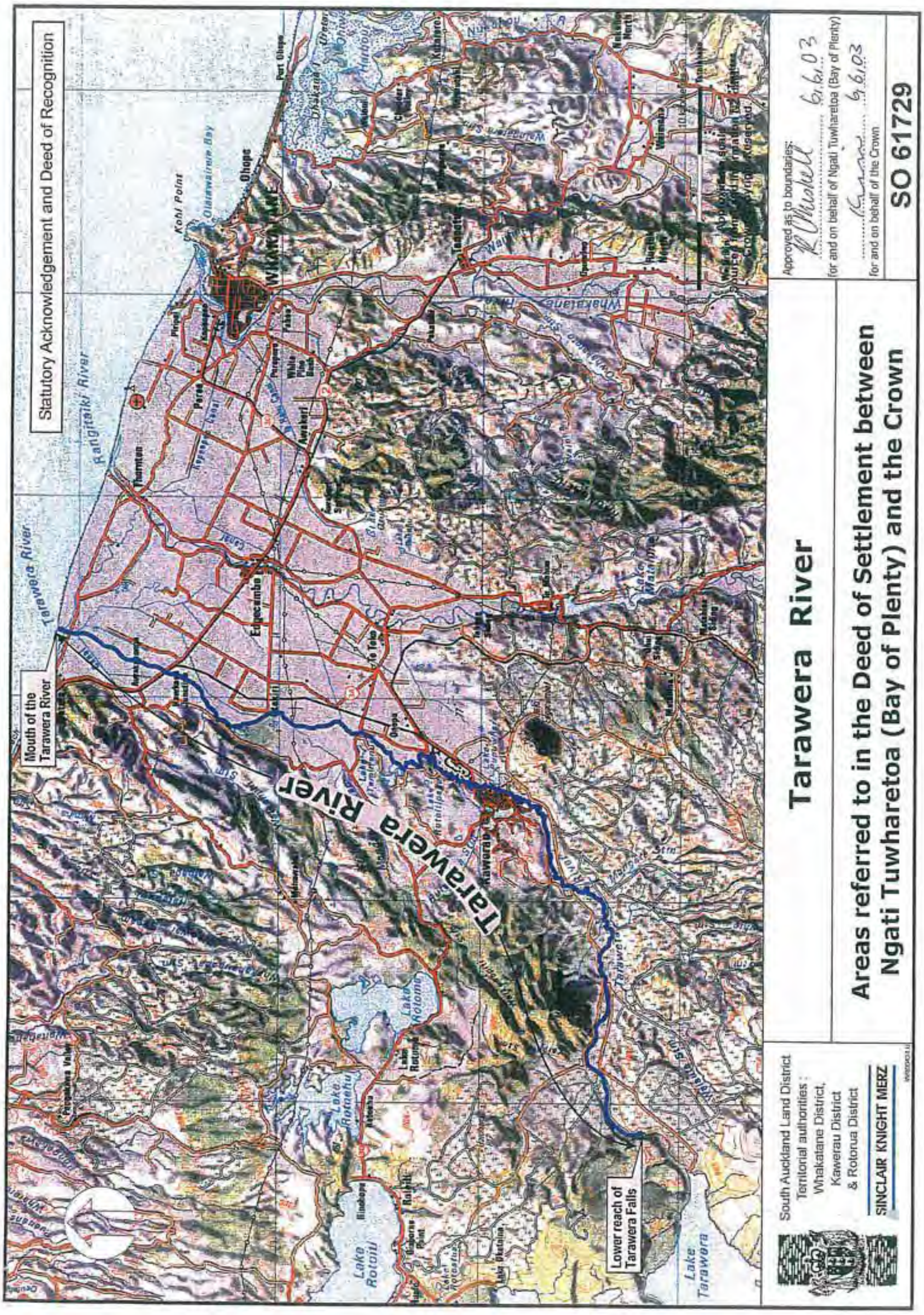
	Note: "Geothermal features" includes vegetation, habitats and fauna. *(b) Manage effects on significant geothermal features in accordance with the management purpose of the geothermal group in which they are classified as follows:* *(c) Remedy or mitigate significant adverse effects on significant geothermal features in group 4 systems.* *(d) Offset mitigation of adverse effects on significant geothermal features or geothermal resources can occur within the wider Taupō volcanic zone rather than being restricted to the Bay of Plenty region.*
Policy GR 2A	*Integrated management of geothermal systems by requiring that:* *(a) Development and use of land within geothermal systems is compatible with the management purpose for each system as specified in Table 12;* *(b) <u>System management plans are used for any geothermal system classified for development</u>;* *(c) Geothermal water injection and reinjection is actively encouraged and provided for." (emphasis added)*
Policy GR 3A	*Provide for the sustainable use of geothermal systems, by requiring that development and use within a geothermal system:* *(a) may occur only if:* *(i) Such use is consistent with the management purposes for each system defined in the Bay of Plenty Regional Council geothermal system classification described in Table 12;* *(ii) <u>The system is operated under a system management plan covering the entire geothermal system where the cumulative abstractive development uses 1000 tonnes or more geothermal water per day</u>; and* *(b) has regard to:* *(i) System characteristics;* *(ii) Adaptive management of the system, including appropriate staging of development;* *(iii) Cultural, historical, and economic values associated with SGFs;* *(iv) The allocation reasonably required for the intended use;* *(v) Demonstrating efficiency of use of the geothermal energy and water resource;* *(vi) Avoiding, remedying or mitigating significant adverse effects on the overlying existing built structures; and* *(vii) Managing the take, use and discharge of energy and/or geothermal water to:* 1. *avoid significant adverse effects on SGFs in group 1, 2 and 6 systems.* 2. *avoid, remedy or mitigate significant adverse effects on SGFs in group 3 systems.* 3. *remedy or mitigate significant adverse effects on SGFs in group 4 systems*
Policy GR 7B Requiring integrated geothermal	*Require integrated system management for significant geothermal system use through a single system management plan for the entire geothermal system, which must contain:*

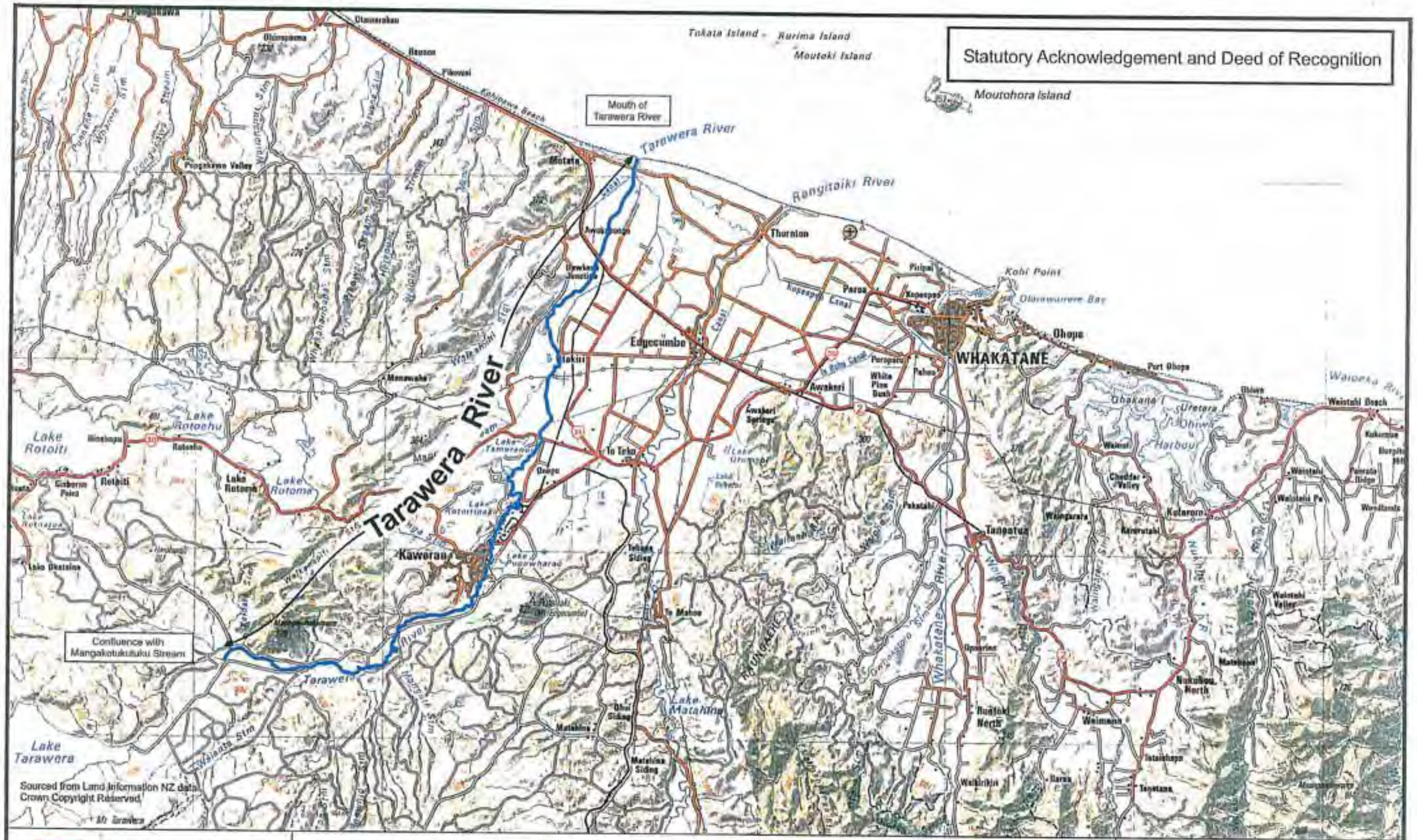
system management	*(a) System management objective;* *(b) Operational flexibility and adaptive management parameters;* *(c) Modelled reservoir and subsidence predictions for geothermal systems where the cumulative take exceeds 6000T/day; (d) A discharge strategy;* *(e) Mechanisms to ensure co-operation between all consent holders for large takes within the same geothermal system and which enable utilisation of, and access to, the geothermal system by consent holders, while not precluding (without sound resource management justification) the utilisation of the system by a trade competitor or other potential user;* *(f) Buffer distances between the production and injection or reinjection wells of adjacent operators in the same geothermal system;* *(g) Mechanisms to remedy or mitigate significant adverse effects on SGFs, including remediation or mitigation of existing effects or protection from potential adverse effects, in any geothermal system;* *(h) Measures to ensure that where the system may be linked to another system, development does not cause effects that are inconsistent with the management purposes for that other system;* *(i) Research, monitoring and reporting of the system, its potentials, attributes and qualities and effects of exercising consents;* *(j) Non-statutory review for minor amendments;* *(k) Provisions for the use of peer review panels to assist the consent authority; and* *(l) Provisions for a system liaison group to facilitate discussion with, and feedback from, stakeholders.*
Policy GR 8B	*Require geothermal discharge, from takes that are subject to a resource consent, to be in accordance with a geothermal discharge strategy that addresses:* *(a) Disposal of geothermal water;* *(b) Return of geothermal water to the system;* *(c) Facilitation of further extraction of energy from the system;* *(d) Avoidance, remediation or mitigation of subsidence, particularly in the built environment;* *(e) Minimising the risk of hydrothermal eruptions especially in the built environment;* *(f) Remediation or mitigation of significant adverse effects on SGFs;* *(g) Avoidance, remediation or mitigation of contamination of surface or ground water; and* *(h) Investigation, research, monitoring and reporting on implementation of the discharge strategy.* *Such discharge strategy shall also have regard to:* *(i) Likely benefits to, or significant adverse effects on, the system or its productive capacity;* *(j) The need for adaptive management and flexibility over time; and* *(k) Benefits, costs and significant adverse effects of the discharge strategy."*
Definition of	*Sustainable use: For geothermal resource use purposes, "sustainable*

'sustainable use'	*use" requires a case by case consideration of the resource for its extractable energy use values.* *In the context of a proposal for extractive use, determining sustainable use will consider:* • *the level and certainty of scientific information on the particular system;* • *the size of the geothermal energy resource;* • *the rate at which the energy within the geothermal system is proposed to be extracted, and the timeframe over which any proposed rate of take of geothermal energy is predicted to be able to be sustained, informed by modelling for a period of at least 50 years (the depletion rate is a matter for decision makers to determine when an application is being considered);* • *the predicted quantity of energy available for extractive use at the end of 50 years;* • *the predicted length of time that the geothermal system will take to recover once extractive use ceases;* • *the overall management of the geothermal resource, including the depth and locations of the proposed take and return of geothermal fluid, and the impacts of such management on the longevity of the resource; and* • *once extractive use has commenced, how closely observed changes to the geothermal resource affecting its productive capacity and longevity match the modelled or predicted effects, by review of the data and other information collected. This information could include: pressure, temperature, chemistry, surface water flow or level and vegetation monitoring indicating the state of the geothermal resource, including identified changes to geothermal features."*
Regional Plan for the Tarawera River Catchment – Objectives, Policies and Methods	
Geothermal Management Group 4	*>70 degrees Celsius, few or no geothermal surface features, high to no modification of field* *High temperature geothermal systems available for sustainable use and development – The use (including abstraction) of geothermal water, heat and energy where the adverse effects of the activity can be avoided, remedied or mitigated:* *(a) Kawerau* *(b) Lake Rotoiti (outflow is in the bed of Lake Rotoiti)* *(c) Rotoma/Puhi Puhi*
Objective 17.4.2	*Protecting freshwater resources from unnecessary contamination from geothermal fluid while maximising the utilization of geothermal waste streams.*
Regional Water and Land Plan – Objectives, Policies and Methods	
Objective 65	*Sustainable use and development of geothermal water, heat and energy with regard to the effects on geothermal surface features and ecosystems, and individual field characteristics.*
Objective 69	*The reinjection of abstracted geothermal water into the same geothermal field from which it came, subject to an assessment of effects.*
Objective 72	*Efficient use of geothermal resources.*

Appendix 3: Statutory Acknowledgement Areas




Statutory Acknowledgement and Deed of Recognition
Mouth of the Tarawera River
Tarawera River
Lower reach of Tarawera Falls
Lake Tarawera
Lake Rotoiti
Lake Rotoehu
Lake Rotoma
Kawerau
Whakatane
Ohope
Kohi Point
Port Ohope
Edgecumbe
Thornton
Rangitaiki River
South Auckland Land District
Territorial authorities : Whakatane District, Kawerau District & Rotorua District
SINCLAIR KNIGHT MERZ
Tarawera River
Areas referred to in the Deed of Settlement between Ngati Tuwharetoa (Bay of Plenty) and the Crown
Approved as to boundaries:
for and on behalf of Ngati Tuwharetoa (Bay of Plenty)
for and on behalf of the Crown
SO 61729



South Auckland Land District
Territorial authority :
Whakatane District

Tarawera River

Areas referred to in the Deed of Settlement between Ngati Awa and the Crown

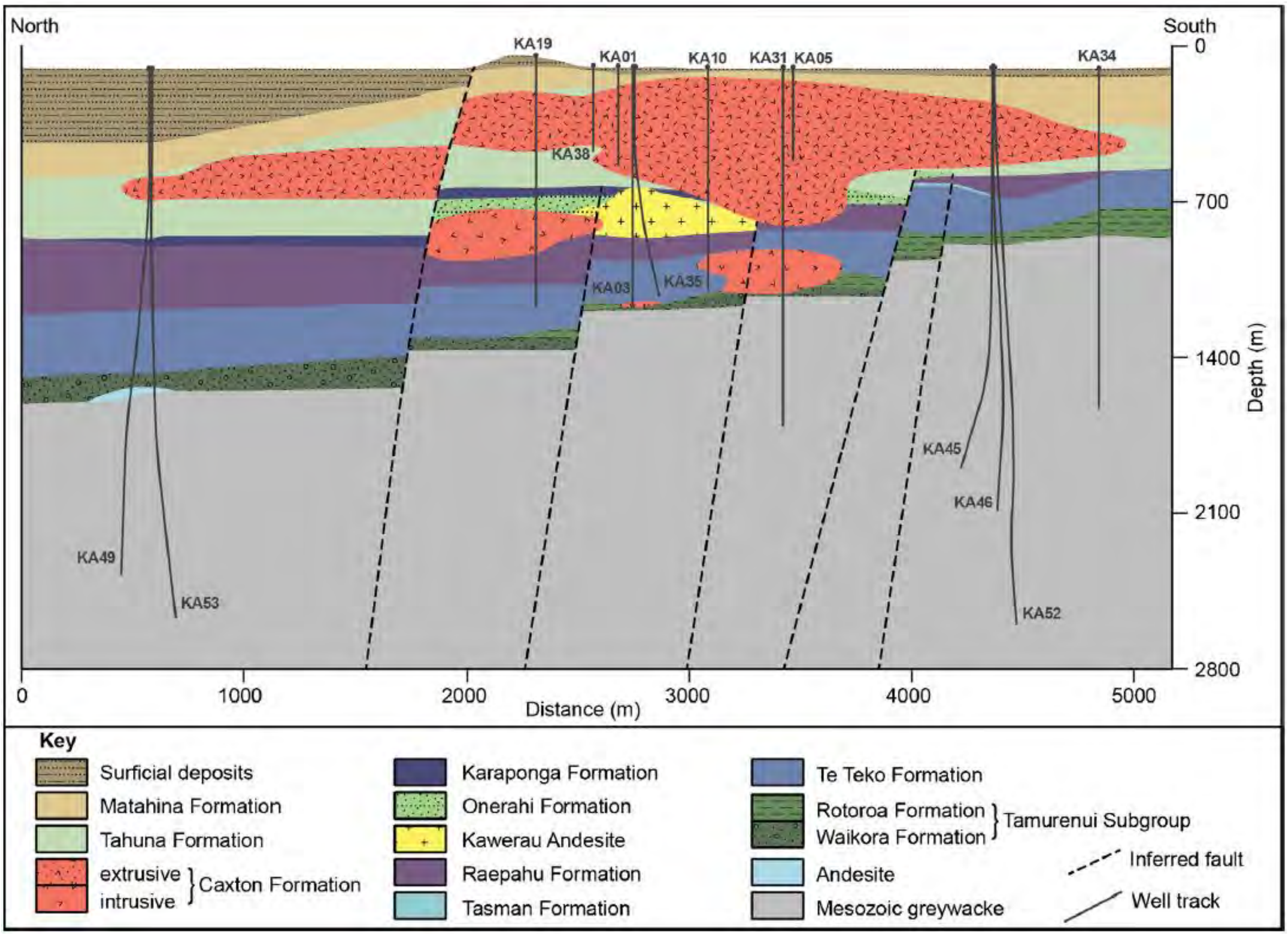
Approved as to boundaries :
.... 27.03.03
for and on behalf of Ngati Awa
.... 27.3.03
for and on behalf of the Crown

SO 61403

Appendix 4: Stratigraphy

Generalised Stratigraphy of the Kawerau Geothermal System		
Formation	**Lithology**	**Thickness (m)**
Recent Alluvium	Sands and gravels; unconsolidated pyroclastics (incl. Whakamana Breccia, Rotoiti Breccia)	10 - 50
Hydrothermal Eruption Breccia	Hydrothermal eruption deposits (14,500 and 9,000 yr BP)	1 - 4, < 10
Unconsolidated pyroclastics	Unwelded pumiceous pyroclastic flows and airfall tuffs	0 - 90
Onepu Formation	Surficial rhyodacite (domes) & porphyritic (crystalrich) intrusive	~ 200
Matahina Formation	Partly welded grey-brown lenticulite and vitric tuff	10 - 410
Tahuna Formation	Crystal-rich sandstone, siltstone, muddy lithic-breccia and unwelded pumice-rhyolite lapilli tuff and ash	0 - 360
Caxton Formation	Buried spherulitic/banded quartz-plagioclase rhyolite domes, and associated intrusives	0 - 450
Karaponga Formation	Partly welded, crystal-lithic lapilli tuff	0 - 180
Onerahi Formation	Tuffaceous to muddy breccias, coarse tuffaceous sandstone	0 - 85
Kawerau Andesite	Augite-plagioclase andesite lava, breccias and tuff	0 – 300
Raepahu Formation	Partly welded crystal-vitric tuff (lithic poor) and lithicrich tuff	0 – 165
Tasman Formation	Muddy breccia, sandstone and siltstone	0 -25
Te Teko Formation	Partly welded grey crystal-vitric tuff	0 - 255
Rotoroa Formation	Tuffaceous sandstone, poorly sorted crystal and vitric, water- laid tuff and sandstone	0 - 200
Waikora Formation	Greywacke pebble conglomerate, and minor intercalated tuff	0 - 450
Greywacke basement	Weathered, sheared greywacke and argillite	-

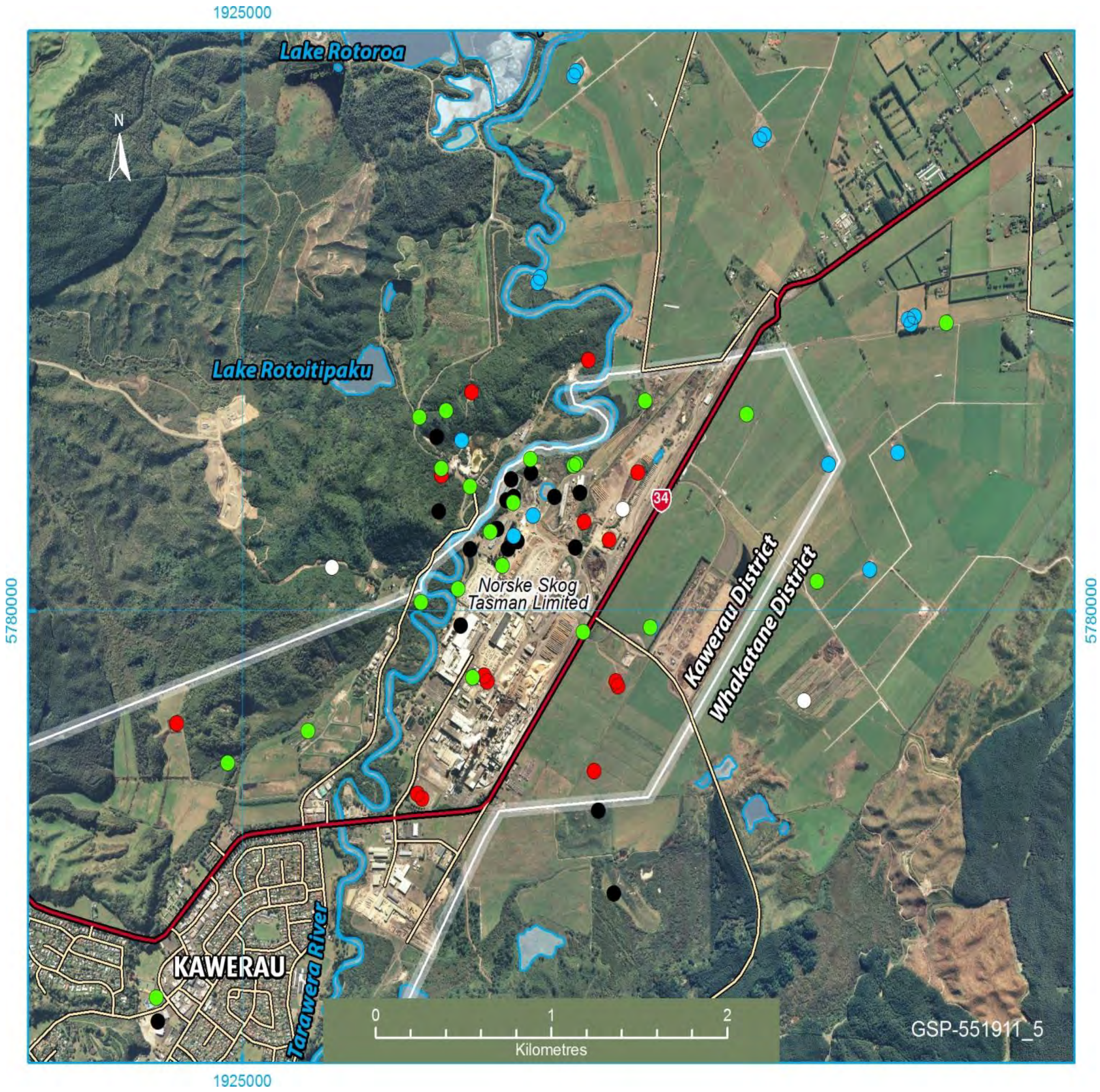
Stratigraphic cross-section from north-northwest to south-southeast across the Kawerau Geothermal System.



Note: Wells near the section line and inferred faults are shown (Milicich et al. 2015).

Section line from Milicich et al. 2015

Appendix 5: Locations of Wells



Appendix 6: Well Ownership and Type

Well no.	Well owner	Date drilled	Type of well
GDL1	GDL	Dec-2007	Injection
GDL2	GDL	Jan-2008	Injection
KA24	GDL	Oct-1976	Production
KA45	KGL	Oct-2007	Abandoned
KAM7	KGL	Nov-2007	Groundwater Monitor
KAM8	KGL	Nov-2007	Groundwater Monitor
KAM10	KGL	Dec-2007	Groundwater Monitor
KAM9	KGL	Dec-2007	Groundwater Monitor
PK04A	KGL	Jul-2004	Injection
PK05	KGL	Apr-2005	Injection
KA44	KGL	Aug-2007	Injection
PK8	KGL	Apr-2010	Injection
KA50	KGL	Jun-2010	Injection
KA51	KGL	Sep-2013	Injection
KA55	KGL	Nov-2016	Injection
PK06	KGL	Jun-2005	Production
PK07	KGL	Aug-2005	Production
KA41	KGL	Dec-2005	Production
KA42	KGL	Jan-2006	Production
KA46	KGL	Nov-2007	Production
KA45A	KGL	Feb-2008	Production
KA52	KGL	Jun-2013	Production
KA56	KGL	Dec-2016	Production
KAM11	KGL	Jun-2008	Reservoir Monitor
PK03	KGL	May-2004	Reservoir Monitor
PK01	KGL	Feb-2004	Suspended
KA43	KGL	May-2007	Suspended
KA48	KGL	Apr-2010	Suspended
KA34	Sequal Lumber	Jan-1983	Reservoir Monitor
KA2	NTGA	Nov-1952	Abandoned
KA1	NTGA	Nov-1952	Abandoned
KA6A	NTGA	Oct-1954	Abandoned
KA5	NTGA	Oct-1954	Abandoned

Well no.	Well owner	Date drilled	Type of well
KA7A	NTGA	Jun-1956	Abandoned
KA10	NTGA	Nov-1956	Abandoned
KA11	NTGA	Dec-1956	Abandoned
KA8	NTGA	Dec-1956	Abandoned
KA12	NTGA	Dec-1956	Abandoned
KA13	NTGA	Jan-1957	Abandoned
KA4	NTGA	Jan-1964	Abandoned
KA21	NTGA	Apr-1975	Abandoned
KA26	NTGA	Oct-1977	Abandoned
KA31	NTGA	Oct-1980	Reservoir Monitor
KA29	NTGA	May-1982	Abandoned
KAM1	NTGA	Nov-1983	Abandoned
KAM5	NTGA	Dec-1989	Abandoned
KAM6	NTGA	Oct-1991	Abandoned
KA37	NTGA	Sep-1993	Abandoned
KAGW1	NTGA	Jan-1991	Groundwater Monitor
KAGW2	NTGA	Sep-1991	Groundwater Monitor
KAGW3	NTGA	Feb-1999	Groundwater Monitor
KAGW4	NTGA	Feb-1999	Groundwater Monitor
KA38	NTGA	Oct-1992	Injection
KA39	NTGA	Dec-1998	Injection
KA40	NTGA	Jun-2002	Injection
KA49	NTGA	Nov-2012	Injection
KA53	NTGA	Jan-2013	Injection
KA36	NTGA	Dec-1990	Offline
KA21ST	NTGA	Feb-1998	Offline
KA19	NTGA	Apr-1971	Production
KA27	NTGA	Jul-1979	Production
KA30	NTGA	May-1980	Production
KA35	NTGA	Apr-1985	Production
KA37A	NTGA	Dec-1998	Production
KA47	NTGA	Jan-2008	Production
KA54	NTGA	Dec-2015	Production
KA3	NTGA	Apr-1967	Reservoir Monitor
KA14	NTGA	May-1957	Reservoir Monitor

Well no.	Well owner	Date drilled	Type of well
KA16	NTGA	Mar-1967	Reservoir Monitor
KA17	NTGA	Jun-1967	Reservoir Monitor
KA23	NTGA	Aug-1975	Reservoir Monitor
KA25	NTGA	Feb-1977	Reservoir Monitor
KA28	NTGA	Aug-1979	Reservoir Monitor
KA32	NTGA	Jun-1981	Reservoir Monitor
KAM2	NTGA	Sep-1983	Reservoir Monitor
KAM4	NTGA	May-1984	Reservoir Monitor
KAM3	NTGA	May-1984	Reservoir Monitor
TI1	TAOM	August- 2016	Injection
TI2	TAOM	July- 2016	Injection
KA22	TAOM	Jun-1977	Production
TP1	TAOM	Jun- 2016	Production

Appendix 7: Process for Updating and Reviewing the Geothermal Numerical Reservoir Model